
Papua New Guinea Liquefied Natural Gas Project

Terrestrial biodiversity analysis of the upstream project area

December 20 2008

This report takes into account the particular instructions and requirements of our client(s). Francis Crome Pty Ltd has had to rely on information from other sources in preparing this report (including the party for whom it is prepared) and is not in a position to, and has not, verified the accuracy or completeness of information so provided. Accordingly, Francis Crome Pty Ltd takes no responsibility for and assumes no liability in respect of, any information provided by others for the purposes of preparing this report nor the consequences of using such information. Neither this report nor any part of it may be used by any third parties and no responsibility whatsoever is undertaken to any third parties.

Contributors

Co-ordinator	Francis H. J. Crome <i>Francis Crome Pty Ltd.</i>
Bats	Greg C. Richards <i>Greg Richards and Associates</i>
Birds	Iain A. Woxvold
Botany	Wayne Takeuchi, <i>Research Botanist</i> <i>The Herbaria and Arnold Arboretum of Harvard University and the Forest Research Institute, Lae</i>
Herpetofauna	Stephen Richards, <i>Honorary Curator</i> <i>South Australian Museum</i>
Mammals	Ted Mamu <i>WWF PNG</i>

Table of contents

1	Acronyms	xiii
2	Geographic conventions	xiv
3	Executive summary	xv
	Introduction	1
4	The PNG LNG Project	2
4.1	Background	2
4.2	Project description	2
4.2.1.1	Upstream development components:	3
4.2.1.2	LNG facilities development components:	4
4.2.1.3	Supporting facilities and infrastructure:	4
5	Study strategy	6
5.1	Challenges	6
5.1.1	The nature of the New Guinea biota	6
5.1.2	Uncertainty in pipeline routing	7
5.1.3	Logistical, security and seasonal constraints	7
5.1.4	Sampling tropical faunas and floras	7
5.1.5	Definition of a project area	8
5.2	Approach	9
6	The project area	11
6.1	Definition	11
6.2	Description	11
6.3	Bioregions	13
7	Data sources	17
7.1	WWF data	17
7.2	LNG specific surveys in 2005 and 2008	17
7.2.1	2005 and 2008 survey area descriptions	18
7.2.1.1	Juha North survey area	18
7.2.1.2	Juha South survey area	18
7.2.1.3	Baia River survey area	19
7.2.1.4	South Karius survey area	19
7.2.1.5	Deviation Camp survey area	20
7.2.1.6	Hides 3 survey area	20
7.2.1.7	Benaria survey area	20
7.2.1.8	Nogoli survey area	20
8	Methods	23
	Biodiversity Assets	27
9	Vegetation	28
9.1	General	28
9.2	Terrain and forest structure	28
9.3	Forest dynamics relevant to impact analysis	29
9.4	Vegetation types	30
10	Flora	37
10.1	Weeds	40
10.2	New species	40
10.3	Conservation status	46
10.4	General comments on sensitivities and potential impacts	47
11	Non-volant mammals	48
11.1	Endemism	51
11.2	New species	51
11.3	Conservation status	51
11.4	General comments on sensitivities and potential impacts	53
12	Bats	55
12.1	New Species and significant additions to the PNG bat fauna	56
12.2	Conservation status	57
12.3	General comments on sensitivities and potential impacts	57
13	Birds	61
13.1	Endemism	64
13.2	Habitat preferences	65

13.3	Migratory species	66
13.4	New species	67
13.5	Conservation status	67
13.6	General comments on sensitivities and potential impacts	69
14	Reptiles	70
14.1	New species	71
14.2	Conservation status	71
14.3	General comments on sensitivities and potential impacts	72
15	Amphibians	73
15.1	Conservation status	74
15.2	New species	75
15.3	General comments on sensitivities and potential impacts	75
16	General conclusions flora and fauna	77
17	Special areas	78
17.1	Special area 1: The Juha Area	78
17.2	Special area 2: Hides Ridge	78
17.3	Special area 3: High-altitude forest above 1800 m on the Homa Deviation	80
18	Focus habitats	81
18.1	Caves	81
18.2	Sink hole swamps	81
18.3	Upland streams	81
18.4	Swamp forests	81
18.5	Stream refuges in unstable landscapes	82
18.6	Lowland rivers in stable landscapes	82
18.7	Off river water bodies	82
19	Conservation areas	83
20	Conservation status of flora and fauna	86
	Estimating Habitat Losses	89
21	Methods	90
21.1	Sources of information on project design and construction	90
21.2	Calculating habitat losses	90
21.2.1	Condition	91
21.2.2	Greenfield or brownfield	92
21.2.3	BVG	92
21.2.4	Side cast factors	92
22	Losses due to construction of facilities	94
22.1	Wells and well pads	94
22.2	Production and processing facilities	94
22.2.1	Juha Production Facility	94
22.2.2	Hides Gas Conditioning Plant	94
22.3	Camps	95
22.3.1	Pioneer camps	95
22.3.2	Temporary camps	95
22.4	Other facilities	95
23	Losses due to construction of pipelines and roads	96
23.1	Pipeline construction description	96
23.2	Logistics roads and tracks	97
23.3	Route descriptions	98
	Impact Analysis.....	127
24	Assessing impacts	128
25	Sources of impacts and mechanisms for their mitigation	131
25.1.1	Habitat loss	132
25.1.1.1	Habitat loss through clearing and earthworks	132
25.1.1.2	Habitat loss through river crossings	134
25.1.2	Edge and barrier effects	135
25.1.2.1	Edge effects	135
25.1.2.2	Barrier effects	136
25.1.2.3	The dilemma of two cleared corridors	137
25.1.3	Physical damage and disturbance to caves	138

	25.1.4	Fauna falling in the pipe trench	139
	25.1.5	Erosion and movement of soil and spoil and changes to hydrology	140
	25.1.6	Materials handling	142
	25.1.7	Disposal of hydrotest fluid	143
	25.1.8	Dust	144
	25.1.9	Loss of breeding and display grounds	144
	25.1.10	Noise, lights and other disturbance to fauna	145
	25.1.11	Project traffic and other operations	145
25.2		Indirect Impacts	145
	25.2.1	Fire	146
	25.2.2	Pests, weeds and disease	146
	25.2.2.1	Dieback and other plant diseases	147
	25.2.2.2	Invasive species - weeds	147
	25.2.2.3	Invasive species – exotic fauna	148
	25.2.2.4	Mitigations for pests, weeds and disease	148
	25.2.3	Hunting	151
	25.2.3.1	Hunting by PNG LNG Project workers and contractors	152
	25.2.3.2	Hunting by non - project personnel	152
	25.2.4	Collection of flora	152
	25.2.4.1	Collection of flora by PNG LNG Project workers and contractors	153
	25.2.4.2	Collection of flora by non - project personnel	153
	25.2.5	Improved Access to project area	153
26		Significance of residual impacts on the habitats and biodiversity of the project area and the KICDP as a whole	155
26.1		Direct impacts on vegetation and flora	155
	26.1.1	Habitat loss	155
	26.1.2	Edge and barrier effects	157
	26.1.2.1	Edge effects	157
	26.1.2.2	Barrier effects	157
	26.1.3	Erosion, movement of soil and spoil, and changes to hydrology	157
	26.1.4	Materials handling	158
	26.1.5	Disposal of hydrotest fluid	158
	26.1.6	Dust	158
26.2		Direct impacts on fauna	158
	26.2.1	Habitat loss	158
	26.2.2	Edge and barrier effects	159
	26.2.2.1	Edge effects	159
	26.2.2.2	Barrier effects	159
	26.2.3	Physical damage and disturbance to caves	160
	26.2.4	Fauna falling in the pipe trench	160
	26.2.5	Erosion, movement of soil and spoil and changes to hydrology	160
	26.2.6	Materials handling	161
	26.2.7	Disposal of hydrotest fluids	161
	26.2.8	Dust	161
	26.2.9	Loss of breeding and display grounds	161
	26.2.10	Noise, lights and other disturbance	162
	26.2.11	Project traffic and other operations	162
26.3		Indirect impacts on vegetation, flora and fauna	162
	26.3.1	Fire	162
	26.3.2	Pests, weeds and disease	162
	26.3.3	Hunting by PNG LNG Project staff and contractors	163
	26.3.4	Hunting by non – project personnel	163
	26.3.5	Collection of flora by PNG LNG Project workers and contractors	163
	26.3.6	Collection of flora by non – project personnel	163

	26.3.7	Increased access to the project area	163
27		Significance of impacts on special areas	164
	27.1	Special area 1: The Juha Area	164
	27.2	Special area 2: Hides Ridge Special Area	164
	27.3	Special area 3: High-altitude forest above 1800 m on the Homa Deviation	164
28		Significance of impacts on focal habitats	166
	28.1	Caves	166
	28.2	Sinkhole swamps	166
	28.3	Upland streams	167
	28.4	Swamp forest	167
	28.5	Stream refuges in unstable landscapes	167
	28.6	Lowland rivers in stable landscapes	167
	28.7	Off river water bodies	168
29		Significance of impacts on conservation areas	169
	29.1	KICDP area	169
	29.2	Wildlife Management Areas	169
	29.3	WWF significant biological areas	170
30		Predicted significance of impacts on listed species	172
	30.1	Critically endangered species	172
	30.2	Endangered species	175
	30.3	Vulnerable species	176
	30.4	Near threatened and data deficient species	183
31		Significance of impacts on migratory fauna	185
32		Overall conclusion	186
33		References	187
		Appendices.....	195
		Plates	267
		Annexes.....	after plates

Tables

Table 1 Methods used in RAP surveys in the project area.	23
Table 2 Summary of survey effort for non-volant mammals, bats and birds in the project area in 2005 and 2008.	24
Table 3 Species new to science recorded by Takeuchi (Annexes 01 and 02) in the project area.	40
Table 4 First records and other notable plants recorded by Takeuchi (Annexes 01 and 02) in the project area.	43
Table 5 Flora listed as of conservation concern in the project area.	46
Table 6 Conservation classifications used by the <i>PNG Fauna (Protection and Control) Act 1966, 1978</i> ('Fauna Act') and IUCN	46
Table 7 Numbers of non-volant mammal species in each bioregion of the project area.	49
Table 8 Non-volant mammal species recorded from only one survey area within the project area.	49
Table 9 Levels of endemicity of nonvolant mammals in bioregions of the project area.	52
Table 10 Non-volant mammals listed as of conservation concern in the project area.	52
Table 11 Habitat preferences of non-volant mammals in the project area.	53
Table 12 Number of species in each bat family in bioregions of the project area.	56
Table 13 Summary of preferred habitats of microbats recorded during the 2008 survey (Annex 06).	58
Table 14 Bats listed as of conservation concern in the project area.	59
Table 15 Cave bat species known or predicted to occur within the project area.	60
Table 16 Levels of endemicity of birds in bioregions of the project area.	65
Table 17 Definition of habitat specialisation classes	66
Table 18 Habitat specialisation in bioregions of the project area.	67
Table 19 Birds listed as of conservation concern in the project area.	68
Table 20 Number of species in each reptile family in bioregions of the project area.	71
Table 21 Reptiles listed as of conservation concern in the project area.	72
Table 22 Number of species in each frog family in bioregions of the project area.	74
Table 23 Amphibians listed as of conservation concern in the project area.	75
Table 24 WWF areas of biological significance (from Leary 1996)	85
Table 25 Classification of condition.	92
Table 26 Extra habitat losses for side cast factors.	93
Table 27 Estimated losses of vegetation to the various project components within the project area.	108
Table 28 Estimated losses of vegetation from Broad Vegetation Groups within the project area.	118
Table 29 Estimated losses of vegetation in different bioregions within the project area.	120
Table 30 Estimated losses of vegetation in brown and green fields areas within the project area.	121
Table 31 Estimated losses of vegetation in WWF Significant Biological Areas.	122
Table 32 Estimated losses of vegetation in Kutubu WMA.	124
Table 33 Magnitude of impact categories used in assessment.	129

Table 34 Value and/or sensitivity of conservation assets.	130
Table 35 Significance matrix.	130
Table 36 Sources of impacts.	131
Table 37 Results from household survey questionnaires about bat caves	138
Table 38 Results from household survey questionnaires about hunting.	152
Table 39 Percent of project footprint allowed to regenerate at end of construction period.	156

Figures

Figure 1 Schematic layout of the PNG LNG Project.	5
Figure 2 Location of the PNG LNG upstream project area.	12
Figure 3 Substrates in the PNG LNG upstream project area.	13
Figure 4 Bioregions of the PNG LNG upstream project area.	16
Figure 5 Biodiversity sample sites within the PNG LNG upstream project area. See Appendix 2 for key to acronyms.	22
Figure 6 Examples of species-effort curves.	25
Figure 7 Distributions of Broad Vegetation Groups within the PNG LNG upstream project area.	36
Figure 8 Relationship between elevation and numbers of species of non-volant mammals at survey areas within the project area (all data from Appendix 5).	50
Figure 9 Relationship between predicted numbers of species of non-volant mammals and elevation within the project area. Each point is a sample site.	50
Figure 10 The relationship between bat species richness and elevation at the seven survey areas of the PNG LNG Project surveys.	57
Figure 11 Dendrogram of similarity of survey areas in terms of bird community composition using combined data from the PNG LNG Project and the WWF surveys.	63
Figure 12 WMAs and WWF significant biological areas within the PNG LNG upstream project area.	84
Figure 13 Sections 1 and 2 of the PNG LNG Upstream Project pipelines.	108
Figure 14 Sections 3 to 6 of the upstream PNG LNG Project pipelines.	109
Figure 15 Sections 7 and 8 (part) of the upstream PNG LNG Project pipelines.	110
Figure 16 Sections 8 (part), 9, 10, 11 and 19 of the upstream PNG LNG Project pipelines.	111
Figure 17 Sections 12, 13, 14 and 20 of the upstream PNG LNG Project pipelines.	112
Figure 18 Sections 15, 16 and 18 of the upstream PNG LNG Project pipelines.	113
Figure 19 Section 17 (part) of the upstream PNG LNG Project pipelines.	114
Figure 20 Section 17 (part) of the upstream PNG LNG Project pipelines.	115

Appendices

Appendix 1 Surveys (WWF and PNG LNG Project) carried out in the PNG LNG upstream project area.	196
Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.	199
Appendix 3 Groupings of FIMS vegetation types used in EIS analysis.	206
Appendix 4 Areas (km ²) of Broad Vegetation Groups in bioregions in the PNG LNG upstream project area.	208
Appendix 5 Non-volant mammals recorded from the PNG LNG upstream project area.	210
Appendix 6 Bats recorded from the PNG LNG upstream project area.	215
Appendix 7 Birds recorded from the PNG LNG upstream project area.	218
Appendix 8 Birds that could occur within the PNG LNG upstream project area.	236
Appendix 9 Reptiles recorded from the PNG LNG upstream project area.	239
Appendix 10 Frogs recorded from the PNG LNG upstream project area.	242
Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area.	247
Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.	254
Appendix 13 Impact analysis for conservation listed species.	261

Plates

Plate 1	Pipe bridge at Hegigio River.
Plate 2	Hides 1 well pad.
Plate 3	The Baia River and the biodiversity survey camp.
Plate 4	The Liddell River at the Juha North survey area.
Plate 5	The Karius Range from Juha South survey area.
Plate 6	Erosion on the Baia River.
Plate 7	The South Karius survey area was in swamplands.
Plate 8	The Karius Range, here with steep scrub covered sides.
Plate 9	The Maruba River at Deviation Camp.
Plate 10	Burnt small crowned <i>Nothofagus</i> forest at the Homa Deviation.
Plate 11	Elliot trap.
Plate 12	Cage trap in tree roots.
Plate 13	Assembling a harp trap.
Plate 14	Camera trap in position.
Plate 15	Bat detector.
Plate 16	Stream disappearing into a sinkhole at Juha North survey area.
Plate 17	A large waterfall has its source in this upwelling from karst near the Liddell River.
Plate 18	Sinkhole swamp on Hides Ridge.
Plate 19	Water ponding on karst on the Oil ROW approaching the Mubi valley.
Plate 20	Successions on landslides in the Baia River area.
Plate 21	Epiphytes in lower montane small crowned forest with <i>Nothofagus</i> .
Plate 22	<i>Dichroa sylvatica</i> .
Plate 23	<i>Garcina archboldiana</i> .
Plate 24	<i>Pentaphragme grandifolium</i> .
Plate 25	<i>Begonia pseudobotrys</i> .
Plate 26	<i>Alocasia holrungii</i> .
Plate 27	<i>Ficus arfakensis</i> .
Plate 28	<i>Agalmyla</i> sp.
Plate 29	<i>Lithocarpus rufovillosus</i> .
Plate 30	<i>Curcuma</i> sp.
Plate 31	<i>Rhododendron</i> sp.
Plate 32	<i>Rhododendron</i> sp.
Plate 33	Plush coated ringtail.
Plate 34	Doria's Tree Kangaroo.
Plate 35	Large tree mouse
Plate 36	Spotted cuscus in Port Moresby market.
Plate 37	Western White-eared Giant-rat.
Plate 38	Mountain Cuscus.
Plate 39	Rock-dwelling Giant-rat.
Plate 40	<i>Rhinolophus euryotis</i> .
Plate 41	<i>Hipposideros calcaratus</i> .

Plate 42	<i>Aselliscus tricuspidatus</i> .
Plate 43	<i>Hipposideros diadema</i> .
Plate 44	<i>Nyctimene aello</i> .
Plate 45	<i>Paranyctimene</i> sp.
Plate 46	Red-bellied Pitta.
Plate 47	Scaly Thrush.
Plate 48	Rufous-backed Honeyeater.
Plate 49	Brown-collared Brush-turkey.
Plate 50	Papuan Frogmouth.
Plate 51	Superb Fruit Dove.
Plate 52	Black Fantail.
Plate 53	Garnet Robin.
Plate 54	Wattled Ploughbill.
Plate 55	Orange-crowned Fairywren
Plate 56	A common skink <i>Lipinia nototaenia</i> .
Plate 57	The gecko <i>Cyrtodactylus</i> sp 1
Plate 58	The agamid <i>Hypsilurus modestus</i> .
Plate 59	Keelback snake <i>Tropidonophis statisticus</i> .
Plate 60	Boelen's Python <i>Morelia boeleni</i> at Moran.
Plate 61	New Guinea Freshwater Crocodile <i>Crocodylus novaeguinea</i> at Baia River.
Plate 62	Water Python <i>Liasis fuscus</i> at Baia River.
Plate 63	Green Tree Python <i>Morelia viridis</i> at Juha.
Plate 64	The common tree frog <i>Litoria infrafrenata</i> .
Plate 65	The torrent frog <i>Litoria wollastoni</i> from Benaria.
Plate 66	The tree frog <i>Litoria pronimia</i> .
Plate 67	An undescribed torrent frog <i>Litoria</i> sp. from Benaria.
Plate 68	The recently described tree frog <i>Litoria majikthise</i> .
Plate 69	A tree frog <i>Litoria</i> ?iris.
Plate 70	The tree frog <i>Litoria arfakiana</i> from South Karius.
Plate 71	A tree frog <i>Nyctimistes</i> sp. with road map eyelids typical of the genus.
Plate 72	The microhylid <i>Asterophrys turpicola</i> .
Plate 73	A new species of microhylid <i>Xenobatrachus</i> sp. from Juha South.
Plate 74	The microhylid <i>Choerophryne allisoni</i> (photo I. Woxvold).
Plate 75	An undescribed species of microhylid <i>Albericus</i> sp1 (small).
Plate 76	A new species of microhylid <i>Oreophryne</i> sp. nov. from near the Homa Deviation.
Plate 77	The ranid frog <i>Rana</i> cf <i>grisea</i> (attribute to S. Richards).
Plate 78	Tree frog laying eggs on leaf above sinkhole swamp on Hides Ridge.
Plate 79	Tree frog eggs on leaf waiting for tadpoles to hatch and drop into sinkhole swamp.
Plate 80	Unbroken low altitude medium crowned forest on the route from Juha to the Hides Gas Conditioning Plant .
Plate 81	The Benaria River.

Plate 82	Forest near the Kondari River looking towards the Tagari River.
Plate 83	Possible site of the Benaria crossing.
Plate 84	The Mubi River.
Plate 85	The northern end of Lake Kutubu.
Plate 86	swamp forest complexes at Lake Kutubu.
Plate 87	The oil ROW in karst near the Kutubu Central Processing Facility.
Plate 88	The oil ROW near the Iwa Range.
Plate 89	The Ai'io River Swamp Forest complexes.
Plate 90	Sago swamps on the Ai'io River.
Plate 91	Manu village.
Plate 92	The Mubi valley.
Plate 93	The oil ROW approaching the Mubi valley.
Plate 94	The oil ROW in the Mubi valley.
Plate 95	Kantobo.
Plate 96	Descent to the Mubi crossing.
Plate 97	The Mubi crossing.
Plate 98	The Kikori floodplain.
Plate 99	The oil ROW in the Kikori.
Plate 100	The road to Gobe.
Plate 101	The Kikori (Kaia) crossing.
Plate 102	Kopi.
Plate 103	The Omati River.
Plate 104	Landfall on the Omati River.
Plate 105	Cutting on road at northern end of Lake Kutubu.
Plate 106	A road through a saddle.
Plate 107	Hand built flowlines at Hides.

Annexes

- Annex 01** Takeuchi, W. (2005). Botanical results from a floristic survey of montane environments within the PNG Gas Project concession. Report to Enesar Consulting Pty. Ltd.
- Annex 02** Takeuchi, W. (2008). Flora of the upstream portion of the PNG LNG Project, Southern highlands and Western Provinces, Papua New Guinea. Report to Coffey Natural Systems.
- Annex 03** Mamu, T., Gebia, O., Enoch, I., Kuduk, M., and Ona, A. (2005) Report for an Assessment Survey of Terrestrial Mammals for PNG Gas Project, Papua New Guinea. Report to Enesar Consulting Pty. Ltd.
- Annex 04** Mamu, T. (2008) Environmental Impact Study of Terrestrial Mammals for the PNG LNG Project, Papua New Guinea. Report to Coffey Natural Systems.
- Annex 05** Richards, G. C. (2005) The Papua New Guinea Gas Project: a study of bat faunal biodiversity and an assessment of potential impacts. Report to Enesar Consulting Pty. Ltd.
- Annex 06** Richards, G. C. (2008) The Papua New Guinea Liquefied Natural Gas Project: A study of bat faunal biodiversity and an assessment of potential impacts. Report to Coffey Natural Systems.
- Annex 07** Woxvold, I. and Crome, F. (2005). A report on the Avifauna of the Papua New Guinea Gas project area. Report to Enesar Consultants Pty. Ltd.
- Annex 08** Woxvold, I. (2008). Avifauna of the upstream portion of the PNG LNG Project, Southern highlands and Western Provinces, Papua New Guinea. Report to Coffey Natural Systems.
- Annex 09** Richards. S. (2005) Biodiversity And Conservation Status Of Herpetofauna Of The Papua New Guinea Gas project area. Report to Enesar Consulting Pty. Ltd.
- Annex 10** Richards. S. (2008) Biodiversity and conservation status of herpetofauna of the Papua New Guinea Liquefied Natural Gas Project. Report to Coffey Natural Systems.

1 Acronyms

asl	above sea level
BVG	Broad Vegetation Group
Kutubu CPF	Kutubu Central Processing Facility
CPM	Central Papuan Mountains EBA
dbh	diameter at breast height (1.2 m above ground)
EBA	Endemic Bird Area
EIS	Environmental Impact Statement
EMP	Environmental Mitigation and Management Plan
FIMS	Forest Inventory Management System
ICDP	Integrated Conservation and Development Project
IUCN	International Union for Conservation of Nature
JVP	Joint Venture Partners
KICDP	Kikori Integrated Conservation and Development Project
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
m	metre
MEG	Mono-ethylene glycol
PNG LNG Project	Papua New Guinea Liquefied Natural Gas Project
PNGGP-1988	The first Papua New Guinea Gas Project EP submitted in 1988.
PNGGP-2005	The second Papua New Guinea Gas Project EIS submitted in 2005.
project area	PNG LNG upstream project area
RAP	Rapid Assessment Program
RoRo	Roll-on roll-off
ROW	Right of Way
SPL	South Papuan Lowlands EBA
WMA	Wildlife Management Area
WWF	World Wildlife Fund

2 Geographic conventions

PNG refers to the entire country of Papua New Guinea including the Bismarcks and northern Solomons

New Guinea refers to the large island of New Guinea (PNG + Indonesia) without satellite islands

New Guinea and its' satellite islands refers to the large island of New Guinea and its satellite islands including the Raja Ampats and the east Papuan Islands (Louisiades and the d'Entrecasteaux groups)

PNG mainland refers to the mainland portion of the country of PNG.

All geographic coordinates in the text and tables are in WGS Zone 54S

3 Executive summary

1. This report provides an overview of the biodiversity of the PNG LNG upstream project area for use in environmental impact assessment of the PNG LNG Project.
2. The report summarises available data on mammals, birds, reptiles, amphibians and flora and integrates data collected by World Wildlife Fund (WWF) since 1995 between the Kikori delta and the Kutubu Central Processing Facility, and biodiversity surveys carried out in 2005 and 2008 specifically for the Papua New Guinea Liquefied Natural Gas (PNG LNG) Project.
3. The PNG LNG project area covers the entire watershed of the Kikori River and extends westwards to tributaries of the Strickland River in the Juha area. The region is largely limestone with volcanics in the north. The altitudinal range is from 3650 m asl in the northeast of the KICDP area to sea level. The highest elevation the Gas Project traverses is around 2800 m asl on the Hides gas field.
4. For impact analysis purposes the project area was divided into 10 bioregions, each characterised by data from a range of sampling sites.
5. Floristic diversity in the project area is very high; the orchids, in particular, may be the most speciose family with 342 species recorded in the vicinity of Kutubu alone.
6. While there is a specialised limestone flora it is not restricted to the limestone of the project area.
7. 86 species of non-volant mammals have been recorded in the project area and the fauna is dominated by rodents. The number of species of arboreal marsupials increases with altitude as does the percent of endemic species.
8. 47 species of bats have been recorded and a further 28 species could occur.
9. 402 species of birds have been recorded in the project area and a further 131 species could occur. The number of species decreases with increasing altitude but is highest in the mid-montane regions. The proportion of the avifauna made up of primary forest species and the proportion of endemic species is highest in the Hides region.
10. Birds-of-paradise are particularly diverse in upland regions.
11. Migratory birds are concentrated in the coastal areas and wetlands in the Kikori Lowlands
12. The reptile fauna remains less well known. 61 species have been recorded in the project area and 11 species new to science have been discovered. Crocodiles and freshwater turtles are restricted to the lowland rivers.
13. 107 species of frogs have been recorded in the project area, which has the highest diversity of amphibians recorded in New Guinea. Over 50 of these

species are new to science. Microhylids make up over half of the total frog fauna.

14. Overall the faunal communities are intact, with many rare species persisting next to oil project facilities, reflecting the pristine nature and isolation of most of the KICDP area, the small footprint of the oil project and the strict environmental controls that have been maintained to date.
15. The Juha area is particularly diverse and apart from a few wells drilled in the 1980s is in superlative condition and is free from hunting and human influences.
16. It is unlikely that many faunal species will be found to be restricted to small, localised areas of the project area but cavernicolous bats may roost or breed only in certain caves.
17. Species diversity declines from the lowlands to the highlands but is generally highest at intermediate altitudes where lowland and upland faunas overlap.
18. The proportion of primary forest specialist birds, marsupials and specialist amphibia increases with altitude.
19. Though overall diversity decreases at higher altitudes, faunal assemblages are most specialised and restricted in the high montane bioregions, i.e. the Western Volcanics and Northern Montane Karst.
20. The lowland regions are species-rich though the faunas tend to include many taxa that are widespread and adapted to disturbed habitats.
21. The Kikori Lowlands and the Moro Region are the most important bioregions for waterbirds and swamp fauna.
22. 142 species of plants and animals are listed as of conservation concern by IUCN or under the Papua New Guinea Fauna (Protection and Control) Act.
23. The *Nothofagus* forest on karst above 1800 m asl on the Hides Ridge, the Juha Area, and the forests above 1800 m asl on the Homa Deviation were identified as a noteworthy area because of a concentration of biodiversity values, the superlative ecological condition of the forest and its sensitivity to fire and dieback.
24. Caves are abundant in the karst of the KICDP area and are critical for conservation of the cave dwelling bats. Particular species require particular types of caves and are very selective in what caves they roost and breed in.
25. Sinkhole swamps, off river water bodies, swamp forests, heads of upland streams, stream refuges in unstable landscapes and river crossings were also identified as special focus habitats requiring particular impact mitigation.
26. General impacts are discussed under the headings of clearing and forest loss, damage and disturbance to caves, erosion, fire, dieback, invasive species, edge effects and hunting.

-
27. Direct impacts from the PNG LNG Project facilities and operations will, like those for oil, remain localised and are predicted after implementation of mitigations to be generally minor or low.
 28. The most important impacts are likely to be indirect impacts such as fire, ingress of weeds, diseases and exotic species, overhunting and improved access to the area.

Introduction

4 The PNG LNG Project

4.1 Background

Oil is being exported from the hydrocarbon fields of Kutubu, Moran, Agogo, Mananda and Gobe in the Southern Highlands and Gulf Provinces of Papua New Guinea along a crude oil export pipeline that runs from a processing facility in the ranges above Moro (**Plate 1**) then along the Kikori valley to a marine terminal, Kumul platform, in the Gulf of Papua. Plans to extract gas from these same fields and export it to Australia have been in existence for some time and an Environmental Plan was prepared in 1998 for what was the first attempt at establishing a PNG Gas Project (PNGGP-1988). The concept was to transport gas in a pipeline paralleling the oil export pipeline, thence sub-sea to Cape York and overland to Gladstone, Queensland. This project was permitted but not constructed. A second PNG Gas Project (PNGGP-2005) aiming to extract the gas at Hides as well as the oil fields was launched in 2004 and an Environmental Impact Statement (EIS) prepared (Enesar 2005) but the project did not proceed.

In 2006 an entirely new project the Papua New Guinea Liquefied Natural Gas Project (PNG LNG Project) was launched. This new project is based on extracting gas, not only from the wells associated with the oil fields, but also from gas deposits to the north and northwest at Juha, Hides and Angore and Southeast Hedinia near Kutubu, and piping it to a Liquefied Natural Gas (LNG) plant on the south coast of PNG for export as LNG in tankers.

The project is divided into two geographical sections. “Upstream” refers to all pipelines and facilities from the Juha gas field to the coast at Omati, plus the marine section from Omati to the landfall at the LNG plant¹. “Downstream” refers to the pipelines and facilities from the landfall at the LNG plant, the LNG plant and associated export facilities.

From here on in the term “PNG LNG Project” refers only to the upstream terrestrial portion of the project.

4.2 Project description

The Papua New Guinea Liquefied Natural Gas (PNG LNG) Project involves the development of a number of gas fields and facilities in a series of development phases to produce liquefied natural gas (LNG) for export. The development will also produce condensate. The development of the Hides, Angore, and Juha gas fields and blowdown of the gas caps at the existing Kutubu, Agogo and Gobe oil fields will supply the gas resources. An extensive onshore and offshore pipeline network will enable transportation of the gas to a new LNG Plant near Port Moresby and stabilised condensate to the existing oil processing and storage, and offloading facilities at the Kutubu Central Processing Facility and Kumul Marine Terminal respectively. Small amounts of condensate are also produced at the LNG Facilities site.

Esso Highlands Limited (Esso), a Papua New Guinea subsidiary of the Exxon Mobil Corporation (ExxonMobil), is the operator of the PNG LNG Project. The PNG LNG Project will be developed in five phases over a period of 10 years to ensure reliability and consistent quality of supply of LNG over the 30 year life of the project.

¹ Technically, from the wellhead to the outlet flange of the onshore pig receiver at the LNG plant

A list of the proposed developments is provided below, and **(Figure 1)** shows a schematic of facilities and pipelines.

4.2.1.1 Upstream development components:

- Hides gas field development:
 - Seven wellpads with a total of eight new wells and re-completion of two existing wells.
 - Hides gathering system including gas flowlines from new and re-completed Hides wells.
 - Hides spinline and mono-ethylene glycol (MEG) Pipeline in the same right of way (ROW).
 - Hides Gas Conditioning Plant.
 - Hides–Kutubu Condensate Pipeline in the same ROW as the LNG Project Gas Pipeline.
- Juha gas field development:
 - Three new wellpads with four new wells.
 - Juha gathering system including gas flowlines from new Juha wells.
 - Juha spines and MEG Pipeline in the same ROWs.
 - Juha Production Facility.
 - Juha–Hides pipelines right of way (ROW) containing three pipelines including Juha–Hides Rich Gas Pipeline, Juha–Hides Liquids Pipeline and Hides–Juha MEG Pipeline.
- Angore gas field development:
 - Two new wellpads with two new wells.
 - Angore gathering system including gas flowlines from new Angore wells.
 - Angore spinline and Angore MEG Pipeline to Hides Gas Conditioning Plant, both in the same ROW.
- Gas from existing fields:
 - Gas treatment at the Agogo Production Facility and a new Agogo Gas Pipeline from the Agogo Production Facility to LNG Project Gas Pipeline.
 - Gas treatment at the Gobe Production Facility and a new Gobe Gas Pipeline from the Gobe Production Facility to LNG Project Gas Pipeline.
 - Gas treatment at the Kutubu Central Processing Facility and a new Kutubu Gas Pipeline from the Kutubu Central Processing Facility to the LNG Project Gas Pipeline.
- South East Hedinia gas field development: one new wellpad and two new wells; new gathering system including gas flow lines from the South East Hedinia new wells to the Kutubu Central Processing Facility in the same ROW as the Kutubu Gas Pipeline.
- Kopi scraper station.
- LNG Project Gas Pipeline:
 - Onshore: from Hides Gas Conditioning Plant to Omati River Landfall.
 - Offshore: Omati River Landfall to Caution Bay Landfall.

4.2.1.2 LNG facilities development components:

- Onshore LNG Plant including gas processing and liquefaction trains, storage tanks, flare system and utilities.
- Marine facilities including jetty, LNG and condensate export berths, materials offloading facility and tug moorage.

4.2.1.3 Supporting facilities and infrastructure:

In addition to the principal gas production, processing and transport, and LNG production and export facilities, the project will involve the following permanent infrastructure and facilities:

- New roads and upgrade of existing roads.
- New bridges and upgrade of existing bridges.
- Upgrade of two existing airfields (upstream at Komo and Tari).
- New helipads (multiple).
- New wharf and an upgrade of the existing Kopi roll-on, roll-off facility.
- Water supply systems and pipelines, wastewater and waste management facilities.
- Operations Camps (at Hides, Juha and Tari).

A series of temporary works and access roads will also be required during the construction phase, including:

- Construction camps (multiple).
- Material/pipe laydown areas.

(information received from Coffey Natural Systems between March and September 2008).

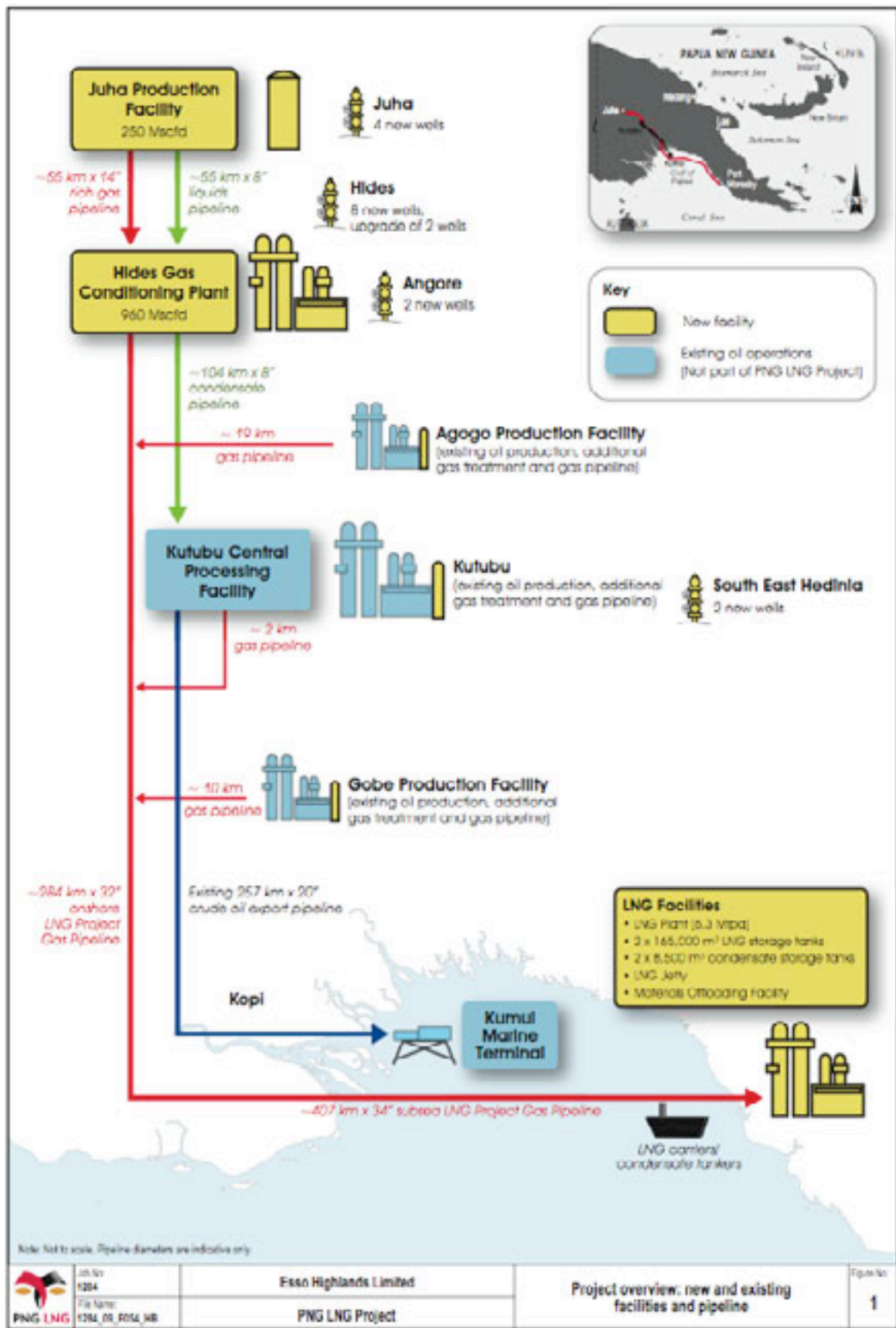


Figure 1 Schematic layout of the PNG LNG Project.

5 Study strategy

Gathering appropriate biodiversity data for impact analysis of a simple project with a small footprint may be a simple matter of a short inventory at the site repeated over a couple of seasons. However, the PNG LNG project is a major linear infrastructure project that traverses from high mountains to the coast in a largely undeveloped mega-diverse tropical forest landscape with virtually no road access to most of it and with landowners noted for their independence who have a power of veto over any survey activities on their lands.

Development of the strategy for biodiversity analysis of the PNG LNG Project has to accommodate the facts of the nature of the New Guinea biota, the uncertainty associated with pipeline routing, the peculiar difficulties of sampling tropical forest faunas and floras, the severe logistical constraints, and the difficulty of defining an appropriate reference area for impact analysis.

5.1 Challenges

5.1.1 The nature of the New Guinea biota

Papua New Guinea is recognised as a country of very high biodiversity: it ranks sixth in the world in terms of endemism for mammals, birds and amphibians; and it ranks fifth in mammals, ninth in birds and second for amphibians in terms of species per 1,000 km². Papua New Guinea is in a special biogeographic position being a transition zone between the flora and fauna of Eurasia and of Australasia. For example, woodpeckers, ungulates, monkeys, and placental carnivores extend east only as far as western Indonesia. Honeyeaters, birds-of-paradise, marsupials and echidnas only go as far west as eastern Indonesia. It is thought that New Guinea and Australia, together with South America, Antarctica and Africa, formed the super-continent Gondwanaland. The tectonic plate holding these land masses floated north, colliding into the plates that held Asia; and in so doing, it carried with it a 'southern' flora and fauna. The mix in New Guinea is most obvious in its vegetation: the montane flora is closely related to that of the southern continents (for example, the presence of southern beech (*Nothofagus* spp.), whereas the lowland flora is more Asian in its affinities.

Biogeographers sometimes stress the affinities of Papua New Guinea's biota at the expense of its peculiarity. The high degree of endemism of the flora at the species and genus level and the fact that many plant families are better represented in New Guinea than anywhere else indicates strong independent development of the biota of New Guinea over a long period of time and, in particular, that New Guinea has developed its own flora (Johns, 1993; Balgooy *et al.* 1996).

The complex geological history of New Guinea, particularly in the east of the island, has produced a similarly complex pattern of speciation in the biota. Different mountain ranges can have different species, and species replace each other along steep altitudinal gradients. Many species are superspecies consisting of several very distinct subspecies on different mountain ranges. This differentiation may be on a small geographic scale but can be genetically and morphologically large. It is best understood in birds, which are the most studied animal group in Papua New Guinea.

5.1.2 Uncertainty in pipeline routing

All things being equal, the ideal pipeline route is a straight line between two points: it would involve clearing the least amount of habitat. This rarely, if ever occurs in reality, and pipeline routes must bend sometimes and must change throughout the design process as information on terrain and other constraints comes to hand. Even when the design is finalised, flexibility is required during construction because, until a survey or construction team gets on the ground, the feasibility of any particular part of the route remains simply an hypothesis. Unmapped terrain features, geological anomalies, emergent safety issues, undiscovered social issues, and small scale biological and cultural finds are amongst a constellation of factors that will force tactical rerouting to find the most appropriate path for a pipeline. Perfect information can never be available in the design phase.

Good biodiversity data must be generated early in the project design phase so that it can strategically inform route choice but, by definition, the route is in an early stage of development when this has to happen. The data generated must also be robust to the inevitable evolution of the route design and be able to respond to the requirement for flexibility even into the construction phase.

5.1.3 Logistical, security and seasonal constraints

The area of the PNG LNG Project is remote and serviced by few roads. Transport is fundamentally by air, i.e helicopter, and all survey work has to be performed from specially constructed fly camps serviced by helicopter. These sites have to be safe, and serviceable from the air thus limiting where they can be placed. Most importantly helicopters can only work in favourable weather which means sampling in the wet season in this high rainfall area is too hazardous. Finally all survey work requires permission from landholders and the absence of local conflict which is not always forthcoming when needed.

Mounting expeditions on foot with carriers could be a way around these issues but was not feasible within the time and safety constraints of the project.

This means that the location of survey sites and the time when they can be sampled cannot be perfectly dictated. A survey site can only be as geographically and temporally close to where it might be ideally put, as logistics, weather and social conditions will allow.

5.1.4 Sampling tropical faunas and floras

Tropical faunas and floras present a range of peculiar sampling issues.

- They are usually very diverse and, at least for birds, most species in a community are rare. Census periods thus need to be long to get exhaustive lists of species present. For example Beehler et al. (1995) concluded that, in the Lakekamu basin, a minimum of 3 weeks is necessary to census 90% of the forest bird fauna present at any one location, while an exhaustive census would require at least 6 weeks. Such census periods are usually impractical and rarely, if ever, achievable.
- Weather can confound sampling. Birds, for example are not as active and are harder to detect during heavy tropical rain, but frogs are more detectable in these conditions and, conversely, less detectable in the drier conditions that favour bird observations.
- Migrant species can only be detected during the right seasons.

-
- Many tropical birds, while not migratory in the sense that the entire population departs for another region, are to some degree nomadic and/or less detectable at certain times of year. Many resident populations undergo altitudinal and horizontal movements within New Guinea. For instance, frugivores and nectarivores are nomadic to varying degrees and their presence depends upon the seasonality of fruiting and flowering plants. In addition, some species that may be present all year round are harder to detect at certain times of year, such as many pigeon species that typically cease calling during the wet season. These phenomena are relatively well understood in Asia (McClure 1974) and Australia (Crome 1993; Nix 1993), though they have not been studied to the same extent in PNG. Some mammals may also undergo, as yet unrecorded local movements and migrations².
 - Not only is there seasonal variation but also year to year variation in species present. Repeated surveys at single locations have consistently shown that the number and variety of resident birds detected varies strongly between years (e.g. Beehler et al. 1995; Diamond and Bishop 2003).
 - As well as complex geographical variation in distribution (**section 5.1.1**) There appears to be natural small scale patchiness in the distribution of many tropical species that has no obvious explanation.
 - Some birds associate in mixed species foraging flocks that occur at unpredictable times through the day, at other times they may be difficult to detect.
 - Some species are particularly hard to catch or detect. For example the New Guinea rodent *Pogonomys loriae* is also found in Queensland, where specimens of have been obtained by shooting, from road kills or brought in by domestic cats. The species has, as yet, never been able to be caught by trapping in Australia and it escaped detection in all mammal surveys prior to the 1980s (F. Crome *pers. obs.*). Similarly some birds are rarely, if ever seen, and can only be detected by mist netting.
 - New Guinea is renowned for the altitudinal variations in faunas – species can replace one another over short altitudinal distances. A sample site may only be 50 m too low in altitude to detect particular species.
 - Positive identification of New Guinea plants requires fertile specimens be collected and then identified back in herbaria. Flowering periods are highly seasonal and there is great year to year and place to place variation in phenology (reproductive patterns). There is a significant element of luck in botanical surveying in the tropics.

5.1.5 Definition of a project area

There is no *a priori* logical, accepted way of defining a project area relevant to analysis of impacts on biodiversity. Impacts vary in their relevance and intensity in space and time and vary from being potentially restricted to the immediate area under construction, e.g loss of a single tree, or potentially be national or international in scale e.g. the accidental

² . For example local informants from Samberigi indicated tree kangaroos migrated in large groups that could be ambushed by hunters at predictable times of the year (*pers. comm.* to F. Crome 2005).

introduction of an exotic disease or pest that may spread through PNG and into the Indonesian part of the island.

In defining a project area for analysis there is a natural tension between defining as small an area as possible around the project footprint in order to minimise the apparent size of the project and expanding the project import to national and global significance.

For the purposes of this analysis an appropriate project area lies between these two extremes and ideally covers an area that is likely to encompass most of the impacts, has some ecological rationale, is an area within which the concept of “local” populations of species has some meaning, and has some obvious relevance to biodiversity conservation.

5.2 Approach

This analysis has taken the view that the definition of project area is the key to approaching the challenges discussed in **section 5.1**.

The joint venture partners (JVPs) of the oil project, and the World Wildlife Fund (WWF) have been involved in a collaboration since 1994 aimed at facilitating conservation efforts in the Kikori basin via an Integrated Conservation and Development Project (ICDP) whereby WWF works with local communities to foster conservation through sustainable development activities.

To achieve this a Kikori ICDP (KICDP) area was defined that encompassed the entire drainage of the Kikori River extending over 300 km from the Southern Highlands to the coast and which includes the existing oil export project and both previous PNG Gas Projects (**Figure 1**). This area was defined using ecological and impact relevant logic in that:

- Secondary impacts brought about by the project attracting people to the project area were considered to be the most significant potential impacts of the oil developments and the KICDP area is an appropriate scale on which to manage such impacts by including all road and river access routes to the area, and by developing relationships with local stakeholders.
- It is a catchment based approach.
- It is large enough to be able to say that the biota that inhabits it does so in viable populations.

The KICDP area is now internationally known as a significant conservation management area and thus has major relevance to biodiversity conservation in New Guinea.

Since 1995 WWF have carried out numerous biodiversity surveys and to date some 70 sites have been sampled in the KICDP area sufficient to provide an excellent characterisation of the area (**section 4.1**, and **Appendix 2**).

If the KICDP area, suitably expanded to include the new Juha gas field, is used as the project area for impact analysis the criteria for project area outlined above in **section 5.1.5** are largely met and the challenges discussed in **section 5.1** can be addressed, as far as is possible. The logic is as follows.

-
1. The large number of WWF sites sampled over several years, together with infill surveys in the areas outside the KICDP area specially carried out for the PNG LNG project can be used *in toto* to provide a suite of species for impact analysis – a “project species suite”.
 2. While any particular facility site or point along a pipeline route will not have the entire project species suite, any one of that suite has a chance of being located somewhere in the whole set of project elements consisting of facilities, the logistics system and the entire length of pipelines (approximately 300 km).
 3. While any one survey under-samples the species present at a site, the set of sites comes much nearer to a total inventory for the entire set of project elements.
 4. Moving the pipeline route over short distances would not require reassessment of biodiversity present because a large enough area has been characterised so that the “project species suite” is likely to include any species that may occur in the new route segment that might not have been in the previous route segment. The impacted biota stays more-or-less the same.
 5. This flexibility afforded to pipeline route design is compensated by including in the impact analysis a broad enough range of species so that the analysis cannot be accused of excluding certain species that may be present but have not been detected. This range can be made more comprehensive by including in the “project species suite” those species that are likely to be present although not yet detected. This can be done for groups with adequate information i.e. non-flying mammals, birds and bats.
 6. By taking a broader view the infill surveys mentioned in point 1 above do not need to be located exactly on a pipeline route but can be located more generally where they can contribute to characterising habitats or areas not or under-represented in the WWF data. This decouples the sampling from logistical constraints to some extent.
 7. By using a large species suite the impact analysis leans on the side of conservatism and provides a stronger test for the project. Such stronger testing is appropriate in terms of the richness and value of the biota that may be at risk.
 8. Mitigations for impacts on the biota will, as far as possible, be developed as general rules for the entire project and so most species will be covered by general mitigations.
 9. For those species that have special requirements and/or are restricted to particular altitudinal zones or habitats mitigations can be developed specific to certain areas and species groups. This can be assisted by regionalisation of the data to some extent and this has been done in this analysis using bioregions (**section 6.3**).
 10. Impacts that require small scale mapping to mitigate, e.g. avoiding caves, can be mitigated at the Environmental Management Plan stage in a clearance survey when the pipeline is pegged just prior to construction crews arriving.

6 The project area

6.1 Definition

The KICDP area is the basis for defining the project area but it does not encompass all potential upstream PNG LNG Project components. Gas development in the Juha area will extend the project beyond the Kikori drainage and into the drainage of the Strickland River in Western Province so a PNG LNG upstream project area (henceforth termed “project area”) has been defined based on extending the KICDP area westwards to encompass the Juha area (**Figure 2**).

This extension does not encompass the entire catchment of the Strickland River but attempts to follow catchment based approaches by including the catchment of the Liddel River, the southern catchment of the Burnett River and the northern catchment of the Wai Asia River. Thus the potential impact areas that might feed into the Strickland River have all been included. Like the KICDP area the extension is undeveloped and largely uninhabited and possesses the same qualities that made the KICDP area valuable from a conservation perspective.

6.2 Description

Limestone, mostly polygonal and doline karst, karst plains and plateaux with karst corridors, dominates the project area. Much of this limestone is polygonal karst³; extremely rugged terrain that is basically shaped like an egg carton with numerous small very steep pinnacles and dolines. The Darai plateau in the west of the project area is the most extensive area (**Figure 3**). Around Kopi the karst consists of towers rising out of the surrounding karst plain. The Kikori River itself flows through a flat karst plain overlain with alluvium. In many places the “soil” consists of a thin living organic root mat overlying the limestone pavement.

There are extensive areas of volcanics in the north and north west of the project area produced by Mt Bosavi, Mt Sisa and Doma Peaks. The beautiful cone of Mt Bosavi dominates the landscape to the west of the oil facilities at Kutubu and is now a focus of WWF activities. North of Bosavi and south west of the Hides gas field sits the blown out crater of Mt Sisa it's lava flows responsible for the basalt soils of the agricultural lands around Komo. The Doma Peaks, northeast and outside the project area, is a region of remnant volcanic cones and domes, volcanic and volcano-alluvial fans, and mudflows resulting from a massive eruption several hundred years ago. Flows from these eruptions to the westward over and through the limestones east of the Hegigio River, have formed a complex landscape which the LNG Project Gas Pipeline has to traverse.

Alluviums are uncommon in the project area and associated with the major river systems.

The northern part of the Juha extension encompasses the northern karst region and the southern part consists of mostly sedimentary lowlands and foothills drained by the Burnett, Liddell, Wai Asia and Baia Rivers (**Plate 3**). The area around the Baia River is highly erosive and land slips are widespread. The northern part of the Juha extension includes the Karius Range and is contiguous with the Hides area.

³ In this report it includes the doline, pyramid and tower karst of Löffler 1977 (following Williams 1971 and 1972)

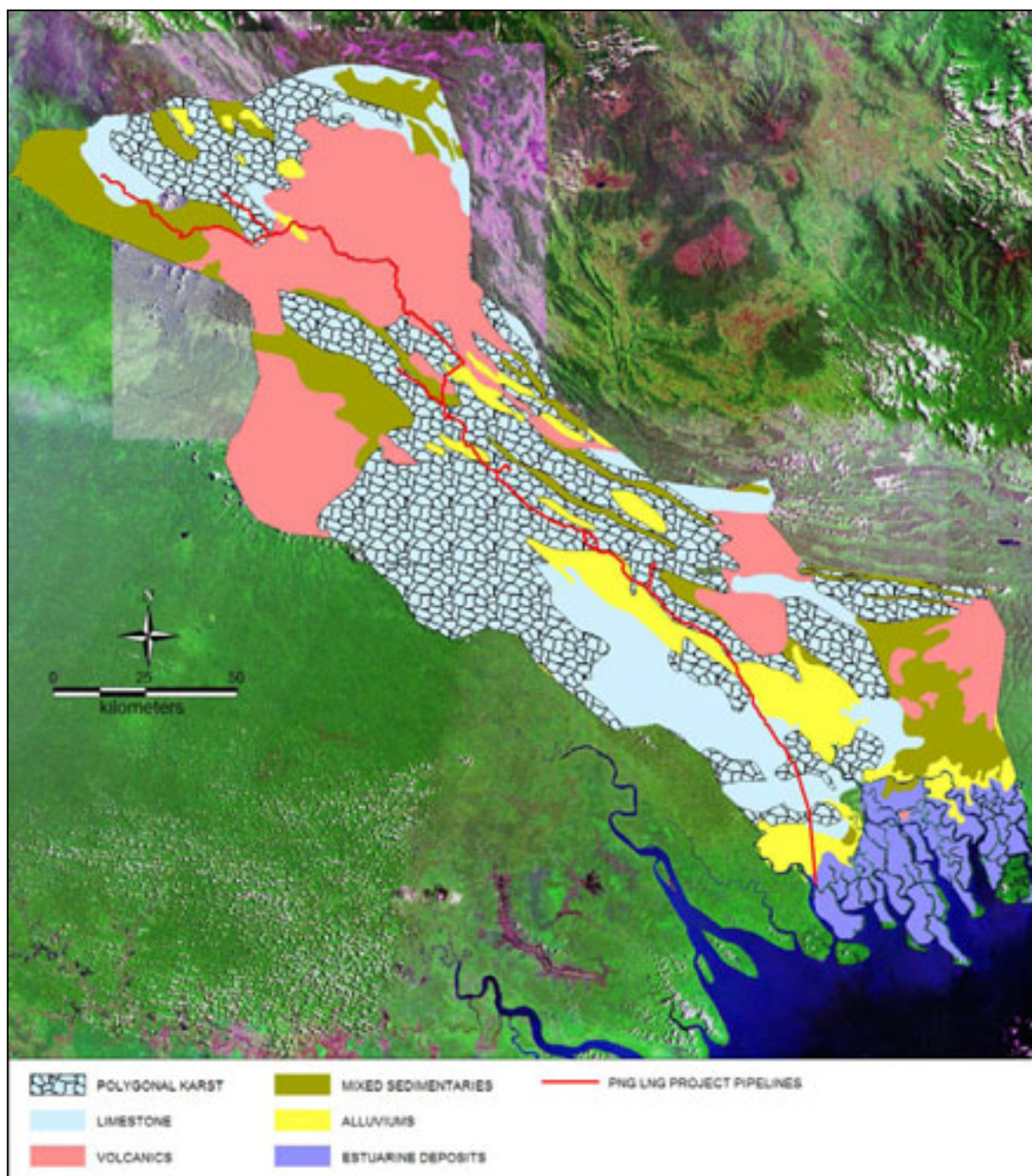


Figure 3 Substrates in the PNG LNG upstream project area.

6.3 Bioregions

The project area ranges from lowlands at sea level to peaks in the Mt Situba area in the north and the Mt Dini area in the north east that rise to 3368 and 3056 meters (m) above sea level (asl) respectively, and encompasses diverse geologies, geomorphologies, soils and habitats. This landscape diversity combined with the broad geographic extent of the PNG LNG Project means a great heterogeneity in biodiversity composition and hence a geographical variation in sensitivity to impacts and therefore relevance of mitigations in different parts of the PNG LNG Project.

To deal with this heterogeneity the project area has been divided into “bioregions”, defined on landscape, geology and ecology, to assist analysis (**Figure 4**). In this analysis a bioregion is an area characterised by landscape, geology, presumed climate and ecological

communities. It is an extension of the old term “land system” commonly used in PNG in the past but is larger and includes presumed fauna as well vegetation characteristics. The bioregions have notional boundaries, with the centres of the bioregions having the core bioregion features, and bioregions blending into each other at the boundaries.

The project area has been divided into 12 bioregions to assist impact analysis.

1. Kikori Lowlands

This is the floodplain of the Kikori River below about 200 m asl consisting of limestone plateaux, karst plains, polygonal karst and some sedimentary hills. The vegetation is various types of lowland rainforest, swamp forests and mangroves. The biota is typically lowland with good representation of riverine and swamp associated species.

2. Sirebi Lowlands

This is a complex lowland region in the southeast in the drainage of the Sirebi River ranging from 40 to 400 m asl and consisting of mixed sedimentary hills, alluviums, polygonal karst and limestone ridges. The vegetation is various lowland rainforest types but no mangroves and few swamp forests. The biota will have fewer swamp related species but more hill species

3. Libano Hegigio

This is a lowland region in the centre west of the project area consisting of mixed sedimentary and limestone ridges and hills of the Libano and Hegigio Rivers upstream of the Kikori junction ranging from about 200 to 600 m asl. The vegetation is various types of lowland and hill rainforest and it has a mixed lowland, riverine and hill fauna.

4. Darai Plateau

This is a distinctive plateau area of very rugged polygonal karst from about 300 m to 1100 m asl with little surface water. The vegetation is various types of lowland and hill rainforests and the flora and fauna is adapted to low nutrient conditions.

5. Western Lowlands

These are the lowlands of the northern tributaries of the Strickland River between about 200 m and 400 m asl consisting of sedimentary and limestone low hills and ridges. Some isolated hills rise to 700 m asl. The vegetation is various types of lowland rainforest and the rainfall is very high giving them montane characteristics. The biota is predominantly a lowland one but with many montane elements.

6. Western Foothills

These are the western and southern foothills of the Karius Range from about 400 to about 1200 m asl consisting of mostly limestone ridges grading into sedimentary ridges in the southwest. The biota is a mixture of lowland and montane.

7. Mubi River Karst

This bioregion consist of the karst and limestone plateaux on the Mubi River's junction with the Kikori River to Lake Kutubu covering most of the drainages of the Digimu and Mubi Rivers. The elevation ranges from approximately 200 to 1300 m asl and the vegetation is a

mixture of various types of hill rainforest with some swamp forests. The biota is rich consisting of lowland and lower montane species and areas of richer soils provide pockets of higher nutrient forests.

8. Moro Region

This is basically Lake Kutubu and the surrounding karst catchment at about 800 to 1000 m asl. The vegetation is types of hill rainforest and perched swamp forests. The biota in this bioregion is enriched with waterbirds associated with the lake.

It has generally been combined with the Iagifu Agogo Limestone Uplands for the WWF biodiversity surveys.

9. Iagifu Agogo Limestone Uplands

This is the high limestone and karst from about 1000 to 1400 m asl that contains the bulk of project facilities west of Moro and south of the Hegigio Gorge. The vegetation is various types of hill and lower montane very wet rainforest and the biota is typical of that of mid montane areas in PNG.

10. Western Volcanics

This is formed by the volcanic cones of Mounts Bosavi and Sisa and consists of cones, plains and footslopes and volcano-alluvial fans between about 280 to 2700 m asl. The bioregion is characterised by rich soils and a range of lowland and montane rainforests are supported. The fauna is diverse consisting of lowland and montane species.

11. Eastern Uplands Volcanics/Karst

This is an upland region of mixed limestone and volcanic hills, ridges, cones and slopes in the northeast of the project area, ranging from about 800 to 1800 m asl. The range of soils and altitudes supports a range of mid montane and montane forests and the biota is basically montane.

12. Northern Montane Karst

This is the high limestone in the north of the project area from 1800 to 3268 m asl and includes the Karius Range, the Hides Ridge and the high Levani Valley. The vegetation ranges from types of montane rainforest to alpine grasslands and the biota is montane and alpine.

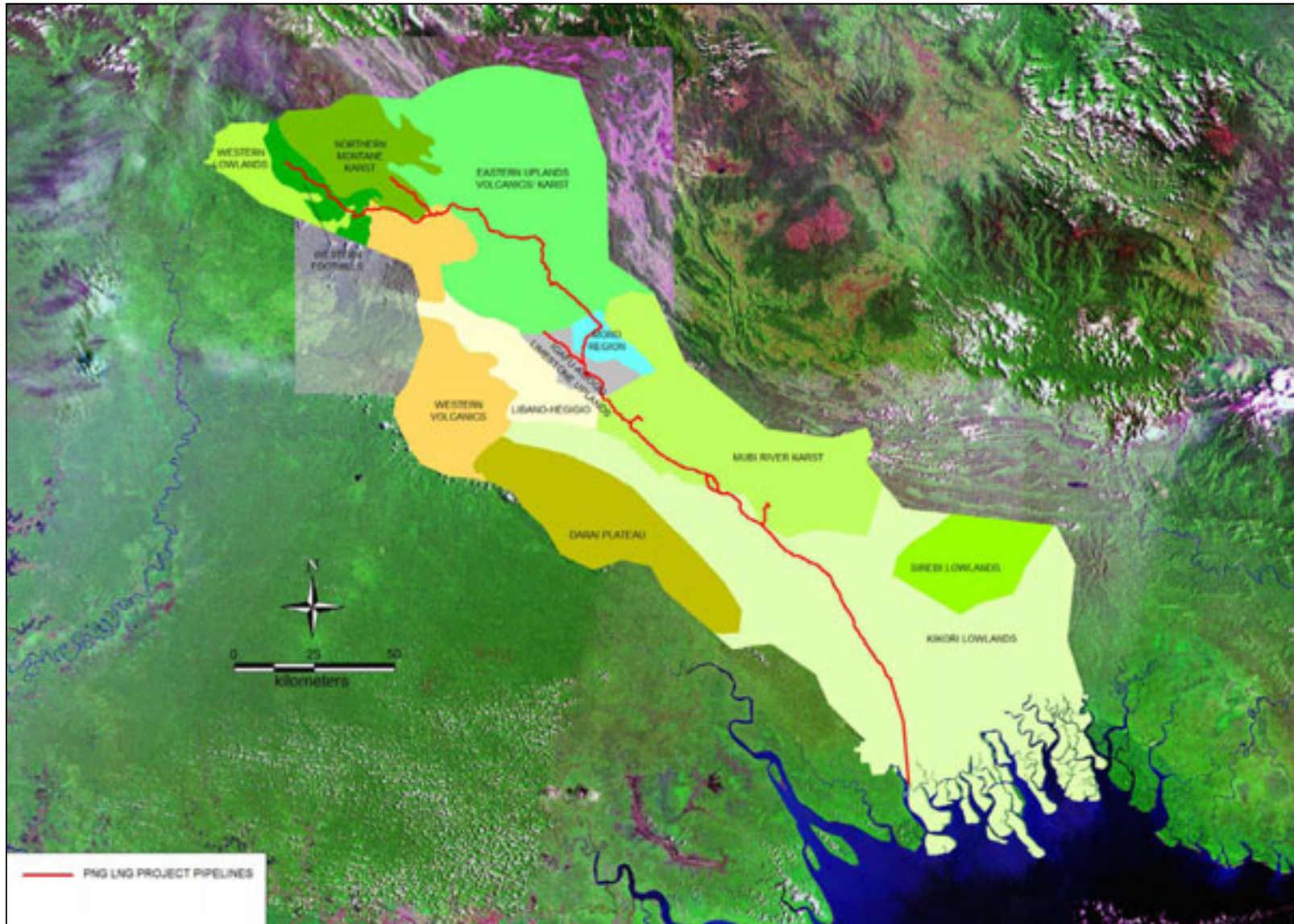


Figure 4 Bioregions of the PNG LNG upstream project area.

7 Data sources

Biodiversity data available for the project area come from WWF data for the KICDP area and surveys commissioned specifically for the PNG LNG Project carried out in 2005 and 2008.

7.1 WWF data

WWF have been surveying the KICDP area since 1995 and have amassed a large body of information from 70 sites within the KICDP area (**Figure 5**). References to the surveys are presented in **Appendix 1** while details of their location, timing and biological focus are presented in **Appendix 2**. Most WWF surveys were carried out at several sample sites within each of the respective survey areas and sample sites have been used when compiling the survey data in **Appendix 2**. The number of sample sites used in each survey depended upon the biological group being surveyed. Mammal surveys tended to sample at specific sample sites whereas bird and reptile surveys sometimes ranged over an area that encompassed several sample sites.

All the WWF fauna data is included in the species catalogues in **Appendices 6 to 11**.

7.2 LNG specific surveys in 2005 and 2008

Areas north of the oil fields, including Hides, had not been biologically explored to any significant extent by WWF, and the inclusion of gas developments at Juha brought the PNG LNG Project out of the Kikori drainage and into mostly uninhabited and previously biologically totally unexplored areas in the Strickland drainage.

Field surveys, therefore, were carried out in the Hides, Nogoli and Benaria areas in 2005, and at four sites on or near the proposed Juha-Hides Rich Gas Line alignment and one northeast of Homa in 2008.

The results of these surveys were produced as independent reports and are included as **Annexes 01 to 10**.

Annex 01 Takeuchi, W. (2005). Botanical results from a floristic survey of montane environments within the PNG Gas Project concession. Report to Enesar Consulting Pty. Ltd.

Annex 02 Takeuchi, W. (2008). Flora of the upstream portion of the PNG LNG Project, Southern highlands and Western Provinces, Papua New Guinea. Report to Coffey Natural Systems.

Annex 03 Mamu, T., Gebia, O., Enoch, I., Kuduk, M., and Ona, A. (2005) Report for an Assessment Survey of Terrestrial Mammals for PNG Gas Project, Papua New Guinea. Report to Enesar Consulting Pty. Ltd.

Annex 04 Mamu, T. (2008) Environmental Impact Study of Terrestrial Mammals for the PNG LNG Project, Papua New Guinea. Report to Coffey Natural Systems.

Annex 05 Richards, G. C. (2005) The Papua New Guinea Gas Project: a study of bat faunal biodiversity and an assessment of potential impacts. Report to Enesar Consulting Pty. Ltd.

-
- Annex 06** Richards, G. C. (2008) The Papua New Guinea Liquefied Natural Gas Project: A study of bat faunal biodiversity and an assessment of potential impacts. Report to Coffey Natural Systems.
- Annex 07** Woxvold, I. and Crome, F. (2005). A report on the Avifauna of the Papua New Guinea Gas project area. Report to Enesar Consultants Pty. Ltd.
- Annex 08** Woxvold, I. (2008). Avifauna of the upstream portion of the PNG LNG Project, Southern highlands and Western Provinces, Papua New Guinea. Report to Coffey Natural Systems.
- Annex 09** Richards. S. (2005) Biodiversity And Conservation Status Of Herpetofauna Of The Papua New Guinea Gas project area. Report to Enesar Consulting Pty. Ltd.
- Annex 10** Richards. S. (2008) Biodiversity and conservation status of herpetofauna of the Papua New Guinea Liquefied Natural Gas Project. Report to Coffey Natural Systems.

The reports from the 2005 surveys (**Annexes 01, 03, 05, 07, 09**) were included as appendices to the EIS for the PNGGP-2005 (Enesar 2005).

Locations of the seven sites are presented in **Figure 5**.

7.2.1 2005 and 2008 survey area descriptions

7.2.1.1 Juha North survey area

This site was located on low hills on the edge of limestone terrain at 213 m asl on the Liddell River, a tributary of the Strickland River (**Plate 4**). There was a waterfall emanating from holes in the limestone close to camp. The forest was small crowned low altitude forest on uplands (Hm)⁴ with evidence of disturbance and hunting. An anomalous feature of the vegetation was the presence of many plant groups normally found only in montane environments above 1,000 m asl including many species in the families Ericaceae, Myrsinaceae, and Myrtaceae. The structure of the vegetation indicates a very high annual rainfall in excess of 8000 mm in this area (**Annex 02**). This area was sampled between 26th March and 2nd April 2008 and sampling occurred over the range of 200 to 450 m asl.

7.2.1.2 Juha South survey area

Located at 953 m asl, Juha South was technically in the transition ecotone between lowland and montane zones but due to local very high rainfall this sample area was in a well-developed mossy montane forest (**Plate 5**). It would classify as an ecotone between small crowned lower montane forest (L) and very small crowned lower montane forest (Ls)⁴. As is generally the case for montane formations, the canopy was low (less than 20 m average height) with large numbers of epiphytes on the trunks and upper branches. The forest understorey was generally rich in cryptogamic growth and was in remarkably pristine condition due to the absence of wild pigs, itself possibly a product of low human population densities. The survey camp was located on an old well pad built by Gulf Oil in 1983/84 and there was waste left by the drillers. Forest regeneration at the survey area was well advanced, composed for the most part of *Ficus*, *Macaranga*, *Timonius*, and urticates.

⁴ vegetation types are from FIMS and described in Hammermaster and Saunders (1995 a and b)

Numerous sinkholes were present on the karst terrain immediately north of the camp. This area was sampled between 11th and 16th Feb 2008 and sampling occurred over the range of 820 to 1,030 m asl.

7.2.1.3 Baia River survey area

The survey area was located at 328 m asl on the banks of the Baia River (**Plate 3**) in an area dominated by landslides. This section of the Baia River and the approaches to the River from South Karius survey area (Camp 4) appears to be highly unstable sedimentary formations with numerous large landslides. This terrain instability is reflected in the composition of substrates at Baia River, which consisted either of colluvial rubble, mainly sedimentary spalls from surrounding cliffs, or alluvium of various consistencies ranging from silt to large boulders. Mineralized soils are not present, an indication that surface renewal and replacement is an ongoing occurrence at this location.

The camp area was in an exclusively lowland vegetation formation with a floristically distinct alluvial and flood zone along the streams (collectively including various communities in Po, Ps, Wsw⁴), and small crowned low altitude forest on uplands (Hm) on higher slopes. There were numerous talus slopes and active landslides with early pioneer and secondary vegetation (**Plate 6**). Baia River riverine communities are mainly composed of pioneer and secondary taxa including *Ficus*, *Macaranga*, *Pimelodendron*, *Pometia*, etc., and apparently represent a flood-resistant or sciophobic subset of taxa from adjacent slopes. This area was sampled between 17th and 22nd Feb 2008 and sampling occurred over the range of 285 to 445 m asl.

7.2.1.4 South Karius survey area

This was located at 1368 m asl at the base of the Karius range in a complex of streams and swamps that form the headwaters of the Baia River. The camp itself was located on the edge of a flat area that had been converted to gardens within the last few years and the surrounding vegetation was an irregular mosaic of natural growth and anthropogenic vegetation.

The camp was located in swamplands (**Plate 7**) with emergent pandanus, best referred to as mixed swamp forest (Fsw)⁴, that merged into small crowned lower montane forest (L) on the surrounding hills. Nearly all of the characteristic genera for this forest type were recorded from habitats around the base camp. However the swampy, alluvial vegetation is clearly distinct from the better-drained hill environments.

The Karius Range immediately to the north is karst (**Plate 8**) while the hills to the south appear to be volcanic.

The structure of the natural-growth vegetation was similar to that at Juha South survey area, however due to the presence of human habitation near the camp, there was a discernable increase in weedy species, including some cosmopolitan plants not found at any of the other locations. The anthropogenic influences are also reflected in the higher incidence of successional stands along the margins of the old growth forest. This area was sampled between 4th to 10th Feb 2008 and sampling occurred over the range of 1,200 to 1,800 m asl. Despite its proximity to the Karius Range this sample area is within the Western Volcanics bioregion because it was not a karst area.

7.2.1.5 Deviation Camp survey area

The camp was located at 2060 m asl approximately 5.5 km southwest of Benaria village and close to the potential pipeline deviation. It was in pristine small crowned *Nothofagus* forest (Ln)⁴ next to a fast flowing tributary of the Muruba River (**Plate 9**). The overstory was composed almost exclusively of *Nothofagus pullei* emergents up to 40 m tall. Subcanopy genera included primarily *Acronychia*, *Elaeocarpus*, *Sphenostemon*, and *Syzygium*. Understories were characterized by dense bryophyte and lycophyte growth, and dominated by the treeferns *Cyathea microphyloides* and *C. perpelvigera*. Most of the floristic diversity was concentrated in the near-ground interval up to ca. 5 m high.

The camp bordered an area of forest burnt in the 1996-7 fires. These regenerating areas were dominated by standing stags and coppicing surviving trees, with saplings up to 15m high (**Plate 10**). There was extensive regeneration of light-demanding *Nothofagus* and other heliophytes such as *Macaranga*, *Omalanthus*, and *Cyathea* spp. (e.g., *C. contaminans*). Paradoxically the understory included many shade adapted species. The puzzling combination suggests either the understory recovered completely in about 10 years despite an open canopy, or the former burn was primarily a crown fire which did not affect the ground flora.

The survey area was sampled between 3rd and 8th April 2008 and sampling occurred over the range of 1,990 to 2,180 m asl.

7.2.1.6 Hides 3 survey area

This survey area was situated at the Hides 3 well site at an elevation of 2,163 m in primary, upper montane small-crowned *Nothofagus* forest (LN/LsN) with many epiphytes, overlying polygonal karst limestone with numerous dolines and sinkholes. Extensive thickets of climbing bamboo were present on the hilltops and ridges, but absent from the darker valleys. Swamps occurred at the bottom of some of the larger, poorly drained dolines. Scree slopes surrounding the well pads were covered in sparse secondary growth. Due to the rugged terrain, this area is rarely visited by local villagers, and apart from the existing well pads and flowlines, the habitat is pristine. This area was sampled between 24th April and 1st May 2005.

7.2.1.7 Benaria survey area

The survey area was 4.6 km west of Benaria mission at an elevation of 1,345 m along an old vehicular track now used only for walking by local residents. This area was populated, and the surrounding habitat has been subjected to varying levels of disturbance. The camp was situated on an approximately 6-ha clearing currently used to graze cattle. Forested areas were characterised by small crowned lower montane forest (L)⁴, riparian forest alongside the Benaria River, and swamp forest. Most of the habitat in the river valley and surrounding smaller hills is dominated by secondary forest in varying stages of regrowth. Primary forest was found mainly on the higher slopes surrounding the valley, and in smaller patches on the lower slopes and in the valley. It was sampled between 1st and 8th May 2005.

7.2.1.8 Nogoli survey area

Opportunistic observations of birds, reptiles and amphibians were made in an area approximately 5 km SE of Nogoli at approximately 1,250 m asl. The survey area consisted of an approximately 140 ha area centred on the intersection of the road between Hides 4

and Nogoli and extending down to the Tagari River. The Tagari River valley, including the area around Nogoli and the site of the proposed Hides Gas Conditioning Plant, is heavily populated. Habitat within the study site included the river, a permanent road, subsistence gardens and secondary growth, and lower montane small-crowned forest (L) with emergent *Araucaria*. It was sampled between 21st and 23rd April 2005.

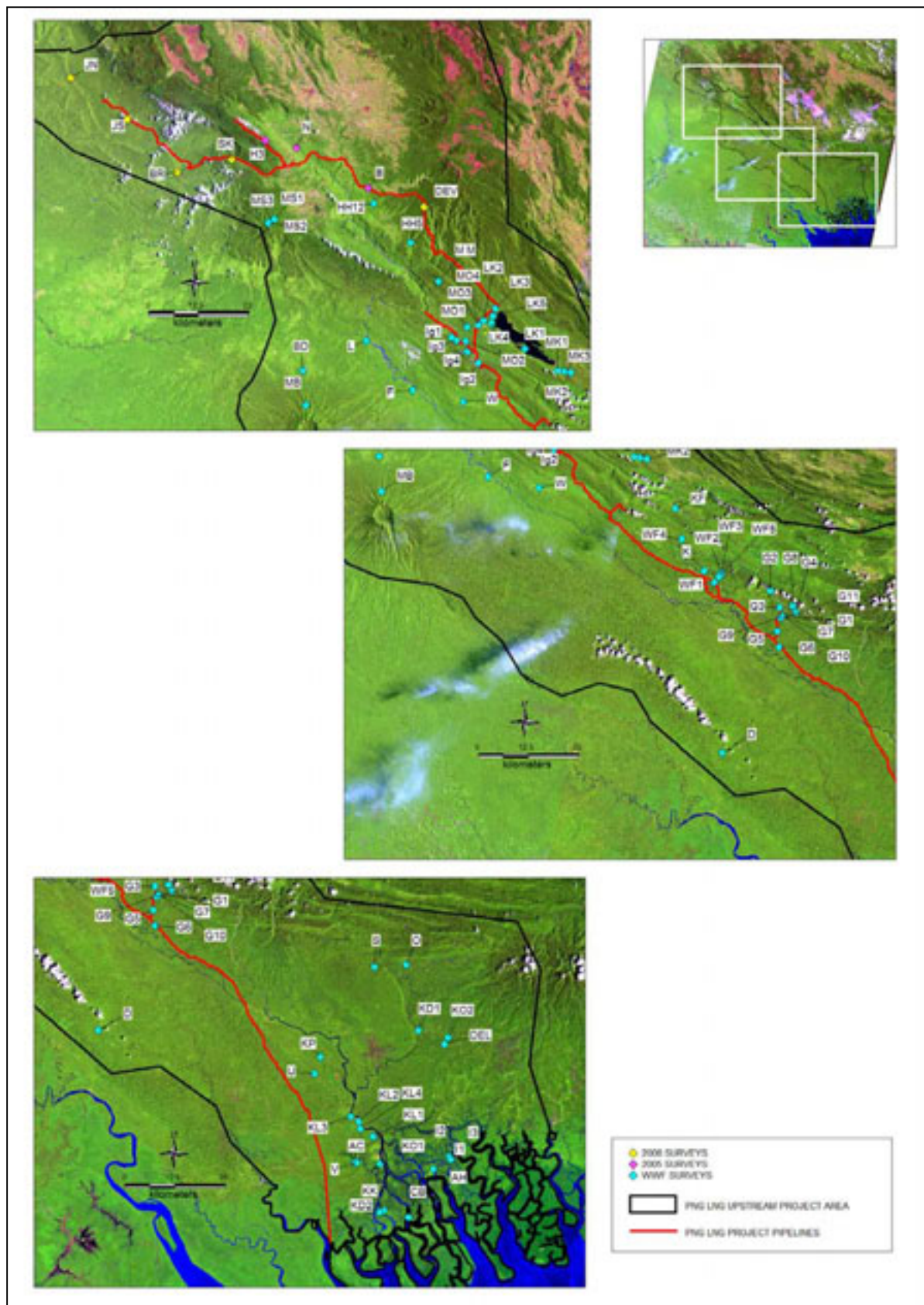


Figure 5 Biodiversity sample sites within the PNG LNG upstream project area. See Appendix 2 for key to acronyms.

8 Methods

All the 2005 and 2008 surveys and most of the WWF surveys, have been carried out using the Rapid Assessment Program (RAP) method, which, while maintaining as many observation and collection protocols as possible, is adaptable and modifies techniques to local conditions so as to maximize the chance of recording species. Basically, observers cover as many different habitat types as possible using as many techniques as possible. **Table 1** presents the commonest techniques used in the surveys in the project area. Not all the WWF surveys listed in **Appendix 1** used all of these techniques, Mamu and Sine (2005), for example, only obtained data from local informants. **Table 2** show survey efforts for fauna in the 2005 and 2008 surveys and **Plates 11 to 15** show a range of equipment used in the surveys.

Table 1 Methods used in RAP surveys in the project area.

Non-volant mammals	Bats	Birds	Amphibians & Reptiles	Plants
Trapping using small Elliot aluminium collapsible traps	Electronic detection (PNG LNG surveys only)	Cruises along roads & tracks recording species seen & heard	Intensive searches on foot in all habitats by day & by night	Intensive searches on foot in all habitats by day
Trapping using large Elliot aluminium collapsible traps	Harp traps	Intensive searches of specific habitats for birds	Spotlighting at night along trails & stream banks	Plot based sampling (recording all species in a given small area)
Trapping using cage traps	Searching caves	Searches for bowers, display grounds & nests	Aural surveys at night along trails & stream banks	
Spotlighting along roads & trails	Spotlighting along roads & trails	Observations at fruiting & flowering trees	Interviews with local people	
Collecting bones & hair from dung & caves	Collecting bones & hair from dung & caves	Recording bird song & identifying species		
Listening for mammal calls	Interviews with local people	Collecting feathers & bones from dung & caves		
Looking for nests & dens		Spotlighting along roads & trails		
Checking spoor (tracks & droppings)		Camera trapping (PNG LNG surveys only)		
Camera trapping (PNG LNG surveys only)		Interviews with local people		
Interviews with local people				

Table 2 Summary of survey effort for non-volant mammals, bats and birds in the project area in 2005 and 2008.

Sampling area	Non-volant mammals							Bats			Birds			All
	# of small Elliots on ground	# of small Elliots on trees	# of small Elliots on dead logs or fallen trees	# of large Elliots	# of cage traps	# of sample nights	Total trap nights	# of sample nights	# of detector nights	# of detector files generated	Transect time (man-hours)	Mist –nets (net-hrs)	Sound recordings h:m:s (# of recordings)	Camera traps - # of camera hours (# of camera)
Juha North	48	0	16	8	5	6	462	7	12	20,346	88	281	1:00:59 (29)	823 (6)
Juha South	34	0	17	9	6	6	396	5	14	25,240	54	92	2:21:38 (34)	609 (6)
Baia River	41	3	12	9	6	6	426	5	12	6,851	60	80	1:22:41 (49)	595 (6)
South Karius	42	4	12	4	6	6	408	5	12	15,408	128	80	0:46:20 (24)	500 (5)
Deviation Camp	15	3	49	9	6	6	492	5	12	7,064	80	35	0:31:24 (19)	747 (7)
Hides 3	81	7	10	32	8	1– 6*	628	6	27	28,926	174	40	1:40:00 (5)	432 (4)
Benaria	91	9	1	30	8	2 – 6*	514	7	29	42,719	194	224	0:35:00 (3)	840 (5)
Nogoli	0	0	0	0	0	0	0	0	0	0	16	0	0:40:00 (1)	0
Overall totals	352	26	117	101	45		3326	40	118	146,554	794	832	8:58:02 (164)	4546

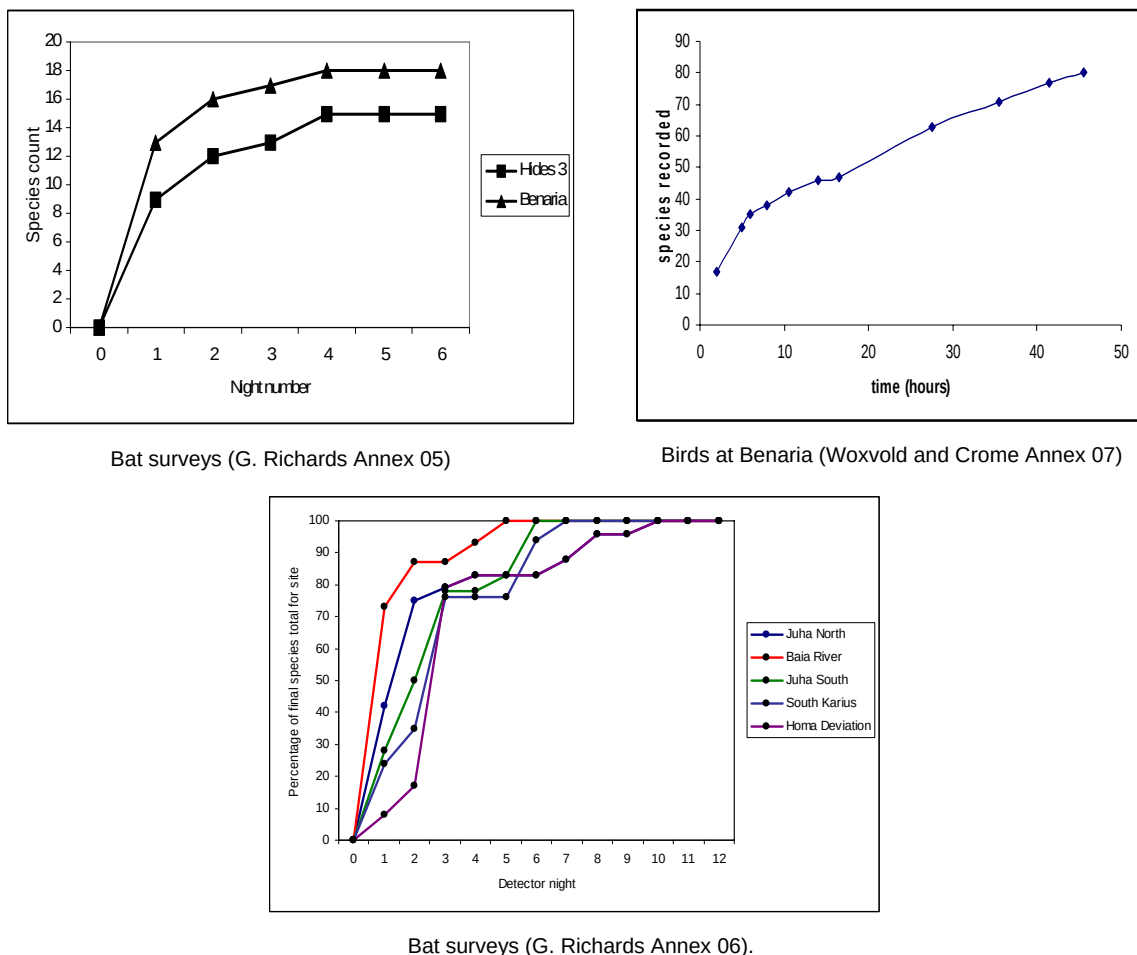
* Some subsites were sampled on fewer nights.

For certain groups such as mammals information from local hunters and residents are important sources of data. Such a record is only accepted if a range of correct ancillary information such as behaviour, calls and breeding is also provided by the informant. Where this information is almost but not totally correct and professional opinion considers the record would not be unusual the record is considered a “probable”.

Survey effort for mammals, bats and birds during the 2005 and 2008 surveys is given in **Table 2**.

Adequacy of sampling to estimate numbers of species present is usually done by comparing the accumulation curves of species detected with time or effort expended. Such curves asymptote towards the actual number of species present. **Figure 6** presents three examples from the 2005 and 2008 survey. Both curves for bats in 2005 and 2008 show that an asymptote has been reached and as many species have been detected as could be. In contrast, the curve for birds at Benaria in 2005 has not asymptoted and more species would be expected.

Figure 6 Examples of species-effort curves.



Biodiversity Assets

9 Vegetation

9.1 General

Virtually the entire project area is covered in tropical forest, its structure and floristics being influenced by altitude, climate, topography, soils, geology, degree of water logging and disturbance regime. Tree size is influenced by soil fertility, climate and time since the last disturbance (Paijmans 1976) but, in general, it declines, as does leaf size and crown size, with increases in altitude, although trunk sizes of individual trees can still be great in mid-altitude zones. Very large trees tend to occur in nutrient rich sites and/or where there has been a longer time since the last forest disturbance, giving trees time to develop great girths.

Species diversity of trees tends to decrease with increases in altitude until the tree line is reached. While trees at all altitudes are generally festooned with epiphytes, the cooler wetter and foggy climates of uplands favour epiphytes, ferns, certain conifers, cool adapted broad-leaved trees and mosses.

9.2 Terrain and forest structure

Limestone and karst which tend to produce poor soils comprise 79% of the project area. On the limestone plains of the lowlands and on some upland ridges, there is often a solid limestone pavement with little evidence of rock breakdown: only a few cracks and fissures are seen in an otherwise smooth, featureless rock face. There is very little soil development in this situation, and the forest in these areas is supported by its own thin root mat covering the pavement. The forests in these situations are prone to wind throw that peels sections of forest off the pavement because as trees increase in size their roots can only continue to spread over the rock and the probability of being blown over increases. This incapacity of tree roots to penetrate into the substrate, combined with the poor limestone soils, limits the size to which trees can grow in this pavement. Such forests therefore tend to be poorly developed - trees tend to have small crowns and thin stems, usually less than 60 cm diameter at breast height (dbh), and numerous large gaps give the impression of an open forest. Nutrient cycling on limestone pavements is highly internalized, with the bulk of the nutrients tied up in the forest itself. Regeneration of these areas appears to be extremely slow and require lichens and fine roots to form a mat in which larger plants and trees can germinate.

In areas of polygonal karst, in upland karst corridors and in the decomposing rock of the upper ridge slopes, tree roots can penetrate into the many fissures and weaknesses in the rock. Consequently, trees have bigger crowns and boles, producing better developed forests overall, similar to those on the richer valley alluvial soils. A feature of polygonal karst is the rarity of flowing streams; most surface water runs into the limestone through numerous fissures or into sinkholes (**Plate 16**). Underground rivers can also break out and form surface streams (**Plate 17**). Where infiltration into the bottoms of dolines becomes retarded sinkhole swamps can develop (**Plate 18**).

Most of the limestone landforms are well drained and perched valleys with terra rossa clays occur in the uplands. The water table in many parts of the lowlands is close to the surface and in areas of impeded drainage, dry forest gives way to palm and pandanus dominated swamp forest, swamps and wetlands. In areas of the Mubi River valley near Kantobo

village, the karst has sections of internal drainage, where standing water can occur after heavy rainfall periods (**Plate 19**) but is not retained long enough to favour swamp forests. Close to the coast, swamp forests and swamps merge into mangroves.

Only some 21% of the project area is on volcanics and alluviums that provide high quality growing conditions for plants. The soils on flat and rolling terrain are preferentially used for shifting cultivation, and the forest in these areas has been cleared or comprises a complex of secondary growth, old growth forest and regenerating areas.

In the Western Lowlands and Western Foothills very high rainfall allows the growth of otherwise montane plants in lowland areas as evidenced by the floristic composition at Juha North and Juha South sample areas (**Annex 02**).

9.3 Forest dynamics relevant to impact analysis

Gap dynamics The dynamics of all the forests in the project area are determined by disturbance. Gap phase dynamics occurs where individual tree deaths produce small canopy gaps (1 ha or less) and seedlings and saplings that have stayed quiescent in the shade of the understorey are 'released' and grow up to fill the gap. There is an element of chance in which particular species fills the gap, and this is one mechanism that maintains the high diversity in tropical forests. Gaps form all the time and produce continuous low-level disturbance.

The need for disturbance in tropical forests tends to make them resilient to human-induced disturbance, but the extent, type and duration of disturbance is critical. Short-term, small-scale disturbances can mimic natural gap phase or small scale catastrophic dynamics. However, major changes to natural dynamics result in system collapse or forest conversion. This can be brought about by large scale clearing, continuous small clearings fragmenting the forest, disturbances being too frequent, fire, weeds and/or disease gaining a foothold, or hydrology being altered. Human behaviour promoting clearing and fire is the single biggest factor influencing forest loss in PNG (Rogers 2005b).

Catastrophic dynamic regimes. When large disturbances, such as landslides, floods, fire, frost, drought or clearing, devastate large areas of forest, the area usually regenerates through successional processes. Where the disturbance has exposed large areas of mineral soil, species that can germinate in such conditions and thrive in full sun are favoured over species that need more organic soils and cannot tolerate open conditions. The Baia River area and the Homa region provide excellent examples of unstable landscapes driving forest succession (**Plate 20**). Catastrophic dynamic regimes are common in PNG.

Catastrophic disturbances, while a force for maintenance of some forests, can also produce ecosystem collapse and convert an area to some other habitat type, usually grasslands or scrublands. Rogers (2005b) gives several examples of catastrophic events that have eliminated forest in certain locales.

Fire This is a potent force in rainforest dynamics and even the wettest tropical forests can burn during drought years. Takeuchi (**Annex 02**) describes the effects of wildfire on very wet montane forest which is usually destroyed in hot fires (**Plate 10**).

Swamp forests on peat and forests on limestone pavements, where the soil is basically the organic root mat of the forest itself, are very sensitive to fire. Fires that destroy the peat or

root mat eliminate the substrate's capacity to support forest growth and, so scrublands, grasslands or bare rock pavement replaces the forest.

In most forests, fire, extensive clearing and/or frost can allow grasses and other flammable species to invade. Such species will carry fire indefinitely if there are continuing sources of ignition (people, lightning), and a permanent grassland can result. Large areas of the grasslands in the highlands were generated this way (Rogers 2005b).

Small-scale catastrophic disturbances where the forest is killed over a few hectares by, for example, disease or a frost are also influential in determining forest structure and composition. Small areas can become dominated by a single species that has regenerated in such medium-sized gaps either from seed or root suckers.

Fire has had a considerable impact on PNG's forests, from the lowlands to the sub-alpine zone. The climatic conditions for severe fire occur about once each decade, however, there is no evidence to suggest that a single area of forest can survive repeated burns at this frequency. Although extensive areas of lowland forests may have originated from past catastrophic fires, such fires may occur once every 100 years or more. With increased population pressure across mainland New Guinea, the risk of repeated fires will increase as will the potential for conversion to permanent grasslands, as has occurred across large areas of the highlands.

9.4 Vegetation types

The vegetation classification system used for the project area is a simplification of the PNG Forest Inventory Mapping System (FIMS) developed by Hammermaster & Saunders (1995a and b) which is the scheme used by nearly all biodiversity assessments in PNG (e.g. Balen *in press*, Beehler & Alonso 2001, Mack 1998, Richards 2007).

The FIMS system was developed from air photo interpretation with limited ground truthing. Mapping may have misclassified areas and small scale variation relevant to management is missed. For example, a recent expedition to Lake Tawa (Richards 2007, Takeuchi 2007a, b, *in press*) discovered that an extensive area of many thousands of hectares mapped by FIMS as subalpine scrub was in fact a new type of vegetation entirely - a montane *Pandanus* savanna. FIMS mapping units are area averages which may or may not give an accurate description of the forest at a specific place - a melange of structural types may occur within an apparently homogenous mapping unit. For example the South Karius Sampling Area was in swamplands not mapped within the FIMS unit of lower montane small-crowned forest (L).

Seventy-five vegetation types or complexes are mapped by the FIMS within the project area. For simplification, these have been grouped into 21 Broad Vegetation Groups (BVGs) plus lakes and streams for mapping (**Appendix 3**). **Figure 7** maps the BVGs, and **Appendix 4** gives the areas of each BVG within the project area.

In the following discussion large crowned trees have canopies greater than 15 m in diameter, medium crowned trees between 8 and 15 m, small crowned trees between 4 and 8 m and very small crowned trees less than 4 m.

montane forest (>3000 m) with/without grassland

This includes FIMS types Mo and Mo/Ga of very small crowned mossy forest (“elfin” forest) and alpine grassland complexes. It is low, 5 to 15 m high with thin crooked stems and no emergents. It only occurs in the far north of the project area and no project infrastructure is planned within this vegetation.

grasslands

Grasslands within the project area are mostly alpine grasslands above the tree line in the north and no project infrastructure is planned within this vegetation.

scrub

There are areas of rocky scrub on the extreme slopes of the Karius Range. No project infrastructure is planned within this vegetation.

lower montane small crowned forest

This BVG includes FIMS types L and L5⁵ and generally occurs above 1000 m asl. This forest has an even to undulating canopy 20 to 30 m high and is very dense to almost closed. *Nothofagus* is absent or very rare but in the vicinity of Idauwi and Nogoli the forests on the ranges have many emergent *Araucaria*. Ferns and epiphytes are common. Trees tend to be thin, and oaks (*Castanopsis* and *Lithocarpus*) are common, dominating in some areas. While somewhat less diverse in tree species composition than other forests, it can have high diversity of smaller plants and epiphytes. At lower elevations in the river valleys, clearing for gardens has heavily disturbed the forest. The project encounters areas of this vegetation frequently at the eastern end of the Juha-Hides Rich Gas Line and for a long length of the LNG Project Gas Pipeline between the Hides Gas Conditioning Plant and Lake Kutubu at elevations of approximately 1,200 m asl and above.

lower montane small crowned forest with conifers

This only occurs in the far high northeast of the project area where lower montane small crowned forest occurs with emergent conifers including the genera *Dacrydium*, *Libocedrus* and *Phyllocladus* (FIMS types Lc and Lc/Gi). No project infrastructure is planned within this vegetation.

lower montane small crowned forest with Nothofagus

This BVG includes FIMS types Ln and Ln/LsN. The closed, even to slightly undulating canopy is 20 to 30 m high and dominated by *Nothofagus pullei* and *N. rubra*. This is a classical mossy forest. *Nothofagus* is concentrated along ridgelines and subcrests. In the drainage channel subcatchments, the canopies are usually lower and the mixed communities typical of Papuan habitats become more apparent. Small patches of seral growth are scattered through the forest as a result of natural canopy-opening mechanisms (e.g. wind throws and tree senescence and death).

⁵ A numerical value following the vegetation type code in the FIMS system represents human impact – e.g. 5 means 50% of forest remains in the mapped FIMS unit.

While, in general, the dynamics of *Nothofagus* communities tend to be site specific (Rogers 2005a), the forests on the Hides Ridge and the Homa Deviation are clearly being maintained by a classic process of patch dynamics and spatial rotation of forest units in different stages of maturation (**Annex 01**). In the Homa Deviation area fire has influenced this vegetation.

As in most other places that this vegetation group occurs, on the Hides Ridge it contains large numbers of epiphytic ferns and orchids (**Plate 21**), which may represent up to 75% of the plant diversity there (**Annexes 01 and 02**).

Large areas of this BVG occur on the Doma Peaks, Mt Sisa, Hides Ridge and between the Benaria and Kondari Rivers. The eastern end of the Juha-Hides Rich Gas Line traverses this vegetation and the LNG Project Gas Pipeline will cross large expanses of this forest above 1,600 m between the Benaria and Kondari Rivers and sporadically at higher elevations between the Kondari River and Lake Kutubu.

The Hides wells and gathering system and Hides Spine are mostly in this BVG on Hides Ridge.

lower montane very small crowned forest complexes

This BVG includes FIMS types Ls and Ls/L and occurs on the central eastern boundary of the project area northeast of Gobe. No project infrastructure is planned within this vegetation.

lower montane very small crowned forest complexes with Nothofagus

This vegetation group includes FIMS types LsN (very small crowned forest with *Nothofagus*) and LsN/L (complex of very small crowned forest with *Nothofagus* and small crowned forest) and is concentrated in the uplands surrounding the Kutubu Central Processing Facility. The forest has a dense, evenly textured, dark-toned canopy 5 to 15 m high. Around Kutubu *Nothofagus* dominates in areas such as along ridges but is far less obvious than in the higher regions to the north. There are fewer ferns but more vines in this vegetation. The LNG Project Gas Pipeline traverses this BVG either side of the Kutubu Central Processing Facility and the Southeast Hedinia Spine are traversed by it also.

medium crowned to small crowned forest complexes

This BVG covers large areas of the southern and central parts of the project area and includes several FIMS complexes of Hm and Hs, according to whether patches of medium or small crowned trees dominate. This vegetation has a canopy 25 to 30 m high with 60% to 80% closure, the smaller crowned forest having thinner trees and a more even canopy with no emergents, while the medium crowned forest has emergents up to 40 m high. The smaller crowned forest tends to develop on the more difficult pavement sites. The Gobe Gas Pipeline, Heartbreak Hill road route and Southeast Hedinia Spine encounter this BVG as does the LNG Project Gas Pipeline between Wassi Falls and the Mubi River and between the Kikori River Crossing and Omati,

medium crowned to small crowned forest complexes with Nothofagus

This BVG includes FIMS type HsN/Hm (complex of small crowned forest with *Nothofagus* and medium crowned forest) and occurs in the central eastern part of the project area. It has a canopy 25 to 30 m high with 60% to 80% closure and is a mixture of medium

crowned forest and small crowned forest. The latter tends to have a more even canopy with no emergents; the former has emergents up to 40 m high. There is an abundance of a range of *Nothofagus* species. The Southeast Hedinia Spine crosses some of this BVG and the LNG Project Gas Pipeline crosses large areas between the Kutubu Central Processing Facility and the Ai'io River.

low altitude large crowned forest

This includes FIMS types H1.N and H18.N and occurs on the slopes of Mt Bosavi. It has an uneven canopy 30 to 35 m high and 80% closure with emergents to 40m. No project infrastructure is planned within this vegetation.

low altitude medium crowned forest

This includes various FIMS complexes of Hm and occurs widely in the project area. The canopy is 25 to 30 m high with 60 to 80% closure and emergents up to 40 m high. Species composition varies widely according to altitude and substrate. In the Juha area this BVG has many upland forest features and plants other than trees may dominate the flora. The project mostly encounters this vegetation at Juha and along the Juha-Hides Rich Gas Line and again sporadically between Lake Kutubu and the Gobe turnoff where this BVG merges into open lowland forest (Po) on the edge of the karst pavements

low altitude small crowned forest with Nothofagus

This BVG includes a range of FIMS types with Hm dominating including Hm.N and Hm8.N (medium crowned forest *Nothofagus* suspected present). It has a fairly even canopy approximately 30 m high with emergents up to 35 m in height. Tree crowns average between 8 and 15 m in diameter, and larger crowns are rare. Orchids and figs are very common, ferns are moderately common, and palms and pandanus are sparse. The understorey is generally open, and there is a ground layer of seedlings, ferns, *Selaginella* and gingers. Conifers such as *Papuacedrus* spp. and *Phyllacladus* spp. become abundant, and oaks (*Castanopsis* and possibly *Lithocarpus*) are common. A single area occurs east of the Kutubu Central Processing Facility and the Agogo gas pipeline traverses part of this.

large to medium crowned lowland forest

This includes FIMS types P1 and P19 and occurs in small areas in or near the Sirebi Bioregion on alluvial fans. It is tall with a canopy 30 to 35 m high and emergents exceed 50m. Structurally it is the best developed forest in the project area. It has likely already been logged. No project infrastructure is planned within this vegetation.

small crowned lowland forest

This BVG includes FIMS type Ps and Ps8 (small crowned forest). This type of forest has a canopy 25 to 30 m high composed of dense small crowns with no emergents, and the canopy is often dominated by single species such as *Intsia* sp. and dipterocarps. This type of forest often occurs on very poor or badly drained substrates, such as on limestone pavements. This BVG will be crossed by the LNG Project gas pipeline between the Gobe turnoff and Omati.

open lowland forest

This BVG includes FIMS type Po (open forest). The canopy is approximately 30 m high and consists of small and medium crowned trees with large crowned emergents up to 40 m high. The canopy profile is very uneven with many large gaps produced probably by frequent tree falls on the limestone pavements. A variety of palms occur, and climbing rattans are common. In low-lying areas, sago palm stands develop, and where they have the opportunity, broad-leaved trees can reach great sizes (greater than 100 cm dbh). The LNG Project gas pipeline encounters this BVG near Gobe and, while the FIMS does not map it as such, the forest at Baia River is of this type (**Annex 02**).

open lowland forests and freshwater swamps

This vegetation group includes FIMS type Po8/Fsw8 and is a complex of open forest and mixed swamp forest. The LNG Project gas pipeline crosses this BVG several times either side of the Gobe turnoff.

swamp forest complexes

This BVG includes a range of FIMS swamp forest (Fsw) complexes and occurs patchily but widely in the project area wherever impeded drainage allows its development. The trees can be large (up to 100 cm dbh) and up to 30 m tall. Thick and thin lianas are common, and epiphytes are abundant. *Selaginella* is common on the forest floor. A feature of this area is the abundance of palms. In frequently inundated areas, sago palms can form almost pure stands (FIMS type Wsw (swamp woodland)). In areas where karstification has produced some relief within these basins or plains, sago palms dominate in the small hollows or dolines, while the raised ridges of limestone support medium crowned or small-crowned lowland hill forest. Where inundation is less frequent, other palms, such as *Arenga* sp. and *Galubia* sp., are dominant.

There are large areas behind the mangrove of the Kikori River mouth and scattered patches towards the centre of the project area. The swampy lands at South Karius survey area are of this BVG but not mapped by FIMS as such. The LNG Project Gas Pipeline traverses large areas of swamp forest complexes approaching the Omati River.

swamp woodland and forest complexes

This vegetation group includes FIMS type Wsw and complexes with Fsw, and occurs around the north of Lake Kutubu, near Kantobo and behind the Kikori River mangroves. Swamp woodland is a dense layer of sago palms (*Metroxylon sagu*) with scattered broad-leaved trees and an understorey of sedges, ferns, reeds and/or grass. Mixed swamp forest has an irregular open canopy of medium to very small crowned trees 20 to 30 m high and an understorey of sago palms visible in gaps in the canopy. Sago and tree density varies, giving this type of forest a very patchy appearance. The LNG Project gas pipeline crosses this BVG to the north of Lake Kutubu and in the Ai'io River valley.

Mangroves

The mangrove vegetation group (FIMS type M) is extensive in the Kikori River delta, but only a thin line of nypa palms (*Nypa fruticans*) fringes the swamp forests at the lower Omati River landfall of the LNG Project Gas Pipeline. The LNG Project Gas Pipeline does not cross any mangrove vegetation except for a fringe of nypa palms at the landfall.

Rivers and lakes

Lake Kutubu is a significant freshwater habitat.

Non forested areas

This areas usually occur on the better soils and indicate human settlement. The project has designed infrastructure to be in cleared areas as far as possible.

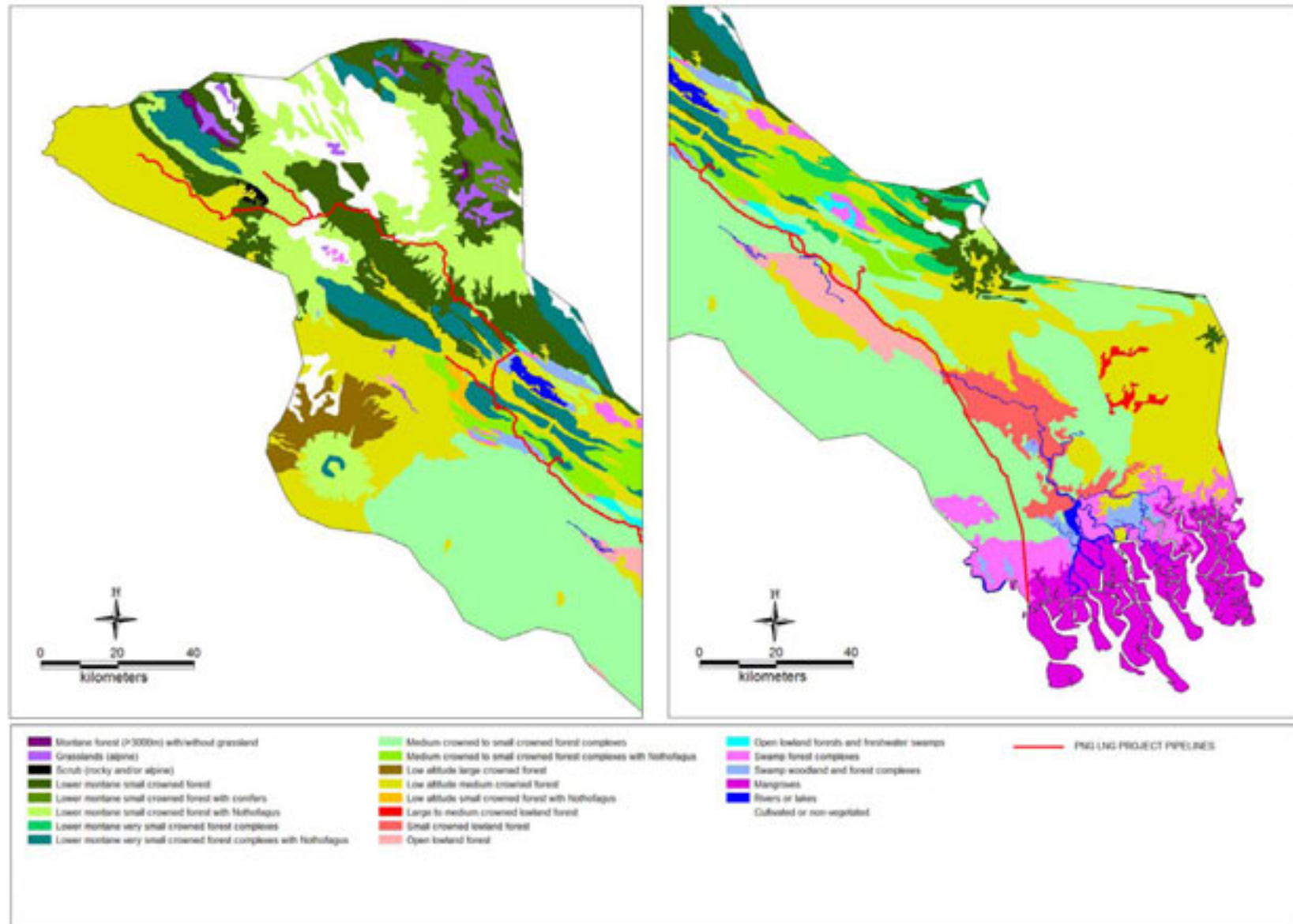


Figure 7 Distributions of Broad Vegetation Groups within the PNG LNG upstream project area.

10 Flora

The island of New Guinea has one of the world's richest floras with more than 25,000 species of vascular plants (Supriatna 1999), including over 3,000 species of ferns (Parris 2007), and 2,800 species of orchids (Schuitemann and de Vogel 2007). New Guinea has the highest numbers of indigenous and endemic plant species within Malesia (Balgooy et al., 1996; Welzen, 1997), and the proportion of endemics may exceed 70% (Johns 1993). This level of plant diversity ranks New Guinea fifth in the world in terms of the number of flowering plants and first for ferns (**Annexes 01 and 02**).

Despite its global significance, our knowledge of the Papuasian flora is very poor (Beehler 1993, Conn 1994, Damas 1998, Johns 1993, Stevens 1989, Takeuchi **Annex 02**, Takeuchi & Golman 2001). Using the number of plant collections in herbaria as a measure, 50 to 100 specimens from an area is generally accepted as meaning the area has been 'well-collected' (Takeuchi **Annex 02**). On this basis there are very few adequately sampled localities in New Guinea (Stevens 1989) - the average collection rate for all of Papuasias (Indonesian New Guinea to Vanuatu) is only 30 specimens per 100 sq km (Frodin 1990) and for most of New Guinea it is less than 25 (Conn 1994). Moreover, the coverage is highly uneven and many areas remain practically unexplored floristically (Frodin 1990). The knowledge of the flora is so poor that a disproportionate number of species are known from only one or very few specimens and numerous new species undoubtedly remain to be discovered. Basic data such as distributions, population variation and rarity are known for very few species at all.

This state of affairs provides a critical backdrop for understanding the flora in the project area. As early as the 1970's the southern karst was identified as one of the areas most in need of botanical exploration (Prance 1977, Stevens 1989, Johns 1993) and the Kikori basin and adjacent uplands, being the largest of all the poorly known regions, was ranked among the 16 major terrestrial unknowns in PNG (Sekhran & Miller 1994). There is arguably no other area in PNG where responsible environmental stewardship will be as consequential for conservation of the endemic flora (Takeuchi **Annex 02**).

A full botanical inventory of the project area would take many years to prepare. Based on the work of Barthlott *et al.* (1996, 2005) who found that the density of tracheophytes (e.g., angiosperms, gymnosperms, ferns and mosses) in New Guinea ranged from 3,000 to over 5,000 species per 10,000 km².

The WWF surveys investigated broad-scale patterns of vegetation composition and forest ecology based on small study plots (Balun and Gebia 1998; Gebia and Balun 2000, 2004), and the results confirm that the project area has high floristic diversity (Crome 2005). Balun (1995) estimated that 1.8 ha of an 'average Kikori forest' contains 372 tree species that attain 10 cm dbh or greater. Gebia and Balun (2004) recorded 876 species in plots on the Darai Plateau and the Libano River, the plots on the rugged Darai karst having more species than those on the alluvial Libano sites.

Takeuchi (**Annexes 01 and 02**) has recorded 1030 species of plants in nine survey areas in the north of the project area⁶ (**Appendix A to Annex 02**). Of these 72% were collected at

⁶ It is not possible to combine the WWF data with Takeuchi's data to get an overall floristic assessment because many of the WWF identifications were made without voucher specimens to confirm identifications.

only one site and 97% at only 2 sites, indicating the wide scale heterogeneity of floristics. Overall, the project area may have a flora of between 6,000 and 12,000 species. **Plates 22 to 32** show some species found in the project area during the 2008 and 2005 surveys.

It might be expected that the richer volcanic soils and alluviums would have higher species diversity than the limestone plains and karst. However, the reverse may be true. Gebia and Balun (2004) claimed the highest diversity areas sampled were the limestones of the Darai Plateau. Takeuchi's results support this: he collected 271 species from limestone sites (Hides 3 + Iagifu-Agogo) compared with 170 species from volcanics (Mt Sisa). However more species were collected at alluvial sites (303 species from the Baia River + South Karius) and most, 522 species, from mixed sites (Benaria + North Juha + South Juha + Deviation) (**Appendix A to Annex 02**).

Whether karst is richer or not, karst geology strongly influences species composition as demonstrated at the Juha South survey area. Although classified as the same FIMS forest type ("L") as the South Karius survey area (on alluviums) and having essentially the same family composition there are significant differences at the species level, with the two sample areas having only nine species in common. The difference is related to the presence of limestone at Juha South survey area, the camp being located on a transition zone between limestone and sedimentary rocks, whereas South Karius survey area was on alluviums (**Annex 02**).

There is no indication that the karst in the project area has its own specialised flora. The 2005 and 2008 surveys confirmed that karst is a good area to find new species and there are certainly many species that are only found in karst in the project area. However, they tend to be broadly distributed over karst in New Guinea and not necessarily restricted to the project area karst. Endemism is expressed on a much larger regional scale than on the local scale of the project area (**Annexes 01 and 02**).

Local climatic and geological conditions are strong influences on local floras as evidenced by results from the Juha North and Juha South survey areas, where, because of the high rainfall, the floras at these lowland and foothill sites had many montane species. Ecotones, such as the geological transition at Juha South survey area often have high diversity because of the mixing of floristic elements.

Over 150 families of tracheophytes have been recorded in the project area. Dominant families in the Darai Plateau and Libano River areas were Orchidaceae, Rubiaceae, Meliaceae, Moraceae, Lauraceae and Araceae, which together accounted for 39.5% of the species (Gebia and Balun 2004). In Takeuchi's collections (**Annex 02**) 76 families were represented by 2 species or less. The Rubiaceae and Moraceae were the most speciose with 77 and 52 species respectively. These 2 and the other 10 families represented by more than 20 species each (Grammitidaceae, Meliaceae, Aspleniaceae, Piperaceae, Poaceae, Elaeocarpaceae, Myrtaceae, Ericaceae, Euphorbiaceae *sens. lat.* and Polypodiaceae) accounted for only 41% of the total species demonstrating little dominance in the flora.

At this stage, it is not possible to determine general trends in family distribution in the project area. The data, however, allow the lowland, lowland hill and upper hill zones (below 1,200 m asl) to be floristically characterised to some extent. Although species density (species per hectare) may be similar across forest types, different species will have different habitat and altitude preferences. In the forests of the upper hill zone between 600 m and 1,200 m asl, around the Ridge Camp and the Agogo Production Facility, the

genera *Castanopsis*, *Chisocheton*, *Cinnamomum*, *Cryptocarya*, *Syzygium*, *Elaeocarpus*, *Elmerillia* and *Opocumonia* are common. The swamp forests in the intermontane basins near, for example, Kantobo village are richer in such genera as *Nauclea*, *Pangium*, *Pometia*, *Sloanea*, *Terminalia*, *Dracontomelon*, *Myristica* and *Aglaiia*. The lowland forests below 400 masl share many species and genera with the uplands, particularly *Elaeocarpus*, *Sloanea* and *Syzygium*, but typically contain the more characteristically lowland genera, such as *Planchonia*, *Intsia*, *Nauclea*, *Bischofia*, *Terminalia*, *Ficus*, *Cananga*, *Alstonia*, *Pometia*, *Diospyros*, *Garcinia*, *Maniltoa*, *Anisoptera*, *Canarium*, and *Pterocarpus*.

The swamp forest complexes and swamp woodland and forest complexes contain a mix of lowland forest and swamp species, such as sago palm and the coastal lowland species *Dillenia alata*, as well as some mangroves (e.g. *Xylocarpus granatum*). Except for the genus *Podocarpus*, conifers are rare in the lowlands.

Palms, of which 55 species have been recorded in the project area (Baker *et al.* 2000), are more common in wetter forests such as those that occur in the lowlands and the intermontane swamps. There is no data yet to suggest that the lowland sections of the project area support any endemic species or genera, but further field studies may identify some.

Forest inventories concentrate on tree species, but epiphytes and ferns may dominate in many areas and there may be more epiphyte and fern species in the project area than tree species. A total of 225 of the 1030 species (22%) in **Appendix A to Annex 02** are ferns. Orchids, most of which are epiphytic, may be the most speciose family in the project area. Clements and Harris (undated) recorded 342 species from 58 genera from Lake Kutubu and surrounding areas between 700 m and 1,400 m asl, and Harris (2003) collected 156 species from the Darai Plateau and 134 from the Libano River area.

High-altitude forests are the least studied. Thirteen species new to science were found in the Hides Range by Takeuchi (**Annex 01**), including a tree fern (*Cyathea* sp.) and three unusual calcium-depositing ferns.

The forests of the project area are highly diverse from a botanical viewpoint, and it must be assumed that all areas along the proposed route are highly diverse. However, the most significant aspect of floristics in relation to impact assessment is whether certain forest types, plant groups or species are concentrated in small areas along the pipeline ROW and could therefore be disproportionately impacted. The forest types associated with the pipeline RoWs and other project infrastructure are generally widespread, the karst flora does not appear to be locally endemic, and the more restricted montane forest above 1,200 m has a flora typical of the New Guinea highlands in general. It is extremely rare that plant species have distributions restricted to one very small area within a forest; most species are broadly and sparsely distributed.

Takeuchi (**Annex 01**) notes that epiphytes make up 75% of the floristic diversity in upland forests of this kind and plants other than trees featured strongly amongst the noteworthy collections made by Takeuchi (**Annex 02**) on the 2008 survey. The lower montane small-crowned forest with *Nothofagus*, in particular, is very rich in epiphytes and has produced a large number of species new to science.

10.1 Weeds

Takeuchi (**Annexes 01 and 02**) noted that Hides 3 survey area was remarkably free of invasive weeds and only two alien species were found, both harmless herbs restricted to construction rubble at helipads. One of these, *Passiflora ligulata* (passionfruit), is likely to have been planted by construction workers. He also discovered that many of the survey areas in 2008 were also in a floristically uncontaminated state. For example, no alien weeds were recorded from Deviation Camp survey area, a situation which is nowadays increasingly rare, even in highly protected forests. The survey areas at Baia River, Juha South and Juha North have at most, only a few benign adventives such as *Bidens pilosa* L. and *Ageratum conyzoides* L., probably brought in by working crews. These accidental introductions are low-growing annuals of limited forest-invasive capacity and are mainly a visual nuisance. He stresses the importance of keeping these areas weed free.

10.2 New species

Takeuchi's (**Annex 01**) collections included 16 species new to science and 15 range extensions. In 2008 (**Annex 02**) he recorded a further 15 species or subspecies new to science, 16 range extensions and additional locations for two range extensions discovered in 2005 (**Tables 3 and 4**). Plant collections in PNG often yield species new to science but the number discovered during the 2005 and 2008 surveys was extraordinarily high and demonstrates the fact that the montane karst and Juha areas, in particular, have been poorly explored.

Table 3 Species new to science recorded by Takeuchi (Annexes 01 and 02) in the project area.

Family	Species & collection numbers	Notes from Takeuchi (Annexes 01 and 02)	Survey area*
2005			
Actinidiaceae	<i>Saurauia</i> sp. nov. A, aff. <i>drimytiliflora</i> Diels; 19018, 19100	Probably a new species in the series Uniflorae.	H
Actinidiaceae	<i>Saurauia</i> sp. nov. B, cf. Uniflorae; 19072, 19096, 19171, 19185	<i>Saurauia</i> sp. B is distinguished by the unusual presence of monostylous flowers.	H
Aspleniaceae	<i>Asplenium</i> sp. nov.; 19243	This miniature fern is known only from a 25 cm plant found on a limestone wall at Hides 3.	H
Cyatheaceae	<i>Cyathea</i> sp. nov., section <i>Gymnosphaera</i> ; 19123	The novelty is distinguished from all other Malesian congeners by the tripinnate fronds with basal pinnae reduced to bare axes.	H
Melastomataceae	<i>Medinilla</i> sp. nov., <i>pseudostipularis</i> group; 19025	The species is distinguished by a dense covering of bristles on branches and calyces.	H
Moraceae	<i>Ficus</i> sp. nov.; 19537	This new vining species discovered at Benaria is immediately distinguished by its exceptionally large fruits (to 67 mm diameter).	B
Myristicaceae	<i>Myristica</i> sp. nov., aff. ' <i>fatua-inutilis</i> group'; 19378	The new species is a sub canopy tree with a dense and persisting indument of stellate hairs on vegetative parts.	B
Myrsinaceae	<i>Ardisia</i> sp. nov., aff. <i>myriosticta</i> K. Sch.; 19136	In view of the large number of restricted endemics in this genus, the discovery of a new <i>Ardisia</i> from the limestone district is hardly surprising.	H
Olacaceae	<i>Opilia</i> sp. nov., aff. <i>imbricata</i> Roxb.; 9156	The Kutubu limestone has a high-canopy congener with considerably larger inflorescences and fruits than the currently known species and is probably an undescribed taxon.	K

Table 3 Species new to science recorded by Takeuchi (Annexes 01 and 02) in the project area.

Family	Species & collection numbers	Notes from Takeuchi (Annexes 01 and 02)	Survey area*
Polypodiaceae	<i>Selliguea</i> sp. nov.; 19267	A remarkable new fern species with leaves only to 17 x 11 mm (sterile) and to 45 x 8 mm (fertile). Known from a single collection, taken in mossy forest around the Hides 2 wellhead.	H
Rubiaceae	<i>Hedyotis</i> sp. nov., aff. <i>nana</i> Merr. & Perry; 19269	A diminutive creeping herbs. The as-yet unnamed plant grows on exposed ground and was seen only in bulldozed clearings around the Hides 2 wellhead.	H
Sapindaceae	<i>Guioa</i> sp. nov., aff. <i>molliuscula</i> Radlk.; 19366	The fruits do not match any of the known species.	B
Thelypteridaceae	<i>Mesophlebium</i> sp. nov.; 19129	The new fern was discovered on the helicopter pad at Hides 3.	H
Unknown family	Unidentified genus; 19239	A sequence of three fern collections cannot be identified and are probably new species. The taxa are characterized by calcium concretions on their exterior surfaces and are probably specialists adapted to the limestone environment. Their character states are so unusual that thus far, it is not possible to provide a family or generic assignment. Collection 19239 is probably referable to the Dryopteridaceae, and the remaining numbers may belong in the Thelypteridaceae, but there are major problems with either identification.	H
Unknown family	Unidentified genus; 19240		H
Unknown family	Unidentified genus: 19240b		H
2008			
Elaeocarpaceae	<i>Elaeocarpus</i> sp. nov., aff. <i>sericoloides</i> A. C. Smith; 22581.	The only known <i>Elaeocarpus</i> with opposite leaves and large fruits is the rarely collected <i>Elaeocarpus sericoloides</i> . A related species with considerably larger leaves, glabrous on all parts, has been found at South Karius.	S
Elaeocarpaceae	<i>Sloanea</i> sp. nov., aff. <i>tieghemii</i> (F.v.M.) A. C. Smith; 22640.	This new species from South Karius is closest to <i>S. tieghemii</i> .	S
Ericaceae	<i>Vaccinium</i> sp. nov., aff. <i>summifaucis</i> Sleumer; 23199.	A specimen culled from a wind thrown <i>Nothofagus</i> is a new <i>Vaccinium</i> in section <i>Bracteata</i> . Considering the size of the genus (ca. 155 species in New Guinea), the novelty is primarily a technical discovery of interest primarily to specialists. However the plant's unusual features still qualify as a significant addition to our knowledge of New Guinea's montane flora.	J
Euphorbiaceae	<i>Macaranga</i> sp. nov. A, aff. 'Dioica Group' sensu Whitmore; 23506 ex F. Crome, 23528-A, 23531, 23540.	Due to their obviousness in open habitats, these light-demanding taxa are well-represented in herbarium collections and the species complement of the genus was thought to be near complete. With the surprising discovery of at least two new species of <i>Macaranga</i> from the regrowth at Juha, it is now obvious that such judgments are premature.	N
Euphorbiaceae	<i>Macaranga</i> sp. nov. B, aff. <i>salicifolia</i> Airy Shaw; 23072, 23153, 23161, 23221.		J
Grammitidaceae	<i>Grammitis</i> sp. nov.; 23273, 23404, 23518, 23551, 23648.	The new <i>Grammitis</i> , with leaves repeatedly forked through 3–4 orders, is a striking addition to the Papuanian flora, and considered one of the most surprising fern discoveries in recent years.	N, J
Meliaceae	<i>Aglaiia</i> sp. nov., aff. <i>puberulanthera</i> C. DC.; 23287, 23300, 23422, 23528-B, 23652, 23665, 23706.	The survey collections are most similar to <i>Aglaiia puberulanthera</i> , a species known thus far from four widely separated localities on mainland New Guinea.	N, J, B

Table 3 Species new to science recorded by Takeuchi (Annexes 01 and 02) in the project area.

Family	Species & collection numbers	Notes from Takeuchi (Annexes 01 and 02)	Survey area*
Meliaceae	<i>Aglaia</i> sp. nov., aff. <i>A. saxonii</i> ; 23575	A remarkable new species with huge lactiferous fruits (14 x 8.5 cm), exceeding by far anything ever reported from Papuaia. With unprecedented leaf and fruit morphology, this new species is a flagship discovery, easily among the most memorable species ever found in the genus.	N
Meliaceae	<i>Dysoxylum</i> sp. nov., aff. <i>phaeotrichum</i> Harms; 22697.	The new species has a whip like inflorescence recalling <i>Dysoxylum phaeotrichum</i> but is distinguished from the latter by several characteristics. The two taxa are similarly restricted to New Guinea's central region and are probably sibling or sister species.	S
Moraceae	<i>Ficus</i> sp. nov., aff. <i>hypophaea</i> Schltr.; 22805.	<i>Ficus</i> is the fifth largest genus in Papuaia, with an estimated 150 species in New Guinea. This root climber in section <i>Rhizocladus</i> was discovered near the Baia River, the second <i>Ficus</i> novelty to be obtained from the project area in recent years (Annex 01). The new vine is distinguished by its large cordate leaves and by sessile figs covered with silky hairs.	B
Myrsinaceae	<i>Fittingia</i> sp. nov., aff. <i>F. mariae</i> Stone; 22622, 23574, 23577, 23698, 23700.	A new <i>Fittingia</i> from Juha North is immediately distinguished by large leaves gradually tapered at both ends and lacking a petiole.	N
Myrtaceae	<i>Syzygium</i> sp. nov., aff. <i>malaccense</i> (L.) Merr. & Perry; 23684.	A new species in the <i>malaccense</i> complex is distinguished by showy yellow flowers inserted singly on the main trunk, or clustered on old wood.	N
Rubiaceae	<i>Psychotria matambuai</i> Takeuchi subsp. ?nov.; 23123, 23128, 23220, 23291.	This tree was originally described from Crater Mt (Eastern Highlands Province) and was regarded as endemic to that general area. With the newly acquired specimens from Juha South, the range is extended substantially westwards. It is common on the Juha limestone, where it grows to 15 m high. Juha specimens have extraordinary fruits to 35 x 28 mm, exceeding all congeneric material from New Guinea, and may require recognition as a subspecific endemic from limestone.	J
Rubiaceae	<i>Versteegia</i> sp. nov.; 23649, 23656, 23667.	<i>Versteegia</i> is a genus of five species endemic to the Papuanian region with four taxa reported from New Guinea, three of which are known only from their types and are still poorly understood. Given its endemic status and overall rarity, <i>Versteegia</i> is a genus of particular significance and interest. Any new addition to this genus can be considered a flagship discovery.	N
Solanaceae	<i>Solanum</i> sp. nov., subg. <i>Lycianthes</i> , aff. <i>S. peranomalum</i> Wernham; 22892.	This climbing <i>Solanum</i> is similar to <i>S. peranomalum</i> Wernham, a species known only from the type locality in south Irian Jaya. However the dense indument of stellate hairs readily distinguishes the new plant from its presumed relative.	B

* (Found at H – Hides 3, B – Benaria, K - Kutubu karst, J - Juha South, N - Juha North, B - Baia River, S - South Karius, D - Deviation Camp)

Table 4 First records and other notable plants recorded by Takeuchi (Annexes 01 and 02) in the project area.

Family	Species & collection numbers	Notes	Survey area*
2005			
Elaeocarpaceae	<i>Elaeocarpus lingualis</i> Knuth; 19336, 19373, 22548	Known with certainty only from the type locality (Huon Peninsula), the Idenburg River, and the Jimi Valley. However, the species is common at the Benaria survey area and was recorded at Juha South in 2008.	B, S
Elaeocarpaceae	<i>Elaeocarpus pachyanthus</i> Schltr.; 19370	Represented in the Lae Herbarium by seven sheets. The survey collection is the first with ripe fruits.	B
Elaeocarpaceae	<i>Sloanea gymnocarpa</i> A. C. Smith; 22988.	The species is apparently rare, with just four prior collections.	B
Lomariopsis Group	<i>Elaphoglossum favigerum</i> Holtt.; 19069	A rare fern previously known only from three specimens collected in Irian Jaya Province.	H
Lomariopsis Group	<i>Elaphoglossum resiniferum</i> Holtt., or aff.; 19235	<i>Elaphoglossum resiniferum</i> was previously only known from the Astrolabe Range of Central Province. The Hides specimen may be a new subspecies.	H
Myrtaceae	<i>Syzygium anomalum</i> Laut., or aff.; 19060	Previously known only from the area around Jayapura in Irian Jaya, this constitutes a first record for PNG.	H
Myrtaceae	<i>Syzygium ubogoensis</i> Takeuchi; 19155, 23118	This rare subcanopy species was first discovered on the Kutubu karst in 1992 and until being discovered at Juha South survey area in 2008 was only known only from the type collection.	K, J
Myrtaceae	<i>Xanthomyrtus bryophila</i> Diels, or aff.; 19064	A first record for PNG. Thus far has been recorded only from Mt Doorman in Irian Jaya.	H
Sapindaceae	<i>Mischocarpus pyriformis</i> (F.v.M.) Radlk. ssp. <i>papuanus</i> (Radlk.) R.W. Ham; 19292	In PNG, known previously only from three provinces (Western, Gulf, and Morobe).	B
Araliaceae	<i>Arthrophyllum proliferum</i> Philipson; 19431	An IUCN-listed 'vulnerable' species known previously from the Kuper Range (2 collections), and also very recently discovered on the ultrabasics near Salamaua.	B
Cucurbitaceae	<i>Zehneria scabridula</i> (Merr. & Perry) de Wilde; 19020	A rare herbaceous vine represented by very few collections.	H
Proteaceae	<i>Bleasdalea papuana</i> (Diels) Domin; 19391	<i>Bleasdalea papuana</i> is classified by IUCN as endangered. The tree is a presumed Gondwanic relict supposedly restricted to a small number of localities in northern New Guinea. The survey collection is the first from the Papuan side. The discovery of <i>Bleasdalea</i> on the Kutubu karst represents a biogeographically significant record.	B

Table 4 First records and other notable plants recorded by Takeuchi (Annexes 01 and 02) in the project area.

Family	Species & collection numbers	Notes	Survey area*
Proteaceae	<i>Helicia acutifolia</i> Sleum.; 19046, 19210, 19218, 19223, 22606, 22753	Until its rediscovery at the Hides 2 and 3 wellheads (Takeuchi Annex 01 , 2007c), <i>Helicia acutifolia</i> had been known only from the type collection made in 1936 at Mt Victoria. It was also found at Juha South and South Karius (Annex 02). <i>H. acutifolia</i> is very common within the project area and is not subject to any obvious threats. The plant was even seen as an invasive colonizer in anthropogenic habitats (pers. obs.), a circumstance which argues against its IUCN status as a taxon in need of conservation monitoring and possible interventions.	H, J, S
Rutaceae	<i>Acronychia rugosa</i> Hartley; 19189	A subcanopy tree represented in herbaria only by fruiting collections. The survey voucher is the first specimen showing the previously unknown flowers.	H
Rutaceae	<i>Halfordia papuana</i> Laut.; Gas Project survey s.n., SISA fide Gebia and Balun (2000)	<i>Halfordia papuana</i> is classified by the IUCN as a critically endangered tree species. This species is moderately common in montane habitats examined by the survey.	H
2008			
Burseraceae.	<i>Canarium acutifolium</i> (DC.) Merr. var. <i>pioriverensis</i> Takeuchi; 23707	Previously only known from the type locality in Chimbu Province	N
Elaeocarpaceae	<i>Aceratium pittosporoides</i> Schltr.; 23803, 23890.	The survey specimens are an altitudinal record (2,080 m), surpassing the previous limit of 1,400 m.	D
Euphorbiaceae	<i>Glochidion beehlerii</i> Takeuchi; 23168	Previously only known from the type locality in Chimbu Province	J
Euphorbiaceae	<i>Macaranga tsonane</i> Whitmore; 22827	The survey voucher from the Baia River is a country record for PNG, the species being only known from two localities in West Irian.	B
Grammitidaceae	<i>Grammitis ornatissima</i> (Ros.) Copel.; 22731, 23253.	This fern is readily distinguished from related taxa by the presence of calcium concretions ('lime dots') on the upper leaf surface. The survey collections are a first record for the PNG Highlands and the southern region.	J, S
Lecythidaceae	<i>Barringtonia josephstaalensis</i> Takeuchi, or aff.; 23504	The species was first described from PNG's Mamose region and presumably recollected several years later on the Bomberai Peninsula of Irian Jaya.	N
Lindsaea Group	<i>Lindsaea wernerii</i> Ros.; 23460.	<i>L. wernerii</i> is an epiphytic fern with scattered occurrences from Sumatra to the Mamose provinces of PNG. The Juha North collection is the easternmost record for the species and extends the range to New Guinea's southern region. The fern is normally a montane plant, but has now been recorded by the survey at an unusually low elevation (200 m).	N
Malvaceae s.l. (Sterculiaceae)	<i>Sterculia monticola</i> Mildbr. var. <i>laxiflora</i> Tantra; 23224	Previous collections of this taxon are all from the Mamose provinces of northeast New Guinea. This record extends the across the central divide and into the southern region.	J

Table 4 First records and other notable plants recorded by Takeuchi (Annexes 01 and 02) in the project area.

Family	Species & collection numbers	Notes	Survey area*
Meliaceae	<i>Dysoxylum</i> sp., aff. <i>pettigrewianum</i> F.M. Bailey; 22900	This common lowland tree has glabrous foliage but an anomalous hairy form has been collected from several localities in NW and NE New Guinea and the Benaria collection is the first for the Southern region. Unfortunately no flowers have yet been obtained for the hairy morphotype, and its status remains unresolved.	B
Myrsinaceae	<i>Discocalyx latepetiolata</i> (Mez) Sleumer; 23555.	An unusual low-elevation record was obtained for this species at Juha North. Prior to this, the species was regarded as a strictly montane tree from 1,065 to 2,835 m). The unexpected occurrences at 240 m are arguably attributable to extremely high rainfalls at the base of the Papuan Fold Belt.	N, D
Myrtaceae	<i>Decaspermum bracteatum</i> (Roxb.) A.J. Scott var. <i>glabrum</i> A.J. Scott; 22462, 22804, 22866, 23557.	The var. <i>glabrum</i> is defined by glabrous calyx tubes, acute calyx lobes, and lax panicles. <i>Decaspermum bracteatum</i> was previously thought to be represented in PNG only by var. <i>bracteatum</i> . The survey collections are the first PNG records for the glabrous form.	B, S
Myrsinaceae	<i>Loheria reiniana</i> (Jacobs) Sleumer; 22617, 22685.	There are only five collections of this species known and it is nowhere common.	S
Rubiaceae	<i>Caelospermum salomonense</i> (Engl.) J.T. Johansson; 22930.	A distributional record for the Trans-Fly and southern region of PNG.	B
Rutaceae	<i>Acronychia cartilaginea</i> Hartley; 23857.	The species was previously known from a single specimen obtained near Tari in 1966.	D
Rutaceae	<i>Acronychia reticulata</i> Laut. subsp. nov.; 23382.	<i>Acronychia reticulata</i> was previously unrecorded from the southern region. The specimen from Juha North is a new subspecies with distinctively foveate fruits.	N
Solanaceae	<i>Solanum memecylonoides</i> Bitter & Schltr.; 23895.	Scientific knowledge of <i>Solanum memecylonoides</i> is very poor. The survey's detailed observations of the plant's habitat, growth form, and coloration of diagnostic structures will enable effective characterization of this rarely seen vine. From the newest observations at Deviation Camp, it is now clear that the species is actually a frail, numerous branched, and low-growing liana starting from the ground (previously described as an epiphyte). The slender stems are horizontal clambering rather than strongly ascendant. Filaments and petals are (atypically) white.	D

* (Found at H – Hides 3, B – Benaria, K - Kutubu karst, J - Juha South, N - Juha North, B - Baia River, S - South Karius, D - Deviation Camp)

10.3 Conservation status

Table 5 lists terrestrial species of plants recorded in the project area that appear on the 2008 IUCN red list of threatened species (<http://www.redlist.org/>), and/or are recorded under the Papua New Guinea *Fauna (Protection and Control) Act 1966, 1978* ('Fauna Act'). The meanings of the classification codes are presented in **Table 6**. The occurrence of species in different bioregions is given in **Appendix 11**.

Table 5 Flora listed as of conservation concern in the project area.

Common Name	Scientific Name	IUCN ¹	PNG Fauna Act ²
Tree	<i>Halfordia papuana</i> Laut.	CR	-
Tree	<i>Bleasdalea papuana</i> (Diels) Domin	EN	-
Tree	<i>Flindersia pimenteliana</i> F.v.M	EN	-
Tree	<i>Arthrophyllum proliferum</i> Philipson	VU	-
Tree	<i>Helicia acutifolia</i> Sleum.	VU	-
Tree	<i>Pterocarpus indicus</i>	VU	-
Tree	<i>Aglaia puberulanthera</i>	VU	-
Tree	<i>Myristica globosa</i>	NT	-

* Species likely to occur but not yet recorded.

1 IUCN status CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Lower Risk But Near Threatened, DD = Data Deficient

2 Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R)

Table 6 Conservation classifications used by the PNG Fauna (Protection and Control) Act 1966, 1978 ('Fauna Act') and IUCN

PNG Fauna (Protection and Control) Act*	
Protected (P)	Taxa declared protected.
Restricted (R)	Taxa not declared protected but restricted for trade because of International market demand and traditional utilization within PNG.
IUCN	
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future.
Lower Risk But Near Threatened (NT)	A taxon is Lower Risk when it has been evaluated, does not satisfy the criteria for any of the categories Critically Endangered, Endangered or Vulnerable. Near threatened taxa are close to qualifying for Vulnerable.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

* The listed species for the PNG Fauna (Protection and Control) Act have been under revision for some time. The present list is based on Sekhran and Miller (2004) who emphasise CITES rulings which controls international trade in fauna. The CITES listings do not necessarily reflect conservation status in a country.

10.4 General comments on sensitivities and potential impacts

As far as can be determined, the flora identified by the PNG LNG Project surveys are diffusely spread through communities in the project area. Moreover, the most significant botanical discoveries of the 2008 surveys and the three most restricted species identified on the 2005 survey (*Zehneria scabridula*, *Saurauia* sp. nov. A, and *Hedyotis* sp. nov.) were mostly forest gap species, or even pioneers adapted to disturbance. Such plants are obligate heliophytes, at least at some point in their life cycle, so it is reasonable to assume that project construction would actually improve their population status by creating new opportunities for establishment (Annex 02).

However even with the shade-adapted plants identified as being of taxonomic or conservation interest, it is very doubtful that the proposed project represents a serious threat. Due to the sparse distributions of the important taxa, the direct construction-related losses are likely to be insignificant when measured against the probable size of existing populations. The diffuse distributions of the flora would make any mitigation measures extremely difficult to implement anyway. Of all the survey areas, probably only Juha South and the montane forests of Hides and possibly the Homa deviation, can be regarded as having significant concentrations of notable species, but even here, this perception may be an artefact of discontinuous spatial sampling.

The knowledge of floristics and vegetation distribution within the project area suggests that only three BVGs need particular consideration for impact analysis; namely - lower montane small crowned forest with *Nothofagus* on the Hides Ridge and to a lesser extent the Homa Deviation, the swamp forest complexes and swamp woodland and forest complexes. These BVGs are the most restricted in distribution within the project area and have particular sensitivities to fire and dieback.

Takeuchi (**Annexes 01 and 02**) recommended no species specific protective actions even in relation to the newly discovered species. Although nearly all of the novelties were seen only once, or at most a few times, this is not sufficient cause for presuming that the plants are at risk. While it is tempting to assume that these species have managed to evade detection because of extreme rarity, a more rational and plausible approach is to view the discoveries within their historical context as improving knowledge within one of Malesia's most poorly documented areas (**Annex 02**). Even if the findings are intriguing, the 2005 and 2008 survey indicate not so much a remarkable local flora, but of a provincial level of documentation so thin that almost any exploration effort can be expected to deliver significant results. "In terms of project impacts, the immediate effects of the contemplated activities will be botanically negligible. The principal concerns will revolve around the long term, indirect consequences of infrastructure development, in particular the collateral costs of improved access to currently pristine environments" (**Annex 02**).

11 Non-volant mammals

Using the combined data from the PNG LNG Project and the WWF surveys there are 598 locality records of 86 species in 10 families of non-volant mammals in the project area. In addition the introduced wild pig (*Sus scrofa*) is ubiquitous. 76 species were known from the project area prior to the PNG LNG Project surveys. The 2005 survey (**Annex 03**) detected three more species and the 2008 survey (**Annex 04**) a further 10. A full list of mammal species recorded at each sample site is given in **Annexes 03** and **04** and the species in each bioregion, using the combined data from the PNG LNG Project and the WWF surveys, is presented in **Appendix 5**. Some species found on the PNG LNG Project surveys are shown in **Plates 33** to **39**. Common English names for non-volant mammals are well established so are used in the following discussion, unless a species does not have one (see **Appendix 5** for the associated scientific names).

Fifty (56%) of the total recorded species are rodents. After rodents, the most speciose groups are the 11 species of possums, 8 species of macropods, the cuscuses, and 7 marsupial carnivores. The genus *Phalanger* (cuscuses) is particularly diverse with six species: Mountain Cuscus, Ground Cuscus, Common Cuscus, cuscus *P. mimicus*, Silky Cuscus and Stein's Cuscus.

Altitude is a major determinant of the distributions of non-volant mammals within New Guinea. **Figure 8** presents the number of species at all sample sites within the project area and shows a tendency for numbers of species to increase with altitude. However several of the sample sites, e.g. at Mt Sisa, were over a large elevational range. To better understand the relationship between diversity and altitude, the total number of species expected to occur within each 100 m altitudinal band was calculated using **Appendix 5** and the known altitudinal range for every species from Flannery (1995)⁷. The data (**Figure 9**) were well fitted by a quadratic and show that the altitudinal range with the highest diversity (over 50 species) is between approximately 1000 and 2000 m asl.

The diversity within bioregions reflects this altitudinal relationship (**Table 7**). The richest bioregions are the Western Volcanics and the Eastern Uplands Volcanics/Karst. They include the optimal altitudinal belt and have some areas of rich volcanic soils with more productive forest in terms of food resources for mammals. The Northern Montane Karst that includes the Hides 3 sample area from the 2005 survey is above the optimal mammal elevation belt and the fauna there is not dominated by rodents and a high diversity of marsupials is maintained. The lowland bioregions in the Kikori drainage are distinctly depauperate in comparison and, considering **Figure 9**, may be close to the maximum number of species that might be expected there.

In contrast to the Kikori Lowlands the Western Lowlands sampled in the 2008 survey are more diverse with 35 species recorded from the Juha North and Baia River survey areas (**Annex 04**) versus 24 in the Kikori Lowlands. The Western Lowlands are however, higher than the Kikori Lowlands (200 to 400 vs. 0 to 200 m asl) and the area is fundamentally low hills as opposed to the extensive lowland plains on the Kikori. Nonetheless, there are only 18 species in common between these two bioregions, with the Western Lowlands having

⁷ Thus if species A occurs from 850 to 1100 m asl it is assumed present in altitude belts 800-900, 900-1000 and 1000-1100 m.

17 species not recorded in the Kikori Lowlands. Only four species recorded in the Kikori Lowlands were not recorded in the Western Lowlands.

Table 7 Numbers of non-volant mammal species in each bioregion of the project area. Combined data from the PNG LNG Project and the WWF surveys.

Family	Kikori Lowlands	Sirebi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
Upper elevation of Bioregion (m asl)	200	400	600	1100	400	1200	1300	1000	1400	2700	1800	3268
Lower elevation of Bioregion (m asl)	0	40	200	300	200	400	200	800	1000	280	800	1800
No of sample sites	8	2	1	3	2	1	5	1	2	4	4	1
Tachyglossidae			2	2	1	1	1			1	1	1
Dasyuridae			2	5	4	4	3		1	6	6	2
Peroryctidae	4		2	2	3	3	4			4	3	3
Phalangeridae	4		3	4	3	6	3		1	6	5	5
Macropodidae	2		4	3	1	4	5			5	5	3
Burramyidae							1			1	1	0
Pseudocheiridae	1				1	2	3			5	5	3
Petauridae	2		1	2	2	2	2			4	3	1
Acrobatidae	1		1	1	1	1	1	1		1	1	1
Muridae	10	3	8	11	19	20	18	4	6	39	28	6
Total Species	24	3	23	30	35	43	41	5	8	72	58	25

Entries are numbers of species.

Table 8 Non-volant mammal species recorded from only one survey area within the project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name	Scientific name	Sample site recorded from ¹
Narrow-striped Dasyure	<i>Phascolosorex dorsalis</i>	Deviation Camp
undescribed species of Murexia	<i>Murexia</i> sp.	MS1 and MS2 (Mt Sisa)
White-Striped Dorcopsis	<i>Dorcopsis hageni</i>	MS1 and MS2 (Mt Sisa)
Macleay's Dorcopsis	<i>Dorcopsulus macleayi</i>	Deviation Camp
New Guinea Pademelon	<i>Thylogale browni</i>	Juha South
Great Tailed Triok	<i>Dactylopsila megalura</i>	MS1 and MS2 (Mt Sisa)
Broad-headed Tree-mouse	<i>Chiruromys lamia</i>	Deviation Camp
Western White-eared Giant-rat	<i>Hyomys dammermani</i>	South Karius
Eastern White-eared Giant-rat	<i>Hyomys goliath</i>	South Karius
Greater Small-toothed Rat	<i>Macruromys major</i>	MS1 and MS2 (Mt Sisa)
Menzie's Mouse	<i>Abeomelomys sevia</i>	Deviation Camp
Monckton's Melomys	<i>Paramelomys moncktoni</i> ²	Juha North
Shaw Mayer's Pogonomelomys	<i>Pogonomelomys mayeri</i>	MS1 and MS2 (Mt Sisa)
Eastern Rat	<i>Rattus mordax</i> ²	Juha North
Large Spiny Rat	<i>Rattus cf. praetor</i>	Gobe2
Undescribed species of Rattus	<i>Rattus</i> sp. nov. (Mt Kemenagi)	Mt Kemenagi Group (MK3)
Undescribed species of Rattus	<i>Rattus</i> sp. nov. Darai (cf. <i>mordax</i>)	Libano Sok

¹ See **Appendix 2** for details.

² Probably present according to local interviews.

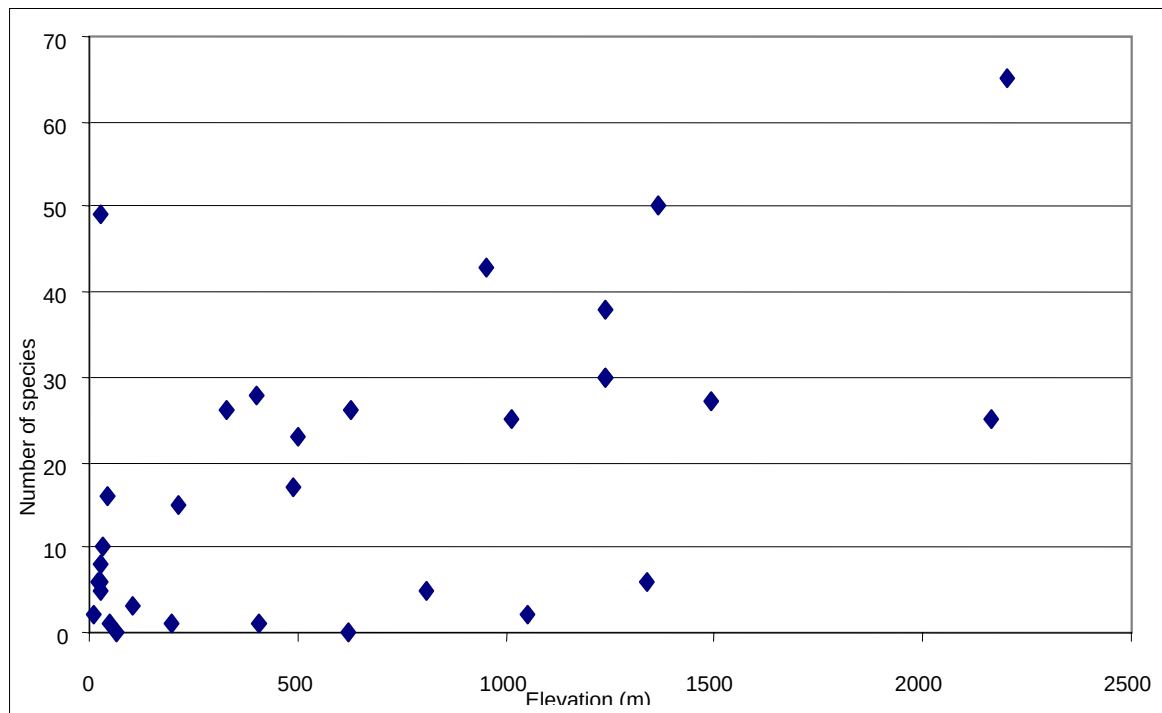


Figure 8 Relationship between elevation and numbers of species of non-volant mammals at survey areas within the project area (all data from Appendix 5).

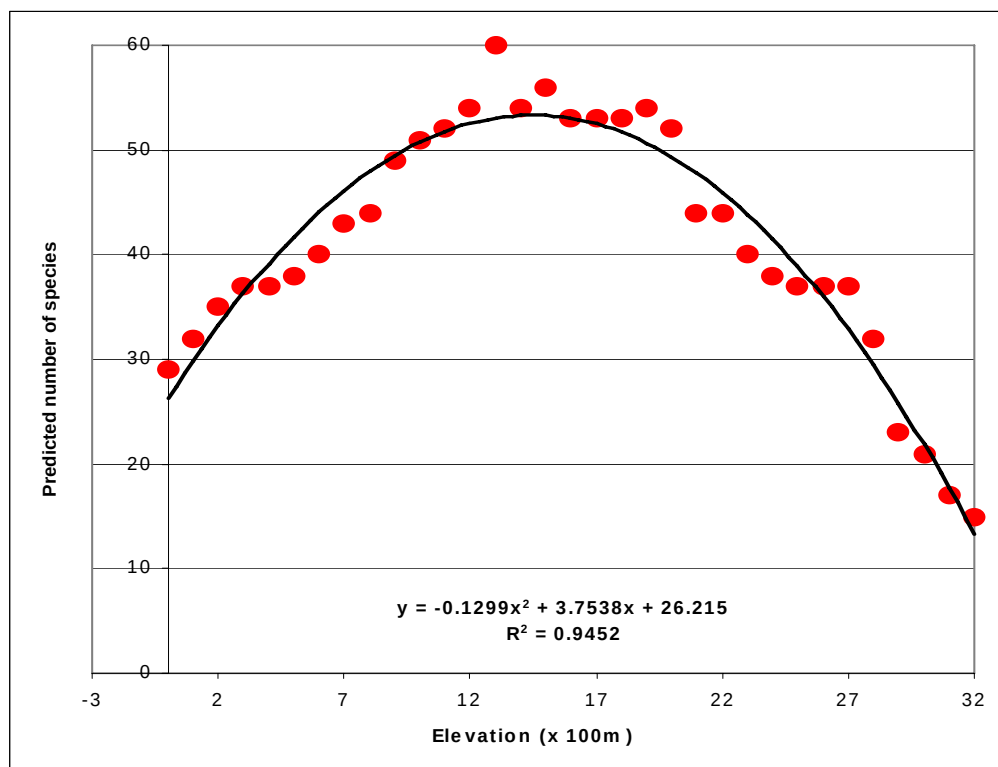


Figure 9 Relationship between predicted numbers of species of non-volant mammals and elevation within the project area. Each point is a sample site.

The 2008 survey (**Annex 04**) also demonstrated the richness of the Western Foothills. Prior to the 2008 survey the Mubi River Karst was considered the richest bioregion after the uplands (Crome 2005) with five sample sites producing 41 species and the highest diversity recorded at any sample site was 27. The single sample site at Juha South survey area

produced 30 species and an additional 13 species were considered highly likely to occur following discussions with local people (**Annex 04**). Further surveys in the Juha area are likely to increase this total considerably.

Seventeen species have only been recorded from a single survey area (**Table 8**). However, as knowledge of the project area increases it is expected that the number of species found at only one location will decrease. For example, five species known only from a single location in the KICDP prior to the 2005 survey were found at Hides 3 or Benaria survey areas during that survey.

No species, except those new to science, are restricted to the project area.

11.1 Endemism

Seventy-five per cent of the species so far recorded from the project area are New Guinea endemics. A system to estimate endemism was developed for the 2005 and 2008 survey. Each species was given an endemism score as follows.

- 5 Endemic to mainland PNG.
- 4 Endemic to the New Guinea and its satellite islands.
3. Endemic to New Guinea and its satellite islands and the Aru Islands.
- 2 Endemic to New Guinea and its satellite islands and New Britain and/or New Ireland and/or the Louisiades.
- 1 Occurs more widely through Australia, Indonesia, the Solomon Islands or the Pacific.

Table 9 presents endemism analyses for bioregions. Ignoring the bioregions with few species, probably due to poor sampling, there is a trend for increasing endemism with increasing altitude. These montane endemics include a large range of rodents e.g. Earless Water Rat, Ernst Mayr's *Leptomys*, New Guinea Rat, Greater Small-toothed Rat and Slender Rat, as well as marsupials such as Long-nosed Murexia, Striped Bandicoot, Mountain Cuscus, Stein's Cuscus, Silky Cuscus, Plush-coated Ringtail, Coppery Ringtail, Pygmy Ringtail and Long-fingered Triok.

11.2 New species

The WWF surveys discovered five species new to science – a new species of marsupial carnivore *Murexia* sp. nov. from Mt Sisa and four new species of rats: *Rattus* sp. nov. cf. *praetor* from Gobe, *Rattus* sp. nov. from Mt Kemenagi, *Rattus* sp. nov. cf. *mordax* from Libano River, and *Rattus* sp. nov. from Gobe, the Darai Plateau and Dark End Lumber sample areas. While no species new to science were discovered during the PNG LNG Project surveys a noteworthy discovery was the Rock-dwelling Giant-rat on the scree slopes of the drill pad at Hides 3 survey area (Plate 39) and a Western White-eared Giant-rat at South Karius survey area (Plate 37).

11.3 Conservation status

Table 10 lists non-volant mammals recorded in the project area that appear on the 2008 IUCN red list of threatened species (<http://www.redlist.org/>), and/or are recorded under the

Papua New Guinea *Fauna (Protection and Control) Act 1966, 1978* ('Fauna Act'). The meanings of the classification codes are presented in **Table 6** and the occurrence of species in different bioregions is given in **Appendix 11**

Table 9 Levels of endemism of nonvolant mammals in bioregions of the project area. Combined data from the PNG LNG Project and the WWF surveys.

Endemism	Kikori Lowlands	Sirebi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands*	Western Volcanics*	Eastern Uplands Volcanics/ Karst*	Northern Montane Karst
5	2	1	3	2	3	3	5		2	10	6	1
4	7		10	12	15	23	20	2	4	41 ¹	36	17
3	1		2	3	4	3	2			4	3	2
2	3	1	3	4	4	5	3	2		4	4	2
1	11	1	5	9	9	9	11	1	1	12	8	3
Total species	24	3	23	30	35	43	41	5	7	70	57	25
Endemism score ²	37.5	33.3	56.5	46.7	51.4	60.5	61.0	40.0	85.7	71.8	73.7	72.0
No of survey sample sites	8	2	1	3	2	1	5	1	2	4	4	1

Endemism rating: 5 - endemic to mainland PNG, 4 - endemic to the New Guinea and its satellite islands, 3 - endemic to New Guinea and its satellite islands and the Aru Islands, 2 - endemic to New Guinea and its satellite islands and New Britain and/or New Ireland and/or the Louisiades, 1 - occurs more widely through Australia, Indonesia, the Solomon Islands or the Pacific. Species of mammals new to science scored as "5".

*The table excludes unidentified *Rattus* species that cannot be assigned a rating (**Appendix 5**) so the totals differ from those in **Table 7**.

1 the unidentified *Hyomys* (either *H. dammermani* or *H. goliath*) recorded at Mt Sisa is considered as *H. dammermani* and scores "4" (**Appendix 5**).

2 =% of species in endemism categories 4 + 5.

Table 10 Non-volant mammals listed as of conservation concern in the project area. Combined data from the PNG LNG Project and the WWF surveys.

Common Name	Scientific Name	IUCN ¹	PNG Fauna Act ¹
Large Leptomys	<i>Leptomys elegans</i>	CR	-
Fly River Leptomys	<i>Leptomys signatus</i>	CR	-
Large Pogonomelomys	<i>Pogonomelomys bruijini</i>	CR	-
Long-beaked Echidna	<i>Zaglossus bartoni</i>	EN	P
Goodfellow's Tree Kangaroo	<i>Dendrolagus goodfellowi</i>	EN	P
Greater Small-toothed Rat	<i>Macruromys major</i>	EN	-
New Guinea Quoll	<i>Dasyurus albopunctatus</i>	VU	-
Stein's Cuscus	<i>Phalanger vestitus</i>	VU	-
Doria's Tree Kangaroo	<i>Dendrolagus dorianus</i>	VU	P
Macleay's Dorcopsis	<i>Dorcopsulus macleayi</i>	VU	R
New Guinea Pademelon	<i>Thylogale browni</i>	VU	-
Plush-coated Ringtail	<i>Pseudochirops corinnae</i>	VU	-
Great Tailed Triok	<i>Dactylopsila megalura</i>	VU	-
One-toothed Shrew Mouse	<i>Mayermys ellermani</i>	VU	-
Long-nosed Murexia	<i>Phascomurexia naso</i>	DD	-
Ground Cuscus	<i>Phalanger gymnotis</i>	DD	-
Lowland Tree Kangaroo	<i>Dendrolagus spadix</i>	DD	P
Lowland Ringtail	<i>Pseudochirulus canescens</i>	DD	-
Giant Naked-tailed Rat	<i>Uromys anak</i>	NT	-
Rock-dwelling Giant Rat	<i>Xenuromys barbatus</i>	NT	-
Short-beaked Echidna	<i>Tachyglossus aculeatus</i>	-	R
Feather-tailed Possum	<i>Distoechurus pennatus</i>	-	R

* Species likely to occur but not yet recorded.

1 CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient; Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R)

Table 11 Habitat preferences of non-volant mammals in the project area. Combined data from the PNG LNG Project and the WWF surveys.

Prefers or tolerates secondary and disturbed areas		Old growth forest only	Habitat needs unknown
Short-beaked Echidna	Grey Black-eared Rat	New Guinea Quoll	Long-beaked Echidna
Black-tailed Antechinus	Dusky Black-eared Rat	Long-nosed Murexia	undescribed species of Murexia
Narrow-striped Dasyure	Grassland Melomys	Short-furred Dasyure	Common Echymipera
Three-striped Dasyure	Black-tailed Melomys	Rafra's Bandicoot	Cuscus
Long-nosed Echymipera	Groove-toothed Shrew Mouse	Ground Cuscus	Great Tailed Triok
Striped Bandicoot	Waterside Rat	Stein's Cuscus	Broad-headed Tree-mouse
Mountain Cuscus	Thomas's Melomys	Doria's Tree Kangaroo	Fly River Leptomys
Common Cuscus	New Melomys species	Goodfellow's Tree Kangaroo	Greater Small-toothed Rat
Silky Cuscus	Lowland Melomys	Lowland Tree Kangaroo	One-toothed Shrew Mouse
Spotted Cuscus	Mountain Melomys	Macleay's Dorcopsis	Long-nosed Melomys
White-Striped Dorcopsis	Shaw Mayer's Pogonomelomys	Lesser Forest Wallaby	Lorentz's Melomys
Grey Dorcopsis	Large Tree Mouse	Plush-coated Ringtail	Monckton's Melomys
New Guinea Pademelon	Chestnut Tree Mouse	Coppery Ringtail	Large Pogonomelomys
Long-tailed Pygmy Possum	Grey-bellied Tree-mouse	Lowland Ringtail	Large Spiny Rat
Painted Ringtail	Pacific Rat	Pygmy Ringtail	Undescribed species of Rattus
Striped Possum	Cape York Rat	Long-fingered Triok	
Sugar Glider	Eastern Rat	Uneven-toothed Rat	
Feather-tailed Possum	New Guinea Rat	Lesser-tree Mouse	
Common Water Rat	Stein's Rat	Earless Water Rat	
Western White-eared Giant-rat	Slender Rat	Rummler's Mouse	
Eastern White-eared giant-rat	Giant Naked-tailed Rat	Ernst Mayer's Leptomys	
White-eared Rat	Mottled-tailed Giant Rat	White-bellied Melomys	
Large Leptomys	Rock-dwelling Giant Rat	Menzie's Mouse	
Long-footed Tree Mouse		Moss Forest Rat	

11.4 General comments on sensitivities and potential impacts

No species of mammal other than the new species that await naming are restricted to the project area. While the new species await identification it is highly likely further surveys will locate them elsewhere. The distribution of rodents in particular is very poorly understood because there are few mammalogists actively engaged in field work on this group in PNG.

The mammal data indicates Hides Ridge (**Annex 03**) and the Juha areas (**Annex 04**) are special areas for mammals because of their richness and, particularly for Juha, remoteness and inaccessibility.

Of the non-volant mammal species recorded in the project area, almost half are known to occupy disturbed habitats such as secondary forest, regrowth and areas cleared for gardens and all are capable of crossing cleared areas if not too wide (**Table 11**). Of the remainder, the biology of approximately 15 species is not well enough known to gauge their habitat preferences, and the rest all prefer old growth forest.

The primary forest species would be unlikely to be sensitive to habitat clearing on small scales of a few hectares and populations are likely to persist, as long as those clearings are embedded in large areas of undisturbed forest. Arboreal species and small mammals restricted to forest interiors may be sensitive to wide clearings that could act as barriers to movement thus splitting populations and reducing population viability.

However more pervasive and wide spread impacts would be habitat degradation from accidental introductions of weeds and exotics and/or if the project accidentally facilitated increased access to the area leading to unsustainable logging and widespread shifting cultivation.

For many species, hunting is a major threatening process and the potential increase of hunting that may be brought about if the project infrastructure allows the public access to areas previously very difficult to access (e.g. at Juha) could be a serious impact. Hunting can rapidly deplete or eliminate the larger species such as tree kangaroos, cuscuses, kangaroos and possums from an area. (**Plate 33** and **34**) The influence of this is obvious in the Western Lowlands and Western Foothills bioregions where there is very low or no hunting pressure in these mostly inaccessible regions and the mammals are abundant. For example at Juha South in the 2008 survey six individual cuscuses were seen feeding during the day near the camp, a situation extraordinarily rare in PNG (**Annex 04**). Controlling this potential impact is a matter of controlling activities of and providing education to project personnel, and ensuring the public does not use infrastructure during both construction and operations phases.

12 Bats

Common English names are rarely used for bats and many species do not have one, so the following discussion uses scientific names except for very prominent and well known species. (See **Appendix 6** for associated common names).

The geological history of New Guinea has produced a bat fauna that is a mixture of (a) New Guinea endemics that appear to be rainforest specialists, (b) southeast Asian or Old World taxa that have speciated over many millions of years, and (c) open-habitat Australian bats (including vespertilionids such as *Scotorepens*, *Chalinolobus* and *Nyctophilus*). The Australian bats are recent infiltrators since low sea levels during the Pleistocene ice ages (10,000 to 20,000 years ago) allowed the connection of New Guinea with Australia.

Over 90 species of bats are known from PNG, of which 71 are known from New Guinea and its satellite islands, and the remainder are found in the Bismarck Archipelago and other offshore islands. This high diversity approaches 10% of the world's species, and 6 of the 18 extant families are represented in this country. The great extent of undisturbed bat habitats, including the rainforests of the central cordillera of New Guinea, and the mangroves, swamp forests and woodlands of the gulf region, provide an array of ecological niches for the bat fauna. A large number of foraging guilds are represented, within both generalist and specialist assemblages (Richards, 2002). **Plates 40 to 45** show some species captured during the 2008 survey.

Bats fall into two major groups. The Megachiroptera comprises about one-fifth of the total PNG species and contains a single family, the Pteropodidae, which includes the large to medium-sized frugivorous flying foxes and the small nectarivorous blossom bats (**Plates 44 and 45**). None of these species echolocate and they use vision to navigate. The five remaining families of bats belong to the Microchiroptera (microbats) which are small to medium-sized, insectivorous species that forage on the wing and echolocate (**Plates 40 to 43**). The microbats are difficult, sometimes impossible, to capture and are best detected by recording their ultrasonic echolocation calls that, like birdcalls, are mostly species specific. WWF did not have this echolocation detecting technology so the biodiversity surveys prior to 2005 have not adequately sampled these microbats. Automated electronic call recording was used as the primary data gathering technique during the 2005 and 2008 survey and to date these data provide the best estimate of the composition of the microbat fauna in any part of the project area.

Using the combined data from the PNG LNG Project and the WWF surveys there are a total of 263 field records of 46 identified and one unidentified bat species from the project area. A further 28 species could occur. All recorded species are presented in Appendix 6 and Table 12 presents data on the diversity of bat families in the project area bioregions.

There is a negative relationship between species diversity and altitude (**Figure 10**), with the Pteropodidae in particular, having most species in lowland and mid elevation areas. The lowlands also seem important for the rarer species. The 2005 surveys (**Annex 05**) notes electronic detection has been able to demonstrate that several microbats previously thought to be rare are probably more common and widespread. This was confirmed in the 2008 surveys (**Annex 06**). Of the 30 species of microbat recorded in 2005 and 2008, only 11 were considered rare i.e. with less than 4 records and/or occurring at less than 2 survey areas. Of these, 9 were recorded from elevations below 300 m asl and only 2 species,

Miniopterus australis and *M. propitristis*, were restricted to high elevations. The low elevation rarer species are foraging specialists: *Murina florium*, *Kerivoula muscina* and the *Phoniscus* are slow-flying highly manoeuvrable species that glean insects from substrates, *Myotis moluccarum* forages for aquatic prey in the backwaters of rivers, and the remaining species, *Hipposideros cervinus*, *Aselliscus tricuspidatus*, *Hipposideros calcaratus cupidus* and, probably, *Emballonura furax* have specialised cave roosting requirements (very hot and humid microclimates).

Table 12 Number of species in each bat family in bioregions of the project area. Combined data from the PNG LNG Project and the WWF surveys.

FAMILY	Kikori Lowlands	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern Montane Karst
Pteropodidae	9	5	5	7	6		8	4	3	5	6	1
Emballonuridae	1			4	1-2 ¹	2-3 ¹	2			4	2-3 ¹	2-3 ¹
Hipposideridae	5	1	4	3	6	3					1	
Rhinolophidae	1		1	2	5	5				5	5	2
Vespertilionidae	3	1			9-10 ²	4-5 ²	5		2	8	8	7
Molossidae					2	2				2	2	2
Total	19	7	10	16	29-31	16-18	15	4	5	24	24-25	14-15

¹ Calls of *Emballonura diana* and/or *E. furax* recorded

² Calls of *Miniopterus macrocneme* and/or *M. medius* recorded

A significant finding of the 2005 and 2008 survey is that fewer species use the interiors of rainforest than may be imagined. The edges of rivers and major clearings or open areas were primary habitats, and more species were recorded along river edges than in any other habitat. This pattern is attributed to the difficulty of echolocating in densely cluttered forest, where fast flying species with low manoeuvrability were rarely recorded. Overall, the species count in river edge habitat and open areas exceeded the number of species recorded in rainforest *per se*. At some survey areas in 2008 only 5 species were recorded in rainforest compared with 13 species at river edges. In total in 2008 only 3680 calls were detected at the 23 forest interior sample sites sampled over the 5 survey areas in rainforest (mean 160 calls/sample site/night) compared to 25,881 from the 18 edge and open habitat sample sites (mean 1,437.8 calls/sample site/night) (**Annex 06**)

Table 13 presents habitat preferences of the microbat species recorded by the 2008 survey. In total, only six species showed a distinct preference for rainforest interiors. This, and the heavy bias towards edges and open areas, may indicate that the PNG microbat fauna may have evolved to accommodate regular broad-scale disturbance, such as landslides and volcanism.

12.1 New Species and significant additions to the PNG bat fauna

Rhinolophus maros, was recorded at Benaria in the 2005 survey and in 2008 at all survey areas except Deviation Camp. The species is new for PNG and was previously only known from eastern Cape York.

The PNG LNG Project surveys also recorded two species that may be new to science.

Paranyctimene sp aff *raptor* - a single individual of this small pteropodid was caught at an elevation of 2060 meters at Deviation Camp survey area (**Plate 45**). It is significantly different in appearance to *P. raptor*, which is only found at elevations from sea level up to 1400 m. (Bonaccorso 1998). It may represent a species new to science.

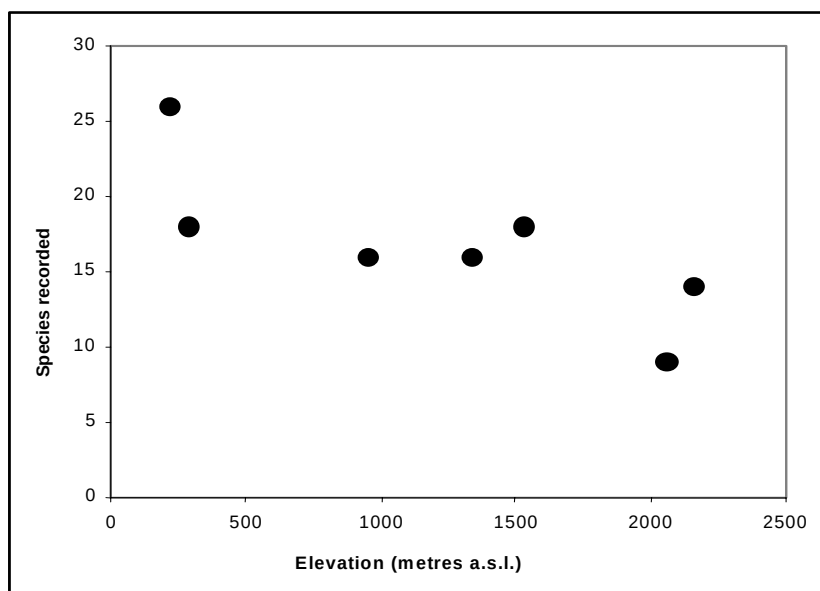


Figure 10 The relationship between bat species richness and elevation at the seven survey areas of the PNG LNG Project surveys.

The same unidentified species of Vespertilionidae (“Vesp Fmin 31”) was recorded by call in both 2005 and 2008. There are very few known species that could be attributable to this call, so there is the possibility that it may be an undiscovered taxon. The mnemonic “Vesp Fmin 31” used by G. Richards (**Annexes 05** and **06**) refers to this species’ echolocation call having a minimum frequency of 31 kHz.

12.2 Conservation status

Table 14 lists bats recorded in the project area that appear on the 2008 IUCN red list of threatened species (<http://www.redlist.org/>), and/or are recorded under the Papua New Guinea *Fauna (Protection and Control) Act 1966, 1978* (‘Fauna Act’). The meanings of the classification codes are presented in **Table 6**. The occurrence of species in different bioregions is given in **Appendix 11**.

12.3 General comments on sensitivities and potential impacts

The habitat analysis (**Table 13**) demonstrates in general that the bat fauna of the project area adapts well to foraging habitat disturbance and disturbance favours many species. However species that roost or breed in caves or congregate in large colonies have sensitivities unrelated to the habitats they forage in. Thirty-four of the species recorded or likely to occur in the project area use caves exclusively. The project area is extensively cavernicolous, but this may not mean that there are numerous caves to house bats because most species have specific requirements of cave structure and microclimates (Hall and Richards 2004). For example *Hipposideros diadema* (**Plate 43**) selects very warm and humid caves with high domed ceilings, *Hipposideros ater* selects very small, very humid caves, usually with an earth floor. Two species that have not yet been recorded but that

could occur in the project area and have very specialised cave microclimate requirements are, *Rhinolophus megaphyllus* and *Miniopterus schreibersii* (Table 15). The former selects large caves with very high humidities, usually with a wet floor with pools of water and the latter needs large caves that are warm but not as humid as *Hipposideros* caves, with domed ceilings for rearing of young which are unable to thermoregulate for the first six weeks of life, requiring mothers to rear them in a place (e.g. dome) that can trap body heat.

Flying foxes (genus *Pteropus*) usually congregate in large colonies, particularly in the lowlands, and these are highly vulnerable to destruction by hunting. Flying foxes that congregate in caves are particularly susceptible to colony destruction. G. Richards (Annex 06) describes the near-extinction of the montane Bulmer's Fruit-bat (*Aproteles bulmerae*) which was known from a single cave. Hunters virtually wiped it out and it is now arguably one of the most endangered mammal in the world. Unconfirmed reports that a cave with Bulmer's Fruit-bat may exist in the northern part of the project area (Annex 06) was obtained in the 2008 survey. If this is correct it is a highly significant finding (see section 30.1).

Thus while the bat fauna is generally tolerant of habitat disturbance, limiting impacts on caves and colonial flying foxes both direct and indirect are the keys to maintaining the bat fauna in the project area.

Table 15 shows which species are cave dwellers.

Table 13 Summary of preferred habitats of microbats recorded during the 2008 survey (Annex 06).

Preferred habitats	Rare and restricted species ¹	Abundant, Common or Uncommon species
Rainforest	<i>Miniopterus australis</i> *	<i>Hipposideros semoni</i>
	<i>Murina florium</i> *	<i>Hipposideros maggietaaylorae</i>
		<i>Nyctophilus microtis</i>
		<i>Nyctophilus microdon</i>
Regrowth	<i>Hipposideros calcaratus</i>	
	<i>Aselliscus tricuspidatus</i> *	
Rainforest lagoons, clearings	<i>Kerivoula/Phoniscus</i> *	
River edges	<i>Miniopterus propitristis</i>	<i>Rhinolophus maros</i>
	<i>Pipistrellus papuanus</i>	<i>Myotis moluccarum</i> *
		<i>Otomops secundus</i>
Rainforest edges		<i>Rhinolophus megaphyllus</i>
		<i>Rhinolophus euryotis</i>
		<i>Hipposideros diadema</i>
		<i>Miniopterus macrocneme/medius</i>
Open areas	<i>Kerivoula muscina</i> *	<i>Mosia nigrescens</i>
		<i>Rhinolophus arcuatus</i>
		<i>Rhinolophus philippinensis</i>
		<i>Philetor brachypterus</i>
		<i>Pipistrellus angulatus</i>
		<i>Pipistrellus collinus</i>
Not clearly defined or unknown	<i>Hipposideros cervinus</i> *	<i>Chaerephon jobensis</i>
	<i>Emballonura furax</i> *	
	Unknown species "Vesp Fmin 31"	

1. Less than five records during the 2008 survey (Annex 06)

* Habitat specialists (i.e. restricted to a habitat).

Table 14 Bats listed as of conservation concern in the project area. Combined data from the PNG LNG Project and the WWF surveys.

Common Name	Scientific Name	IUCN ¹	PNG Fauna Act ¹
Bulmers' Fruit Bat *	<i>Aproteles bulmerae</i>	CR	-
Thomas' Big-eared Bat *	<i>Pharotis imogene</i>	CR	-
Lesser Tube-nosed Bat	<i>Nyctimene draconilla</i>	VU	-
Moss-forest Blossom Bat *	<i>Syconycteris hobbit</i>	VU	-
Large-eared Sheath-tailed Bat	<i>Emballonura diana</i>	VU	-
New Guinea Sheath-tailed Bat	<i>Emballonura furax</i>	VU	-
Papuan Sheath-tailed Bat *	<i>Saccolaimus mixtus</i>	VU	-
Telefomin Leaf-nosed Bat *	<i>Hipposideros corynophyllus</i>	VU	-
Fly River Leaf-nosed Bat *	<i>Hipposideros muscinus</i>	VU	-
Small-toothed Big-eared Bat	<i>Nyctophilus microdon</i>	VU	-
Greater Big-eared Bat *	<i>Nyctophilus timoriensis</i>	VU	-
Fly River Trumpet-eared Bat	<i>Kerivoula muscina</i>	VU	-
Papuan Mastiff-bat *	<i>Otomops papuensis</i>	VU	-
Mantled Mastiff-bat	<i>Otomops secundus</i>	VU	-
Lesser Bare-backed Bat	<i>Dobsonia minor</i>	NT	-
Greater Tube-nosed Bat	<i>Nyctimene aello</i>	NT	-
Round-eared Tube-nosed Bat	<i>Nyctimene cyclotis</i>	NT	-
Green Tube-nosed Bat	<i>Paranyctimene raptor</i>	NT	-
Raffray's Sheath-tailed Bat	<i>Emballonura raffrayana</i>	NT	-
Yellow-bellied Sheath-tailed Bat *	<i>Saccolaimus flaviventris</i>	NT	-
Southern Sheath-tailed Bat *	<i>Taphozous australis</i>	NT	-
Hill's Leaf-nosed Bat *	<i>Hipposideros edwardshilli</i>	NT	-
Greater Leaf-nosed Bat	<i>Hipposideros semoni</i>	NT	-
Wollaston's Leaf-nosed Bat	<i>Hipposideros wollastoni</i>	NT	-
Large-eared Horseshoe Bat	<i>Rhinolophus philippinensis</i>	NT	-
Papuan Pipistrelle	<i>Pipistrellus papuanus</i>	NT	-
Watt's Pipistrelle *	<i>Pipistrellus wattsi</i>	NT	-

* Species likely to occur but not yet recorded.

¹ CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient; Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R)

Table 15 Cave bat species known or predicted to occur within the project area. Combined data from the PNG LNG Project and the WWF surveys.

Elevation range (m)	0 - 500	600-1000	1100-1500	1600-2000	>2000
Pteropodidae					
<i>Aproteles bulmerae</i>				P	P
<i>Dobsonia minor</i>	X	X			
<i>Dobsonia magna</i>	X	X	X	X	X
<i>Rousettus amplexicaudatus</i> *	P				
Emballonuridae					
<i>Emballonura beccarii</i> *	P	P	P	P	
<i>Emballonura diana</i>	X	X	X	X	X
<i>Emballonura furax</i>	X	X	X	X	X
<i>Emballonura raffrayana</i>	X	X	X	X	X
<i>Mosia nigrescens</i>	X	X	X	X	X
<i>Taphozous australis</i> *	P				
Rhinolophidae					
<i>Rhinolophus arcuatus</i>	X	X	X	X	X
<i>Rhinolophus euryotis</i>	X	X	X	X	
<i>Rhinolophus maros</i>	X	X	X		
<i>Rhinolophus megaphyllus</i>	X	X	X	X	X
<i>Rhinolophus philippinensis</i>	X	X	X		
Hipposideridae					
<i>Aselliscus tricuspidatus</i>	X	X			
<i>Hipposideros ater</i> *	P	P	P	P	
<i>Hipposideros calcaratus</i>	X	X			
<i>Hipposideros cervinus</i>	X	X	X		
<i>Hipposideros corynophyllus</i> *				P	
<i>Hipposideros diadema</i>	X	X	X		
<i>Hipposideros edwardshilli</i> *	P				
<i>Hipposideros maggietaylorae</i>	X	X			
<i>Hipposideros muscinus</i> *	P	P			
<i>Hipposideros semoni</i>	X	X	X		
<i>Hipposideros wollastoni</i>	X	X	X	X	X
Miniopteridae					
<i>Miniopterus australis</i>	X	X	X	X	
<i>Miniopterus macrocneme</i>	X	X	X	X	X
<i>Miniopterus magnater</i>	X	X	X	X	X
<i>Miniopterus medius</i>	X	X	X	X	X
<i>Miniopterus propitristis</i>	X	X	X	X	
<i>Miniopterus schreibersii</i> *	P	P	P	P	P
Vespertilionidae					
<i>Myotis moluccarum</i>	X	X	X		
<i>Pipistrellus papuanus</i>	X	X	X		
Total species recorded or predicted	32	29	24	19	13

X – recorded, P = Not yet recorded in the project area but predicted to occur.

13 Birds

Common English names for birds are well established so are used in the following discussion (see **Appendix 7** for the associated scientific names).

Papua New Guinea has a diverse and distinctive avifauna. 914 species have been recorded from the Indonesian border to Guadalcanal, which ranks PNG approximately 11th in the world in terms of its bird diversity yet it is only 54th in area⁸. New Guinea and its satellite islands is the centre of diversity for a wide range of avian families and supports most of the world's species of birds of paradise, bowerbirds, cassowaries and owl-nightjars. The island's unique avifauna also includes the world's largest pigeon and the smallest parrot. Despite a decline in research on birds in PNG and Indonesian New Guinea in the last 20 years (**Annex 08**) birds remain the best known group of vertebrates in PNG.

Approximately 728 species (Beehler et al. 1986) have been recorded on New Guinea and its satellite islands. Of these some 43 species are only recorded on small islands leaving 685 species recorded for New Guinea. 645 of these have been recorded on the PNG mainland, the rest being recorded so far only from Indonesian New Guinea.

Woxvold and Crome (**Annex 07**) and Woxvold (**Annex 08**) present a detailed account of birds in the project area. Combining data from the PNG LNG Project and the WWF surveys, from 1995 to 2008 there have been some 2,625 field records of 402 bird species in the project area⁹. 23% of these records were generated by the PNG LNG Project surveys. All recorded species are presented in **Appendix 7**¹⁰. A further 131 species could occur (**Appendix 8**). **Plates 46 to 55** show some species captured during the PNG LNG Project surveys.

Parrots, pigeons, honeyeaters and birds-of-paradise are the largest families and between them account for over 28% of the total species in the project area. Both the lowlands and mid montane bioregions have higher species numbers than the higher montane areas, a well-known phenomenon in mountain avifauna. This mid-altitude region is an overlap zone where the ranges of montane and lowland species intersect.

The high diversity within many families of non-passerine forest birds reflects a long history in the region. New Guinea's rainforests support a high proportion of frugivores and nectarivores (Beehler et al. 1986). There are 16 species of fruit-doves (*Ptilonopus*) (**Plate 51**) and imperial-pigeons (*Ducula*), all specialist fruit eaters and important dispersers of seeds of rainforest trees, as well as 14 species of brush-tongued lorries and lorikeets, which are significant pollinators. Other important frugivores are the cassowaries, two species of which occur in the project area. They are dispersers of a large number of trees and vines,

⁸ Amongst megadiverse nations PNG is beaten only by Ecuador, Democratic Republic of Congo and Malaysia in terms of species/km² (data from <http://www.environment.gov.au/biodiversity/abrs/publications/other/species-numbers/05-comparisons.html>)

⁹ The difficult to identify swiftlets *Aerodramus nuditarsus*, *A. hirundinaceus* and *A. vanikorensis* are included as a single "species"

¹⁰ Appendix includes records of four species without a definite determination, *Talagala* sp., *Meliphaga* sp. *Podargus* sp. and *Aegotheles* sp., not included in this total.

many with fruits too large to be dispersed by any other specialist frugivores. Cassowaries are still abundant, particularly along the section of the existing crude oil export pipeline ROW in the Mubi River Karst bioregion, and along the proposed route for the Juha-Hides Rich Gas Line.

Many of the passerine families recorded in the area belong to a larger group with its centre of evolution in the Australasian region. Notable speciose groups include Meliphagidae (honeyeaters – 33 species) (**Plate 48**), Pardalotidae (warblers and scrubwrens – 17 species) and Petroicidae (robins – 17 species) (**Plate 53**). The Corvidae is a large passerine family with 92 species recorded within the project area. In its current form, the family comprises a number of taxa until recently identified as separate families, and includes, amongst others, the jewel-babblers, whistlers and allies, birds-of-paradise, cuckooshrikes, fantails (**Plate 52**) and monarch flycatchers.

Of particular note is the high diversity of birds-of-paradise. The project area supports at least half of the 40 living species, and nearly two-thirds of the 31 species recorded in New Guinea and its' satellite islands. Many have restricted distributions (total area and/or altitude), and a number are of significant conservation value.

An important find in the 2005 survey was the Greater Melampitta. This is one of New Guinea's most enigmatic birds, being restricted to rugged limestone country where it roosts and nests below ground (the world's only passerine to do so). It has also been recorded at Gobe and Agogo (Diamond and Bishop 2003).

Of significance was the confirmation of populations of Blue Bird-of-paradise in the Benaria area. The 2005 survey recorded this species as possible (**Annex 07**) and it was confirmed in 2008 (**Annex 08**). This species has a very restricted altitudinal range in the mid mountains and was severely impacted by the wildfires in the highlands in the late 1990s.

There is now sufficient information on the birds of the project area to examine broad patterns in bird community distribution. By understanding which parts of the project area have similar bird communities then impact mitigation can be more precisely targeted. Woxvold (**Annex 08**) analysed the entire bird data set to determine similarities between survey areas. He used a clustering method that successively links survey areas that are most similar to each other to produce a tree structure (dendrogram) where the branches on the tree are groups of similar survey areas (**Figure 11**).

The dendrogram shows that the first survey areas to group together (i.e. are most similar) are a group of lowland and hill sites in the Kikori drainage then Gobe and the group of areas around Moro and Kutubu (orange box on **Figure 11**). This large group is united by the occurrence of waterbirds in the community and the presence of many species that tolerate disturbance (**section 13.2**). Juha North and Baia River survey areas form a group by themselves quite distinct from the lower altitude survey areas (green box on **Figure 11**) as do the Darai plateau and Libano Sok. Benaria and Nogoli group together and finally all these survey areas group together in a large cluster of low to mid montane sites (grey box on **Figure 11**). This major grouping is set apart from a second major cluster of montane sites (blue box on **Figure 11**) within which Mt Bosavi and Juha South cluster as a pair and Mt Sisa, Deviation Camp and Hides 3 (buff box on **Figure 11**) the three highest survey areas. The single sites at the bottom of **Figure 11** are aberrant sites with insufficient data to be correctly grouped.

These groupings do not mean the survey areas within a cluster are identical rather that they are more similar to each other than to other survey areas. For example the Western Lowlands group of Juha North and Baia River survey areas show distinct differences. Both areas are some distance from human settlement and hunting pressure is very low and a number of commonly hunted taxa prone to local extinction in settled areas (e.g. Thick-billed Ground-Pigeon, Pheasant Pigeon and the Southern Crowned-Pigeon) were found in good numbers. However bird species richness was much lower at Baia River. **Woxvold (Annex 08)** attributes this difference to the inherent patchiness in distributions of tropical birds and the possibility that some species are restricted to more stable, and floristically richer habitats in stream heads or on top of low escarpments in this highly dynamic, landslide prone area.

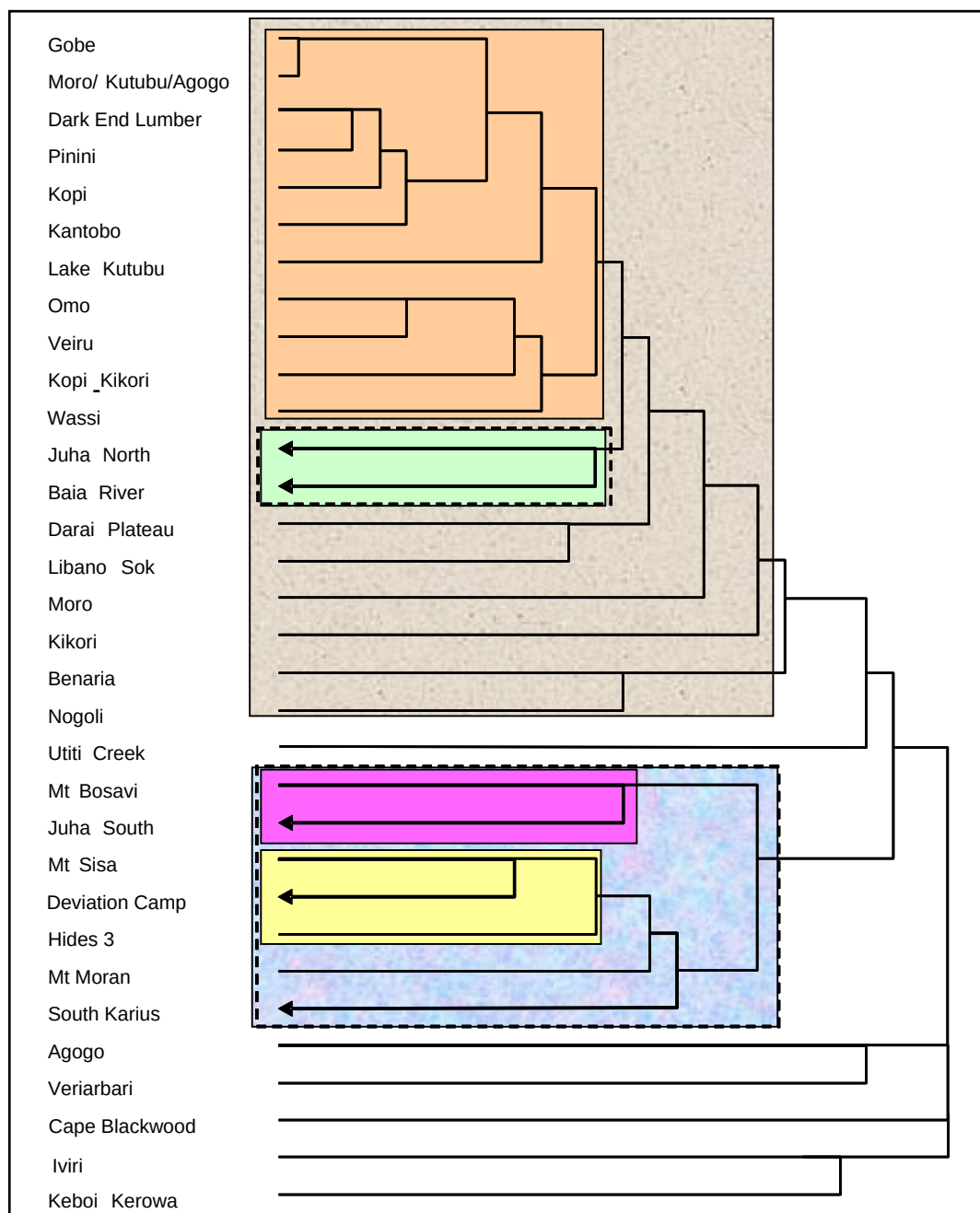


Figure 11 Dendrogram of similarity of survey areas in terms of bird community composition using combined data from the PNG LNG Project and the WWF surveys.

13.1 Endemism

330 or some two thirds of the bird species of New Guinea and its satellite islands are endemic (Coates 1985 and 1990, Beehler *et al.* 1986). This has been recognised by Birdlife International who have described eight distinct “Endemic Bird Areas” (EBAs) within New Guinea: West Papuan Lowlands, West Papuan Highlands, North Papuan Mountains, North Papuan Lowlands, Adelbert and Huon Ranges, Central Papuan Mountains, South Papuan Lowlands and the Trans Fly. Each of these regions supports a high concentration of what is termed ‘Restricted Range Species’¹¹ found nowhere else (Stattersfield *et al.* 1998). PNG as a whole ranks fourth amongst all countries in the world in terms of numbers of restricted-range species (Birdlife International 2008).

The project area lies entirely within two of these EBAs – the Central Papuan Mountains (CPM) and the South Papuan Lowlands (SPL). The former has the second highest number of restricted-range species of all EBAs in the southeast Asian island region and includes nine endemic genera (BirdLife International, 2003). It ranks seventh in the world (out of 128 EBAs) in terms of numbers of restricted range species.

Eighteen restricted-range species of the CPM have been recorded in the project area and a further 16 could occur there. All but five of them are high mountain specialists. There are far fewer restricted-range species within the South Papuan Lowlands EBA. Two restricted-range species of the SPA have been recorded in the project area and two more could occur (**Appendix 7** and **Appendix 8**).

In order to determine whether endemic species were concentrated in certain parts of the project area each species was assigned to an endemism class as follows:

- 5 Endemic to the PNG mainland and satellite islands (includes Waigeo, Salawati and Misool). Excludes New Britain, and New Ireland.
- 4 Endemic to the large island of New Guinea and its’ satellite islands.
3. Endemic to the large island of New Guinea and its’ satellite islands and the Aru Islands.
- 2 Endemic to the large island of New Guinea and its’ satellite islands and New Britain and/or New Ireland and/or the Louisiades.
- 1 Occurs more widely through Australia, Indonesia, the Solomon Islands or the Pacific.

The numbers of species in each endemism class within each bioregion are shown in **Table 16**. An endemism score was calculated for each bioregion as the% of species with scores of either four or five in each bioregion. Endemism increases from the lowlands to the montane bioregions and the most important bioregions in terms of avian endemism are the Western Volcanics bioregion and the Northern Montane Karst bioregion. The latter has 78% of it’s avifauna being endemic to mainland PNG or New Guinea. None of these endemics are restricted the project area.

¹¹ Species with geographic ranges <50,000 km² (Stattersfield *et al.* 1998)

The Kikori and Sirebi lowlands have the lowest endemism; a result of the large number of more widespread wetland and secondary species in these bioregions. The higher endemism score for the Western Lowlands however, is due not so much to the higher number of endemics there but to the lack of widespread species (Class 1) which would be found in secondary forests, grassland and wetlands, habitats which are rare in the Western Lowlands. The Western Lowlands are also slightly higher and hillier which would promote higher diversity than the Kikori bioregion.

Table 16 Levels of endemism of birds in bioregions of the project area. Combined data from the PNG LNG Project and the WWF surveys.

Endemism Class	Kikori Lowlands	Sirebi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region *	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern Montane Karst
5	1	1	1	1	1	1	1	1	6	7	3
4	46	13	14	25	38	34	75	74	94	69	47
3	31	19	13	15	25	10	33	31	7	10	3
2	10	4	4	4	7	8	12	12	6	8	2
1	137	37	31	25	51	29	96	102	47	57	9
Total species¹	225	74	63	70	122	82	217	220	160	151	64
endemism score ²	21	19	24	37	32	43	35	34	63	50	78
No of survey sample sites	11	1	1	1	2	1	3	3	3	4	1

Endemism rating as in text

*Includes the Iagifu Agogo Limestone Uplands

1 = totals differ from those in Appendix 7 because species only identified to genus not included.

2 =% of species in endemism categories 4 + 5.

13.2 Habitat preferences

Habitat specificity is highly significant for impact analysis so species were classified according to broad habitat specializations (**Table 17**).

Table 18 presents broad habitat preferences of the avifauna in the bioregions. Forest species comprise the majority of species recorded, particularly the passerines. Most forest species can tolerate disturbance to some extent, and the majority can be recorded in secondary forests and sometimes scrublands and gardens. Primary forest specialists occur in all bioregions but there is a tendency for the number of primary forest specialists to increase in the mid altitude bioregions.

The percentage of primary forest specialists + adaptable forest species is a better indicator of the abundance of forest specialists in a bioregion. Such specialists will not survive in a landscape devoid of intact forest. The montane bioregions contain by far the highest proportions of forest specialists. Forest specialists comprise almost 90% of the avifauna of the Northern Montane Karst as represented by the Hides survey area. Surprisingly the Western Foothills (Juha region) has 80% forest specialists yet it is of moderately low elevation at around 1000 m asl. This Juha anomaly suggests that one of the reasons for the high percentage of specialists in these areas is the rarity of secondary habitats. The

percentage of forest specialists in a local avifauna would decline as the amount of secondary habitat increases so this is an indicator of disturbance.

Table 17 Definition of habitat specialisation classes

Habitat Class	Definition	Sensitivity to forest loss
Primary forest specialist	Restricted to old growth forest	Highly sensitive and will take a long time to recolonise regrowing forest.
Adaptable forest species	A forest species that will also use secondary forests but needs old growth forest in the landscape.	Moderately sensitive and will rapidly recolonise regrowing forest.
Generalist forest species	A forest species that will use a range of forest, secondary growth, gardens and scrublands.	Not sensitive or may be advantaged by forest clearing and subsequent regrowth.
Riverine specialists	Species preferring rivers and riverbanks	Highly sensitive to loss of riverine vegetation.
Aerial species	Species such as swifts that forage above the canopy.	Moderately sensitive as they need forest canopies to forage over
Grassland species	Grassland and scrubland species	Not sensitive unless at high altitude where grasslands regrow slowly.
Wetland species	Species of floodlands, swamps, lakes.	Species of open lakes and floodlands not sensitive unless wetland eliminated. Swampland species will recolonise regrowth areas but loss of swamp forest will eliminate species.
Mangroves specialists	Species of mangrove and/or beach dune forests	Moderately sensitive and will recolonise regrowing mangroves.
Seabirds		Not sensitive

While the forest species are the obvious component of the avifauna, a wide range of wetland and grassland species has also been recorded in the project area including 23 wader species (curlews, sandpipers and plovers – Scolopacidae and Charadriidae), 11 species of herons and egrets (Ardeidae), and 11 species of the predominantly marine gulls and terns (Lariidae). These birds are most abundant in the lowlands and again around Moro and Lake Kutubu, where these habitats are most widespread.

13.3 Migratory species

There is global concern about conservation of migratory species, particularly waterbirds, and a variety of international treaties relevant to conservation of these species exist e.g the Ramsar Convention on Wetlands, and the Convention on the Conservation of Migratory Species of Wild Animals (CMS)¹².

An account of migratory bird species in the project area and the kinds of migratory behaviour is presented in **Annexes 07** and **08**. Over 86% of the species in the project area are residents in which none or only part of the population migrates. Partial migration, which may be altitudinal and/or intra-country and has not yet been studied in PNG, is well known in Asia (McClure 1974) and Australia (Crome 1993, Nix 1993).

¹² PNG is a contracting party to the RAMSAR convention (http://www.ramsar.org/key_cp_e.htm) but not a party to CMS. However it has participated in the CMS MOU on Pacific island Cetaceans.

http://www.cms.int/about/Nonparties_participating_in_CMS_Agreements_MoU.pdf

The few true migrants, where the entire population migrates, are concentrated in the Kikori Lowlands bioregion and include the migratory waders (Scolopacidae and Charadriidae) that breed in the northern hemisphere and visit tidal and coastal mudflats from September to April. These habitats in the Gulf Province have not been surveyed extensively, and the numbers of wader species recorded for the project area is relatively small. Whether they are significant wintering grounds as Diamond and Bishop (2000) and Watkins (2000) suggest remains to be seen.

A smaller number of Australian and Eurasian migrants visit the project area's forests and clearings from May to October. These include the Forest and Sacred Kingfishers, Dollar-bird, Channel-billed Cuckoo, Brown Falcon, Australian Hobby, Black-faced Cuckooshrike and Satin Flycatcher from Australia and the White-throated Needletail from Eurasia.

Table 18 Habitat specialisation in bioregions of the project area (entries are numbers of species).

Habitat types	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region *	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern Montane Karst
Primary forest specialist	11	3	2	8	14	11	19	17	19	15	14
Adaptable forest species	98	47	37	46	74	55	132	132	108	93	42
Generalist forest species	50	17	16	12	27	16	44	46	27	33	7
Aerial species	7	1	1	2	4		5	5	2	5	1
Grassland species	1						1	1	1	1	
Riverine specialists	4	2	2	1	2		5	3	2	2	
Wetland species	41	3	4		1		9	16	1	2	
Mangroves specialists	4	1	1	1			1				
Seabirds	9						1				
Totals	225	74	63	70	122	82	217	220	160	151	64
% forest specialists (1 +2)	48.4	67.6	61.9	77.1	72.1	80.5	69.6	67.7	79.4	71.5	87.5

*Includes the lagifu Agogo Limestone Uplands

13.4 New species

No species of bird new to science has been found in the project area to date, however, in 2005, a call of an unidentified owl was heard at the Hides 3 survey area. The call was heard well and did not fit the description of any advertising call known from this group. Subsequently K. D. Bishop, an authority on PNG bird calls, agreed that the call of this bird was distinct from other calls known from New Guinea owls (K. D. Bishop 2005, *pers. comm. to I. Woxvold*). It is possible this call may be of a species new to science.

13.5 Conservation status

Table 19 lists birds recorded in the project area that appear on the 2008 IUCN red list of threatened species (<http://www.redlist.org/>), and/or are recorded under the Papua New Guinea *Fauna (Protection and Control) Act 1966, 1978* ('Fauna Act'). The meanings of the

classification codes are presented in **Table 6**. The occurrence of species in different bioregions is given in **Appendix 11**.

Table 19 Birds listed as of conservation concern in the project area. Combined data from the PNG LNG Project and the WWF surveys.

Common Name	Scientific Name	IUCN ¹	PNG Fauna Act ¹	Common Name	Scientific Name	IUCN ¹	PNG Fauna Act ¹
Papuan Whipbird *	<i>Androphobus viridis</i>	CR	-	Palm Cockatoo	<i>Probosciger aterrimus</i>	-	P
Southern Cassowary	<i>Casuarius casuarius</i>	VU	R	Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	-	R
Salvadori's Teal	<i>Salvadorina waigiensis</i>	VU	P	Pheasant Pigeon	<i>Otidiphaps nobilis</i>	-	R
Pesquet's Parrot	<i>Psittichas fulgidus</i>	VU	R	Little Curlew *	<i>Numenius minutus</i>	-	R
Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>	VU	P	Osprey *	<i>Pandion haliaetus</i>	-	P
New Guinea Eagle	<i>Harpyopsis novaeguineae</i>	VU	-	White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>	-	R
Antarctic Giant-Petrel *	<i>Macronectes giganteus</i>	VU	-	Eastern Marsh-Harrier	<i>Circus spilonotus</i>	-	R
Long-bearded Melidectes *	<i>Melidectes princeps</i>	VU	-	Swamp Harrier *	<i>Circus approximans</i>	-	R
Black Sickbill	<i>Epimachus fastuosus</i>	VU	P	Australian Kestrel	<i>Falco cenchroides</i>	-	R
Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>	VU	P	Oriental Hobby	<i>Falco severus</i>	-	R
Dwarf Cassowary	<i>Casuarius bennetti</i>	NT	-	Australian Hobby	<i>Falco longipennis</i>	-	R
Striated Lorikeet	<i>Charmosyna multistriata</i>	NT	-	Brown Falcon	<i>Falco berigora</i>	-	R
New Guinea Flightless Rail	<i>Megacrex inepta</i>	NT	-	Peregrine Falcon	<i>Falco peregrinus</i>	-	R
Black-tailed Godwit	<i>Limosa limosa</i>	NT	-	Little Egret	<i>Egretta garzetta</i>	-	P
Asian Dowitcher	<i>Limnodromus semipalmatus</i>	NT	-	Great Egret	<i>Ardea alba</i>	-	P
Buff-breasted Sandpiper *	<i>Tryngites subruficollis</i>	NT	--	Intermediate Egret	<i>Mesophoyx intermedia</i>	-	P
Beach Thick-knee	<i>Esacus giganteus</i>	NT	-	Flame Bowerbird *	<i>Sericulus aureus</i>	-	R
Doria's Goshawk *	<i>Megatriorchis doriae</i>	NT	-	Crested Bird-of-paradise *	<i>Cnemophilus macgregorii</i>	-	P
Gurney's Eagle	<i>Aquila gurneyi</i>	NT	R	Loria's Bird-of-paradise	<i>Cnemophilus lorae</i>	-	P
Forest Bittern	<i>Zonotrichia heliosylus</i>	NT	-	Glossy-mantled Manucode	<i>Manucodia atra</i>	-	P
Black-necked Stork *	<i>Ephippiorhynchus asiaticus</i>	NT	R	Crinkle-collared Manucode	<i>Manucodia chalybata</i>	-	P
Archbold's Bowerbird *	<i>Archboldia papuensis</i>	NT	-	Trumpet Manucode	<i>Manucodia keraudrenii</i>	-	P
White-bellied Pitohui *	<i>Pitohui incertus</i>	NT	-	Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>	-	P
Olive-yellow Robin	<i>Poecilodryas placens</i>	NT	-	Brown Sickbill	<i>Epimachus meyeri</i>	-	P
Yellow-breasted Bird-of-paradise	<i>Loboparadisaea sericea</i>	NT	P	Black-billed Sickbill	<i>Epimachus alberti</i>	-	P
Ribbon-tailed Astropia	<i>Astrapia mayeri</i>	NT	P	Superb Bird-of-paradise	<i>Lophorina superba</i>	-	P
Yellow-eyed Starling	<i>Aplonis mystacea</i>	NT	-	Carola's Parotia	<i>Parotia carolae</i>	-	P
Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>	DD	-	Lawe's Parotia	<i>Parotia lawesii</i>	-	P
Papuan Hawk-Owl *	<i>Uroglaux dimorpha</i>	DD	-	Magnificent Riflebird	<i>Ptiloris magnificus</i>	-	P
Starry Owlet-Nightjar *	<i>Aegotheles tatei</i>	DD	-	Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>	-	P
Wallace's Owlet-Nightjar *	<i>Aegotheles wallacii</i>	DD	-	King Bird-of-paradise	<i>Cicinnurus regius</i>	-	P
Chestnut-shouldered Goshawk *	<i>Erythrotriorchis buergeri</i>	DD	-	Stephanie's Astropia	<i>Astrapia stephaniae</i>	-	P
Obscure Berrypecker *	<i>Melanocharis arfakiana</i>	DD	-	King-of-Saxony Bird-of-paradise	<i>Pteridopora alberti</i>	-	P
Blyth's Hornbill	<i>Aceros plicatus</i>	-	P	Twelve-wired Bird-of-paradise	<i>Seleucidis melanoleuca</i>	-	P
Papuan Lorikeet	<i>Charmosyna papou</i>	-	R	Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>	-	P

* Species likely to occur but not yet recorded.

1 CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient; Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R).

13.6 General comments on sensitivities and potential impacts

No bird species is restricted to the project area and no species has the bulk of their range within it so the project is unlikely to generate any global extinctions of any species. The Hides area was singled out by the 2005 survey (**Annex 07**) as an area of particular avifaunal significance and the 2008 survey (**Annex 08**) has also indicated that the Juha area is likewise of great ornithological value. The Juha area is particularly rich in birds and it has been little disturbed forming a “region (that) constitutes an increasingly rare example of a large expanse of relatively intact and well connected tropical lowland, hill and montane forests. This area is of extremely high conservation value due to its large size, remoteness, connectivity with pristine habitat in surrounding areas, and the persistence of a variety of intact habitats covering a range of topographies and soil types” (**Annex 08**).

Forest clearing is likely to impact most upon forest interior specialists, ground-foraging birds and birds-of-paradise and bowerbirds, the latter through loss of traditional terrestrial and arboreal mating areas (display trees, playgrounds and bowers). However, in considering the overall sensitivity of the avifauna of the project area the experience with the oil developments indicates that the avifauna has survived and thrived along and around project infrastructure. Indeed, the Juha South survey area was richest in birds and this was immediately surrounding an old well site. This indicates a capacity to cope with well managed small scale clearings and long narrow linear infrastructure clearings. However, any impact would be related to the size of clearings and if cleared areas expand then inevitably the avian resources of the project area would also decline.

Certain habitats may be of particular significance and may require special mitigations: locations of lekking sites of birds-of-paradise and bowerbirds; stream side vegetation, forest refuges in unstable areas and wetlands, although the project does not traverse any wetlands that are important for concentrations of migratory waders.

Indirect impacts from improving access within the project area are perhaps the more significant potential impacts to manage. Improving access to uninhabited areas of forest for others, e.g. hunters (**Plate 49**), loggers shifting, cultivators etc. usually leads to deforestation, forest degradation and loss of wildlife via settlement processes, clearing along roads for gardens and small agricultural plots, commencement/acceleration of legal and illegal logging, over hunting, ingress of weeds and pathogens and increased occurrence of fires.

Many PNG birds suffer greatly from hunting and species that are targeted for food and/or decorative plumage are often locally extinct or exist in very low numbers in suitable habitat near settled areas. The presence and relative abundance of such species therefore serves as a sensitive indicator of the local degree of hunting pressure (Diamond and Bishop 2003). Should regular hunting become a by-product of improving access for others, there exists the potential for a high level impact on local populations of many species, including a number of globally threatened birds (**Annex 08**).

14 Reptiles

Only some snakes and larger lizards have regularly used English common names so the following discussion mostly uses scientific names except where well known species are discussed in which case both are given (**Appendix 9** has no common names for reptiles). **Plates 56 to 63** show some species caught on the 2005 and 2008 survey.

The herpetofauna is the least known group of terrestrial vertebrates in Papua New Guinea and the WWF and the PNG LNG Project surveys have added considerably to knowledge of the PNG fauna. Surveys in the project area have concentrated on frogs, and the reptile fauna is under-sampled (**Annex 09**). In particular, the distribution of the freshwater turtles, popular food items with locals, is very poorly known.

Using combined data from the PNG LNG Project and the WWF surveys, there are 131 locality records of 61 species of reptiles in the project area. **Appendix 9** lists all species recorded and **Table 20** the number of species in each bioregion. There is a distinct reduction of reptile diversity with increasing altitude and reptiles are most speciose in the lowland bioregions. Not many species of reptiles in New Guinea tolerate the cold wet climates of the montane regions, so upland sites have very low diversity of reptiles e.g. only three species at Deviation Camp survey area, five at South Karius survey area, three at Mt Sisa survey area and six at Hides survey area (**Annexes 09 and 10**).

The bulk of reptile species are small to medium sized skinks (**Plate 56**) inhabiting forest or forest clearings and they are the only lizards found so far in the high montane karst areas (**Appendix 9**). The more spectacular arboreal rainforest geckos (*Cyrtodactylus*) (**Plate 57**), goannas and dragons (Agamidae) (**Plate 58**) tend to have lowland to low montane distributions. Amongst the snakes Boelen's Python *Morelia boeleni* (**Plate 60**) is a montane specialist.

Within the project area lowland sites have typical southern New Guinea reptile assemblages. Snakes are far commoner in the lowlands where the warmer conditions favour them.

Local site conditions are major influences on the reptile fauna. For example the fauna at the lowland Baia River survey area is depauperate being largely a subset of the faunas at the Juha North survey area and elsewhere in the gulf region (**Annexes 09 and 10**), a number of common, widespread skinks (*Emoia* spp.) were absent or rare at this survey area, and small lizards were remarkably rare compared to equivalent sites elsewhere in the project area. This low abundance and diversity may be related to the extremely dynamic landscape at Baia River (**Annex 10**).

Arguably the most important reptile occurring in the project area is the New Guinea Freshwater Crocodile *Crocodylus novaeguineae* (**Annex 10**) discovered by the 2008 survey in the Western Lowlands at Baia River survey area (**Plate 61**). Prior to this the species was only known within the project area from the Libano River (Richards and Allison 2003), although the Estuarine Crocodile *C. porosus* is known in the project area from several locations. A permanent pool adjacent to the Baia River, whose unstable banks provide unsuitable nesting habitat for the species, provided a nursery habitat for the species. Such pools isolated from the river channel provide a nesting habitat that is less

likely to be destroyed during the nesting season and provide important off-river breeding and nursery habitats.

The crocodiles, larger snakes and goannas (*Varanus*) are keenly hunted by locals and can be targets for indirect impacts. *Varanus indicus* was observed at Baia River in 2008 and *Varanus salvadori* recorded at Dark End Lumber survey area (**Annexes 09 and 10**). Other species important as human food are the pythons including Brown Water Python *Liasis fuscus* (**Plate 62**), Amethystine Python *Morelia amethystina*, Green Python *Morelia viridis* (**Plate 63**) and D'Albertis Python *Leiopython albertisi*. The rare Boelen's Python *Morelia boeleni* is known from two localities, Moran and South Karius survey areas, in higher parts of the project area (**Plate 60**).

14.1 New species

The WWF surveys have discovered 11 species of lizards new to science in the project area – one agamid of the genus *Hypsilurus*, two *Cyrtodactylus* geckos and eight skinks: three species of *Sphenomorphus*, two of *Emoia*, and one each of *Lipinia*, *Pauascincus* and *Carlia*. The 2005 surveys (**Annex 09**) discovered another three *Sphenomorphus* sp. nov. cf. *S. papuae* (pale stripes), *Lipinia* sp. 2 and *Lygisaurus* sp. The 2005 and 2008 surveys (**Annexes 09 and 10**) also added a further 13 species to the known reptile fauna of the project area, five of which remain to be identified, and many range extensions.

Table 20 Number of species in each reptile family in bioregions of the project area. Combined data from the PNG LNG Project and the WWF surveys.

Family	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern montane Karst
Upper elevation of Bioregion (m asl)	200	600	1100	400	1200	1300	1000	2700	3000+	3000+
Lower elevation of Bioregion (m asl)	0	200	300	200	400	200	800	280	800	1800
Crocodylidae	1		1	1						
Agamidae	2	2	3	2	1				1	
Gekkonidae	2	2	4	4		1	2		1	
Scincidae	5	7	8	9	5			5	9	4
Varanidae	2		1	1						
Elapidae	3			1						
Pythonidae	2	1	2	2				1	3	1
Colubridae	4		2	2	1			1	2	1
Totals	21	12	21	22	7	1	2	7	16	6

14.2 Conservation status

Table 21 lists reptiles recorded in the project area that appear on the 2008 IUCN red list of threatened species (<http://www.redlist.org/>), and/or are recorded under the Papua New Guinea Fauna (Protection and Control) Act 1966, 1978 ('Fauna Act'). The meanings of the classification codes are presented in **Table 6**. The occurrence of species in different bioregions is given in **Appendix 11**

Table 21 Reptiles listed as of conservation concern in the project area. Combined data from the PNG LNG Project and the WWF surveys.

Common Name	Scientific Name	IUCN ¹	PNG Fauna Act ¹
Saltwater crocodile	<i>Crocodylus porosus</i>	-	R
New Guinea freshwater crocodile	<i>Crocodylus novaeguinea</i>	-	R
Mangrove monitor	<i>Varanus indicus</i>	-	R
Gould's monitor	<i>Varanus dorianus</i>	-	R
Salvadori's monitor	<i>Varanus salvadori</i>	-	R
Ground boa	<i>Candoia aspera</i>	-	R
Pacific boa	<i>Candoia carinata</i>	-	R
Amethystine python	<i>Morelia amethystina</i>	-	R
Boelen's Python	<i>Morelia boeleni</i>	-	R
Green Tree Python	<i>Morelia viridis</i>	-	R
Olive Python	<i>Liasis fuscus</i>	-	R

* Species likely to occur but not yet recorded.

1 CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient; Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R)

14.3 General comments on sensitivities and potential impacts

While the reptile fauna is depauperate, there are 13 new species at present only known from the project area. Like amphibians and plants, new species of reptiles are to be expected and further exploration will likely increase the ranges of the species, moreover some, such as those from Benaria and likely most of the skinks, tolerate or even prefer secondary and open habitats. Like the mammals and birds these and all the other species of reptiles exist alongside the oil developments and are not threatened by small scale clearings and it is likely to be indirect impacts that will be most in need of managing, particularly overhunting of the larger species – crocodiles, snakes (**Plate 62**) and goannas.

S. Richards (**Annex 10**) identified off-river waterbodies in the Baia River valley as being important breeding sites for freshwater crocodiles (**Plate 61**), and suggested that that they need some protection during construction operations of the PNG LNG Project.

15 Amphibians

Few frogs have English common names so the following discussion uses scientific names (there are no common names in **Appendix 10**).

Using combined data from the PNG LNG Project and the WWF surveys, there are 350 locality records of 107 species making the frog fauna of the project area the most diverse assemblage documented for any catchment in New Guinea. The total amounts to a third of the New Guinea fauna. (**Annexes 09 and 10**). **Appendix 10** lists all species recorded and **Table 22** the number of species in each bioregion. **Plates 64 to 77** show some species caught on the 2005 and 2008 surveys.

The tree frogs (Hylidae) (**Plates 64 to 71**) and the Microhylidae (**Plates 72 to 76**) dominate the fauna. The only other family with more than a few species is the Ranidae (**Plate 77**). The Microhylidae have radiated extensively in the constantly moist montane habitats of New Guinea because these small terrestrial frogs have a reproductive strategy independent of free standing water. They lay their eggs in terrestrial environments humid enough for their embryos to develop. Hylidae occupy a range of niches, occupying specific microhabitats such as streams, torrents, pools, stream edges, tree canopies etc. A range of Hylidae lay their eggs in water that has collected in stumps or dead branches. One particularly interesting adaptation some species have is to stick their eggs to leaves above pools into which the tadpoles drop after hatching (**Plates 78 and 79**).

The richest survey area within the project area was the Juha North survey area where 36 species including several new to science were recorded, the highest of any survey area in New Guinea. S. Richards (**Annex 10**) singled out the Juha area as a particularly important place to manage impacts.

Altitude plays a significant role in determining the distributions of most frogs because at very high elevations, the temperatures are too cold for most species. Those that live there are specialised to these cool cloud forests e.g. most of the species of *Albericus* (**Plate 75**). However, maximum frog diversity occurs in the low mountain zone between 500 and 1500 m asl. (**Annex 10**).

The availability of standing water has dramatic effects on frog community composition. For example 50% to 66% of species at each of the five 2008 survey areas, all of which had standing or flowing water, were Microhylidae and 25% to 33% Hylidae. By comparison seven of the nine species at Hides 3 survey area, which is in polygonal karst with no flowing and little standing water, were Microhylidae. Because Hylidae need water, the Microhylidae with their terrestrial reproductive strategy, can dominate in these situations of high humidity with no standing or flowing water (**Annexes 09 and 10**).

Water, in this case a permanent stream, also explains the stronger representation of hylids at Deviation Camp, which is at a similar altitude to Hides 3. The stream provided excellent habitat for an assemblage of stream-breeding frogs.

While most of the frogs occupy widespread habitats several species form a community restricted to very clear swift mountain torrents. These include *Litoria cf arfakiana*, *Litoria wollastoni* (**Plate 65**), *Rana cf grisea* (**Plate 77**), *Nyctimystes pulcher*, *Nyctimystes kuduki*, *Litoria* sp. nov. 'yellow-legs', *Litoria* sp. nov. 6 (Torrent chirper), *Litoria* sp. nov. 12

(Trilling torrent), *Litoria* sp. nov. 13 (cf *multiplica*), *Litoria* sp. nov. 14 (cf Ok Menga) and *Nyctimystes* sp. nov.

These 11 species of torrent dwellers are perhaps the frogs most sensitive to impacts from the project. The clear, fast-flowing mountain streams of the northern part of the project area, including the headwaters of the Baia River, the rivers at Juha and the Maruba River, were identified as significant habitats by S. Richards (**Annexes 09 and 10**). Retaining the clarity and hydrology of these streams is important but the structure and density of riparian vegetation associated with the streams is a factor determining the species of frogs that are able to persist. For example, common, widespread species e.g. *Litoria angiana*, *L. arfakiana* (**Plate 70**), and *L. micromembrana* dominated in more open, disturbed stretches of stream at the 2008 survey areas whereas the two undescribed species of frogs at South Karius, were in upstream stretches retaining dense riparian vegetation.

Although many of these species are likely to occur in other streams of similar morphology in the project area, these fast-flowing streams are a significant habitat for a unique assemblage of frogs and they are identified as a significant habitat requiring careful management during construction activities.

19 of the species in **Appendix 10** are known from only one sample site in the project area. However this does not mean they are rare, rather it is a reflection of survey activity. For example the 2005 survey extended the ranges of two species from the Moro area to Benaria and discovered *Litoria wollastoni* not previously known from the project area. Until the 2005 and 2008 survey *Hylophorbus richardsi* was only known from Mt Sisa. It was discovered at Hides 3 in 2005 and then at Deviation Camp in 2008 which extended its' distribution widely in the montane zone.

Table 22 Number of species in each frog family in bioregions of the project area. Combined data from the PNG LNG Project and the WWF surveys.

Family	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern montane Karst
Microhylidae	17	21	15	21	24	19	18	22	22	7
Hylidae	6	7	4	12	9	6	16	8	17	2
Myobatrachidae	1	1	1		1		1	1	1	
Ranidae	4	4	2	3	2	1	3	2	2	
Totals	28	33	22	36	36	26	38	33	42	9

15.1 Conservation status

Table 23 lists amphibians recorded in the project area that appear on the 2008 IUCN red list of threatened species (<http://www.redlist.org/>), and/or are recorded under the Papua New Guinea *Fauna (Protection and Control) Act 1966, 1978* ('Fauna Act'). The meanings of the classification codes are presented in **Table 6**. The occurrence of species in different bioregions is given in **Appendix 11**.

Table 23 Amphibians listed as of conservation concern in the project area.

Common Name	Scientific Name	IUCN ¹	PNG Fauna Act ¹
Frog	<i>Choerophryne allisoni</i>	DD	-
Frog	<i>Cophixalus cryptotympanum</i>	DD	-
Frog	<i>Hylophorbus richardsi</i>	DD	-
Frog	<i>Oreophryne notata</i>	DD	-
Frog	<i>Litoria majikthise</i>	DD	-

* Species likely to occur but not yet recorded.

¹ CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient; Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R)

15.2 New species

The surveys from 1997 to 2008 have discovered numerous species of frogs new to science. The WWF surveys found 50, and the 2008 survey (**Annex 10**) added at least another ten, six of them in the Juha region: seven microhylids - four species of *Xenobatrachus* (**Plate 73**) and three of *Oreophryne* (**Plate 76**), and three hylids - one species of *Nyctimystes* and one of *Litoria*.

All surveys extend the ranges of species previously known only from one or two localities e.g. the 2008 survey (**Annex 10**) extended the ranges of six undescribed species, *Asterophrys* sp. nov., *Cophixalus* sp. nov. 5. (triple-calls), *Copiula* sp. nov. 3. (tiny), *Litoria majikthise* (**Plate 68**), *Litoria* sp. nov. 1 cf *nigropunctata* 1 (bleating call) and *Litoria* sp. nov. 7 (small, green torrent). known previously from only one locality each in the project area into the Juha and/or Homa Deviation areas. The 2008 survey also extended the range of *Litoria* sp. nov. 14 (cf Ok Menga), previously only known from the Star Mountains, into the project area.

15.3 General comments on sensitivities and potential impacts

The frog fauna of the project area is exceptionally diverse and this diversity has persisted along-side the major oilfields and infrastructure of the existing oil project. Observations during the 2005 and 2008 survey have clarified the resilience of the frog fauna to disturbance in a general sense. There were high densities of most species persisting within a few meters of the forest edge at the well pad at Hides 3 survey area in 2005 and it was also clear that the most diverse assemblage of frogs yet reported from a single site in PNG at Juha South survey area has been able to persist in the immediate vicinity of a well pad development. This, and the observations throughout the existing hydrocarbon developments in the project area, indicate there has been negligible impact on the local herpetofauna. On the other hand the observations in 2005 at Nogoli survey area, an area where forest clearing and disturbance has been extensive, show a depauperate fauna of only widespread species with broad habitat tolerances.

Given the general resilience of the fauna to local disturbance there are some areas that require special attention: S. Richards (**Annex 09**) demonstrated the importance of the Hides Ridge, and S. Richards (**Annex 10**) emphasised the significance of the Juha area because of its remoteness and lack of human interference. At a smaller scale the surveys have demonstrated the importance of maintaining water quality and stream side vegetation in swift flowing rocky streams in both the highlands (South Karius and Deviation Camp survey areas) and some lowland sites (Juha North survey area).

The major potential impacts of the project on frog diversity and biodiversity may be indirect impacts from improved access to currently remote areas. Permanent roads are likely to lead to increased habitat destruction along and adjacent to roads as local populations move into previously inaccessible areas. This may not occur until the project ceases, if controls of road access are effective, but in the long-term is likely to be a particularly significant issue. The key to maintaining a healthy frog fauna is to prevent ongoing habitat degradation and destruction brought about by indirect impacts as a result of improving access to the forest.

16 General conclusions flora and fauna

The amount of data collected in the WWF and PNG LNG surveys enables a number of generalisations to be made about the flora and fauna that are relevant to impact assessment.

1. The project area is confirmed to be of very high biological significance with high levels of endemism.
2. Surveys continue to find new species in the project area and this is a reflection of the poor state of knowledge of PNG's biodiversity.
3. The faunal communities are intact, with many rare species persisting next to oil and gas facilities, reflecting the more-or-less pristine nature and isolation of most of the project area, the small footprint of the oil and gas developments to date and the effective environmental controls that have been maintained to date.
4. It is unlikely that many fauna or flora species will be found to be restricted to small, localised areas of the project area.
5. Cavernicolous bats, on the other hand, may roost or breed only in certain caves.
6. Species diversity declines from the lowlands to the highlands but tends to be highest at intermediate altitudes where lowland and upland faunas overlap.
7. The proportion of forest specialists increases with altitude.
8. Though overall diversity decreases at higher altitudes, fauna assemblages are most specialised and restricted in the high montane bioregions i.e. the Western Volcanics and Northern Montane Karst.
9. The Juha region, in the western Lowlands and Western Foothills, retains a more or less undisturbed particularly rich fauna and flora distinct from that in the Kikori drainage.
10. The lowland regions are rich in species but the faunas tend to include many taxa that are widespread and adapted to disturbed habitats.
11. The Kikori Lowlands and the Moro Region are the most important bioregions for waterbirds and swamp fauna.
12. The wetlands of the Kikori Lowlands are the most important habitat for overwintering migratory waders.

17 Special areas

The PNG LNG surveys have identified three areas that have particularly high biodiversity value and require singling out for special protective measures in any project development plan.

17.1 Special area 1: The Juha Area

The 2008 surveys emphasised the significance of the Juha area in terms of:

- The remoteness of the region and the lack of human influence on the vegetation and fauna.
- The lack of weeds and other exotics in the area.
- No or low populations of wild pigs.
- The virtual absence of hunting.
- The occurrence of many bird and mammal species in abundance that elsewhere have been exterminated or severely reduced in populations.
- The richness of the frog fauna, the Juha South survey area being the richest site yet surveyed in New Guinea.
- The high diversity of mammals and birds.
- The occurrence of montane species of flora and fauna at very low altitudes.
- 10 species of plants new to science, some of them of particular botanical significance.
- 13 frogs in the project area only known in this area
- Six species of frogs new to science found in this area.

As for the Hides Special area, the exploration wells have had no material impact in this area and its ecological values are maintained by its difficulty of access. There are one or two tiny villages near, but not within, the area but their impact has likewise been minimal to undetectable.

In view of the areas remoteness, richness and mostly untouched forests it is suggested the area receive particular environmental management, focusing on the restriction of access to the region along project infrastructure so as to eliminate indirect impacts like fire, hunting, logging and settlement and ingress of weeds, pests and pathogens.

17.2 Special area 2: Hides Ridge

The high-altitude *Nothofagus* forest on karst above 1,800 m shares with the higher regions of Mt Sisa and the forests on the Homa Deviation a montane fauna in a mostly undisturbed environment. The broad vegetation group is lower montane small crowned forest with *Nothofagus* and the FIMS type is a mixture of very small crowned lower montane forest

with *Nothofagus* and small crowned lower montane forest with *Nothofagus*. The gas wells, and the flow lines and helicopter pads that have been cut by hand have had little material impact in this area and its ecological values are maintained by its difficulty of access. The epiphytes and ferns are the major component of plant biodiversity in this forest type, trees being the structure upon which this is developed.

The features of this area identified in the 2005 survey were:

- 12 of the 16 new plant species discovered by Takeuchi (**Annex 01**) were from Hides Ridge, including a new tree fern.
- New species of plants from Hides Ridge include three remarkable calcium-depositing ferns that are likely restricted to these high altitude karst areas.
- High diversity of high altitude birds-of-paradise.
- High concentration of limited range endemic high altitude birds.
- The presence of the elusive and rare Greater Melampitta.
- An abundance of arboreal mammals.
- The occurrence of the rare Rock-dwelling Giant-rat.
- Potential for occurrence of caves of the critically endangered Bulmer's Fruit-bat.
- The occurrence of a new species of vespertilionid bat "Vesp Fmin 31".
- An abundance of high flying rare mastiff bats.
- The occurrence of the rare and elusive bat *Murina florum*.
- Three of the five IUCN listed frog species in the project area occur at Hides Ridge.
- At least three species of frogs are known only from Mt Sisa and Hides and another four from Mt Sisa, the Home Deviation and Hides.
- "The forests around Hides 3 are of high significance for conservation of poorly known frogs" (**Annex 09**).
- The forest is in superlative condition and only two exotic weeds were recorded, neither an ecological problem.

This forest type is sensitive to fire, and the high altitude means slow growth rates and slow regeneration (Rogers 2005b). How these high-altitude forests on karst respond and regenerate in relation to disturbance, fire and disease is poorly known. *Nothofagus* itself shows both gap phase and catastrophic regeneration patterns and depending upon the species can regenerate from root suckers as well as seeds.

N. pullei, the commonest species at Hides Ridge, sometimes occurs in patchy even aged stands suggesting regrowth events after infrequent, but large scale catastrophic disturbance but the "type of disturbance required for the establishment of monodominant stands is unclear" (Rogers 2005a). *Nothofagus* is also susceptible to dieback.

Growth rates of *Nothofagus* trees left after logging can be quite high. *Nothofagus* can live in excess of 500 years and slow growing individuals one m in diameter may be over 300 years old.

Research in *Nothofagus* forests has concentrated on *Nothofagus* itself but in the forests such as those in the Hides Ridge, 75% of the plant diversity exists as epiphytes and lithophytes in the tree crowns, on boles and rocks. The trees act as a structure for the development of this community but how this epiphyte community itself responds to disturbance events is completely unknown.

The Hides Ridge area warrants the development of special erosion control and regeneration management systems for construction, but controlling access to this area to eliminate indirect impacts from fire, hunting, logging and settlement and ingress of weeds, pests and pathogens is the most important management system that needs to be developed.

17.3 Special area 3: High-altitude forest above 1800 m on the Homa Deviation

The area above 1800 m asl on the Homa Deviation has similar qualities to Hides Ridge, in particular it is weed free (**Annex 02**) and has one of the highest mammal diversities in the project area (**Annex 04**). However it differs from Hides Ridge in two fundamental ways: it is not a pure karst area and generally has better soils, and the walking trail from Homa to Benaria traverses this region.

Construction through this area may require application of similar erosion control and regeneration management that may be developed for Hides Ridge but, since the ROW will be near or follow the traditional walking track, access management needs to allow for this traditional traffic.

18 Focus habitats

Certain habitats, because of their value and/or sensitivity may require particular management during construction and operations.

18.1 Caves

Caves are abundant in the karst areas of the project area and are critical for conservation of the cave-dwelling bats. G. Richards (**Annex 06**) demonstrates that particular species require particular types of caves and are very selective in what caves they roost and breed in.

Caves in the uplands may support colonies of the extremely rare and critically endangered Bulmer's Fruit-bat.

18.2 Sink hole swamps

These are microhabitats of particular importance in high-altitude karst. They are small pools or swamps at the bottom of dolines or depressions in the karst where water does not drain away, falling leaf litter and other organic debris presumably impeding drainage. They are the only habitats where tree frogs and other water-dependent frogs can breed in these karst areas, which usually have few flowing streams (**Plate 18**).

18.3 Upland streams

Stream condition is important for maintaining populations of torrent-dwelling frogs and birds such as Salvadori's Teal, Torrent-lark, and Torrent Robin. The torrent dwelling frogs in particular require fast flowing clear rocky streams with intact riparian vegetation. Such vegetation can also be a specialised habitat for hydromyine rodents but less commonly for birds in these higher elevations (**Plate 9**).

18.4 Swamp forests

Swamp forests complexes and swamp woodland and forest complexes support a range of specialist vertebrates including Twelve-wired Bird-of-paradise, New Guinea Flightless Rail and a range of turtles and crocodiles. Swamp forests tend to be resilient to physical disturbance of the vegetation but can be destroyed by fire in drought years and eliminated permanently by changes to hydrology. The upland swamp forests are of particular interest.

Swamp forests are not always wet but have a drying and wetting regime that keeps them as swamp complexes. Drier conditions promote the growth of trees and wetter conditions the growth of palms, particularly sago palms. Ponding converts them to freshwater swamps and ingress of seawater to mangroves. Dry conditions convert them to dryer forest formations, scrublands or grasslands.

Changes to hydrology brought about by e.g. causeways may affect the wetland characteristics of these forests.

Fire can eliminate these complexes if they are developed on peat substrates, which can readily burn when dried out.

18.5 Stream refuges in unstable landscapes

The experience at Baia River suggests that in areas of high instability where landslides are common, areas of more mature habitat on more stable substrates such as in stream heads or small plateaux act as refuges for the regional fauna. In these unstable landscapes the major rivers are so dynamic that construction can cause little harm to them in biodiversity terms and environmental management would most appropriately be focussed on managing construction in these more stable refuge areas.

18.6 Lowland rivers in stable landscapes

The lowland rivers in the more stable landscapes are important for crocodiles and freshwater turtles. Within the project area there does not appear to be a specialised bird fauna restricted to riverine forest as there is in gallery forests in dry woodlands. However, a range of species is particularly abundant in these habitats, including kingfishers and Shining Flycatcher. Riverine forest is most important in the lowlands where it supports a variety of large fruiting trees. Consequently, lowland riverine forest is particularly rich in pigeons and parrots, although no species is restricted to this habitat. Many birds will move into these habitats in the drier parts of the year and at hot times of the day, particularly in the lowlands. At such times the riverine forests act as refuges.

18.7 Off river water bodies

The discovery of breeding New Guinea freshwater crocodiles in a small off river water hole alongside the Baia River during the 2008 survey suggests that these habitats in unstable lowland landscapes need special management (**Plate 61**). Such habitats are created by localised damming of runoff by landslides and can be recreated with earthmoving machinery. They may be one of the more easily managed of the focus habitats.

19 Conservation areas

The biological complexity and value of New Guinea (see **section 5.1.1**) combined with the fact that much of the island is still forested, has led to the recognition that large areas of PNG are of very high conservation value. Sekhran and Miller (1994) and Beehler (1993) presented preliminary analyses of areas of particular importance and high conservation value. These areas cover most of Papua New Guinea, but the Kikori basin is given particular significance because of its remoteness and intactness.

The KICDP area is one of the world's great wilderness areas and this status has been maintained alongside an existing oil project. Within it there are five designated government conservation areas (**Figure 12**).

- the Lake Kutubu Wildlife Management Area (WMA) of 25,455 ha
- the Neiru/Aird Hills WMA of 3,963 ha southeast of Kopi
- The Libano-Arisai WMA of 3,964 ha on Libano Creek
- The Libano-Hose WMA of 7,736 ha adjoining Libano-Arisai
- The Sulamesi WMA of 86,451 ha on Mt Bosavi

The Lake Kutubu WMA, the only WMA that the project footprint intersects, is a RAMSAR listed wetland but does not have a specific wetland management plan. It is currently managed under the WMA arrangement.

Eleven other areas of particular biodiversity significance in the southern parts of the project area have been identified by WWF (Leary 1996). These are described in **Table 24**. As yet, none of the WWF significant biological areas has received official recognition as a reserve within Papua New Guinea.

Leary (1996) made her assessment before many of the WWF biodiversity surveys had been undertaken, and it does not cover the northern parts of the project area. At least one of her areas (Area 4: Upper Sirebi River and Lubi River) is being intensively logged. The findings of several WWF biodiversity surveys indicate high value for the whole project area, and the designation of identification is more related to relative degree of isolation and human settlement. **Figure 12** presents the original WWF significant biological areas.

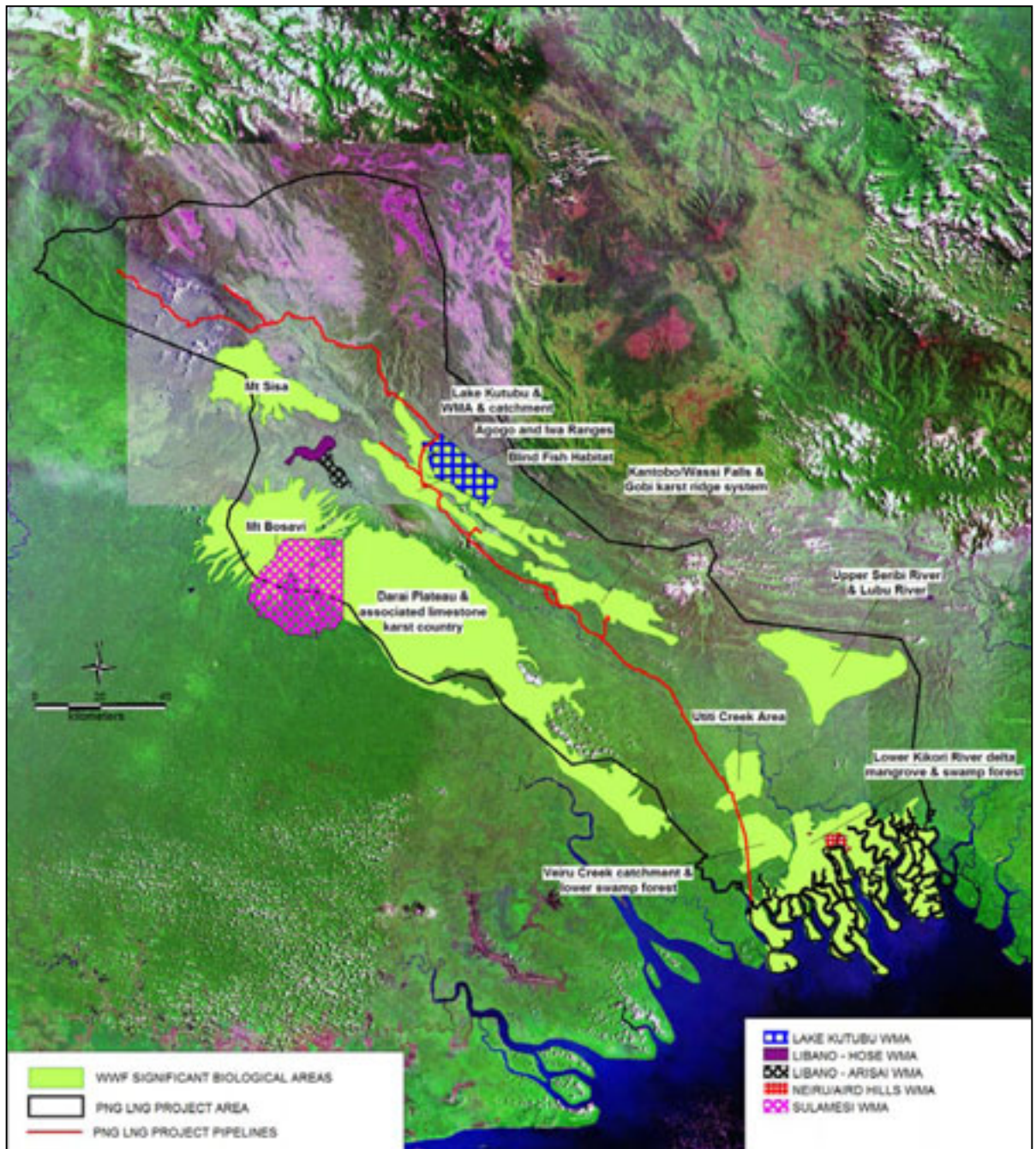


Figure 12 WMAs and WWF significant biological areas within the PNG LNG upstream project area.

Table 24 WWF areas of biological significance (from Leary 1996)

Area 1 Lower Kikori River delta mangrove and Swamp Forest	Together with the Turama and Purari mangrove forests this is one of the most extensive stands of mangroves in PNG. The rich fish biodiversity found in them and the importance of mangroves as breeding areas for fish and prawns warranted designation of this area.
Area 2 Veiru Creek Catchment and Lower Swamp Forests	This area has many rock-walled tidal creeks, is habitat for New Guinea flightless rail <i>Megacrex inepta</i> , has a diverse bird and bat fauna and has over 600 moth species.
Area 3 Utiti Creek Area	This area has diverse and abundant mammal fauna, including rare bats.
Area 4 Upper Seribi River and Lubu River	This area has cold waters which pass through an extensive system of underground caverns, are anomalously cold and "harbour a displaced upland aquatic insect biota" (Leary 1996). It also has high fish, bird and flora diversity.
Area 5 Darai Plateau and Associated Limestone Karst Country	This area has large tract of tower limestone, and because the area is uninhabited and fauna populations are largely intact.
Area 6 Mount Bosavi	This area has an isolated volcano and has a rich, basically undisturbed, fauna and flora. It supports over 900 moth species, a very rich bird fauna, a diverse mammal fauna and unique characteristics of the aquatic insect fauna.
Area 7a Kantobo/Wassi Falls and Gobi Karst Ridge system	This area has generally high biodiversity.
Area 7b Blind fish habitat	This area is special for new species of blind cave fish apparently restricted to the area.
Area 7c Agogo and Iwa Ranges	This area has generally high biodiversity.
Area 7d Lake Kutubu WMA and catchment of Wage/Kaimari Creeks draining into the Digimu River near Moro	This area is identified for the special values of lake Kutubu and the endemic species therein and the generally high biodiversity of its environs.
Area 8 Mount Sisa	This area has potentially rich mammal and moth fauna.

20 Conservation status of flora and fauna

Appendix 11 lists terrestrial species of plants and animals recorded in the project area that appear on the 2008 IUCN red list of threatened species (<http://www.redlist.org/>), and/or are recorded under the Papua New Guinea *Fauna (Protection and Control) Act 1966, 1978* ('Fauna Act'). The meanings of the classification codes are presented in **Table 6**.

113 listed species of fauna and flora plants have been recorded in the project area and a further 12 bats and 17 birds could occur (**Appendix 11**). 82 are listed only by the IUCN, 50 are listed only in the Fauna Act and 10 species are on both lists. The discrepancy is due to the list for the Fauna Act being based on Table 8.2 of Sekhran and Miller (1994). None of the IUCN critically endangered or endangered species are on the Fauna Act list.

30 species as listed as Protected under the Fauna Act and 30 as Restricted occur in the project area. These are mostly species that are hunted. The majority of birds are raptors and birds-of-paradise, and the reptiles are crocodiles, snakes and goannas. While all except the lowland bioregions have high numbers of listed species, the Eastern Uplands Volcanics/ Karst and the Western Volcanics bioregions have the highest concentrations (**Appendix 11**).

Estimating Habitat Losses

21 Methods

21.1 Sources of information on project design and construction

This analysis is based on a variety of internal documents and communications on project development provided by Coffey Natural Systems. Project layout was available as the following MAPINFO™ and ARCGIS™ files (received 02/06/08)

1. Facilities location points (LNG_Facility_Location.tab received 05/05/08)
2. Well location points (Proposed_Wells.tab received 22/09/08 and JuhaWells.shp received 08/07/08)
3. camp and pipeyard locations (LNG_PipeYard_Location.tab received 7/10/08) and mainline valve stations (MLV.tab received 7/10/08)
4. Drawing of the layout of the Hides Gas Conditioning Plant (HGCP_Facility_Design.TAB received 05/05/08)
5. Proposed Pipeline ROWs (EIS_Pipelines_Alignment.tab received 7/10/08)

A description of pipeline construction is presented in **sections 23.1** and **23.2** below.

Habitat losses were estimated using MAPINFO™ with imagery and project data provided by Coffey Natural Systems. Imagery available was

1. High resolution (0.25 m) colour aerial photography captured in late 2005¹³ along the route for the 1995 PNG Gas project (not available for entire project area).
2. High resolution (1 m) Ikonos imagery captured in 2007¹⁴ of the Tagari area.
3. Low resolution (8.5 m) Landsat imagery capture pre 2005¹⁵ of the entire project area.

21.2 Calculating habitat losses

Habitat losses for the project were calculated according to the type of BVG lost, its condition i.e. level of disturbance and whether it was a greenfield or brownfield area. In addition estimated habitat losses were increased for construction in steep terrain using “sidecast factors”.

Habitat losses were calculated for

¹³ Received 21/03/06 and covered in the following MAPINFO™ tables: Hides_Geo_000001.TAB to Hides_Geo_000020.TAB; 33 sets of tiles: set 1: I1_Tile000001.TAB to I1_Tile000084.TAB through to set 33: I33_Tile000001.TAB to I33_Tile000007.TAB; ITEM_A_001.TAB to ITEM_A_019.TAB; ITEM_B_001.TAB to ITEM_B_063.TAB; and ITEM_C_001.TAB to ITEM_C_026.TAB.

¹⁴ HGCP_IKONOS80cm_ECW_24Apr-16May-2007_Wgs84_Utm54S.ecw

¹⁵ Satellite Imagery over onshore pipeline TM/Pan using edge technique UTM Zone 54S WGS84 ETM 98/64 (Acquired 7-Aug-01), ETM 98/65 (Acquired 1-Dec-02), ETM 99/65 (Acquired 24-Sep-91), ETM 99/64 (Acquired 4-Jul-02).

-
- all pipeline ROWs
 - all flowlines
 - upgrading the crude export oil pipeline roads for logistics use
 - all facilities
 - temporary camps
 - HDD crossing points

Using the GIS the various pipeline route were segmented according to unique combinations of BVG, condition, side cast factors and green- or brownfield. By summing and multiplying by the width of the ROW clearing it is then possible to calculate the areas of various condition/BVG/green-brown combinations that are predicted to be lost. The use of the side cast factors is explained in **section 21.2.4**.

The width of the ROW clearing, or the pipeline construction disturbance area for the various upstream PNG LNG Project ROWs and flowlines was taken as 35 m: 30 m for the ROW and an extra 5 m to account for possible extra clearing either side of the ROW as described in **section 23.1**, unless otherwise stated in the route descriptions (**section 23.3**).

Calculations for facilities, camps and HDD crossing points was done similarly with each entity's polygon being overlain on BVG, condition, side cast factors and green- or brownfield layers in the GIS and areas calculated of each unique combination within the polygon.

For losses due to construction of new logistics roads a clearing width of 15 m was assumed based on constructing an 8 m road pavement.

Losses due to upgrading the crude export oil pipeline roads were estimated by assuming 5 m would be cleared from either side of the existing road.

Calculations could not be made for access tracks (shoo fly roads) as no locations were available for them. Instead for areas where shoo fly roads may be required an additional 20% of forest loss was assumed.

No losses were calculated for the Hides Gas Conditioning Plant to Idauwi road upgrade, for upgrades of existing roads that will form important logistics routes i.e. the highlands, the ring road between Kutubu and Tari and the Kutubu to Homa road

21.2.1 Condition

Habitat condition refers to the degree of disturbance of the vegetation which can vary from "old growth" to bare ground. There are nine classes of habitat condition in **Table 25**; six for vegetated areas (codes A1, A2, C, D, E, L) and three for "industrial" areas (codes O, R and F).

Old growth, or pristine forest, is class A1 and the definition used here is the Asian Development Bank (ADB 1995) definition – "A relatively intact forest characterized by a large number of species of trees, shrubs and climbers that has remained unmodified by external interventions (human or natural) over a prolonged period of time."

A1 through to L represent a hierarchy of forest structural quality and measure of pristineness, but they do not necessarily represent biodiversity rankings. For example “old growth but with some disturbance” and “late secondary or heavily disturbed old growth” are often more diverse than “old growth” forest.

21.2.2 Greenfield or brownfield

Brownfield are all areas previously impacted by the oil project. This includes the area from Lake Kutubu to Kopi, Gobi, Agogo, Southeast Mananda, Moran and around Nogoli. Greenfield are areas not previously disturbed by development and include hand-built flowlines at Hides and remote areas with wells that have been drilled using helicopter access.

Table 25 Classification of condition.

Code	Condition	Description
A1	Old growth or pristine forest	Old growth or primary habitat without human or natural disturbance.
A2	Old growth but with some disturbance	Old growth forest occurring near settlements, garden areas, roads or industrial facilities or where small tracks are visible in the forest. and/or Also old growth forest away from settlements with areas of natural disturbance e.g landslides.
C	Late secondary or heavily disturbed old growth	Forest that has been heavily disturbed
D	Pioneer/early secondary	Regenerating forest
E	Gardens secondary complexes	Complex of open areas, fresh gardens, fallow areas, patches of regrowth, secondary forest, heavily and lightly disturbed old growth forest.
L	Logged forest	Forest that has been logged legally or illegally commercially logged as evidenced by logging roads on air photos or satellite imagery.
V	River	Surface of river or waterway
O	Oil ROW	Open pavement of main crude export pipeline or flowline ROW + grassy edge of road and edge regrowth.
R	Road	Open pavement of road + grassy edge of road and edge regrowth.
F	Facility	Area within an exiting oil facility.

21.2.3 BVG

The type of BVG was determined from the FIMS mapping

21.2.4 Side cast factors

The pipeline construction disturbance areas minimal areas of clearing which terrain difficulties can exacerbate because upslope of the ROW benches may need to be cut, and material pushed over the side when roads and benches are cut (side cast), will smother vegetation downslope and cause tree deaths, particularly in steep terrain that requires significant benching. A side cast factor (multiplier) of 1, 2 or 3 according to steepness of terrain was therefore assigned to various segments of the ROWs.

- Class 1 - little clearing expected beyond the nominal ROW
- Class 2 - steep terrain but with slopes generally less than 12% but up to 15%
- Class 3 - very rugged terrain with slopes sometimes exceeding 20%

The application of side cast factors is shown in **Table 26**. The rationale for extra areas lost from roads and the crude export oil pipeline ROW is that extension of these areas outwards involves first a loss of degraded vegetation adjacent to the ROW then beyond that a loss of higher quality habitat that had not been influenced by the road or crude export oil pipeline ROW construction.

In the following discussion the areas of habitat that are indicated in the tables and text are estimates only, predictions based on current understanding of project layout and construction methods. They may not reflect the actual losses if measured by ground surveys after project construction is completed.

Table 26 Extra habitat losses for side cast factors.

Code	Condition	Side cast factor		
		1	2	3
A1	Old growth	Habitat loss x 1	Habitat loss x 2	Habitat loss x 3
A2	Old growth but with some disturbance			
C	Late secondary or heavily disturbed old growth			
D	Pioneer/early secondary			
E	Gardens & secondary complexes			
L	Logged forest			
O	Oil ROW	Habitat loss x 1 in Condition class D	Habitat loss x 1 in Condition class D + equal area of habitat lost in Condition code C	Habitat loss x 1 in Condition class D + equal area of habitat lost in Condition code C + equal area of habitat lost in Condition code A2
R	Road			
F	Facility			

22 Losses due to construction of facilities

22.1 Wells and well pads

There are already four old wells at Juha (1X, 2X, 3X, 4X). Four new wells will be drilled from three new well pad in low altitude medium crowned forest in a single drilling campaign planned for Phase 4 of the project.

Hides is a key resource for the project and as well as supplying gas to the PNG LNG Project will continue to supply gas to generate electricity for the Porgera mine. Wells will be drilled from three old and four new wellpads in two drilling campaigns. All of these are in lower montane small crowned forest with *Nothofagus*.

Two new wells will be developed each on its own well pad at Angore during Phase 2. Both pads are located in late secondary or heavily disturbed old growth lower montane small crowned forest.

A single well pad will be constructed at Southeast Hedinia in lower montane very small crowned forest complexes with *Nothofagus*.

Estimating well pad size as 2.0 ha, the total vegetation losses due to well pads at Juha, Hides, Angore and Southeast Hedinia is given in **Table 27**.

Gas from Kutubu, Agogo, Moran and Gobe will not involve drilling any new wells.

22.2 Production and processing facilities

22.2.1 Juha Production Facility

The Juha Production Facility will be installed in Phase 4 and will separate condensate then compress and dehydrate the gas for transportation in separate liquids and gas pipelines, both in the same trench, to the Hides Gas Conditioning Plant. There will be a helipad and a flare with 150 m clearance radius. The facility is not intended to be permanently manned but will have 20 accommodation units for overnight maintenance visits. The area of the facility was calculated from a preliminary concept design and yielded an estimated loss of approximately 31 ha of old growth low altitude medium crowned forest (**Table 27**).

22.2.2 Hides Gas Conditioning Plant

The Hides Gas Conditioning Plant and associated Industrial Park is situated in a complex of gardens and regrowth near the village of Laite and will accommodate 220 people in 100 accommodation units. It will receive well stream fluids from Hides and Angore, gas and liquids from Juha and produce condensate and dried gas.

There is no old growth forest in this area and the plant will result in the loss of about 78 ha of gardens and late secondary complexes, eight ha of Pioneer/early secondary vegetation and four ha of Late secondary or heavily disturbed old growth lower montane small crowned forest with *Nothofagus*.

22.3 Camps

22.3.1 Pioneer camps

Pioneer camps will need to be used to build the temporary construction camps (see **section 22.3.2**) as well as to service the many surveying and early works crews. No detail is available on the number or locations but each camp is likely to be less than one ha and some will be in old growth forest. The pioneer camp at the Mubi River, for excavation of the initial civil works, may be replaced by an accommodation barge.

22.3.2 Temporary camps

At least nine temporary contractor construction camps and/or pipeyards for infrastructure and pipelines will be necessary at Kopi, Gobe, Mubi River, Kikori, Moro, Tamadigi, Tambera, Idauwi, and the Hides Gas Conditioning Plant where the construction camp will be within the footprint of the facility. Portions of the camp at the Hides Gas Conditioning Plant will ultimately be used for the permanent camp for operations. The camps will contain static and mobile components, the latter to support working fronts.

The estimated area of habitat loss for the remaining temporary camps and pipeyards is given in **Table 27**¹⁶. The bulk of this will be available for regeneration on completion of the project.

Juha may be constructed from the camp at the Hides Gas Conditioning Plant but if a temporary construction camp is built at Juha it will be within the footprint of the Juha Production Facility.

22.4 Other facilities

Other facilities that may involve some habitat loss are horizontal directional drilling sites at the Tagari, Mubi, Wah and Kikori Rivers, Kopi expansion, wharf and Roll-on – Roll-off (RoRo) facility.

New quarries may also be required but existing ones will be used where possible. Airfield upgrades will be within existing disturbance zones next to airfields.

There may be up to 12 cathodic protection stations each involving approximately 0.6 ha of clearing. This clearing is not circular but encompasses areas for the rectifier, solar panels, an underground electrical powerline approximately 150m x 5m and a ground bed to bury the anodes approximately 10m x 150m.

Only the HDD sites are included in estimates of habitat losses because the location of the other facilities is not precisely known. In total these excluded facilities would amount to no more than 20 ha.

¹⁶ Locations from GIS layer "LNG_Camp_Location"

23 Losses due to construction of pipelines and roads

23.1 Pipeline construction description

The following brief description of pipeline construction is from documents provided by Coffey Natural Systems.

Pipelines will be mostly buried within a cleared ROW, a construction surface from which crews can install the pipeline, which is wide enough to safely accommodate trench digging machinery, trench, trench spoil and a track road to allow vehicles to pass safely. The width of the LNG pipeline ROW will be nominally 30 m consisting of, from one side to another, 7.5 m for storage of felled brush and trench spoil, 5.5 m for the sloping-sided trench to accommodate the 32 inch pipe, 3 m for pipe storage and setback, 7 m for sideboom operation and 7 m for a traffic lane for construction traffic. On Hides Ridge the ROW for the 22 inch spinline will be maintained at 18 m.

The width of clearing may differ from the ROW width. It may be wider (up to 50 m) at road and pipeline crossings, river crossings, the offshore landfall tie-in, swampy areas, particular terrain, and where large amounts of brush need to be stored. It may need to be widened in some places for vehicle passing and materials and machinery parking and storage areas. In very confined areas it may be narrower.

In general the ROW will not be used for logistics traffic which instead will use a system of roads and tracks. In places where the logistics roads and the ROW are side by side clearing width may be up to 50 m wide.

In sloping terrain the ROW is benched to various extents to maintain an appropriate grade, which depends upon terrain, geology and whether or not the ROW has a permanent access track within it. Drainage and, where specified, appropriate erosion control systems are installed. The ROW surface is formed sufficiently to take project traffic which may involve installing a thin rock pavement.

A pipeline construction unit, or spread, carries out the full range of operations including ROW clearing and preparation, trenching, pipe stringing, welding, hydrostatic testing, backfilling and final cleanup. Clearing and pipeline construction activities would be conducted over a period of approximately three to six months or a maximum of one season in any one area.

First the ROW would be surveyed and staked to identify the centreline and then prepared by clearing and grading, as necessary. Clearing would include removal of aboveground vegetation and rocks to the side of the ROW. Any trees and large shrub debris that need to be removed would be felled and stockpiled alongside the ROW. Larger logs maybe be salvaged if required by the Forestry Department or for construction use in the project. Smaller shrub vegetation moved to the side of the ROW would be conserved and spread over the ROW after construction is completed to help control erosion, serve as mulch, and provide a source of seed for re-vegetation.

The pipeline trench would be centred on a line usually about 10 m from one side of the ROW. The trench would be excavated mechanically and the limit of open trench would typically not exceed 10 km along the ROW. Equipment such as backhoes and clamshell buckets would be used in areas of loose or unconsolidated rock. A minimum of 0.7 m of

cover from the top of the pipe to the ground surface typically would be provided. Cover would be greater at road and water crossings. If solid rock is encountered, blasting would be required. A minimum of 0.50 m of cover would be provided when the ditch is in rock.

A trench may have a combination of pipes for gas, condensate, well fluids and Mono-ethylene glycol¹⁷, as well as fibre optic cables. Trenches may be up to 2.3 m deep e.g. to accommodate the LNG Project Gas Pipeline and the Hides Gas Conditioning Plant to Kutubu Central Processing Facility condensate pipeline, suitably separated one above the other.

Pipe would be transported to the ROW by tractor-trailer trucks. The pipe would be unloaded and strung along the ROW using sidebooms and other equipment. A hydraulic pipe-bending machine would bend the pipe in the field, using cold bending. Laying the pipe would involve swabbing, lining up, and welding. The pipeline contractor would secure all open ended pipes at the end of the work period with "night caps.

When ready to be welded together the pipe lengths are swabbed clean the ends bevelled, lined up and welded. Valves and other pipe fittings would be installed as welding proceeds. After welds have been inspected and any required re-welding completed, the pipe end joint would be cleaned and wrapped to provide a homogeneous protective coating. The coating would be inspected and repaired, if necessary, prior to side booms lowering the pipe into the trench. In rocky areas the bottom of the ditch would be padded to provide a uniform bearing surface for the pipe. Once in the trench, pipe would be padded with sand or soil where necessary to protect its coating during backfill operations. Backfill material displaced by the pipeline would be replaced in the trench and crowned on top of the ditch to compensate for future settling. Excess backfill material would be spread over graded parts of the ROW. Ditching should produce sufficient backfill material. However, in some rocky areas backfill might need to be imported. The ROW would then be returned to the approximate preconstruction or stable grade, and cleanup and restoration activities would commence.

Cleanup and regeneration of the ROW would be undertaken once backfilling and compaction are completed. Materials removed during clearing and stockpiled on one side of the ROW would be spread over the cleared area. The ROW would be returned to its natural contour and graded to the extent feasible. Ground and aerial markers with kilometre indicators would be installed along the pipeline route to aid in maintenance and possible emergency response. With the exception of the system easement (which includes areas occupied by valves, communication towers, pump stations, and other permanent aboveground facilities), all of the remaining cleared ROW area would be allowed to return to its former use after construction activities cease. The 10 to 15 m wide portion of the system easement that encompasses the pipeline need to be kept free of large trees and buildings..

23.2 Logistics roads and tracks

The PNG LNG Project has defined four types of roads.

Project roads are new roads to be purpose built by the PNG LNG Project that will provide vehicular access to the Hides Gas Conditioning Plant, aviation facilities, and the Juha

¹⁷ An inhibitor to prevents hydrate forming in flow lines.

Production Facility. They are intended to remain private, i.e., for project use only, and the public will not have access to them during or after construction.

Public roads are existing roadways whose access is not controlled or limited by the PNG LNG Project. Where available, existing public roads will be incorporated into the project's logistical corridors and upgraded as necessary and will re-open to unrestricted public use after completion of the construction phase of the PNG LNG Project.

Controlled access roads are existing private roadways controlled by other operators in the region and made available for use by the PNG LNG Project.

Access tracks are new, access corridors that will provide vehicle access to the well pads and are for project use only.

In addition to these access roads temporary construction tracks (sho fly roads) may be required to access the ROW where terrain does not allow certain vehicles to use the ROW.

23.3 Route descriptions

In the discussion below the term alignment is used for the cleared corridor in which the ROW, with its trench and pipeline(s) is located.

Minor streams are defined as less than 10 m wide with water less than a meter deep and will be usually crossed by trenching and reinstatement. Associated tracks will either ford the stream or be carried on a road bridge. Major streams greater than 10 m wide will either be trenched or crossed by horizontal directional drilling.

The alignment has been divided into sections for analysis of habitat loss.

Section 1 Juha Wells to the Baia River catchment

The alignment in this section (**Figure 13**) starts at the Juha Production Facility and contains the ROW for the Juha-Hides Rich Gas Line and the Juha-Hides Liquids Line in a single trench and is some 14 km long. Prior to the start of the alignment well fluids are gathered from Juha A, B and C, which are located near and around the Juha Production Facility in a gathering system of flowlines and spelines. The Juha A and C MEG pipelines will be in the same trenches as the well fluids flowlines and spelines.

The wells, Juha Production Facility and the start of the alignment are located on a rough karst plateau in old growth low altitude medium crowned forest. The terrain surrounding the Juha Production Facility is steep and vegetated in a mixture of limestone and other sedimentary rocks. From the Juha Production Facility the alignment heads southeast for about nine km skirting between karst and other sedimentary geologies until it crosses a large tributary of the Wai Asia River still at about 900 m asl, and still in unbroken forest (**Plate 80**). The crossing may be trenched or crossed by horizontal directional drilling. From this crossing the alignment traverses another six km of forest at the same altitude then enters the unstable landscapes of the central Baia River catchment. Throughout this section the vegetation has distinct montane characteristics despite being classified as a low altitude forest. There is no human habitation in this section and the forest is untouched except for the old isolated Juha well pads. Streams frequently descend into sinkholes in the karst (**Plate 16**).

There is to be no separate logistics road into the Juha area, instead the alignment will include the access road, which will remain private and controlled.

No high resolution imagery was available for this section and an alignment width of 35 m was presumed for estimating habitat losses. Shoo fly roads may be needed in this section.

Estimated habitat losses, including that from the gathering system, are presented in **Table 27**.

Section 2 Baia River catchment to South Karius

The alignment in this section (**Figure 13**) contains the ROW for the Juha-Hides Rich Gas Line and the Juha-Hides Liquids Line in a single trench and is some 27 km long.

Throughout its length the alignment traverses the upper catchment of the Baia River crossing the Baia River itself after about 9 km. The Baia River downstream of the proposed crossing point is wide, wild and has highly unstable banks (**Plates 3** and **6**), but the proposed crossing point itself is above the first major widening of the river and where the alignment reaches its lowest point at about 380 m asl. The river will be trenched or crossed by horizontal directional drilling. Once over the river, the terrain is highly unstable sedimentary formations with numerous large landslides (**Plate 20**) so the alignment hugs the edge of the more stable northern parts of the catchment. From the Baia River the alignment climbs around a steep spur and ascends eastwards through lower montane small crowned forest to the swamplands of the South Karius area at about 1450 m asl. This swampy alluvial valley is squeezed between Mt Sisa and the Karius Range and supports recently developed gardens, the first human settlements along the route (**Plate 7**), some 40 km from the Juha Production Facility. The alignment eventually moves into a narrow valley up to the catchment boundary of the Baia River.

There is to be no separate road into the Juha area, instead the alignment includes the access road, which will remain private and controlled.

No high resolution imagery was available for this section and an alignment width of 35 m was presumed for estimating habitat losses. Shoo fly roads may be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 3 South Karius to the Hides Gas Conditioning Plant

The alignment in this section (**Figure 14**) contains the ROW for the Juha-Hides Rich Gas Line and the Juha-Hides Liquids Line in a single trench and is some 12 km long terminating at the Hides Gas Conditioning Plant.

For the first 5 km the alignment travels along a narrow valley south of the Karius Range in good quality lower montane small crowned forest with *Nothofagus* before entering the heavily settled areas around Komo and Laite villages at about 1800 m asl. The alignment generally avoids the cultivated areas by skirting the southeastern footslopes of the Karius Range.

There is to be no separate road into the Juha area, instead the alignment includes the access road, which will remain private and controlled.

No high resolution imagery was available for this section and an alignment width of 35 m was presumed for estimating habitat losses. Shoo fly roads may be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 4 The Hides Uplands section

The alignment in this section (**Figure 14**) contains the gathering system to take well fluids and gas from the Hides wells to the Hides Gas Conditioning Plant. The gathering system consists of flowlines, spinelines and MEG lines in the same trench. The alignment is approximately 21 km long to its junction with the Juha-Hides Rich Gas Line.

The alignment traverses rugged polygonal karst between elevations of 2800 and 2000 m. The well pads are on hilltops (**Plate 2**) and the alignment picks its way along the top of the range past numerous sinkholes. The vegetation of this area is lower montane small-crowned forest with *Nothofagus*. The dolines frequently have swamps at their bottoms (sinkhole swamps) and there are numerous caves. The logistics track will be within the alignment. This section joins the South Karius to the Hides Gas Conditioning Plant section at about 3 km west of the Hides Gas Conditioning Plant.

High resolution imagery was available and an alignment width of 18 m was presumed for estimating habitat losses in this section. Shoo fly roads will be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 5 Hides Gas Conditioning Plant to Dagia River

The alignment in this section (**Figure 14**) contains the ROW for the LNG Project Gas Pipeline and the Hides Gas Conditioning Plant to Kutubu CPF Condensate Pipeline in a single trench and is some 14 km long. From Angore to the Hides Gas Conditioning Plant it also contains the spinelines from the Angore wells to the Hides Gas Conditioning Plant and the MEG pipelines from the Hides Gas Conditioning Plant to the Angore wells.

The alignment descends from the Hides Gas Conditioning Plant into the Tagari valley and crosses the Lajauko to Komo road before reaching the Tagari River at about 5 km from the Hides Gas Conditioning Plant. The rolling alluvial plains west of the Tagari River are vegetated in lower montane small crowned forest which is subject to shifting cultivation. The Tagari River is reached at about 1 km south of Angore rest hut and will be crossed by horizontal directional drilling. The alignment then has to climb a steep well forested ridge which rises to about 1400 m asl east of the river then descends south-eastward through cultivated lower montane small crowned forest on the volcanic footslopes east of the river. The gas pipeline from the Angore well pad A joins with the alignment at about 8.5 km from the Hides Gas Conditioning Plant. The alignment comes very close to the Angore well pad B a further 1.5 km along then reaches the Dagia River, which will be trenched, at about 14 km from the Hides Gas Conditioning Plant.

The alignment will not be used for logistics traffic which instead will use an upgraded Hides Gas Conditioning Plant – Idauwi road.

Moderate resolution imagery was available and an alignment width of 35 m was presumed for estimating habitat losses in this section.

Predicted habitat losses are presented in **Table 27**.

Section 6 Dagia River to Benaria River

The alignment in this section (**Figure 14**) contains the ROW for the LNG Project Gas Pipeline and the Hides Gas Conditioning Plant to Kutubu CPF Condensate Pipeline in a single trench and is some nine km long.

From the Dagia River the alignment meets the Hides Gas Conditioning Plant to Idauwi road and then more-or-less travels along the same route towards the Benaria River. It will be offset from the road and be designed to cross it as few times as possible. The alignment traverses volcanic footslopes in the vicinity of Tambaruma skirting west of the Pali Range, crossing rolling, volcanic hills in a corridor of regrowth forest between 1200 and 1400 m asl, before it reaches the Benaria River (**Plate 81**). This section terminates some two km from the Benaria River.

High resolution imagery was available and an alignment width of 35 m was presumed for estimating habitat losses in this section.

Predicted habitat losses are presented in **Table 27**.

Section 7 Benaria River to Kondari River

The alignment in this section (**Figure 15**) contains the ROW for the LNG Project Gas Pipeline and the Hides Gas Conditioning Plant to Kutubu CPF Condensate Pipeline in a single trench and is some 33 km long from the Benaria River to the Kondari River.

The terrain and soils between the Benaria and Kondari rivers are very difficult for construction. The pipeline requires the terrain to be sufficiently stable for safety and in this area of highly unstable volcanic slopes there is limited choice as to where the ROW can be located.

The alignment crosses the Benaria River near where the old Tari road crosses and, while traffic will use a newly constructed bridge, the pipeline will be trenched across the river near the original bridge site (**Plate 83**). The alignment then runs eastwards and climbs steeply up a ridge with advanced secondary growth forest, passing an abandoned village site, close to the camp of the 2005 survey (see **Annex 07**), before rapidly rising to near 2100 m asl into lower montane small crowned forest with *Nothofagus*. It then continues east before crossing the headwaters of the Bakari and Maruba Rivers and turning south. It then traverses west of the Bakari River, along the valley and the watershed of Iaroro Creek, for some 5 km before a steep descent into the Bakari River valley and thence to the village of Homa. From Homa the alignment continues south for some 2.5 km to cross the Kondari River, which will be trenched.

Except for the first five km near the Benaria River and another five km at Homa the alignment traverses old growth forest. The area is very steep.

No high resolution imagery was available and an alignment width of 35 m was presumed for estimating habitat losses in this section. Shoo fly roads will be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 8 Kondari River to Lake Kutubu

The alignment in this section (**Figures 14 and 15**) contains the ROW for the LNG Project Gas Pipeline and the Hides Gas Conditioning Plant to Kutubu CPF Condensate Pipeline in a single trench and is some 25 km long.

From the Kondari River the alignment more-or-less parallels the Kutubu to Homa road crossing a densely forested pass north of Mt Barina thence on to Pua'a village in the cultivated Aiu River valley. It then leaves the road and follows a long-abandoned track on a ridge in polygonal karst that forms the watershed between the Mubi River and Tibi Creek before descending into the Kutubu swamplands to join the main road north of Lake Kutubu.

The road from Kutubu to Homa will act as the logistics road.

The valleys of the Mubi and Aiu Rivers are settled (**Plate 84**) and cultivated.

High resolution imagery was only available for the first 4 km of this section and an alignment width of 35 m was presumed for estimating habitat losses. Shoo fly roads may be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 9 Kutubu to Moro

The alignment in this section (**Figure 16**) contains the ROW for the LNG Project Gas Pipeline and the Hides Gas Conditioning Plant to Kutubu CPF Condensate Pipeline in a single trench and is some seven km long.

This section traverses north of Lake Kutubu (**Plate 85**) mostly avoiding the swamp forests north of the lake by traversing north of the road and crossing the karst ridges (**Plate 86**) either side of Wage Creek, approaching Moro from the north, then passing it to the west.

The karst ridges are vegetated in low altitude medium crowned forest and the river valleys and the plain to the north of lake Kutubu in swamp woodland and forest complexes.

High resolution imagery was available for most of this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 10 Moro to Kutubu Central Processing Facility turnoff

The alignment in this section (**Figure 16**) contains the ROW for the LNG Project Gas Pipeline and the Hides Gas Conditioning Plant to Kutubu CPF Condensate Pipeline in a single trench and is some 12 km long.

From Moro the alignment departs from the Moro to Kutubu Central Processing Facility road and uses a different route some 300 to 600 m east of the road. It traverses steep karst clothed in low altitude medium crowned forest around Moro and climbs into lower montane very small crowned forest complexes with *Nothofagus* near the ridge. The route climbs to a peak of 1400 m asl before reaching a point some 1.5 km east north east of the Kutubu CPF at which point the condensate pipeline from the Hides Gas Conditioning Plant runs some 2.5 km south then west to the Kutubu CPF which is located at some 1000 m asl. The LNG Project Gas Pipeline connects to the Kutubu CPF along the same route and in the same trench. High resolution imagery was available for most of this section and an alignment

width of 35 m was presumed for estimating habitat losses. Shoo fly roads may be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 11 Kutubu Central Processing Facility to Ai'io River

The alignment in this section (**Figure 16**) contains the ROW for the LNG Project Gas Pipeline and is some 11 km long.

From the turnoff into the Kutubu Central Processing Facility, the alignment runs south east then south. It is offset to the north and east from the existing road by approximately a kilometre, and does not cross the road until about 2 km north of the Ai'io River. By offsetting in this way the alignment generally avoids the steeper karst through which the crude export oil pipeline ROW runs, and only has to traverse about 3.5 km of steep polygonal karst when descending the Iwa Range (**Plate 88**) to the Ai'io River near the village of Hedinia. The alignment traverses mostly old growth lower montane very small crowned forest complexes with *Nothofagus* (**Plate 87**) and medium crowned to small crowned forest complexes with *Nothofagus*. The route descends from a high point of about 1,000 m asl, at the turnoff into the Kutubu Central Processing Facility, to about 400 m asl at the Ai'io River. The roads associated with the crude oil export pipeline in this section are currently trafficable by construction vehicles but will be upgraded as required.

High resolution imagery was available for 50% of this section and an alignment width of 35 m was presumed for estimating habitat losses. Shoo fly roads may be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 12 Ai'io River Valley

The alignment in this section (**Figure 17**) contains the ROW for the LNG Project Gas Pipeline and is some 16 km long.

The alignment parallels the crude export oil pipeline ROW and will be constructed either directly alongside or offset to leave a strip of forest between the two. The route is currently trafficable and the existing road here will be upgraded to act as a logistics route.

The alignment first crosses the Ai'io River, which will be trenched for the pipeline, then traverses the alluviums of the Ai'io River valley at an altitude of about 450 m asl. The terra rossa soils overly limestone and support swamp woodland and forest complexes with sago and other palms at the northwestern end of the valley (**Plates 89 and 90**). To the southeast, the forest grades into medium crowned to small crowned forest complexes as the alignment climbs up into polygonal karst. The valley contains several villages, including Manu village (**Plate 91**) and a village established on the crude export oil pipeline ROW near the Ai'io River.

High resolution imagery was available for most of this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 13 Ai'io River to Wassi Falls

The alignment in this section (**Figure 17**) contains the ROW for the LNG Project Gas Pipeline and is some 33 km long.

The alignment parallels the crude export oil pipeline ROW and will be constructed either directly alongside or offset to leave a strip of forest between the two. The route is currently trafficable and the existing road here will be upgraded to act as a logistics route.

From the Ai'io River valley the alignment continues alongside the crude export oil pipeline ROW into an uplifted area of polygonal karst clothed in medium crowned to small crowned forest complexes (**Plates 92, 93 and 94**) from whence it descends via a long narrow valley into the valley of the Mubi River overlooking the village of Kantobo (**Plate 95**). The karst in this section has many areas where drainage is impeded. Sinkholes, small valleys and sections of the crude export oil pipeline ROW retain water during wet periods (**Plate 19**).

High resolution imagery was available for most of this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 14 Wassi Falls to the Mubi River

The alignment in this section (**Figure 17**) contains the ROW for the LNG Project Gas Pipeline and is some five km long.

This short section forms the second major descent of the alignment, this time into the Kikori River lowlands at about 40 m asl through steep terrain some distance from Wassi Falls. The alignment continues to parallel the crude export oil pipeline ROW down the range (**Plate 96**) and, after descending through an area of terra rossa clays, it crosses the Mubi River near its junction with the Kikori River (**Plate 97**). It is unlikely the LNG Project Gas Pipeline will be able to be constructed in or close to the ROW of the crude export oil pipeline but instead will be offset and within old growth rather than the regrowth forest along the edge of the crude export oil pipeline ROW.

Road traffic cannot negotiate the crude export oil pipeline ROW down "heartbreak hill" because grades frequently exceed 20% so a bypass road will be constructed. Starting at about 56 km from the Kutubu Central Processing Facility the access road turns south then negotiates down the karst and traverses southeast to the Mubi River where it rejoins the alignment. This new project road will remain private and for project use only.

The Mubi River at the crossing point is 100 m wide. A three span bridge will be built here to accommodate project traffic but the pipeline will be trenched or crossed by horizontal directional drilling.

High resolution imagery was available for most of this section and an alignment width of 35 m was presumed for estimating habitat losses. Shoo fly roads may be needed in this section.

Predicted habitat losses are presented in **Table 27**.

Section 15 Mubi River to the Gobe Turnoff

The alignment in this section (**Figure 18**) contains the ROW for the LNG Project Gas Pipeline and is some 18 km long.

The alignment parallels the crude export oil pipeline ROW which is mostly overgrown with secondary vegetation and un-trafficable and will be constructed either directly alongside or offset to leave a strip of forest between the two. A new private project road will be constructed along the crude export oil pipeline ROW and the alignment will be adjacent to the new road.

For the first 7 km from the Mubi River the route passes through mudstone overlain with terra rossa clays developed on karst plains and vegetated in medium crowned to small crowned forest complexes (**Plate 98** and **99**). From there, the soils become very thin and support open lowland forest. The forest root mat sits on hard limestone pavement. The alignment then traverses low altitude medium-crowned forest as it approaches the tie-in point of the Gobe Gas Pipeline (**Plate 100**).

High resolution imagery was available for most of this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 16 Gobe Turnoff to Kikori River crossing

The alignment in this section (**Figure 18**) contains the ROW for the LNG Project Gas Pipeline and is some 34 km long.

The alignment more or less parallels the crude export oil pipeline ROW, and will be constructed either directly alongside or offset to leave a strip of forest between the two. The route is currently trafficable and the existing road associated with the crude oil export pipeline here will be upgraded to act as a logistics route.

From the Gobe airfield the alignment again runs over karst plains to another section of polygonal karst approximately 8 km from the Gobe airfield. This karst is not severe and while sinkholes and pinnacles occur frequently, particularly northwest of the Kikori (Kaia) River crossing (**Plate 101**), the alignment approaches very few. The karst plains are vegetated in open lowland forest, and the polygonal karst areas support low altitude medium crowned forest. A permanent two span bridge of 120 m will be constructed over the Kikori River to replace the ferry and will accommodate project traffic but the pipe will cross the river by horizontal directional drilling. Another large bridge (46 m) will be built across the Wah River 13 km from Gobe airfield and again the pipe will cross the river by horizontal directional drilling.

High resolution imagery was available for most of this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 17 Kikori River Crossing to Omati

The alignment in this section (**Figures 19** and **20**) contains the ROW for the LNG Project Gas Pipeline and is some 66 km long.

The alignment now departs from the crude export oil pipeline ROW and tracks southeast across the small crowned lowland forests of the Kikori River floodplain before climbing into the eastern footslopes of a large mass of polygonal karst clothed in medium crowned to small crowned forest complexes. The alignment then traverses logged small crowned

lowland forests and medium crowned to small crowned forest complexes on limestone plateaux with narrow karst corridors. Several old logging roads are crossed here. The vegetation on the plain is likely to be on very shallow to non-existent soils, and in places may consist of simply a root mat and litter on the limestone pavement with patches of swamp forest in low lying areas. In the higher polygonal karst, the root mass is likely to penetrate into the limestone and there may be pockets of good soils that that supported the merchantable timber the logging companies sought.

The alignment continues its route through limestone plateaux and, at about 29 km south east of the Kikori River, crosses a small range of polygonal karst and descending, once again, onto the limestone plateaux, but this time into an area where drainage is more impeded and swamp vegetation is more frequent.

The alignment then skirts the swamplands at the headwaters of Veiru Creek before crossing another small rugged limestone range that rises out of the swamplands some 13 km south-south-west of Kopi. This range has also been logged.

The alignment finally heads more-or-less south for 13 km to Omati. It passes isolated karst pinnacles then enters medium crowned to small crowned forest complexes and swamp forest complexes (**Plate 103**). The forests south of the range become wetter and swampy, and sago becomes more and more dominant until the Omati River landfall, which is lined with a thin fringe of *Nypa* palm (**Plate 104**). The muds overlying the karst plain are not deep. Raised areas within the plain are dominated by broad-leaved trees, and lower areas are dominated by sago.

It is likely the existing system of logging roads will be used for logistics in this section, with pipe and other loads being carted from Kopi along temporarily upgraded logging tracks. At the end of the project construction phase, these tracks will be returned to the condition in which the PNG LNG Project found them.

No high resolution imagery was available for this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 18 Gobe Gas Pipeline

The alignment in this section (**Figure 18**) contains the ROW for the Gobe Gas Pipeline and is some 9.5 km long.

The alignment will parallel the existing Gobe road to the Gobe Production Facility. It traverses polygonal karst with medium crowned to small crowned forest complexes.

High resolution imagery was available for this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 19 Agogo Gas Pipeline

The alignment in this section (**Figure 16**) contains the ROW for the Agogo Gas Pipeline and is some 19 km long.

The alignment parallels the Agogo to Kutubu crude oil pipeline and will be constructed either directly alongside or offset to leave a strip of forest between the two. The existing road will act as a logistics route.

The alignment passes through lower montane very small crowned forest complexes with *Nothofagus*, low altitude medium crowned forest, and medium crowned to small crowned forest complexes with *Nothofagus*.

No high resolution imagery was available for this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

Section 20 South East Hedinia

The alignment (**Figure 17**) carries the South East Hedinia spinline which pipeline transports gas from wells at the Southeast Hedinia oil field to the Kutubu Central Processing Facility and the South East Hedinia MEG Line.

The well pads are in polygonal karst at about 1150 m asl. The alignment passes through lower montane very small crowned forest complexes with *Nothofagus* for about 4.5 km then through medium crowned to small crowned forest complexes with *Nothofagus* for another kilometre before it joins with the main LNG Project Gas Pipeline ROW. The Hedinia pipeline then goes to the Kutubu CPF in the same trench as the LNG Project Gas Pipeline.

No high resolution imagery was available for this section and an alignment width of 35 m was presumed for estimating habitat losses.

Predicted habitat losses are presented in **Table 27**.

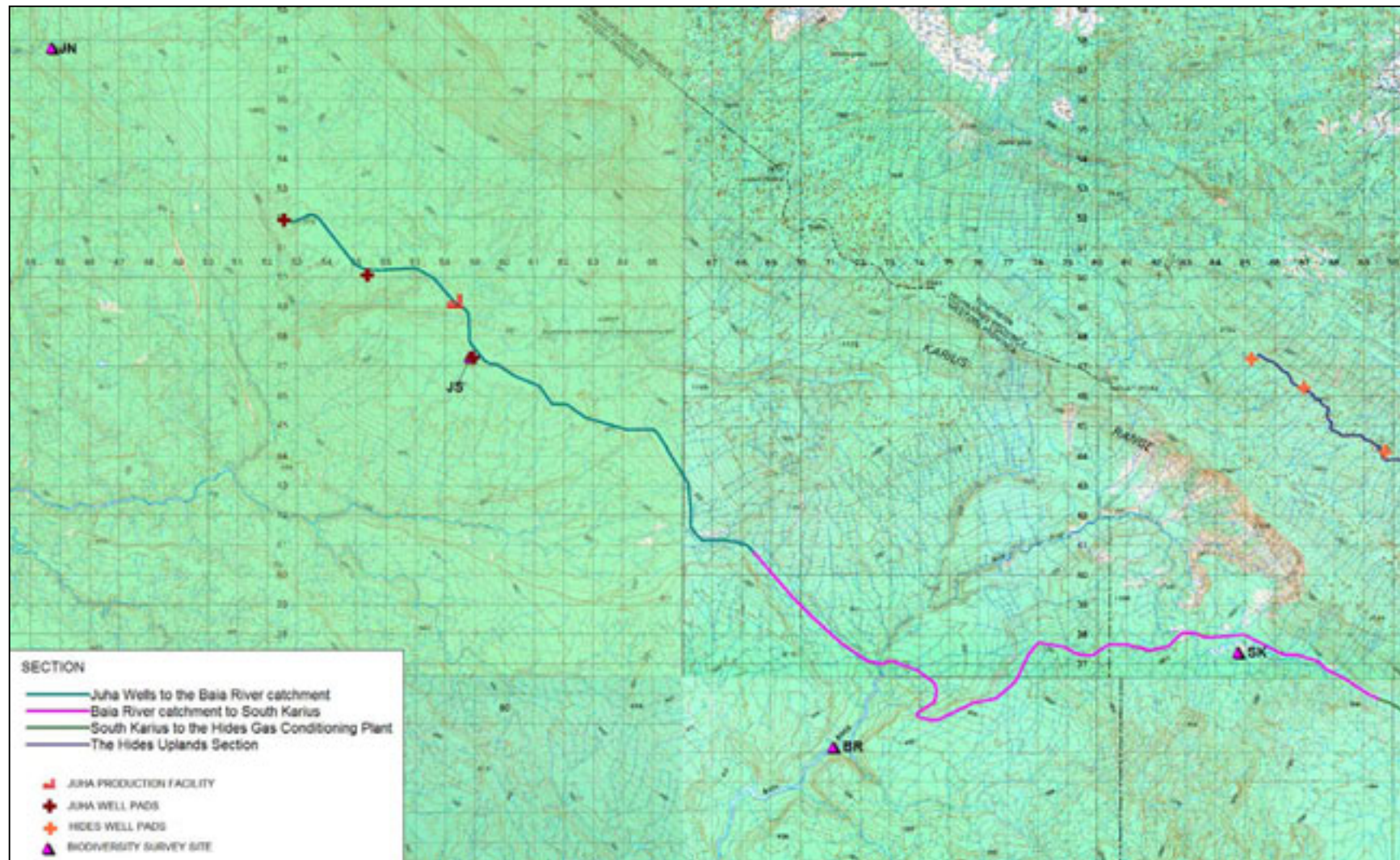


Figure 13 Sections 1 and 2 of the PNG LNG Upstream Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

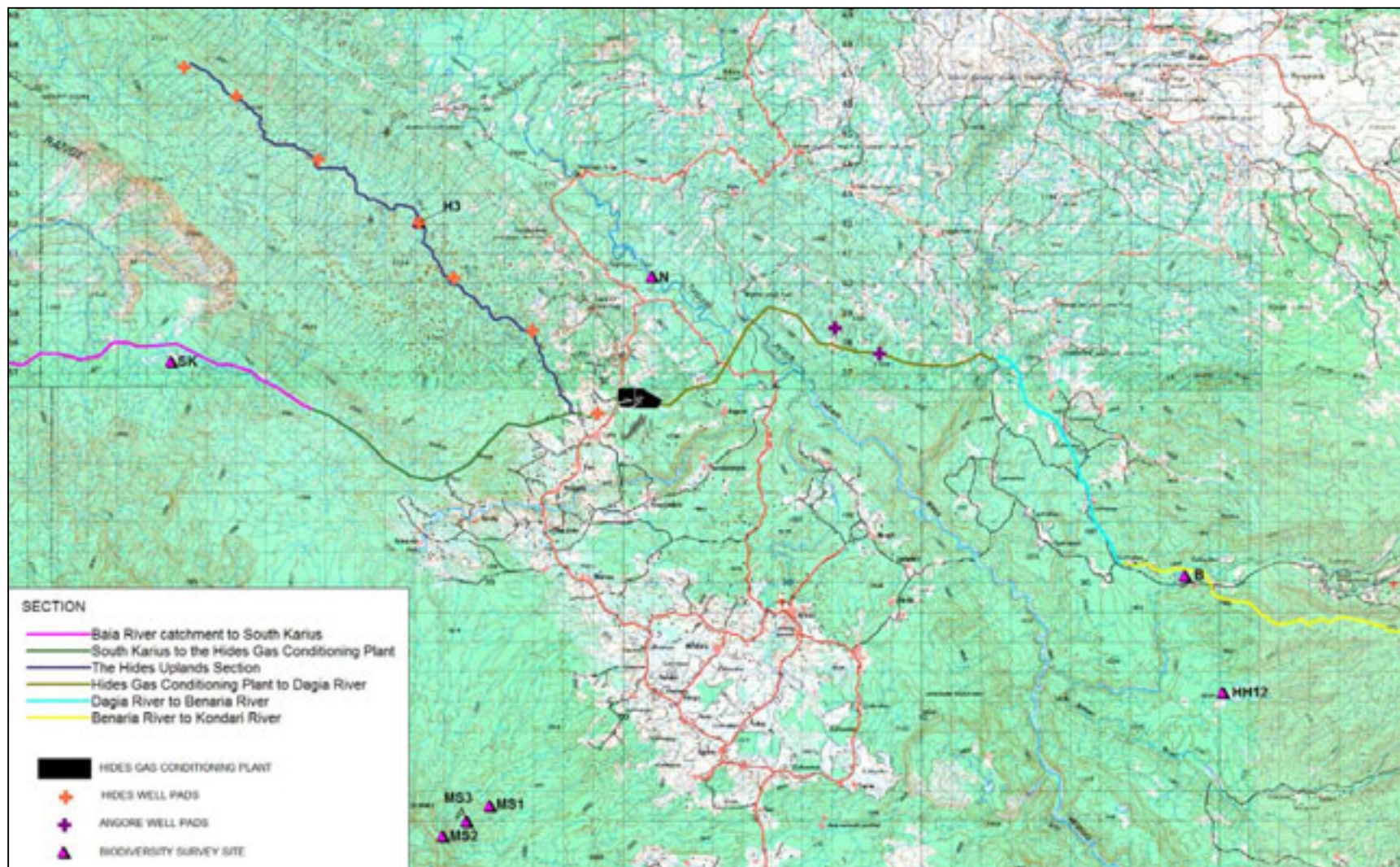


Figure 14 Sections 3 to 6 of the upstream PNG LNG Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

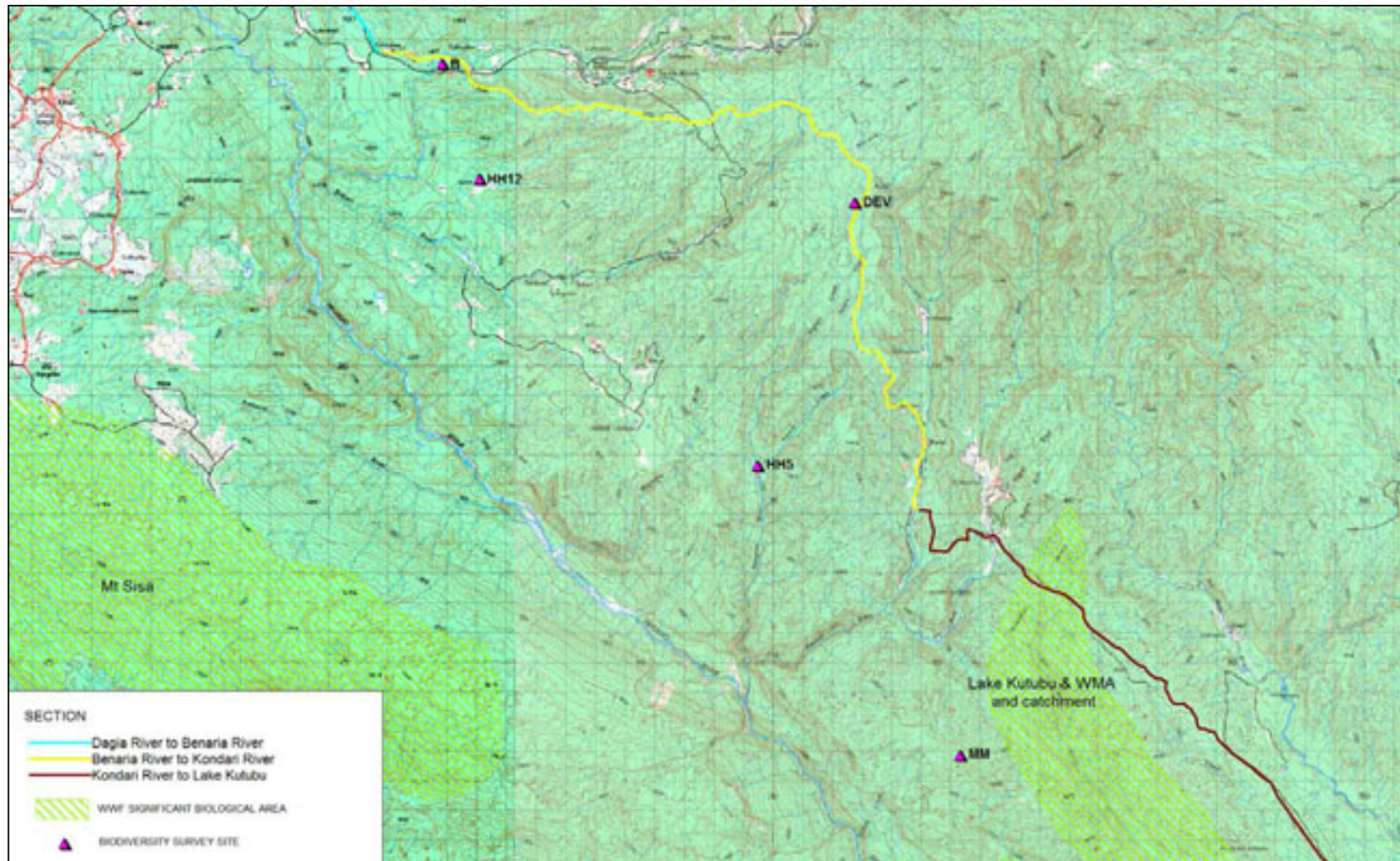


Figure 15 Sections 7 and 8 (part) of the upstream PNG LNG Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

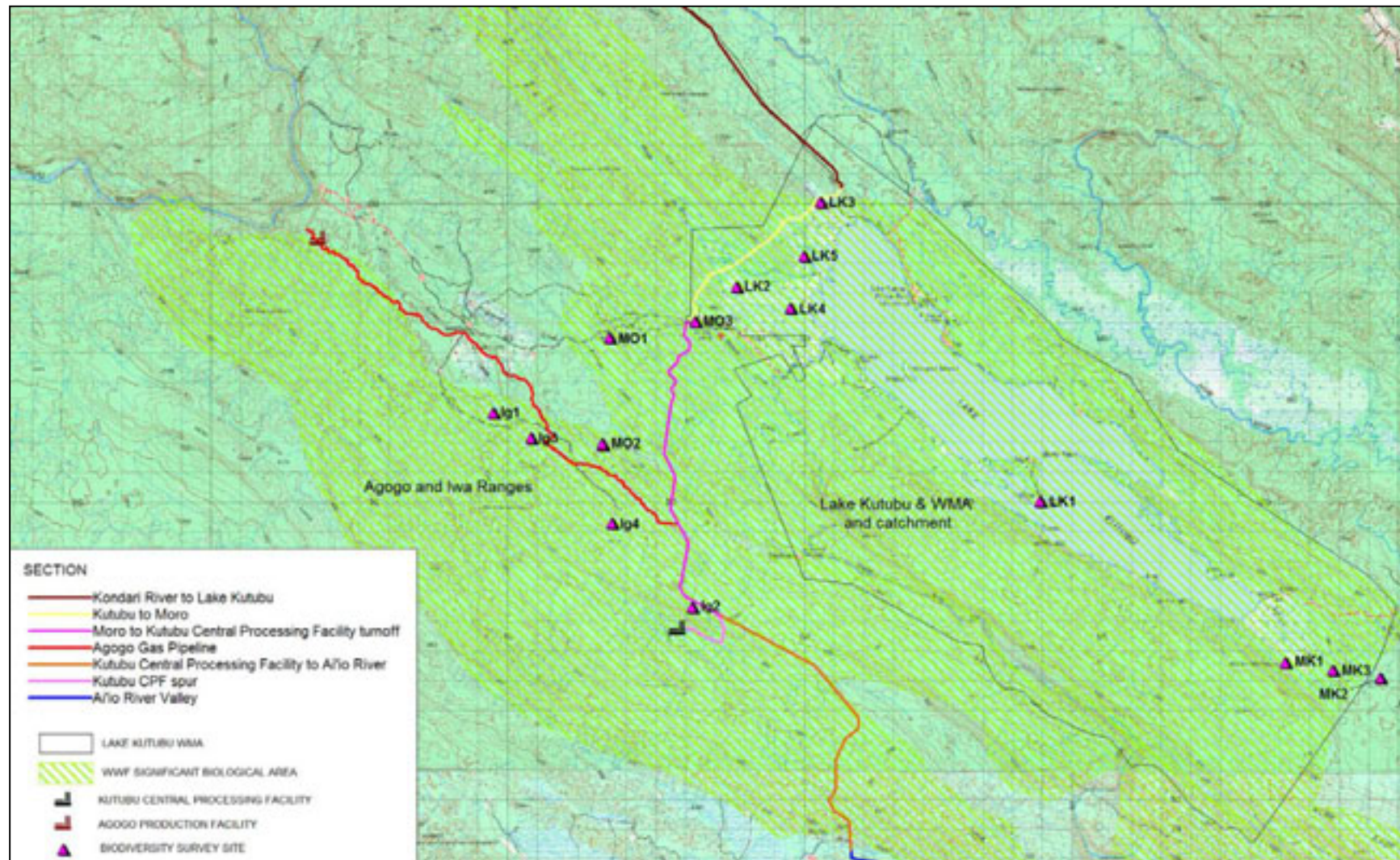


Figure 16 Sections 8 (part), 9, 10, 11 and 19 of the upstream PNG LNG Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

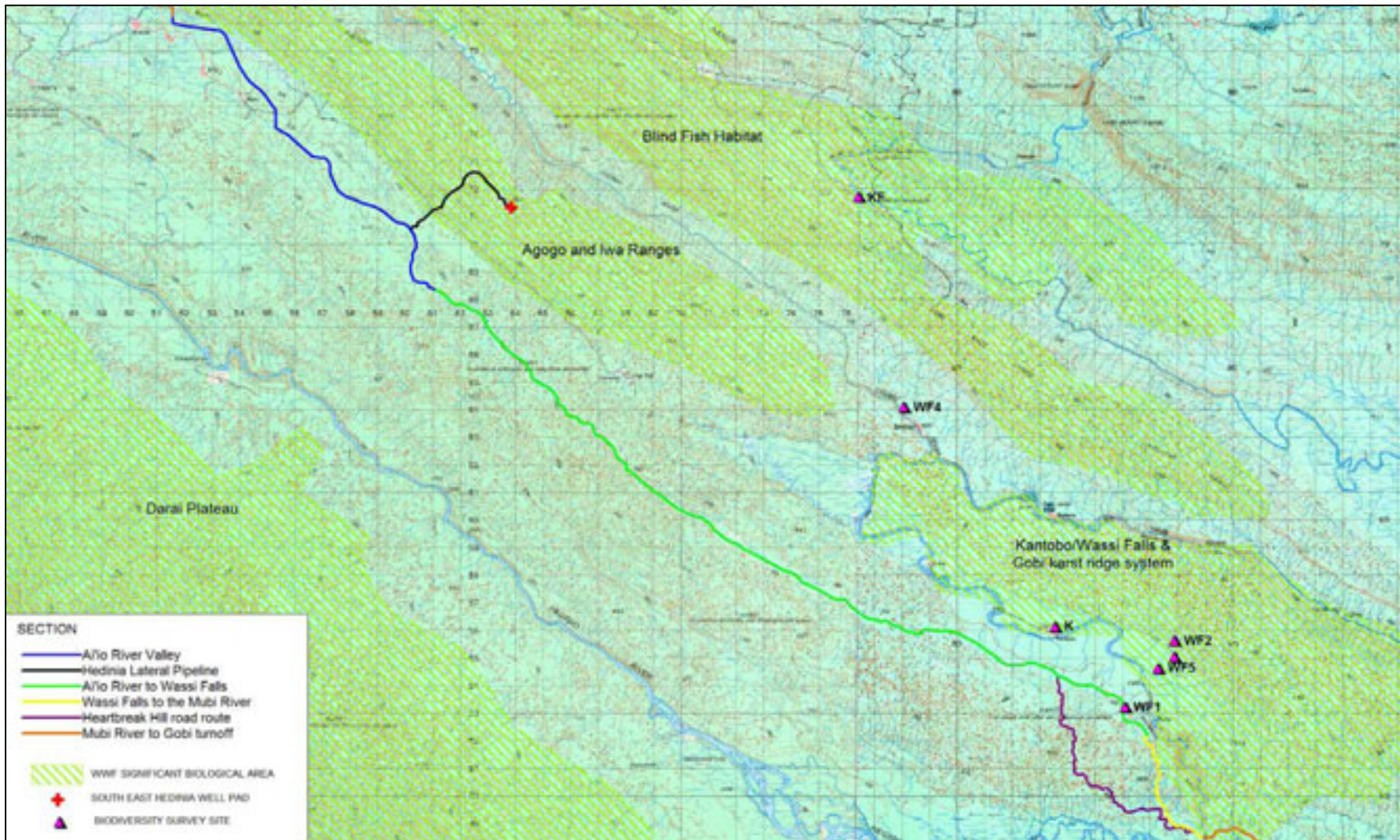


Figure 17 Sections 12, 13, 14 and 20 of the upstream PNG LNG Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

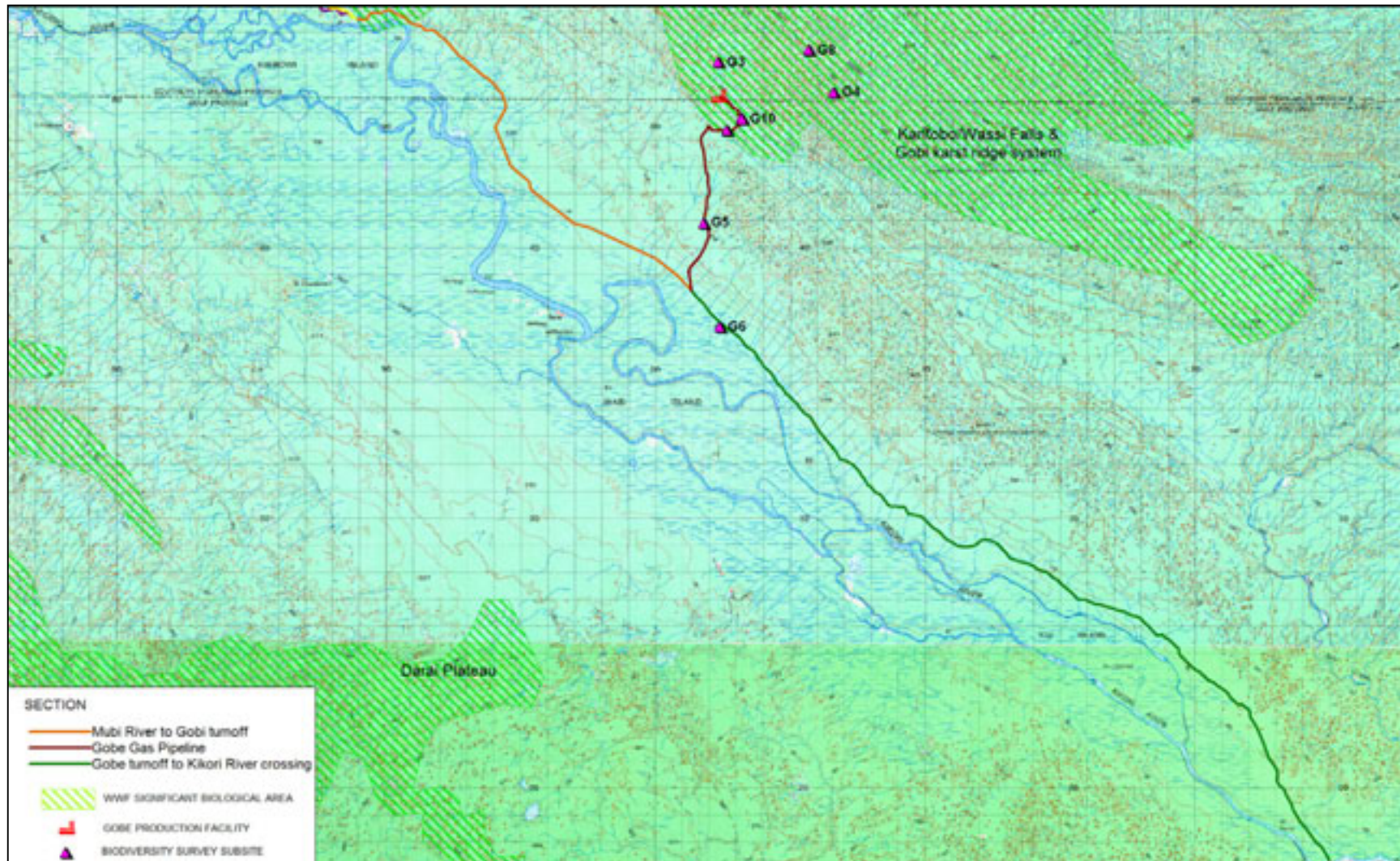


Figure 18 Sections 15, 16 and 18 of the upstream PNG LNG Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

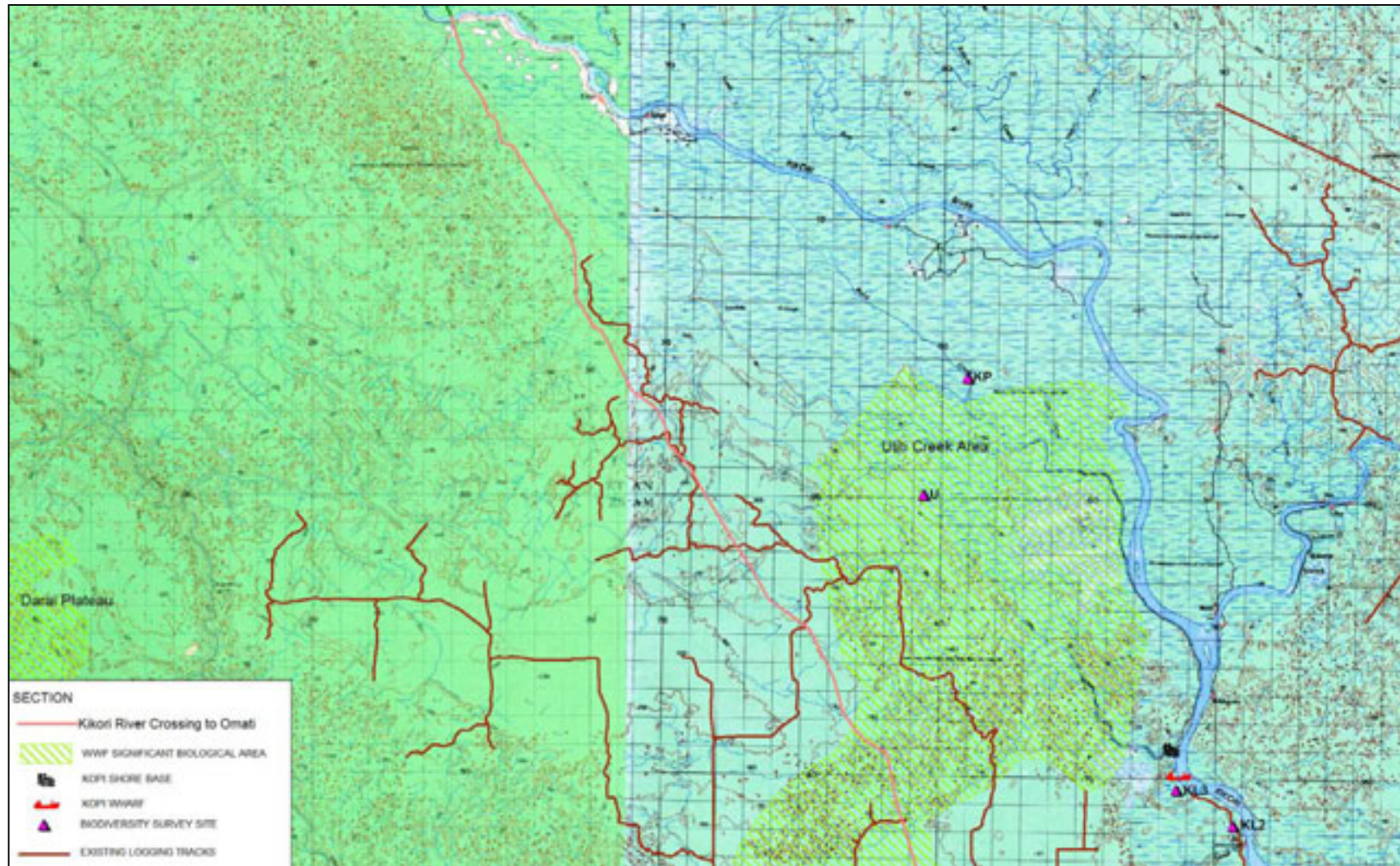


Figure 19 Section 17 (part) of the upstream PNG LNG Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

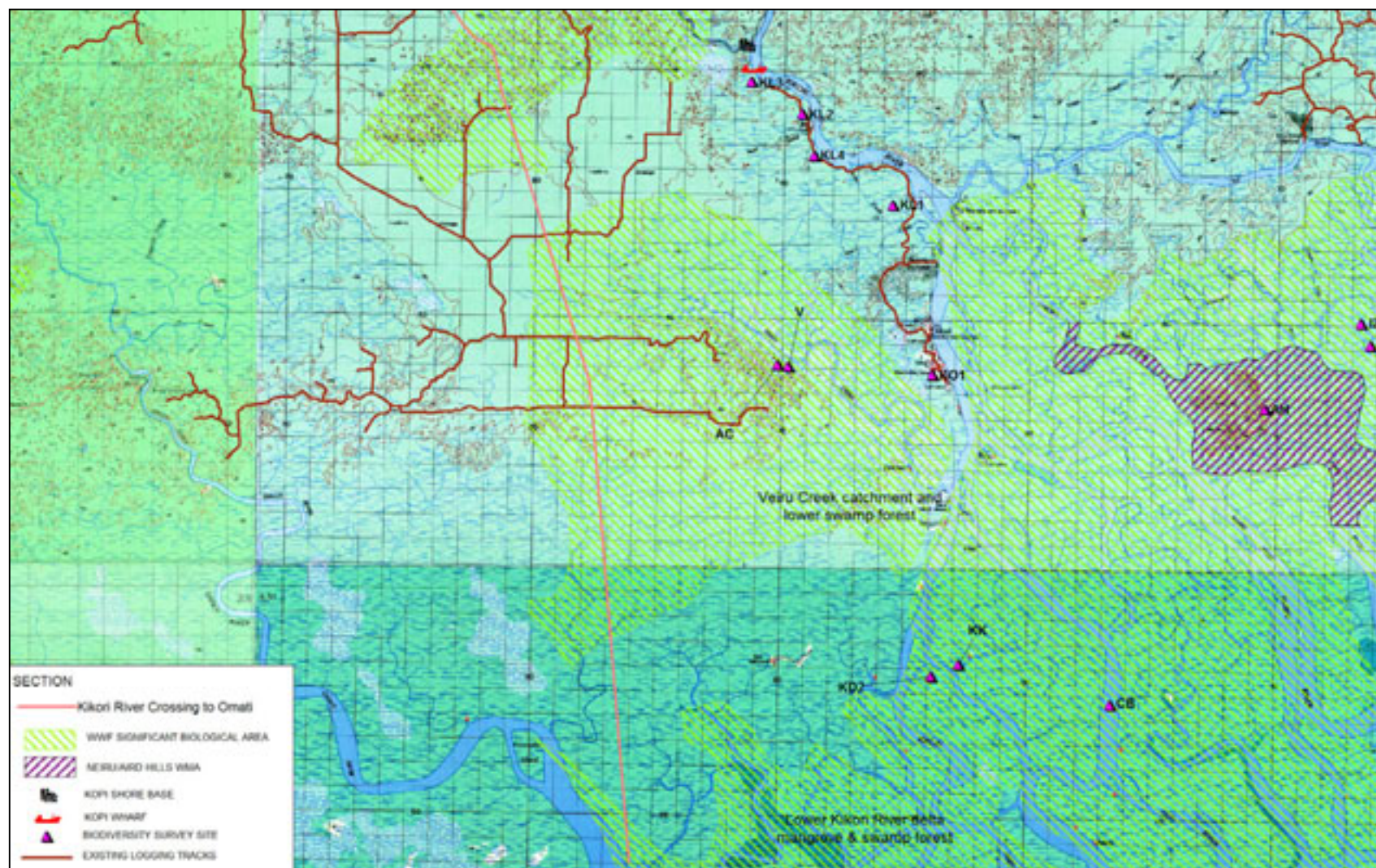


Figure 20 Section 17 (part) of the upstream PNG LNG Project pipelines (topographic grid = 1 km). Codes to biodiversity survey sites in Appendix 2.

Table 27 Estimated losses of vegetation (ha) to the various project components within the project area.*

Project Component	Condition								Totals
	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/early secondary	Gardens secondary complexes	Logged forest	River	Existing Facility area	
	A1	A2	C	D	E	L	V	F	
ROWS									
Juha Wells to the Baia River catchment	97	0	15	0	0	0	2	0	113
Baia River catchment to South Karius	142	15	36	0	0	0	1	0	194
South Karius to the Hides Gas Conditioning Plant	20	8	5	3	14	0	0	7	57
Hides Uplands Section (Hides gathering system)	97	8	0	12	15	0	0	0	133
Hides Gas Conditioning Plant to Dagia River	0	0	32	0	47	0	0	1	80
Angore spinline A	0	0	1	0	1	0	0	0	2
Dagia River to Benaria River	0	2	7	0	22	0	0	0	30
Benaria River to Kondari River	124	42	7	0	60	0	1	0	234
Kondari River to Lake Kutubu	114	1	57	34	12	0	0	0	218
Kutubu to Moro	0	36	2	6	0	0	0	0	44
Moro to Kutubu Central Processing Facility turnoff	53	44	0	0	2	0	0	0	100
Kutubu CPF spur	14	0	0	6	0	0	0	0	20
Kutubu Central Processing Facility to Ai'io River	65	37	2	4	0	0	0	0	108
Ai'io River Valley	10	16	0	22	6	0	0	0	55
Ai'io River to Wassi Falls	0	3	47	112	0	0	0	0	162
Mubi River to Gobi turnoff	7	27	3	24	0	0	0	2	63
Wassi Falls to the Mubi River	15	0	15	21	0	0	0	0	52
Gobe turnoff to Kikori River crossing	0	3	4	112	0	0	0	0	119
Kikori River Crossing to Omati	86	6	0	2	0	148	1	0	243
Gobe Gas Pipeline	0	0	4	39	0	0	0	0	43
Agogo Gas Pipeline	0	134	0	0	0	0	0	0	134
Southeast Hedinia Spinline	54	3	0	0	0	0	0	0	58

Table 27 Estimated losses of vegetation (ha) to the various project components within the project area.*

Project Component	Condition								Totals
	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/early secondary	Gardens secondary complexes	Logged forest	River	Existing Facility area	
	A1	A2	C	D	E	L	V	F	
Subtotals	899	386	238	397	178	148	5	10	2261
Logistics									
Heartbreak Hill road route	100	20	1	1	0	0	0	0	123
Logistics road along crude export oil pipeline ROW	0	0	0	148	0	0	0	0	148
Subtotals	100	20	1	150	0	0	0	0	272
Other									
Well Pads									
Well Pads Angore	0	0	4	0	0	0	0	0	4
Well Pads Hides	6	2	0	0	0	6	0	6	14
Well Pads Juha	6	0	0	0	0	0	0	0	6
Well Pad Southeast Hedinia	2	0	0	0	0	0	0	0	2
Facilities									0
JPF	31	0	0	0	0		0	0	31
HGCP	0	0	0	0	78	0	0	0	78
Temporary camps and pipeyards	11	16	44	14	54	0	0	0	144
HDD sites	0	0	1	1	2	0	0	0	4
Subtotals	57	19	49	15	134	0	0	6	279
Grand Total	1,056	424	288	561	312	148	5	16	2,811

* discrepancies in totals due to rounding errors from original EXCEL tables

Table 28 Estimated losses of vegetation from Broad Vegetation Groups (ha) within the project area.*

Broad Vegetation Group	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/early secondary	Gardens secondary complexes	Logged Forest	River	Existing Facility area	Totals	area in KICDP	% loss KICDP	area of BVG in project area	% loss project area
	A1	A2	C	D	E	L	V	F					
montane forest (>3000m) with/without grassland	0	0	0	0	0	0	0	0	0	5,137	0%	6,410	0%
grasslands	0	0	0	0	0	0	0	0	0	34,586	0%	34,631	0%
scrub	0	0	0	0	0	0	0	0	0	698	0%	1,964	0%
lower montane small crowned forest	149	4	119	30	121	0	0	0	422	195,514	0.216%	218,897	0.193%
lower montane small crowned forest with conifers	0	0	0	0	0	0	0	0	0	26,416	0%	26,417	0.000%
lower montane small crowned forest with <i>Nothofagus</i>	258	75	23	16	87	0	0	7	466	186,814	0.250%	197,725	0.236%
lower montane very small crowned forest complexes	0	0	0	0	0	0	0	0	0	33,372	0%	33,372	0%
lower montane very small crowned forest complexes with <i>Nothofagus</i>	106	74	0	1	0	0	0	0	181	84,013	0.216%	98,894	0.183%
medium crowned to small crowned forest complexes	152	30	87	271	4	143	0	0	687	579,184	0.119%	579,184	0.119%
medium crowned to small crowned forest complexes with <i>Nothofagus</i>	54	66	2	17	0	0	0	0	139	55,585	0.249%	55,585	0.249%
low altitude large crowned forest	0	0	0	0	0	0	0	0	0	38,276	0%	38,277	0%
low altitude medium crowned forest	255	118	32	125	8	0	0	0	538	399,999	0.135%	491,041	0.110%
low altitude small crowned forest with <i>Nothofagus</i>	0	10	0	0	0	0	0	0	10	4,517	0.214%	4,517	0.214%

Table 28 Estimated losses of vegetation from Broad Vegetation Groups (ha) within the project area.*

Broad Vegetation Group	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/early secondary	Gardens secondary complexes	Logged Forest	River	Existing Facility area	Totals	area in KICDP	% loss KICDP	area of BVG in project area	% loss project area
	A1	A2	C	D	E	L	V	F					
large to medium crowned lowland forest	0	0	0	0	0	0	0	0	0	6,279	0%	6,279	0%
small crowned lowland forest	13	6	0	46	1	5	0	0	71	55,475	0.129%	55,475	0.129%
open lowland forest	7	21	24	37	0	0	0	2	91	38,938	0.233%	38,938	0.233%
open lowland forests and freshwater swamps	0	0	0	4	0	0	0	0	4	6,750	0.056%	6,750	0.056%
swamp forest complexes	56	0	0	0	0	0	0	0	56	77,152	0.073%	77,152	0.073%
swamp woodland and forest complexes	7	21	1	11	2	0	0	0	42	24,036	0.175%	24,036	0.175%
mangroves	0	0	0	0	0	0	0	0	0	124,327	0.000%	124,327	0%
non forested areas	0	0	0	3	90	0	0	7	99	126,789	0.078%	126,789	0.078%
rivers or lakes	0	0	0	0	0	0	5	0	5	18,434	0.027%	18,434	0.027%
Totals	1,056	424	288	561	312	148	5	16	2,811	2,122,293	0.132%	2,265,096	0.124%

* discrepancies in totals due to rounding errors from original EXCEL tables

Table 29 Estimated losses of vegetation in different bioregions (km2) within the project area. *

		Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro region	Iagifu- Agogo Limestone Uplands	Western Volcanics	Eastern Upland Volcanics/ Karst	Northern Montane Karst	Totals
Area (ha) of vegetation in Bioregion		773,405	97,077	80,234	178,520	50,616	41,381	283,689	23,973	33,617	178,471	415,791	108,322	2,265,096
Old growth	A1	176	0	0	0	20	208	110	52	125	60	193	111	1,056
Old growth but with some disturbance	A2	55	0	0	0	0	0	34	68	183	11	51	22	424
Late secondary or heavily disturbed old growth	C	53	0	0	0	0	29	61	2	2	7	112	22	288
Pioneer/early secondary	D	260	0	0	0	0	0	226	6	20	3	34	12	561
Gardens secondary complexes	E	2	0	0	0	0	0	6	7	0	140	157	0	312
Logged forest	L	148	0	0	0	0	0	0	0	0	0	0	0	148
River	V	1	0	0	0	0	2	0	0	0	0	1	0	5
Existing Facility area	F	2	0	0	0	0	0	0	0	0	8	0	6	16
Totals		698	0	0	0	21	238	437	135	331	230	548	175	2811
% of vegetation lost from bioregion		0.090%	0%	0%	0%	0.041%	0.576%	0.154%	0.564%	0.984%	0.129%	0.132%	0.161%	0.124%

* discrepancies in totals due to rounding errors from original EXCEL tables

Table 30 Estimated losses of vegetation in brown and green fields areas (km2) within the project area.*

	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/early secondary	Gardens secondary complexes	Logged forest	River	Existing Facility area	Totals
	A1	A2	C	D	E	L	V	F	
Brownfields	332	341	118	515	121	0	1	14	1442
Greenfields	724	83	170	46	191	148	4	2	1370
Totals	1056	424	288	561	312	148	5	16	2811
%greenfields	68.5%	19.7%	59.1%	8.2%	61.4%	100.0%	78.6%	12.6%	48.7%

* discrepancies in totals due to rounding errors from original EXCEL tables.

Table 31 Estimated losses of vegetation in WWF Significant Biological Areas (ha).*

	Condition									
Broad Vegetation Group	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/ early secondary	Gardens secondary complexes	Logged forest	River	Total loss	Area of BVG in zone	% loss
	A1	A2	C	D	E	L	V			
Agogo and Iwa Ranges										
low altitude medium crowned forest	7.8	6.6	0	0.7	0	0	0	15.1	2,751	0.55
lower montane very small crowned forest complexes with <i>Nothofagus</i>	106.0	74.3	0	0.8	0	0	0	181.1	11,317	1.60
medium crowned to small crowned forest complexes with <i>Nothofagus</i>	52.0	52.7	2.1	16.1	0	0	0	123.0	14,301	0.86
low altitude small crowned forest with <i>Nothofagus</i>	0	0	0	0	0	0	0	0.0	4,340	0
swamp woodland and forest complexes	0	0	0	0	0	0	0	0.0	6	0
Totals	165.8	133.6	2.1	17.6	0	0	0	319.2	32,716	0.98
Kantobo/Wassi Falls & Gobi karst ridge system										
lower montane very small crowned forest complexes	0	0	0	0	0	0	0	0	2,405	0
medium crowned to small crowned forest complexes	0	0	0	0	0	0	0	0	15,056	0
medium crowned to small crowned forest complexes with <i>Nothofagus</i>	0	0	0	28.5	0.2	0	0.4	29.2	10,309	0.19
low altitude medium crowned forest	0	0	0	0	0	0	0	0	3,318	0
open lowland forests and freshwater swamps	0	0	0	0	0	0	0	0	1,354	0
rivers or lakes	0	0	0	0	0	0	0	0	21	0
Totals	0	0	0	28.5	0.2	0	0.4	29.2	32,463	0.09
Lake Kutubu & WMA and catchment										
lower montane small crowned forest	11.2	0	4.7	4.4	0	0	0	20.2	2,274	0.89
lower montane small crowned forest with <i>Nothofagus</i>	1.7	0	3.3	0	4.9	0	0	9.9	2,340	0.42
lower montane very small crowned forest complexes with <i>Nothofagus</i>	0	0	0	0	0	0	0	0	10,154	0
medium crowned to small crowned forest complexes with <i>Nothofagus</i>	0	0	0	0	0	0	0	0	14	0
low altitude medium crowned forest	15.4	56.9	1.6	0	2.2	0	0	76.0	13,335	0.57
swamp forest complexes	0	0	0	0	0	0	0	0	11	0
swamp woodland and forest complexes		8.9	0.3	4.3			0.1	13.7	2,142	0.64
cultivated or non-vegetated	0	0	0	0	0	0	0	0	53	0

Table 31 Estimated losses of vegetation in WWF Significant Biological Areas (ha).*

Broad Vegetation Group	Condition							Total loss	Area of BVG in zone	% loss
	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/ early secondary	Gardens secondary complexes	Logged forest	River			
	A1	A2	C	D	E	L	V			
rivers or lakes	0	0	0	0	0	0	0	0	5,186	0
Totals	28.2	65.8	9.9	8.7	7.1	0	0.1	119.8	35,510	0.34
Lower Kikori River delta mangrove & swamp forest										
low altitude medium crowned forest	0	0	0	0	0	0	0	0	1,419	0
swamp forest complexes	6.6	0	0	0	0	0	0	6.6	19,456	0.03
swamp woodland and forest complexes	0	0	0	0	0	0	0	0	6,737	0
mangroves	0	0	0	0	0	0	0	0	113,714	0
rivers or lakes	0	0	0	0	0	0	0	0	5,607	0
channels of Kikori delta	0	0	0	0	0	0	0	0	23,186	0
Totals	6.6	0	0	0	0	0	0	6.6	170,118	0
Utiti Creek area										
grasslands	0	0	0	0	0	0	0	0	118	0
medium crowned to small crowned forest complexes	0	0	0	5.4	0	36.8	0	42.1	12,137	0.35
small crowned lowland forest	0	0	0	11.2	0	0	0	11.2	4,252	0.26
swamp woodland and forest complexes	0	0	0	0	0	0	0	0	998	0
Totals	0	0	0	16.6	0	36.8	0	53.3	17,504	0.30
Veiru Creek catchment & lower swamp forest										
medium crowned to small crowned forest complexes	2.8	0	0	0	0	30.1	0	32.9	7,923	0.42
small crowned lowland forest	0	0	0	0	0	0	0	0	2,701	0
swamp forest complexes	24.3	0	0	0	0	0	0.5	24.8	7,011	0.35
swamp woodland and forest complexes	0	0	0	0	0	0	0	0	3,008	0
rivers or lakes	0	0	0	0	0	0	0	0	265	0
Totals	27.1	0	0	0	0	30.1	0.5	57.7	20,908	0.28

* discrepancies in totals due to rounding errors from original EXCEL tables

Table 32 Estimated losses of vegetation in Kutubu WMA (ha).*

Broad Vegetation Group	Condition							Total loss	Area of BVG in WMA	% loss
	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/ early secondary	Gardens secondary complexes	Logged forest	River			
	A1	A2	C	D	E	L	V			
low altitude medium crowned forest	0.0	25.7	1.3	0.6	0	0	0.0	27.6	9,698	0.28
lower montane small crowned forest	17.0	2.2	0.0	0.0	0	0	0.0	19.1	838	2.28
lower montane small crowned forest with <i>Nothofagus</i>	0	0	0	0	0	0	0	0	1,755	0
lower montane very small crowned forest complexes with <i>Nothofagus</i>	0	0	0	0	0	0	0	0	5,919	0
open lowland forests and freshwater swamps	0	0	0	0	0	0	0	0	15	0
swamp woodland and forest complexes	0.0	14.6	0.5	5.2	0	0	0.2	20.4	1,951	1.05
swamp forest complexes	0	0	0	0	0	0	0	0	39	0
cultivated or non-vegetated	0	0	0	0	0	0	0	0	53	0
rivers or lakes	0	0	0	0	0	0	0	0	5,186	0
Totals	17.0	42.4	1.8	5.7	0.0	0.0	0.2	67.1	25,455	0.26

* discrepancies in totals due to rounding errors from original EXCEL tables

Impact Analysis

24 Assessing impacts

This overview considers impact assessment to be a predictive activity, partly objective and partly subjective. It relies heavily on the biodiversity data that has been gathered for the project, the general understanding of the dynamics of the habitats and species involved, and on the experience that has been gained with other hydrocarbon and resource projects. It relies on the professional judgment and experience of specialists as well as hard evidence. With such a diverse region as the project area the knowledge of species biologies and of habitat dynamics varies from reasonable to non-existent so impact assessments need to be guided by a decision system that attempts to produce consistency across assessments.

The system used here is a modification of the system provided by Coffey Natural Systems which has, as its core, the concept of significance of an impact, which in this case has the common English meaning of the word and is not, and should not be confused with classical statistical significance.

Significance derives from two elements:

1. The magnitude of change - including scale, duration and likelihood of the occurrence.
2. The value or sensitivity to change of the receptor (species or habitats).

Magnitude of impact

The magnitude of impact is defined for three classes of effects:

- Habitat impacts concern the impact of clearing on habitat
- Population impacts refer to effects on populations.
- Other ecological effects refer to impacts that degrade habitat or reduce population viability e.g. barrier effects, fire, exotic species, contamination etc.

Categories and definitions of magnitude are shown in **Table 33**. For the upstream component of the PNG LNG Project a basic geographical unit for assessment is the PNG LNG upstream project area.

The value or sensitivity of the conservation asset

Conservation asset value is defined for sites and species as in **Table 34**.

Significance

Combinations of impact magnitude and conservation asset value have been assigned impact significance levels of major, moderate, low, minor or positive (**Table 35**).

Significance is assessed for each impact as if unmitigated and to a residual impact after mitigation (**section 25**)

Table 33 Magnitude of impact categories used in assessment.

Magnitude of Impact	Habitat	Other ecological effects (barrier effects, contamination, exotics etc.)	Populations
Very High (VH)	Large impact on substrates and habitats that will be permanent and reduce ecosystem survival and health over large areas within the project area or a local region possibly even leading to system collapse. Recovery, if possible, is likely to take more than 25 years or never.	Impact may be widespread effecting > 10% of project area or local region, perhaps even up to a national scale.	Populations will be lost from impact site and losses may cause local extinctions in a Special Area or within the entire project area or local region.
High (H)	Substrates will be lost and replacement or treatment may be difficult or impossible. If replaced there is a strong possibility that succession may not lead to original habitats and there is a reasonable chance of long-term reduction in site capacity to support original habitat. Loss and/or degradation of habitat extends more than one km beyond impact site. Habitat regeneration, if allowed, will be slowed and good tree cover in forest may take up to 25 years after substrate treatment or replacement. Loss of habitat may affect up to 10% of the habitat's range within the project area or within any one Special Area.	Impact is regional affecting up to 10% of project area or local region.	Impacts will involve local loss of population for at least 25 years or recolonisation may never occur. Any losses of local population likely to seriously reduce chances of species persisting in a Special Area and/or would significantly reduce likelihood of species persisting in the project area or local region. No national impacts.
Medium (M)	Substrates will be lost and replacement or treatment may be necessary to initiate successions. However there is unlikely to be any long-term reduction in site capacity to support original habitat. Loss of and/or degradation of habitat extends up to 500 m beyond impact site. Habitat regeneration will be slowed and good tree cover in forest may take up to 12 years after substrate treatment.	Detectable up to 10 km from impact site.	Impacts will involve local loss of population for up to seven years or recolonisation may never occur. However loss of the local population highly unlikely to affect persistence of the species within the project area or local region.
Low (L)	Substrates may be disturbed or lost but habitat can readily develop on remaining substrate with slowing of successions by only 1-3 years at most. Generally only a short-term (1-3 years) reduction in site capacity to support original habitat. Impacts restricted to immediately around impact site. Habitat regeneration capable of starting within one to three years and successions likely to proceed normally to good tree cover in forest within five years after start of succession.	Effects immediate surrounds from impact and detectable up to two km from impact site.	Impacts likely to involve loss of a portion of the local population that will reduce the chances of long-term survival in remaining habitat around the project component and species may be temporarily lost. Recolonisation will be rapid and occur within three years after development of successions to the stage of canopy closure.
Negligible (N)	Deleterious impacts unlikely to be detectable on habitats.	Not detectable.	Species populations may lose a few individuals or home ranges may retract but there is unlikely to be any long term lowering of the viability of local populations, i.e., those around the project component site. Changes only detectable by intensive population monitoring pre and post impact.
Positive (P)	Change is likely to benefit the species community or ecosystem. This will be detectable by RAP surveys pre- and post-impact showing occurrence of species at sites that they did not occur at before.		

Table 34 Value and/or sensitivity of conservation assets.

Value category	Sites and/or habitats	Species
Cat. 1 (Very High Value)	- An internationally designated site. - A Special Area within the project area. - A designated national protected area e.g WMA. - An area with an unusually high concentration of VH and H species. - Site supports 20% or more of a national population of any species.	A population of internationally important species in IUCN category Critically Endangered.
Cat. 2 (High Value)	- A sustainable area of priority habitat identified by WWF. - Habitat of peculiar sensitivity that is hard to restore or regenerate (focal habitat) - Site supports up to 20% of national population of any species.	A population of internationally important species in IUCN categories Endangered or Vulnerable.
Cat. 3 (Moderate value)	- A local reserve - A high diversity area with a moderate concentration of VH and H species - Site supports up to 10% of national population of any species.	A population of a species in IUCN category Near Threatened and/or classified as P under PNG legislation.
Cat. 4 (Minor value)	- Sites that enrich the local area. - A low to moderate diversity area with a low concentration of VH and H species	A population of a species that is either classified by IUCN as Data Deficient and/or as R under PNG legislation.
Cat. 5 (Least value)	Lower ecological value	A population of a species that is classified by IUCN as of Least Concern or is unclassified and is not listed under PNG legislation.

Table 35 Significance matrix.

Magnitude of impact	Value of conservation asset				
	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5
Very High	major	major	major	low	minimal
High	major	moderate	moderate	low	minimal
Medium	moderate	moderate	low	low	minimal
Low	moderate	low	low	low	minimal
Negligible	minimal	minimal	minimal	minimal	minimal
Positive	positive	positive	positive	positive	positive

25 Sources of impacts and mechanisms for their mitigation

This section canvasses the different sources for impacts, both direct and indirect (**Table 36**).

Table 36 Sources of impacts.

source of impact	Construction		Operations	
	Vegetation and Flora	Fauna	Vegetation and Flora	Fauna
Direct impacts				
Habitat loss	X	X		
Edge effects	X	X	A	A
Barrier effects	X	X	A	A
Physical damage and disturbance to caves		X		X
Fauna falling in the pipe trench		X		
Erosion, movement of spoil and changes to hydrology	X	X	A	A
Materials handling	X	X	X	C
Disposal of Hydrotest fluids	X	X		
Dust	X	X	X	C
Loss of breeding and display grounds		X		A
Noise, lights and other disturbance		X		X
Project traffic and other operations		X		C
indirect impacts				
Fire	X	X	I	I
Dieback	X	X	I	I
Invasive species – weeds	X	X	I	I
Invasive species – exotic fauna	X	X	I	I
Hunting by PNG LNG Project workers and contractors		X		X
Hunting by non - project personnel		X		I
Collection of flora by PNG LNG Project workers and contractors	X		X	
Collection of flora by non - project personnel	X		I	
Improved access to project area			I	I

X = impact concentrated at this phase; C = impact continuing but at a low level; A = impact ameliorating with time; I = impact possibly increasing with time.

The process of impact analysis consisted of compiling all suggested mitigations from the many specialist reports produced for the PNG LNG Project and reviewing them at a workshop with engineers and managers from the clients and from Coffey Natural Systems. In this review mitigations were considered on the basis of practicality, usefulness and cost effectiveness and were either accepted without modification, modified or rejected. New mitigations were also devised. The resultant set of mitigations was then circulated amongst the various sections of the PNG LNG project and a final set of mitigations compiled by Coffey Natural Systems. The mitigations from this final set relevant to terrestrial biodiversity (presented in **Appendix 12**) was then used to make the impact analysis in **section 26**. The original wording of suggested mitigations is retained in the Annexes.

25.1.1 Habitat loss

25.1.1.1 *Habitat loss through clearing and earthworks*

Loss and degradation of habitat is a primary cause of loss of biodiversity. The impact depends upon the amount lost, its shape, the extent to which the loss is one-off or continuing and the extent to which regeneration occurs.

Tropical forest dynamics depend upon disturbance of some sort, such as natural tree falls, and New Guinea forests, in general, tolerate disturbance caused by, for instance, earthquakes, landslides or coastal cyclones. If clearing mimics these regional phenomena there need be no permanent change to forest landscape dynamics and overall habitat persistence. However, permanent change comes about when substrates are irrevocably altered or when disturbance regimes change landscape dynamics radically by, for example, increasing in fire frequency, continuous and expanding clearing, loss of soils, changes to hydrology etc.

The clearing required for the PNG LNG Project will be mostly for ROWs and roads i.e. long narrow clearings. So long as clearing does not propagate from the edge of the ROW, this need not have a great impact. As far as the vertebrate fauna is concerned such linear clearings will rarely eliminate whole territories of primary forest specialists. With clearing for facilities, temporary camps and lay down areas, quarries etc. the significance of the loss depends upon the size of the clearing and the habitat in which the construction is located (see, however, “Edge Effects” **section 25.1.2.1**).

In steep terrain, clearing is exacerbated by side casting and cutting and, in very steep terrain, the loss may triple the real extent of clearing (**section 21.2.4**)

The following mitigations from **Appendix 12** are designed to reduce possible impacts.

- The standard ROW width for the project is 30 m and following construction the ROW will be allowed to naturally regenerate except for 15 m, to allow for a gap in the canopy for aerial surveillance of the pipeline. If there is a requirement to exceed the ROW design width, the contractor shall seek approval through a formal procedure from the Operator.
- No machinery will leave the ROW or access roads to unnecessarily clear additional forest.
- Clearing of riparian vegetation will be limited to the width required to safely accommodate pipeline ROW/access way and watercourse crossings. Also, the number of watercourse crossings will be reduced, to the extent practicable, to limit riparian soil erosion and sediment delivery to watercourses.
- Well pads will be designed and located reduce the extent of vegetation clearing and earthworks by limiting to the extent practicable, the size of the well pads.
- ROWs and roadways will be located within or adjacent to existing disturbed areas where practicable.
- The design criteria for ROW width on Hides Ridge, which includes the access road, is 18 m. During operations the ROW will be allowed to regenerate except

for a 10 m access road required for ongoing drilling and maintenance access to the wellpads on the ridge.

- If practical and safe, retain trees over 1 m dbh at camp locations.
- Where trees are to be felled by hand, use directional felling for trees > 50 cm dbh so they land in natural slots between standing trees or along the axis of tracks to reduce damage to the remaining forest.
- Reduce machinery scraping stems of standing trees adjacent to or off the ROW.
- Develop a revegetation management plan that will be detailed in the EMP and which will include measures to specifically assist revegetation in areas found to be slow to revegetate naturally.
- Areas requiring active revegetation will be identified:
 - o On Hides Ridge.
 - o In areas between Idauwi and Homa, in particular unstable volcanic terrains.
 - o Along sections of the existing Moro to Homa public road.
- Conduct fine-scale routing of the ROW/access ways to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel waterbodies and other karst terrain, where practicable.
- Provide protection for stream heads in the Baia River area and elsewhere in the upstream project area above 1,800 m, to reduce erosion material entering them.
- No quarries beyond cut to be established on the Hides Ridge where practicable.
- Minimise the number of quarries developed by:
 - o Using previously worked (old) quarries, where practicable.
 - o Using limestone generated by construction activities for road-base material.
- Reduce the number of special vehicle parks, and place in areas of existing disturbance where practicable.
- No construction camps allowed on Hides Ridges beyond Hides Wellpad A (with the exception of drilling camps).
- If a temporary drilling camp is necessary on Hides Ridge there should be only one and it is to be located at Hides Wellpad D and to be used by successive drilling campaigns.
- Promote use of timber felled during well pad, pipeline, access way/ROW and facility site clearing for project uses to the extent practicable.

-
- No herbicides to be used unless for the eradication of a serious invasive environmental weed.
 - Develop practical procedures for temporary fly camps and pioneer camps that have similar environmental intent as those for construction camps.
 - The extent of clearing and earthworks along the ROW will be limited and the time period that surfaces are exposed prior to natural revegetation will be reduced to the extent practicable.
 - Locate temporary Juha drilling camp within the footprint of the Juha Production Facility
 - Locate temporary Angore drilling camp within the footprint of the Hides Gas Conditioning Plant.
 - Where practicable, utilise land clearing techniques that preserve the rootstock of removed vegetation in the ground. Spread cleared vegetation back on to the ROW as mulch, where practicable.

25.1.1.2 *Habitat loss through river crossings*

Rivers in New Guinea can be fast and powerful. The lowland rivers carry huge silt loads and the upland torrents carry large boulders and trees during rainstorms. In these energetic situations trenching makes little difference to amphibious fauna, such as torrent frogs, which are adapted to a shifting substrate. Loss of riverine vegetation, however, may impact on fauna that preferentially use riverbanks such as hydromyine rodents (water rats).

The major impact on terrestrial biodiversity as a result of habitat loss at streams may not be at the major crossings but in the small creeks higher up the catchment. Experience in logging coups shows holes, riffles and small quiet streams can be filled with silt eroded from access roads (Crome *et. al* 1992) and S. Richards (**Annex 10**) notes the importance of stream heads at high altitudes. This will be an issue for stream dwelling frogs but the length of small streams affected in this way will be small. Suggested mitigation at river crossings were devised by the aquatic fauna studies for the PNG LNG Project. Particularly important mitigations from **Appendix 12** are.

- Clearing of riparian vegetation will be limited to the width required to safely accommodate pipeline ROW/access way and watercourse crossings. Also, the number of watercourse crossings will be reduced, to the extent practicable, to limit riparian soil erosion and sediment delivery to watercourses.
- Develop a watercourse crossing construction management plan that addresses the sensitivities of crossings on an individual watercourse basis. Plans are to consider, where relevant:
 - o Watercourse diversions requirements.
 - o Disturbance limits.
 - o Equipment limitations.
 - o Erosion control measures.

-
- o Fine-scale routing at crossing sites to limit disturbance of particularly large and established riparian vegetation and complex bank habitat structure.
 - o Delay the clearing of banks of watercourses for temporary vehicle crossing until the need for the crossing is imminent, where practicable.
 - Where practicable, trees felled into watercourses will be removed and used for revegetation works, where practicable.
 - Where practical, stabilise cleared banks to provide a suitable habitat for recolonisation.
 - Where practicable, the pipeline ROW/access way alignment approaches to watercourses will be kept as close to right angles as possible to limit disturbances to the banks of watercourses.

25.1.2 Edge and barrier effects

25.1.2.1 Edge effects

Edge effects occur where two dissimilar habitats abut each other such as a clearing next to a forest. Each influences the other along the boundary and for varying distances into each habitat and this contact zone is called an ecotone. Edge effects in forests in such situations include physiological and ecological effects propagating into the forest from the edge of a clearing. These effects can produce continued degradation of forest adjacent to the edge and possibly continuing retreat of the forest edge. They come about by:

- Exposure of the forest edge to sun and wind. The drying effect penetrates the forest and changes the microclimate producing windier, dryer, hotter and lighter conditions in the forest next to the clearing.
- The ground layer desiccating, and the forest edge becoming more susceptible to fire.
- Weeds, exotic species, and other species adapted to drier habitats and secondary forest invading the forest along the edge.

Edge effects may penetrate several hundred metres into the forest (see e.g. Laurence and Bierregaard 1997), however, through most of the project area, regrowth and sealing of the forest edge is rapid so edge effects will be short lived. However, at higher altitudes the process will be slower and edge effects will last longer.

Edge effects may impact most on primary forest specialist fauna (**Table 17**) such as microhylid frogs and interior bird species that are adapted to dark humid forest interior microclimates. Such species retreat from the forest edge as it dries out and becomes lighter. Generalist forest species (**Table 17**) and grassland fauna species adapted to drier, more open habitats can invade the forest edge and compete with primary forest specialists. As the edge seals itself and microclimate conditions are restored, primary forest specialists can recolonise and the invading species retreat where edge effects diminish over time.

Edge effect can be a two way situation and in the right climatic and fire regime circumstances, and if allowed by landowners, forest penetrates into cleared areas and the forest edge advances.

Edge effects that promote forest erosion and degradation and retreat of primary forest species are more severe in the following circumstances:

- Where there is a wide cleared area next to the forest that allows the wind full exposure to the forest face.
- Where construction has damaged the forest edge more than necessary by:
 - o Felling large trees indiscriminately so as to damage standing trees. This allows disease to penetrate and increases the likelihood of tree death.
 - o Scraping trees with machinery or boulders.
- On high altitude steep slopes exposed to the wind above cuttings.
- Where roads and other linear clearings act together to surround small blocks of forest, which allows edge effects to penetrate from all sides.
- On the sections between hairpin bends on mountain roads.

Most of the mitigations suggested above for habitat loss (**section 25.1.1**) are effective for reducing edge effect, particularly those related to maintaining as narrow a clearing width as possible. The most significant mitigations in this respect are those that allow the ROWs and roads to revegetate along the edges:

- The standard ROW width for the project is 30 m and following construction the ROW will be allowed to naturally regenerate except for 15 m, to allow for a gap in the canopy for aerial surveillance of the pipeline. If there is a requirement to exceed the ROW design width, the contractor shall seek approval through a formal procedure from the Operator.
- The standard ROW width for the project is 30 m and following construction the ROW will be allowed to naturally regenerate except for 15 m, to allow for a gap in the canopy for aerial surveillance of the pipeline. If there is a requirement to exceed the ROW design width, the contractor shall seek approval through a formal procedure from the Operator.

25.1.2.2 *Barrier effects*

Barrier effects are related to edge effects and occur where a linear strip of a habitat (habitat A) occurs within another (Habitat B) and provides a barrier of hostile habitat that discourages or prevents the free movement of animals and seeds within habitat B. In extreme circumstances a population can be split into two separate and isolated subpopulations, each with a reduced chance of survival because of reduced numbers and the prevention in-migration. Rivers provide barriers to many forest animals and long liner clearings in forest provide another, particularly to Type 1 forest species.

Quantitative studies of this barrier effect have been mostly performed in temperate habitats and barrier effects have been demonstrated for a wide range of mammals from mice to caribou (e.g. Oxley et al. 1974, Swihart and Slade 1984, Dyer *et al.* 2002). Quantitative information from the far more complex and speciose tropical rainforests is rare. Goosem (1997) reviews a range of research from the tropics that demonstrates that some specialist terrestrial and arboreal marsupials, some Type 1 and Type 2 forest birds (**section 13.2**),

and several reptiles and amphibians have a particular aversion to crossing roads. Some species of vertebrate fauna completely avoided crossing gaps but there was no pattern as to what particular type of species these were. Other species had their movement rates reduced by as much as 90 to 99% by roads between 12 m and 20 m wide. An untrafficked ROW does not present the same barrier effect as a road, in that a road's barrier effect is exacerbated by the dangers of being run over. Nonetheless, all linear cleared corridors present some kind of barrier to many species.

The important issue for barrier effects is whether the ability to cross a gap is reduced to the extent that population dynamics of a species is altered and there is an increased risk of local extinction of populations. For this to happen the barrier would have to operate so as to cut the population into two or more subpopulations.

Barrier effects can be mitigated by maintaining as narrow a cleared ROW as possible, allowing the ROW and access roads to regenerate as far as possible, and, ideally, allowing the canopy to close wherever possible. The mitigations suggested for habitat loss and edge effects will be effective in reducing barrier effects.

25.1.2.3 *The dilemma of two cleared corridors*

The relative disposition of the ROWs and logistics tracks presents a dilemma in determining the best approach to mitigate edge and barrier effects.

In many areas the ROW and track are separated by a considerable distance and are connected by shoo fly roads and each results in a separate source of edge and barrier effects.

In other parts a logistics track and a ROW are close together or abut each other. In such circumstances the severity of edge and barrier effects will depend upon the degree to which the two linear clearings are offset. If they are side by side a much wider clearing will result and edge effects are likely to be, and barrier effects definitely will be, more severe.

If the ROW and logistics road are offset, leaving a strip of forest between them, there will be two narrower clearings. Edge effects will erode the ecological and biodiversity quality of the intervening strip. In strips left in hairpin bends in mountains, and on steep exposed slopes these 'median strips' will degrade considerably but in flatter, more protected areas they will retain many forest characteristics. However, the benefit if such strips, even if degraded somewhat, is that they are likely to reduce edge effects on the forest either side of the clearings, and, above all, they can reduce barrier effects by providing a stepping stone to cross the ROW/road combination.

On the other hand, two separate corridors allows two separate pathways for weeds, pests and pathogens to penetrate the forest which makes mitigation and management more complex.

ROW construction is likely to prefer offsetting the ROW from any logistics roads for safety, security and efficiency reasons and, so long as the pests, weeds and pathogen plans are effective (**section 25.2.2.4**) it is the most appropriate option to reduce barrier effects.

In very steep terrain shoo fly roads or even a completely separate access track will be necessary e.g. at heartbreak hill. In these circumstances the two linear clearings may be preferable in that it would reduce side cast and the width of high wide cuttings.

As a rule of thumb the following is suggested

1. On Hides Ridge, where dieback prevention is a major issue, a single corridor of clearing is preferable, unless separating the access track and the ROW enables the ROW to be kept narrow and reduces the size of cuttings. In these circumstances hygiene mitigations to prevent spread of dieback has to be maintained rigorously.
2. Construction from the Hides Gas Conditioning Plant to Juha is best done along a single corridor to make control of pests and weeds easier.
3. Along the crude oil export pipeline road, and elsewhere where the ROWs parallel a road, maintain a narrow strip between the road and ROW to reduce barrier effects. A median strip of 50 m would help animals cross, would be logistically easy to manage for pest, weed and pathogen control, and would maintain the ROW within Class A2 forest. A wider median strip of several hundred metres would likely push much of the pipeline construction disturbance area into Old Growth (Class A1) and present extra difficulties for pest, weed and pathogen management .

25.1.3 Physical damage and disturbance to caves

Roosting and/or breeding bats can be impacted via disturbance or damage to caves. Potential mechanisms of impacts include the following:

- Roosts and maternity colonies in caves being eliminated during construction by physical damage to a cave.
- Roosts and maternity colonies in caves being eliminated during construction or disturbance from blasting. Cave bats are very sensitive to disturbance and blasting within 100 m of a cave can impact a colony.
- Cave dwelling species being hunted, particularly the Bulmer's Fruit-bat.
- Cave bats, particularly horseshoe (Hipposideridae) and leaf-nosed bats (Rhinolophidae), being disturbed by human visitation without direct killing for food. Frequent disturbance can cause mortality, especially during the breeding season when young are unable to fly and fall to the ground when their mothers are panicked.

Respondents in the household survey carried out for the PNG Gas Project EIS (Enesar 2005) were questioned about caves with bats (**Table 37**). There was a large response from all regions along the proposed pipeline route indicating potential bat caves occur throughout.

Table 37 Results from household survey questionnaires about bat caves

Question	Hides	Moran	Kutubu	Gobe	Kikori	Total
Are there caves with bats nearby?	46.67	75.31	52.93	41.76	53.03	49.61
Are there caves with flying foxes nearby?	49.25	75.31	53.44	34.12	44.95	49.44
Number questioned	932	81	393	170	198	1774

(entries are% saying "yes").

One of the major mitigations is to carry out pre-construction surveying for caves inhabited by bats. The intensity of survey would depend upon the altitude and the geology. Volcanic and sedimentary areas are unlikely to have caves. Of particular importance is the possibility of as yet unknown cave/s of Bulmer's Fruit Bat in the higher areas of the Northern Montane karst and the Eastern Upland Volcanics/Karst (**section 30.1**).

A range of survey intensities is possible.

- **Grade 1 survey** In karst above 1800 m asl survey 50 m either side of the ROW by a team of local people with a biologist to look for caves with large entrances, the only kind likely to be used by Bulmer's Fruit-bat.
- **Grade 2 survey** In karst below 1800 m asl where blasting may be contemplated survey for caves 50 m either side along the route using a local team and only alert a biologist if a cave with bats is discovered.
- **Grade 3 survey** In rock types other than karst solicit information from local people and/or the archaeological survey team as to the locations of any known caves.

Reducing the impacts on caves may be generally achieved by the following mitigations:

- Investigate a potential Bulmer's Fruit-bat colony near Angore and design and implement a management plan should a colony be found near Angore or elsewhere in the project area.
- Conduct grade 1 bat surveys where practicable prior to construction in areas likely to be inhabited by bats, grade 2 bat surveys in areas where blasting is contemplated, and grade 3 bat surveys where required (after checking with the local community for presence of bat caves near the route) to limit disturbance.
- Consider restricting access to caves with bats and prohibit unnecessary disturbance by project workers.
- Limit or control where practicable, blasting within 100 m of known colonies of cave bats.
- Conduct a pre-clearance survey of pinnacles along the ROW/roadways for caves to determine presence of bat colonies and where colonies are located in proximity to the ROW/roadways, establish procedures to reduce disturbance, where practicable. Potential quarry sites should not be located near caves with colonies containing protected bat species.
- Establish cave management protocols for worker and contractor inductions, to prohibit unnecessary disturbance of bat colonies by project workers.

25.1.4 Fauna falling in the pipe trench

Some fauna species may fall in the trench, be unable to escape and perish. The species that may be affected include reptiles, frogs, small mammals, and terrestrial flightless birds such as the two cassowary species and the New Guinea Flightless Rail.

Deaths of a few individual animals will have little effect upon entire populations unless they are from a small population of a very rare species. The three critically endangered rodents

that may be affected include *Leptomys elegans*, *Leptomys signatus* and *Pogonomelomys bruijni*.

The pipe trench may be up to two m deep and so it is unsafe for people to descend into the trench to rescue fauna. In some places the trench may have sloping sides and, where this is the case, fauna will be able to scramble out. In cases where the trench has deep, vertical walls it could be patrolled and, if an animal is found, a rescue system devised on the spot e.g. a branch or other “natural ladder” could be placed in the trench to assist the animals’ escape.

While being a potential impact issue, the trench also presents a research opportunity. The long trench would act like a trap and if biologists (e.g. from WWF) were allowed access to the ROW they could identify the species and add to knowledge of fauna distributions in the project area.

The following mitigations are suggested to limit the possibility of fauna deaths in the trench.

- Where safe and practicable, patrol open trench to rescue and record fauna that fall into the open pipeline trench.

25.1.5 Erosion and movement of soil and spoil and changes to hydrology

Erosion, sidecasting and dumping of spoil has the potential to impacts biodiversity through:

- Increasing direct loss of habitat
- Changing to hydrology of wetlands and forests
- Filling of sinkhole swamps and other waterbodies.

Cuts for the ROW, fly roads and logistics roads in very steep terrain could result in large amounts of side cast material falling downslope and smothering and killing more forest, thus increasing the width of clearing.

Erosion, side casting and dumping of spoil impact fauna not only through increases in habitat loss but also by enhancing barrier effects. The latter can be the more significant in upland habitats where steep cuttings could present very wide barriers to sensitive fauna, such as upland arboreal mammals and frogs. Where regeneration of side cast occurs readily the effects will be short term.

Hydrological changes can be ecosystem-wide impacts that result in major effects on habitats. Forests adapted to dryland conditions die if flooded for even short periods. Mangroves will die if tidal effects are changed drastically. Swamp forests and woodlands, which are adapted to periods of flooding and drying, may die if the dynamics of flooding and drying are altered. Changes to hydrology can be brought about by causeways and roads damming areas and/or promoting drainage of others. Rainforests on floodplains will start to die if flooded continuously for more than six months (Rogers 2005b).

Flooding at the wrong time can impact habitat and biota directly through changes in seasonal and breeding cycles but it is unlikely the project can induce such seasonal changes in hydrology. Instead the major potential hydrological impacting mechanism would be habitat loss. Species adapted to swamp woodland and forest complexes, such as New Guinea flightless rail, are most at risk.

Mitigations suggested above to reduce impacts of habitat loss will also be effective in minimising potential impacts from erosion, movement of soil and spoil and changes to hydrology. Particularly important mitigations are:

- Conduct fine-scale routing of the ROW/access ways to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel waterbodies and other karst terrain, where practicable.
- Provide protection for stream heads in the Baia River area and elsewhere in the upstream project area above 1,800 m, to reduce erosion material entering them.
- On Hides Ridge and between Hides Ridge and Juha, align the route to bypass potentially high-value conservation swamps or swamps in sinkholes <50 m deep where practicable. At sites where this is impractical reduce side cast into these high value habitats¹⁸.
- Where practical, stabilise cleared banks to provide a suitable habitat for recolonisation.
- Where practicable, the pipeline ROW/access way alignment approaches to watercourses will be kept as close to right angles as possible to limit disturbances to the banks of watercourses.
- The duration of construction activities at watercourse crossings will be as short as practicable.
- Develop an erosion and sediment control plan for all construction-related activities to:
 - o Implement good industry practice erosion and sediment control measures at watercourse crossings, as necessary.
 - o Prohibit stockpiling spoil and topsoil materials close to waterways (i.e., maintaining a minimum of 10 m from the waterline).
 - o Control sediment runoff from stockpiles and cleared areas around watercourses.
 - o Implement sediment control measures downstream of side-cast material where safe and practicable.
 - o Limit erosion and sediment delivery to streams from new quarries.
 - o Prohibit side-casting material directly into waterways where practicable.
 - o Grade pipeline ROW/roadway alignments adjacent to streams away from watercourses.

¹⁸ This includes off river water bodies on the Baia River.

-
- o Monitor and maintain erosion and sediment control measures until adequate soil stabilisation has been achieved.
 - o Install diversion drains to intercept uncontaminated surface runoff around facilities and away from construction areas.
 - o Install sediment control structures to intercept sediment-laden surface runoff to reduce sediment delivery to watercourses.
 - o Monitor for and rectify areas of problematic erosion at reclaimed watercourse crossings."

25.1.6 Materials handling

Terrestrial fauna can be directly impacted by ingesting or contacting spilt fuels, oils, chemicals, radioactive isotopes, solid and liquid wastes. They can also become trapped by wire and other abandoned hardware. If contaminants enter streams, they can impact on frogs.

During construction there is the potential for contaminating materials to enter sinkhole swamps or off-river waterbodies and impact on the frogs and reptiles that inhabit them. The effects are likely to be local and limited except in the Hides Ridge Special Area where these sinkhole swamps support many hyliid frogs.

The most sensitive site for contamination for flora is the Hides Ridge Special Area where most of the drainage is internal and contaminants can find their way into sinkhole swamps.

Large accidental fuel spills from tankers are a major potential impact to be aware of and adequate emergency response procedures are important.

The following mitigations to help reduce impacts from material handling are suggested.

- Prohibit disposal of any waste into forest, streams or sinkholes.
- Dispose of drilling fluids cuttings, and other drilling materials in an appropriate manner away from Hides Ridge.
- Dispose of wastes from ROW/access way construction activities (not spoil) and camps (including the drilling camp) away from Hides Ridge.
- Waste management procedures will be established to control and appropriately manage all non-biodegradable materials.
- Manage sewage in an appropriate manner to limit environmental contamination.
- Incinerate organic waste and bury at specified sites.
- Diesel storage system will be purpose built, above ground and within double walled tanks or containment bunds. Oil spill prevention and response plans will be in place.
- Fuel, lubricating oils and chemicals will be stored in appropriately sized designated areas that have impervious liners and bunds, or are in double hulled tanks. This includes temporary fuel stores along the ROW and access roads.

-
- Procedures for vehicle/equipment refuelling will be implemented to prevent spillages, and appropriate spill containment equipment will be available at refuelling sites and construction sites. All drivers will be appropriately trained in emergency spill response procedures.
 - Vehicles and machinery maintained to a high level of safety with respect to leaks. Drivers will be appropriately trained and have the required driving licence.
 - The washing of equipment, vehicles or machinery near or within watercourses will be prohibited.
 - Establish appropriate fuel handling transport and storage procedures in EMPs.
 - Establish appropriate materials handling, storage and disposal in EMPs.
 - Establish appropriate storage and handling of radioactive material in EMPs.
 - Prohibit wash down or fuel handling near or in streams.
 - Establish appropriate waste handling procedures in EMPs.

25.1.7 Disposal of hydrotest fluid

Prior to commencement of operations the pipeline would be tested hydrostatically to ensure it is strong enough to maintain the design internal pressure and that there are no leaks. Testing would be conducted in manageable segments. Before hydrostatic testing is carried out scrapers or pigs would be pushed through the pipeline with compressed air to remove welding slag, dirt, debris, or other items that might have accumulated during the construction process. The pipeline would then be filled with water, pressurized, and tested to establish design limits. In accordance with accepted pipeline practice, the amount of water drawn from a stream or river would be limited to a maximum of 10 percent of the flow at the time of extraction. In conformance with waste management plans, hydrostatic test water would be, to the extent practicable, disposed to the ground surface into infiltration beds or percolation ponds, incorporating erosion control measures (e.g., energy dissipation devices) and, if needed, filtering devices to remove sediments from the pipeline. A record of the hydrostatic test would be made and retained for the entire operational life of the pipeline.

Hydrotest fluids can contain biocides, oxygen scavengers and other additives and their disposal presents two special issues: one related to the potential toxicity impacts of biocides on aquatic organisms in the receiving waters and the other to the translocation of organisms. Biocides in the hydrotest fluid at the point of discharge have the potential to impact on receiving water organisms such as amphibians through residual toxicity. On the other hand, hydrotest fluid without biocides could allow the transport of living organisms, including pathogens, between stream catchments (i.e., translocation). It is not only exotic species that are of concern. Cross-contamination of streams with native species also serves to break down the natural biodiversity patterns in remote, relatively undisturbed areas like the project area.

In general, the transport of contaminating organism is by far the more important ecological issue rather than potential local toxicity effects from biocides. The incorporation of biocides is an effective quarantine mitigation that will prevent cross contamination of catchments.

The following mitigations are designed to deal with any potential impacts:

- On Hides Ridge, hydrotest water sourced off the Ridge will be discharged into the same watershed as its source to prevent cross contamination with live organisms from another catchment.
- Carry out the disposal of hydrotest waters in accordance with good industry-practice engineering codes for system gauging, hydrotesting and disposal.
 - o Develop hydrotest disposal management plan that includes adherence to guidelines and measures as follows:
 - o Disposal of hydrotest waters in accordance with good industry-practice engineering codes for system gauging, hydrotesting and disposal.
 - o Measures to hold and treat hydrotest waste water where necessary prior to release so the quality meets the requirements of the relevant water discharge permit.
 - o Pre-discharge sampling and analysis of hydrotest water to check that quality complies with the conditions attached to the relevant water discharge permit.
 - o If the waste water is to be discharged to land for infiltration, the outflow energies will be dissipated (e.g., via sprinkler or T-bar arrangements) to prevent problematic soil erosion.

25.1.8 Dust

Dust may coat the leaves of plants along the forest edge and reduce photosynthesis but the frequent rainstorms in the project area wash the dust away and make this a temporary phenomenon. It is possible the input of dust to the forest edge actually increases the soil fertility and speeds up the growing vegetation sealing the forest edge, thus reducing edge effects a little. Dust impacts on rainforest fauna are little understood but in the very wet climate of the project area it is unlikely dust impacts will last more than a few days at a time.

No suggestions are made for dust suppression beyond what the PNG LNG Project may deem appropriate for worker health considerations and the following mitigation would be effective.

- Speed limits will be controlled via posted speed limit signs on project unsealed roads and pipeline rights of way (ROWS) (when required) and vehicles kept to marked trafficable areas which will be maintained in a damp and compacted condition (when required) to enhance safety and minimise dust emissions.

25.1.9 Loss of breeding and display grounds

Birds-of-paradise and Bowerbirds are lekking species, i.e. males display communally in special display areas and compete for the attention of females. These display areas may be trees or specially prepared sites on the ground. Lekking areas are often traditional and form breeding epicentres for local populations of species (Frith and Beehler 1998). The best known species to do this is the Raggiana Bird-of-paradise where dozens of males congregate in spreading trees to display. Display grounds can cover several hundred

hectares with widely dispersed bowers or display sites, sometimes strung along a narrow ridge (see e.g. Crome and Moore 1989). A road or ROW can disturb a significant portion of such lekking grounds. A suggested mitigation is to:

- Establish procedures to prohibit PNG LNG Project workers or contractors disturbing bird-of-paradise and bowerbird display grounds or trees identified next to the ROW. Conduct a pre-clearance survey to identify such sites.
- If practical and safe, retain trees over 1 m dbh at camp locations.

25.1.10 Noise, lights and other disturbance to fauna

Fauna adapt readily to noise but lights can affect the behaviour of nocturnal birds.

The issues are very local, and experience with the existing oil and gas facilities show that fauna have not been impacted by noise and lights. Any disturbance to fauna causing them to retreat from construction sites will be temporary and, as long as indirect impacts are controlled, fauna will return to the site.

Direct disturbance by humans does impact on fauna, and lack of such disturbance is a major factor in maintaining the high biodiversity values that occur in the project area alongside the existing oil and gas facilities.

During construction and operations disturbance to nocturnal fauna may be reduced by appropriate positioning of lights.

The only mitigations suggested is to:

- Direct lights at facilities etc. to eliminate shine into surrounding forest, where security allows.

25.1.11 Project traffic and other operations

Fauna can be killed by project traffic and machinery on roads. Suggested mitigations are:

- Speed limits will be controlled via posted speed limit signs on project unsealed roads and pipeline rights of way (ROWS) (when required) and vehicles kept to marked trafficable areas which will be maintained in a damp and compacted condition (when required) to enhance safety and minimise dust emissions.
- Speed limits will be controlled via posted speed limit signs on project unsealed roads and pipeline ROWs (when required) and vehicles kept to marked trafficable areas.

25.2 Indirect Impacts

All the biodiversity surveys (**Annexes 01 to 10**) concluded that indirect impacts associated with the PNG LNG Project are likely to be of more important than direct impacts. Isolation and difficulty of access have probably been the essential factor in maintaining the integrity of the project area and the KICDP area.

Indirect impacts can come from construction and operations of the PNG LNG Project itself and from the increased access that roading could allow. Mitigating indirect impacts resulting from project activities may be straightforward but mitigating these same impacts

resulting from activities of others that are using project infrastructure is likely to be more difficult.

The major potential indirect impacts are fire, the introduction of exotic weeds, fauna and pathogens, hunting, collection of flora and forest products and improved access to the project area increasing forest loss and degradation.

25.2.1 Fire

Fire is a potent ecological factor in tropical forest dynamics. During drier periods even very wet forests can burn. Broad-scale fires are not uncommon in New Guinea, occurring mostly in El Niño years, but can be catastrophic events with long-term effects that can be widespread and often involve permanent deforestation. Fires with widespread impacts can occur when small fires burn out of control.

Large areas of forest within the project area overlie limestone pavements and karst and the soils are shallow – often just a thin root mat over solid limestone. Fire in these forests can burn away the root mat leaving bare rock or subsoil, upon which regeneration is impossible or takes many decades or centuries to occur. Similarly fire in swamp forest complexes and swamp woodland and forest complexes can burn the peat and organic soil result in permanent deforestation.

It is unclear how the high *Nothofagus* forests in the Hides Ridge Special Area would respond to fire, although Rogers (2005a and b) notes that periodic fire may have a role in regeneration in *Nothofagus* forest. The survey area at the Homa Deviation was on the edge of a large forest fire from 1997 and Takeuchi (**Annex 02**) describes the effects of fire on upland forests.

There is a converse to this, in that cleared ROWs and roads can act as firebreaks to stop the spread of wildfires that come into the project area from elsewhere.

The wide spread influence of fire suggest that it be a major focus of mitigations. Possible mitigations are:

- If fire hazard exists, pushed vegetation can be left to rot at forest edge rather than burnt.
- Develop and implement a fire management plan for the construction and operations phases of the PNG LNG Project aimed at reducing the likelihood of the project starting any wildfires to very low. The plan will include banning the burning of cleared vegetation and other fires in the montane environment in drought years.

25.2.2 Pests, weeds and disease

The spread of noxious and undesirable organisms is a global ecological problem and, because the PNG LNG Project traverses such a large area of PNG and penetrates into previously undeveloped areas, probably, one of the most serious potential impacts in the project area. Unlike local habitat loss, which generally acts as at a local level, pests, weeds and diseases, which are always introduced at a local level, often a single point, can rapidly spread and have landscape wide effects.

25.2.2.1 Dieback and other plant diseases

Dieback is a serious disease caused by a range of root-rotting fungi that can kill a huge variety of plants and has been found in parts of the project area (Rogers 2005 a and b). The disease manifests under a range of environmental conditions. For example drought may play an important role in dieback in New Guinea by stressing trees and predisposing them to infection, and in the lowlands changes to drainage patterns brought about by road construction can produce dieback.

Causes are less obvious in the highland *Nothofagus* forest where dieback patches of up to several hectares of dead and dying mature trees can occur. In these forests dieback may reflect natural senescence of a stand as well as infection by fungi (Rogers 2005a).

Rogers (2005a) describes the relationship between climatic conditions and dieback in *Nothofagus dombeyi* forest in Patagonia which is subject to “episodic drought-induced mortality where a range of factors predisposes trees and stands to dieback.... At the stand level climatic/biotic effects make forests more susceptible to subsequent stress by reducing vigour, therefore stands of *Nothofagus* that have been subjected to insect attack (e.g. borers), fire, drought and frost in the past may be more predisposed to dieback than stress free stands. Stands growing in sub-optimal conditions may also be more susceptible to drought-induced dieback....stands growing on steep slopes, associated with high rockiness are more susceptible to dieback”.

Abundant regeneration has been reported from some dieback stands in PNG suggesting that the disease does not inevitably prevent successful regeneration of *Nothofagus*.

Forest hygiene plans recognise that not only vehicles but equipment, such as chainsaws, can carry dieback spores and that the interconnected root systems of *Nothofagus* allow rapid spread of the disease beyond the initial infection point.

While dieback is the major focus of plant diseases in the project area there are a range of exotic diseases elsewhere, including within PNG e.g. Brown root rot *Phellinus noxius* and Pink disease *Corticium salmonicolor* (FAO 2008) that have not been recorded in the project area.

25.2.2.2 Invasive species - weeds

Exotic weeds are major issues for forest conservation worldwide and many weeds present serious environmental problems. Some weeds such as *Piper aduncum* L. are capable of altering even rainforest habitats. (see e.g. Leps *et al.* 2002; Rogers & Hartemink 2000). Such species are not yet present in the upland forests of the project area but this could easily change with increased human activity in the project area. Once weeds penetrate native habitats they can bring about permanent changes and loss of biodiversity. Intact tropical forests tend to be resistant to invasion and it is a problem usually associated with opening up of forests by roads and clearing allowing weeds and other exotics to enter and establish. See Grice and Setter (2003) for an exposition of rainforest weeds in Australia.

The impacts of weeds may not be immediate and a lag period of several decades may go by before a species “breaks out” and becomes a pest. The issue is not simply one for conservation but has implications for subsistence agriculture.

The potential impact of weeds, is best approached by a quarantine and hygiene plan but to be effective such plans need to be rigorously applied at all levels of the project including

pioneering stages and early works. They also need to be applied not only to exotic species but to existing know weeds in PNG where appropriate.

Any prohibitions on importing and translocating plant material should include all plants, even native ones, since intermixing of plants from different geographic provenances can impact the integrity of local genetic resources. Takeuchi (**Annex 02**) gives examples where human cultivation has already been “implicated in corrupting the biogeographic and taxonomic status of woody species”. He gives the example of the Juha populations of *Psychotria matambuai* which appear to be infraspecifically quite distinct from eastern forms but this could be erased or reduced if seeds or plants from elsewhere in PNG were allowed to contaminate the Juha gene pool.

Takeuchi (**Annex 02**) goes on to say “The possibility of genetic effects would be even greater with introduction of native plants having known propensities for hybridization, e.g. the many species of montane *Rubus*.” It is a common activity of workers and labourers to introduce plants and establish little gardens at work sites. It may be one of the greatest challenges facing the PNG LNG Project to control this, yet it is the only effective way to mitigate the potential severe effects of the possible introduction of alien plants into the pristine parts of the PNG LNG upstream project area.

Worst of all, are the deliberate introductions of alien plants into the local flora, particularly if they have congeners there. At the Hides 3 wellhead, for example, the 2005 survey documented plantings of *Passiflora ligularis* Juss. at the drill pad (**Annex 01**). This species is native to the South American Andes and occupies the same niche as local passion fruit species and is potentially capable of physically displacing them. If hybridization were to occur, the unique identity of the local species could be lost through genetic dilution.

Takeuchi (**Annex 02**) gives several examples from the Porgera area of how weeds, particularly the vine *Passiflora mollissima* (H.B.K.) Bailey, has invaded the montane habitats along roads. Originally from South America, *P. mollissima* has become a serious pest in many Malesian and oceanic ecosystems (Wilde 1972, HDOA 1992). Unlike the weeds so far recorded in the PNG LNG project area, this vine has a proven capacity for forest destruction because of its ability to form dense thickets over native vegetation.

Internationally, there is a clear connection between road construction and processes of floristic degradation (Conservation International 2003).

25.2.2.3 Invasive species – exotic fauna

Like weeds, invasive animals can be serious agricultural and/or environmental pests and have far reaching landscape impacts. Species such as Small Indian Mongoose (*Herpestes javanicus*), Rosy Wolfsnail (*Euglandina rosea*), Slider Turtle (*Trachemys scripta elegans*) and Cane Toad (*Bufo marinus*) have had a major impact in tropical areas. Of particular concern is the spread of the Crazy Ant (*Anoplolepis gracilipes*) now established in Australia and the Crab-eating Macaque (*Macaca fascicularis*) established in West Irian.

Exotics can be introduced accidentally on freight and in containers, deliberately or by ignorance.

25.2.2.4 Mitigations for pests, weeds and disease

Quarantine and hygiene procedures can be used to mitigate the potential impacts of pests weeds and diseases. Mitigations to be developed are as follows:

-
- Establish and enforce a project wide quarantine management plan to be developed in the project EMPs which will encompass personnel and freight movements in and out of and within the project areas, and establish inspection and treatment standards and procedures for all freight types, including pipe and imported rock.
 - A weed, exotic pest and pathogen management plan will be established to protect the biodiversity of Hides Ridge and Juha area. This will include establishment of chemical washdown points at or near the Hides Gas Conditioning Plant to prevent weeds and pathogens being transported to and within Hides Ridge and Juha for the life of the project. The plan will be detailed in the Environmental Management Plan.
 - Develop a management plan to reduce impacts on *Nothofagus* forest and the spread of dieback. Design to allow adequate surface and subsurface flows and avoid redirection of stream flows where practicable.
 - Establish procedures to prohibit PNG LNG Project workers or contractors from establishing any gardens, or introducing or transporting any plants, seeds or animals within the project area (including the translocation of fish species).
 - Implement a weed and exotic pest control management plan that identifies foreign and invasive weed and exotic pest threats and appropriate control measures.
 - Implement vehicle wash down facilities. Ban the import of exotic species, including seed into the project area.
 - Prohibit transportation of live animals, plants or seeds to the Juha or Hides Ridge areas.
 - Encourage WWF in their conservation activities in the project area.
 - Encourage conservation education in villages in the project area.

The above mitigations may best be integrated into one or more quarantine and hygiene plans elaborated into a specific EMP dealing with pests, weeds and diseases. Such an EMP might contain the following.

1. Australia has been effective in reducing the introduction of exotics into Australia and PNG and appears to have similar legislation and quarantine systems. The PNG LNG Project is not bound by Australian systems but aiming for a similar level of control, and possibly using similar procedures may be appropriate.
2. The inbound overseas freight to the PNG LNG Project (upstream and downstream) coming through Port Moresby and Lae may overwhelm government resources at these points. The Project could usefully negotiate with government and, if necessary, augment resources and procedures at these entry points to ensure an appropriate level of quarantine is practically achieved.
3. A quarantine station at Kopi needs to be set up along similar lines to Lae and Port Moresby but obviously smaller.

-
4. A quarantine station at Komo needs to be set up to check incoming overseas airfreight along reduced but similar lines to any international airport.
 5. All freight coming through these four points needs to be dealt with including rock and other bulk freight that may harbour exotics.
 6. Procedures need to be developed for checking inbound foreign freight at Port Moresby, Lae, Komo and Kopi that are efficient and effective. Procedures at Australia ports and international airfields may be effectively adapted to the PNG situation. It is likely a sampling system will be appropriate whereby freight loads are totally inspected or samples only inspected based on the nature of the cargo, origins of cargo and transport craft, the presence of known exotics in country of origin and embarkation and intelligence within the quarantine community
 7. Procedures for eliminating exotics when found are likely to be available from other quarantine jurisdictions.
 8. Trucks travelling from Lae or Kopi to site are best prohibited from picking up and carrying non-project freight, people and their plants and animals.
 9. The present Oil Search system of checking baggage of personnel in and out of Moro could be effectively adopted at all entry points and suitably expanded to cope with the expected flows of project workers in and out of the project area.
 10. Appropriate operations of vehicle wash down facilities so as to ensure soils and weeds do not get into Hides and Juha but at the same time do not hinder construction unduly. Disposal of washed material needs to be environmentally appropriate.
 11. A washdown facility at H4 may be most appropriate to protect Hides and the same one could be used for Juha when that part of the project starts.
 12. The washdown facility at H4 and a second wash down facility at Moro would be effective in reducing spread of weeds into new areas of the project being developed between the HGCP and Kutubu. The Moro facility need only be used for vehicles heading to the Benaria River to Kondari River section of the ROW.
 13. A small wash down facility will need to be associated with the Kopi quarantine station to deal with any dirty machinery or plant that may arrive.
 14. Procedures need to be rigorously applied at all levels of the project including pioneering stages and early works.
 15. Any prohibitions on importing and translocating plant material should include all plants, even native ones.
 16. During operations a scaled down quarantine procedure may be appropriate with Lae and Port Moresby reduced to normal government operations and Kopi and Komo retained at levels appropriate to freight and personnel movements. The wash down facilities and bans on transport of plants animals and soil would be maintained.

-
17. It needs to be determined whether the dieback hygiene plan is best developed as a separate plan or as part of a project wide quarantine and hygiene plan.

25.2.3 Hunting

Many birds, larger mammals and reptiles of New Guinea suffer greatly from hunting, in particular, those species that are specifically targeted for food and/or decorative plumage. Species of particular interest to hunters include: tree kangaroos, cuscus and possums, the larger rats, flying foxes, cassowaries, megapodes, Blyth's Hornbill, larger lorikeets, parrots, pigeons, raptors, New Guinea Flightless Rail, crocodiles, freshwater turtles, and numerous well-plumed birds-of-paradise including Black Sickbill, Brown Sickbill, Black-billed Sickbill, Carola's Parotia, Lawes's Parotia, Magnificent Riflebird, Ribbon-tailed Astrapia, King-of-Saxony Bird-of-paradise, Twelve-wired Bird-of-paradise, Raggiana Bird-of-paradise and Blue Bird-of-paradise.

Mack and Wright (1998) show how hunting has seriously impacted the large and slow-flying Pesquet's Parrot and many species are often locally extinct or exist in very low numbers in suitable habitat near human occupation (**Annex 03**).

Hunting for subsistence and/or commercial exploitation for bush meat has become a significant biodiversity impact in tropical forests worldwide and is the major avenue whereby logging reduces populations of vertebrates. For an overview of the problem see Bennet and Robinson (2000).

The household surveys carried out for the PNG Gas Project EIS (Enesar 2005) have produced the following statistics on hunting in the KICDP (**Table 38**).

Hunting is an important activity with respondents averaging 6.5 days per month hunting and the major species targeted being pigs, cassowaries and cuscuses. Approximately 50% of all respondents indicated they targeted birds. There is evidence that hunting patterns have changed with a minority indicating that they hunted just as much as five years ago. This is hard to interpret, as there was no question as to whether hunting time had declined or increased. There is evidence that hunters have to travel further for game, particularly at Kutubu and Gobe. Whether this is a response to declining game populations or a response designed to increase compensation opportunities is hard to determine. The data for cassowaries indicates that they are becoming much harder to hunt suggesting declining populations of these valuable animals. Only at Kikori, where the larger species are commonest, did more than a quarter of respondents say they were as easy to hunt as before.

Approximately half of respondents indicated that birds and mammals have declined in the past 10 years. Again, whether this is due to real declines or to facilitate compensation opportunities is hard to judge. When asked what species had declined 274 people (222 from Hides) volunteered data, with 60% claiming birds-of paradise had declined and 44% possums. The questionnaires also confirmed that pythons had declined.

The data indicates that hunting is still an important activity with a certain amount of trade occurring and evidence that prey species are declining in some places. The patterns of responses also indicate that hunting may be more prevalent in the uplands. It is difficult to gauge the impact of hunting using average statistics because individual specialised hunters can have a disproportionate effect on wildlife populations. Basically hunting is a skill that requires dedication and some professionalism. Skilled professional hunters working in

teams servicing a wildlife products market can have a profound impact on populations of wildlife as the story of a reformed hunter in Cambodia attests. In his career hunting meat for various “clients” Yor Ngone killed 19 tigers, 40 leopards, 500 to 800 wild cattle, 43 bears and 30 elephants (Vuthy 2005).

Table 38 Results from household survey questionnaires about hunting (entries are% saying “yes”).

Question	Hides	Moran	Kutubu	Gobe	Kikori	Total
Mean days per month spent hunting (% volunteering information in brackets)	5.4 (82)	5.8 (68)	8.9 (83)	5.6 (88)	7.3 (85)	6.5 (83)
Do you still hunt as much as you did five years ago?	25.2	34.6	44.0	5.3	59.1	31.7
Do you have to go further away to hunt now because game is scarcer?	43.6	53.1	83.5	86.5	49.0	57.6
Are cassowaries as easy to get as they used to be?	21.0	25.9	15.3	2.9	36.9	20.0
Have you noticed any bird species that have declined in the last 10 years?	54.2	38.3	63.4	58.9	43.4	54.7
Have you noticed any possums, rats, echidna species that have declined in the last 10 years?	53.7	40.7	50.9	55.3	42.9	51.4
Does anyone come to buy game from you, dead or alive?	25.4	21.0	32.8	14.1	23.7	25.6
Number questioned	932	81	393	170	198	1774

For impact assessment purposes hunting is divided into that done by PNG LNG Project workers and contractors and that done by non – project personnel.

25.2.3.1 Hunting by PNG LNG Project workers and contractors

Suggested mitigations that would help reduce hunting impacts from PNG LNG Project workers and contractors are:

- Prohibit disturbance to or harassment of wildlife, hunting of fauna, gathering of plants or bush foods, or possession of wildlife products by project workers or contractors while working, travelling in project vehicles, and residing in project field accommodation.
- Implement appropriate inductions to encourage staff to comply with hunting and collecting regulations.

25.2.3.2 Hunting by non - project personnel

This can only be mitigated by managing access along project roads to those areas of the project area opened up by the PNG LNG Project .

25.2.4 Collection of flora

Sustained collection of specific plants (e.g. orchids), firewood or construction timber in small areas such as around camps may locally degrade habitat. This can be mitigated by controlling workers harvesting local flora and forest resources.

For impact assessment purposes collection of flora is divided into that done by PNG LNG Project workers and contractors and that done by non – project personnel.

25.2.4.1 *Collection of flora by PNG LNG Project workers and contractors*

Suggested mitigations that would help reduce impacts from PNG LNG Project workers and contractors are:

- Prohibit disturbance to or harassment of wildlife, hunting of fauna, gathering of plants or bush foods, or possession of wildlife products by project workers or contractors while working, travelling in project vehicles, and residing in project field accommodation.
- Implement appropriate inductions to encourage staff to comply with hunting and collecting regulations.

25.2.4.2 *Collection of flora by non - project personnel*

This can only be mitigated by managing access along project roads to those areas of the project area opened up by the PNG LNG Project .

25.2.5 *Improved Access to project area*

All indirect impact will be exacerbated by improving accessibility to people along the logistics roads. Technically it will be possible to drive from Tari to Kopi and Tari to Juha quickly and easily. There is thus a possibility of a long-term high-level impact on the forest and the fauna of the project area and the KICDP area. The impacts of roading that opens up areas of tropical forests are well understood in the research literature and are discussed at length in numerous articles on web sites of conservation organisations. Scholarly approaches to the topic can be found in Laurance et al. (2004), Trombulak and Frissell (2000) and Forman and Alexander (1998).

Increased accessibility can result in:

1. Settlement and clearing along roads for gardens and small agricultural plots.
2. Illegal logging, acceleration of legal logging, and changing the economics of logging to make previously unprofitable areas profitable by reducing or eliminating costs of building access roads.
3. Over hunting. The abundance of particularly attractive prey species in proximity to oil and gas facilities is one of the characteristics of the KICDP area. Should regular hunting become a by-product of the construction of access roads, there exists the potential for a high level impact on local populations of many species, including a number of globally threatened taxa.
4. Ingress of weeds, pests and pathogens brought in accidentally or deliberately.
5. Elimination of the genetic uniqueness of areas such as Juha and Hides by introduction of other plants.
6. Increase in fire frequency and large-scale deforestation.
7. The enhanced opportunities for agricultural entrepreneurs to establish industrial scale agriculture, biofuels or tree crops. Soils in the KICDP area are poor and impede rational development opportunities, but that need not

stop a determined dreamer. A failed plantation clears as much forest as a successful one.

8. Road access to the New Guinea highlands and more airfields may make the development of prawn or fish farms viable in the mangroves of the delta. The Mahakam delta in Kalimantan is now stripped of what was once one of the largest mangrove areas in the world (Dutrieux 2001).

The global experience with roads in tropical forests indicates that long term uncontrolled access results in loss of fauna and often deforestation leading to landscape fragmentation. There is a potential for this problem to occur at all altitudes from the Kikori lowlands to the Hides and Juha gas fields.

It is difficult for the project to mitigate these impacts because the issue is entangled with social and development policies of the national and provincial governments of PNG. Suggested approaches that could be considered may include:

- All new project roads constructed between Kopi and the Hides Gas Conditioning Plant will be made impassable following completion of construction. They will therefore not be available for ongoing use by either the project or general public.
- All ROWs/access ways made impassable at conclusion of project construction, between the Omati River Landfall and the Kopi by-pass deviation, and on Hides Ridge at the end of the project.
- Control access to Hides Ridge and Juha on the Juha and Hides Ridge access ways to the west of Hides Wellpad A and implement a permit system for vehicle access for the lifetime of the project.
- Establish pipeline security procedures, including procedures for heavy logging trucks on road sections where the pipeline is buried.
- Encourage WWF in their conservation activities in the project area.
- Encourage conservation education in villages in the project area.

26 Significance of residual impacts on the habitats and biodiversity of the project area and the KICDP as a whole

Residual impacts are those that it is postulated would remain after application of the mitigations in **Appendix 12**.

26.1 Direct impacts on vegetation and flora

26.1.1 Habitat loss

It is estimated a total of approximately 2811 ha will be cleared, of which some 37% will be in cleared areas or secondary vegetation of some kind. 37.5% (1056 ha) will be old growth forest (Class A1) and 15% (424 ha) in disturbed old growth (Class A2) (**Table 27**). These figures should not be considered exact and may vary by 15 to 20% depending upon the final configuration of the project. 60% of these old growth losses will be in greenfield areas but the total losses will be about half and half in greenfield and brownfield (**Table 30**).

The project components contributing most to the loss of old growth forest are

1. The Juha Production Facility and Juha Gas Pipeline ROW (289 ha = 27% of the total loss of old growth forest.
2. Section 7 Benaria River to Kondari River (124 ha = 12%).
3. Section 8 Kondari River to Lake Kutubu (114 ha = 11%).
4. The Heartbreak Hill road route (100 ha = 9%).
5. Section 4 The Hides Uplands (97.4 ha = 9%).
6. Section 17 Kikori River crossing to Omati (86.4 ha = 8%).

Between them these six elements account for three quarters of predicted total old growth losses.

Losses of old growth and disturbed old growth (Classes A1 and A2) are concentrated in five BVGs – lower montane small crowned forest, lower montane small crowned forest with *Nothofagus*, lower montane very small crowned forest complexes with *Nothofagus*, medium crowned to small crowned forest complexes, and low altitude medium crowned forest (**Table 28**). 87% of old growth losses (920 ha) are in these BVGs and 82% of classes A1 + A2 (1221 ha).

It is not possible to express the old growth forest losses as a percentage of old growth within the entire project area, the KICDP area, or any bioregion because there is no current information on the total amount of old growth forests in those areas nor within any area of BVG. However it is possible to examine losses of vegetation irrespective of condition (Column 10 in **Table 28**), and none exceeds a quarter of a percent of any BVG within the project area. The percent total loss from the project area is some 0.124%, suggesting that no particular vegetation type is put at conservation risk by clearing for the upstream portion of the PNG LNG Project.

Clearing will be concentrated in certain parts of the project Area. **Table 29** presents losses in the various bioregions. Three bioregions will not be impacted by clearing at all – Seribi Lowlands, Libano-Hegigio and the Darai Plateau. Of the remaining bioregions, the Iagifu-Agogo Limestone Uplands and the Moro Region will lose 0.98% and 0.56% respectively. These are small, centrally located bioregions that host the oil facilities. The Western Lowlands will lose a similar percentage to the Moro region but the latter is a small discrete area around lake Kutubu, whereas the former is a part of a much more extensive region that extends to the west and south. The figures suggest no bioregion will be put at conservation risk by clearing for the PNG LNG Project.

When assessing impacts the following are relevant.

- 90% of the clearing is in a long thin line and not concentrated in any particular area of the project area.
- Of the remaining areas to be cleared (“Other” in **Table 27**), the Juha Processing Facility will produce the largest single loss of old growth (31 ha); of all other patches of clearing in old growth or Classes A1 and C forest, none are over 15 ha.
- These losses are not designed to be permanent. While the logistics roads will remain open, the ROW will be allowed to revegetate for all but 15 m over the pipe (10 m on Hides), and the shoo fly roads, temporary construction camps and laydown areas will be restored or allowed to regenerate. This means that 76% and 80% respectively of the areas of old growth (A1) and disturbed old growth (A2) lost will start to regenerate within a year or two (**Table 39**). Within 30 years, at project end, this will have regenerated to late secondary forest with high biodiversity values and the remaining cleared areas will then start regenerating.

Table 39 Percent of project footprint allowed to regenerate at end of construction period.

	Old growth	Old growth but with some disturbance	Late secondary or heavily disturbed old growth	Pioneer/ early secondary	Gardens secondary complexes	Logged forest	Existing Facility area	Total
	A1	A2	C	D	E	L	F	
area (ha) lost	1056	424	288	561	312	148	16	2805
area (ha) regenerating after 2-3 years	807	342	215	400	264	91	6	2125
% regenerating	76%	81%	75%	71%	85%	61%	38%	76%

The magnitude of the impact of habitat loss on vegetation and flora before mitigation is therefore estimated to be low but negligible after. Considering the vegetation and flora of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of loss of habitat on vegetation and flora is predicted to be minimal.

26.1.2 Edge and barrier effects

26.1.2.1 Edge effects

Experience with the oil project indicates that below about 1800 m asl edge effects from previous pipeline construction are temporary and that the forest edge rapidly seals over in all habitats. Taking care that construction does not excessively damage trees remaining along the edge will reduce or eliminate the potential for further erosion of the edge.

The magnitude of the impact of edge effects on flora before mitigation is therefore estimated to be low but negligible after mitigation. Considering the Vegetation and flora of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of edge effects on flora is predicted to be minimal.

26.1.2.2 Barrier effects

The narrow ROW is predicted to present no significant barrier to movement of spores or pollen. The bulk of species in the PNG flora have their seeds dispersed by birds and/or bats and seed dispersal may be reduced because of barrier effects realised through inhibition of disperser movements. However, it is unlikely the ROWs and access roads will provide a barrier to any canopy or subcanopy bird or bat species that might be a pollinator or disperser. The magnitude of the impact of barrier effects on flora before mitigation is therefore estimated to be low but negligible after. Considering the vegetation and flora of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of barrier effects on flora is predicted to be minimal.

26.1.3 Erosion, movement of soil and spoil, and changes to hydrology

In most areas sidecast will regenerate and stabilise so habitat loss and increased barrier effects produced by this phenomenon will ameliorate over the medium term.

Regeneration will be slow, will not occur, or forest will be replaced by grasses on some sites. These are areas of potential instability where forest erosion through fire and landslides can occur. This is predicted to produce localised sites of impact but over the entire project area the residual impact is expected to be minimal.

These sites only have a capacity to produce widespread major impacts if they act as foci to carry fire in dry years (**section 26.3.1**). Without mitigation the impact could be major. The mitigations aimed at promoting regeneration in difficult areas where regeneration may be slow is predicted to reduce the potential impact of fire to minimal.

Construction is likely to only temporarily disturb hydrology and then in limited areas and major habitat changes are not expected. Without mitigation the impacts on the swamp forest complexes and swamp woodland and forest complexes, in particular, could be major but with mitigations the residual impact is predicted to be low.

Overall the magnitude of the impacts before mitigation is therefore estimated to be low but negligible after. Considering the vegetation and flora of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of erosion, movement of soil and spoil, and changes to hydrology on vegetation and flora is predicted to be minimal.

26.1.4 Materials handling

Unless major spills occur, impacts from materials handling will be localised to construction and operations areas.

The magnitude of the impact of materials handling on flora before mitigation is therefore estimated to be low but negligible after. Considering the vegetation and flora of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of materials handling on vegetation and flora is predicted to be minimal.

26.1.5 Disposal of hydrotest fluid

Hydrotest fluid is unlikely to act like a weedkiller for terrestrial vascular plants.

The magnitude of the impact of disposal of hydrotest fluid on flora even without mitigation is estimated to be negligible. Considering the vegetation and flora of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of disposal of hydrotest fluid on vegetation and flora is predicted to be minimal.

26.1.6 Dust

It is predicted that dust will have minimal short term impacts on vegetation and flora.

The magnitude of the impact of dust on flora even without mitigation is estimated to be negligible. Considering the Vegetation and flora of the project area as a Category 1 conservation asset the overall significance after mitigation of the residual impact after mitigation of dust on vegetation and flora is predicted to be minimal.

26.2 Direct impacts on fauna

26.2.1 Habitat loss

So long as clearing does not propagate from the edge, long narrow clearings *per se.* are likely to have minimal impacts on fauna as the major effect of such clearings is likely to be through edge and barrier effects (**section 26.2.2**). Such linear clearings will rarely eliminate whole territories of primary forest specialist vertebrates.

The single patch of 31 ha to be cleared for the Juha Production Facility will eliminate some territories or ranges of many vertebrate species, including the larger arboreal marsupials like tree kangaroos and cuscuses. Areas of such size can be lost to landslides under natural circumstances and this loss of individual territories or ranges is not likely to eliminate a species from the bioregion or the project area. However, while regeneration starts within a year or so on landslides, it will not be allowed to happen for 30 years on the Juha Production Facility site. Maintaining the full pre-construction species complement at Juha until decommissioning requires that the vertebrate populations are not further stressed by extra clearing and/or hunting. In this respect, the mitigations designing to prohibit hunting by project staff, and restrict clearing (**sections 25.2.3 and 25.1.1**) are important.

Considering the discussion in **section 26.1.1**, the magnitude of the impact of habitat loss on fauna before mitigation is estimated to be low but negligible after. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of habitat loss on fauna is predicted to be minimal.

26.2.2 Edge and barrier effects

26.2.2.1 Edge effects

While the long, thin nature of the clearing for the ROWs and roads means that the impacts of forest loss on fauna is diminished, it produces an edge effect through long sections of forest. Sealing of the edge are likely to be rapid and edge effects diminish relatively quickly in volcanic areas, such as between the Maruba and Kondari Rivers, and alluvial areas but it will be slower in karst. However, edge effects over most of the ROW should start to ameliorate as the ROW starts to regenerate at the end of construction.

Experience with the oil project indicates that below about 1800 m asl edge effects are temporary and that the forest edge rapidly seals over in all habitats except the higher karst where cold conditions reduces growth rates.

A range of mitigations are designed to reduce damage to the ROW and road edges and therefore to reduce edge effects but the most important factor is the width of the pipeline construction disturbance area and the location of the ROW in relation to the logistics road. As indicated in **section 25.1.2.1**, wide gaps of 50 m and above, exposed edges, and damage to the edge all exacerbate and prolong edge effects. Considering that in most areas the pipeline construction disturbance area will be 35 m or less, that where they are in close proximity, roads and ROW will be offset, and that regeneration will be allowed and promoted over most of the ROW (**section 26.1.1**) the magnitude of the impact of edge effects on fauna before mitigation is estimated to be medium but negligible after mitigation in most areas and low in high altitude karst areas.

Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of edge effects on fauna is predicted to be minimal in most areas and moderate in high altitude karst areas.

26.2.2.2 Barrier effects

Where pipeline construction disturbance area is 35 m or less it is unlikely this will be a complete barrier to any vertebrate species in or likely to occur in the project area, especially as the ROW will be allowed to regenerate to 15 m after construction. Moreover, this 15 m will not be bare ground but simply kept free of tree canopy; leaf litter will accumulate in this gap and shrub and small tree growth will occur. Although some species may still be inhibited from crossing such gaps it is likely to be only a few and it is unlikely that inhibition will reach 100%. As an example the road systems of the existing oil and gas facilities have been used as the means of sampling vertebrates by scientists of WWF and elsewhere, and virtually all species have been recorded close to the edge or in the gaps at some stage; especially where the gaps are narrow, covered in leaf litter and shrubs, and little traversed by humans.

Thus the magnitude of the impact of barrier effects on most fauna before mitigation over most of the ROWs is estimated to be low but negligible after. However there are some species in some areas where the barrier effects may be more severe.

1. A range of arboreal mammals occurring at higher elevations, such as in the Hides Ridge Special Area, rarely if ever come to the ground and may have difficulties crossing the ROW unless there is a canopy connection across the gap.

-
2. The microhylid frogs at these upper elevations also may have difficulty crossing dry roads and it is possible that some terrestrial primary forest specialist mammal species may also be severely inhibited from crossing.
 3. In very rugged areas, high, wide cuts are necessary and the barrier effect will be intensified due to the extra width resulting from the cuts and the steep bare batters (**Plate 105**). This may prove difficult for many fauna species, particularly arboreal species, to negotiate. The barrier effect will be hard to mitigate at these cuttings.

The barrier effect in these areas, however, is, again, unlikely to be 100% i.e. capable of splitting a local population into two subpopulations. The high cuttings inevitably give way to less severe terrain and there will always be places where the ROW will be narrow enough to allow movements across it e.g. where the ROW passes through a saddle (**Plate 106 and 107**) or along a ridge. An examination of LIDAR topographic imagery in 2005 indicated there may be up to 40 saddles or ridges in the Hides Special Area where the ROW will be narrow enough to allow fauna movement once the forest edge regenerates.

In these special circumstances, the magnitude of the impact of barrier effects on fauna before mitigation is estimated to be high but medium after mitigation and regeneration of the ROW.

Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of barrier effects on fauna is predicted to be minimal for most areas and species, and moderate for arboreal species in high karst areas and for many species at high wide cuttings. None of these impacts are likely to eliminate any species or population from the project area, the KICDP area or any bioregion.

26.2.3 Physical damage and disturbance to caves

Mitigations for caves will probably reduce potential impacts on cave fauna to negligible levels. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of physical damage and disturbance to caves on bats is predicted to be minimal.

26.2.4 Fauna falling in the pipe trench

The death of some fauna in the pipe trench would be an animal welfare rather than a population dynamics issues and would have no conservation consequences. Rather than see the trench as a conservation problem it could be viewed as a scientific opportunity to increase knowledge of the KICDP area fauna (**section 25.1.4**).

The magnitude of the impact before mitigation of fauna falling in the pipe trench is estimated to be low but negligible after. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of fauna falling in the pipe trench is predicted to be minimal.

26.2.5 Erosion, movement of soil and spoil and changes to hydrology

In most areas sidecast will regenerate and stabilise so habitat loss and increased barrier effects produced by this phenomenon will ameliorate over the medium term. So long as grasses do not establish in these regenerating side slopes and thus increase the fire frequency probability then, overall, the magnitude of the impacts on fauna before mitigation is estimated to be low but negligible after.

Where barrier effects are enhanced in the special circumstances and the particular species discussed in **section 25.1.2.2** the impact on those fauna before mitigation is estimated to be high but medium after mitigation and regeneration of the ROW.

Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of erosion, movement of soils and spoil, and changes to hydrology on fauna is predicted to be minimal for most areas and species and moderate for arboreal species in high karst areas and for many species at high wide cuttings. None of these impacts are likely to eliminate any species or population from the project area, the KICDP area or any bioregion

26.2.6 Materials handling

Poor materials handling including catastrophic spills from fuel tankers have the potential to have a moderate and short-term impact on biodiversity but limited in extent.

Unless major spills occur, impacts on fauna from materials handling will be localised to construction and operations areas, limited in extent and short lived.

The magnitude of the impact of materials handling before mitigation is estimated to be low but negligible after mitigation. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of materials handling on fauna is predicted to be minimal.

26.2.7 Disposal of hydrotest fluids

As suggested in **section 25.1.7** ensuring that cross contamination of streams does not occur is more important than local losses of some amphibians.

Overall the magnitude of the impacts on fauna before mitigation is estimated to be negligible. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of hydrotest fluid on fauna is predicted to be minimal.

26.2.8 Dust

Dust is unlikely to be a major issue in this extremely high rainfall area. There is no prolonged dry season. Overall the magnitude of the impacts on fauna before mitigation is estimated to be negligible. Considering the Fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of dust on fauna is predicted to be minimal.

26.2.9 Loss of breeding and display grounds

Some bird-of-paradise display trees and sites will be lost to construction but considering the large areas of potential trees for display sites they are likely to be important but not a critical resource.

The magnitude of the impact of loss of breeding and display grounds before mitigation is estimated to be low but negligible after mitigation. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of loss of display and breeding grounds on fauna is predicted to be minimal.

26.2.10 Noise, lights and other disturbance

Any disturbance to fauna causing them to retreat from construction sites will be temporary and, as long as indirect impacts are controlled, fauna will return to the site.

The magnitude of the impact from noise, lights and other human disturbance before mitigation is estimated to be low but negligible after. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of noise and lights and other disturbance on fauna is predicted to be minimal.

26.2.11 Project traffic and other operations

With standard project traffic control and speed limit procedures, loss of fauna to project traffic and machinery operations is predicted to be minimal.

Overall the magnitude of the impacts on fauna before mitigation is estimated to be negligible. Considering the fauna of the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of project traffic on fauna is predicted to be minimal.

26.3 Indirect impacts on vegetation, flora and fauna

26.3.1 Fire

The length of the project footprint means that propagation of fire from points along the ROW has the potential to promote widespread ecosystem degradation over large areas of the project area and KICDP area should wildfire start and spread.

In some circumstances the ROW could act as a fire break and break the spread of fires from elsewhere in PNG travelling east west or vice versa. This could be a positive impact.

The magnitude of the potential impact of fire before mitigation is estimated to be high but low after. Considering the project area as a Category 1 conservation asset, the overall significance of the residual impact of fire on biodiversity is predicted to be moderate.

26.3.2 Pests, weeds and disease

The enormous amount of material to be imported, the project traffic, the big workforce, the length of the project footprint and the long period of construction activities presents a unique opportunity for exotic weeds and fauna and introduced and native diseases, like dieback, to invade and spread. Unmitigated, the magnitude of the impact of invasions of weeds and exotic fauna and other pests would be very high and, likewise with diseases, the spread of dieback in *Nothofagus* dominated forests or of an exotic plant disease in forests in general has the potential to generate a very high impact if unmitigated

Considering the project area as a Category 1 conservation asset the significance of potential impacts without mitigations in this category would be major and likely to be of national significance.

Rigorous quarantine procedures and control on personnel movements and behaviour as suggested in **section 25.2.2.4**, if enforced with sufficient resources, could reduce the magnitude of residual impacts to low and the overall significance of the residual impact after mitigation to moderate.

26.3.3 Hunting by PNG LNG Project staff and contractors

Implementation of hunting bans and bans on possession of wildlife products by project personnel and contractors, including all pioneer and survey personnel, should eliminate all hunting by PNG LNG Project staff and contractors.

Thus while the magnitude of the overall potential impact of hunting by PNG LNG Project staff and contractors before mitigation is estimated to be medium it is estimated to be negligible after. Considering the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of hunting by project staff is predicted to be minimal.

26.3.4 Hunting by non – project personnel

Extra hunting by others would only come about if access was permitted along the PNG LNG Project infrastructure. The potential magnitude of the impact on fauna could be high without mitigation but if mitigations aimed at controlling access to the project area are implemented (**section 25.2.5**) the residual impact could be reduced to low. Considering the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of hunting by non-project personnel is predicted to be moderate.

26.3.5 Collection of flora by PNG LNG Project workers and contractors

While the magnitude of the overall potential impact of collecting flora by PNG LNG Project staff and contractors before mitigation is estimated to be low it is estimated to be negligible after. Considering the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of flora collection by project staff is predicted to be minimal.

26.3.6 Collection of flora by non – project personnel

Extra collecting by others would only come about if access was permitted along the PNG LNG Project infrastructure (**section 25.2.5**).

The potential magnitude of the impact on flora could be moderate without mitigation but if mitigations aimed at controlling access to the project area (**section 26.3.7**) are implemented the residual impact could be reduced to negligible. Considering the project area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of flora collection by non-project personnel is predicted to be minimal.

26.3.7 Increased access to the project area

Unless public access to the project area is controlled by keeping all newly constructed project roads private the potential magnitude of the impact is likely to be very high. Without control of the roads the procedures to minimise impacts of fires, weeds and exotic fauna will be negated by the activities of non - project personnel to whom the procedures do not apply.

Thus considering the project area as a Category 1 conservation asset, the overall significance of the impact if not mitigated is predicted to be major.

If the roads remain private and controlled the overall magnitude of impact could be reduced to low and the overall residual impacts to moderate. If they are opened to the public the eventual impact will remain as major and exacerbate all the other indirect impacts.

27 Significance of impacts on special areas

27.1 Special area 1: The Juha Area

The direct impacts discussed above are unlikely to operate any more severely in the isolated and pristine Juha Area than elsewhere in the project area, except for the fact that the habitats, flora and faunal populations are in superlative condition. Unmitigated, the magnitude of the direct impacts in this area could be medium and considering that this area is a Category 1 conservation asset, the overall significance of the impact without mitigation would be moderate. Once mitigated, however, the impact magnitude could be reduced to negligible and the significance of the residual impact to minimal.

However the major potential impact of the PNG LNG Project will be through reducing the isolation of the area and the protection it engenders which will allow indirect impacts to possibly manifest i.e. wildfire, pests, weeds and diseases, hunting, and increased access. These indirect impacts have the potential to destroy the area's biodiversity and ecological characteristics. If unmitigated the severity of all indirect impacts could be Very High and the significance of the impact Major.

The keys to reducing residual impacts in this area to acceptable levels are the plans related to quarantine and access control and control of the PNG LNG Projects' workforce. If these are effectively implemented the magnitude of indirect impacts could be reduced to low or negligible and the significance of the residual impacts after mitigation to low or minimal.

27.2 Special area 2: Hides Ridge Special Area

Without mitigation the magnitude of direct impacts from construction in this special area has the potential to be very high and considering that this area is a Category 1 conservation asset, the overall significance of the impact before mitigation would be major. With the special mitigations focussed on reducing construction footprints, damage to the forest edge, materials handling, strict control of the workforce, and quarantine, the magnitude of the residual direct impacts of construction in this area could be reduced to low and the significance of the residual impact after mitigation to moderate.

Indirect impacts are the most significant to this special area. Invasion by weeds or exotic pest fauna, the spread of dieback, over-hunting by non-project personnel and assisting the spread of logging and deforestation could produce very high magnitude impact and therefore be of major significance. Mitigations aimed at controlling access to this special area, good quarantine plans and developing a fire management plan are expected to reduce the probability of these events occurring to low levels. The residual impact is therefore considered likely to be of low magnitude and therefore of moderate significance.

27.3 Special area 3: High-altitude forest above 1800 m on the Homa Deviation

This area is not as sensitive as Hides Ridge, being located on better soils. The forests are in superlative condition and free of weeds. It is close to Benaria and the walking track from Homa to Benaria passes through it. It is an area where revegetation could be focussed and special efforts made to control side cast.

Unmitigated, the magnitude of direct impacts may be medium and indirect impacts very high but mitigations could reduce these to negligible for direct and low for indirect impacts. The significance of the residual impacts after mitigation would be minimal for direct and moderate for indirect impacts.

28 Significance of impacts on focal habitats

28.1 Caves

Unmitigated, the magnitude of direct and indirect impacts may be high. The mitigations for caves aim to identify whether significant caves occur near to the works and then to implement mitigations dependent upon the proximity of the cave and the species that inhabit it. When added to other mitigations to control workers and contractors disturbing caves, to control blasting near caves and to avoid locating quarries near caves there is a suite of measures which should reduce magnitude of direct and indirect impacts to low.

Considering caves are a Category 2 conservation asset the significance of residual direct and indirect impacts after mitigation are likely to be minimal.

28.2 Sinkhole swamps

Potential impacts on swamps in shallow sinkholes (< 50 m vertical depth) are predicted to be highest in the Hides Ridge Special Area. The impact is difficult to mitigate safely and effectively and the construction will result in some shallow sinkholes being impacted. An examination of LIDAR topographic imagery indicates there may be up to 2 sinkholes or dolines per kilometre within 100 m of the Hides Spine line and that may be impacted by spoil sidecast i.e. approximately 40. Not all of these will contain sinkhole swamps and not all will be impacted.

An estimate was made of the total sinkholes and dolines in a 50 km² area, approximately five km wide centred on the Hides Spine line above 1800 m asl. Dolines and sinkholes were counted in five one km² quadrats randomly placed on the LIDAR topographic maps of the area. The mean number of dolines and sinkholes per quadrat was 11.6 with a 95% confidence interval of 3.355. This gives an estimate of dolines and sinkholes in the 50 km² area of between 410 and 745. Thus between 5% and 9% of the dolines and sinkholes in this area are likely to be impacted.

Sinkhole swamps likely form by the plugging of the drainage holes in sinkholes or the inhibition of drainage through the limestone at the bottom of dolines as a result of organic matter and silt being washed into the depressions. This process may be mimicked by sidecast washing down to the bottoms of dolines and sinkholes. As well as destroying sinkhole swamps this process may also help create them.

Considering the fraction of sinkholes that will be impacted, the large areas of sinkholes and dolines on the nearby Karius Range and in the ranges to the northwest, the overall magnitude of impacts before mitigation is likely to be moderate but low after mitigation that aims to protect them.

Sinkhole swamps are a Category 2 conservation asset so the significance of the residual impacts is likely to be low.

Indirect impacts will act on these habitats like any other in the PNG LNG upstream project area and invasive weeds, pests and diseases are likely to be the major potential impactors. Given the mitigations proposed the likely significance of the residual impacts after mitigation is low.

28.3 Upland streams

Protection of the heads of upland streams is meant to protect their amphibian communities. The potential magnitude of impacts could be high but if stream heads above 1800 m can be kept free of silt then this could be reduced to low.

Upland streams are a Category 2 conservation asset so the significance of residual direct impacts after mitigation is likely to be low.

Indirect impacts will act on these habitats like any other in the PNG LNG upstream project area and fire and invasive weeds, pests and diseases are likely to be the major potential impactors. Given the mitigations proposed this could be reduced to low and the likely significance of any residual impacts after mitigation to low.

28.4 Swamp forest

Swamp forest complexes and Swamp woodland and forest complexes will be cleared near Lake Kutubu and in the Kikori Crossing to Omati section of the ROW. The magnitude of the direct impacts is predicted to be initially medium and limited in extent. It is predicted that rapid growth rates of vegetation and mitigations will reduce the residual magnitude to low. These forests are a Category 2 conservation asset so the significance of direct impacts before mitigation is predicted to be moderate and low after mitigations.

Indirect impacts could be more severe and a wildfire burning the substrates in dry year and/or the introduction of a vigorous exotic weed species could have very high magnitude impacts but mitigations could reduce this to low and the likely significance of any residual impacts after mitigation to low.

No changes to the overall occurrence of these BVGs is likely.

28.5 Stream refuges in unstable landscapes

In the Baia River area the heads of streams and the associated forests need protection during construction. It is likely that these areas co-occur with the more stable areas suitable for construction and it may not be possible to mitigate their loss.

The magnitude of the impact is likely to be high before and medium after mitigation. Stream Refuges in unstable landscapes are a Category 2 conservation asset so the significance of residual direct impacts after mitigation are likely to be moderate.

Indirect impacts could be more severe. A wildfire burning the refuges in a dry year and/or the introduction of a vigorous exotic weed species, and/or increasing hunting could have very high magnitude impacts in these refuges, but mitigations could reduce this to low and the significance of any residual impact after mitigation to low.

28.6 Lowland rivers in stable landscapes

While rivers are a special habitat none of the specialist reports suggested major mitigations are required at the smaller pipeline crossing points, where some loss of riparian vegetation will occur. However, at the crossing points of large rivers where horizontal directional drilling is required the areas needed for operations will be set back from the rivers so the riverine vegetation will only be disturbed at the access track crossings.

The magnitude of the direct impacts is predicted to be initially medium and limited in extent. It is predicted that rapid growth rates of vegetation and hydrological mitigations will reduce the residual magnitude to negligible. Considering these rivers are a Category 2 conservation asset, so the significance of residual direct and indirect impacts after mitigation are likely to be minimal.

28.7 Off river water bodies

There are probably numerous off river water bodies along the major rivers in the lowlands and the loss of one or two at the main crossing points is likely to produce an impact of low magnitude. At the Baia River where these water bodies are known to occur the impact may be of medium magnitude because of the instability of this landscape. Should a water body be destroyed and another constructed in its place, the magnitude of the impact could be reduced to negligible.

Off river water bodies are a Category 2 conservation asset so the significance of residual direct impacts after mitigation is likely to be minimal.

Indirect impacts could be more severe. A wildfire burning the refuges in a dry year and/or the introduction of a vigorous exotic weed species, and/or increasing hunting could have very high magnitude impacts in these refuges, but mitigations could reduce this to low and the significance of any residual impact after mitigation to low.

29 Significance of impacts on conservation areas

29.1 KICDP area

The significance of impacts within the KICDP area will be virtually the same as those for the project area with the exception that the percentage of vegetation lost will be slightly increased because the KICDP has a smaller area. Losses of vegetation within the KICDP are presented in **Table 28** and, as for the project area, no BVG within the KICDP area will lose more than a quarter of a percent of its area¹⁹. With the regeneration that will be allowed on the ROWs and construction areas these losses will be rapidly regained.

Overall it is estimated that direct impacts on the KICDP before mitigations would be of moderate magnitude and low to negligible after mitigation. Being a Category 1 conservation asset (**Table 34**), the overall significance of residual direct impacts after mitigation is predicted to be low to minimal.

As for the project area the most important impacts to mitigate are indirect impacts. Introduction of a vigorous weed, disease or pest, a major wildfire or improved access leading to widespread forest degradation or conversion could have system wide impacts within the KICDP. The KICDP was originally set up to manage potential indirect impacts and the need for the areas continuing active management will be even more necessary with the arrival of the PNG LNG Project.

Unmitigated indirect impacts could have a very high magnitude and in this category 1 conservation asset the impact would be of major significance. With the many mitigations designed to reduce the likelihood of indirect impacts, the magnitude could be reduced to low and the significance of residual indirect impacts after mitigation are likely to be moderate.

29.2 Wildlife Management Areas

The Kutubu WMA is the only WMA that the project footprint intersects and where direct impacts will occur. The other four WMAs (Neiru/Aird Hills, Libano-Arisai, Libano-Hose and Sulamesi) are distant from the project footprint and no direct impacts are expected.

Table 31 presents estimated vegetation losses in the Lake Kutubu WMA. Approximately one third of a percent of the WMAs terrestrial habitats will be lost and up to 2.28% of the WMA's lower montane small crowned forest. With the ROW allowed to regenerate for half its width these losses will be regained rapidly and if there are no WMA wide impacts there should be no species losses from the WMA.

¹⁹ Calculating the total area of the KICDP is not straightforward as there was no GIS layer available to make the calculation. A figure of 2.3 million hectares was obtained from a joint publication of WWF and Chevron but an area digitized for the PNG Project EIS based on the Kikori catchment boundary gave a smaller figure. The WWF figure is an estimate only and is believed to include some areas towards the Doma Peaks in Enga Province that are outside the catchment but included by WWF for convenience. For the calculation here the digitized southern boundary of the KICDP was refined to match the complex delta topography in the FIMS data so the area in the tables differs slightly from those in the PNG Gas Project GIS.

Overall, it is estimated that direct impacts before mitigations on the Kutubu WMA would be of moderate magnitude and low to negligible after mitigation. Being a Category 1 conservation asset (**Table 34**), the overall significance of residual direct impacts after mitigation is predicted to be low to minimal.

As for the KICDP area, unmitigated indirect impacts have a far greater potential to impact on the Kutubu WMA. In the case of the possible introduction of weeds, pests and pathogens, aquatic species have to be considered as very significant because the conservation of Lake Kutubu is the central rationale for the WMAs existence. In this respect also the swamp forests form a critical part of the lake ecosystems and need to be protected from wildfires.

Indirect impacts within the project Area have the potential to impact on the other four WMAs that will be free from any direct impacts. As for the KICDP area, wildfire management, quarantine and the control of access along the PNG LNG Project infrastructure are the fundamental mitigations that will be used to manage any indirect impacts on the WMAs.

The WMAs are all category 1 conservation assets and unmitigated indirect impacts could have a very high magnitude and be of major significance. With the many mitigations designed to reduce the likelihood of indirect impacts, the magnitude could be reduced to low and the significance of residual indirect impacts after mitigation are likely to be moderate.

29.3 WWF significant biological areas

Predicted vegetation losses in the WWF significant biological areas is given in **Table 32**. Five of the areas, Upper Seribi River and Lubu River, Mount Bosavi, Darai Plateau, Blind Fish habitat, and Mt Sisa, will receive no direct impacts, and the vegetation losses in six of the remainder is less than half a percent. Only in the Agogo and Iwa Ranges significant biological area do the losses approach 1%.

In two of the impacted areas, Utiti Creek and Kantobo/Wassi Falls & Gobi karst ridge system, there will be no loss of either old growth (A1) or disturbed old growth (A2). However, the bulk of predicted losses in the Agogo and Iwa Ranges significant biological area are old growth (A1) and disturbed old growth (A2).

These vegetation losses are highly unlikely to lead to any extinctions or diminution of fauna or flora populations in any significant biological area but the losses of old growth and disturbed old growth in the Agogo and Iwa Ranges significant biological area need to be considered in the context that this significant biological area also hosts the oil facilities and infrastructure. The losses from the PNG LNG Project are in addition to what losses have already occurred from hydrocarbon resource development, but the PNG LNG Project mitigation of allowing the ROW to grow back to 15 m in the short term means that only 50 ha (0.15%) will remain clear until project decommissioning 30 years later, and this “clear” area will have leaf litter and probably a shrub layer developed on it.

Of the six WWF significant biological areas that the PNG LNG Project intersects for all but the Agogo and Iwa Ranges area it is estimated that overall direct impacts before mitigations would be of low magnitude and negligible after. Being Category 2 conservation assets, the overall significance of residual direct impacts after mitigation is predicted to be minimal.

For the Agogo and Iwa Ranges direct impacts may be of a higher magnitude approaching medium. However, experience with the oil project indicates biodiversity conservation values remain unchanged in the Agogo and Iwa Ranges so the magnitude of residual direct impacts after mitigation are predicted to be low. Nonetheless, it is suggested that WWF be encouraged or supported to monitor biodiversity within this WWF significant biological area, since it is at the heart of hydrocarbon developments and its continued health will be a litmus test of the biodiversity performance of the PNG LNG project.

Unmitigated, indirect impacts have a much greater potential to impact on the WWF significant biological areas. Possible introduction of weeds, pests and pathogens could immediately impact on the core set of WWF significant areas along the pipeline routes and eventually reach those WWF significant biological areas on the periphery of the project area that escaped any initial direct impact.

As for the WMAs and the KICDP area as a whole, the control of wildfire initiation, quarantine, and the control of access along the PNG LNG Project infrastructure are fundamental mitigations required to manage any indirect impacts on the WWF significant biological areas.

The significant biological areas are all Category 2 conservation assets and unmitigated indirect impacts could have a very high magnitude and be of major significance. With the mitigations designed to reduce the likelihood of indirect impacts the magnitude of the impacts could be reduced to low and the significance of any residual indirect impacts after mitigation would be low.

30 Predicted significance of impacts on listed species

Impact analysis on all listed species is presented in **Appendix 13** and this section provides background summaries to the analysis.

In **Appendix 13** the unmitigated impact of wildfire, dieback and invasion of exotic weeds and fauna on every species is considered to be major or moderate because these impacts have the potential for large scale or ecosystem wide effects that would impact a large part of a species' range in the project area

For species that are prime targets for hunting, indirect impacts brought about by improving access are major issues. It is assumed control of roads and access will be effective, so, in most cases, the residual significance of this impact is considered to be negligible for most species other than the largest and most valuable to hunters. For the latter it is assumed the keenness to acquire the animals will likely render mitigations less than 100% effective so the residual is considered to be low.

30.1 Critically endangered species

1. Large Leptomys (*Leptomys elegans*) There are museum specimens of this rare carnivorous rat from Mt Sisa and it has been collected by WWF at Wassi Falls. Records without voucher specimens come from Iagifu, Juha South and South Karius. The species is also recorded from Mt Victory in Northern province and several montane localities in Central Province (Musser *et al.* 2008)

Its status as critically endangered is the result of its rarity but it can be locally common and has been caught in secondary growth (Flannery 1995). According to Dwyer (1984) "It is known to invade gardens that are returning to brush about ten years after abandonment, and persisting as viable populations thereafter". This indicates that the residual significance of forest clearing during construction impacts will be minimal and that it will be able to cross the scrubby vegetated gaps of the ROW easily. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce the residual significance of the impact to minimal. The species is too small to hunt so the significance of the residual indirect impact of hunting after mitigation is also likely to be minimal.

2. Fly River Leptomys (*Leptomys signatus*) Prior to the WWF surveys this rat was only known from one locality in the Fly River. It has since been found on the Darai Plateau although the skulls have not been confirmed as *L. signatus* yet (Leary 2004, Musser *et al.* 2008). There are specimens of this species from Mt Bosavi in the Bishop Museum and it could occur elsewhere in the project area. Its biology is unknown but the Fly River specimens were caught in bamboo overlooking a tidal section of river within a complex of swamp forest, rainforest and mangroves, while the Darai animals were from a drainage line in rainforest. The fact that all the other species of *Leptomys* survive in secondary forest and garden regrowth combined with the mosaic nature of the Fly river specimens' habitats suggested this species is not a forest interior specialist and probably, like *L. elegans* may survive in secondary vegetation. Neither the Darai Plateau nor Bosavi populations of this very poorly known species are approached by the PNG LNG project.

If any populations occur in the lower Kikori swamp forests they are likely to be little impacted by the clearing for the PNG LNG Project and the residual significance of direct

impacts during construction will be minimal. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce the residual significance of any impact to minimal. The species is too small to hunt so the significance of any residual indirect impact of hunting after mitigation is also likely to be minimal.

3. Large Pogonomelomys (*Pogonomelomys bruijnii*) There are museum specimens of this rat from Mt Sisa. This population will not be impacted at all by the PNG LNG Project which has no components at Mt Sisa. The species could occur elsewhere in higher regions of the project area. It can tolerate some degree of disturbance and the residual significance of direct impacts during construction will be minimal should any populations occur along the ROWs or facility areas. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce the residual significance of the impact to minimal. The species is too small to hunt so the significance of the residual indirect impact of hunting after mitigation is also likely to be minimal.

4. Bulmer's Fruit-bat (*Aproteles bulmerae*) This cave-dependent flying fox was originally described from subfossil material in an archaeological dig at 1530 m. asl at the Kiowa rock shelter, 2 km east of Chauve Government Station, Chimbu Province in layers dated between 10,000 and 11,000 years before present. Menzies (1977) described the species from 200 skulls which were "kitchen waste" in a human occupation site in a small entrance to a large limestone cave complex. Living animals were subsequently discovered in 1975 in the Hindenburg Wall area in Luplupwintem cave, at an altitude of 2400 m. Luplupwintem is close to the main walking track between Tabubil, the Ok Tedi mine and Telefomin (Flannery 1995).

In 1975, thousands of bats were present at Luplupwintem but in 1977 only two bats were seen (Hyndman and Menzies 1977). Local informants advised that several groups of hunters entered the cave and virtually eliminated the colony. The cave has a 100 m drop at the entry, so hunters were keen enough to use ropes to get to their prey. A small number of bats were again resident in Luplupwintem in 1992 (Flannery and Seri 1993).

This colony, another that is now "extinct or dislocated" (Bonaccorso 1998), and one that was discovered several years ago in the Central Highlands, are the only known colonies of this species worldwide.

In the 2005 survey it was suggested that an undiscovered colony could occur in large caves in the higher karst areas of the project area such as on the Hides Ridge (**Annex 05**). During the 2008 survey a resident of Angore village described what may be a colony of Bulmer's Fruit-Bat (**Annex 06**). This anecdotal evidence is strong enough to warrant investigations in the Angore area so it is suggested that it be determined as to whether a colony really exists, and, if so, to develop a special management plan for the cave. Accordingly a specific mitigation has been devised viz.

- Investigate potential Bulmer's Fruit-bat colony near Angore and design and implement a management plan should a colony be found near Angore or elsewhere in the project area.

If a colony of this species does exist, mitigations to protect caves from direct physical impacts by project disturbance control of PNG LNG Project workers and mitigations to address improved access to the project area will likely result in the significance of any residual direct or indirect impacts to minimal and low respectively.

5. *Pharotis imogene* This species is a member of the long-eared bat group, which generally forage by gleaning prey from substrates such as bark or leaves, and for this purpose, they have short, broad wings that allow slow and manoeuvrable flight. The characteristic long ears allow these bats to listen for insect calls so that they can localize potential prey, and they sometimes do this without using echolocation (Hosken *et al* 1994).

G. Richards (**Annex 06**) presents a detailed account of the complex history of discovery of this enigmatic species and suggests that it is most likely extinct. It is only known 500 km east of the project area (**Annexes 05 and 06**) in savannah and mangroves. Very little is known about the biology and ecology of *P. imogene*, however, in view of the fact that 45 specimens have been collected at the one site it is believed the species roosts and has maternity colonies in large tree hollows.

In the unlikely event that it exists in the project area, the narrow corridor of the gas pipelines would doubtfully have an impact upon any local population of the species.

If colonies exist, they are likely to be in tree hollows and may be disturbed if the tree is felled so careful felling of trees that contain hollows is generally recommended for such species. A technique has been developed to reduce damage to bat roosts in tree holes in savannas whereby machinery is used to gently lower trees. This is not feasible in rainforest where trees are close together and connected to each other with climbers. Pushing trees with bulldozers in rainforest tends to bring down several trees together in a tangle. In such cases tree holes can be easily obstructed by vines and vegetation, trapping the bat colony inside.

The following mitigation which aims to reduce damage to trees off the ROW will be effective in reducing impacts on any putative colony of this species that may occur.

- Where trees are to be felled by hand, use directional felling for trees > 50 cm dbh so they land in natural slots between standing trees or along the axis of tracks to reduce damage.

With this protocol, there is then a greater chance of the tree hole remaining unobstructed thus allowing escape of the bats. This would preclude the need for the type of trapping program recommended by Bonaccorso (1998) and the IUCN during their 2005 Global Mammal Assessment.

This should reduce the significance of any putative residual direct impacts after mitigation to minimal. The species is too small to hunt so the significance of the residual indirect impact of hunting after mitigation will be minimal also.

6. *Papuan Whiptail* this is the only critically endangered bird that could occur in the project area. It is a primary forest species known only from high altitudes in the Snow Mountains and westwards but may extend into the northern part of the project area. Impacts would manifest via clearing and possible edge and barrier effects. The species is not hunted. The mitigations suggested for the high altitude special areas would reduce the significance of any residual direct and indirect impacts after mitigation to minimal.

7. *Halfordia papuana* This tree was recorded at the Hides 3 survey area. According to Takeuchi (**Annex 01**) this species is “moderately common in montane habitats examined by the survey”. A communication from W. Takeuchi (to F. Crome 28/07/05) states

“I do not think particular emphasis needs to be placed on *Halfordia* as a conservation asset. In my opinion, the current IUCN ranking is primarily due to taxonomic confusion more than actual rarity”.

Considering this, the significance of any residual direct or indirect impacts after mitigation are likely to be minimal.

30.2 Endangered species

1. Long-beaked Echidna (*Zaglossus bartoni*) This echidna is threatened by hunting rather than habitat loss. Individuals could perish if they fall into the open pipe trench. Mitigation and by assisting escape from the trench will reduce direct impacts to minimal. After mitigation direct impacts will have a minimal residual significance as a whole in the project area. The indirect impact of hunting brought about by improving access to the project area could cause local reductions of the species but the significance of any residual impacts after mitigation could be reduced to minimal.

2. Goodfellow's Tree Kangaroo (*Dendrolagus goodfellowi*) As a group tree kangaroos cope with moderate, sometimes high, amounts of forest disturbance and it is likely to be widely distributed within the project area, so forest loss and disturbance by the PNG LNG Project is unlikely to impact heavily on this species. All species often travel on the ground and are able to cross wide forest gaps. This tree kangaroo is endangered through over-hunting and the magnitude of the indirect impact of hunting brought about by improving access to the project area could be major and easily cause local extinctions of the species because of the popularity of this species as prey. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

3. Greater Small-toothed Rat (*Macruromys major*) This is a rare rodent confined to mid altitudes but widely distributed in New Guinea. It's habits and sensitivities are unknown but it's wide distribution suggests the significance of even unmitigated direct impacts through forest disturbance will be low for this species. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce local impacts to minimal. The species is too small to hunt so the indirect impact of hunting brought about by improving access to the project area is also likely to be minimal. The significance of other residual indirect impacts after mitigation are likely to be minimal.

4. *Bleesdalea papuana* According to Takeuchi (**Annex 01**) “The tree is a presumed Gondwanic relict supposedly restricted to a small number of localities in northern New Guinea (Smith & Haas 1975). The survey collection is the first from the Papuan side. The discovery of *Bleesdalea* on the Kutubu karst represents a biogeographically significant record”. The species was located on an abandoned village site at the top of a ridge near Benaria camp. Considering its capacity to grow in disturbed and previously cleared areas the significance of even unmitigated direct impacts are likely to be minimal. Accidental introduction of an exotic weed could impact on this species but mitigations through quarantine plans could reduce the likelihood of the introduction of such a weed to low levels. The significance of other residual indirect impacts after mitigation are likely to be minimal.

5. *Flindersia pimenteliana* F.v.M Five species of *Flindersia* in New Guinea area commercial timbers, of which four are IUCN-listed, *F. pimenteliana* is distributed from the

Vogelkop Peninsula to Milne Bay Province and, after the 2008 survey, the Western Province (**Annex 02**). This species is classified because it is a logging target. In North Queensland it was an important commercial species until logging terminated in the late 1980s and it is still a very common species, indicating good tolerance to very heavy logging pressure (F. Crome *pers. obs.*). The significance of other residual indirect impacts after mitigation are likely to be minimal.

30.3 Vulnerable species

1. New Guinea Quoll (*Dasyurus albopunctatus*) This species is tolerant of some habitat disturbance. It is declining around villages and settled areas in New Guinea, however, and the reasons for the decline are unknown. Other species of quolls that occur in Australia are declining because of habitat loss, predation, competition by dogs, cats and foxes and, possibly, disease. It is unlikely that construction of the long, narrow linear infrastructure will eliminate any quoll territories and they are able to cross roads and gaps readily. It is likely to be widely distributed within the project area, so the significance of even unmitigated direct impacts from clearing are likely to be minimal. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce the significance of local impacts to minimal. Moderate indirect impacts if unmitigated could occur by wildfires destroying habitat and disease introduction resulting in local declines, which would result in a potential residual significance of low. Control of indirect impact sources could reduce the significance of any residual indirect impacts after mitigation to minimal.

2. Stein's Cuscus (*Phalanger vestitus*) Most species of cuscus are tolerant of forest disturbance and often forage in secondary areas, this species is likely to be widely distributed within the project area, so the significance of direct impacts after mitigation are likely to be minimal. This species is threatened by hunting. The indirect impact of hunting brought about by improving access to the project area could easily cause local extinctions of the species because of the popularity of this species as prey. The significance of the impact without mitigation could be moderate but mitigations listed under **section 25.2.5** and banning hunting by PNG LNG Project workers could reduce the significance of any residual indirect impacts after mitigation to minimal.

3. Doria's Tree-Kangaroo (*Dendrolagus dorianus*) This species is threatened by hunting. As a group, tree kangaroos cope with moderate, sometimes high, amounts of forest disturbance and this species it is likely to be widely distributed within the project area. All species often travel on the ground and are able to cross wide forest gaps. The significance after mitigation of the impact of forest loss and disturbance by the PNG LNG Project is unlikely to be minimal. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce the significance of local impacts to minimal. This tree kangaroo is endangered through over-hunting and the magnitude of the indirect impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species because of the popularity of this species as prey. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

4. Macleay's Dorcopsis (*Dorcopsulus macleayi*) This tiny terrestrial wallaby is restricted to a narrow altitudinal zone of 1000 m to 1800 m asl and was recorded at the Deviation Camp area. Individuals could perish if they fall into the open pipe trench but mitigation by

assisting escape from the trench will reduce the residual significance after mitigation to minimal. The long narrow areas of habitat lost through clearing for the ROW are likely to present a low magnitude of impact but in areas where the clearing exceeds 35 m a barrier effect is likely until the ROW edges regenerate to a good bush cover, and in these situations a moderate impact magnitude is likely. The barrier effect can only be mitigated with time. The indirect impact of hunting brought about by improving access to the project area could easily cause local extinctions of the species and the residual significance of any indirect impacts after mitigations listed under **section 25.2.5** would be moderate.

5. New Guinea Pademelon (*Thylogale browni*) This is a medium sized terrestrial wallaby reported from the Juha area. It is a widespread, common species and prefers disturbed habitats and the residual significance of direct impacts after mitigation are predicted to be minimal. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce the significance of local impacts to minimal. It suffers heavily from hunting and the magnitude of the indirect impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species because of the popularity of this species as prey. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

6. Plush-coated Ringtail (*Pseudochirops corinnae*) This species is threatened by hunting and is also potentially impacted by barrier effects at high cuttings on the Hides Ridge and near the Deviation Camp area. In areas where steep cuttings occur the magnitude of the barrier effect will be high, but with mitigations that allow regeneration of the ROWs the residual significance of the direct impacts is likely to be low. The magnitude of indirect impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

7. Great Tailed Triok (*Dactylopsila magalura*) This is one of the rarer mammals of New Guinea and is poorly known but there is a hunter record from Mt Sisa. It is known to be hunted and may prefer old growth forest. The Mt Sisa population does not occur within the PNG LNG project footprint. The residual significance after mitigation of direct impacts through habitat loss are likely to be minimal but hunting could increase after improving access to the project area and easily cause local extinctions of the species. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

8. One-toothed Shrew Mouse (*Mayeremys ellermani*) This is a rodent restricted to high altitude mossy forests and there are three records from local information in the project area at Hides, Homa-Idauwi and the Deviation Camp. This rodent is rare, but widely distributed, in New Guinea and has been caught in the vicinity of villages suggesting the residual significance of direct impacts by forest disturbance will be minimal. Individuals could perish if they fall into the open pipe trench but mitigation by assisting escape from the trench will reduce the residual significance of impacts to minimal. The species is too small to hunt so the residual impact of hunting after mitigation brought about by improving access to the

project area is also likely to be minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

9. Lesser Tube-nosed Bat (*Nyctimene draconila*) This is a frugivorous species associated with freshwater swamps and rivers in the lowlands (< 100 m asl). It roosts individually or in small groups under leaves. Any individuals disturbed by falling trees will relocate to new roost sites. Since extensive vegetation clearance is not required for the pipeline within the range of this coastal species the significance of direct impacts, even unmitigated, are likely to be minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

10. Moss-forest Blossom Bat (*Syconycteris hobbit*) This species has not been recorded in the project area yet but could occur. It is a nectar feeding species that roosts individually or in small groups under leaves and in pandanus. Any individuals disturbed by falling trees will relocate to new roost sites. Since extensive vegetation clearance is not required for the pipeline within the range of this coastal species the significance of direct impacts, even unmitigated, are likely to be minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

11. Large-eared Sheath-tailed Bat (*Emballonura diana*) and New Guinea Sheath-tailed Bat (*E. furax*) These species roost in the twilight zone of caves. They are considered to be rare but this may be an artefact of past survey methodology because calls attributed to these species were frequently recorded during the 2005 and 2008 surveys. Mitigations aimed at limiting disturbance to caves will limit the residual significance after mitigation of direct impacts on these species to minimal levels. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

12. Papuan Sheath-tailed Bat (*Saccolaimus mixtus*) This lowland species has only been recorded below 100 m asl and has not been recorded in the project area yet but could occur. It appears to be a high and fast flying species that would have an extensive foraging range and would not be impacted by the narrow pipeline corridor, but colonies roosting in tree hollows may be impacted during vegetation clearance. Some colonies may be lost by being trapped in tree hollows after trees are felled but the loss of one or a few colonies is unlikely to impact on the species as a whole. The mitigation of directional felling will assist in reducing any such losses. Any individuals disturbed by falling trees will relocate to new roost sites and the residual significance after mitigation of direct impacts on the species will be minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If

hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

13. Telefomin Leaf-nosed Bat (*Hipposideros corynolophus*) Very little is known about this species apart from its use of caves as day roosts: “It seems to be particularly common in deep caves at 1600 to 1800 m elevation” (Flannery 1995). It has a very restricted distribution, being found only at five localities in the Telefomin area, Sandaun Province. Flannery (*op.cit.*) mentions another specimen from Irian Jaya but considers this identification to be tentative. Bonaccorso (1998) extends the elevational range to 1400 – 1800 m. This species has not been recorded in the project area yet but could occur. Should it do so, mitigations for cave disturbance and indirect impacts, are likely to result in the significance of any residual direct or indirect impacts after mitigation to minimal.

14. Fly River Leaf-nosed Bat (*Hipposideros muscinus*) This species has not been recorded in the project area yet but could occur. This is a cave dwelling species known only from below 600 m asl. It is likely to be impacted by cave disturbance but mitigations aimed at limiting disturbance to caves will result in residual significance of direct impacts to minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts is likely to be minimal.

15. Small-toothed Big-eared Bat (*Nyctophilus microdon*) This bat is found only at high altitudes and from few localities but its rarity may be an artefact of survey methodology. It is unlikely to be impacted by pipeline construction as individuals have extensive foraging ranges, but colonies roosting in tree hollows may be lost during vegetation clearance. Tree falls are a normal part of forest dynamics and the colonies are likely to relocate to new trees. Some colonies may be lost by being trapped in tree hollows after trees are felled but the loss of one or a few colonies is unlikely to impact on the species as a whole. The mitigation of directional felling will assist in reducing any such losses. The significance of residual direct impacts of the PNG LNG Project on this species after mitigation are likely to be minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

16. Greater Big-eared Bat (*Nyctophilus timoriensis*) This species has not been recorded in the project area yet but could occur. It is a species of sclerophyll forest and woodland in Australia, and apparently also mid-montane forests to 1600m in New Guinea. Most Australian *Nyctophilus* that inhabit rainforest roost in tree hollows or dense foliage such as epiphytic ferns, a resource that is unlikely to be significantly reduced by the pipeline construction. The significance of residual direct impacts after mitigation on this species, if it occurs, are likely to be minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the

mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

17. Fly River Trumpet-eared Bat (*Kerivoula muscina*) This species has not been recorded in the project area yet but could occur. Species of this group of bats roost in foliage, occasionally tree hollows. Because this species is known to utilize disturbed habitats, and has flexible roost selection, the residual significance after mitigation of direct impacts is likely to be minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

18. Papuan Mastiff-bat (*Otomops papuensis*) This species is known from only two localities in New Guinea and has not been recorded in the project area yet but could occur. The residual significance after mitigation of direct impacts are likely to be minima as individuals have extensive foraging ranges. Colonies roosting in tree hollows may suffer during vegetation clearance, however tree falls are a normal part of forest dynamics and the colonies are likely to relocate to new trees. Some colonies may be lost by being trapped in tree hollows after trees are felled but the loss of one or a few colonies is unlikely to impact on the species as a whole. The mitigation of directional felling will assist in reducing any such losses. The direct impacts of the PNG LNG Project on this species are likely to be minimal after mitigation. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the PNG LNG Project area but this is also likely to be minimal. Other indirect impacts are likely to be minimal after mitigation.

19. Mantled Mastiff-bat (*Otomops secundus*) Prior to the 2005 and 2008 survey this species was only known from three localities. Its' rarity is likely to be the result of "inadequate sampling effort and techniques, rather than a true reflection of population status" (**Annex 05**). The residual significance after mitigation of direct impacts are likely to be minimal as individuals have extensive foraging ranges. Colonies roosting in tree hollows may suffer during vegetation clearance, however tree falls are a normal part of forest dynamics and the colonies are likely to relocate to new trees. Some colonies may be lost by being trapped in tree hollows after trees are felled but the mitigation of directional felling will assist in reducing any the significance of such losses to minimal. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The significance of any other residual indirect impacts after mitigation are likely to be minimal.

20. Southern Cassowary (*Casuarius casuarius*) This species is threatened by hunting but is very tolerant of habitat disturbance. It will not be impacted by forest disturbance nor any barrier effects and the residual significance after mitigation of direct impacts is likely to be minimal. Increased hunting is likely to occur as the result of indirect impacts through increased public access to the area. Cassowaries are valuable animals and primary hunting targets. They can readily be hunted to local extinction. The magnitude of indirect

impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

21. Salvadori's Teal (*Salvadorina waigiensis*) This species is threatened by hunting and hydrological changes to the mountain torrents it inhabits. No long-term hydrological changes to montane streams are predicted as a result of PNG LNG Project construction and so the residual significance after mitigation of direct impacts is likely to be low. The magnitude of indirect impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

22. Pesquet's Parrot (*Psitttrichas fulgidus*) This species is tolerant of habitat disturbance as evidenced by its abundance around the oil project facilities but it is very sensitive to hunting. The residual significance after mitigation of direct impacts is likely to be minimal. Increased hunting is likely to occur as the result of indirect impacts through increased public access to the area. The magnitude of indirect impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

23. Southern Crowned-Pigeon (*Goura scheepmakeri*) This terrestrial species is very tolerant of habitat disturbance and where not hunted, occurs in even badly damaged and secondary forest. It is very sensitive to hunting. It will not be impacted by forest disturbance nor any barrier effects and residual significance after mitigation of direct impacts is likely to be minimal. The magnitude of indirect impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

24. New Guinea Eagle (*Harpyopsis novaeguineae*) This species is sensitive to habitat disturbance and is threatened by hunting. Territories are very large so the narrow linear disturbance of the PNG LNG Project is unlikely to eliminate any territories. The residual significance after mitigation of direct impacts is likely to be minimal. Increased hunting is likely to occur as the result of indirect impacts through increased public access to the area. Because of the huge territory sizes loss of birds near the pipeline corridor would have ramifications far beyond the project footprint. They can readily be hunted to local extinction. Hunting by either PNG LNG Project personnel or others could have major impacts if not mitigated. Strictly banning hunting by PNG LNG Project workers and mitigating indirect impacts on this species through mitigations listed under **section 25.2.5** would reduce the residual impact to low.

25. Long-bearded Melidectes (*Melidectes principis*) This species is endemic to the eastern highlands and inhabits very high wet forest near the tree line. It has not been recorded yet, but could occur in the northern sections of the project area away from the

project footprint so it is considered there will be no direct impacts. The species may be sensitive to fire induced habitat changes (Diamond 1972). Mitigations of indirect impacts of fire through a fire management plan (**section 25.2.1**) would reduce the significance of residual indirect impacts after mitigation to minimal.

26. Black Sicklebill (*Epimachus fastuosus*) This species is tolerant of habitat disturbance as evidenced by its abundance around the existing oil and gas facilities but is sensitive to hunting. It will not be impacted by forest disturbance the residual significance after mitigation of direct impacts is likely to be minimal. The magnitude of indirect impact of hunting brought about by improving access to the project area could be moderate and perhaps cause local extinctions of the species. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to low.

27. Blue Bird-of-Paradise (*Paradisaea rudolphi*) This species only occupies a narrow mid montane belt of New Guinea and, like all members of this genus, this species is tolerant of some habitat disturbance. It is threatened by hunting and loss of its mid montane forests to fire. Because of its narrow range and clumped distribution, the significance of both direct and indirect impacts have the potential to be major if unmitigated. Mitigations aimed at reducing the PNG LNG Project's effects on potential frequency of fires (**section 25.2.1**), banning hunting by PNG LNG Project workers and controlling access by mitigations listed under **section 25.2.5** would mean the significance of residual direct impacts could be reduced to minimal and that of indirect impacts to low.

28. *Arthrophyllum proliferum* Philipson This is a plant known previously from the Kuper Range, and recently discovered on the ultrabasic rocks near Salamaua (**Annex 01**). The discovery of the species on the 2005 and 2008 surveys is the first documented record for the species outside of Morobe Province and substantially extends its range into the Papuan region. Considering the range of the species, the narrowness of the construction corridor and the unlikely possibility that all the individuals within the project area are in one small area on the proposed pipeline route, the likely significance of residual direct impacts on this species are minimal even before mitigation. The species is not specifically harvested by villagers. Mitigations of the several indirect impacts would reduce the significance of residual indirect impacts after mitigation to minimal.

29. *Helicia acutifolia* Sleum. This species had been known only from the type collection made in 1936 at Mt Victoria (Foreman, 1976, 1995) but was rediscovered at the Hides 2 and 3 wellheads (Takeuchi **Annex 01**, 2007c). The 2008 survey also located it at Juha South and South Karius Sampling Areas where there were numerous sightings (Takeuchi **Annex 02**). *H. acutifolia* is very common within the project area and is not subject to any obvious threats, and was even seen as an invasive colonizer in anthropogenic habitats (**Annex 02**). The significance of residual direct and indirect impacts even without mitigation are likely to be minimal.

30. *Pterocarpus indicus* Willd. This species is classified because it is a logging target. However these trees are among the most common species in Papuasias (**Annex 02**). The significance of residual direct and indirect impacts even without mitigation are likely to be minimal.

31. *Aglaia puberulanthera* The new species of *Aglaia* is closely related to this species which is known thus far from four widely separated localities on New Guinea (Pannell 1992) and prior to the 2008 survey was only known in PNG from the Waria-Kokoda district in Northern Province (Takeuchi 2001). The new species is likely to have the same IUCN status as *A. puberulanthera* and was recorded in 2008 from the Juha North and Juha South Sampling Areas I. Despite its presumed rarity, the species is very common in the Juha area and is not at conservation risk (**Annex 02**). The significance of residual direct and indirect impacts after mitigation are likely to be minimal.

30.4 Near threatened and data deficient species

The remaining species in **Appendix 11** are either near threatened, data deficient or listed under the PNG Fauna (Protection and Control) Act and not by IUCN.

Most of these species that inhabit forested landscapes are threatened by hunting (**Appendix 11**) and are tolerant of some habitat disturbance and thus not likely to be directly impacted by construction of the PNG LNG Project. The residual significance after mitigation of direct impacts is likely to be minimal. The magnitude of indirect impact of hunting brought about by improving access to the project area could be low. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal for most species.

The magnitude of the impact of hunting brought about by increased access to the KICDP area could be high for valuable species such as Ground Cuscus (*Phalanger gymnotis*), Lowland Tree Kangaroo (*Dendrolagus spadix*), Lowland Ringtail (*Pseudochirulus canescens*), Giant Naked-tailed Rat (*Uromys anak*), Rock-dwelling Giant Rat (*Xenuromys barbatus*), Dwarf Cassowary (*Casuarius bennetti*), New Guinea Flightless Rail (*Megacrex inepta*), Gurney's Eagle (*Aquila gurneyi*), Archbold's Bowerbird (*Archboldia papuensis*) the birds-of-paradise, species of *Varanus* and crocodiles and result in local declines or even extinctions. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation on these species may be reduced to minimal or low.

All the remaining species may be directly impacted by construction. However, all of them can use secondary habitats and none are sufficiently rare to have an entire population eliminated.

Short-beaked Echidna (*Tachyglossus aculeatus*), Long-nosed Murexia (*Phascomurexia naso*), Ground Cuscus (*Phalanger gymnotis*), Giant Naked-tailed Rat (*Uromys anak*), Rock-dwelling Giant Rat (*Xenuromys barbatus*) and New Guinea Flightless Rail (*Megacrex inepta*), could fall into the trench and perish but mitigation by assisting escape from the trench will reduce the significance of residual direct impacts to minimal.

The bats *Dobsonia minor*, *Emballonura raffrayana*, *Hipposideros semoni*, *H. wollastoni*, *H. edwardshillii*, *Pipistrellus papuanus*, *P. watsii*, *Rhinolophus philippinensis*, and *Taphozous australis* inhabit caves and could be impacted by cave disturbance but mitigations aimed at limiting disturbance to caves, listed above, will limit the significance of residual direct impacts on these species to minimal levels. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the

mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The residual significance after mitigation of other indirect impacts are likely to be minimal.

The remaining species of near threatened bats roost under leaves or in tree hollows and may suffer during vegetation clearance. Tree falls are a normal part of forest dynamics and the colonies or individuals are likely to relocate to new trees. Some colonies may be lost by being trapped in tree hollows after trees are felled but the loss of one or a few colonies is unlikely to impact on the species as a whole. The mitigation of directional felling will assist in reducing any such losses. The significance of residual direct impacts of on these species is likely to be minimal even before mitigation. Small colonial bats are harvested in parts of PNG so there could be some impact from increased hunting brought about by improving access to the project area. If hunting by PNG LNG Project workers is banned and the mitigations for access listed in **section 25.2.5** are implemented the significance of any residual indirect impacts of hunting after mitigation may be reduced to minimal. The residual significance after mitigation of other indirect impacts are likely to be minimal.

Asian Dowitcher (*Limnodromus semipalmatus*), Beach Thick-knee (*Esacus giganteus*), Black-necked Stork (*Ephippiorhynchus asiaticus*) and Buff-breasted Sandpiper (*Tryngites subruficollis*), and the three egrets could only be impacted by loss of wetlands. However, since the PNG LNG Project will result in no loss of or impacts on areas of wetlands where these species could occur the significance of any residual impacts on them are likely to be minimal even without mitigation. There is no evidence these species are hunted.

The remaining bird species that have been recorded may be impacted by loss of habitat but, considering that none are very rare, that they have broad distributions and the linear construction is unlikely to eliminate whole territories of individuals, the significance of residual direct impacts on these species is likely to be minimal. There is no evidence these species are hunted.

The five species of amphibians are all data deficient. All but four are microhylids and could be impacted by changes to forest microclimate brought about by clearing and edge and barrier effects during construction. Mitigations aimed at reducing the width of the ROW and edge effects could reduce the significance of residual direct impacts on these species to minimal. The significance of residual indirect impacts after mitigations assuming quarantine mitigations are effective and diseases are not introduced, are likely to be minimal.

Myristica globosa is a logging target, but among the most common species in Papuaia (**Annex 02**) and the significance of residual direct and indirect impacts on the species is likely to be minimal even before mitigation.

31 Significance of impacts on migratory fauna

No significant habitats of migratory species will be impacted in any part of the project area and the significance of residual direct and indirect impacts after mitigation are likely to be minimal.

32 Overall conclusion

In his book “Collapse” Jared Diamond (2005) devotes most of a chapter to the existing Kutubu Petroleum Development Project. He analyses the reasons why “In effect, the Kutubu oil field is by far the largest and most rigorously controlled “national park” in Papua New Guinea”. The reasons why the KICDP area retains wilderness values yet contains one of the major export earners of PNG is a result of the fastidious operational, security, environmental and safety systems of owners and operators and the limited access to the area.

Construction of the upstream portion of the PNG LNG Project need not itself change this situation for terrestrial biodiversity. The residual direct impacts of construction will be mostly minimal and the amounts of forest that will be lost are low in relation to the area of forest in the project area and KICDP area. A narrow ROW, that will be allowed to regenerate back to 15 m wide, will limit edge and fragmentation effects and judicious mitigation can reduce residual direct impacts in the special areas, KICDP, WMAs and WWF significant biological areas to very low levels.

The generally low to minimal residual significance of direct impacts is a product of the fact that clearing and construction is not concentrated in a particular area but spread over several hundred kilometers. However, it is this same vast spread that facilitates the greatest risk to biodiversity – indirect impacts. During construction and over the 30-year life of the PNG LNG Project, the potential indirect impacts of wildfire, dieback, weed and pest invasion and enhancing access to these remote and pristine parts of PNG present, realistically, the greatest challenges to the PNG LNG Project. Without mitigations the consequences of indirect impacts could be very severe.

High quality, efficient and focussed quarantine and hygiene systems together with fire management and assiduous control of use of the project infrastructure by others are the keys to maintaining the conservation assets of the project area.

If indirect impacts can be effectively mitigated then the KICDP area and the Kutubu reputation can remain intact. If not, the owners and operators of the hydrocarbon projects are likely to be singled out as culpable.

33 References

- ADB (1995) *The Bank's Policy On Forestry*. <http://www.adb.org/Documents/Policies/Forestry/forestry.pdf>
- Baker, W. J., King, K., Banka, R. and Gebia, O. (2000). *Expedition Report Papua New Guinea 17 November – 21 December 2000*. Report to WWF.
- Balen, van B., (ed.) *In press. A Biodiversity Assessment for the Western Mamberamo, Papua Province, Indonesia*. RAP Bulletin of Biological Assessment. Conservation International, Arlington, VA.
- Balگوو, M. M. J. van, Hovenkamp, P. and Welzen, P. van. (1996). Phytogeography of the Pacific–floristic and historical distribution patterns in plants. In: Keast, A. and Miller, S. (eds.) *The Origin and Evolution of Pacific Island Biotas: New Guinea to Eastern Polynesia: Patterns and Processes*. SPB Academic Press, Amsterdam, the Netherlands. Pp 191–214.
- Balun L. (1995) *A report on the plant diversity study of the Kikori basin*. In: *Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea*. In Hartshorn, G. S., Burrows, I., Leary, T., Seri, L., Allen, G., Polhemus, D., Balun, L., Orsak, L., Bigilale, E., Kinbag, F., Kinibel, A., Dal, C., Wasel, H., Ellis, G. & Forney, M. (1995). *Field survey of biodiversity in the Kikori River Basin. Papua New Guinea*. WWF KICDP area Report.
- Balun, L. and Gebia, O. (1998). Plant diversity along altitudinal gradient in tropical rainforest communities in the Gobe area, southern highlands province, Papua New Guinea. WWF Report.
- Barthlott, W., Lauer, W., and Placke, A. (1996). Global distribution of species diversity in vascular plants: towards a world map of phytodiversity. *Erdkunde. Archiv. fur wissenschaftliche Geographie* 50: 317–327.
- Barthlott, W., Mutke, J., Rafiqpoor, D., Kier, G. and Kreft, H. (2005). Global centres of vascular plant diversity. *Nova Acta Leopoldina* NF 92 (342): 61–83.
- Beehler B. M., Pratt T. K., and Zimmerman D. A. (1986). *Birds of New Guinea*. Princeton University Press, Princeton, N. J.
- Beehler, B. (ed.) (1993). *Papua New Guinea Conservation Needs Assessment, Vol. 2*. Corporate Press, Inc., Landover, Maryland.
- Beehler, B. and Alonso, L. E. (eds.) (2001). *Southern New Ireland, Papua New Guinea: a Biodiversity Assessment*. RAP Bulletin of Biological Assessment 21. Conservation International, Washington, DC.
- Beehler, B. M., Sengo, J. B., Filardi, C. and Merg K. (1995). Documenting the lowland rainforest avifauna in Papua New Guinea – effects of patchy distributions, survey effort and methodology. *Emu* 95: 149-161.
- Bennett, E. L. and Robinson, J. G. (2000). Hunting of Wildlife in Tropical Forests Implications for Biodiversity and Forest Peoples. Biodiversity Series - Impact Studies paper no. 76. World Bank Environment Department.

BirdLife International (2003) *BirdLife's online World Bird Database: the site for bird conservation*. Version 2.0. Cambridge, UK: BirdLife International. Available: <http://www.birdlife.org> (accessed 25/5/2008)

BirdLife International (2008). *EBA program*. Cambridge, UK: BirdLife International. Available: http://www.birdlife.org/datazone/ebas/eba_programme.html (accessed 25/5/2008)

Bishop, K. D. (2007). *pers. comm. to I. Woxvold*, June 2007.

Bonaccorso, F. J. (1998). *Bats of Papua New Guinea*. Conservation International Tropical Field Guide Series 2, Conservation International: Washington DC.

Clements, M. and Harris, W. (undated) Orchid survey of the Lake Kutubu area for WWF International. Document provided by WWF.

Coates, B. J. (1985). *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville*. Volume I, Non-Passerines. Dove Publications, Alderley, Queensland.

Coates B. J. (1990). *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville*. Volume II, Passerines. Dove Publications, Alderley, Queensland.

Conn, B. J. (1994). Documentation of the flora of New Guinea. In: Peng, C.-I and Chou, C. H. (eds.) *Biodiversity and Terrestrial Ecosystems*. Institute of Botany, *Academia Sinica Monograph* 14: 123–156.

Conservation International. (2003). Ecosystem profile: Sumatra, Sundaland. URL: http://www.cepf.net/xp/cepf/where_we_work/sundaland/full_strategy.xml. (link tested active as of May 6, 2008).

Crome, F. H. J. (2005). Biodiversity studies for the PNG Gas Project. *Report to Exxon-Mobil and Enesar Consultants Pty Ltd*.

Crome, F. H. J. (1993). Post World Heritage Bird Conservation Problems in North East Queensland. Pp. 93 - 104 in Catterall, C. P., Driscoll, P. V., Hulsman, K., Muir, D. and Taplin, A. (eds.) *Birds and their Habitats: Status and Conservation in Queensland*. Queensland Ornithological Society Inc., Brisbane.

Crome, F. H. J. and Moore, L.A. (1989). Display site constancy of bowerbirds and the effects of logging on Mt. Windsor Tableland, North Queensland. *Emu* 89:47-52.

Crome, F. H. J., Moore L. A., and Richards, G. C. (1992). A study of logging damage in upland rainforest in North Queensland. *Forest Ecology And Management* 49: 1-29.

Damas, K. (1998). The present status of plant conservation in Papua New Guinea. In: Peng, C.-I and Lowry P. P. II, (eds.) *Rare, Threatened, and Endangered Floras of Asia and the Pacific Rim*. Institute of Botany, *Academia Sinica Monograph* 16: 171–179.

Diamond J. and Bishop K. D. (2000). *Birds of Mt. Sisa*. WWF KICDP area Report.

Diamond J. and Bishop K. D. (2003). *Seasonality in Birds in the Kikori River Catchment: Year-2003 Studies*. WWF KICDP area Report.

Diamond, J. (1972). *Avifauna of the Eastern Highlands of New Guinea*. Publications of the Nuttall Ornithological Club #12. The Club, Cambridge, Mass.

Diamond, J. (2005). *Collapse How Societies Choose to Fail or Survive*. Viking Books, New York.

Dutrieux, E. (2001). The Mahakam delta environment, from the 80's up to now: a synthesis of a 15-year investigation. Pp. 63 – 68 in Kusumastano, T., Bengen, D. G., Widig, B. and Soesno, I. (eds.) *Optimising development and sustainable issue at coastal areal: problems and solutions for sustainable management of Mahakam delta*. Proceeding of International Workshop, Jakarta 4 – 5 April 2001. Centre for Coastal and Marine Resources Studies – Bogor Agricultural University.

Dwyer, P. (1984) From garden to forest: small rodents and plant succession in Papua New Guinea. *Australian Mammalogy* 7: 29-36.

Dyer, S. J., O'Neill, J. P., Wasel, S. M. and Boutin, S. (2002). Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. *Canadian Journal of Zoology* 80: 839 - 845

Enesar. (2005). PNG Gas Project Environmental Impact Statement. A report prepared by Enesar Consulting Pty Ltd for Esso Highlands Ltd.

FAO (2008). <http://www.fao.org/forestry/23831/en/png/> accessed 1/10/08

Flannery, T. F. (1995). *Mammals of New Guinea*. Revised and Updated Edition. Robert Brown and Associates, Sydney, Australia.

Flannery, T. F. and Seri, L. (1993). Rediscovery of *Aproteles bulmerae* (Chiroptera: Pteropodidae) . Morphology, ecology and conservation. *Mammalia* 57: 19-25

Foreman, D. B. (1976). *A Taxonomic Study of the Genus Helicia Lour. (Proteaceae) in New Guinea and Australia with Notes on Origin, Distribution and Ecology*. University of New England, Armidale, New South Wales:.

Foreman, D. B. (1995). Proteaceae. In: Conn, B. J. (ed.) *Handbooks of the Flora of Papua New Guinea* Vol. 3. Melbourne University Press, Carlton, Victoria. Pp 221–270.

Forman, R. T. and Alexander, L. E. (1998). Roads and their major ecological effects *Annual Review of Ecology and Systematics* 29: 207-231.

Frith, C. J. and Beehler, B. M. (1998). The Birds of Paradise *Paradisaeidae*. Oxford University Press, Oxford.

Frodin, D. G. (1990). Botanical progress in Papuasias. In: Baas, P., Kalkman, K. and Geesink, R. (eds.) *The Plant Diversity of Malesia, Proceedings of the Flora Malesiana Symposium Commemorating Prof. Dr. C. G. G. J. van Steenis*. Kluwer Academic Publishers, Dordrecht, Boston, and London. Pp 235–247.

Gebia, O. and Balun, L. (2000). *A study on two forest communities in the Kikori River catchment of Papua New Guinea*. WWF KICDP area Report SR-00-01.

Gebia, O. and Balun, L (2004). *Species diversity and composition in Darai limestone karst and the Libano alluvial forest of Gulf and Southern Highlands Provinces. WWF KICDP area Report SR-04-01.*

Goosem, M. (1997). Internal fragmentation: The effects of roads, highways and powerline clearings on movements and mortality of rainforest vertebrates. Pp. 241 – 255 in Laurence, W. F., and Bierregaard, R. O. Jr. (eds.). *Tropical Forest Remnants. Ecology, Management, and Conservation of Fragmented Communities.* University of Chicago Press, Chicago.

Grice, A. C. and Setter, M. J. (2003). *Weeds of Rainforests and Associated Ecosystems. Cooperative Research Centre for Tropical Rainforest Ecology and Management.* Rainforest CRC, Cairns.

Hall, L. S. and Richards, G. (2004). Flying around underground: cave bats. Pp. 111-126 (Chapter 4) in, *Beneath the Surface. A Natural History of Australian Caves* (ed. B. Finlayson and E. Hamilton-Smith). University of NSW Press: Sydney.

Hammermaster, E. T. and Saunders, J. C. (1995a). *Forest Resources and Vegetation Mapping of Papua New Guinea.* PNGRIS Publ. 4, CSIRO and AIDAB, Canberra.

Hammermaster, E. T. and Saunders, J. C. (1995b). *Forest Resources and Vegetation Mapping of Papua New Guinea.* 1: 250,000 vegetation map overlays separately issued as working copies to PNGRIS Publ. 4, CSIRO and AIDAB, Canberra.

Harris W. K. (2003) *Survey of the Orchid Floras of Darai and Libano Areas, Papua New Guinea.* WWF KICDP area Report.

HDOA (Hawaii Department of Agriculture). (1992). *List of plant species designated as noxious weeds for eradication or control purposes.* Hawaii Department of Agriculture, Honolulu.

Hosken, D. J., Bailey, W. J., O'Shea, J. E. and Roberts, J.D. (1994). Localization of insect calls by the bat *Nyctophilus geoffroyi* (Chiroptera: Vespertilionidae): a laboratory study. *Australian Journal of Zoology* 42: 177-184.

Hyndman, D. and Menzies, J. I. (1980) *Aproteles bulmerae* (Chiroptera: Pteropodidae) of New Guinea is not extinct. *Journal of Mammalogy* 61: 159-160.

Johns, R. J. (1993). Biodiversity and conservation of the native flora of Papua New Guinea. Pp 15–75 in: Beehler, B. (ed.) *Papua New Guinea Conservation Needs Assessment Report, Vol. 2.* PNG Dept. of Environment and Conservation, Boroko.

Laurance, S. G. W., Stouffer, P. C. and Laurance, W. F. (2004). Effects of Road Clearings on Movement Patterns of Understorey Rainforest Birds in Central Amazonia. *Conservation Biology* 18: 1099-1109

Laurence, W. F. and Bierregaard, R. O. Jr. (eds.) (1997). *Tropical Forest Remnants. Ecology, Management, and Conservation of Fragmented Communities.* University of Chicago Press, Chicago.

Leary, T. (1996). *Areas of known exceptional biodiversity or conservation significance in the Kikori Integrated Conservation and Development project area, Papua New Guinea.* WWF Report, Port Moresby, Papua New Guinea.

-
- Leary T. (2004). Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province, July - August, 2003. WWF KICDP Area Report.
- Leps, J., Novotny, V., Cizek, L., Molem, K., Isua, B., Boen, W. et al. (2002). Successful invasion of the neotropical species *Piper aduncum* in rain forests in Papua New Guinea. *Appl. Veg. Sci.* 5: 255–262.
- Löffler, E. (1977). *Geomorphology of Papua New Guinea*. CSIRO and ANU Press. Canberra.
- McClure, H. E. (1973). *Migration and Survival of the Birds of Asia*. US Army Medical Component, S. E. A. T. O, Bangkok.
- Mack, A. L. and Wright, D. B. (1998). The Vulturine Parrot, *Psitttrichas fulgidus*, a threatened New Guinea endemic: notes on its biology and conservation. *Bird Conservation International* 8: 158 – 194.
- Mack, A., (ed.) (1998). *A Biological Assessment of the Lakekamu Basin, Papua New Guinea*. Rapid Assessment Program Working Papers 9. Conservation International, Washington, DC.
- Mamu, T. and Sine, R. (2005). A Preliminary Fauna Assessment of the Forest Corridor of Homa – Irawi Proposed Road, Tari, Southern Highlands Province. A supplementary report to Oilsearch HSES.
- McClure, H. E. (1974). *Migration and Survival of the Birds of Asia*. US Army Medical Component, S. E. A. T. O, Bangkok.
- Menzies, J. I. (1977). Fossil and subfossil fruit bats from the mountains of New Guinea. *Australian Journal of Zoology* 25: 329-336.
- Musser, G. G., Helgen, K. M. and Lunde, D. P. (2008). Systematic revision of New Guinea *Leptomys* (Muridae, Murinae) with descriptions of two new species. *Amer. Mus. Novitates*. No. 3624:1-22.
- Nix, H. E. (1993). Bird distributions in relation to imperatives for habitat conservation in Queensland. Pp. 12 – 22 in Catterall, C. P., Driscoll, P. V., Hulsman, K., Muir, D. and Taplin, A. (eds.) *Birds and their Habitats: Status and Conservation in Queensland*. Queensland ornithological Society Inc., Brisbane.
- Oxley, D. J., Fenton, J. M. B. and Carmody, G. R. (1974). The effects of roads on populations of small mammals. *Journal of Applied Ecology* 11:51 – 59.
- Paijmans, K. (1976). *New Guinea Vegetation*. CSIRO, Canberra.
- Pannell, C. M., (1992). A Taxonomic Monograph of the Genus *Aglaia* Lour. (Meliaceae). *Kew Bull. Additional Series XVI*. HMSO, London.
- Parris, B., S. (2007). Chapter 3.4. Ferns and lycophytes of Papua. Pp 335–343 in: Marshall, A. J. and Beehler, B. M. (eds.) *The Ecology of Papua*. The Ecology of Indonesia Volume 5. Conservation International. Periplus HK Editions, Singapore.
- Prance, G. T. (1977). Floristic inventory of the tropics: where do we stand? *Ann. Missouri Bot. Gard.* 64: 659–684.

Richards, G. C. (2002). *Ecological and evolutionary determinants of bat community structure in south-east Australian forests*. Unpublished PhD Thesis, Biological Sciences, University of NSW: Sydney.

Richards S. (2000). *Herpetofauna and Odonata of Dark End Lumber (Gulf Province) and Mt Sisa (Southern Highlands Province), Papua New Guinea*. WWF Report.

Richards, S., (ed.) 2007. *A Rapid Biodiversity Assessment of the Kaijende Highlands, Enga Province, Papua New Guinea*. RAP Bulletin of Biological Assessment 45. Conservation International, Arlington, VA.

Richards S. and Allison A. (2003). *Frogs and Reptiles of Darai Plateau and Libano (Southern Highlands and Gulf Provinces), Papua New Guinea. Results of a Biodiversity Survey 22 July – 12 August 2003*. WWF KICDP area Report.

Rogers H. M., and Hartemink, A. E. (2000). Soil seed bank and growth rates of an invasive species, *Piper aduncum*, in the lowlands of Papua New Guinea. *J. Trop. Ecol.* 16: 243–251.

Rogers, H. (2005a). *Nothofagus* in Papua New Guinea. A Brief Review for the PNG Gas Project EIA. Report to Enesar Consultants Pty. Ltd.

Rogers, H. (2005b). Fire and Dieback in Papua New Guinea's Forests Brief Review for the PNG Gas Project EIA. Report to Enesar Consultants Pty. Ltd.

Schuiteman, A., and de Vogel, E. (2007). Orchidaceae of Papua. In: A. J. Marshall and B. M. Beehler, (eds.) *The Ecology of Papua. The Ecology of Indonesia* Volume 5. Conservation International. Periplus HK Editions, Singapore. Pp 435–456.

Sekhran, N., and Miller, S. (eds.) (1994). *Papua New Guinea Country Study on Biological Diversity*. Colorcraft Ltd, Hong Kong.

Smith, A. C. and Haas, J. E. (1975). Studies of Pacific island plants. XXIX. *Bleasdalea* and related genera of Proteaceae. *American Journal of Botany* 62: 133–147.

Stattersfield, A. J., Crosby, M. J., Long, A. J. and Wege, D. C. (1998). *Endemic Bird Areas of the World. Priorities for Bird Conservation*. Birdlife International, Cambridge, UK.

Stevens, P. F. (1989). New Guinea. Pp 120–132 in Campbell, D. G. and Hammond, H. D. (eds.) *Floristic Inventory of Tropical Countries: the Status of Plant Systematics, Collections, and Vegetation, Plus Recommendations for the Future*. New York Botanical Gardens, New York.

Supriatna, J., (ed.) (1999). *The Irian Jaya Biodiversity Conservation Priority-Setting Workshop. Final report*. Conservation International, Washington, DC.

Swihart, R. K. and Slade, N. (1984). Road crossing in *Sigmodon hispidus* and *Microtus ochrogaster*. *Journal of Mammalogy* 65: 357 – 360.

Takeuchi, W. (2001). New and noteworthy plants from recent botanical surveys in Papua New Guinea, 7. *Edinb. J. Bot.* 58: 159–172.

Takeuchi, W. (2007a). Vascular plants of the Kaijende Highlands, Papua New Guinea: taxonomic and vegetation survey. In: Richards, S. J., (ed). *A Rapid Biodiversity*

Assessment of the Kaijende Highlands, Enga Province, Papua New Guinea. RAP Bulletin of Biological Assessment 45. Conservation International, Arlington, VA. Pp 25–39, 71–86.

Takeuchi, W. (2007b). Additions to the flora of the Kaijende Highlands, Papua New Guinea: *Macaranga daviesii* (Euphorbiaceae), a new calciphilous species from the Paiela limestone. *Harvard Papers in Botany* 12: 389–394.

Takeuchi, W. (2007c). A new fern and two floristic records from the Karius limestone of Papua New Guinea. *Edinb. J. Bot.* 64 (1): 7–15.

Takeuchi, W. (*in press*). Additions to the flora of the Kaijende Highlands, Papua New Guinea: *Glochidion welzenii* (Euphorbiaceae), a new species from the Paiela limestone district. *Blumea* 53.

Takeuchi, W. and Golman, M. (2001). Botanical documentation imperatives: some conclusions from contemporary surveys in Papuasia. *Sida* 19: 445–468.

Trombulak, S. C. and Frissell, C. A. (2000). Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conservation Biology* 14:18 – 30.

Vuthy, L. (2005). Yor Ngone – tiger trapper. *Tigerpaper* 19: 19 – 21.

Watkins D. (2000) *Kikori Delta of Gulf Province, Papua New Guinea, Recently Identified as Internationally Important Area for Migratory Shorebirds along the East Asian-Australasian Flyway*. Wetlands International Report.

Welzen, P.C. van. (1997). Increased speciation in New Guinea: tectonic causes? Pp 363–387 in Dransfield, J., Coode, M. J. E. and Simpson, D. A. (eds.) *Plant Diversity in Malesia III. Proceedings of the Third International Flora Malesiana Symposium 1995*. Royal Botanic Gardens, Kew.

Wilde, W. J. J. O. de. (1972). Passifloraceae. *Flora Malesiana* ser. I, 7 (2): 405–434.

Williams, P. W. (1971). Illustrating morphometric analysis of karst from with examples from New guinea. *Zeitschrift für Geomorphologie*. 15 :40 – 61.

Williams, P. W. (1972). Morphometric analysis of polygonal karst in New guinea. *Bulletin of the Geological Society of America* 83: 761-796.

Appendices

Appendix 1 Surveys (WWF and PNG LNG Project) carried out in the PNG LNG upstream project area.

Reference	B*	M	H	P	F	I	Code
Hartshorn G. S., Burrows I., Leary T., Seri L., Allen G., Polhemus D., Balun L., Orsak L., Bigilale E., Kinbag F., Kinibel A., Dal C., Wasel H., Ellis G. & Forney M., (1995). Field survey of biodiversity in the Kikori River Basin. Papua New Guinea. WWF KICDP area Report		X	X	X	X	X	1
Seri L., Leary T. & Kinbag F. (1995) Report on the non-flying mammal component of the field survey of biodiversity in the Kikori ICDP area. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report		X					1a
Leary T., Seri L. & Kinbag F. (1995) Report on the bat component of the field survey of biodiversity in the Kikori ICDP area. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report.		X					1b
Burrows I. (1995) A field survey of the avifauna of the Kikori River Basin. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report.	X						1c
Allen G. R. (1995) The fishes of the Kikori River system, Papua New Guinea. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report.					X		1d
Orsak L. J. & Easen N. (1995) An assessment of the moth fauna (Lepidoptera: Heterocera) of the Kikori Basin (Gulf, Southern Highlands Provinces), Papua New Guinea. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report.						X	1e
Polhemus D. A. (1995) A preliminary biodiversity survey of aquatic Heteroptera and other aquatic insect groups in the Kikori River basin, Papua New Guinea. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report.						X	1f
Balun L. (1995) A report on the plant diversity study of the Kikori basin. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report.				X			1g
Leary T. & Seri L. (1995?). Survey of Birds and Mammals at Utiti Creek. Unpublished WWF KICDP area Report.	X	X					2
Diamond J. & Bishop K. D. (2000) Birds of Mt. Sisa. WWF KICDP area Report.	X						6a
Leary T. (2001) Mammal Survey of Two Sites on the Northeast Slopes of Mt Sisa, Southern Highlands Province, PNG - October 1999. WWF KICDP area Report.		X					6b
Richards S. (2000) Herpetofauna and Odonata of Dark End Lumber (Gulf Province) and Mt Sisa (Southern Highlands Province), Papua New Guinea. WWF Report.			X			X	6c
Gebia O. & Balun L. (2000) A Study on Two Forest Communities in the Kikori River Catchment of Papua New Guinea. WWF KICDP area Report.				X			6d
Leary T. & Kinibel A. (2001) A Survey of the Moth Fauna (Lepidoptera: Heterocera) of Mt Sisa, Southern Highlands, PNG - October 1999. WWF KICDP area Report.						X	6e
Diamond J. & Bishop K. D. (2000?) Local Avifauna of the Kikori River Catchment Surveyed in 1999. WWF KICDP area Report.	X						7
Diamond J. & Bishop K. D. (2003?) Seasonality in Birds in the Kikori River Catchment: Year-2003 Studies. WWF KICDP area Report.	X						9
Jaensch R. (1997?) Birds Recorded at Lake Kutubu, Moro and Agogo Range, Papua New Guinea, 30 July to 2 August 1997. Wetlands International Report.	X						10
Jaensch R. & Kulmoi P. (199?) Birds Recorded at Tubo Lodge, Lake Kutubu, August 1997 and February 1998. Wetlands International Report.	X						11
Jaensch R. (1999?) Birds of the Lake Kutubu Swamp Forest Papua New Guinea (Summary Report). Wetlands International Report.	X						12
Jaensch R. & Watkins D. (2000?) Birds Recorded in the Lower Kikori River and Kikori Delta Areas Papua New Guinea (First). Wetlands International Report.	X						13
Leary T. (2002?) Brief Report on Iviri Mammal Monitoring - December 2001. WWF KICDP area Report.	X	X					14

Appendix 1 Surveys (WWF and PNG LNG Project) carried out in the PNG LNG upstream project area.

Reference	B*	M	H	P	F	I	Code
Leary T. (2004a?) Brief Report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003. WWF KICDP area Report.	X	X					15
Leary T. (2004b?) Brief Report on Keboi Kerowa Mammal Monitoring - July 2004. WWF KICDP area Report.	X	X					16
Igag P. (2003?) Report on Bird Survey for the Darai and Libano Sites of Kikori ICDP, 2003. WWF KICDP area Report.	X						17a
Leary T. (2004) Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province, July - August, 2003. WWF KICDP area Report.		X					17b
Richards S. & Allison A. (2003) Frogs and Reptiles of Darai Plateau and Libano (Southern Highlands and Gulf Provinces), Papua New Guinea. Results of a Biodiversity Survey 22 July – 12 August 2003. WWF KICDP area Report.			X				17c
Gebia O. & Balun L. (2004) Species Diversity and Composition in Darai Limestone Karst and the Libano Alluvial Forest of Gulf and Southern Highlands Provinces. WWF KICDP area Report.				X			17d
Harris W. K. (2003) Survey of the Orchid Floras of Darai and Libano Areas, Papua New Guinea. WWF KICDP area Report.				X			17e
Vui R. (2003) A Preliminary Freshwater Fish Fauna Inventory Report of Libano, Proposed Wildlife Management Area (WMA), Southern Highlands Province. 3rd to 13th August 2003. WWF KICDP area Report.					X		17f
Leary T. (1997) Subistence Catch Monitoring - Lake Kutubu, Southern Highlands Province, PNG. September 1995 - February 1997. WWF KICDP area Report.					X	X	19
Leary T. (1998) Mammals of the Lake Kutubu Swamp Forests. Wetlands International Report.		X					20
Bickford D. (1999?) Herpetological survey of Iviri and Keboi Kerowa eco-forestry areas in the Kikori ICDP, Gulf Province, Papua New Guinea. A Report to WWF on fieldwork conducted between November 14 and December 2, 1998. WWF KICDP area Report.			X				21
Richards S. (2002a) Frogs and Reptiles of Moro, Gobe and Kopi (Southern Highlands and Gulf Provinces), Papua New Guinea. Results of a Dry-Season Survey 19 October – 1 November 2001. WWF KICDP area Report.			X				22
Richards S. (2002b) Updated List of Frogs from Moro, Gobe and Kopi (Southern Highlands and Gulf Provinces), Papua New Guinea. Preliminary Results of a Wet-Season Survey 14 – 30 May 2002. WWF KICDP area Report.			X				23
Leary T. (1999) Mammal Survey of the Gobe Oil Field Area, Southern Highlands and Gulf Provinces, Papua New Guinea - December, 1998. WWF KICDP area Report.		X					24a
Balun L. & Gebia O. (1999?) Study on the Biological Diversity of Two Adjoining Forest Ecotypes: Mangrove and Rainforest Ecosystem, in the Gulf and Southern Highland Province. WWF KICDP area Report.				X			24b
Gebia O., Mamu T. & Sipsip B. (2003) Preliminary Analysis of Flowering and Fruiting Patterns of Canopy and Understorey Trees in a Lowland Tropical Rain Forest Site in Kikori, Gulf Province, Papua New Guinea. WWF KICDP area Report.				X			25
Gebia O. (2002) Species Composition and Structure of One Hectare Logged Forest Plot in the Mature Mangrove Forest, Kikori, Gulf Province, PNG – August 2001. WWF KICDP area Report.				X			26
Gebia O. (2003) Tree Diversity and Species Composition of a One-Hectare Plot in the Mixed Mangrove tidal swamp forest at Keboi Kerowa area, Kikori, Gulf Province, PNG. WWF KICDP area Report.				X			27
Baker W. J., King K., Banka R. & Gebia O. (200?) Expedition Report, Papua New Guinea, 17 November - 21 December 2000. Report to Royal Botanic Gardens. Kew.				X			28
Richards S. (1997) Herpetofauna of the Kikori River Basin. Enesar Consulting Report.			X				29
Leary T. (2000) Rare Dolphins Found in the Kikori River Delta Area. WWF/PNG National Museum and Art Gallery Report.		X					30
Balun L. (2004?) An Audit on the Status of the Flora and Fauna of the Porora Forest,		X	X	X			31

Appendix 1 Surveys (WWF and PNG LNG Project) carried out in the PNG LNG upstream project area.

Reference	B*	M	H	P	F	I	Code
South East Mananda Forest, Southern Highlands Province. WWF KICDP area Report.							
Namo R. (2004a) Annotated Checklist of Mammals of Kikori Basin. WWF KICDP area Report.		X					32
Namo R. (2004b) An Annotated Checklist of Freshwater Fish and Crustaceans of Kikori Basin. WWF KICDP area Report.					X	X	33
Mamu, T. and Sine, R. 2005. A Preliminary Fauna Assessment of the Forest Corridor of Homa – Irawi Proposed Road, Tari, Southern Highlands Province. A supplementary report to Oilsearch HSES.	X	X	X			X	34
Mamu, T., Gebia, O., Enoch, I., Kuduk, M., and Ona, A. (2005) Report for an Assessment Survey of Terrestrial Mammals for PNG Gas Project, Papua New Guinea. Report to Enesar Consulting Pty. Ltd. (Annex 03)		X					35
Richards, G. C. (2005) The Papua New Guinea Gas Project: a study of bat faunal biodiversity and an assessment of potential impacts. Report to Enesar Consulting Pty. Ltd. (Annex 05)		X					36
Richards. S. (2005) Biodiversity And Conservation Status Of Herpetofauna Of The Papua New Guinea Gas project area. Report to Enesar Consulting Pty. Ltd. (Annex 09)			X				37
Woxvold, I. and Crome, F. (2005). A report on the Avifauna of the Papua New Guinea Gas project area. Report to Enesar Consultants Pty. Ltd. (Annex 07)	X						38
Takeuchi, W. (2005). Botanical results from a floristic survey of montane environments within the PNG Gas Project concession. Report to Enesar Consulting Pty. Ltd. (Annex 01)				X			39
Mamu, T. (2008) Environmental Impact Study of Terrestrial Mammals for the PNG LNG Project, Papua New Guinea. Report to Coffey Natural Systems. (Annex 04)		X					40
Richards, G. C. (2008) The Papua New Guinea Liquefied Natural Gas Project: A study of bat faunal biodiversity and an assessment of potential impacts. Report to Coffey Natural Systems. (Annex 07)		X					41
Richards. S. (2008) Biodiversity and conservation status of herpetofauna of the Papua New Guinea Liquefied Natural Gas Project. Report to Coffey Natural Systems. (Annex 10)			X				42
Woxvold, I. (2008). Avifauna of the upstream portion of the PNG LNG Project, Southern highlands and Western Provinces, Papua New Guinea. Report to Coffey Natural Systems. (Annex 09)	X						43
Takeuchi, W. (2008). Flora of the upstream portion of the PNG LNG Project, Southern highlands and Western Provinces, Papua New Guinea. Report to Coffey Natural Systems. (Annex 02)				X			44
Leary, T. and Seri, L. (1997). An annotated checklist of mammals recorded in the Kikori River Basin, Papua New Guinea. Science in New Guinea 23 (2): 79 – 100.		X					45

* B = birds, m = mammals, H = amphibians and reptiles, F = Fish, I = invertebrates, P = plants

Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.

Bioregion	Survey area*	Survey area code*	Sample site*	Sample site code*	Lat*	Long*	Altitude*	Groups sampled (entries are reference codes from Appendix 1)						Habitat*	survey Year	Survey month	Surveyors
								B	M	H	P	F	I				
Kikori Lowlands	Aird Hills	AH	Aird Hills	AH	7.44	144.3698	50		MS**								
Kikori Lowlands	Au Cave	AC	Au Cave	AC	7.425	144.1916	20										
Kikori Lowlands	Dark End Lumber	DEL	Dark End Lumber	DEL	7.15722	144.39305	30-60	7		6c	6d		6c	Tropical wet forest and semi-saturated rainforest	1999	Oct	WWF
Kikori Lowlands	Iviri	I	Iviri 1	I1	7.41666	144.40833	20-40			21	24b			Mangrove forest	1998	Nov-Dec	WWF
Kikori Lowlands	Iviri	I	Iviri 2	I2	7.40861	144.40472	20-40				34			Mangrove forest	2001	August	WWF
Kikori Lowlands	Iviri	I	Iviri 3	I3	7.41666	144.40833	20-40	14	14					Mangrove forest	2001	Dec	WWF
Kikori Lowlands	Keboi Kerowa	KK	Keboi Kerowa	KK	7.53333	144.25833	~10-40			21	24b			Mangrove forest	1998	Nov-Dec	WWF
Kikori Lowlands	Kikori delta	KD	Kikori basin	KD1	7.125	144.33333	10-120				28			Tropical lowland rainforest, Karst, swamp forest, mangrove	2000	Nov	WWF & Royal Botanic Gardens, Kew
Kikori Lowlands	Kikori delta	KD	Kikori delta	KD2	7.53777	144.24833	0+	7						River, streams, mangroves & tidal mudflats	1999	Sept-Oct	WWF
Kikori Lowlands	Cape Blackwood	CB	Kikori Delta, Cape Blackwood	CB	7.54777	144.31388	0+	13						Mangrove forest & mudflats	2000	March	Wetlands International
Kikori Lowlands	Kopi-Kikori	KO	Kikori1	KO1	7.42833	144.24833	10	13						Tropical wet forest	2000	Mar	Wetlands International
Kikori Lowlands	Kopi-Kikori	KO	Kikori2	KO2	7.14138	144.4	40-60				25			Lowland tropical rainforest	1999-2002	Oct 99-Oct 02	WWF
Kikori Lowlands	Kopi Group	KL	KL1 to KL3	KL4	7.34870	144.20449	0							Tropical wet forest			
Kikori Lowlands	Kopi	KL	Kopi	KL2	7.33333	144.2	20					1d		ponds, tidal creek	1995	March	WWF
Kikori Lowlands	Kopi	KL	Kopi	KL3	7.32166	144.18138	~20	9						Tropical wet forest	1998	April-May	WWF

Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.

Bioregion	Survey area*	Survey area code*	Sample site*	Sample site code*	Lat*	Long*	Altitude*	Groups sampled (entries are reference codes from Appendix 1)						Habitat*	survey Year	Survey month	Surveyors
								B	M	H	P	F	I				
Kikori Lowlands	Kopi	KL	Kopi/Kikori	KL1	7.36666	144.23333	~10-20	1a					1f	Tropical wet forest	1995	Feb	WWF
Kikori Lowlands	Pinini Creek	KP	Pinini Creek	KP	7.18778	144.11244	20+	9						Lowland forest & creek	2001	Feb	WWF
Kikori Lowlands	Utiti Creek	U	Utiti Creek	U	7.22583	144.09833	35	2	1a, 1b, 2					Tropical wet forest	1995	July-Aug	WWF
Kikori Lowlands	Veiru Creek	V	Veiru Creek	V	7.42555	144.19555	30	1c	1a, 1b		1g	1d	1e, 1f	Tropical wet forest, sago swamp, Karst and creeks	1995	Feb-March	WWF
Kikori Lowlands	Kikori delta	KD	Veriabari	KD4	?	?	0+	13						Coconut grove, mangrove forest, beach & mudflats	2000	March	Wetlands International
Kikori Lowlands	Kikori delta	KD	Veriabari, Lower Kikori Deltaic Plains	KD3	?	?	0		30					Aquatic	1999	Dec	WWF/National Museum
Sirebi Lowlands	Sirebi	S	Omo & Sirebi Rivers & creeks	S	6.98333	144.23333	45-70		1d, 1f			1d	1e, 1f	Rivers, streams & springs	1995	Feb-March	WWF
Sirebi Lowlands	Omo	O	Omo village	O	6.97805	144.30416	40-170	1c	1a, 1b		1g		1e, 1f	Pre-Montane rainforest - tropical rainforest, Karst	1995	March	WWF
Libano-Hegigio	Fogomaiyu	F	Fogomaiyu	F	6.5116	143.07958	200		MS								
Libano-Hegigio	Libano Sok	LK	Libano Sok	L	6.40044	142.975	200-600	17a	17b	17c	17d, 17e	17f		Lowland alluvial and hill forest	2003	July-Aug	WWF
Libano-Hegigio	Waro	W	Waro	W	6.5371	143.1953			MS								
Darai Plateau	Darai Plateau	D	Darai Plateau	D	7.13075	143.6105	300-700	17a	17b	17c	17d, 17e			Lowland hill forest	2003	July-Aug	WWF
Mubi River Karst	Gobe1	G	G1 to G9	G10	6.82297	143.74422	626		24a		24b		6e	Small-crowned Lowland Hill Forest	1996	Oct	WWF

Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.

Bioregion	Survey area*	Survey area code*	Sample site*	Sample site code*	Lat*	Long*	Altitude*	Groups sampled (entries are reference codes from Appendix 1)						Habitat*	survey Year	Survey month	Surveyors
								B	M	H	P	F	I				
Mubi River Karst	Gobe2	G	G2 to G6	G11	6.82727	143.73944	626		24a		24b		6e	Small-crowned Lowland Hill Forest	1997	Nov	WWF
Mubi River Karst	Gobe	G	Gobe	G1	6.82347	143.74472	~50-1280	9						Tropical wet forest, pre-Montane rainforest	1998	April-May	WWF
Mubi River Karst	Gobe	G	Gobe	G7	6.82347	143.74472	~50-1280	9						Tropical wet forest, pre-Montane rainforest	1999	Oct	WWF
Mubi River Karst	Gobe	G	Gobe	G8	6.8	143.76666	±520				28			Sub-Montane & Montane forest, Karst	2000	Nov	WWF & Royal Botanic Gardens, Kew
Mubi River Karst	Gobe	G	Gobe	G9	6.82347	143.74472	55-1341	9						Tropical wet forest, pre-Montane rainforest	2001	Jan-Feb	WWF
Mubi River Karst	Gobe	G	Gobe 98 A	G2	6.76666	143.71611	1310		24a		24b		6e	Small-crowned Lowland Hill Forest	1998	Dec	WWF
Mubi River Karst	Gobe	G	Gobe 98 B	G3	6.80416	143.73638	910		24a		24b		6e	Medium-crowned Lowland Hill Forest	1998	Dec	WWF
Mubi River Karst	Gobe	G	Gobe 98 C	G4	6.81416	143.77527	610		24a		24b		6e	Small-crowned Lowland Hill Forest	1998	Dec	WWF
Mubi River Karst	Gobe	G	Gobe 98 D	G5	6.85833	143.73194	250		24a		24b		6e	Medium-crowned Lowland Hill Forest	1998	Dec	WWF
Mubi River Karst	Gobe	G	Gobe 98 E	G6	6.89305	143.7375	50		24a		24b		6e	Small-crowned Forest	1998	Dec	WWF

Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.

Bioregion	Survey area*	Survey area code*	Sample site*	Sample site code*	Lat*	Long*	Altitude*	Groups sampled (entries are reference codes from Appendix 1)						Habitat*	survey Year	Survey month	Surveyors
								B	M	H	P	F	I				
Mubi River Karst	Kaffa cave	KF	Kaffa cave	KF	6.58111	143.50138	620		?					Medium crowned lowland hill forest	1996	Oct	WWF
Mubi River Karst	Kantobo	K	Kantobo	K	6.72173	143.56652	400-420	9						Rainforest b/w Moro and Gobe, beyond Namatigi village	1998	April-May	WWF
Mubi River Karst	Mt Kemenagi Group	MK	MK1 and MK2	MK3	6.46763	143.4225	1015		1a					Pre-Montane rainforest	1995	July	
Mubi River Karst	Mt.Kemenagi	MK	Mt.Kemenagi 1	MK1	6.46527	143.40805	900		1a					Pre-Montane rainforest	1995	July	WWF
Mubi River Karst	Mt.Kemenagi	MK	Mt.Kemenagi 2	MK2	6.47	143.43694	1130		1a					Pre-Montane rainforest	1994	June	WWF
Mubi River Karst	Wassi Falls	WF	Wassi Falls 1	WF1	6.74805	143.58972	380 - 420	1c	1a, 1b				1e, 1f	Tropical wet forest	1995	March	WWF
Mubi River Karst	Wassi Falls	WF	Wassi Falls 2	WF2	6.72611	143.60583	490		1a, 1b					Tropical wet forest	1995	July	WWF
Mubi River Karst	Wassi Falls	WF	Wassi Falls 3	WF3	6.73138	143.60583	600		1a, 1b					Pre-Montane rainforest	1995	July	WWF
Mubi River Karst	Wassi Falls	WF	Wassi Falls/Kantobo	WF4	6.65	143.51666	380-420				1g	1d	1e, 1f	Creeks and pools, 9 sites	1995	March	WWF
Mubi River Karst	Wassi Falls Group	WF	WF1 to WF4	WF5	6.73518	143.60046	497		1a, 1b, 2					Pre-Montane rainforest	1995	July	WWF
Western Volcanics	Bosavi-Didesa	BD	Bosavi-Didesa	BD	6.46667	142.83333			MS								
Western Volcanics	Mt Sisa Group	MS	MS1 and MS2	MS3	6.12986	142.76069	2200	6a	6a	6c	6d		6c, 6e	Upper Montane <i>Nothofagus</i> forest	2000	Nov	WWF
Western Volcanics	Mt Bosavi	MB	Mt Bosavi	MB	6.54527	142.83972	1250-1725	1c	1a, 1b		1g	1d	1e, 1f	Pre-Montane semi-saturated rainforest, lower Montane semi-saturated rainforest	1995	March	WWF

Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.

Bioregion	Survey area*	Survey area code*	Sample site*	Sample site code*	Lat*	Long*	Altitude*	Groups sampled (entries are reference codes from Appendix 1)						Habitat*	survey Year	Survey month	Surveyors
								B	M	H	P	F	I				
Western Volcanics	Mt Sisa	MS	Mt Sisa bottom camp	MS1	6.12527	142.76777	1840	6a	6a	6c	6d		6c, 6e	Lower Montane <i>Nothofagus</i> forest	1999	Oct	WWF
Western Volcanics	Mt Sisa	MS	Mt Sisa top camp	MS2	6.13444	142.75361	2560	6a	6a	6c	6d		6c, 6e	Upper Montane <i>Nothofagus</i> forest	1999	Oct	WWF
Moro Region	Lake Kutubu	LK	Kutubu swamp forest 1	LK2	6.35222	143.24055	?		20					Swamp forest	1998	Oct	Wetlands International
Moro Region	Lake Kutubu	LK	Kutubu swamp forest 2	LK3	6.32638	143.26611	?		20					Swamp forest	1998	Oct	Wetlands International
Moro Region	Lake Kutubu	LK	Kutubu swamp forest 3	LK4	6.35861	143.25694	?		20					Swamp forest	1998	Oct	Wetlands International
Moro Region	Lake Kutubu	LK	Lake Kutubu	LK1	6.41666	143.33333	808		19			19		Lake, rivers & streams	1995-97	N/A	WWF
Moro Region	Lake Kutubu Group	LK	Lk1 to LK3	LK5	6.34278	143.26095	808		20					Swamp forest	1999	Nov	Wetlands International
Moro Region	Moro	MO	Moro	MO3	6.36277	143.22805	740-1000	10						Primary pre-Montane rainforest	1997	July-Aug	Wetlands International & WWF-US
Moro Region	Moro	MO	Moro	MO4	6.36277	143.22805	800-1300			22				Pre-Montane rainforest, streams & Ponds	2001	Oct	WWF
Moro Region	Moro-Kutubu	MO	Moro/Kutubu/Agogo	MO1	6.36789	143.20200	740-1350	1c			1g	1d	1e, 1f	Primary pre-Montane rainforest; rivers, creeks & lake	1995	March	WWF
Moro Region	Moro-Kutubu	MO	Moro/Kutubu/Agogo	MO2	6.4	143.2	790-1438	9						Primary pre-Montane rainforest	1998	April-May	WWF
Iagifu Agogo limestone Uplands	Iagifu-Agogo	Ig	Henry's Trail - Agogo Rd	Ig3	6.39833	143.17833	1050		1a, 1b					Primary pre-Montane rainforest	1995	March	WWF

Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.

Bioregion	Survey area*	Survey area code*	Sample site*	Sample site code*	Lat*	Long*	Altitude*	Groups sampled (entries are reference codes from Appendix 1)						Habitat*	survey Year	Survey month	Surveyors
								B	M	H	P	F	I				
Iagifu Agogo limestone Uplands	Iagifu-Agogo	Ig	Iagifu Ridge	Ig2	6.44944	143.2275	1330-1350		1a, 1b					Primary pre-Montane rainforest	1995	March	WWF
Iagifu Agogo limestone Uplands	Iagifu-Agogo	Ig	Iagifu/Agogo/Ridge	Ig1	6.39083	143.16666	1000+	10						Primary pre-Montane rainforest	1997	July-Aug	Wetlands International & WWF-US
Iagifu Agogo limestone Uplands	Iagifu Group	Ig	Ig2 and Ig3	Ig4	6.42388	143.20291	1050		1a, 1b					Primary pre-Montane rainforest	1996	April	WWF
Eastern Upland Volcanics/Karst	Homa- Idauwi	B	Benaria	B	6.05478	142.97845	1345 - 1545	38	35, 36	36	39			Small-crowned Lowland Hill Forest, grassland, secondary growth, river	2003	May	2005 survey
Eastern Upland Volcanics/Karst	Homa- Idauwi	HH	Homa-Idauwi (H12)	HH12	6.09	142.99	1239		34					Small-crowned Lowland Hill Forest			WWF
Eastern Upland Volcanics/Karst	Homa- Idauwi	HH	Homa-Idauwi (H5)	HH5	6.17722	143.07527	1239		34					Small-crowned Lowland Hill Forest			WWF
Eastern Upland Volcanics/Karst	Mt Moran	MM	Mt Moran	MM	6.26548	143.13738	1650	9						Pre-Montane rainforest			WWF
Eastern Upland Volcanics/Karst	Nogoli	N	Nogoli	N	5.9648	142.8164	1200	38		37				Small-crowned Lowland Hill Forest, grassland, secondary growth, river	2003	May	2005 survey
Northern Montane Karst	Hides	H3	Hides	H3	5.9485	142.7455	2163-2400	38	35, 36	37	39			Upper Montane <i>Nothofagus</i> forest	2003	May	2005 survey
Western Lowlands	Camp 1 Juha North	JN	Camp 1 Juha North	JN	5.8078	142.3083	213	43	40,41	42	44			Small-crowned Lowland Hill Forest	2008	March	2008 survey

Appendix 2 Survey areas (WWF and PNG LNG Project) with biodiversity records within the PNG LNG upstream project area.

Bioregion	Survey area*	Survey area code*	Sample site*	Sample site code*	Lat*	Long*	Altitude*	Groups sampled (entries are reference codes from Appendix 1)						Habitat*	survey Year	Survey month	Surveyors
								B	M	H	P	F	I				
WesternFoothills	Camp 2 Juha South	JS	Camp 2 Juha South	JS	5.90189	142.436	953	43	40,41	42	44			lower montane small crowned forest	2008	Feb	2008 survey
Western Lowlands	Camp 3 Baia River	BR	Camp 3 Baia River	BR	6.0205	142.5473	328	43	40,41	42	44			Small Crowned Lowland Forest and Open Lowland Forest	2008	Mar	2008 survey
Western Lowlands	Camp 4 South Karius	SK	Camp 4 South Karius	SK	5.99112	142.6706	1368	43	40,41	42	44			lower montane small crowned forest	2008	Apr	2008 survey
Eastern Upland Volcanics/Karst	Camp 5 Deviation	DEV	Camp 5 Deviation	DEV	6.096767	143.1045	1975	43	40,41	42	44			lower montane small crowned forest with <i>Nothofagus</i>	2008	March	2008 survey

Where data in a report covered several sample sites and could not be disaggregated, a new sample site designation was assigned to that data and the co-ordinates and altitude of the “new” sample site were calculated as the average of the sample sites the data covered.

* survey area = main survey area; survey area Code = code for main survey area in GIS; Sample site = sample site within survey area; Sample site Code = code for sample site in GIS; Lat & Long = decimal degrees WGS 84 Zone 54S; Altitude = m; habitat as recorded in original paper.

† B = birds, m = mammals, H = reptiles and amphibians, P = plants, F = fish and I = invertebrates.

** Museum specimen with locality data was collected.

Appendix 3 Groupings of FIMS vegetation types used in EIS analysis.

Broad Vegetation Group	Vegetation Type (fields in FIMS GIS)	
	Veg_Type	Veg_Type_Description
montane forest (>3000m) with/without grassland	Mo	Montane Forest - above 3000 m - Very small crowned Forest
	Mo/Ga	Complex - Very small crowned Forest/Alpine grassland
	Mo/Ga?Sc	Complex - Very small crowned Forest/Alpine grassland/Scrub
grasslands	Ga	Grassland and Herbland - Alpine grassland
	Gi	Grassland and Herbland - Subalpine grassland
	Gri	Grassland and Herbland - Riverine successions dominated by grass
	Gri/Po	Complex - Riverine successions dominated by grass/Open Forest
	Gsw	Grassland and Herbland - Swamp grassland
	Ga/Sc	Alpine grassland/Scrub complex
scrub	Sc	Scrub - Scrub
lower montane small crowned forest	L	Lower Montane Forest - above 1000 m - Small crowned Forest
	L/Ls	Complex - Small crowned Forest/Very small crowned Forest
	L5	Lower Montane Forest - above 1000 m - Small crowned Forest
	L8	Lower Montane Forest - above 1000 m - Small crowned Forest
lower montane small crowned forest with conifers	Lc	Lower Montane Forest - above 1000 m - Small crowned Forest with conifers
	Lc/Gi	Complex - Small crowned Forest with conifers/Subalpine grassland
	Lc/Ls/Gi	Complex - Small crowned Forest with conifers/Very small crowned Forest/Subalpine grassland
lower montane small crowned forest with <i>Nothofagus</i>	LN/LsN	Complex - Small crowned Forest with <i>Nothofagus</i> /Very small crowned Forest with <i>Nothofagus</i>
	L/LN	Complex - Small crowned Forest/Small crowned Forest with <i>Nothofagus</i>
	LN	Lower Montane Forest - above 1000 m - Small crowned Forest with <i>Nothofagus</i>
	LN5	Lower Montane Forest - above 1000 m - Small crowned Forest with <i>Nothofagus</i>
	LN8	Lower Montane Forest - above 1000 m - Small crowned Forest with <i>Nothofagus</i>
lower montane very small crowned forest complexes	Ls	Lower Montane Forest - above 1000 m - Very small crowned Forest
	Ls/L	Complex - Very small crowned Forest/Small crowned Forest
	Ls/Gi	Complex - Very small crowned Forest/Subalpine grassland
lower montane very small crowned forest complexes with <i>Nothofagus</i>	Ls/LsN	Complex - Very small crowned Forest/Very small crowned Forest with <i>Nothofagus</i>
	Ls/LN	Complex - Very small crowned Forest/Small crowned Forest with <i>Nothofagus</i>
	LsN	Lower Montane Forest - above 1000 m - Very small crowned Forest with <i>Nothofagus</i>
	LsN/L	Complex - Very small crowned Forest with <i>Nothofagus</i> /Small crowned Forest
	LsN/LN	Complex - Very small crowned Forest with <i>Nothofagus</i> /Small crowned Forest with <i>Nothofagus</i>
	LsN/Sc	Complex - Very small crowned Forest with <i>Nothofagus</i> /Scrub
medium crowned to small crowned forest complexes	Hm/Hs	Complex - Medium crowned Forest/Small crowned Forest
	Hm/Hs/Fsw	Complex - Medium crowned Forest/Small crowned Forest/Mixed swamp Forest
	Hm8/Hs8	Complex - Medium crowned Forest/Small crowned Forest
	Hm9/Hs9	Complex - Medium crowned Forest/Small crowned Forest
	Hs/Hm	Complex - Small crowned Forest/Medium crowned Forest
medium crowned to small crowned forest complexes with <i>Nothofagus</i>	HsN/Hm	Complex - Small crowned Forest with <i>Nothofagus</i> /Medium crowned Forest
low altitude large crowned forest	HL.N	Low Altitude Forest On Uplands - below 1000m - Large Crowned Forest - presence of <i>Nothofagus</i> noted or suspected

Appendix 3 Groupings of FIMS vegetation types used in EIS analysis.

Broad Vegetation Group	Vegetation Type (fields in FIMS GIS)	
	Veg_Type	Veg_Type_Description
	HI8.N	Low Altitude Forest On Uplands - below 1000m - Large Crowned Forest - presence of <i>Nothofagus</i> noted or suspected
low altitude medium crowned forest	Hm	Low Altitude Forest On Uplands - below 1000m - Medium crowned Forest
	Hm.Ar	Low Altitude Forest On Uplands - below 1000m - Medium crowned Forest - Presence of <i>Araucaria</i> noted
	Hm.N	Low Altitude Forest On Uplands - below 1000m - Medium crowned Forest - presence of <i>Nothofagus</i> noted or suspected
	Hm8	Low Altitude Forest On Uplands - below 1000m - Medium crowned Forest
	Hm8.N	Low Altitude Forest On Uplands - below 1000m - Medium crowned Forest - presence of <i>Nothofagus</i> noted or suspected
	Hm9	Low Altitude Forest On Uplands - below 1000m - Medium crowned Forest
	Hs	Low Altitude Forest On Uplands - below 1000m - Small crowned Forest
	Hs8	Low Altitude Forest On Uplands - below 1000m - Small crowned Forest
	Hm5	Low Altitude Forest On Uplands - below 1000m - Medium crowned Forest
	Hm5/Hs5	Complex - Medium crowned Forest/Small crowned Forest
low altitude small crowned forest with <i>Nothofagus</i>	HsN	Low Altitude Forest On Uplands - below 1000m - Small crowned Forest with <i>Nothofagus</i>
large to medium crowned lowland forest	PI	Low Altitude Forest On Plains And Fans - below 1000m - Large to medium crowned Forest
	PI9	Low Altitude Forest On Plains And Fans - below 1000m - Large to medium crowned Forest
small crowned lowland forest	Ps	Low Altitude Forest On Plains And Fans - below 1000m - Small crowned Forest
	Ps/Hs	Complex - Small crowned Forest/Small crowned Forest
	Ps5	Low Altitude Forest On Plains And Fans - below 1000m - Small crowned Forest
	Ps8	Low Altitude Forest On Plains And Fans - below 1000m - Small crowned Forest
open lowland forest	Po	Low Altitude Forest On Plains And Fans - below 1000m - Open Forest
	Po8	Low Altitude Forest On Plains And Fans - below 1000m - Open Forest
open lowland forests and freshwater swamps	Po/Fsw	Complex - Open Forest/Mixed swamp Forest
	Po/Fsw8	Complex - Open Forest/Mixed swamp Forest
	Po8/Fsw8	Complex - Open Forest/Mixed swamp Forest
swamp forest complexes	Fsw	Swamp Forest - Mixed swamp Forest
	Fsw/Gsw	Complex - Mixed swamp Forest/Swamp grassland
	Fsw/M	Complex - Mixed swamp Forest/Mangrove
	Fsw/Wsw	Complex - Mixed swamp Forest/Swamp woodland
	Fsw/Wsw/M	Complex - Mixed swamp Forest/Swamp woodland/Mangrove
	Fsw5	Swamp Forest - Mixed swamp Forest
	Fsw8	Swamp Forest - Mixed swamp Forest
	Fsw8/Wsw	Complex - Mixed swamp Forest/Swamp woodland
	Hs/Fsw	Complex - Small crowned Forest/Mixed swamp Forest
swamp woodland and forest complexes	Wsw	Woodland - Swamp woodland
	Wsw/Fsw	Complex - Swamp woodland/Mixed swamp Forest
	Wsw/Fsw8	Complex - Swamp woodland/Mixed swamp Forest
	Wsw/M	Complex - Swamp woodland/Mangrove
mangroves	M	Estuarine Communities - Mangrove
cultivated or non-vegetated	E	Other Non-vegetation and Areas Dominated By Land Use - Lakes and larger rivers
	O	Other Non-vegetation and Areas Dominated By Land Use - No Forest (Land use intensity classes 0-4)
	U	Other Non-vegetation and Areas Dominated By Land Use - Larger urban areas

Appendix 4 Areas (km²) of Broad Vegetation Groups in bioregions in the PNG LNG upstream project area.

BVG	Kikori Lowlands	Sirebi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu-Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Grand Total
montane forest (>3000m) with/without grassland											3,315	3,095	6,410
grasslands ¹	118		1,097							231	28,921	4,265	34,631
scrub ²						221						1,743	1,964
lower montane small crowned forest	7,527	816	861			1,876	38,093	1,773	927	15,158	124,755	27,110	218,897
lower montane small crowned forest with conifers											25,638	779	26,417
lower montane small crowned forest with <i>nothofagus</i>			397				5,580	1,566		53,619	95,513	41,050	197,725
lower montane very small crowned forest complexes	2,026						31,347						33,372
lower montane very small crowned forest complexes with <i>Nothofagus</i>							24,258	2,617	11,381	2,108	40,997	17,533	98,894
medium crowned to small crowned forest complexes	278,295	57,286	10,687	176,309			55,757			849			579,184
medium crowned to small crowned forest complexes with <i>Nothofagus</i>			3,257				43,723		8,111		495		55,585
low altitude large crowned forest			51							38,226			38,277
low altitude medium crowned forest	171,823	36,500	59,807	1,542	50,616	39,284	54,769	10,433	8,942	46,291	10,728	306	491,041
low altitude small crowned forest with <i>Nothofagus</i>			339						4,178				4,517
large to medium crowned lowland forest	3,824	2,455											6,279
small crowned lowland forest	55,456	19											55,475
open lowland forest	37,404		865	668									38,938
open lowland forests and freshwater							6,438	304			8		6,750

Appendix 4 Areas (km²) of Broad Vegetation Groups in bioregions in the PNG LNG upstream project area.

BVG	Kikori Lowlands	Sirebi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu-Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Grand Total
swamps													
swamp forest complexes	66,227		971				9,097	56		800			77,152
swamp woodland and forest complexes	13,064		1,901				6,886	1,989	75	122			24,036
mangroves	124,327												124,327
cultivated or non-vegetated	65						7,741	53		21,066	85,422	12,442	126,789
rivers or lakes ³	13,248							5,182	4				18,434
Totals	773,405	97,077	80,234	178,520	50,616	41,381	283,689	23,973	33,617	178,471	415,791	108,322	2,265,096

Areas calculated from FIMS data by F. Crome.

1 mostly alpine grasslands.

2 montane scrubs on rocky slopes.

3 FIMS only maps lakes and largest rivers and estuaries.

Appendix 5 Non-volant mammals recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	Kikori Lowlands	Sirebi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Tachyglossidae	<i>Zaglossus bartoni</i>	Long-beaked Echidna			1	1	1	1	2			2	4	1	13
Tachyglossidae	<i>Tachyglossus aculeatus</i>	Short-beaked Echidna			1	1									2
Dasyuridae	<i>Dasyurus albopunctatus</i>	New Guinea Quoll			1	1	1	1	1		1	2	4	1	13
Dasyuridae	<i>Murexechinus melanurus</i>	Black-tailed Antechinus				1	1	1	1			2	1		7
Dasyuridae	<i>Phascomurexia naso</i>	Long-nosed Murexia				1						2	1		4
Dasyuridae	<i>Phascolosorex dorsalis</i>	Narrow-striped Dasyure											1		1
Dasyuridae	<i>Murexia longicauda</i>	Short-furred Dasyure				1	1	1				2	4	1	10
Dasyuridae	<i>Murexia sp.</i>	undescribed species of Murexia										1			1
Dasyuridae	<i>Myoictis melas</i>	Three-striped Dasyure			1	1	1	1	1			3	2		10
Peroryctidae	<i>Echymipera kalubu</i>	Common Echymipera	4		1	1	1	1	3			2	4	1	18
Peroryctidae	<i>Echymipera rufescens</i>	Long-nosed Echymipera	1		1				1			1			4
Peroryctidae	<i>Microperoryctes longicauda</i>	Striped Bandicoot	1				1	1	3			2	4	1	13
Peroryctidae	<i>Peroryctes raffrayana</i>	Raffray's Bandicoot	2			1	1	1	1			2	2	1	11
Phalangeridae	<i>Phalanger carmelitae</i>	Mountain Cuscus						1				3	4	1	9
Phalangeridae	<i>Phalanger gymnotis</i>	Ground Cuscus	3		1	1	1	1	2			3	4	1	17
Phalangeridae	<i>Phalanger intercastellanus</i>	Common Cuscus	1			1	1	1	2		1	3			10
Phalangeridae	<i>Phalanger mimicus</i>	Cuscus	3		1	1									5
Phalangeridae	<i>Phalanger sericeus</i>	Silky Cuscus						1				2	4	1	8
Phalangeridae	<i>Phalanger vestitus</i>	Stein's Cuscus						1				2	4	1	8
Phalangeridae	<i>Spiloglossus maculatus</i>	Spotted Cuscus	3		1	2	1	1	2			3	3	1	17
Macropodidae	<i>Dendrolagus dorianus</i>	Doria's Tree Kangaroo			1	1		1	4			3	4	1	15

Appendix 5 Non-volant mammals recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	Kikori Lowlands	Sirebi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Macropodidae	<i>Dendrolagus goodfellowi</i>	Goodfellow's Tree Kangaroo			1	1		1	1			2	4	1	11
Macropodidae	<i>Dendrolagus spadix</i>	Lowland Tree Kangaroo	2		1		1		2			2	2		10
Macropodidae	<i>Dorcopsis hageni</i>	White-Striped Dorcopsis										1			1
Macropodidae	<i>Dorcopsis luctuosa</i>	Grey Dorcopsis	3		1	1			1						6
Macropodidae	<i>Dorcopsulus macleayi</i>	Macleay's Dorcopsis											1		1
Macropodidae	<i>Dorcopsulus vanheurni</i>	Lesser Forest Wallaby						1	2			2	2	1	8
Macropodidae	<i>Thylogale browni</i>	New Guinea Pademelon						1							1
Burramyidae	<i>Cercartetus caudatus</i>	Long-tailed Pygmy Possum							1			2	4		7
Pseudocheiridae	<i>Pseudochirops corinnae</i>	Plush-coated Ringtail						1				2	4	1	8
Pseudocheiridae	<i>Pseudochirops cupreus</i>	Coppery Ringtail							1			3	4	1	9
Pseudocheiridae	<i>Pseudochirulus canescens</i>	Lowland Ringtail	2				1		1			2	2		8
Pseudocheiridae	<i>Pseudochirulus forbesi</i>	Painted Ringtail						1	1			2	1		5
Pseudocheiridae	<i>Pseudochirulus mayeri</i>	Pygmy Ringtail										2	4	1	7
Petauridae	<i>Dactylopsila megalura</i>	Great Tailed Triok										1			1
Petauridae	<i>Dactylopsila palpator</i>	Long-fingered Triok										2	2		4
Petauridae	<i>Dactylopsila trivirgata</i>	Striped Possum	1			2	1	1	2			3	4		14
Petauridae	<i>Petaurus breviceps</i>	Sugar Glider	3		1	2	1	1	3			3	4	1	19
Acrobatidae	<i>Distoechurus pennatus</i>	Feather-tailed Possum	2		1	1	1	1	1	1		2	3	1	14
Muridae	<i>Anisomys imitator</i>	Uneven-toothed Rat				1	1	1	1		1	2	3		10
Muridae	<i>Chiruromys lamia</i>	Broad-headed Tree-mouse											1		1
Muridae	<i>Chiruromys vates</i>	Lesser-tree Mouse				2	1	1				3	1		8

Appendix 5 Non-volant mammals recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	Kikori Lowlands	Sirebi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Muridae	<i>Crossomys moncktoni</i>	Earless Water Rat										2	4	1	7
Muridae	<i>Coccymys rummleri</i>	Rummler's Mouse											2		2
Muridae	<i>Hydromys chrysogaster</i>	Common Water Rat	1				1	1				2	2		7
Muridae	<i>Hyomys dammermani</i>	Western White-eared Giant-rat										1			1
Muridae	<i>Hyomys goliath</i>	Eastern White-eared giant-rat										1			1
Muridae	<i>Hyomys goliath/ H. dammermani</i>	White-eared Rat										1			1
Muridae	<i>Leptomys elegans</i>	Large Leptomys						1	1		1	2			5
Muridae	<i>Leptomys signatus</i>	Fly River Leptomys			1							1			1
Muridae	<i>Leptomys ernstmayeri</i>	Ernst Mayer's Leptomys										1	2		3
Muridae	<i>Lorentzimys nouhuysi</i>	Long-footed Tree Mouse			1		1	1	2	1		3	1		10
Muridae	<i>Macruromys major</i>	Greater Small-toothed Rat										1			1
Muridae	<i>Mallomys aroaensis</i>	Grey Black-eared Rat										2	1		3
Muridae	<i>Mallomys rothschildi</i>	Dusky Black-eared Rat										3	1		4
Muridae	<i>Mayermys ellermani</i>	One-toothed Shrew Mouse											2	1	3
Muridae	<i>Melomys leucogaster</i>	White-bellied Melomys	4			1		1	1	1		2	3		13
Muridae	<i>Melomys lutillus</i>	Grassland Melomys					2	1				1	2		6
Muridae	<i>Melomys rufescens</i>	Black-tailed Melomys	2		1	2	2	1	2	1		2	4	1	18
Muridae	<i>Microhydromys richardsoni</i>	Groove-toothed Shrew Mouse			1							1			2
Muridae	<i>Parahydromys asper</i>	Waterside Rat						1				2	2	1	6
Muridae	<i>Abeomelomys sevia</i>	Menzie's Mouse											1		1
Muridae	<i>Paramelomys levipes?</i>	Long-nosed Melomys		1					2			1			4

Appendix 5 Non-volant mammals recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	Kikori Lowlands	Sirebi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Muridae	<i>Paramelomys lorentzii</i>	Lorentz's Melomys					1					1			2
Muridae	<i>Paramelomys mollis</i>	Thomas's Melomys						1				2	2		5
Muridae	<i>Paramelomys moncktoni</i>	Monckton's Melomys					1								1
Muridae	<i>Paramelomys sp.aff. moncktoni</i>	New Melomys species					1	1							2
Muridae	<i>Paramelomys platyops</i>	Lowland Melomys	2	1	1	1	2	1	3	1		2	1		15
Muridae	<i>Paramelomys rubex</i>	Mountain Melomys	1					1	3		1	3	4	1	14
Muridae	<i>Pogonomelomys bruijni</i>	Large Pogonomelomys										2			2
Muridae	<i>Pogonomelomys mayeri</i>	Shaw Mayer's Pogonomelomys										1			1
Muridae	<i>Pogonomys loriae</i>	Large Tree Mouse	2			1	2	1	1			3	4	1	15
Muridae	<i>Pogonomys macrourus</i>	Chestnut Tree Mouse				1	2	1				3	1		8
Muridae	<i>Pogonomys sylvestris</i>	Grey-bellied Tree-mouse										2	2		4
Muridae	<i>Rattus exulans</i>	Pacific Rat	1				1					1			3
Muridae	<i>Rattus leucopus</i>	Cape York Rat	6	1	1	2	1	1	3			2			17
Muridae	<i>Rattus mordax</i>	Eastern Rat					1								1
Muridae	<i>Rattus novaeguineae</i>	New Guinea Rat							1		1	1			3
Muridae	<i>Rattus sp.</i>	Rat									1	1	1		3
Muridae	<i>Rattus cf. praetor</i>	Large Spiny Rat							1						1
Muridae	<i>Rattus sp. nov. (Mt Kemenagi)</i>	Undescribed species of Rattus	1		1	1			2						5
Muridae	<i>Rattus steini</i>	Stein's Rat					1	1	1			2	1		6
Muridae	<i>Stenomys niobe</i>	Moss Forest Rat						1	1			3	3		8
Muridae	<i>Stenomys verecundus</i>	Slender Rat			1	1	1	1	1		1	3	1		10

Appendix 5 Non-volant mammals recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	Kikori Lowlands	Sirebi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Muridae	<i>Uromys anak</i>	Giant Naked-tailed Rat										2	3		5
Muridae	<i>Uromys caudimaculatus</i>	Mottled-tailed Giant Rat	3			2	2	1	3			3	1		15
Muridae	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat					1		1			1			3
Total species			24	3	23	30	35	43	41	5	8	72	58	25	86*

Entries are number of sample sites at which species recorded. Combined data from the PNG LNG Project and the WWF surveys.

* Excluding entry for *Hyomys goliath*/ *H. dammermani*

Appendix 6 Bats recorded from the PNG LNG upstream project area.

Family	Scientific name	Common name	Kikori Lowlands	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Foothills	Western Lowlands	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Pteropodidae	<i>Dobsonia magna</i>	Greater Bare-backed Fruit Bat	4	1				1	1	1	1	2	3		14
Pteropodidae	<i>Dobsonia minor</i>	Lesser Bare-backed Bat	1		1	1			1						4
Pteropodidae	<i>Macroglossus minimus</i>	Least Blossom Bat	3	1	1	1		1	1						8
Pteropodidae	<i>Nyctimene aello</i>	Greater Tube-nosed Bat	2			1		1	1						5
Pteropodidae	<i>Nyctimene albiventer</i>	Common Tube-nosed Bat	2	1		2		1	3	1		1	2		13
Pteropodidae	<i>Nyctimene cyclotis</i>	Round-eared Tube-nosed Bat								1		1	2		4
Pteropodidae	<i>Nyctimene draconilla</i>	Lesser Tube-nosed Bat										1			1
Pteropodidae	<i>Paranyctimene raptor</i>	Green Tube-nosed Bat	2	1	1	2		1	3				2		12
Pteropodidae	<i>Paranyctimene sp. aff. raptor</i>	Tube-nosed Bat											1		1
Pteropodidae	<i>Pteropus macrotis</i>	Big-eared Flying fox	2												2
Pteropodidae	<i>Pteropus neohibernicus</i>	Giant Flying-fox	4		1	1			3		1				10
Pteropodidae	<i>Syconycteris australis</i>	Common Blossom Bat	5	1	1	1		2	4	1	2	3	3	1	24
Emballonuridae	<i>Emballonura diana</i>	Large-eared Sheath-tailed Bat				1						1			2
Emballonuridae	<i>Emballonura furax</i>	New Guinea Sheath-tailed Bat				1						1			2
Emballonuridae	<i>Emballonura diana/furax</i>	Large-eared/New Guinea Sheath-tailed Bat					1	1					1	1	4
Emballonuridae	<i>Emballonura raffrayana</i>	Raffray's Sheath-tailed Bat				1			1			1			3
Emballonuridae	<i>Mosia nigrescens</i>	Lesser Sheath-tailed Bat	1			1	1		1			1	2	1	8
Hipposideridae	<i>Aselliscus tricuspidatus</i>	Trident Leaf-nosed Bat	1					1							2
Hipposideridae	<i>Hipposideros calcaratus</i>	Spurred Leaf-nosed Bat			1	1		1							3
Hipposideridae	<i>Hipposideros cervinus</i>	Fawn Leaf-nosed Bat	3	1	1	1		1							7
Hipposideridae	<i>Hipposideros diadema</i>	Diadem Leaf-nosed Bat	1			3	1	2							7

Appendix 6 Bats recorded from the PNG LNG upstream project area.

Family	Scientific name	Common name	Kikori Lowlands	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Foothills	Western Lowlands	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Hipposideridae	<i>Hipposideros maggietaylorae</i>	Maggie Taylor's Leaf-nosed Bat	2		1		1	2							6
Hipposideridae	<i>Hipposideros semoni</i>	Greater Leaf-nosed Bat					1	2					1		4
Hipposideridae	<i>Hipposideros wollastoni</i>	Wollaston's Leaf-nosed Bat	1		1										2
Rhinolophidae	<i>Rhinolophus arcuatus</i>	Western Horseshoe Bat				2	1	2				2	1	1	9
Rhinolophidae	<i>Rhinolophus euryotis</i>	New Guinea Horseshoe Bat			1		1	2				2	1		7
Rhinolophidae	<i>Rhinolophus maros</i>	Greater Horseshoe Bat					1	2				1	1		5
Rhinolophidae	<i>Rhinolophus megaphyllus</i>	Eastern Horseshoe Bat	1				1	2				1	1	1	7
Rhinolophidae	<i>Rhinolophus philippinensis</i>	Large-eared Horseshoe Bat				1	1	2				1	3		8
Vespertilionidae	"Vesp Fmin 31"	Unidentified species												1	1
Vespertilionidae	<i>Kerivoula muscina</i>	Fly River Trumpet-eared Bat						1							1
Vespertilionidae	<i>Miniopterus australis</i>	Little Bent-wing Bat	3	1					1				1		6
Vespertilionidae	<i>Miniopterus macrocneme</i>	Long-legged Bat							1						1
Vespertilionidae	<i>Miniopterus macrocneme/medius</i>	Long-legged/ Javan Bent-wing Bat					1	2							3
Vespertilionidae	<i>Miniopterus magnater</i>	Western Bent-wing Bat	2						3			1	1	1	8
Vespertilionidae	<i>Miniopterus medius</i>	Javan Bent-wing Bat	2						3		1	1			7
Vespertilionidae	<i>Miniopterus propitristis</i>	Greater Melanesian Bent-wing Bat									1	2	1		4
Vespertilionidae	<i>Murina florum</i>	Flores Tube-nosed Bat						1						1	2
Vespertilionidae	<i>Myotis moluccarum</i>	Arafura Large-footed Bat						1							1
Vespertilionidae	<i>Nyctophilus microdon</i>	Small-toothed Big-eared Bat										1	1	1	3
Vespertilionidae	<i>Nyctophilus microtis</i>	Papuan Big-eared Bat					1	2				1	2		6
Vespertilionidae	<i>Philetor brachypterus</i>	Rohu's Bat					1	2				2	2	1	8

Appendix 6 Bats recorded from the PNG LNG upstream project area.

Family	Scientific name	Common name	Kikori Lowlands	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Foothills	Western Lowlands	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Vespertilionidae	<i>Phoniscus papuensis</i>	Golden-tipped Bat							1						1
Vespertilionidae	<i>Pipistrellus angulatus</i>	New Guinea Pipistrelle						2				1	2	1	6
Vespertilionidae	<i>Pipistrellus collinus</i>	Mountain Pipistrelle					1	2				1	1	1	6
Vespertilionidae	<i>Pipistrellus papuanus</i>	Papuan Pipistrelle						1							1
Molossidae	<i>Chaerephon jobensis</i>	Wrinkle-lipped Mastiff-bat					1	1							2
Molossidae	<i>Otomops secundus</i>	Mantled Mastiff-bat					1	2				1	2	1	7
Molossidae	<i>Tadarida kuboriensis</i>	New Guinea Mastiff-bat										1	2	1	4
Total species			19	7	10	16	16	29	15	4	5	24	24	14	262

Entries are number of sample sites at which species recorded.

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Casuariidae	<i>Casuarus casuarus</i>	Southern Cassowary		4	1	1				1				1		8
Casuariidae	<i>Casuarus bennetti</i>	Dwarf Cassowary				1		2	1	2	1		3	2	1	13
Megapodiidae	<i>Aepyodius arfakianus</i>	Wattled Brush-turkey									1		2	1		4
Megapodiidae	<i>Talegalla fuscirostris</i>	Black-billed Brush-turkey		4	1		1			3	1			1		11
Megapodiidae	<i>Talegalla jobiensis</i>	Brown-collared Brush-turkey						1						2		3
Megapodiidae	<i>Talegalla sp.</i>	Brush-turkey		2									1			3
Megapodiidae	<i>Megapodius reinwardt</i>	Orange-footed Scrubfowl		5						2	1					8
Megapodiidae	<i>Megapodius decollatus</i>	New Guinea Scrubfowl						1	1				1	2		5
Phasianidae	<i>Coturnix chinensis</i>	Blue-breasted Quail											1	1		2
Dendrocygnidae	<i>Dendrocygna guttata</i>	Spotted Whistling-Duck		3						1						4
Dendrocygnidae	<i>Dendrocygna arcuata</i>	Wandering Whistling-Duck		1												1
Anatidae	<i>Nettapus pulchellus</i>	Green Pygmy-goose								1	1					2
Anatidae	<i>Salvadorina waigiensis</i>	Salvadori's Teal											1			1
Anatidae	<i>Anas superciliosa</i>	Pacific Black Duck									2					2
Anatidae	<i>Anas gracilis</i>	Grey Teal								1						1
Bucerotidae	<i>Aceros plicatus</i>	Blyth's Hornbill		7	1	1	1	2		3	3			2		20
Coraciidae	<i>Eurystomus orientalis</i>	Dollarbird		5	1	1			1	3	3			1		15
Alcedinidae	<i>Alcedo azurea</i>	Azure Kingfisher		5	1					2	3					11
Alcedinidae	<i>Alcedo pusilla</i>	Little Kingfisher		6						1						7
Alcedinidae	<i>Ceyx lepidus</i>	Variable Kingfisher		4		1	1			3	1					10
Dacelonidae	<i>Dacelo gaudichaud</i>	Rufous-bellied Kookaburra		9	1			2		3	2					17
Dacelonidae	<i>Clytoceyx rex</i>	Shovel-billed Kookaburra		1				1		1			1			4
Dacelonidae	<i>Todirhamphus nigrocyaneus</i>	Blue-black Kingfisher		1												1
Dacelonidae	<i>Todirhamphus macleayi</i>	Forest Kingfisher		3	1					2				1		7
Dacelonidae	<i>Todirhamphus sanctus</i>	Sacred Kingfisher		6						1	3	1				11

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Dacelonidae	<i>Melidora macrorrhina</i>	Hook-billed Kingfisher		4	1	1	1	2		2	1					12
Dacelonidae	<i>Syma torotoro</i>	Yellow-billed Kingfisher		3			1	2		2	2					10
Dacelonidae	<i>Syma megarhyncha</i>	Mountain Kingfisher							1		1		3	2		7
Meropidae	<i>Merops ornatus</i>	Rainbow Bee-eater		5				1	1	1	3			2		13
Cuculidae	<i>Oriental/Himalayan Cuckoo</i>	Cuculus saturatus/optatus		3						2	1		1			7
Cuculidae	<i>Cacomantis variolosus</i>	Brush Cuckoo		7	1				1	3	3					15
Cuculidae	<i>Cacomantis castaneiventris</i>	Chestnut-breasted Cuckoo		3		1	1	1		2	1		1	2		12
Cuculidae	<i>Cacomantis flabelliformis</i>	Fan-tailed Cuckoo							1		2		2	2	1	8
Cuculidae	<i>Rhamphomantis megarhynchus</i>	Long-billed Cuckoo		1				1		2						4
Cuculidae	<i>Chrysococcyx russatus</i>	Gould's Bronze-Cuckoo		4	1					2	2					9
Cuculidae	<i>Chrysococcyx ruficollis</i>	Rufous-throated Bronze-Cuckoo											1			1
Cuculidae	<i>Chrysococcyx meyeri</i>	White-eared Bronze-Cuckoo						1	1	2	2		1			7
Cuculidae	<i>Caliechthrus leucolophus</i>	White-crowned Koel		3				1	1	2	2		2	1		12
Cuculidae	<i>Microdynamis parva</i>	Dwarf Koel		3				1		2	2			1		9
Cuculidae	<i>Eudynamis scolopacea</i>	Asian Koel		6	1	1			1	3	2		1	2		17
Cuculidae	<i>Scythrops novaehollandiae</i>	Channel-billed Cuckoo		4		1				1			1			7
Centropodidae	<i>Centropus menbeki</i>	Greater Black Coucal		6	1	1				2	2					12
Centropodidae	<i>Centropus bernsteini</i>	Lesser Black Coucal		4						2						6
Psittacidae	<i>Chalcopsitta scintillata</i>	Yellow-streaked Lory		6	1			1	1	3	2					14
Psittacidae	<i>Pseudeos fuscata</i>	Dusky Lory		4				2	1	3	2		3	1		16
Psittacidae	<i>Trichoglossus haematodus</i>	Rainbow Lorikeet		6	1	1	1	2	1	3	3		2	2		22
Psittacidae	<i>Psitteuteles goldiei</i>	Goldie's Lorikeet								1	1		1			3
Psittacidae	<i>Lorius lory</i>	Black-capped Lory		6	1	1	1	2	1	3	3		2			20
Psittacidae	<i>Chamosyna multistriata</i>	Striated Lorikeet	SPL							1	1					2

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Psittacidae	<i>Charmosyna wilhelminae</i>	Pygmy Lorikeet		1						2	1					4
Psittacidae	<i>Charmosyna placentis</i>	Red-flanked Lorikeet		6	1			1		3	1					12
Psittacidae	<i>Charmosyna pulchella</i>	Fairy Lorikeet						1	1	1	1		2	2		8
Psittacidae	<i>Charmosyna josefinae</i>	Josephine's Lorikeet								1	1					2
Psittacidae	<i>Charmosyna papou</i>	Papuan Lorikeet											3	2	1	6
Psittacidae	<i>Oreopsittacus arfaki</i>	Plum-faced Lorikeet											1			1
Psittacidae	<i>Neopsittacus musschenbroekii</i>	Yellow-billed Lorikeet											1	3	1	5
Psittacidae	<i>Neopsittacus pullicauda</i>	Orange-billed Lorikeet													1	1
Psittacidae	<i>Psittichas fulgidus</i>	Pesquet's Parrot		5	1	1	1	2	1	3	2	1	2			19
Psittacidae	<i>Micropsitta keiensis</i>	Yellow-capped Pygmy-Parrot		2			1	1								4
Psittacidae	<i>Micropsitta pusio</i>	Buff-faced Pygmy-Parrot		4						2	2					8
Psittacidae	<i>Micropsitta bruijnii</i>	Red-breasted Pygmy-Parrot						1		1	2		1	2		7
Psittacidae	<i>Cyclopsitta guliemitertii</i>	Orange-breasted Fig-Parrot		6	1					2	3					12
Psittacidae	<i>Cyclopsitta diophthalma</i>	Double-eyed Fig-Parrot		2						2	1		1	1		7
Psittacidae	<i>Psittaculirostris desmarestii</i>	Large Fig-Parrot		2						2	2				1	7
Psittacidae	<i>Psittacella madaraszi</i>	Madarasz's Tiger-Parrot											1			1
Psittacidae	<i>Geoffroyus geoffroyi</i>	Red-cheeked Parrot		7	1					3	2					13
Psittacidae	<i>Geoffroyus simplex</i>	Blue-collared Parrot						1	1	2	1		2	2		9
Psittacidae	<i>Eclectus roratus</i>	Eclectus Parrot		6	1	1	1	2	1	3	3					18
Psittacidae	<i>Alisterus chloropterus</i>	Papuan King-Parrot			1					2	1		2	2	1	9
Psittacidae	<i>Loriculus aurantiifrons</i>	Orange-fronted Hanging-Parrot		3						2	2					7
Psittacidae	<i>Probosciger aterrimus</i>	Palm Cockatoo		7	1	1	1	1	1	3	3		1			19
Psittacidae	<i>Cacatua galerita</i>	Sulphur-crested Cockatoo		8	1	1		2	1	3	3		2	2		23
Apodidae	<i>Collocalia esculenta</i>	Glossy Swiftlet		6	1		1	2		3	3		3	4	1	24

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Apodidae	<i>Aerodramus hirundinaceus/vanikorensis/nuditarsus</i>	Swiftlet (Mountain/Uniform/Bare-legged)		7	1			2	1	1	3	1	3	3	1	6
Apodidae	<i>Mearnsia novaeguineae</i>	Papuan Needletail		6						2						8
Apodidae	<i>Hirundapus caudacutus</i>	White-throated Needletail		2										1		3
Hemiprocnidae	<i>Hemiprocne mystacea</i>	Moustached Treeswift		3			1	1		3	3			2		13
Tytonidae	<i>Tyto tenebricosa</i>	Greater Sooty-Owl		1				1	1	2	1		2	1		9
Strigidae	<i>Ninox rufa</i>	Rufous Owl								2						2
Strigidae	<i>Ninox theomacha</i>	Jungle Hawk-Owl		1			1	1	1	1	1		3	1		10
Aegothelidae	<i>Aegotheles insignis</i>	Feline Owlet-Nightjar								1	1		1			3
Aegothelidae	<i>Aegotheles bennettii</i>	Barred Owlet-Nightjar									1					1
Aegothelidae	<i>Aegotheles albertsi</i>	Mountain Owlet-Nightjar											2			2
Aegothelidae	<i>Aegotheles sp.</i>	Aegotheles sp.		1						2	1					4
Podargidae	<i>Podargus papuensis</i>	Papuan Frogmouth		4		1	1			3	1		1	2		13
Podargidae	<i>Podargus ocellatus</i>	Marbled Frogmouth		3	1	1	1	1	1	2	1		1	1		13
Podargidae	<i>Podargus sp.</i>	Frogmouth sp.						1								1
Eurostopodidae	<i>Eurostopodus papuensis</i>	Papuan Eared-Nightjar					1			1						2
Eurostopodidae	<i>Eurostopodus archboldi</i>	Mountain Eared-Nightjar	CPM												1	1
Caprimulgidae	<i>Caprimulgus macrurus</i>	Large-tailed Nightjar				1			1		1			1		4
Columbidae	<i>Columba vitiensis</i>	Metallic Pigeon						1			1			1		3
Columbidae	<i>Macropygia amboinensis</i>	Slender-billed Cuckoo-Dove		4	1	1	1	2	1	3	3		1	3	1	21
Columbidae	<i>Macropygia nigrirostris</i>	Black-billed Cuckoo-Dove		2						2	1		2	2		9
Columbidae	<i>Reinwardtoena reinwardtsi</i>	Great Cuckoo-Dove		5	1		1	2	1	3	3		3	1	1	21
Columbidae	<i>Chalcophaps indica</i>	Emerald Dove						1								1
Columbidae	<i>Chalcophaps stephani</i>	Stephan's Dove		3		1	1			2	1					8

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Columbidae	<i>Henicophaps albifrons</i>	New Guinea Bronzewing		2				2		2	1					7
Columbidae	<i>Gallicolumba rufigula</i>	Cinnamon Ground-Dove						1	1	2	1					5
Columbidae	<i>Gallicolumba jobiensis</i>	White-bibbed Ground-Dove						1								1
Columbidae	<i>Gallicolumba beccarii</i>	Bronze Ground-Dove												1	1	2
Columbidae	<i>Trugon terrestris</i>	Thick-billed Ground-Pigeon		3			1	1		1						6
Columbidae	<i>Otidiphaps nobilis</i>	Pheasant Pigeon		3				2		3	1		1			10
Columbidae	<i>Ptilinopus magnificus</i>	Wompoo Fruit-Dove		5	1		1	2		3	3		1			16
Columbidae	<i>Ptilinopus perlatus</i>	Pink-spotted Fruit-Dove		5	1					2	2		1			11
Columbidae	<i>Ptilinopus ornatus</i>	Ornate Fruit-Dove						1	1	1	2		3	4	1	13
Columbidae	<i>Ptilinopus aurantiifrons</i>	Orange-fronted Fruit-Dove		2												2
Columbidae	<i>Ptilinopus superbus</i>	Superb Fruit-Dove		3				2	1	3	2			2		13
Columbidae	<i>Ptilinopus coronulatus</i>	Coroneted Fruit-Dove		2		1	1	1		1						6
Columbidae	<i>Ptilinopus pulchellus</i>	Beautiful Fruit-Dove		4		1	1	2		3	3					14
Columbidae	<i>Ptilinopus rivoli</i>	White-bibbed Fruit-Dove								1	1		2	3		7
Columbidae	<i>Ptilinopus iozonus</i>	Orange-bellied Fruit-Dove		7	1			1		3	1					13
Columbidae	<i>Ptilinopus naina</i>	Dwarf Fruit-Dove		3						2	1					6
Columbidae	<i>Ducula rufigaster</i>	Purple-tailed Imperial-Pigeon		5	1		1	1		2	2					12
Columbidae	<i>Ducula chalconota</i>	Shining Imperial-Pigeon									3		2		1	6
Columbidae	<i>Ducula pinon</i>	Pinon Imperial-Pigeon		6	1	1	1	1		3	2					15
Columbidae	<i>Ducula mullerii</i>	Collared Imperial-Pigeon		1	1			1								3
Columbidae	<i>Ducula zoeae</i>	Banded Imperial-Pigeon		6	1	1	1	2	1	3	3			2		20
Columbidae	<i>Ducula spilorrhoa</i>	Torresian Imperial-Pigeon		2												2
Columbidae	<i>Gymnophaps albertisii</i>	Papuan Mountain-Pigeon		3				1	1	2	3		3	4	1	18
Columbidae	<i>Goura scheepmakeri</i>	Southern Crowned-Pigeon		6	1	1		2		1						11
Rallidae	<i>Rallina forbesi</i>	Forbes's Forest-Rail	CPM						1						1	2

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Rallidae	<i>Rallina tricolor</i>	Red-necked Crake		2				1		1	2					6
Rallidae	<i>Gallirallus philippensis</i>	Buff-banded Rail		1									1			2
Rallidae	<i>Amaurornis moluccana</i>	Rufous-tailed Waterhen		1		1				2	1					5
Rallidae	<i>Porzana cinerea</i>	White-browed Crake									1					1
Rallidae	<i>Megacrex inepta</i>	New Guinea Flightless Rail		2						1						3
Rallidae	<i>Gallinula tenebrosa</i>	Dusky Moorhen									1					1
Scolopacidae	<i>Limosa limosa</i>	Black-tailed Godwit		2												2
Scolopacidae	<i>Limosa lapponica</i>	Bar-tailed Godwit		1												1
Scolopacidae	<i>Numenius phaeopus</i>	Whimbrel		3												3
Scolopacidae	<i>Numenius madagascariensis</i>	Far Eastern Curlew		2												2
Scolopacidae	<i>Tringa stagnatilis</i>	Marsh Sandpiper		2												2
Scolopacidae	<i>Tringa nebularia</i>	Common Greenshank		2												2
Scolopacidae	<i>Xenus cinereus</i>	Terek Sandpiper		2												2
Scolopacidae	<i>Actitis hypoleucos</i>	Common Sandpiper		6	1			1		2						10
Scolopacidae	<i>Heteroscelus brevipes</i>	Grey-tailed Tattler		2												2
Scolopacidae	<i>Arenaria interpres</i>	Ruddy Turnstone		1												1
Scolopacidae	<i>Limnodromus semipalmatus</i>	Asian Dowitcher		1												1
Scolopacidae	<i>Calidris tenuirostris</i>	Great Knot		2												2
Scolopacidae	<i>Calidris canutus</i>	Red Knot		1												1
Scolopacidae	<i>Calidris alba</i>	Sanderling		2												2
Scolopacidae	<i>Calidris ruficollis</i>	Red-necked Stint		2												2
Scolopacidae	<i>Calidris acuminata</i>	Sharp-tailed Sandpiper		1												1
Scolopacidae	<i>Calidris ferruginea</i>	Curlew Sandpiper		1												1
Burhinidae	<i>Esacus giganteus</i>	Beach Thick-knee		1												1
Charadriidae	<i>Pluvialis fulva</i>	Pacific Golden-Plover		2												2

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Charadriidae	<i>Pluvialis squatarola</i>	Grey Plover		1												1
Charadriidae	<i>Charadrius dubius</i>	Little Ringed Plover		1		1				1	1					4
Charadriidae	<i>Charadrius mongolus</i>	Mongolian Plover		2												2
Charadriidae	<i>Charadrius leschenaultii</i>	Greater Sand Plover		2												2
Charadriidae	<i>Vanellus miles</i>	Masked Lapwing								1						1
Glareolidae	<i>Stiltia isabellae</i>	Australian Pratincole		1												1
Laridae	<i>Larus novaehollandiae</i>	Silver Gull		1												1
Laridae	<i>Gelochelidon nilotica</i>	Gull-billed Tern		2												2
Laridae	<i>Sterna caspia</i>	Caspian Tern		1												1
Laridae	<i>Sterna bengalensis</i>	Lesser Crested-Tern		1												1
Laridae	<i>Sterna bergii</i>	Great Crested-Tern		2												2
Laridae	<i>Sterna sumatrana</i>	Black-naped Tern		1												1
Laridae	<i>Sterna hirundo</i>	Common Tern		1												1
Laridae	<i>Sterna albifrons</i>	Little Tern		4												4
Laridae	<i>Chlidonias hybridus</i>	Whiskered Tern		1												1
Laridae	<i>Chlidonias leucopterus</i>	White-winged Tern		1												1
Laridae	<i>Anous minutus</i>	Black Noddy		1												1
Accipitridae	<i>Aviceda subcristata</i>	Pacific Baza		4				1		2	3					10
Accipitridae	<i>Henicopernis longicauda</i>	Long-tailed Honey-buzzard		2	1			1	1	2	2				1	10
Accipitridae	<i>Haliastur sphenurus</i>	Whistling Kite		1												1
Accipitridae	<i>Haliastur indus</i>	Brahminy Kite		6	1	1				2	2		1	1	1	15
Accipitridae	<i>Haliaeetus leucogaster</i>	White-bellied Fish-Eagle		2							1					3
Accipitridae	<i>Circus spilonotus</i>	Eastern Marsh-Harrier									1					1
Accipitridae	<i>Accipiter novaehollandiae</i>	Grey Goshawk		6				1		3	2			1		13
Accipitridae	<i>Accipiter fasciatus</i>	Brown Goshawk												1		1

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Accipitridae	<i>Accipiter melanochlamys</i>	Black-mantled Goshawk											1	2	1	4
Accipitridae	<i>Accipiter poliocephalus</i>	Grey-headed Goshawk		1						1	1					3
Accipitridae	<i>Accipiter cirrocephalus</i>	Collared Sparrowhawk		1						1	1			1		4
Accipitridae	<i>Accipiter meyerianus</i>	Meyer's Goshawk							1		1				1	3
Accipitridae	<i>Harpyopsis novaeguineae</i>	New Guinea Eagle		2		1			1	1	1		2			8
Accipitridae	<i>Aquila gurneyi</i>	Gurney's Eagle						1			1		1			3
Accipitridae	<i>Hieraaetus morphnoides</i>	Little Eagle		1				2		3	1					7
Falconidae	<i>Falco cenchroides</i>	Australian Kestrel		2												2
Falconidae	<i>Falco severus</i>	Oriental Hobby									1					1
Falconidae	<i>Falco longipennis</i>	Australian Hobby		1												1
Falconidae	<i>Falco berigora</i>	Brown Falcon								1	1			1		3
Falconidae	<i>Falco peregrinus</i>	Peregrine Falcon		1						1	2	1				5
Podicipedidae	<i>Tachybaptus novaehollandiae</i>	Australasian Grebe									1					1
Anhingidae	<i>Anhinga novaehollandiae</i>	Australian Darter		4							1					5
Phalacrocoracidae	<i>Phalacrocorax melanoleucos</i>	Little Pied Cormorant		4	1						1			1		7
Phalacrocoracidae	<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant		1										1		2
Ardeidae	<i>Egretta garzetta</i>	Little Egret		3						1	1					5
Ardeidae	<i>Egretta sacra</i>	Pacific Reef-Egret		2												2
Ardeidae	<i>Ardea alba</i>	Great Egret		5		1				1	1					8
Ardeidae	<i>Ardea sumatrana</i>	Great-billed Heron		1												1
Ardeidae	<i>Ardea picata</i>	Pied Heron									2					2
Ardeidae	<i>Mesophoyx intermedia</i>	Intermediate Egret									2					2
Ardeidae	<i>Bubulcus ibis</i>	Cattle Egret									1					1
Ardeidae	<i>Butorides striatus</i>	Striated Heron		4												4
Ardeidae	<i>Nycticorax caledonicus</i>	Rufous Night-Heron		2		1										3

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Ardeidae	<i>Zonerodius heliosylus</i>	Forest Bittern						1		1						2
Ardeidae	<i>Dupetor flavicollis</i>	Black Bittern			1											1
Threskiornithidae	<i>Threskiornis spinicollis</i>	Straw-necked Ibis								1						1
Pelecanidae	<i>Pelecanus conspicillatus</i>	Australian Pelican		2												2
Fregatidae	<i>Fregata ariel</i>	Lesser Frigatebird		1						1						2
Pittidae	<i>Pitta sordida</i>	Hooded Pitta		5	1					2	1		1			10
Pittidae	<i>Pitta erythrogaster</i>	Red-bellied Pitta		4			1	1	1	3	1					11
Climacteridae	<i>Cormobates placens</i>	Papuan Treecreeper											1			1
Ptilonorhynchidae	<i>Ailuroedus buccoides</i>	White-eared Catbird		3		1	1	1	1	3	1					11
Ptilonorhynchidae	<i>Ailuroedus melanotis</i>	Spotted Catbird							1	1	1		2	1		6
Ptilonorhynchidae	<i>Amblyornis macgregoriae</i>	Macgregor's Bowerbird											3	1		4
Maluridae	<i>Clytomyias insignis</i>	Orange-crowned Fairywren											1		1	2
Maluridae	<i>Sipodotus wallacii</i>	Wallace's Fairywren									1					1
Maluridae	<i>Malurus alboscapulatus</i>	White-shouldered Fairywren				1		1		2	3	1	1	2		11
Maluridae	<i>Malurus cyanocephalus</i>	Emperor Fairywren		5						2	2					9
Meliphagidae	<i>Myzomela eques</i>	Red-throated Myzomela		1				1		2	1					5
Meliphagidae	<i>Myzomela obscura</i>	Dusky Myzomela		3												3
Meliphagidae	<i>Myzomela cruentata</i>	Red Myzomela							1	1	1		2			5
Meliphagidae	<i>Myzomela nigrita</i>	Black Myzomela		1					1	1	1					4
Meliphagidae	<i>Myzomela adolphinae</i>	Mountain Myzomela									1					1
Meliphagidae	<i>Myzomela rosenbergii</i>	Red-collared Myzomela											3	1		4
Meliphagidae	<i>Timeliopsis fulvigula</i>	Olive Straightbill											1		1	2
Meliphagidae	<i>Melilestes megarhynchus</i>	Long-billed Honeyeater		5	1	1	1	2	1	2	3		1	2		19
Meliphagidae	<i>Glycichaera fallax</i>	Green-backed Honeyeater		2						1	1					4
Meliphagidae	<i>Meliphaga mimikae</i>	Mottle-breasted Honeyeater		1				2	1	2	1		1			8

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Meliphagidae	<i>Meliphaga orientalis</i>	Hill-forest Honeyeater							1	1	1		1	1		5
Meliphagidae	<i>Meliphaga albonotata</i>	Scrub Honeyeater		2				1		3	3		1	2		12
Meliphagidae	<i>Meliphaga aruensis</i>	Puff-backed Honeyeater		4		1	1			2	1					9
Meliphagidae	<i>Meliphaga analoga</i>	Mimic Honeyeater		4	1	1	1	1		2	1			1		12
Meliphagidae	<i>Meliphaga gracilis</i>	Graceful Honeyeater		1												1
Meliphagidae	<i>Meliphaga flavirictus</i>	Yellow-gaped Honeyeater		1												1
Meliphagidae	<i>Meliphaga sp.</i>	Meliphaga sp.		2						2	1					5
Meliphagidae	<i>Lichenostomus subfrenatus</i>	Black-throated Honeyeater											2			2
Meliphagidae	<i>Lichenostomus obscurus</i>	Obscure Honeyeater		1			1			2	1					5
Meliphagidae	<i>Lichenostomus versicolor</i>	Varied Honeyeater		2												2
Meliphagidae	<i>Xanthotis flaviventer</i>	Tawny-breasted Honeyeater		6	1	1	1	2	1	3	3		1	2		21
Meliphagidae	<i>Xanthotis polygramma</i>	Spotted Honeyeater								1	1		1	1		4
Meliphagidae	<i>Pycnopygius ixoides</i>	Plain Honeyeater		1						1	1		1			4
Meliphagidae	<i>Pycnopygius stictocephalus</i>	Streak-headed Honeyeater		3				1		2	2					8
Meliphagidae	<i>Philemon meyeri</i>	Meyer's Friarbird						1		2	2					5
Meliphagidae	<i>Philemon novaeguineae</i>	New Guinea Friarbird		7	1	1	1	2		3	3			1		19
Meliphagidae	<i>Ptiloprora guisei</i>	Rufous-backed Honeyeater	CPM										3	1	1	5
Meliphagidae	<i>Ptiloprora perstriata</i>	Black-backed Honeyeater	CPM										1		1	2
Meliphagidae	<i>Melidectes belfordi</i>	Belford's Melidectes	CPM												1	1
Meliphagidae	<i>Melidectes rufocrissalis</i>	Yellow-browed Melidectes	CPM										3	2		5
Meliphagidae	<i>Melidectes torquatus</i>	Ornate Melidectes											1	1		2
Meliphagidae	<i>Melipotes fumigatus</i>	Smoky Honeyeater											3	2	1	6
Meliphagidae	<i>Ramsayornis modestus</i>	Brown-backed Honeyeater		1												1
Pardalotidae	<i>Crateroscelis murina</i>	Rusty Mouse-warbler		5	1	1	1	2	1	3	3			2		19
Pardalotidae	<i>Crateroscelis nigrorufa</i>	Bicolored Mouse-warbler											1			1

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Pardalotidae	<i>Crateroscelis robusta</i>	Mountain Mouse-warbler											3	2	1	6
Pardalotidae	<i>Sericornis beccarii</i>	Tropical / Beccari's Scrubwren								1	1		2			4
Pardalotidae	<i>Sericornis nouhuysi</i>	Large Scrubwren											3	1	1	5
Pardalotidae	<i>Sericornis perspicillatus</i>	Buff-faced Scrubwren											3	2	1	6
Pardalotidae	<i>Sericornis arfakianus</i>	Grey-green Scrubwren							1				2			3
Pardalotidae	<i>Sericornis papuensis</i>	Papuan Scrubwren											1	1	1	3
Pardalotidae	<i>Sericornis spilodera</i>	Pale-billed Scrubwren		2	1	1	1	1	1	2	1		1			11
Pardalotidae	<i>Acanthiza murina</i>	Papuan Thornbill	CPM												1	1
Pardalotidae	<i>Gerygone cinerea</i>	Mountain Gerygone											1	1	1	3
Pardalotidae	<i>Gerygone chloronotus</i>	Green-backed Gerygone		3				2	1	2	3			2		13
Pardalotidae	<i>Gerygone palpebrosa</i>	Fairy Gerygone		3						3	2		2			10
Pardalotidae	<i>Gerygone chrysogaster</i>	Yellow-bellied Gerygone		5	1	1	1	1		3	2					14
Pardalotidae	<i>Gerygone magnirostris</i>	Large-billed Gerygone		4						1	1					6
Pardalotidae	<i>Gerygone ruficollis</i>	Brown-breasted Gerygone											3	2	1	6
Pardalotidae	<i>Gerygone levigaster</i>	Mangrove Gerygone		1												1
Petroicidae	<i>Amalocichla incerta</i>	Lesser Ground-robin											2	2		4
Petroicidae	<i>Monachella muelleriana</i>	Torrent Robin		1	1	1		2		2	1			2		10
Petroicidae	<i>Microeca griseocephala</i>	Yellow-legged Flyrobin								1	1		1			3
Petroicidae	<i>Microeca flavovirescens</i>	Olive Flyrobin					1	1		2	1			2		7
Petroicidae	<i>Microeca papuana</i>	Canary Flyrobin											2	1	1	4
Petroicidae	<i>Eugerygone rubra</i>	Garnet Robin											1		1	2
Petroicidae	<i>Tregellasia leucops</i>	White-faced Robin								1	1		1	1		4
Petroicidae	<i>Eopsaltria pulverulenta</i>	Mangrove Robin		1												1
Petroicidae	<i>Poecilodryas hypoleuca</i>	Black-sided Robin		6			1			3	2					12

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Petroicidae	<i>Poecilodryas placens</i>	Olive-yellow Robin	SPL				1			1	1					3
Petroicidae	<i>Poecilodryas albonotata</i>	Black-throated Robin											2	2		4
Petroicidae	<i>Peneothello sigillatus</i>	White-winged Robin											1		1	2
Petroicidae	<i>Peneothello cyanus</i>	Blue-grey Robin											3	2	1	6
Petroicidae	<i>Peneothello bimaculatus</i>	White-rumped Robin					1		1	2	1					5
Petroicidae	<i>Heteromyias albispecularis</i>	Ashy Robin											1	1		2
Petroicidae	<i>Pachycephalopsis poliosoma</i>	White-eyed Robin							1	1	1		1	1		5
Petroicidae	<i>Drymodes superciliaris</i>	Northern Scrub-Robin						1	1	1	1		1			5
Orthonycidae	<i>Orthonyx temminckii</i>	Logrunner												1		1
Pomatostomidae	<i>Pomatostomus isidorei</i>	New Guinea Babbler		3						1						4
Laniidae	<i>Lanius schach</i>	Long-tailed Shrike											1	1		2
Corvidae: quail-thrushes, whipbirds	<i>Ptilorrhoa leucosticta</i>	Spotted Jewel-babbler											2	2		4
Corvidae: quail-thrushes, whipbirds	<i>Ptilorrhoa caerulescens</i>	Blue Jewel-babbler		5	1	1	1	1		3						12
Corvidae: quail-thrushes, whipbirds	<i>Ptilorrhoa castanonota</i>	Chestnut-backed Jewel-babbler					1	1	1	1	2		1			7
Corvidae: quail-thrushes, whipbirds	<i>Ifrita kowaldi</i>	Ifrit											2	2	1	5
Corvidae: sittellas	<i>Daphoenositta chrysoptera</i>	Varied Sittella											1		1	2
Corvidae: shrike-tits	<i>Rhagologus leucostigma</i>	Mottled Whistler											2	1		3
Corvidae: whistlers	<i>Pachycare flavogrisea</i>	Goldenface							1	1	1		1	3		7
Corvidae: whistlers	<i>Aleadryas rufinucha</i>	Rufous-naped Whistler											3	2	1	6
Corvidae: whistlers	<i>Pachycephala hyperythra</i>	Rusty Whistler					1	1	1	3	1					7
Corvidae: whistlers	<i>Pachycephala modesta</i>	Brown-backed Whistler											1	2	1	4
Corvidae: whistlers	<i>Pachycephala griseiceps</i>	Grey-headed Whistler		3						2	1		1	2		9

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Corvidae: whistlers	<i>Pachycephala soror</i>	Slater's Whistler							1	1			3	3	1	9
Corvidae: whistlers	<i>Pachycephala schlegelii</i>	Regent Whistler											2	1		3
Corvidae: whistlers	<i>Pachycephala monacha</i>	Black-headed Whistler												1	1	2
Corvidae: whistlers	<i>Pachycephala leucogastra</i>	White-bellied Whistler									1					1
Corvidae: whistlers	<i>Colluricincla megarhyncha</i>	Little Shrike-thrush		5	1	1	1	2	1	3	3		2	3		22
Corvidae: whistlers	<i>Pitohui kirhocephalus</i>	Variable Pitohui		7	1			2		2	2		1			15
Corvidae: whistlers	<i>Pitohui dichrous</i>	Hooded Pitohui					1			1	2			3		7
Corvidae: whistlers	<i>Pitohui ferrugineus</i>	Rusty Pitohui		5		1	1	2		3	2					14
Corvidae: whistlers	<i>Pitohui cristatus</i>	Crested Pitohui					1	1	1	2	1		1			7
Corvidae: whistlers	<i>Pitohui nigrescens</i>	Black Pitohui											1	1		2
Corvidae: whistlers	<i>Eulacestoma nigropectus</i>	Wattled Ploughbill	CPM											1	1	2
Corvidae: crows	<i>Corvus tristis</i>	Grey Crow		4	1	1	1	2		3	3			1		16
Corvidae: birds-of-paradise	<i>Melampitta lugubris</i>	Lesser Melampitta												1		1
Corvidae: birds-of-paradise	<i>Melampitta gigantea</i>	Greater Melampitta	CPM							1	1				1	3
Corvidae: birds-of-paradise	<i>Loboparadisea sericea</i>	Yellow-breasted Bird-of-paradise	CPM										2		1	3
Corvidae: birds-of-paradise	<i>Cnemophilus loriae</i>	Loria's Bird-of-paradise	CPM										2	1		3
Corvidae: birds-of-paradise	<i>Manucodia atra</i>	Glossy-mantled Manucode		5				1		2						7
Corvidae: birds-of-paradise	<i>Manucodia chalybata</i>	Crinkle-collared Manucode					1		1	3	2					8
Corvidae: birds-of-paradise	<i>Manucodia keraudrenii</i>	Trumpet Manucode		5				1		2			1			9
Corvidae: birds-of-paradise	<i>Paradigalla brevicauda</i>	Short-tailed Paradigalla	CPM										2	2	1	5
Corvidae: birds-of-paradise	<i>Epimachus fastuosus</i>	Black Sickbill											3	1	1	5
Corvidae: birds-of-paradise	<i>Epimachus meyeri</i>	Brown Sickbill	CPM										1	1	1	3
Corvidae: birds-of-paradise	<i>Epimachus albertsi</i>	Black-billed Sickbill									1					1
Corvidae: birds-of-paradise	<i>Lophorina superba</i>	Superb Bird-of-paradise									1		3	3	1	8

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Corvidae: birds-of-paradise	<i>Parotia carolae</i>	Carola's Parotia							1	1	1		2			5
Corvidae: birds-of-paradise	<i>Parotia lawesii</i>	Lawe's Parotia	CPM										2	2	1	5
Corvidae: birds-of-paradise	<i>Ptiloris magnificus</i>	Magnificent Riflebird		3				2	1	3	2			2		13
Corvidae: birds-of-paradise	<i>Cicinnurus magnificus</i>	Magnificent Bird-of-paradise					1	2	1	2	2		1	1		10
Corvidae: birds-of-paradise	<i>Cicinnurus regius</i>	King Bird-of-paradise		5	1	1	1	2		3	3					16
Corvidae: birds-of-paradise	<i>Astrapia mayeri</i>	Ribbon-tailed Astrapia	CPM										2	1	1	4
Corvidae: birds-of-paradise	<i>Astrapia stephaniae</i>	Stephanie's Astrapia												2		2
Corvidae: birds-of-paradise	<i>Pteridophora alberti</i>	King-of-Saxony Bird-of-paradise	CPM										2	1	1	4
Corvidae: birds-of-paradise	<i>Seleucidis melanoleuca</i>	Twelve-wired Bird-of-paradise		5						1	1					7
Corvidae: birds-of-paradise	<i>Paradisaea raggiana</i>	Raggiana Bird-of-paradise		4	1	1	1	2	1	3	3		1	2		19
Corvidae: birds-of-paradise	<i>Paradisaea rudolphi</i>	Blue Bird-of-paradise	CPM										1	1		2
Corvidae: currawongs, woodswallows	<i>Cracticus cassicus</i>	Hooded Butcherbird		5	1	1	1	2		3	3					16
Corvidae: currawongs, woodswallows	<i>Cracticus quoyi</i>	Black Butcherbird		4		1	1	1	1	3	1		1			13
Corvidae: currawongs, woodswallows	<i>Artamus leucorhynchus</i>	White-breasted Woodswallow		2												2
Corvidae: currawongs, woodswallows	<i>Artamus maximus</i>	Great Woodswallow									3		1	3		7
Corvidae: currawongs, woodswallows	<i>Peltops blainvillii</i>	Lowland Peltops		4						3	2					9
Corvidae: currawongs, woodswallows	<i>Peltops montanus</i>	Mountain Peltops							1	1	2		3	3		10
Corvidae: orioles, cuckooshrikes	<i>Oriolus szalayi</i>	Brown Oriole		5			1	2		3	1			2		14
Corvidae: orioles, cuckooshrikes	<i>Coracina novaehollandiae</i>	Black-faced Cuckooshrike		2												2

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Corvidae: orioles, cuckooshrikes	<i>Coracina caeruleogrisea</i>	Stout-billed Cuckooshrike							1	1	3		1	1		7
Corvidae: orioles, cuckooshrikes	<i>Coracina lineata</i>	Yellow-eyed Cuckooshrike								1	1					2
Corvidae: orioles, cuckooshrikes	<i>Coracina boyeri</i>	Boyer's Cuckooshrike		4						2	2					8
Corvidae: orioles, cuckooshrikes	<i>Coracina papuensis</i>	White-bellied Cuckooshrike		2												2
Corvidae: orioles, cuckooshrikes	<i>Coracina longicauda</i>	Hooded Cuckooshrike											1	2	1	4
Corvidae: orioles, cuckooshrikes	<i>Coracina tenuirostris</i>	Slender-billed Cicadabird						1			1					2
Corvidae: orioles, cuckooshrikes	<i>Coracina incerta</i>	Black-shouldered Cicadabird		3					1	2	1		1	3		11
Corvidae: orioles, cuckooshrikes	<i>Coracina schisticeps</i>	Grey-headed Cuckooshrike		5	1			2	1	3	3					15
Corvidae: orioles, cuckooshrikes	<i>Coracina melas</i>	New Guinea Cuckooshrike		4				2	1	2	3					12
Corvidae: orioles, cuckooshrikes	<i>Coracina montana</i>	Black-bellied Cuckooshrike								1	1		3	3	1	9
Corvidae: orioles, cuckooshrikes	<i>Campochaera sloetii</i>	Golden Cuckooshrike		5	1			1		3	3					13
Corvidae: orioles, cuckooshrikes	<i>Lalage leucomela</i>	Varied Triller		6	1			1		2	3		1	2		16
Corvidae: fantails	<i>Rhipidura leucophrys</i>	Willie-wagtail		4	1	1		1		1	3	1	1	2		15
Corvidae: fantails	<i>Rhipidura rufiventris</i>	Northern Fantail		3			1			3	2			1		10
Corvidae: fantails	<i>Rhipidura threnothorax</i>	Sooty Thicket-Fantail		3	1	1	1	2		3	1					12
Corvidae: fantails	<i>Rhipidura maculipectus</i>	Black Thicket-Fantail		4						2	1					7
Corvidae: fantails	<i>Rhipidura leucothorax</i>	White-bellied Thicket-Fantail		5	1	1		1		2	2					12
Corvidae: fantails	<i>Rhipidura atra</i>	Black Fantail							1		1		3	3	1	9

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Corvidae: fantails	<i>Rhipidura hyperythra</i>	Chestnut-bellied Fantail							1	3	1			2		7
Corvidae: fantails	<i>Rhipidura albolimbata</i>	Friendly Fantail											3	2	1	6
Corvidae: fantails	<i>Rhipidura phasiana</i>	Mangrove Fantail		1												1
Corvidae: fantails	<i>Rhipidura brachyrhyncha</i>	Dimorphic Fantail											1		1	2
Corvidae: fantails	<i>Rhipidura rufidorsa</i>	Rufous-backed Fantail		2		1	1			2	2					8
Corvidae: drongos	<i>Chaetorhynchus papuensis</i>	Pygmy Drongo							1	1	1		3			6
Corvidae: drongos	<i>Dicrurus bracteatus</i>	Spangled Drongo		6	1	1	1	2		3	3					17
Corvidae: monarchs, magpie-larks	<i>Monarcha axillaris</i>	Black Monarch							1	1	1		2	2	1	8
Corvidae: monarchs, magpie-larks	<i>Monarcha rubiensis</i>	Rufous Monarch									1					1
Corvidae: monarchs, magpie-larks	<i>Monarcha frater</i>	Black-winged Monarch							1	1	1		1	2		6
Corvidae: monarchs, magpie-larks	<i>Monarcha guttulus</i>	Spot-winged Monarch		6	1	1	1	1		3	3			1		17
Corvidae: monarchs, magpie-larks	<i>Monarcha manadensis</i>	Hooded Monarch		4						3						7
Corvidae: monarchs, magpie-larks	<i>Monarcha chrysomela</i>	Golden Monarch		4				1	1	2	2					10
Corvidae: monarchs, magpie-larks	<i>Arses telescopthalmus</i>	Friiled Monarch		6	1	1		1		3	2		1	1		16
Corvidae: bush-shrikes	<i>Myiagra cyanoleuca</i>	Satin Flycatcher		1												1
Corvidae: bush-shrikes	<i>Myiagra alecto</i>	Shining Flycatcher		7	1	1	1			1						11
Corvidae: bush-shrikes	<i>Machaerirhynchus flaviventer</i>	Yellow-breasted Boatbill							1	2	1		1			5
Corvidae: bush-shrikes	<i>Machaerirhynchus nigripectus</i>	Black-breasted Boatbill											3	2	1	6
Corvidae: bush-shrikes	<i>Grallina bruijini</i>	Torrent-lark											1	1		2
Muscicapidae	<i>Zoothera heinei</i>	Russet-tailed Thrush							1					1		2
Muscicapidae	<i>Turdus poliocephalus</i>	Island Thrush												1	1	2

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Muscicapidae	<i>Saxicola caprata</i>	Pied Bushchat									2			2		4
Sturnidae	<i>Aplonis cantoroides</i>	Singing Starling						2								2
Sturnidae	<i>Aplonis metallica</i>	Metallic Starling		6	1			1		2	1					11
Sturnidae	<i>Aplonis mystacea</i>	Yellow-eyed Starling		3		1		1		1						6
Sturnidae	<i>Mino anais</i>	Golden Myna		1	1		1	2		3						8
Sturnidae	<i>Mino dumontii</i>	Yellow-faced Myna		6	1	1	1	2		3	3					17
Hirundinidae	<i>Hirundo tahitica</i>	Pacific Swallow		5		1		1		2	2	1		1		13
Hirundinidae	<i>Hirundo daurica</i>	Red-rumped Swallow						1								1
Hirundinidae	<i>Hirundo nigricans</i>	Tree Martin		1						1	1					3
Zosteropidae	<i>Zosterops minor</i>	Black-fronted White-eye			1					1	2		2	3		9
Zosteropidae	<i>Zosterops novaeguineae</i>	New Guinea White-eye												1	1	2
Sylviidae	<i>Locustella fasciolata</i>	Gray's Grasshopper-Warbler									1					1
Sylviidae	<i>Acrocephalus stentoreus</i>	Clamorous Reed-Warbler									2					2
Sylviidae	<i>Phylloscopus trivirgatus</i>	Mountain Leaf-Warbler							1	1	1		3	3		9
Sylviidae	<i>Megalurus timoriensis</i>	Tawny Grassbird											1			1
Nectariniidae	<i>Dicaeum geelvinkianum</i>	Red-capped Flowerpecker		6	1		1	2	1	3	3		3	2		22
Nectariniidae	<i>Nectarinia aspasia</i>	Black Sunbird		7	1			2		2	2					14
Nectariniidae	<i>Nectarinia jugularis</i>	Olive-backed Sunbird		1												1
Melanocharitidae	<i>Melanocharis nigra</i>	Black Berrypecker		4		1	1		1	3	1		1	1		13
Melanocharitidae	<i>Melanocharis longicauda</i>	Lemon-breasted Berrypecker							1		1		1	1		4
Melanocharitidae	<i>Melanocharis versteri</i>	Fan-tailed Berrypecker											2	1	1	4
Melanocharitidae	<i>Melanocharis striativentris</i>	Streaked Berrypecker													1	1
Melanocharitidae	<i>Melanocharis crassirostris</i>	Spotted Berrypecker											1			1
Melanocharitidae	<i>Toxorhamphus poliopterus</i>	Grey-winged Longbill					1		1	1	2		2	1		8
Melanocharitidae	<i>Toxorhamphus novaeguineae</i>	Green-crowned Longbill		5	1			1		3						10

Appendix 7 Birds recorded from the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Melanocharitidae	<i>Toxorhamphus iliolophus</i>	Plumed Longbill		3	1		1	1	1	3	1		1	1		13
Melanocharitidae	<i>Oedistoma pygmaeum</i>	Pygmy Longbill		1						2	1					4
Paramythiidae	<i>Oreocharis arfaki</i>	Tit Berrypecker											3			3
Paramythiidae	<i>Paramythia montium</i>	Crested Berrypecker											1	1		2
Passeridae	<i>Motacilla cinerea</i>	Grey Wagtail						2		1						3
Passeridae	<i>Erythrura trichroa</i>	Blue-faced Parrotfinch						1		1	1		3	2		8
Passeridae	<i>Lonchura leucosticta</i>	White-spotted Munia		3							1					4
Passeridae	<i>Lonchura spectabilis</i>	Hooded Munia											1	2		3
Total species				229	75	63	70	124	83	220	223	7	162	152	65	407

Entries are number of sample sites at which species recorded. Combined data from the PNG LNG Project and the WWF surveys.

1. Endemic Bird Area: CPM – Central Papuan Mountains; SPL - South Papuan Lowlands.

Appendix 8 Birds that could occur within the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹
Phasianidae	<i>Coturnix ypsilophora</i>	Brown Quail	
Dendrocygnidae	<i>Dendrocygna eytoni</i>	Plumed Whistling-Duck	
Anatidae	<i>Tadorna radjah</i>	Radjah Shelduck	
Anatidae	<i>Nettapus coromandelianus</i>	Cotton Pygmy-goose	
Anatidae	<i>Mareca penelope</i>	Eurasian Wigeon	
Anatidae	<i>Anas acuta</i>	Northern Pintail	
Anatidae	<i>Anas querquedula</i>	Garganey	
Anatidae	<i>Aythya australis</i>	Hardhead	
Turnicidae	<i>Turnix maculosa</i>	Red-backed Buttonquail	
Dacelonidae	<i>Todirhamphus chloris</i>	Collared Kingfisher	
Dacelonidae	<i>Tanysiptera galatea</i>	Common Paradise-Kingfisher	
Cuculidae	<i>Cuculus pallidus</i>	Pallid Cuckoo	
Cuculidae	<i>Chrysococcyx lucidus</i>	Shining Bronze-Cuckoo	
Cuculidae	<i>Chrysococcyx basalis</i>	Horsfield's Bronze-Cuckoo	
Centropodidae	<i>Centropus phasianinus</i>	Pheasant Coucal	
Psittacidae	<i>Psittacella brehmii</i>	Brehm's Tiger-Parrot	
Psittacidae	<i>Psittacella picta</i>	Painted Tiger-Parrot	CPM
Psittacidae	<i>Psittacella modesta</i>	Modest Tiger-Parrot	CPM
Tytonidae	<i>Tyto capensis</i>	African Grass-Owl	
Strigidae	<i>Ninox connivens</i>	Barking Owl	
Strigidae	<i>Uroglaux dimorpha</i>	Papuan Hawk-Owl	
Aegothelidae	<i>Aegotheles tatei</i>	Starry Owlet-Nightjar	
Aegothelidae	<i>Aegotheles wallacii</i>	Wallace's Owlet-Nightjar	
Aegothelidae	<i>Aegotheles archboldi</i>	Archbold's Owlet-Nightjar	CPM
Eurostopodidae	<i>Eurostopodus mystacalis</i>	White-throated Eared-Nightjar	
Columbidae	<i>Geopelia striata</i>	Zebra Dove	
Columbidae	<i>Geopelia humeralis</i>	Bar-shouldered Dove	
Columbidae	<i>Ptilinopus aurantiifrons</i>	Orange-fronted Fruit-Dove	
Rallidae	<i>Rallina rubra</i>	Chestnut Forest-Rail	
Rallidae	<i>Lewinia pectoralis</i>	Lewin's Rail	
Rallidae	<i>Gymnocrex plumbeiventris</i>	Bare-eyed Rail	
Rallidae	<i>Porzana pusilla</i>	Baillon's Crake	
Rallidae	<i>Porzana tabuensis</i>	Spotless Crake	
Rallidae	<i>Porphyrio porphyrio</i>	Purple Swampphen	
Rallidae	<i>Fulica atra</i>	Common Coot	
Scolopacidae	<i>Scolopax rosenbergii</i>	New Guinea Woodcock	
Scolopacidae	<i>Gallinago hardwickii</i>	Latham's Snipe	
Scolopacidae	<i>Gallinago megala</i>	Swinhoe's Snipe	
Scolopacidae	<i>Numenius minutus</i>	Little Curlew	
Scolopacidae	<i>Tringa totanus</i>	Common Redshank	
Scolopacidae	<i>Tringa glareola</i>	Wood Sandpiper	
Scolopacidae	<i>Heteroscelus incanus</i>	Wandering Tattler	
Scolopacidae	<i>Limnodromus scolopaceus</i>	Long-billed Dowitcher	
Scolopacidae	<i>Calidris minuta</i>	Little Stint	
Scolopacidae	<i>Calidris subminuta</i>	Long-toed Stint	
Scolopacidae	<i>Calidris bairdii</i>	Baird's Sandpiper	
Scolopacidae	<i>Calidris melanotos</i>	Pectoral Sandpiper	
Scolopacidae	<i>Tryngites subruficollis</i>	Buff-breasted Sandpiper	
Scolopacidae	<i>Limicola falcinellus</i>	Broad-billed Sandpiper	
Scolopacidae	<i>Philomachus pugnax</i>	Ruff	
Scolopacidae	<i>Phalaropus lobatus</i>	Red-necked Phalarope	
Jacaniidae	<i>Irediparra gallinacea</i>	Comb-crested Jacana	
Charadriidae	<i>Haematopus longirostris</i>	Pied Oystercatcher	
Charadriidae	<i>Himantopus leucocephalus</i>	White-headed Stilt	
Charadriidae	<i>Charadrius veredus</i>	Oriental Plover	
Charadriidae	<i>Erythronyx cinctus</i>	Red-kneed Dotterel	

Appendix 8 Birds that could occur within the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹
Glareolidae	<i>Glareola maldivarum</i>	Oriental Pratincole	
Accipitridae	<i>Pandion haliaetus</i>	Osprey	
Accipitridae	<i>Macheiramphus alcinus</i>	Bat Hawk	
Accipitridae	<i>Elanus caeruleus</i>	Black-winged Kite	
Accipitridae	<i>Milvus migrans</i>	Black Kite	
Accipitridae	<i>Circus approximans</i>	Swamp Harrier	
Accipitridae	<i>Erythrotriorchis buergeri</i>	Chestnut-shouldered Goshawk	
Accipitridae	<i>Megatriorchis doriae</i>	Doria's Goshawk	
Podicipedidae	<i>Tachybaptus ruficollis</i>	Little Grebe	
Phaethontidae	<i>Phaethon rubricauda</i>	Red-tailed Tropicbird	
Phaethontidae	<i>Phaethon lepturus</i>	White-tailed Tropicbird	
Sulidae	<i>Papasula abbotti</i>	Abbott's Booby	
Sulidae	<i>Sula dactylatra</i>	Masked Booby	
Sulidae	<i>Sula sula</i>	Red-footed Booby	
Sulidae	<i>Sula leucogaster</i>	Brown Booby	
Phalacrocoracidae	<i>Phalacrocorax varius</i>	Pied Cormorant	
Phalacrocoracidae	<i>Phalacrocorax carbo</i>	Great Cormorant	
Ardeidae	<i>Egretta novaehollandiae</i>	White-faced Heron	
Ardeidae	<i>Ardea pacifica</i>	Pacific Heron	
Ardeidae	<i>Zonerodius heliosylus</i>	Forest Bittern	
Ardeidae	<i>Ixobrychus minutus</i>	Little Bittern	
Ardeidae	<i>Ixobrychus sinensis</i>	Yellow Bittern	
Threskiornithidae	<i>Plegadis falcinellus</i>	Glossy Ibis	
Threskiornithidae	<i>Threskiornis molucca</i>	Australian Ibis	
Threskiornithidae	<i>Platalea regia</i>	Royal Spoonbill	
Ciconiidae	<i>Ephippiorhynchus asiaticus</i>	Black-necked Stork	
Fregatidae	<i>Fregata minor</i>	Great Frigatebird	
Ptilonorhynchidae	<i>Archboldia papuensis</i>	Archbold's Bowerbird	CPM
Ptilonorhynchidae	<i>Sericulus aureus</i>	Flame Bowerbird	
Maluridae	<i>Malurus grayi</i>	Broad-billed Fairywren	
Meliphagidae	<i>Myzomela erythrocephala</i>	Red-headed Myzomela	
Meliphagidae	<i>Timeliopsis griseigula</i>	Tawny Straightbill	
Meliphagidae	<i>Pycnopygius cinereus</i>	Marbled Honeyeater	
Meliphagidae	<i>Ptiloprora plumbea</i>	Leaden Honeyeater	CPM
Meliphagidae	<i>Ptiloprora meekiana</i>	Olive-streaked Honeyeater	CPM
Meliphagidae	<i>Melidectes fuscus</i>	Sooty Melidectes	CPM
Meliphagidae	<i>Melidectes princeps</i>	Long-bearded Melidectes	CPM
Meliphagidae	<i>Conopophila albogularis</i>	Rufous-banded Honeyeater	
Petroicidae	<i>Amalocichla sclateriana</i>	Greater Ground-robin	CPM
Petroicidae	<i>Microeca flavigaster</i>	Lemon-bellied Flyrobin	
Petroicidae	<i>Pachycephalopsis hattamensis</i>	Green-backed Robin	CPM
Orthonyctidae	<i>Orthonyx temminckii</i>	Logrunner	
Corvidae: quail-thrushes, whipbirds	<i>Cinclosoma ajax</i>	Painted Quail-thrush	SPL
Corvidae: quail-thrushes, whipbirds	<i>Androphobus viridis</i>	Papuan Whipbird	CPM
Corvidae: sittellas	<i>Daphoenositta miranda</i>	Black Sittella	CPM
Corvidae: whistlers	<i>Pitohui incertus</i>	White-bellied Pitohui	SPL
Corvidae: whistlers	<i>Colluricincla umbrina</i>	Sooty Shrike-thrush	CPM
Corvidae: whistlers	<i>Pachycephala melanura</i>	Black-tailed Whistler	
Corvidae: whistlers	<i>Pachycephala aurea</i>	Golden-backed Whistler	
Corvidae: whistlers	<i>Pachycephala leucogastra</i>	White-bellied Whistler	
Corvidae: birds-of-paradise	<i>Melampitta lugubris</i>	Lesser Melampitta	
Corvidae: birds-of-paradise	<i>Cnemophilus macgregorii</i>	Crested Bird-of-paradise	CPM
Corvidae: birds-of-paradise	<i>Astrapia stephaniae</i>	Stephanie's Astrapia	
Corvidae: orioles, cuckooshrikes	<i>Sphecotheres viridis</i>	Green Figbird	

Appendix 8 Birds that could occur within the PNG LNG upstream project area.

Family	Scientific Name	Common name	EBA ¹
Corvidae: fantails	<i>Rhipidura rufifrons</i>	Rufous Fantail	
Corvidae: monarchs, magpie-larks	<i>Monarcha melanopsis</i>	Black-faced Monarch	
Corvidae: bush-shrikes	<i>Myiagra rubecula</i>	Leaden Flycatcher	
Corvidae: bush-shrikes	<i>Grallina bruijni</i>	Torrent-lark	
Muscicapidae	<i>Monticola solitarius</i>	Blue Rock-Thrush	
Muscicapidae	<i>Muscicapa griseisticta</i>	Grey-streaked Flycatcher	
Muscicapidae	<i>Luscinia calliope</i>	Siberian Rubythroat	
Sturnidae	<i>Aplonis cantoroides</i>	Singing Starling	
Hirundinidae	<i>Riparia riparia</i>	Sand Martin	
Hirundinidae	<i>Hirundo rustica</i>	Barn Swallow	
Hirundinidae	<i>Hirundo neoxena</i>	Welcome Swallow	
Hirundinidae	<i>Hirundo ariel</i>	Fairy Martin	
Cisticolidae	<i>Cisticola exilis</i>	Golden-headed Cisticola	
Zosteropidae	<i>Zosterops fuscicapillus</i>	Capped White-eye	
Sylviidae	<i>Acrocephalus arundinaceus</i>	Great Reed-Warbler	
Sylviidae	<i>Megalurus timoriensis</i>	Tawny Grassbird	
Melanocharitidae	<i>Melanocharis arfakiana</i>	Obscure Berrypecker	CPM
Passeridae	<i>Motacilla flava</i>	Yellow Wagtail	
Passeridae	<i>Oreostruthus fuliginosus</i>	Mountain Firetail	CPM
Passeridae	<i>Erythrura papuana</i>	Papuan Parrotfinch	

1. Endemic Bird Area: CPM – Central Papuan Mountains; SPL - South Papuan Lowlands.

Appendix 9 Reptiles recorded from the PNG LNG upstream project area.

Family	Species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Crocodylidae	<i>Crocodylus porosus</i>	2										2
Crocodylidae	<i>Crocodylus novaeguinea</i>			1	1							2
Agamidae	<i>Hypsilurus dilophus</i>	1	1	1								3
Agamidae	<i>Hypsilurus modestus</i>	1	1	1	2	1				1		7
Agamidae	<i>Hypsilurus sp. (semi-aquatic)</i>			1	2							3
Gekkonidae	<i>Cyrtodactylus capreoloides</i>				1			1				2
Gekkonidae	<i>Cyrtodactylus lorae</i>		1	1				1				3
Gekkonidae	<i>Cyrtodactylus novaeguineae</i>	1		1								2
Gekkonidae	<i>Cyrtodactylus papuensis</i>			1								1
Gekkonidae	<i>Cyrtodactylus serratus</i>				2							2
Gekkonidae	<i>Cyrtodactylus sp. nov. 1 (cf louisiadensis)</i>	1			2							3
Gekkonidae	<i>Cyrtodactylus sp. nov. 2 (nr marmoratus)</i>						1					1
Gekkonidae	<i>Hemidactylus frenatus</i>				1					1		2
Gekkonidae	<i>Nactus pelagicus</i>		1	1								2
Scincidae	<i>Carlia aramia</i>	2	1	1								4
Scincidae	<i>Carlia sp (no available name)</i>									2		2
Scincidae	<i>Emoia caeruleocauda</i>			1	2							3
Scincidae	<i>Emoia kordoana</i>		1	1	1							3
Scincidae	<i>Emoia longicauda</i>			1	2							3
Scincidae	<i>Emoia pallidiceps?</i>		1		1							2
Scincidae	<i>Emoia physicina</i>	1										1
Scincidae	<i>Emoia sp. 1</i>								1		1	2
Scincidae	<i>Emoia sp 2 (obscura?)</i>				2	1				1		4
Scincidae	<i>Eugongylus rufescens</i>			1								1
Scincidae	<i>Lipinia nototaenia</i>				1							1
Scincidae	<i>Lipinia sp. 1</i>		1			1						2
Scincidae	<i>Lipinia sp. 2</i>									1		1

Appendix 9 Reptiles recorded from the PNG LNG upstream project area.

Family	Species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Scincidae	<i>Lobulia elegans</i>								1	1	1	3
Scincidae	<i>Lygisaurus novaeguineae</i>	1										1
Scincidae	<i>Lygisaurus sp</i>									2		2
Scincidae	<i>Papuascincus sp.</i>								1	1	1	3
Scincidae	<i>Sphenomorphus muelleri</i>									1		1
Scincidae	<i>Sphenomorphus meyeri</i>			1	1							2
Scincidae	<i>Sphenomorphus pratti</i>		1									1
Scincidae	<i>Sphenomorphus schultzei</i>					1						1
Scincidae	<i>Sphenomorphus simus</i>	1	1	1	2	1						6
Scincidae	<i>Sphenomorphus sp (annectens complex)</i>									1		1
Scincidae	<i>Sphenomorphus sp. nov. cf jobiensis</i>	1	1	1	1	1				1		6
Scincidae	<i>Sphenomorphus sp. nov. cf. papuae (pale stripes)</i>								1		1	2
Scincidae	<i>Sphenomorphus sp. nov. cf. leptofasciatus (dark stripes)</i>								1			1
Varanidae	<i>Varanus indicus</i>	1			1							2
Varanidae	<i>Varanus dorianus</i>			1								1
Varanidae	<i>Varanus salvadori</i>	1										1
Elapidae	<i>Acanthophis antarcticus</i>	1										1
Elapidae	<i>Aspidomorphus muelleri</i>	1										1
Elapidae	<i>Toxicocalamus loriae</i>				1							1
Elapidae	<i>Toxicocalamus preussi angustitinctus</i>	1										1
Pythonidae	<i>Candoia aspera</i>			1								1

Appendix 9 Reptiles recorded from the PNG LNG upstream project area.

Family	Species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Pythonidae	<i>Candoia carinata</i>	1										1
Pythonidae	<i>Morelia amethystina</i>	1	1							1	1	4
Pythonidae	<i>Morelia boeleni</i> *								1	1		2
Pythonidae	<i>Morelia viridis</i>			1	1					1		3
Pythonidae	<i>Liasis fuscus</i>				1							1
Colubridae	<i>Boiga irregularis</i>	2			1							3
Colubridae	<i>Dendrelaphis calligastra</i>	1			1	1						3
Colubridae	<i>Dendrelaphis gastrosticta</i>									2		2
Colubridae	<i>Stegonotus modestus</i>			1						2		3
Colubridae	<i>Stegonotus parvus</i>	1										1
Colubridae	<i>Stegonotus cucullatus</i>	1										1
Colubridae	<i>Tropidonophis statisticus</i>								2		1	3
Colubridae	<i>Tropidonophis novaeguinea</i>			1								1
Total species		21	12	21	22	7	1	2	7	16	6	

Entries are number of sample sites at which species recorded. Combined data from the PNG LNG Project and the WWF surveys.

Appendix 10 Frogs recorded from the PNG LNG upstream project area.

Family	species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern Montane Karst	Total sites recorded
Microhylidae	<i>Albericus tuberculus</i>						1	1				2
Microhylidae	<i>Albericus sp. nov. 1 (rattler)</i>						1	1	2	2		6
Microhylidae	<i>Albericus sp. nov. 2 (short peeper)</i>							1	1	1		3
Microhylidae	<i>Albericus sp. nov. 3 (rasper)</i>		1		1	1	1	1				5
Microhylidae	<i>Albericus sp. nov. 4 (large)</i>								1	1	1	3
Microhylidae	<i>Albericus sp. nov. 5 (medium)</i>								1	1	1	3
Microhylidae	<i>Albericus sp. nov. 6 (clicker)</i>		1	1	1			1				4
Microhylidae	<i>Albericus sp. nov. 7 (peeper 2)</i>		1									1
Microhylidae	<i>Asterophrys turpicola</i>	1		1	2		1					5
Microhylidae	<i>Asterophrys sp. nov.</i>								1	1		2
Microhylidae	<i>Austrochaperina derongo</i>		1	1	2	1		1	1			7
Microhylidae	<i>Austrochaperina guttata</i>	1										1
Microhylidae	<i>Austrochaperina palmipes</i>	1										1
Microhylidae	<i>Austrochaperina rivularis</i>					1						1
Microhylidae	<i>Austrochaperina sp. nov. 1 (small)</i>	1	1	1	1	1	1	1	1	1		9
Microhylidae	<i>Austrochaperina sp. nov. 2 (cf derongo)</i>		1									1
Microhylidae	<i>Austrochaperina sp. nov. 3 (medium)</i>					1						1
Microhylidae	<i>Callulops doriae</i>	2			1		1					4
Microhylidae	<i>Callulops slateri</i>	2	1	1	2	1	1	1				9
Microhylidae	<i>Callulops wilhelmanus</i>								1		1	2
Microhylidae	<i>Callulops sp. nov. 1 (C. robusta group)</i>	1	1		1	1	1					5
Microhylidae	<i>Callulops sp. nov. 2 (small)</i>									1		1
Microhylidae	<i>Choerophryne allisoni</i>								1		1	2

Appendix 10 Frogs recorded from the PNG LNG upstream project area.

Family	species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern Montane Karst	Total sites recorded
Microhylidae	<i>Choerophryne burtoni</i>				1	1			1	1		4
Microhylidae	<i>Cophixalus cryptotympanum</i>									1		1
Microhylidae	<i>Cophixalus shellyi?</i>								1	2		3
Microhylidae	<i>Cophixalus sp. nov. 1 (eye-spikes)</i>					1		1	1	1		4
Microhylidae	<i>Cophixalus sp. nov. 2 (buzz call)</i>	1	1		2	1	1					6
Microhylidae	<i>Cophixalus sp. nov. 3 (cf balbus)</i>		1	1	1		1					4
Microhylidae	<i>Cophixalus sp. nov. 4 (musical call)</i>						1	1	1			3
Microhylidae	<i>Cophixalus sp. nov. 5. (triple-calls)</i>									2		2
Microhylidae	<i>Cophixalus sp. nov. 6. (tiny)</i>		1									1
Microhylidae	<i>Cophixalus sp. nov. (cf shellyi)</i>									1		1
Microhylidae	<i>Copiula sp. nov. 1 (small, fast call)</i>	2										2
Microhylidae	<i>Copiula sp. nov. 2 (2-note call)</i>		1	1				1				3
Microhylidae	<i>Copiula sp. nov. 3. (tiny)</i>					1	1					2
Microhylidae	<i>Copiula sp. nov. 4. (large)</i>				1	1						2
Microhylidae	<i>Hylophorbus richardsi</i>								1	1	1	3
Microhylidae	<i>Hylophorbus rufescens</i>	1			2							3
Microhylidae	<i>Hylophorbus sp. nov. 1 (Moro broad head)</i>		1	1		1		1	1	2		7
Microhylidae	<i>Hylophorbus sp. nov. 2 (zig-zag)</i>	1					1					2
Microhylidae	<i>Hylophorbus sp. nov. 3 (slow call)</i>	1	1	1		1	1	1		1		7
Microhylidae	<i>Hylophorbus sp. nov. 4 (tiny)</i>		1									1
Microhylidae	<i>Liophryne schlaginhaufeni</i>		1	1			1	1				4
Microhylidae	<i>Mantophryne lateralis</i>	2		1	2	1						6
Microhylidae	<i>Oreophryne notata</i>								1	1	1	3

Appendix 10 Frogs recorded from the PNG LNG upstream project area.

Family	species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern Montane Karst	Total sites recorded
Microhylidae	<i>Oreophryne</i> sp. nov. 1 (small rattler)	2	1	1	2		1	1	1			9
Microhylidae	<i>Oreophryne</i> sp. nov. 2 (loud rattler)				1	1	1	1	1	1		6
Microhylidae	<i>Oreophryne</i> sp. nov. 3 (large peeper)	2	1	1		1	1	1		2		9
Microhylidae	<i>Oreophryne</i> sp. nov. 4. (large, montane)								1		1	2
Microhylidae	<i>Oreophryne</i> sp. nov. 5. (small peeper)				2							2
Microhylidae	<i>Oreophryne</i> sp. nov. 6. (tiny peeper)*									1		1
Microhylidae	<i>Oreophryne</i> sp. nov. 7. (medium)*									1		1
Microhylidae	<i>Oreophryne</i> sp. nov. 8. (long rattle)								1			1
Microhylidae	<i>Oreophryne</i> sp. nov. 9. (cf notata)*				1	1						2
Microhylidae	<i>Sphenophryne cornuta</i>	2	1	1	2	1	1	1				9
Microhylidae	<i>Xenorhina parkerorum</i>								1	1		2
Microhylidae	<i>Xenobatrachus</i> sp. nov. 1 (small)		1	1								2
Microhylidae	<i>Xenobatrachus</i> sp. nov. 2 (slow call)	2	1		2	1						6
Microhylidae	<i>Xenobatrachus</i> sp. nov. (fast call)*				1	1			1			3
Microhylidae	<i>Xenobatrachus</i> sp. nov. 4 (tiny)*					1						1
Microhylidae	<i>Xenobatrachus</i> sp. nov. 5 (colourful)*					1						1
Microhylidae	<i>Xenobatrachus</i> sp. nov. 6 (bi-coloured legs)*?					1						1
Hylidae	<i>Litoria amboinensis</i>						1	1				2
Hylidae	<i>Litoria angiana</i>								2	1		3
Hylidae	<i>Litoria arfakiana</i>				2	1		1	1	1		6
Hylidae	<i>Litoria auae</i>	1	1		2	1		1		1		7
Hylidae	<i>Litoria darlingtoni</i>								2	1		3
Hylidae	<i>Litoria eucnemis</i>					1		1		1		3

Appendix 10 Frogs recorded from the PNG LNG upstream project area.

Family	species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands Volcanics/Karst	Northern Montane Karst	Total sites recorded
Hylidae	<i>Litoria havina</i>				1	1		1		1		4
Hylidae	<i>Litoria infrafronata</i>	2	1	1	2			1		1		8
Hylidae	<i>Litoria iris</i>								2	1	1	4
Hylidae	<i>Litoria majikthise</i>		1		1	1						3
Hylidae	<i>Litoria micromembrana</i>								2			2
Hylidae	<i>Litoria modica</i>					1			2	2		5
Hylidae	<i>Litoria pronimia</i>						1	1		1	1	4
Hylidae	<i>Litoria prora</i>	1					1	1				3
Hylidae	<i>Litoria richardsi</i>		1									1
Hylidae	<i>Litoria sauroni</i>	1	1				1					3
Hylidae	<i>Litoria spartacus</i>				1			1		1		3
Hylidae	<i>Litoria thesaurensis</i>			1	1			1				3
Hylidae	<i>Litoria wollastoni</i>									1		1
Hylidae	<i>Litoria sp. nov. 1 cf nigropunctata 1 (bleating call)</i>					1		1				2
Hylidae	<i>Litoria sp. nov. 2 cf nigropunctata 2 (Darai)</i>		1									1
Hylidae	<i>Litoria sp. nov. 3 (nr bicolor)</i>	1										1
Hylidae	<i>Litoria sp. nov. 4 (nr genimaculata 1 - yellow eye)</i>							1				1
Hylidae	<i>Litoria sp. nov. 5 (nr genimaculata 2)</i>	2	1		1	1						5
Hylidae	<i>Litoria sp. nov. 6 (Torrent chirper)</i>								1			1
Hylidae	<i>Litoria sp. nov. 7 (small, green torrent)</i>			1	1							2
Hylidae	<i>Litoria sp. nov. 8 (scarlet venter)</i>				1		1	1		2		5
Hylidae	<i>Litoria sp. nov. 9 (yellow venter)</i>						1	1				2
Hylidae	<i>Litoria sp. nov. 10 (Libano torrent)</i>			1								1

Appendix 10 Frogs recorded from the PNG LNG upstream project area.

Family	species	Kikori Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Western Volcanics	Eastern Uplands/ Volcanics/ Karst	Northern Montane Karst	Total sites recorded
Hylidae	<i>Litoria sp. nov. 11 (cf pygmaea)</i>									1		1
Hylidae	<i>Litoria sp. nov. 12 (Trilling torrent)*</i>									1		1
Hylidae	<i>Litoria sp. nov. 13 (cf multiplica)*</i>					1						1
Hylidae	<i>Litoria sp. nov. 14 (cf Ok Menga)</i>				1							1
Hylidae	<i>Nyctimystes pulcher</i>				2			1				3
Hylidae	<i>Nyctimystes kudoku</i>							1		1		2
Hylidae	<i>Nyctimystes sp. nov.*</i>								1	1		2
Myobatrachidae	<i>Lechriodus aganoposis</i>								2	2		4
Myobatrachidae	<i>Lechriodus melanopyga</i>	1	1	1		1		1				5
Ranidae	<i>Rana arfaki</i>	1	1	1	2			1				6
Ranidae	<i>Rana daemeli</i>	2	1	1	2	1	1	1	1	2		12
Ranidae	<i>Rana cf grisea 1</i>		1		2	1		1	1	4		10
Ranidae	<i>Rana cf grisea 2</i>		1									1
Ranidae	<i>Rana novaeguineae</i>	1										1
Ranidae	<i>Rana sp. nov.</i>	1										1
Total Species		28	33	22	36	36	26	38	33	42	9	

Entries are number of sample sites at which species recorded. Combined data from the PNG LNG Project and the WWF surveys.

* a species new to science discovered on the 2008 survey.

Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name ¹	Scientific Name	IUCN ²	PNG Fauna Act ³	H ⁴	C ⁵	Kikori Lowlands ⁷	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands ⁸	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
Large Leptomys	<i>Leptomys elegans</i>	CR			X						X	X		X	X		
Fly River Leptomys	<i>Leptomys signatus</i>	CR			X			X							X		
Large Pogonomelomys	<i>Pogonomelomys bruijini</i>	CR			X										X		
Bulmers' Fruit Bat *	<i>Aproteles bulmerae</i>	CR		X	X												
Thomas' Big-eared Bat *	<i>Pharotis imogene</i>	CR															
Papuan Whipbird *	<i>Androphobus viridis</i>	CR			X												
Tree	<i>Halfordia papuana</i> Laut.	CR			X												
Long-beaked Echidna	<i>Zaglossus bartoni</i>	EN		X	X			X	X	X	X	X			X	X	X
Goodfellow's Tree Kangaroo	<i>Dendrolagus goodfellowi</i>	EN		X				X	X		X	X			X	X	X
Greater Small-toothed Rat	<i>Macruromys major</i>	EN			X										X		
Tree	<i>Bleasdalea papuana</i> (Diels) Domin	EN			X												
Tree	<i>Flindersia pimenteliana</i> F.v.M	EN									X						
New Guinea Quoll	<i>Dasyurus albopunctatus</i>	VU		X	X			X	X	X	X	X		X	X	X	X
Stein's Cuscus	<i>Phalanger vestitus</i>	VU		X							X				X	X	X
Doria's Tree Kangaroo	<i>Dendrolagus dorianus</i>	VU		X				X	X		X	X			X	X	X
Macleay's Dorcopsis	<i>Dorcopsulus macleayi</i>	VU		X												X	
New Guinea Pademelon	<i>Thylogale browni</i>	VU		X							X						
Plush-coated Ringtail	<i>Pseudochirops corinnae</i>	VU		X	X						X				X	X	X
Great Tailed Triok	<i>Dactylopsila megalura</i>	VU		X											X		
One-toothed Shrew Mouse	<i>Mayermys ellermani</i>	VU			X											X	X
Lesser Tube-nosed Bat	<i>Nyctimene draconilla</i>	VU			X										X		

Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name ¹	Scientific Name	IUCN ²	PNG Fauna Act ³	H ⁴	C ⁵	Kikori Lowlands ⁷	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands ⁸	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
Moss-forest Blossom Bat *	<i>Syconycteris hobbit</i>	VU			X												
Large-eared Sheath-tailed Bat	<i>Emballonura diana</i>	VU			X				X						X		
New Guinea Sheath-tailed Bat	<i>Emballonura furax</i>	VU			X				X						X		
Papuan Sheath-tailed Bat *	<i>Saccolaimus mixtus</i>	VU			X												
Telefomin Leaf-nosed Bat *	<i>Hipposideros corynophyllus</i>	VU															
Fly River Leaf-nosed Bat *	<i>Hipposideros muscinus</i>	VU			X												
Small-toothed Big-eared Bat	<i>Nyctophilus microdon</i>	VU			X										X	X	X
Greater Big-eared Bat *	<i>Nyctophilus timoriensis</i>	VU			X												
Fly River Trumpet-eared Bat	<i>Kerivoula muscina</i>	VU			X					X							
Papuan Mastiff-bat *	<i>Otomops papuensis</i>	VU			X												
Mantled Mastiff-bat	<i>Otomops secundus</i>	VU			X					X	X				X	X	X
Southern Cassowary	<i>Casuarius casuarius</i>	VU	R	X		X	X	X				X				X	
Salvadori's Teal	<i>Salvadorina waigiensis</i>	VU	P	X	X										X		
Pesquet's Parrot	<i>Psittichas fulgidus</i>	VU	R	X		X	X	X	X	X	X	X	X		X		
Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>	VU	P	X		X	X	X		X		X					
New Guinea Eagle	<i>Harpyopsis novaeguineae</i>	VU		X		X		X			X	X	X		X		
Long-bearded Melidectes *	<i>Melidectes princeps</i>	VU			X												
Black Sickbill	<i>Epimachus fastuosus</i>	VU	P	X	X										X	X	X
Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>	VU	P	X											X	X	
Tree	<i>Arthrophyllum proliferum</i> <i>Philipson</i>	VU			X												

Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name ¹	Scientific Name	IUCN ²	PNG Fauna Act ³	H ⁴	C ⁵	Kikori Lowlands ⁷	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands ⁸	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
Tree	<i>Helicia acutifolia Sleum.</i>	VU			X												
Tree	<i>Pterocarpus indicus</i>	VU															
Tree	<i>Aglaia puberulanthera</i>	VU															
Giant Naked-tailed Rat	<i>Uromys anak</i>	NT		X	X										X	X	
Rock-dwelling Giant Rat	<i>Xenuromys barbatus</i>	NT		X	X					X		X			X		
Lesser Bare-backed Bat	<i>Dobsonia minor</i>	NT		X	X	X		X	X			X					
Greater Tube-nosed Bat	<i>Nyctimene aello</i>	NT			X	X			X	X		X					
Round-eared Tube-nosed Bat	<i>Nyctimene cyclotis</i>	NT			X								X		X	X	
Green Tube-nosed Bat	<i>Paranyctimene raptor</i>	NT			X	X	X	X	X	X		X				X	
Raffray's Sheath-tailed Bat	<i>Emballonura raffrayana</i>	NT			X				X			X			X		
Yellow-bellied Sheath-tailed Bat *	<i>Saccolaimus flaviventris</i>	NT															
Southern Sheath-tailed Bat *	<i>Taphozous australis</i>	NT															
Hill's Leaf-nosed Bat *	<i>Hipposideros edwardshilli</i>	NT			X												
Greater Leaf-nosed Bat	<i>Hipposideros semoni</i>	NT			X					X	X					X	
Wollaston's Leaf-nosed Bat	<i>Hipposideros wollastoni</i>	NT			X	X		X									
Large-eared Horseshoe Bat	<i>Rhinolophus philippinensis</i>	NT			X				X	X	X				X	X	
Papuan Pipistrelle	<i>Pipistrellus papuanus</i>	NT			X					X							
Watt's Pipistrelle *	<i>Pipistrellus watti</i>	NT															
Dwarf Cassowary	<i>Casuarius bennetti</i>	NT		X				X		X	X	X	X		X	X	X
Striated Lorikeet	<i>Charmosyna multistriata</i>	NT		X								X	X				
New Guinea Flightless Rail	<i>Megacrex inepta</i>	NT		X		X						X					

Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name ¹	Scientific Name	IUCN ²	PNG Fauna Act ³	H ⁴	C ⁵	Kikori Lowlands ⁷	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands ⁸	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
Black-tailed Godwit	<i>Limosa limosa</i>	NT				X											
Asian Dowitcher	<i>Limnodromus semipalmatus</i>	NT				X											
Buff-breasted Sandpiper *	<i>Tryngites subruficollis</i>	NT															
Beach Thick-knee	<i>Esacus giganteus</i>	NT				X											
Doria's Goshawk *	<i>Megatriorchis doriae</i>	NT		X	X												
Gurney's Eagle	<i>Aquila gurneyi</i>	NT	R	X						X			X		X		
Forest Bittern	<i>Zonerodius heliosylus</i>	NT			X					X		X					
Black-necked Stork *	<i>Ephippiorhynchus asiaticus</i>	NT	R	X	X												
Archbold's Bowerbird *	<i>Archboldia papuensis</i>	NT		X	X												
White-bellied Pitohui *	<i>Pitohui incertus</i>	NT															
Olive-yellow Robin	<i>Poecilodryas placens</i>	NT							X			X	X				
Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>	NT	P												X		X
Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>	NT	P	X	X										X	X	X
Yellow-eyed Starling	<i>Aplonis mystacea</i>	NT				X		X		X		X					
Tree	<i>Myristica globosa</i>	NT															
Long-nosed Murexia	<i>Phascomurexia naso</i>	DD			X				X						X	X	
Ground Cuscus	<i>Phalanger gymnotis</i>	DD		X		X		X	X	X	X	X			X	X	X
Lowland Tree Kangaroo	<i>Dendrolagus spadix</i>	DD		X		X		X		X		X			X	X	
Lowland Ringtail	<i>Pseudochirulus canescens</i>	DD		X	X	X				X		X			X	X	
Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>	DD												X			

Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name ¹	Scientific Name	IUCN ²	PNG Fauna Act ³	H ⁴	C ⁵	Kikori Lowlands ⁷	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands ⁸	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
Papuan Hawk-Owl *	<i>Uroglaux dimorpha</i>	DD															
Starry Owlet-Nightjar *	<i>Aegotheles tatei</i>	DD															
Wallace's Owlet-Nightjar *	<i>Aegotheles wallacii</i>	DD			X												
Chestnut-shouldered Goshawk *	<i>Erythrorhynchus buergeri</i>	DD		X	X												
Obscure Berrypecker *	<i>Melanochoris arfakiana</i>	DD			X												
Frog	<i>Choerophryne allisoni</i>	DD													X		X
Frog	<i>Cophixalus cryptotympanum</i>	DD														X	
Frog	<i>Hylophorbus richardsi</i>	DD													X	X	X
Frog	<i>Oreophryne notata</i>	DD													X	X	X
Frog	<i>Litoria majkthise</i>	DD						X		X	X						
Short-beaked Echidna	<i>Tachyglossus aculeatus</i>		R	X	X			X	X								
Feather-tailed Possum	<i>Distoechurus pennatus</i>		R	X		X		X	X	X	X	X	X		X	X	X
Blyth's Hornbill	<i>Aceros plicatus</i>		P	X		X	X	X	X	X		X	X			X	
Papuan Lorikeet	<i>Charmosyna papou</i>		R	X											X	X	X
Palm Cockatoo	<i>Probosciger aterrimus</i>		P	X		X	X	X	X	X	X	X	X		X		
Sulphur-crested Cockatoo	<i>Cacatua galerita</i>		R	X		X	X	X		X	X	X	X		X	X	
Pheasant Pigeon	<i>Otidiphaps nobilis</i>		R	X		X				X		X	X		X		
Little Curlew *	<i>Numenius minutus</i>		R														
Osprey *	<i>Pandion haliaetus</i>		P														
White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>		R	X		X							X				
Eastern Marsh-Harrier	<i>Circus spilonotus</i>		R	X									X				
Swamp Harrier *	<i>Circus approximans</i>		R														

Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name ¹	Scientific Name	IUCN ²	PNG Fauna Act ³	H ⁴	C ⁵	Kikori Lowlands ⁷	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands ⁸	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
Australian Kestrel	<i>Falco cenchroides</i>		R			X											
Oriental Hobby	<i>Falco severus</i>		R										X				
Australian Hobby	<i>Falco longipennis</i>		R			X											
Brown Falcon	<i>Falco berigora</i>		R									X	X			X	
Peregrine Falcon	<i>Falco peregrinus</i>		R			X						X	X				
Little Egret	<i>Egretta garzetta</i>		P			X						X	X				
Great Egret	<i>Ardea alba</i>		P			X		X				X	X				
Intermediate Egret	<i>Mesophoyx intermedia</i>		P										X				
Flame Bowerbird *	<i>Sericulus aureus</i>		R	X													
Crested Bird-of-paradise *	<i>Cnemophilus macgregorii</i>		P	X													
Loria's Bird-of-paradise	<i>Cnemophilus loriae</i>		P												X	X	
Glossy-mantled Manucode	<i>Manucodia atra</i>		P			X						X					
Crinkle-collared Manucode	<i>Manucodia chalybata</i>		P						X	X	X	X	X				
Trumpet Manucode	<i>Manucodia keraudrenii</i>		P			X				X		X			X		
Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>		P	X											X	X	X
Brown Sicklebill	<i>Epimachus meyeri</i>		P	X	X										X	X	X
Black-billed Sicklebill	<i>Epimachus albertisi</i>		P	X	X								X				
Superb Bird-of-paradise	<i>Lophorina superba</i>		P	X									X		X	X	X
Carola's Parotia	<i>Parotia carolae</i>		P	X	X						X	X	X		X		
Lawe's Parotia	<i>Parotia lawesii</i>		P	X	X										X	X	X
Magnificent Riflebird	<i>Ptiloris magnificus</i>		P	X		X				X	X	X	X			X	
Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>		P	X					X	X	X	X	X		X	X	

Appendix 11 Conservation status of flora and fauna in bioregions of the PNG LNG upstream project area. Combined data from the PNG LNG Project and the WWF surveys.

Common name ¹	Scientific Name	IUCN ²	PNG Fauna Act ³	H ⁴	C ⁵	Kikori Lowlands ⁷	Seribi Lowlands	Darai Plateau	Libano-Hegigio	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagifu Agogo Limestone Uplands ⁸	Western Volcanics	Eastern Uplands Volcanics/ Karst	Northern Montane Karst
King Bird-of-paradise	<i>Cicinnurus regius</i>		P	X		X	X	X	X	X		X	X				
Stephanie's Astrapia	<i>Astrapia stephaniae</i>		P	X												X	
King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>		P	X	X										X	X	X
Twelve-wired Bird-of-paradise	<i>Seleucidis melanoleuca</i>		P	X	X	X						X	X				
Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>		P	X	X	X	X	X	X	X	X	X	X		X	X	
Saltwater crocodile	<i>Crocodylus porosus</i>		R	X		X											
New Guinea freshwater crocodile	<i>Crocodylus novaeguinea</i>		R	X					X	X							
Mangrove monitor	<i>Varanus indicus</i>		R	X		X				X							
Gould's monitor	<i>Varanus dorianus</i>		R	X					X								
Salvadori's monitor	<i>Varanus salvadori</i>		R	X		X											
Ground boa	<i>Candoia aspera</i>		R	X					X								
Pacific boa	<i>Candoia carinata</i>		R	X		X											
Amethystine python	<i>Morelia amethystina</i>		R	X		X		X								X	X
Boelen's Python	<i>Morelia boeleni</i>		R	X											X	X	
Green Tree Python	<i>Morelia viridis</i>		R	X					X	X						X	
Olive Python	<i>Liasis fuscus</i>		R	X						X							

¹ species likely to occur but not yet recorded are asterisked

² IUCN status CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Lower Risk But Near Threatened, DD = Data Deficient

³ Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R)

⁴ Impacted by hunting

⁵ Potentially impacted by construction.

⁷ X – occurs in bioregion

⁸ combined with Moro bioregion for birds, frogs and reptiles.

Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.

Code	Mitigation	Biodiversity group			Project phase		Direct impacts													Indirect impacts								
		Habitat	Flora	Fauna	Construction	Operations	Habitat loss	Edge effects	Barrier effects	Physical damage and disturbance to caves	Fauna falling in the pipe trench	Erosion, spoil & changes to hydrology	Material handling	Disposal of hydrotest fluids	Dust	Loss of Breeding & display grounds	Noise, lights and other disturbance	Project traffic and other operation	Fire	Dieback	Invasives – weeds	Invasives - fauna	Hunting by project workers & contractors	Hunting by non - project personnel	Collecting flora by project workers & contractors	Collecting flora by non - project personnel	Improved access to	
31	The standard ROW width for the project is 30 m and following construction the ROW will be allowed to naturally regenerate except for 15 m, to allow for a gap in the canopy for aerial surveillance of the pipeline. If there is a requirement to exceed the ROW design width, the contractor shall seek approval through a formal procedure from the Operator.	X	X	X	X		X	X	X							X												
37	No machinery will leave the ROW or access roads to unnecessarily clear additional forest.	X	X	X	X		X	X	X						X													
20	Clearing of riparian vegetation will be limited to the width required to safely accommodate pipeline ROW/access way and watercourse crossings. Also, the number of watercourse crossings will be reduced, to the extent practicable, to limit riparian soil erosion and sediment delivery to watercourses.	X	X	X	X		X		X																			
148	Develop a watercourse crossing construction management plan that addresses the sensitivities of crossings on an individual watercourse basis. Plans are to consider, where relevant: - Watercourse diversions requirements. - Disturbance limits. - Equipment limitations. - Erosion control measures. - Fine-scale routing at crossing sites to limit disturbance of particularly large and established riparian vegetation and complex bank habitat structure. - Delay the clearing of banks of watercourses for temporary vehicle crossing until the need for the crossing is imminent, where practicable.	X	X	X	X		X		X																			
152	Where practicable, trees felled into watercourses will be removed and used for revegetation works, where practicable.	X	X	X	X		X																					
154	Where practical, stabilise cleared banks to provide a suitable habitat for recolonisation.	X	X	X	X		X	X	X																			
155	Where practicable, the pipeline ROW/access way alignment approaches to watercourses will be kept as close to right angles as possible to limit disturbances to the banks of watercourses.	X	X	X	X		X	X	X																			
239	Well pads will be designed and located reduce the extent of vegetation clearing and earthworks by limiting to the extent practicable, the size of the well pads.	X	X	X	X		X									X												
199	The duration of construction activities at watercourse crossings will be as short as practicable.	X	X	X	X		X									X												
156	Conduct fine-scale routing of the ROW/access ways to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel waterbodies and other karst terrain, where practicable.	X	X	X	X		X									X												
237	ROWs and roadways will be located within or adjacent to existing disturbed areas where practicable.	X	X	X	X		X	X	X																			

Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.

Code	Mitigation	Biodiversity group			Project phase		Direct impacts														Indirect impacts									
		Habitat	Flora	Fauna	Construction	Operations	Habitat loss	Edge effects	Barrier effects	Physical damage and disturbance to caves	Fauna falling in the pipe trench	Erosion, spoil & changes to hydrology	Material handling	Disposal of hydrotest fluids	Dust	Loss of Breeding & display grounds	Noise, lights and other disturbance	Project traffic and other operation	Fire	Dieback	Invasives – weeds	Invasives - fauna	Hunting by project workers & contractors	Hunting by non - project personnel	Collecting flora by project workers & contractors	Collecting flora by non - project personnel	Improved access to project area			
30	Where practicable, utilise land clearing techniques that preserve the rootstock of removed vegetation in the ground. Spread cleared vegetation back on to the ROW as mulch, where practicable.	X	X		X		X	X	X			X																		
32	The design criteria for ROW width on Hides Ridge, which includes the access road, is 18 m. During operations the ROW will be allowed to regenerate except for a 10 m access road required for ongoing drilling and maintenance access to the wellpads on the ridge.	X	X	X	X	X	X	X	X			X				X					X									
44	If practical and safe, retain trees over 1 m dbh at camp locations.	X	X	X	X		X									X														
34	Where trees are to be felled by hand, use directional felling for trees > 50 cm dbh so they land in natural slots between standing trees or along the axis of tracks to reduce damage to the remaining forest.	X	X	X	X		X	X	X							X					X									
35	Reduce machinery scraping stems of standing trees adjacent to or off the ROW.	X	X	X	X		X	X	X							X					X									
98	Develop a revegetation management plan that will be detailed in the EMP and which will include measures to specifically assist revegetation in areas found to be slow to revegetate naturally.	X	X	X	X		X	X	X			X																		
102	Areas requiring active revegetation will be identified:	X	X	X	X		X	X	X			X																		
156	Conduct fine-scale routing of the ROW/access ways to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel waterbodies and other karst terrain, where practicable.	X	X	X			X					X																		
41	Provide protection for stream heads in the Baia River area and elsewhere in the upstream project area above 1,800 m, to reduce erosion material entering them.	X		X	X	X	X					X				X					X									
40	On Hides Ridge and between Hides Ridge and Juha, align the route to bypass potentially high-value conservation swamps or swamps in sinkholes <50 m deep where practicable. At sites where this is impractical reduce side cast into these high value habitats.	X		X	X		X					X				X					X									
22	No quarries beyond cut to be established on the Hides Ridge where practicable.	X	X	X	X		X									X														
23	Minimise the number of quarries developed by: –Using previously worked (old) quarries, where practicable. –Using limestone generated by construction activities for road-base material.	X	X	X	X		X									X														
68	Conduct a pre-clearance survey of pinnacles along the ROW/roadways for caves to determine presence of bat colonies and where colonies are located in proximity to the ROW/roadways, establish procedures to reduce disturbance, where practicable. Potential quarry sites should not be located near caves with colonies containing protected bat species.	X		X	X		X			X													X							
24	Reduce number of special vehicle parks, and place in areas of existing disturbance where practicable.	X	X	X	X		X									X														

Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.

Code	Mitigation	Biodiversity group			Project phase		Direct impacts											Indirect impacts										
		Habitat	Flora	Fauna	Construction	Operations	Habitat loss	Edge effects	Barrier effects	Physical damage and disturbance to caves	Fauna falling in the pipe trench	Erosion, spoil & changes to hydrology	Material handling	Disposal of hydrotest fluids	Dust	Loss of Breeding & display grounds	Noise, lights and other disturbance	Project traffic and other operation	Fire	Dieback	Invasives – weeds	Invasives - fauna	Hunting by project workers & contractors	Hunting by non - project personnel	Collecting flora by project workers & contractors	Collecting flora by non - project personnel	Improved access to project area	
25	No construction camps allowed on Hides Ridges beyond Hides Wellpad A (with the exception of drilling camps).	X	X	X	X		X									X												
26	If a temporary drilling camp is necessary on Hides Ridge there should be only one and it is to be located at Hides Wellpad D and to be used by successive drilling campaigns.	X	X	X	X		X									X												
27	Promote use of timber felled during well pad, pipeline, access way/ROW and facility site clearing for project uses to the extent practicable.	X	X	X	X		X				X																	
67	Direct lights at facilities etc. to eliminate shine into surrounding forest, where security allows.	X	X	X	X	X											X											
3	Speed limits will be controlled via posted speed limit signs on project unsealed roads and pipeline rights of way (ROWs) (when required) and vehicles kept to marked trafficable areas which will be maintained in a damp and compacted condition (when required) to enhance safety and minimise dust emissions.			X	X									X		X	X											
82	Control speed limits on project unsealed roads and pipeline ROWs via posted speed limit signs, and vehicles kept to marked trafficable areas to prevent injury to fauna.			X	X	X											X											
36	No herbicides to be used unless for the eradication of a serious invasive environmental weed.	X	X	X		X	X	X	X							X												
111	Develop an erosion and sediment control plan for all construction-related activities to: - Implement good industry practice erosion and sediment control measures at watercourse crossings, as necessary. - Prohibit stockpiling spoil and topsoil materials close to waterways (i.e., maintaining a minimum of 10 m from the waterline). - Control sediment runoff from stockpiles and cleared areas around watercourses - Implement sediment control measures downstream of side-cast material where safe and practicable - Limit erosion and sediment delivery to streams from new quarries. - Grade pipeline ROW/roadway alignments adjacent to streams away from watercourses. - Monitor and maintain erosion and sediment control measures until adequate soil stabilisation has been achieved. - Install diversion drains to intercept uncontaminated surface runoff around facilities and away from construction areas. - Install sediment control structures to intercept sediment-laden surface runoff to reduce sediment delivery to watercourses. - Monitor for and rectify areas of problematic erosion at reclaimed watercourse crossings.	X	X	X	X	X	X					X				X					X							
12	On Hides Ridge, hydrotest water sourced off the Ridge will be discharged into the same watershed as its source to prevent cross contamination with live organisms from another catchment.	X	X	X	X								X								X	X						
53	Prohibit disposal of any waste into forest, streams or sinkholes.	X	X	X	X	X						X																

Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.

Code	Mitigation	Biodiversity group			Project phase		Direct impacts														Indirect impacts									
		Habitat	Flora	Fauna	Construction	Operations	Habitat loss	Edge effects	Barrier effects	Physical damage and disturbance to caves	Fauna falling in the pipe trench	Erosion, spoil & changes to hydrology	Material handling	Disposal of hydrotest fluids	Dust	Loss of Breeding & display grounds	Noise, lights and other disturbance	Project traffic and other operation	Fire	Dieback	Invasives – weeds	Invasives - fauna	Hunting by project workers & contractors	Hunting by non - project personnel	Collecting flora by project workers & contractors	Collecting flora by non - project personnel	Improved access to project area			
54	Dispose of drilling fluids cuttings, and other drilling materials in an appropriate manner away from Hides Ridge.	X	X	X	X							X																		
55	Dispose of wastes from ROW/access way construction activities (not spoil) and camps (including the drilling camp) away from Hides Ridge.			X			X					X				X														
56	Waste management procedures will be established to control and appropriately manage all non-biodegradable materials.			X	X	X						X																		
57	Manage sewage in an appropriate manner to limit environmental contamination.	X	X	X	X	X						X																		
58	Incinerate organic waste and bury at specified sites.	X	X	X	X	X						X																		
172	Fuel, lubricating oils and chemicals will be stored in appropriately sized designated areas that have impervious liners and bunds, or are in double hulled tanks. This includes temporary fuel stores along the ROW and access roads.	X	X	X	X	X						X																		
60	Prohibit wash down or fuel handling near or in streams.	X	X	X	X	X						X																		
62	Establish appropriate fuel handling transport and storage procedures in EMPs.	X	X	X	X	X						X																		
63	Establish appropriate materials handling, storage and disposal in EMPs.	X	X	X	X	X						X																		
64	Establish appropriate storage and handling of radioactive material in EMPs.	X	X	X	X	X						X																		
65	Establish appropriate waste handling procedures in EMPs.	X	X	X	X	X						X																		
29	Develop practical procedures for temporary fly camps and pioneer camps that have similar environmental intent as those for construction camps.	X	X	X	X		X												X	X	X	X		X						
71	Investigate the potential Bulmer's Fruit-bat colony near Angore and design and implement a management plan should a colony be found near Angore or elsewhere in the project area.	X		X	X	X	X			X																				
72	Establish cave management protocols for worker and contractor inductions, to prohibit unnecessary disturbance of bat colonies by project workers.			X	X		X			X													X							
74	Consider restricting access to caves with bats and prohibit unnecessary disturbance by project workers.			X	X		X			X																				
75	Limit or control where practicable, blasting within 100 m of known colonies of cave bats.			X	X		X			X																				

Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.

Code	Mitigation	Biodiversity group			Project phase		Direct impacts											Indirect impacts									
		Habitat	Flora	Fauna	Construction	Operations	Habitat loss	Edge effects	Barrier effects	Physical damage and disturbance to caves	Fauna falling in the pipe trench	Erosion, spoil & changes to hydrology	Material handling	Disposal of hydrotest fluids	Dust	Loss of Breeding & display grounds	Noise, lights and other disturbance	Project traffic and other operation	Fire	Dieback	Invasives – weeds	Invasives - fauna	Hunting by project workers & contractors	Hunting by non - project personnel	Collecting flora by project workers & contractors	Collecting flora by non - project personnel	Improved access to project area
77	Conduct grade 1 bat surveys where practicable prior to construction in areas likely to be inhabited by bats, grade 2 bat surveys in areas where blasting is contemplated, and grade 3 bat surveys where required (after checking with the local community for presence of bat caves near the route) to limit disturbance.	X		X	X		X			X																	
15	Where safe and practicable, patrol open trench to rescue and record fauna that fall into the open pipeline trench.			X	X					X																	
52	Establish procedures to prohibit PNG LNG Project workers or contractors disturbing bird-of-paradise and bowerbird display grounds or trees identified next to the ROW. Conduct a pre-clearance survey to identify such sites.			X	X	X									X							X					
80	Prohibit disturbance/harassment of wildlife, hunting of fauna, gathering of plants or bush foods, or possession of wildlife products by project workers or contractors while working, travelling in project vehicles, and residing in project field accommodation.			X	X	X				X												X		X	X		
14	Implement appropriate inductions to encourage staff to comply with hunting and collecting regulations.			X	X	X					X											X		X	X		
50	Establish procedures to prohibit PNG LNG Project workers or contractors from establishing any gardens, or introducing or transporting any plants, seeds or animals within the project area (including the translocation of fish species).	X	X	X	X	X	X													X	X	X					
51	Establish and enforce a project wide quarantine management plan to be developed in the project EMPs which will encompass personnel and freight movements in and out of and within the project areas, and establish inspection and treatment standards and procedures for all freight types, including pipe and imported rock.	X	X	X	X	X														X	X	X					
94	Implement a weed and exotic pest control management plan that identifies foreign and invasive weed and exotic pest threats and appropriate control measures.	X	X	X	X	X														X	X	X					
90	Implement vehicle wash down facilities. Ban the import of exotic species, including seed into the project area.	X	X	X	X	X														X	X	X					
13	A weed, exotic pest and pathogen management plan will be established to protect the biodiversity of Hides Ridge and Juha area. This will include establishment of chemical washdown points at or near the Hides Gas Conditioning Plant to prevent weeds and pathogens being transported to and within Hides Ridge and Juha for the life of the project. The plan will be detailed in the Environmental Management Plan.	X	X	X	X	X														X	X	X					
9	Prohibit transportation of live animals, plants or seeds to the Juha or Hides Ridge areas.	X	X	X	X	X														X	X	X					
17	If fire hazard exists, pushed vegetation can be left to rot at forest edge rather than burnt.	X	X	X	X	X													X								

Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.

Code	Mitigation	Biodiversity group			Project phase		Direct impacts													Indirect impacts							
		Habitat	Flora	Fauna	Construction	Operations	Habitat loss	Edge effects	Barrier effects	Physical damage and disturbance to caves	Fauna falling in the pipe trench	Erosion, spoil & changes to hydrology	Material handling	Disposal of hydrotest fluids	Dust	Loss of Breeding & display grounds	Noise, lights and other disturbance	Project traffic and other operation	Fire	Dieback	Invasives – weeds	Invasives - fauna	Hunting by project workers & contractors	Hunting by non - project personnel	Collecting flora by project workers & contractors	Collecting flora by non - project personnel	Improved access to project area
43	Develop and implement a fire management plan for the construction and operations phases of the PNG LNG Project aimed at reducing the likelihood of the project starting any wildfires to very low. The plan will include banning the burning of cleared vegetation and other fires in the montane environment in drought years.	X	X	X	X	X	X									X			X								
45	All new project roads constructed between Kopi and the Hides Gas Conditioning Plant will be made impassable following completion of construction. They will therefore not be available for ongoing use by either the project or general public.	X	X	X		X																	X	X	X	X	X
46	All ROWs/access ways made impassable at conclusion of project construction, between the Omati River Landfall and the Kopi by-pass deviation, and on Hides Ridge at the end of the project.	X	X	X																			X	X	X	X	X
47	Control access to Hides Ridge and Juha on the Juha and Hides Ridge access ways to the west of Hides Wellpad A and implement a permit system for vehicle access for the lifetime of the project.	X	X	X		X																	X	X	X	X	X
48	Establish pipeline security procedures, including procedures for heavy logging trucks on road sections where the pipeline is buried.	X	X	X	X	X																					X
18	Encourage WWF in their conservation activities in the project area.	X	X	X		X													X	X	X	X		X		X	X
19	Encourage conservation education in villages in the project area.	X	X	X	X	X													X	X	X	X		X		X	X
N1	The extent of clearing and earthworks along the ROW will be limited and the time period that surfaces are exposed prior to natural revegetation will be reduced to the extent practicable.	X	X	X	X	X	X	X	X			X			X												
N2	Locate temporary Juha drilling camp within the footprint of the Juha Production Facility	X	X	X	X		X									X											
N3	Locate temporary Angore drilling camp within the footprint of the Hides Gas Conditioning Plant.	X	X	X	X		X									X											
93	Develop a management plan to reduce impacts on <i>Nothofagus</i> forest and the spread of dieback. Design to allow adequate surface and subsurface flows and avoid redirection of stream flows where practicable.	X	X	X	X		X	X												X							
N	In karst areas fine particle size organic matting or a lattice framework or similar will be used to trap organic matter across sidecast where safe and practicable.	X			X		X					X															

Appendix 12 Relevance (X) of proposed mitigations in relation to sources of impacts.

Code	Mitigation	Biodiversity group			Project phase	Direct impacts											Indirect impacts										
		Habitat	Flora	Fauna		Construction	Operations	Habitat loss	Edge effects	Barrier effects	Physical damage and disturbance to pathways	Fauna falling in the pipe trench	Erosion, spoil & changes to hydrology	Material handling	Disposal of hydrotest fluids	Dust	Loss of Breeding & display grounds	Noise, lights and other disturbance	Project traffic and other operation	Fire	Dieback	Invasives – weeds	Invasives - fauna	Hunting by project workers & contractors	Hunting by non - project personnel	Collecting flora by project workers & contractors	Collecting flora by non - project personnel
167	Develop hydrotest disposal management plan that includes adherence to guidelines and measures as follows: - Disposal of hydrotest waters in accordance with good industry-practice engineering codes for system gauging, hydrotesting and disposal. - Measures to hold and treat hydrotest waste water where necessary prior to release so the quality meets the requirements of the relevant water discharge permit. - Pre-discharge sampling and analysis of hydrotest water to check that quality complies with the conditions attached to the relevant water discharge permit. - If the waste water is to be discharged to land for infiltration, the outflow energies will be dissipated (e.g., via sprinkler or T-bar arrangements) to prevent problematic soil erosion.	X		X	X								X														
173	Procedures for vehicle/equipment refuelling will be implemented to prevent spillages, and appropriate spill containment equipment will be available at refuelling sites and construction sites. All drivers will be appropriately trained in emergency spill response procedures.	X	X	X	X	X						X															

Appendix 13 Impact analysis for conservation listed species.

Common name	Scientific Name	Value ²	Direct impact magnitude ¹							Indirect impact magnitude ¹				Impact significance before mitigation		Impact significance after mitigation ²	
			Habitat Loss	Edge & Barrier Effects ³	Cave disturbance	Fauna Falling into the Pipeline Trench	Loss of Breeding & Display Grounds	Dust, noise and lights	Other ⁴	Fire	Invasive Species – Weeds, fauna & diseases	Hunting & plant harvesting	Improved Access and increased hunting	Direct	Indirect	Direct	Indirect
Large Leptomys	<i>Leptomys elegans</i>	1	L			M			L	M	M			major	major	minimal	minimal
Fly River Leptomys	<i>Leptomys signatus</i>	1	L			M			L	M	M			major	major	minimal	minimal
Large Pogonomelomys	<i>Pogonomelomys bruijni</i>	1	L			M			L	M	M			major	major	minimal	minimal
Bulmers' Fruit Bat *	<i>Aproteles bulmerae</i>	1			VH					M	M	VH	VH	major	major	minimal	low
Thomas' Big-eared Bat *	<i>Pharotis imogene</i>	1	M							M	M			major	major	minimal	minimal
Papuan Whipbird *	<i>Androphobus viridis</i>	1	L	L(M)						M	M			major	major	minimal	minimal
Tree	<i>Halfordia papuana</i> Laut.	1	L							M	M		M	major	major	minimal	minimal
Long-beaked Echidna	<i>Zaglossus bartoni</i>	2	L	L(M)		M			L	M	M	M	M	moderate	moderate	minimal	minimal
New Guinea Quoll	<i>Dasyurus albopunctatus</i>	2	L	L(M)		L			L	M	M	M	M	moderate	moderate	minimal	minimal
Stein's Cuscus	<i>Phalanger vestitus</i>	2	L	L(M)		L			L	M	M	M	M	moderate	moderate	minimal	minimal
Doria's Tree Kangaroo	<i>Dendrolagus dorianus</i>	2	L	L(M)		L			L	M	M	M	M	moderate	moderate	minimal	low
Goodfellow's Tree Kangaroo	<i>Dendrolagus goodfellowi</i>	2	L	L(M)		L			L	M	M	M	VH	moderate	major	minimal	low
Tree	<i>Flindersia pimenteliana</i> F.v.M.	2	L							M	M		M	moderate	major	minimal	low
Macleay's Dorcopsis	<i>Dorcopsulus macleayi</i>	2	L	L(M)		L			L	M	M	M	M	moderate	moderate	minimal	low
New Guinea Pademelon	<i>Thylogale browni</i>	2	L	L(M)		L			L	M	M	M	M	moderate	moderate	minimal	low
Plush-coated Ringtail	<i>Pseudochirops corinnae</i>	2	L	L(M)		L			L	M	M	M	M	moderate	moderate	minimal	low
Great Tailed Triok	<i>Dactylopsila megalura</i>	2	L	L(M)		L			L	M	M	M	L	moderate	moderate	minimal	low
Greater Small-toothed Rat	<i>Macruromys major</i>	2	N	L(M)		M			L	M	M		L	low	moderate	minimal	minimal
One-toothed Shrew Mouse	<i>Mayermys ellermani</i>	2	N	L(M)		M			L	M	M		L	moderate	moderate	minimal	minimal
Lesser Tube-nosed Bat	<i>Nyctimene draconilla</i>	2	N							M	M			minimal	moderate	minimal	minimal
Moss-forest Blossom Bat *	<i>Syconycteris hobbit</i>	2	N							M	M			minimal	moderate	minimal	minimal
Large-eared Sheath-tailed Bat	<i>Emballonura diana</i>	2	N		M					M	M			moderate	moderate	minimal	minimal
New Guinea Sheath-tailed Bat	<i>Emballonura furax</i>	2	N		M					M	M			moderate	moderate	minimal	minimal
Papuan Sheath-tailed Bat *	<i>Saccolaimus mixtus</i>	2	N							M	M			minimal	moderate	minimal	minimal
Telefomin Leaf-nosed Bat *	<i>Hipposideros corynophyllus</i>	2	N		M					M	M			moderate	moderate	minimal	minimal
Fly River Leaf-nosed Bat *	<i>Hipposideros muscinus</i>	2	N		M					M	M			moderate	moderate	minimal	minimal
Small-toothed Big-eared Bat	<i>Nyctophilus microdon</i>	2	N							M	M			minimal	moderate	minimal	minimal

Common name	Scientific Name	Value ²	Direct impact magnitude ¹							Indirect impact magnitude ¹				Impact significance before mitigation		Impact significance after mitigation ²	
			Habitat Loss	Edge & Barrier Effects ³	Cave disturbance	Fauna Falling into the Pipeline Trench	Loss of Breeding & Display Grounds	Dust, noise and lights	Other ⁴	Fire	Invasive Species – Weeds, fauna & diseases	Hunting & plant harvesting	Improved Access and increased hunting	Direct	Indirect	Direct	Indirect
Greater Big-eared Bat *	<i>Nyctophilus timoriensis</i>	2	N							M	M			minimal	moderate	minimal	minimal
Fly River Trumpet-eared Bat	<i>Kerivoula muscina</i>	2	N							M	M			minimal	moderate	minimal	minimal
Papuan Mastiff-bat *	<i>Otomops papuensis</i>	2	N							M	M			minimal	moderate	minimal	minimal
Mantled Mastiff-bat	<i>Otomops secundus</i>	2	N							M	M			minimal	moderate	minimal	minimal
Southern Cassowary	<i>Casuarius casuarius</i>	2	N			L			L	M	M	H	H	moderate	moderate	minimal	low
Salvadori's Teal	<i>Salvadorina waigiensis</i>	2	L							M	M	H	H	moderate	moderate	minimal	low
Pesquet's Parrot	<i>Psittichas fulgidus</i>	2	N							M	M	M	M	moderate	moderate	minimal	minimal
Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>	2	L							M	M	M	M	moderate	moderate	minimal	low
New Guinea Eagle	<i>Harpyopsis novaeguineae</i>	2	N							M	M	VH	VH	major	major	minimal	low
Long-bearded Melidectes *	<i>Melidectes princeps</i>	2	N							M	M			minimal	moderate	minimal	minimal
Black Sickbill	<i>Epimachus fastuosus</i>	2	N							M	M	H	H	moderate	moderate	minimal	low
Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>	2	N				H			M	M	VH	VH	major	major	minimal	low
Tree	<i>Bleasdalea papuana</i> (Diels) Domin	2	N							M	M			minimal	moderate	minimal	minimal
Tree	<i>Arthrophyllum proliferum</i> Philipson	2	N							M	M			minimal	moderate	minimal	minimal
Tree	<i>Helicia acutifolia</i> Sleum.	2	N							M	M			minimal	moderate	minimal	minimal
Tree	<i>Pterocarpus indicus</i>	2	N							M	M			minimal	moderate	minimal	minimal
Tree	<i>Aglaia puberulanthera</i>	2	N							M	M			minimal	moderate	minimal	minimal
Tree	<i>Myristica globosa</i>	3	N							M	M			minimal	low	minimal	minimal
Giant Naked-tailed Rat	<i>Uromys anak</i>	3	L	L(M)		L			L	M	M	L	M	low	low	minimal	minimal
Rock-dwelling Giant Rat	<i>Xenuromys barbatus</i>	3	L	L(M)		L			L	M	M	L	M	low	low	minimal	minimal
Lesser Bare-backed Bat	<i>Dobsonia minor</i>	3	N		M					M	M	L	M	low	low	minimal	minimal
Greater Tube-nosed Bat	<i>Nyctimene aello</i>	3	N							M	M			minimal	low	minimal	minimal
Round-eared Tube-nosed Bat	<i>Nyctimene cyclotis</i>	3	N							M	M			minimal	low	minimal	minimal
Green Tube-nosed Bat	<i>Paranyctimene raptor</i>	3	N							M	M			minimal	low	minimal	minimal
Raffray's Sheath-tailed Bat	<i>Emballonura raffrayana</i>	3	N		M					M	M			low	low	minimal	minimal
Yellow-bellied Sheath-tailed Bat *	<i>Saccolaimus flaviventris</i>	3	N							M	M			minimal	low	minimal	minimal
Southern Sheath-tailed Bat *	<i>Taphozous australis</i>	3	N		M					M	M			low	low	minimal	minimal
Hill's Leaf-nosed Bat *	<i>Hipposideros edwardshilli</i>	3	N		M					M	M			low	low	minimal	minimal
Greater Leaf-nosed Bat	<i>Hipposideros semoni</i>	3	N		M					M	M			low	low	minimal	minimal

Common name	Scientific Name	Value ²	Direct impact magnitude ¹							Indirect impact magnitude ¹				Impact significance before mitigation		Impact significance after mitigation ²	
			Habitat Loss	Edge & Barrier Effects ³	Cave disturbance	Fauna Falling into the Pipeline Trench	Loss of Breeding & Display Grounds	Dust, noise and lights	Other ⁴	Fire	Invasive Species – Weeds, fauna & diseases	Hunting & plant harvesting	Improved Access and increased hunting	Direct	Indirect	Direct	Indirect
Wollaston's Leaf-nosed Bat	<i>Hipposideros wollastoni</i>	3	N		M					M	M			low	low	minimal	minimal
Large-eared Horseshoe Bat	<i>Rhinolophus philippinensis</i>	3	N		M					M	M			low	low	minimal	minimal
Papuan Pipistrelle	<i>Pipistrellus papuanus</i>	3	N		M					M	M			low	low	minimal	minimal
Watt's Pipistrelle *	<i>Pipistrellus wattsi</i>	3	N							M	M			minimal	low	minimal	minimal
Dwarf Cassowary	<i>Casuarius bennetti</i>	3	N						L	M	M	H	VH	moderate	moderate	minimal	low
Blyth's Hornbill	<i>Aceros plicatus</i>	3	N							M	M	L	M	low	low	minimal	minimal
Striated Lorikeet	<i>Charmosyna multistriata</i>	3	N							M	M	L	M	low	low	minimal	minimal
Palm Cockatoo	<i>Probosciger aterrimus</i>	3	N							M	M	L	M	low	low	minimal	minimal
New Guinea Flightless Rail	<i>Megacrex inepta</i>	3	N	L(M)					L	M	M	L	L	low	low	minimal	minimal
Black-tailed Godwit	<i>Limosa limosa</i>	3	N							L	M			minimal	low	minimal	minimal
Asian Dowitcher	<i>Limnodromus semipalmatus</i>	3	N							L	M			minimal	low	minimal	minimal
Buff-breasted Sandpiper *	<i>Tryngites subruficollis</i>	3	N							L	M			minimal	low	minimal	minimal
Beach Thick-knee	<i>Esacus giganteus</i>	3	N							L	M			minimal	low	minimal	minimal
Osprey *	<i>Pandion haliaetus</i>	3	N							M	M			minimal	low	minimal	minimal
Doria's Goshawk *	<i>Megatriorchis doriae</i>	3	N							M	M	L	M	low	low	minimal	minimal
Gurney's Eagle	<i>Aquila gurneyi</i>	3	L							M	M	L	L	low	low	minimal	minimal
Little Egret	<i>Egretta garzetta</i>	3	N							M	M			minimal	low	minimal	minimal
Great Egret	<i>Ardea alba</i>	3	N							L	M			minimal	low	minimal	minimal
Intermediate Egret	<i>Mesophoyx intermedia</i>	3	N							L	M			minimal	low	minimal	minimal
Forest Bittern	<i>Zonerodius heliosylus</i>	3	L							M	M	L	L	low	low	minimal	minimal
Black-necked Stork *	<i>Ephippiorhynchus asiaticus</i>	3	N							L	M			minimal	low	minimal	minimal
Archbold's Bowerbird *	<i>Archboldia papuensis</i>	3	N	L(M)			H			M	M	L	H	moderate	moderate	minimal	minimal
White-bellied Pitohui *	<i>Pitohui incertus</i>	3	N	L(M)						M	M			low	low	minimal	minimal
Olive-yellow Robin	<i>Poecilodryas placens</i>	3	N	L(M)						M	M			low	low	minimal	minimal
Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>	3	N							M	M			minimal	low	minimal	minimal
Crested Bird-of-paradise *	<i>Cnemophilus macgregorii</i>	3	N				L			M	M	L	L	low	low	minimal	minimal
Loria's Bird-of-paradise	<i>Cnemophilus loriae</i>	3	N							M	M			minimal	low	minimal	minimal
Glossy-mantled Manucode	<i>Manucodia atra</i>	3	N							M	M			minimal	low	minimal	minimal
Crinkle-collared Manucode	<i>Manucodia chalybata</i>	3	N							M	M			minimal	low	minimal	minimal
Trumpet Manucode	<i>Manucodia keraudrenii</i>	3	N							M	M			minimal	low	minimal	minimal
Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>	3	N							M	M			minimal	low	minimal	minimal
Brown Sicklebill	<i>Epimachus meyeri</i>	3	N				L			M	M	L	M	low	low	minimal	low

Common name	Scientific Name	Value ²	Direct impact magnitude ¹							Indirect impact magnitude ¹				Impact significance before mitigation		Impact significance after mitigation ²	
			Habitat Loss	Edge & Barrier Effects ³	Cave disturbance	Fauna Falling into the Pipeline Trench	Loss of Breeding & Display Grounds	Dust, noise and lights	Other ⁴	Fire	Invasive Species – Weeds, fauna & diseases	Hunting & plant harvesting	Improved Access and increased hunting	Direct	Indirect	Direct	Indirect
Black-billed Sickbill	<i>Epimachus albertisi</i>	3	N							M	M	L	M	low	low	minimal	low
Superb Bird-of-paradise	<i>Lophorina superba</i>	3	N							M	M	L	M	low	low	minimal	low
Carola's Parotia	<i>Parotia carolae</i>	3	N							M	M	L	M	low	low	minimal	minimal
Lawe's Parotia	<i>Parotia lawesii</i>	3	N							M	M	L	M	low	low	minimal	minimal
Magnificent Riflebird	<i>Ptiloris magnificus</i>	3	N							M	M	L	L	low	low	minimal	minimal
Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>	3	N							M	M	L	L	low	low	minimal	minimal
King Bird-of-paradise	<i>Cicinnurus regius</i>	3	N							M	M	L	L	low	low	minimal	minimal
Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>	3	N							M	M	L	M	low	low	minimal	minimal
Stephanie's Astrapia	<i>Astrapia stephaniae</i>	3	N							M	M	L	M	low	low	minimal	low
King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>	3	N							M	M	L	M	low	low	minimal	low
Twelve-wired Bird-of-paradise	<i>Seleucidis melanoleuca</i>	3	N							M	M	L	M	low	low	minimal	low
Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>	3	N							M	M	L	M	low	low	minimal	minimal
Yellow-eyed Starling	<i>Aplonis mystacea</i>	3	N							M	M			minimal	low	minimal	minimal
Short-beaked Echidna	<i>Tachyglossus aculeatus</i>	4	N	L(M)		L			L	M	M	L	M	low	low	minimal	minimal
Long-nosed Murexia	<i>Phascomurexia naso</i>	4	N	L(M)		L			L	M	M			low	low	minimal	minimal
Ground Cuscus	<i>Phalanger gymnotis</i>	4	N	L(M)		L			L	M	M		M	low	low	minimal	low
Lowland Tree Kangaroo	<i>Dendrolagus spadix</i>	4	N	L(M)		L			L	M	M	M	VH	low	low	minimal	low
Lowland Ringtail	<i>Pseudochirulus canescens</i>	4	N	L(M)					L	M	M	M	M	low	low	minimal	low
Feather-tailed Possum	<i>Distoechurus pennatus</i>	4	N	M		L			L	M	M	L		low	low	minimal	minimal
Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>	4	N	L(M)						M	M			low	low	minimal	minimal
Papuan Lorikeet	<i>Charmosyna papou</i>	4	N							M	M	M	M	low	low	minimal	minimal
Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	4	N							M	M	M	M	low	low	minimal	minimal
Papuan Hawk-Owl *	<i>Uroglaux dimorpha</i>	4	N						L	M	M			low	low	minimal	minimal
Starry Owlet-Nightjar *	<i>Aegotheles tatei</i>	4	N	L(M)					L	M	M			low	low	minimal	minimal
Wallace's Owlet-Nightjar *	<i>Aegotheles wallacii</i>	4	N	L(M)					L	M	M			low	low	minimal	minimal
Pheasant Pigeon	<i>Otidiphaps nobilis</i>	4	N							M	M	M	M	low	low	minimal	minimal
Little Curlew *	<i>Numenius minutus</i>	4	N							L	M			minimal	low	minimal	minimal
White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>	4	N							L	M			minimal	low	minimal	minimal
Eastern Marsh-Harrier	<i>Circus spilonotus</i>	4	N							L	M			minimal	low	minimal	minimal
Swamp Harrier *	<i>Circus approximans</i>	4	N							L	M			minimal	low	minimal	minimal

Common name	Scientific Name	Value ²	Direct impact magnitude ¹							Indirect impact magnitude ¹				Impact significance before mitigation		Impact significance after mitigation ²	
			Habitat Loss	Edge & Barrier Effects ³	Cave disturbance	Fauna Falling into the Pipeline Trench	Loss of Breeding & Display Grounds	Dust, noise and lights	Other ⁴	Fire	Invasive Species – Weeds, fauna & diseases	Hunting & plant harvesting	Improved Access and increased hunting	Direct	Indirect	Direct	Indirect
Chestnut-shouldered Goshawk *	<i>Erythrotriorchis buergeri</i>	4	N							M	M			minimal	low	minimal	minimal
Australian Kestrel	<i>Falco cenchroides</i>	4	N							P	M			minimal	minimal	minimal	minimal
Oriental Hobby	<i>Falco severus</i>	4	N							P	M			minimal	minimal	minimal	minimal
Australian Hobby	<i>Falco longipennis</i>	4	N							L	M			minimal	minimal	minimal	minimal
Brown Falcon	<i>Falco berigora</i>	4	N							P	M			minimal	minimal	minimal	minimal
Peregrine Falcon	<i>Falco peregrinus</i>	4	N							M	M			minimal	minimal	minimal	minimal
Flame Bowerbird *	<i>Sericulus aureus</i>	4	N	L(M)			M			M	M	L		low	low	minimal	minimal
Obscure Berrypecker *	<i>Melanocharis arfakiana</i>	4	N	L(M)						M	M			minimal	minimal	minimal	minimal
Saltwater crocodile	<i>Crocodylus porosus</i>	4	N							M	M	L	H	low	low	minimal	low
New Guinea freshwater crocodile	<i>Crocodylus novaeguinea</i>	4	N							M	M	L	H	low	low	minimal	low
Mangrove monitor	<i>Varanus indicus</i>	4	N			L			L	M	M	L	H	low	low	minimal	low
Gould's monitor	<i>Varanus dorianus</i>	4	N			L			L	M	M	L	H	low	low	minimal	low
Salvadori's monitor	<i>Varanus salvadori</i>	4	N			L			L	M	M	L	H	low	low	minimal	low
Ground boa	<i>Candoia aspera</i>	4	N			L			L	M	M	L	M	low	low	minimal	low
Pacific boa	<i>Candoia carinata</i>	4	N			L			L	M	M	L	M	low	low	minimal	low
Amethystine python	<i>Morelia amethystina</i>	4	N	L(M)		L			L	M	M	L	H	low	low	minimal	low
Boelen's Python	<i>Morelia boeleni</i>	4	N	L(M)		L			L	M	M	H	H	low	low	minimal	low
Green Tree Python	<i>Morelia viridis</i>	4	N	L(M)		L			L	M	M	L	H	low	low	minimal	low
Olive Python	<i>Liasis fuscus</i>	4	N	L(M)		L			L	M	M	L	H	low	low	minimal	low
Frog	<i>Choerophryne allisoni</i>	4	L	L(M)		L			L	M	M			low	low	minimal	minimal
Frog	<i>Cophixalus cryptotympanum</i>	4	L	L(M)		L			L	M	M			low	low	minimal	minimal
Frog	<i>Hylophorbus richardsi</i>	4	L	L(M)		L			L	M	M			low	low	minimal	minimal
Frog	<i>Oreophryne notata</i>	4	L	L(M)		L			L	M	M			low	low	minimal	minimal
Frog	<i>Litoria majikthise</i>	4	L	L(M)					L	M	M			low	low	minimal	minimal

1 VH – very high, H – High, m – Moderate, L – Low, N – negligible (see **Table 33**)

2 Value according to **Table 34**.

3 L(M) - low impact with 30 m ROW but moderate impact if total width of clearing exceeds 50 m.

4 Includes hydrotest fluid disposal, materials handling and project traffic .

* Not yet recorded in project area but could occur.

Plates

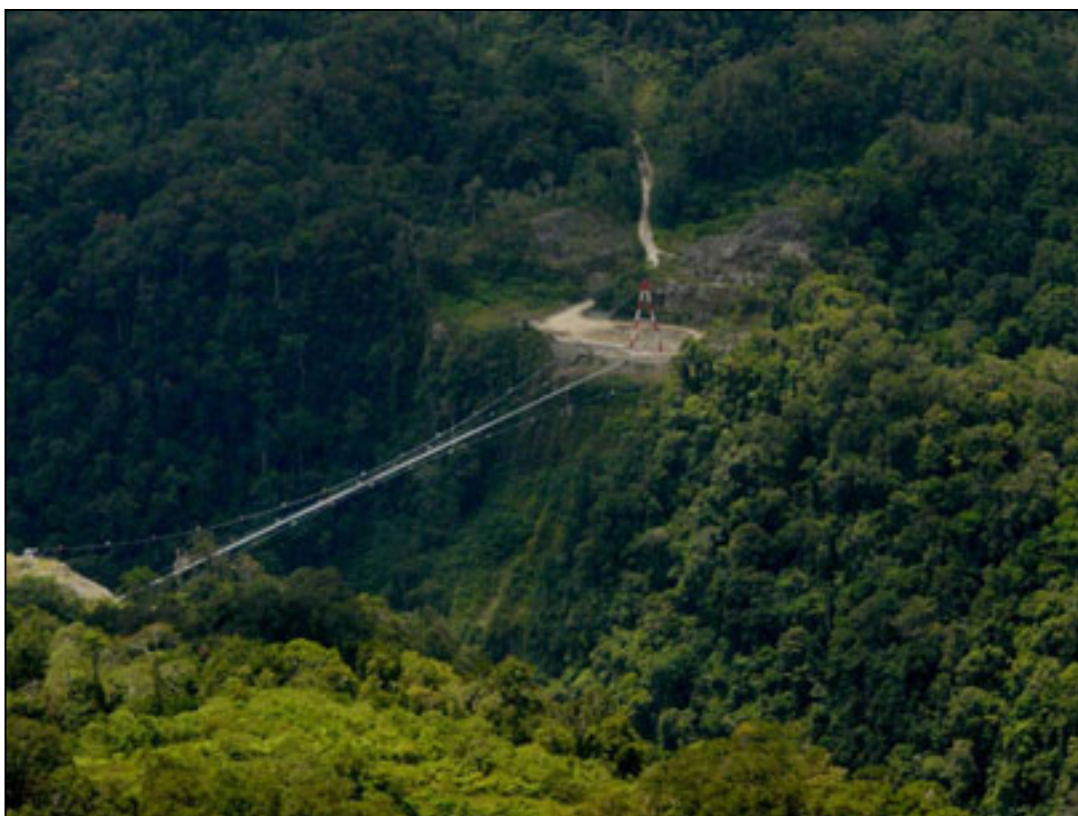


Plate 1 Pipe bridge at Hegigio River (photo G. Richards).



Plate 2 Hides 1 well pad.



Plate 3 The Baia River and the biodiversity survey camp.



Plate 4 The Liddell River at the Juha North survey area.



Plate 5 The Karius Range from Juha South survey area.



Plate 6 Erosion on the Baia River.



Plate 7 The South Karius survey area was in swamplands.



Plate 8 The Karius Range, here with steep scrub covered sides (photo I. Woxvold).



Plate 9 The Maruba River at Deviation Camp.



Plate 10 Burnt small crowned Nothofagus forest at the Homa Deviation.



Plate 11 Elliot trap.



Plate 12 Cage trap in tree roots.



Plate 13 Assembling a harp trap.



Plate 14 Camera trap in position.



Plate 15 Bat detector.



Plate 16 Stream disappearing into a sinkhole at Juha North survey area (photo I. Woxvold).



Plate 17 A large waterfall has its source in this upwelling from karst near the Liddell River (photo S. Richards).



Plate 18 Sinkhole swamp on Hides Ridge (photo I. Woxvold).



Plate 19 Water ponding on karst on the Oil ROW approaching the Mubi valley.



Plate 20 Successions on landslides in the Baia River area.



Plate 21 Epiphytes in Lower montane small crowned forest with *Nothofagus* (photo I. Woxvold).



Plate 22 *Dichroa sylvatica* (photo W. Takeuchi).



Plate 23 *Garcina archboldiana* (photo W. Takeuchi).



Plate 24 *Pentaphragme grandifolium* (photo W. Takeuchi).



Plate 25 *Begonia pseudobotryrs* (photo W. Takeuchi).



Plate 26 *Alocasia holrungii* (photo W. Takeuchi).



Plate 27 *Ficus arfakensis* (photo W. Takeuchi).



Plate 28 *Agalmyla* sp. (photo W. Takeuchi).



Plate 29 *Lithocarpus rufovillosus* (photo W. Takeuchi).



Plate 30 *Curcuma* sp (photo W. Takeuchi).



Plate 31 *Rhododendron* sp (photo W. Takeuchi).



Plate 32 *Rhododendron* sp (photo W. Takeuchi).



Plate 33 Plush coated ringtail.



Plate 34 Doria's Tree Kangaroo.



Plate 35 Large tree mouse (photo T. Mamu)



Plate 36 Spotted cuscus in Port Moresby market (photo T. Mamu).



Plate 37 Western White-eared Giant-rat (photo G. Richards).



Plate 38 Mountain Cuscus (photo T. Mamu).



Plate 39 Rock-dwelling Giant-rat (photo S. Richards).



Plate 40 *Rhinolophus euryotis* (photo G. Richards).



Plate 41 *Hipposideros calcaratus* (photo G. Richards).



Plate 42 *Aselliscus tricuspидatus* (photo G. Richards).



Plate 43 *Hipposideros diadema* (photo G. Richards).



Plate 44 *Nyctimene aello* (photo G. Richards).



Plate 45 *Paranyctimene* sp. (photo G. Richards).



Plate 46 Red-bellied Pitta (photo I. Woxvold).



Plate 47 Scaly Thrush (photo I. Woxvold).



Plate 48 Rufous-backed Honeyeater (photo I. Woxvold).



Plate 49 Brown-collared Brush-turkey (photo I. Woxvold).



Plate 50 Papuan Frogmouth (photo S. Richards).



Plate 51 Superb Fruit Dove (photo I. Woxvold).



Plate 52 Black Fantail (photo I. Woxvold).



Plate 53 Garnet Robin (photo I. Woxvold).



Plate 54 Wattled Ploughbill (photo G. Richards).



Plate 55 Orange-crowned Fairywren (photo I. Woxvold).



Plate 56 A common skink *Lipinia nototaenia* (Photo S. Richards).



Plate 57 The gecko *Cyrtodactylus* sp 1 (Photo S. Richards)



Plate 58 The agamid *Hypsilurus modestus* (photo S. Richards).



Plate 59 Keelback snake *Tropidonophis statisticus* (photo S. Richards).



Plate 60 Boelen's Python *Morelia boeleni* at Moran (photo courtesy Oilsearch).



Plate 61 New Guinea Freshwater Crocodile *Crocodylus novaeguineae* at Baia River (photo S. Richards).



Plate 62 Water Python *Liasis fuscus* at Baia River (photo courtesy M. Dokup).



Plate 63 Green Tree Python *Morelia viridis* at Juha (photo S. Richards).



Plate 64 The common tree frog *Litoria infrafulva* (photo S. Richards).



Plate 65 The torrent frog *Litoria wollastoni* from Benaria (photo S. Richards).



Plate 66 The tree frog *Litoria pronimia* (photo S. Richards).



Plate 67 An undescribed torrent frog *Litoria* sp. from Benaria (photo S. Richards).



Plate 68 The recently described tree frog *Litoria majikthise* (photo S. Richards).



Plate 69 A tree frog *Litoria iris* (photo S. Richards).



Plate 70 The tree frog *Litoria arfakiana* from South Karius (photo S. Richards).



Plate 71 A tree frog *Nyctimistes* sp. with road map eyelids typical of the genus (photo S. Richards).



Plate 72 The microhylid *Asterophrys turpicola* (Photo S. Richards).



Plate 73 A new species of microhylid *Xenobatrachus* sp. from Juha South (photo S. Richards).



Plate 74 The microhylid *Choerophryne allisoni* (photo I. Woxvold).



Plate 75 An undescribed species of microhylid *Albericus* sp1 (small) (photo S. Richards).



Plate 76 A new species of microhylid *Oreophryne* sp. nov. from near the Homa Deviation (photo S. Richards).



Plate 77 The ranid frog *Rana* cf *grisea* (attribute to S. Richards).



Plate 78 Tree frog laying eggs on leaf above sinkhole swamp on Hides Ridge (photo S. Richards).



Plate 79 Tree frog eggs on leaf waiting for tadpoles to hatch and drop into sinkhole swamp (photo S. Richards).



Plate 80 Unbroken Low altitude medium crowned forest on the route from Juha to the HGCP .



Plate 81 The Benaria River.



Plate 82 Forest near the Kondari River looking towards the Tagari River.



Plate 83 Possible site of the Benaria crossing.



Plate 84 The Mubi River.



Plate 85 The northern end of Lake Kutubu.



Plate 86 Swamp forest complexes at Lake Kutubu.



Plate 87 The oil ROW in karst near the Kutubu CPF.



Plate 88 The oil ROW near the Iwa Range.



Plate 89 The Ai'io River Swamp Forest complexes.



Plate 90 Sago swamps on the Ai'io River.



Plate 91 Manu village.



Plate 92 The Mubi valley.



Plate 93 The oil ROW approaching the Mubi valley.



Plate 94 The oil ROW in the Mubi valley.



Plate 95 Kantobo.



Plate 96 Descent to the Mubi crossing.



Plate 97 The Mubi crossing.



Plate 98 The Kikori floodplain.



Plate 99 The oil ROW in the Kikori.



Plate 100 The road to Gobe.



Plate 101 The Kikori (Kaia) crossing.



Plate 102 Kopi.



Plate 103 The Omati River.



Plate 104 Landfall on the Omati River.



Plate 105 Cutting on road at northern end of Lake Kutubu.



Plate 106 A road through a saddle.



Plate 107 Hand built flowlines at Hides.

Annex 01

Biodiversity survey results:

Flora at Hides, Nogoli and Benaria in 2005

This report originally appeared in the PNG Gas Project EIS as:
Supporting Study 2: "Botanical results from a floristic survey of montane
environments within the PNG gas project area"

**BOTANICAL RESULTS FROM A FLORISTIC
SURVEY OF MONTANE ENVIRONMENTS WITHIN
THE PNG GAS PROJECT AREA**

W. Takeuchi

**Tropical Research Biologist, the Herbaria and Arnold Arboretum of
Harvard University**

Forest Research Institute, POB 314, Lae, PNG

A Report to ENESAR Consultants Pty. Ltd.

8th July 2005

Table of Contents

EXECUTIVE SUMMARY	4
PREFACE	4
INTRODUCTION; THE SURVEY IN REGIONAL PERSPECTIVE	5
MATERIALS AND METHODS	6
RESULTS.....	8
1. General findings.....	8
2. Noteworthy collections	9
DISCUSSION.....	17
1. Ecological versus taxonomic survey.....	17
2. Proposed management actions and mitigation measures.	19
PROJECT IMPACTS	20
LITERATURE CITED	21
APPENDIX 1. CHECKLIST OF PLANTS	26
FIGURES 1 To 31	46

EXECUTIVE SUMMARY

A floristic summary is presented of forest communities along the proposed PNG Gas Project pipeline. Two montane environments were assessed using standard rapid-assessment methods often employed in Papuan plant inventories. The vegetation types examined by this study included: 1) *Nothofagus* small-crowned forest on limestone karst (LsN), and 2) mixed small-crowned lower montane forest (L) with scattered anthropogenic clearings. Species-level determinations are provided for most of the 568 specimens obtained during the intensive 2-week field schedule. The cumulative checklist for the project area currently includes 659 tracheophytic taxa (134 ferns and fern allies, 4 gymnosperms, 52 monocotyledons, and 469 dicotyledons) and incorporates results reported by earlier investigations in the same environments.

Distributional records, rare plants, and other noteworthy taxa are discussed with particular attention to their presumed conservation significance. The collective findings are distilled into a series of proposed management actions highlighting the taxonomic value of the most critical botanical assets. At least 13 plants have been determined as species new to science.

PREFACE

This study is part of a suite of terrestrial biodiversity investigations that have been conducted for the EIS for the proposed PNG Gas Project. This study report forms Supporting Study 2 of the EIS and the findings herein support the assessment of potential impacts on terrestrial biodiversity that are discussed in Supporting Study 1 of the EIS. A detailed description of proposed PNG Gas Project is given in Chapter 2 of the Main EIS report.

INTRODUCTION; THE SURVEY IN REGIONAL PERSPECTIVE

Although the true size of its inventory is unknown and subject to considerable speculation, there is no doubt that New Guinea is home to one of the world's richest floras. Modern botanical commentators estimate at least 20,000 species are probably present on the island (Johns 1993; Womersley 1978). Using orchids and ferns as biodiversity benchmarks, the most recent assessment places the upper limit at 25,000+ vascular plants (Supriatna 1999).

For many genera, New Guinea is a regional center for specific radiation, and the conspectus for certain groups can attain levels usually seen only on continental perspectives. Ferns, for example, are represented by 3,000 species (Parris in press), and orchids by 2,800 (Vogel and Schuitemann in press). This extraordinary diversification is correlated with the presence of an impressive range of floristic environments comparable to those on other high islands, but expressed on larger spatial scales resulting in elevated species-area values. Barthlott et al. (1996) reported a tracheophytic density of 3,000 to 5,000+ species per 10,000 sq km, and determined the species richness for the area around Mt. Wilhelm as comprising one of the world's 6 phytomaxima. Current compilations from *Flora Malesiana* indicate that New Guinea has the highest numbers of indigenous and endemic plant species within Malesia (Balgooy et al. 1996; Welzen 1997). Johns (1993) estimated that the overall percentage of endemics exceeds 70%.

The status of Papuan plant exploration and documentation has been reviewed in a number of general accounts (Beehler 1993; Conn 1994; Damas 1998; Frodin & Gressitt 1982; Johns 1993; Stevens 1989; Takeuchi & Golman 2001). Such evaluations consistently highlight the acutely inadequate coverage of our existing knowledge. On a regional basis, the collections density (CD) for New Guinea is one of the lowest for Malesia, with only the Celebes and Sumatra having similar density indices (Stevens 1989: 127). Assuming a standard of 50–100 collections per 100 sq km as representing 'well-collected' areas, there are very few localities in New Guinea which can be regarded as adequately sampled (ibid.). The overall CD for Papuasia is only 30 collections per 100 sq km (Frodin 1990) and for most of New Guinea the CD is less than 25 (Conn 1994). The documentation coverage is so poor that a disproportionate fraction of the flora is known only from one or very few specimens, and basic floristic parameters (e.g. geographic distributions, population variation, rarity values) are uncertain or speculative. Numerous species undoubtedly remain undiscovered.

This penurious state of affairs provides a critical backdrop for understanding the value of exploratory work in areas such as the Kikori basin. Although the collections intensity for Papua New Guinea (PNG) is now nearing the benchmark CD of 50 collections per 100 sq km, the geographic distribution of the coverage is highly uneven and many areas remain practically unknown (Frodin 1990: 237). At an early point in PNG's

sovereign history, Prance (1977) had already identified the Kikori district as an area specifically in need of investigation. This appraisal has been reaffirmed in subsequent country reviews by Stevens (1989) and Johns (1993).

The Kikori basin (as the Southern Scarp Wet Zone) is ranked among the 16 major terrestrial unknowns in PNG (Sekhran & Miller 1995) and comprises the largest of all the unknown regions. Based on a critical combination of biodiversity values and environmental threats, Takeuchi & Golman (2001) selected Kikori and its adjacent lowlands as the single highest-priority target for botanical survey in PNG. Because the floristic documentation for Gulf Province is the lowest in the Papuan region, unplanned development can easily result in unintended biodiversity losses (ibid.). There is arguably no other area in PNG where responsible environmental stewardship will be as consequential for conservation of the endemic flora.

MATERIALS AND METHODS

The floristic reconnaissance of habitats addressed by this study was confined to two montane sites at the northwestern end of the PNG Gas Project concession. The first of these localities consisted of limestone karst formations and pristine mossy forest around the Hides 2 and 3 wellheads (base camp at 05°56'54" S, 142°44'43" E, elev. 2270 m). A second venue on the banks of the Benaria River (base camp at 06°03'17" S, 142°58'43" E, elev. 1370 m) included a mosaic of anthropogenic and natural-growth communities of more variable floristic quality. Approximately one week of fieldwork was conducted at each site (April 24–30 at Hides, and May 1–9 at Benaria).

The forest survey was based on procedures commonly employed in contemporary biodiversity surveys within Papuasia (cf. Beehler & Alonso 2001; Mack 1998; Mack & Alonso 2000). The concept of multidisciplinary evaluations based on short-duration sampling was first developed by Conservation International for their Rapid Assessment Program (RAP) but the methodology has since been adopted by numerous operators with similar requirements for site assessment. Particularly in New Guinea, RAP-style surveys are currently the principal means by which botanical data are obtained and compiled for wilderness areas. The Gas Project botanical survey is thus a continuation of contemporary trends, being patterned after the same protocols established by comparable operations.

In conformity with rapid-format surveys, the botanical work was based primarily on *ad libitum* collecting of tracheophytic plants (i.e. ferns, gymnosperms, and angiosperms). A survey team consisting of the writer and two parataxonomists (Ali Towati and Thomas Jisaka) collected herbarium specimens during daily hikes at the study sites. Voucher specimens were obtained on an opportunistic basis from all fertile taxa encountered around the camps, using tree climbers and 15 m extensible pruning poles as required. Accessory documentation such as bottled

flowers, carpological specimens, and photographs (5 megapixel digital imagery) were also taken from the more interesting collections. Specimens for exsiccatae were secured in sets of 1–5+ duplicates, then field-packed in 70% ethanol for subsequent processing at Lae. Identifications were done primarily at the PNG Forest Research Institute (FRI) and Lae National Herbarium (LAE), but a number of overseas specialists were also consulted (cf. Appendix 1 credits). Whenever possible, taxonomic determinations were confirmed using keys from formally published literature and/or by comparing genuinely annotated reference sheets cited by authorities. In cases where several revisions are available for a genus or family, the most recent one has been selected as the basis for making the identifications.

The botanical results were compiled into a checklist (Appendix 1) incorporating results from other investigations in the area encompassed by the Gas Project. Genera have been assigned to families in accordance with the following sources: ferns and fern allies (Croft 1986); gymnosperms (Laubenfels 1988), and angiosperms (Angiosperm Phylogeny Group 1998, 2003).

RESULTS

1. General findings.

The vegetation at site 1 (Hides basecamp) is a mossy mid-montane forest in exemplary natural-growth condition. Only 2 alien species were recorded from this general environment and the plants involved (*Bidens pilosa* and *Passiflora ligulata*) are both benign herbs found exclusively on construction rubble at the helipads. Although the *Bidens* is clearly an accidental introduction, *Passiflora ligulata* (i.e., passion fruit) is cultivated in certain parts of the Highlands for its edible fruits (de Wilde 1972a, b) and was probably planted at the site by local workers (Figures 1, 2). Within the forest proper, the communities are entirely of endemic or indigenous composition.

The montane karst is a mossy forest with an emergent overstory of *Nothofagus pullei* and *N. rubra* along ridgelines and subcrests (Figure 3). In the draws following the drainage channels, the canopies are usually lower and the mixed communities typical of Papuan habitats become more apparent. Small patches of seral growth are scattered through the forest as a result of natural canopy-opening mechanisms (e.g., windthrows and tree senescence). The community structure of this environment is clearly being maintained by a classic process of patch dynamics and spatial rotation of forest units in different stages of maturation.

The wider region around the Hides wellheads is classified by the Forest Inventory Mapping System, the planning database employed by the PNG Forest Authority, as a '*Nothofagus* small-crowned montane forest on limestone karst' (category code LN or LsN). Such ecosystems generally contain large numbers of epiphytic ferns and orchids, and this is obviously the case at Hides. Up to 75% of the floristic diversity in Papuan mossy forests will consist of plants growing among the tree crowns and branches (Takeuchi & Wiakabu 2001). The floristic impact of tree felling in such habitats should thus be primarily assessed not in terms of the tree losses themselves, but of the removal of epiphytes. In this connection, it is relevant to note that at least 3 fern species previously unknown to science have been discovered around Hides 3.

At site 2 (Benaria River base camp) the vegetation consists of an irregular mosaic of naturally-occurring and anthropogenic landscapes. A complete community sequence of floristic succession is represented in the surrounding foothills; ranging from early subsistence-garden regrowth to mature closed-canopy forest. *Lithocarpus rufovillosus* (Figures 4, 5) and *Spiraeopsis celebica* are the most common arborescent taxa in ridgeline forests of the area, but elsewhere the canopy and substage elements are generally too diffuse to permit designation of indicator or characteristic species. *Myristica* is exceptionally diverse in local understories, recalling a situation analogous to *Saurauia* at Hides (Figures 6–8). However the apparent richness in certain groups is offset by a lower level of overall floristic quality. There is an obvious increase in human traffic and anthropogenic activities at Benaria which is reflected in the number of weed

registers obtained at that site. To the extent that project impacts will be comparatively less for habitats which have already experienced floristic alteration, Hides should be of far greater concern to environmental planners than areas like Benaria.

According to the FIMS classification (Hammermaster & Saunders 1995a, b), the Benaria forest environment is grouped under code class 'L' (mixed small-crowned lower montane forest with *inter alia*: *Alphitonia* (Figures 9, 10), *Castanopsis*, *Cinnamomum*, *Cryptocarya*, *Dryadodaphne*, *Elaeocarpus*, *Elmerrillia*, *Galbulimima*, *Garcinia*, *Gordonia*, *Lithocarpus*, *Litsea*, *Podocarpus*, *Pouteria*, *Spiraeopsis*, and *Syzygium*). This presumed composition, determined by extrapolation from aerial photographic mapping, was for the most part verified by ground truthing and voucher collecting during the recent survey (see Appendix 1; all the FIMS character genera were recorded with the sole exception of *Dryadodaphne*). However the current mapping system will probably be of limited value in any description of community patterns at Benaria. The 1:250,000 scale of the FIMS classification has insufficient resolution to detect forest fragmentation at the spatial levels characteristic of anthropogenic influence. The area around Benaria includes a degraded vegetation mosaic which cannot be resolved by the current system. Human population growth is also causing vegetation changes, which will complicate future characterization of forest-type distributions.

Taken collectively, the survey findings provide a floristic profile that is typical of the Highlands region in general (Figures 11–15). There is for example, substantial taxonomic overlap with the extensive species list developed at comparable elevations for Crater Mountain (Takeuchi 1999, 2000b). Although specialized substrate environments are widely assumed to be associated with increased endemism, this expectation has not been corroborated on the Kutubu limestone, the largest formation of its kind in New Guinea. The karst flora has a substantial endemic component (Figures 16, 17), but endemism patterns are generally expressed on a regional rather than localized basis. The overwhelming majority of the plants recorded by the survey have ranges extending far outside the limestone district (Figures 18–21). Even the new records obtained by the survey involve taxa primarily from non-limestone habitats in Irian Jaya or eastern Papua.

2. Noteworthy collections

The project checklist currently consists of 659 vascular plant taxa (Appendix 1). Included in the collective accounting are 134 pteridophyte species (ferns and fern allies), 4 gymnosperms, 52 monocotyledons, and 469 dicotyledons. The tallies are distributed through 26 pteridophyte families, 4 gymnosperm families, 102 APG (Angiosperm Phylogeny Group) families, and a cumulative total of 349 genera.

Distributional records, rare taxa of conservation value, species new to science, and other noteworthy plants are briefly discussed below in family sequence:

Actinidiaceae

Saurauia sp. nov. A, aff. *drimytilflora* Diels; 19018, 19100

Probably a new species in the series Uniflorae. a small group defined by single flowers emerging from leafy axils.

The survey collections do not match any of the taxa recognized in existing keys or published descriptions (e.g., Diels 1922; Royen 1982; Smith 1941).

Actinidiaceae

Saurauia sp. nov. B, cf. Uniflorae; 19072, 19096, 19171, 19185

Saurauia is an exceptionally diversified genus in the limestone habitat, as evidenced by the presence of a second unknown plant closely related to the preceding morphospecies. The two plants in series Uniflorae are similar in overall aspect, but have very significant and consistent differences in indument and floral structure. These distinctions are correlated to habitat partitioning, the present taxon occurring only in closed forest and its congener (sp. nov. A) occupying seral sites like the Hides wellheads. The novelties are probably sister species derived from divergence into contrasting habitats.

Saurauia sp. B is distinguished by the unusual presence of monostylous flowers. Nearly all Papuan *Saurauia* have 3 to 5 styles. Although clearly connected, the two novelties are not assignable to the same series on Diels (1922): sp. B will actually key to series Armatae because of its spiny branches, while sp. A is inermous (unarmed) and thus to be placed elsewhere (viz., series Uniflorae). The infrageneric system adopted by Diels (1922) is highly artificial and often results in unrelated taxa being grouped together, or as in the present case, with apparently allied taxa being separated.

Araliaceae

Arthrophyllum proliferum Philipson; 19431

The paniculate inflorescence is the distinguishing feature of this subcanopy representative in the ginseng family (Philipson 1977, 1979).

Arthrophyllum proliferum is an IUCN-listed 'vulnerable' species known previously from the Kuper Range (2 collections), and also very recently discovered on the ultrabasics near Salamaua (Takeuchi et al. 19051, 19053; May 2005). The survey collection is the first documented record for the species outside of Morobe Province and substantially extends its range into the Papuan region.

Aspleniaceae

Asplenium sp. nov.; 19243

A new species of spleenwort, with coarsely toothed pinnae and sori reaching nearly to the leaf margin. The miniature fern is known only from a 25 cm plant found on a limestone wall at Hides 3.

Cucurbitaceae

Zehneria scabridula (Merr. & Perry) de Wilde; 19020

A rare herbaceous vine represented by very few collections (de Wilde, pers. comm.).

Zehneria scabridula is apparently an early successional species, judging from specimen labels reporting its presence in old subsistence gardens and other disturbed sites. The survey voucher was collected on exposed hardpan at the Hides 3 helipad. Even 'weeds' are potential conservation assets when they represent range-restricted or rarely-seen taxa.

Cyatheaceae

Cyathea sp. nov., section *Gymnosphaera*; 19123

Cyathea is the largest fern genus in Papuasia, with 78 species on the New Guinea mainland (86 if the offshore islands are included). Holttum (1963, 1964) has provided an authoritative treatment for all of Malesia.

The new fern from the Hides karst is referable to section *Gymnosphaera* (Bl.) Holttum, a group represented by 17 species, of which 7 species are found in New Guinea. The novelty is immediately distinguished from all other Malesian congeners by the tripinnate fronds with basal pinnae reduced to bare axes (i.e. aphlebioid).

Elaeocarpaceae

Elaeocarpus lingualis Knuth; 19336, 19373

Known with certainty only from the type locality (Huon Peninsula), the Idenburg River, and the Jimi Valley (Coode 1981: 144). However, the species is common at the Benaria locality.

Elaeocarpaceae

Elaeocarpus pachyanthus Schltr.; 19370

Represented in the Lae Herbarium by 7 sheets. The survey collection is the first with ripe fruits (cf. Coode 1981).

Lomariopsis Group

Elaphoglossum favigerum Holtt.; 19069

A rare fern newly recorded for PNG. The species was previously known only from 3 specimens collected in Irian Jaya Province (Holttum 1966, 1978: 310).

Lomariopsis Group

Elaphoglossum resiniferum Holtt., or aff.; 19235

Elaphoglossum resiniferum was first discovered in the Astrolabe Range of Central Province (Holttum 1966, 1978) and has since been known only from the initial collection. Although there are no specimens available for comparison at LAE, the plant's distinctive features leave little doubt of its identity.

The survey voucher has a number of disconforming characters which would justify its publication as a new subspecies.

Melastomataceae

Medinilla sp. nov., pseudostipular group; 19025

The pseudostipular species were recently revised by Bodegom and Veldkamp (2001). Of the 15 taxa comprising this distinctive group, 13 were newly described in the current revision (ibid.).

The latest novelty is distinguished by a dense covering of bristles on branches and calyces.

Moraceae

Ficus sp. nov.; 19537

Ficus is one of the largest woody genera in Papuasias, with 151 species currently recognized for the New Guinea region (Weiblen in press). The genus is represented by a diverse array of growth forms, including vines, hemi-epiphytes (stranglers), miniature understorey shrubs, and arborescent taxa ranging from subcanopy trees to tall emergents (Figures 22–24).

The new vining species discovered at Benaria is immediately distinguished by its exceptionally large fruits (to 67 mm diam.) with large foliaceous bracts at its base and an exposed orifice at the summit (Figure 25). All the known Papuasian species have the summit orifice closed by ostiolar bracts.

Myristicaceae

Myristica sp. nov., aff. '*fatua-inutilis* group'; 19378 (Figures 26, 27)

Myristica is represented in New Guinea by 98 species, of which an astonishing 74 have been discovered and/or described only within the last 10 years (de Wilde 1995, 1998, 2000; Figures 28, 29). Modern taxonomic study has revealed a consistent pattern of localized

endemism in this speciose genus, one of the most diverse of all the woody genera in Papuasia.

The new species is a sub canopy tree with a dense and persisting indument of stellate hairs on vegetative parts. Formerly included under the *fatua-inutilis* complex, the taxa most closely related to the presumed novelty have been reassigned for the most part into different species, none of which affords a reasonable match to the survey collection.

Myrsinaceae

Ardisia sp. nov., aff. *myriosticta* K. Sch.; 19136

Ardisia has been revised for New Guinea and the Moluccas by Sleumer (1988). Of the 31 species recognized for this area, 22 are known only from their type localities.

The survey voucher does not match any of the taxa in Sleumer's conspectus. It comes closest to *A. myriosticta* K. Sch. or possibly *A. dasyneura* Mez, but cannot be accommodated under either of those names. In view of the large number of restricted endemics in this genus, the discovery of a new *Ardisia* from the limestone district is hardly surprising.

Myrtaceae

Syzygium anomalum Laut., or aff.; 19060

This name affords a good match on Hartley and Perry's (1973) revision of Papuan *Syzygium*.

Syzygium anomalum was known only from the area around Jayapura in Irian Jaya. The survey collection constitutes a first record for PNG.

Myrtaceae

Syzygium ubogoensis Takeuchi; 9155

This rare subcanopy species was first discovered on the Kutubu karst in 1992 (Takeuchi 2002). Despite its distinctive features, it is still known only from the type collection.

Xanthomyrtus bryophila Diels, or aff.; 19064

A first record for PNG.

Xanthomyrtus bryophila has thus far been recorded only from Mt Doorman in Irian Jaya Province (Scott 1979). Although the survey specimen keys directly to the species, there are several characters deviating from the type description. These can be conservatively attributed to population variation and the scanty material on which the type description was based.

Olacaceae

Opilia sp. nov., aff. *imbricata* Roxb.; 9156

Opilia is represented in New Guinea by a single species (*A. imbricata*) distributed throughout the Indo-Malesian region as far eastwards as India (Sleumer 1980, 1984). The Kutubu limestone has a high-canopy congener with considerably larger inflorescences and fruits than the currently known species and is probably an undescribed taxon.

Polypodiaceae

Selliguea sp. nov.; 19267

A remarkable new fern species.

With leaves only to 17 x 11 mm (sterile) and to 45 x 8 mm (fertile), this previously unknown *Selliguea* is by far the smallest of all the Papuanian congeners. The character states are so atypical that the generic identity of the plant is only apparent under the dissecting scope.

The new polypody is known from a single collection, taken in mossy karst forest around the Hides 2 wellhead.

Proteaceae

Bleasdalea papuana (Diels) Domin; 19391

Bleasdalea papuana is one of only 15 plant species red-listed by IUCN (International Union for Conservation of Nature and Natural Resources; www.redlist.org) as an endangered species from Papuasia. The tree is a presumed Gondwanic relict supposedly restricted to a small number of localities in northern New Guinea (Smith & Haas 1975). The survey collection is the first from the Papuan side.

The discovery of *Bleasdalea* on the Kutubu karst represents a biogeographically significant record, since it provides a direct tectonic connection to the plant's putative Austrocratonic source region (cf. Pigram & Davies 1987).

Proteaceae

Helicia acutifolia Sleum.; 19046, 19210, 19218, 19223

Listed as a 'vulnerable' species by IUCN.

Helicia acutifolia has not been seen since its initial discovery in 1936 (Mt Victoria, Central Province). The survey specimens key directly to this binomial on Foreman (1976, 1995) and afford an exact match with the only existing collection. Despite its past absence from the botanical record, the species is moderately common in the forest around the Hides wellheads.

Rubiaceae

Hedyotis sp. nov., aff. *nana* Merr. & Perry; 19269

An obviously new species, the third representative in a group of diminutive creeping herbs endemic to high elevations in New Guinea. Easily distinguished by its linear-elliptic leaves and persisting stipules with deeply divided margins.

The as-yet unnamed plant grows on exposed ground in the manner of *H. trichoclada* Merr. & Perry and *H. nana* Merr. & Perry. It was seen only in bulldozed clearings around the Hides 2 wellhead.

Rutaceae

Acronychia rugosa Hartley; 19189

Acronychia rugosa is a subcanopy tree represented in herbaria only by fruiting collections (cf. Hartley 1974, 2001). The survey voucher is the first specimen showing the previously unknown flowers.

Rutaceae

Halfordia papuana Laut.; Enesar survey s.n., SISA fide Gebia and Balun (2000)

Halfordia papuana is classified by the IUCN as a 'critically endangered' tree species, one of only 13 plants from New Guinea with this ranking. Because of nomenclatural issues, which were not considered at the time of its inclusion onto the IUCN lists, the correct name for *H. papuana* is probably *H. kendack* (Montr.) Guill or *H. drupifera* F.v.M., both of which have publication priority over the currently used binomial.

Irrespective of the taxonomic issues, there is just one species of *Halfordia* in Papuasia (Hartley 1986: 627), and this species is moderately common in montane habitats examined by the survey (Figure 30).

Sapindaceae

Guioa sp. nov., aff. *molliuscula* Radlk.; 19366

The velutinous indument places the collection in the '*molliuscula* group' (cf. Welzen 1989, 1994) but the fruits do not match any of the known species.

Sapindaceae

Mischocarpus pyriformis (F.v.M.) Radlk. ssp. *papuanus* (Radlk.) R.W. Ham; 19292

In PNG, known previously only from 3 provinces (Western, Gulf, and Morobe; Ham 1977, 1994: 665). Judging from the number of

collections, the nominate subspecies is much more common than the one present at Hides (Figure 31).

Thelypteridaceae

Mesophlebium sp. nov.; 19129

Mesophlebium is represented by 17 species, of which only 2 are present in New Guinea (Holttum 1981). The genus is very rare in Papuasia.

The new fern was discovered on the helicopter pad at Hides 3 (many plants were unknowingly trampled by the survey participants). It is immediately distinguished from all other congeners by the firm-textured leaves with recurved segments.

Unidentified genera; 19239, 19240, 19240b

A sequence of three fern collections cannot be identified and are probably new species. The taxa are characterized by calcium concretions on their exterior surfaces and are probably specialists adapted to the limestone environment. Their character states are so unusual that thus far, it is not possible to provide a generic assignment. Collection 19239 is probably referable to the Dryopteridaceae, and the remaining numbers may belong in the Thelypteridaceae, but there are major problems with either identification.

DISCUSSION

1. *Ecological versus taxonomic survey.*

Since the inception of commercial operations in the Kutubu Petroleum License, a considerable amount of botanical work has occurred under the sponsorship of the oil field operators, primarily with the involvement of the World Wildlife Fund (WWF) as a coordinating partner. Inasmuch as the WWF investigations are part of the scientific record, it is appropriate to review the significance of these earlier studies in their present relation to the Gas Pipeline assessment.

Beginning in ca. 1995, an active data acquisition program has produced a substantial number of WWF-sponsored technical reports. As part of a broader multidisciplinary agenda, the WWF botanical work was strictly focused on community ecology, and was particularly directed at the determination of β -diversity patterns in the forest environments within the petroleum exploration concession. In order to characterize these patterns, the original investigators established a succession of study plots along an elevational and forest gradient, quantitatively assessing changes in species richness between the various stations in their site sequence (e.g., Gebia & Balun 2000, 2004). Although the past investigations are superficially similar to the recent plant survey, the two activity schedules are not equivalent. In fact, they are very different, and in some respects, even incommensurable. The former community-ecological studies on one hand, and the recent plant-taxonomic investigations on the other, employed different methodologies, were directed at contrasting objectives, and not unexpectedly yielded different findings.

The ecosystems emphasis adopted by WWF enabled its principals to establish a reasonable baseline for forest compositions in the Kutubu area. For example, it is now apparent that the general sequence of floristic richness is in the (ascending) order (cf. Gebia & Balun 2004): lowland forest (Omo formation), mid-montane forest, lowland alluvial hill forest, and lowland limestone karst. There are obvious management advantages in knowing which forest environments have the highest species contents, and in being able to relate alpha diversity to changes in habitat. The former studies were able to provide these insights by consciously structuring the research agenda to achieve the desired determinations. Taxonomic itineraries would not have been able to produce the same results.

However the exclusive focus on stand-level investigation implicitly overlooks the fact that forest values are determined not only at the community level of alpha diversity, but also by the specific taxa comprising those communities. In other words, a forest unit with high species counts consisting of cosmopolitan plants is not necessarily of superior conservation significance to one of lower richness, but containing a disproportionate number of rare endemics. The taxonomic inquiry required to achieve such valuations was conspicuously absent from the WWF ecological studies. Not even one new species or country record was reported in all the previous years of ecological work, because the kind of analysis required for such

discovery was not a part of the WWF schedule. Although some major records were secured by visiting palm and orchid specialists (e.g., Baker 1997), the specialist coverage has thus far included only 2 of the 132 tracheophytic families documented from the karst environment. The numerous discoveries made by the recent survey are a clear indication of lost opportunities and of the documentation lacunae which still exist within the project concession. In view of the limitations inherent in rapid assessment, it is reasonable to assume that most of the district's botanical assets remain unknown. There is considerable potential for future discoveries of a highly consequential nature.

Much of what has occurred within the hydrocarbon concession is reminiscent of past debates regarding the effectiveness of biotic evaluations. Rapid assessment methodologies are primarily qualitative in their data outputs, and although recent surveys in New Guinea have attempted to add a quantitative component with plots, this approach has proved far less effective than initially anticipated (Takeuchi & Wiakabu 2001). In spite of an intuitive bias for quantitative information as being somehow more 'scientific' than opportunistic collecting, plot studies are seriously disadvantaged by their associated time expenditure and sterile vouchers. By their very nature, plots are spatially restricted in coverage, so that many (probably most!) species go unregistered by such methods. Some of the problems associated with quantitative methodologies have been discussed in detail by Kartawinata (1990) for Indonesia, and by Takeuchi (2003a) for PNG. Where the intent is to develop a cost-effective species-level appraisal, there is still no better solution than simple walk-through collecting by experienced field personnel, followed by rigorous examination of the gatherings. Especially when it is desirable to identify assets of potential conservation interest, botanical evaluation has to be conducted at the species level, rather than the community-ecosystem level of macroenvironmental variation. Ironically, a taxonomic orientation was adopted by WWF in relation to its zoological studies, with the result that the faunal resources deserving of protection are considerably better known than the botanical ones.

The most effective sampling strategy is obviously one in which both methods (ecological and taxonomic) are combined into a holistic program of site evaluation. Such an agenda was recently adopted for the Kamiali Wildlife Management Area in Morobe Province, where an itinerary based on intensive collection was implemented prior to establishment of floristic transects (Takeuchi 2003b). Sterile vouchers can be determined to a high degree of confidence when matched to fertile specimens obtained from comprehensive taxonomic assessment, thereby removing one of the most serious limitations in plot-based sampling. Substantial numbers of new taxa were also revealed as a collateral benefit of the integrated procedures (*ibid.*). If a similar strategy had been employed at the outset of the KICDP botanical investigations, many of the existing gaps in floristic knowledge could have been addressed in accordance with a rational schedule. Notwithstanding the management issues involved, the recent findings are a stark reminder of how much remains to be done.

2. Proposed management actions and mitigation measures.

As far as can be determined, the botanical assets identified by the survey are diffusely spread through primary growth communities in the project area. The only probable exceptions are *Zehneria scabridula*, *Saurauia* sp. nov. A, and *Hedyotis* sp. nov. These taxa are apparently adapted to seral conditions, so it is reasonable to assume that pipeline construction would actually improve their population status by creating new opportunities for establishment. However even with the other high-value taxa, it is very doubtful that the proposed project represents a serious conservation threat. The amount of forest projected for removal is really quite negligible compared to the total standing acreage. And due to the low-density distributions of the significant taxa, the direct construction-related losses will be insignificant when measured against the probable size of existing populations. The diffuse occurrences of the plants with conservation value would make any mitigation measures extremely difficult to implement anyway. Because of the manner in which the plants are distributed, the survey was unable to identify any sites with significant concentrations of rare species. In general, the investigated environments are relatively homogeneous, without any marked abiotic discontinuities which would create specialized habitats within the larger forest matrix.

No protective actions are recommended even in relation to the newly discovered species. Although nearly all of the novelties were seen only once, or at most a few times, this is not sufficient cause for presuming that the plants are at risk. The very fact that the species are present in natural-growth habitat implies the existence of unseen and viable populations through the surrounding forest. Otherwise the plants would not have been discovered in the first place. While it is tempting to assume that these species have managed to evade detection because of extreme rarity, a more rational and plausible approach is to view the discoveries within their historical context. As already noted in the introduction to this section, the Kutubu district is a conspicuous biotic unknown within one of Malesia's most poorly documented regions. Even if the findings are intriguing, the pipeline survey is indicative not so much of a remarkable local flora, but of a provincial level of documentation so thin that almost any exploration effort can be expected to deliver significant results. The present discoveries should be understood in that sense, against the background of a grossly inadequate level of knowledge which ranks among the world's worst. When the megadiversity status of a flora is conjoined with historically low levels of exploration and documentation, discoveries of previously unknown plants are virtually inevitable. In fact, even locally common plants will be determined as having novelty status under such conditions (e.g., Takeuchi 2000a, 2001, 2003a, b).

PROJECT IMPACTS

In terms of project impacts, the immediate effects of the contemplated activities will be botanically insignificant. The principal concerns will revolve around the long term, indirect consequences of infrastructure development, in particular the collateral costs of improved access to currently pristine environments.

Although habitat-altering weeds such as *Piper aduncum* L. (see Leps et al. 2002; Rogers & Hartemink 2000) are not present in the upland forests, this may change with increased human traffic into the montane areas. Irrespective of precautions which might be adopted against the entry of noxious plants, satellite imagery has established a clear connection between road construction and processes of floristic degradation (Conservation International 2003). Nowadays, in a world where the spread of aggressive species is increasingly contributing to homogenization of native floras, areas such as the Hides karst are becoming rare ecological resources. In terms of preservation status and taxonomic content, the karst flora is an outstanding example of an intact forest ecosystem, and one highly deserving of enlightened corporate stewardship.

The MAJOR environmental recommendation from the botanical studies is that appropriate consideration should be given to restricting access to exemplary habitats like the Hides karst.

LITERATURE CITED

Angiosperm Phylogeny Group. 1998. An ordinal classification for the families of flowering plants. *Ann. Missouri Bot. Gard.* 85 (4): 531–553.

Angiosperm Phylogeny Group. 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Linn. Soc. London, Bot. Journ. Linn. Soc.* 141: 399–436.

Baker, W.J. 1997. Rattans and rheophytes–palms of the Mubi River. *Principes* 41 (3): 148–157.

Balgooy, M.M.J. van, P. Hovenkamp, and P. van Welzen. 1996. Phytogeography of the Pacific–floristic and historical distribution patterns in plants. In: A. Keast and S. Miller, eds. *The Origin and Evolution of Pacific Island Biotas: New Guinea to Eastern Polynesia: Patterns and Processes*. SPB Academic Press, Amsterdam, the Netherlands. Pp 191–214.

Barthlott, W., W. Lauer, and A. Placke. 1996. Global distribution of species diversity in vascular plants: towards a world map of phytodiversity. *Erdkunde. Archiv fur wissenschaftliche Geographie* 50: 317–327.

Beehler, B., ed. 1993. *Papua New Guinea conservation needs assessment*, vol. 2. Corporate Press, Inc., Landover, Maryland, 434 pp.

Beehler, B. and L.E. Alonso, eds. 2001. *Southern New Ireland, Papua New Guinea: a biodiversity assessment*. RAP Bulletin of Biological Assessment 21, Conservation International, Washington, DC, 101 pp.

Bodegom, S. and J.F. Veldkamp. 2001. Revision of the pseudo-stipular species of *Medinilla* (Melastomataceae). *Blumea* 46: 527–567.

Conn, B.J. 1994. Documentation of the flora of New Guinea. In: C.-I Peng and C.H. Chou, eds. *Biodiversity and Terrestrial Ecosystems*. Institute of Botany, Academia Sinica Monograph 14: 123–156.

Conservation International. 2003. Ecosystem profile: Sumatra, Sundaland. URL: http://www.cepf.net/xp/cepf/where_we_work/sundaland/full_strategy.xml.

Coode, M.J.E. 1981. Elaeocarpaceae. In: Henty, E.E., ed. *Handbooks of the Flora of Papua New Guinea*, vol. 2. Pp 38–185.

Croft, J.R. 1986 (unpublished). Keys to the genera of pteridophytes in Papuasiasia.

Damas, K. 1998. The present status of plant conservation in Papua New Guinea. In: C.-I Peng and P.P. Lowry II, eds. *Rare, threatened, and endangered floras of Asia and the Pacific rim*. Institute of Botany, Academia Sinica Monograph 16: 171–179.

Diels, L. 1922. Die Dilleniaceen von Papuasien. *Bot. Jahrb.* 57: 436–459.

Foreman, D.B. 1976. A Taxonomic Study of the Genus *Helicia* Lour. (Proteaceae) in New Guinea and Australia with Notes on Origin, Distribution

and Ecology. M.S. thesis. University of New England, Armidale, New South Wales, 363 pp.

Foreman, D.B. 1995. Proteaceae. In: B.J. Conn, ed. Handbooks of the flora of Papua New Guinea, vol. 3. Melbourne University Press, Carlton, Victoria. Pp 221–270.

Frodin, D. G. 1990. Botanical progress in Papuasias. In: P. Baas, K. Kalkman and R. Geesink, eds. The Plant Diversity of Malesia, Proceedings of the Flora Malesiana Symposium Commemorating Prof. Dr. C. G. G. J. van Steenis. Kluwer Academic Publishers, Dordrecht, Boston, and London. Pp 235–247.

Frodin, D.G. and J.L. Gressitt. 1982. Biological exploration in New Guinea. In: J.L. Gressitt, ed. Biogeography and Ecology of New Guinea: 87–130. Junk (Monogr. Biol. 42), The Hague.

Gebia, O. and L. Balun. 2000. A study on two forest communities in the Kikori River catchment of Papua New Guinea. WWF KICDP Report SR-00-01.

Gebia, O. and L. Balun. 2004. Species diversity and composition in Darai limestone karst and the Libano alluvial forest of Gulf and Southern Highlands Provinces. WWF KICDP Report SR-04-01.

Hammermaster, E.T. and J.C. Saunders. 1995a. Forest Resources and Vegetation Mapping of Papua New Guinea. PNGRIS Publ. no. 4, Canberra, CSIRO and AIDAB.

Hammermaster, E.T. and J.C. Saunders. 1995b. Forest Resources and Vegetation Mapping of Papua New Guinea. 1:250,000 vegetation map overlays separately issued as working copies to PNGRIS Publ. 4, Canberra, CSIRO and AIDAB.

Ham, R.W.J.M. van der. 1977. A revision of *Mischocarpus* (Sapindaceae). Blumea 23 (2): 251–288.

Ham, R.W.J.M. van der. 1994. *Mischocarpus*. In: F. Adema, P.W. Leenhouts, and P.C. van Welzen, eds. Flora Malesiana ser. 1, 11: 658–669.

Hartley, T.G. 1974. A revision of the genus *Acronychia* (Rutaceae). Journal of the Arnold Arboretum 55 (3): 469–523, and (4): 525–567.

Hartley, T.G. 1986. Floristic relationships of the rainforest flora of New Guinea. Telopea 2 (6): 619–630.

Hartley, T.G. 2001. On the taxonomy and biogeography of *Euodia* and *Melicope* (Rutaceae). Allertonia 8 (1): 1–341.

Hartley, T.G. and L.M. Perry. 1973. A provisional key and enumeration of species of *Syzygium* (Myrtaceae) from Papuasias. Journal of the Arnold Arboretum 54 (2): 160–227.

Holttum, R.E. 1963. Cyatheaceae. Flora Malesiana ser. II, 1 (2): 65–176.

Holttum, R.E. 1964. The tree-ferns of the genus *Cyathea* in Australasia and the Pacific. Blumea 12 (2): 241–274.

Holttum, R.E. 1966. *Florae Malesianae Precursores XLIV*. The fern genus *Elaphoglossum* in Malesia, with descriptions of new species. *Blumea* 14 (2): 317–326.

Holttum, R.E. 1978. *Lomariopsis* group. *Flora Malesiana* ser. II, 1 (4): 255–330.

Holttum, R.E. 1981. *Thelypteridaceae*. *Flora Malesiana* ser. II, 1 (5): 331–599.

Johns, R.J. 1993. Biodiversity and conservation of the native flora of Papua New Guinea. In: B. Beehler, ed. *Papua New Guinea conservation needs assessment report*, vol. 2. PNG Dept. of Environment and Conservation, Boroko. Pp 15–75.

Kartawinata, K. 1990. A review of natural vegetation studies in Malesia, with special reference to Indonesia. In: Baas, P., K. Kalkman, and R. Geesink, eds. *The Plant Diversity of Malesia, Proceedings of the Flora Malesiana Symposium Commemorating Prof. Dr. C.G.G.J. van Steenis*. Kluwer Academic Publishers. Pp 121–132.

Laubenfels, D.J. de. 1988. *Coniferales*. *Flora Malesiana* ser. I, 10 (3): 337–453.

Leeuwenberg, A.J.M. 2003. Series of revisions of *Apocynaceae* LIII. *Melodinus*. *Syst. Geogr. Pl.* 73: 3–62.

Leps, J., Novotny, V., Cizek, L., Molem, K., Isua, B., Boen, W. et al. 2002. Successful invasion of the neotropical species *Piper aduncum* in rain forests in Papua New Guinea. *Applied Vegetation Science* 5: 255–262.

Mack, A., ed. 1998. *A Biological Assessment of the Lakekamu Basin, Papua New Guinea*. Rapid Assessment Program Working Papers no. 9, Conservation International, Washington, DC, 187 pp.

Mack, A. and L.E. Alonso, eds. 2000. *A Biological Assessment of the Wapoga River Area of Northwestern Irian Jaya, Indonesia*. RAP Bulletin of Biological Assessment 14, Conservation International, Washington, DC.

Parris, B.S. In press. Chapter 3. Floristics: Ferns and fern allies. *The Ecology of Papua. The Ecology of Indonesia Series*. Volume 5. Conservation International. Periplus HK Editions, Singapore.

Philipson, W.R. 1977. A revision of the Malesian species of *Arthrophyllum* Bl. (*Araliaceae*). *Gardens' Bulletin Singapore* 30: 299–312.

Philipson, W.R. 1979. *Araliaceae*–I. *Flora Malesiana* ser. I, 9 (1): 1–105.

Pigram, C.J. and H.L. Davies. 1987. Terranes and the accretion history of the New Guinea orogen. *Journal of Australian Geology and Geophysics* 10: 193–211.

Prance, G.T. 1977. Floristic inventory of the tropics: where do we stand? *Ann. Missouri Bot. Gard.* 64: 659–684.

Rogers H.M. and A.E. Hartemink. 2000. Soil seed bank and growth rates of an invasive species, *Piper aduncum*, in the lowlands of Papua New Guinea. *Journal of Tropical Ecology* 16: 243–251.

Royen, P. van. 1982. The Alpine Flora of New Guinea. Volume 3: Taxonomic Part Winteraceae to Polygonaceae. J. Cramer, Vaduz. Pp 1233–2404.

Scott, A.J. 1979. A revision of *Xanthomyrtus* (Myrtaceae). Kew Bulletin 33: 461–484.

Sekhran, N. and S. Miller, eds. 1995. Papua New Guinea Country Study on Biological Diversity. Hong Kong, Colorcraft Ltd. Pp 1–438.

Sleumer, H. 1980. A taxonomic account of the Olacaceae of Asia, Malesia, and the adjacent areas. Blumea 26 (1): 145–168.

Sleumer, H. 1984. Olacaceae. Flora Malesiana ser. I, 10 (1): 1–29.

Sleumer, H. 1988. A revision of the genus *Ardisia* Sw. (Myrsinaceae) in New Guinea. Blumea 33 (1): 115–140.

Smith, A.C. 1941. Studies of Papuan plants, I. Jour. Arn. Arb. 22 (1): 60–80.

Smith, A.C. and J.E. Haas. 1975. Studies of Pacific island plants. XXIX. *Bleasdalea* and related genera of Proteaceae. American Journal of Botany 62 (2): 133–147.

Stevens, P.F. 1989. New Guinea. In: D.G. Campbell and H.D. Hammond, eds. Floristic Inventory of Tropical Countries: the Status of Plant Systematics, Collections, and Vegetation, Plus Recommendations for the Future. New York Bot. Gard., New York. Pp 120–132.

Supriatna, J., ed. 1999. The Irian Jaya biodiversity conservation priority-setting workshop. Final report. Conservation International, Washington, DC.

Takeuchi, W. 1999. New plants from Crater Mt., Papua New Guinea, and an annotated checklist of the species. Sida 18 (4): 961–1006.

Takeuchi, W. 2000a. A floristic and ethnobotanical account of the Josephstaal Forest Management Agreement Area, Papua New Guinea. Sida 19 (1): 1–63.

Takeuchi, W. 2000b. Additions to the flora of Crater Mt., Papua New Guinea. Sida 19 (2): 237–247.

Takeuchi, W. 2001. New and noteworthy plants from recent botanical surveys in Papua New Guinea, 7. Edinburgh Journal of Botany 58: 159–172.

Takeuchi, W. 2002. Notes and new species in Papuan *Syzygium* (Myrtaceae). Edinburgh Journal of Botany 59 (2): 259–272.

Takeuchi, W. 2003a. Plant discoveries from PABITRA-related exploration in Papua New Guinea. Organisms, Diversity and Evolution 3(2): 77–84. Elctr. suppl.: color pictures, pdf-format, at <http://www.senckenberg.uni-frankfurt.de/odes/03-03.htm>.

Takeuchi, W. 2003b. Botanical summary of a lowland ultrabasic flora in Papua New Guinea. Sida 20 (4): 1491–1559.

Takeuchi, W. and M. Golman. 2001. Botanical documentation imperatives: some conclusions from contemporary surveys in Papuasia. *Sida* 19 (3): 445–468.

Takeuchi, W. and J. Wiakabu. 2001. A transect-based floristic reconnaissance of Southern New Ireland. In: B. Beehler and L.E. Alonso, eds. *Southern New Ireland, Papua New Guinea: A Biological Assessment*. RAP Bulletin of Biological Assessment 21. Conservation International, Washington, DC. Pp 32–39, 73–88.

Verdcourt, B. 1979. A manual of New Guinea legumes. Papua New Guinea Office of Forests, Division of Botany, Bulletin 11, 645 pp.

Vogel, E. and A. Schuitemann. In press. Chapter 3. Floristics: Orchidaceae. *The Ecology of Papua. The Ecology of Indonesia Series*. Volume 5. Conservation International. Periplus HK Editions, Singapore.

Weiblen, G. In press. Chapter 3. Floristics: Moraceae. *The Ecology of Papua. The Ecology of Indonesia Series*. Volume 5. Conservation International. Periplus HK Editions, Singapore.

Welzen, P.C. van. 1989. *Guioa* Cav. (Sapindaceae): taxonomy, phylogeny, and historical biogeography. *Leiden Botanical Series* 12: 1–315.

Welzen, P.C. van. 1994. *Guioa*. In: F. Adema, P.W. Leenhouts, and P.C. van Welzen, eds. *Flora Malesiana ser. I*, 11: 548–598.

Welzen, P.C. van. 1997. Increased speciation in New Guinea: tectonic causes? In: J. Dransfield, M.J.E. Coode, and D.A. Simpson, eds. *Plant Diversity in Malesia III. Proceedings of the Third International Flora Malesiana Symposium 1995*. Pp 363–387.

Wilde, W.J.J.O. de. 1972a. The indigenous Old World *Passifloras*. *Blumea* 20 (1): 227–250.

Wilde, W.J.J.O. de. 1972b. *Passifloraceae*. *Flora Malesiana ser. I*, 7 (2): 405–434.

Wilde, W.J.J.O. de. 1995. Census of *Myristica* (Myristicaceae) in New Guinea anno 1994. *Blumea* 40 (2): 237–344.

Wilde, W.J.J.O. de. 1998. The myrmecophilous species of *Myristica* (Myristicaceae) from New Guinea. *Blumea* 43: 165–182.

Wilde, W.J.J.O. de. 2000. *Myristicaceae*. *Fl. Malesiana ser. I*, vol. 14: 1–632.

Womersley, J.S., ed. 1978. *Handbooks of the flora of Papua New Guinea*. Vol. I. Melbourne University Press, 278 pp.

APPENDIX 1. CHECKLIST OF PLANTS

The checklist is a compilation of collections and sightings from montane habitats along or near the proposed pipeline route. Specimens from the Enesar survey have been identified by the writer unless otherwise noted. Determinations to WWF-sponsored collections have been extracted from WWF technical reports, with caveats discussed in the text.

The writer has examined only the gatherings obtained under his personal number series. Binomials from WWF-sponsored surveys are also incorporated into the checklist, if necessary with updated nomenclature (these adjusted names are indicated with an asterisk). In cases where vouchers have not been examined, the subject plants may not be actually present within the project concession. Discretion has been exercised in exclusion of undocumented records that appear dubious. Taxa are scored only if identified at least to species-group affinity (i.e., generic-level identifications have been omitted pending confirmation).

Sources for records - This Survey

- 19000 series numbers = Enesar survey vouchers collected by W. Takeuchi, A. Towati, and T. Jisaka.
 - 19000-19271 from Hides.
 - 19272-19568 from Benaria.

Sources for records - Other Data

- 7000 and 9000 series numbers = collections made by W. Takeuchi in 1991–1992 from the Kutubu limestone above the Hegigio River.
- SISA = taxa enumerated from Mt Sisa by Gebia and Balun (2000).
- SR = sight record of common/distinctive species known to the writer at one or more of the four collection sites.
- sn = sin numéro (collection without number).
- nv = non visus, specimens not seen at LAE but cited in the literature and/or entered in LAE logbooks.
- Other collectors are indicated by name.

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Ferns and Fern Allies					
Adiantaceae					
<i>Adiantum aneitense</i> Carr	19265				
<i>Adiantum caudatum</i> L.				SISA	
<i>Syngamma</i> cf. <i>schlechteri</i> Brause			9147		
<i>Taenitis blechnoides</i> (Willd.) Sw.	19242				
Aspleniaceae					
<i>Asplenium acrobryum</i> Christ	19190				
<i>Asplenium adiantoides</i> (L.) C. Chr. or aff.		19310			
<i>Asplenium</i> aff. <i>caudatum</i> Forst.		19526, 19530			
<i>Asplenium cromwellianum</i> Ros.				SISA	
<i>Asplenium decorum</i> Kunze		19398, 19415			
<i>Asplenium macrophyllum</i> Sw.		19518, 19568			
<i>Asplenium nidus</i> L. var. <i>nidus</i>					SR
<i>Asplenium pellucidum</i> Lam. or aff.		19327, 19445			
<i>Asplenium phyllitidis</i> Don ssp. <i>malesicum</i> Holttum		19397			
<i>Asplenium remotum</i> S. Moore		19410			
<i>Asplenium scandens</i> J.J. Sm.			9195		
<i>Asplenium submarginatum</i> Ros.			9190		

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Asplenium tenerum</i> Forst. f.		19385, 19516			
<i>Asplenium</i> sp. nov.	19243				
<i>Diplora</i> aff. <i>longifolia</i> Presl			9232		
Athyriaceae					
<i>Diplazium accedens</i> Bl.					SR
<i>Diplazium armatum</i> (Copel.) Holtt.	19143, 19153, 19229, 19252				
<i>Diplazium asperum</i> Bl.		19525			
<i>Diplazium cyatheifolium</i> (Rich.) Presl	19065				
<i>Diplazium scotinum</i> Ros.	19245				
<i>Diplazium</i> sp. = <i>Callipteris spinulosa</i> (Blume) J. Smith		19508			
Blechnaceae					
<i>Blechnum hieronymi</i> Brause	19067, 19231, 19254				
* <i>Blechnum decorum</i> Brause (=B. <i>hieronymi</i>)				SISA	
Cyatheaceae					
<i>Cyathea auriculifera</i> Copel.				SISA	
<i>Cyathea</i> cf. <i>geluensis</i> Ros.				SISA	
<i>Cyathea</i> cf. <i>hornei</i> (Bak.) Copel.				SISA	
<i>Cyathea foersterii</i> Ros.				SISA	
<i>Cyathea microphyllodes</i> Ros.	19050, 19112				
<i>Cyathea perpallidigera</i> Holtt.				SISA	
<i>Cyathea</i> sp. nov. section <i>Gymnosphaera</i>	19123				
Davalliaceae					
<i>Davallia divaricata</i> Bl. var. <i>divaricata</i>		19357			
<i>Davallia pectinata</i> Sm.					SR
<i>Davallia repens</i> (L.f.) Kuhn		19486	9230		
<i>Davallia solida</i> (Forster) Swartz					SR
<i>Davallodes novoguineense</i> (Rosenst.) Copel.	19115				
* <i>Humata similis</i> Copel. (=D. <i>repens</i>)				SISA	
* <i>Humata deltoidea</i> Copel. (=D. <i>repens</i>)				SISA	
Dennstaedtiaceae					
<i>Dennstaedtia novoguineensis</i> (Ros.) Copel.		19276			
<i>Histiopteris caudatum</i> (Copel.) Holttum				SISA	
<i>Histiopteris incisa</i> (Thunb.) J. Smith	19113				
<i>Hypolepis papuana</i> Bailey				SISA	
<i>Pteridium aquilinum</i> (L.) Kuhn					SR
Dryopteridaceae					
<i>Arachniodes aristata</i> (Forst. f.) Tindale		19565			
<i>Ctenitis alpina</i> (Ros.) Copel.				SISA	
Equisetaceae					
<i>Equisetum ramosissimum</i> Desf. ssp. <i>debile</i> (Vauch.) Hauke					SR
Gleicheniaceae					
<i>Dicranopteris linearis</i> (Burm. f.) Underw.					SR
* <i>Diplopterygium sordidum</i> (=Gleichenia <i>sordida</i>)				SISA	
<i>Gleichenia hirta</i> Bl. var. <i>lanuginosa</i> (v.A.v.R.) Holtt.	19042				
<i>Gleichenia sordida</i> Copel.	19194				
Grammitidaceae					
<i>Ctenopteris integripaleata</i> Copel.	19195				
<i>Ctenopteris stellatosetosa</i> Copel.	19051, 19147				

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Ctenopteris subulatipinna (v.A.v.R.) Copel.				SISA	
Ctenopteris subsecundodissecta (Zoll.) Copel.	19052, 19116				
Ctenopteris taxodioides (Baker) Copel.				SISA	
Ctenopteris yoderi Copel.	19066, 19120				
Grammitis dolichosora (Copel.) Copel.				SISA	
Grammitis padangensis (Baker) Copel.				SISA	
Grammitis scabristipes (Baker) Copel.				SISA	
Grammitis sumatrana (Baker) Copel.	19114, 19146, 19180				
Prosaptia alata (Bl.) Christ		19412			
Prosaptia contigua (Forst.) Presl	19149	19414			
Hymenophyllaceae					
Hymenophyllum geluense Ros.				SISA	
Trichomanes imbricatum (Bl.) Copel.				SISA	
Trichomanes obscurum Bl.				SISA	
Lindsaea Group					
Lindsaea obtusa J. Sm.		19322, 19394			
Sphenomeris chinensis (L.) Maxon		19485			
Lomariopsis Group					
Bolbitis heteroclita (Presl) Ching			9219		
Elaphoglossum favigerum Holtt.	19069				
*Elaphoglossum heterolepium v.A.v.R.				SISA (Dubious Record)	
Elaphoglossum novoguineense v.A.v.R.				SISA	
Elaphoglossum resiniferum Holtt. or aff.	19235				
Lomagramma sinuata C. Chr.		19299			
Lycopodiaceae					
Huperzia phlegmaria (L.) Rothm.		19441	9208		
Huperzia phlegmarioides (Gaud.) Rothm.		19495			
Hyperzia sp. ?nov.; 'phlegmaria-phelgmarioides facies'		19441			
Lycopodium clavatum L.				SISA	
Marattiaceae					
Marattia coronata Copel. or aff.	19177				
Marattia cf. costulisora Alston				SISA	
Marattia tafaensis C. Chr.				SISA	
Matoniaceae					
*Phanerosorus albido-squamatus' (dubious name; there is no such binomial)				SISA	
Oleandraceae					
Nephrolepis acuminata (Houtt.) Kuhn		19365, 19396, 19399			
Nephrolepis (closest to) falcata (Cav.) C. Chr.		19446			
Nephrolepis lauterbachii Christ		19442			
Oleandra archboldii Copel.			9234		
Oleandra wernerii Ros.				SISA	
Plagiogyriaceae					
*Plagiogyria glauca (Bl.) Mett.				SISA	
Polypodiaceae					
Aglaomorpha drynarioides (Hook.) Roos			9245		
Aglaomorpha heraclea (Kunze) Copel.		19353	9171		
Aglaomorpha hieronymi (Brause) Copel.		19489			
Belvisia mucronata (Fée) Copel. var. mucronata		19529			

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Belvisia novoguineensis</i> (Rosen.) Copel.	19175, 19187				
<i>Drynaria rigidula</i> Bedd.					SR
<i>Drynaria sparsisora</i> (Desvaux) T. Moore					SR
<i>Goniophlebium</i> cf. <i>subauriculatum</i> (Bl.) Presl				SISA	
<i>Lecanopteris deparioides</i> (Ces.) Baker			9152		
<i>Loxogramme paltonioides</i> Copel.	19135				
<i>Microsorium commutatum</i> Copel.	19080	19326, 19406, 19556			
<i>Microsorium membranifolium</i> (R. Br.) Ching			9133		
<i>Microsorium papuanum</i> (Baker) Parris	19026, 19078	19532			
<i>Microsorium pteropus</i> (Bl.) Copel.			9233		
<i>Microsorium punctatum</i> (L.) Copel.					SR
<i>Pyrrosia</i> cf. <i>adnascens</i> (Sw.) Ching				SISA	
<i>Pyrrosia foveolata</i> (Alston) Morton var. <i>foveolata</i>		19517			
<i>Pyrrosia longifolia</i> (N.L. Burm.) Morton				SISA	
<i>Selliguea albidosquamata</i> (Bl.) Parris	19048, 19134, 19204, 19246	19390	9229		
<i>Selliguea enervis</i> (Cav.) Ching		19476, 19487	9231		
<i>Selliguea plantaginea</i> Brack.		19497			
<i>Selliguea</i> sp. nov.	19267				
Psilotaceae					
<i>Psilotum nudum</i> (L.) Beauv.		19364			
Pteridaceae					
<i>Pteris blumeana</i> Agardh	19219, 19230				
<i>Pteris excelsa</i> Gaud.		19313			
<i>Pteris pacifica</i> Hieron.	19156		9134		
<i>Pteris vittata</i> L.	19091				
Selaginellaceae					
<i>Selaginella</i> aff. 'angustiramea-hieronymiana group'		19305			
Tectaria Group					
<i>Tectaria repanda</i> (Willd.) Holtt.		19314			
Thelypteridaceae					
<i>Amphineuron subattenuatum</i> (Ros.) Holtt.	19181				
<i>Coryphopteris habbemensis</i> (Copel.) Holtt.				SISA	
<i>Mesophlebium</i> sp. nov.	19129				
<i>Plesioneuron fulgens</i> (Brause) Holtt.	19241				
<i>Pneumatopteris sogerensis</i> (Gepp) Holtt.		19296			
<i>Pneumatopteris superba</i> (Brause) Holtt.	19199				
<i>Pronephrium womersleyi</i> Holtt.			9113		
<i>Pseudophegopteris</i> cf. <i>padulosa</i> (Bl.) Ching				SISA	
<i>Pseudophegopteris</i> cf. <i>cyclocarpa</i> Holtt.				SISA	
<i>Sphaerostephanos acrostichoides</i> (Desv.) Holtt.	19087, 19132, 19145				
<i>Sphaerostephanos archboldii</i> (C. Chr.) Holtt.	19105				
<i>Sphaerostephanos confertus</i> (Brause) Holtt.				SISA	
<i>Sphaerostephanos hispiduliformis</i> (C. Chr.) Holtt.	19111				
<i>Sphaerostephanos pilososquamatus</i> (v.A.v.R.) Holtt.		19325, 19329			
<i>Sphaerostephanos unitus</i> (L.) Holtt. var. <i>papilliferus</i> Holtt.	19081, 19089				
<i>Sphaerostephanos veitchii</i> Holtt.		19308, 19330			
Vittariaceae					
<i>Antrophyum alatum</i> Brack.			9132		

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Antrophyum plantagineum</i> (Cav.) Kaulfuss	19202, 19237				
<i>Haplopteris angustifolia</i> (Bl.) Crane		19416			
<i>Haplopteris elongata</i> (Sw.) Crane		19566			
Gymnosperms					
Araucariaceae					
<i>Araucaria cunninghamii</i> D. Don					SR (also fide Gray undated)
Cupressaceae					
<i>Libocedrus papuana</i> F.v.M. var <i>papuana</i>	19057				
Phyllocladaceae					
<i>Phyllocladus hypophyllus</i> Hk. f.	19055				
Podocarpaceae					
<i>Podocarpus neriifolius</i> D. Don				SISA	
Monocots					
Araceae					
<i>Alocasia hollrungii</i> Engl.				SISA	
<i>Alocasia nicolsonii</i> Hay					SR
<i>Amydrium zippelianum</i> (Schott) Nicolson		19505			
<i>Cyrtosperma macrotum</i> Becc. ex Engl.			9110		
<i>Epipremnum</i> cf. <i>papuanum</i> v.A.v.R.				SISA	
<i>Holochlamys beccarii</i> Engl.					SR
<i>Pothos ledermannii</i> Engl. & Krause				SISA	
<i>Pothos zippelii</i> Schott			7245		
<i>Rhaphidophora conocephala</i> v.A.v.R.				SISA	
Areaceae					
<i>Areca catechu</i> L.					SR
<i>Areca macrocalyx</i> Zipp. ex Bl.				SISA	
<i>Calamus cuthbertsonii</i> Becc.				SISA	
<i>Calamus humboldtianus</i> Becc.			9197		
<i>Caryota rumphiana</i> Martelli					SR
<i>Cocos nucifera</i> L.					SR
<i>Metroxylon sagu</i> Rottb.					SR
Commelinaceae					
<i>Floscopa scandens</i> Lour.		19311			
<i>Polia thyrsiflora</i> (Bl.) Steud.			7259		
Costaceae					
<i>Costus speciosus</i> (Koen.) J.E. Sm.					SR
<i>Tapeinochilos ananassae</i> (Hassk.) K. Schum.		19534			
<i>Tapeinochilos brassii</i> Gideon			9106 (det. O. Gideon)		
<i>Tapeinochilos pubescens</i> Ridl.			7257		
Cyperaceae					
<i>Mapania macrocephala</i> (Gaud.) K. Sch.			9172		
<i>Mapania sumatrana</i> (Miq.) Benth.			9173		
<i>Scleria terrestris</i> (L.) Fass.		19351			
Hemerocallidaceae					
* <i>Geitonoplesium cymosum</i> (R. Br.) Hook.				SISA	
Laxmanniaceae					
<i>Cordyline fruticosa</i> (L.) A. Chev.					SR
Liliaceae sens. lat.					
<i>Dianella ensifolia</i> (L.) DC.				SISA	
Orchidaceae					

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Appendicula polystachya</i> Schltr.			9109 (det. N. Howcroft)		
<i>Bulbophyllum foetidum</i> Schltr.		19377 (det. E. de Vogel)			
<i>Calanthe</i> (<i>Styloglossum</i> group)			9239 (det. N. Howcroft)		
<i>Dendrobium</i> cf. <i>cuthbertsonii</i> F.v.M.				SISA	
* <i>Dendrobium</i> <i>flox</i> (dubious name; no such binomial known)				SISA	
<i>Dendrobium fulgibum</i> Schltr.			9148 (det. N. Howcroft)		
<i>Dendrobium torricellianum</i> Krzl.			9168 (det. N. Howcroft)		
<i>Dipodium pandanum</i> Bail.			9241		
<i>Lepidogyne sceptrum</i> Schltr.			9227 (det. N. Howcroft)		
<i>Podochilus imitans</i> Schltr.			9166 (det. N. Howcroft)		
Pandanaceae					
<i>Freycinetia naumannii</i> Warb.				SISA	
<i>Pandanus conoideus</i> Lamk				SISA	
<i>Pandanus englerianus</i> Mart.				SISA	
<i>Pandanus julianetti</i> Mart.				SISA	
<i>Pandanus kaernbachii</i> Warb.				SISA	
Poaceae					
<i>Axonopus compressus</i> (Swartz) Beauv.					SR
<i>Bambusa vulgaris</i> Schrad.					SR
<i>Chrysopogon aciculatus</i> (Retz.) Trin.					SR
<i>Coix lachryma-jobi</i> L.					SR
<i>Miscanthus floridulus</i> (Labill.) Warb.	19094				
<i>Nastus productus</i> (Pilg.) Holtt.				SISA	
<i>Pennisetum purpureum</i> Schumach.		19460			
<i>Zea mays</i> L.					SR
Smilacaceae					
<i>Smilax calophylla</i> Wall.				SISA	
<i>Smilax luzonensis</i> Presl				SISA	
Zingiberaceae					
<i>Curcuma australasica</i> Hook. f.			9226		
Dicots					
Acanthaceae					
<i>Dicliptera papuana</i> Warb.		19328			
<i>Rungia klossii</i> S. Moore					SR
Actinidiaceae					
<i>Saurauia</i> aff. <i>bifida</i> Warb.	19021				
<i>Saurauia</i> aff. <i>calyptrata</i> Laut.	19128				
<i>Saurauia conferta</i> Warb.	19154		9189		
<i>Saurauia defaurii</i> (F.v.M.) Diels				SISA	
<i>Saurauia</i> aff. <i>drimytiflora</i> Diels	19018, 19100				
<i>Saurauia</i> aff. <i>drimytiflora</i> Diels (2nd morphospecies)	19072, 19096, 19171, 19185				
<i>Saurauia naumannii</i> Diels	19127				
<i>Saurauia</i> cf. <i>nudiflora</i> DC.				SISA	
<i>Saurauia rufa</i> Burkill	19001				
<i>Saurauia scaberrima</i> Laut.				SISA	
<i>Saurauia schumanniana</i> Diels				SISA	

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Saurauia trugul Royen	19000				
Saurauia ser. Setosae aff. ?klinkii Laut. & K. Sch.		19338, 19361			
Saurauia ser. Setosae aff. 'xiphophylla facies'	19011				
Amaranthaceae					
Achyranthes bidentata Bl.		19318			
Iresine herbstii Hook. f.			7242		
Anacardiaceae					
Buchanania arborescens Bl.			9154		
Dracontomelon dao (Blanco) Merr. & Rolfe					SR
Rhus caudata Laut.				SISA	
Rhus taitensis Guillemain		19369	Schodde 2451 (Moro), Jacobs 9134 (Waro)		
Annonaceae					
Cyathocalyx osmanthus Diels			9130		
Mitrella kentii (Bl.) Miq.		19557			
Apiaceae					
Centella asiatica (L.) Urb.		19343			
Apocynaceae sens. lat.					
Asclepias physocarpa Schltr.					SR
Cerbera floribunda K. Sch.		19340			
Melodinus forbesii Fawc.		19374			
Melodinus novoguineensis (Wernh.) Pichon				SISA	
Papuechites aambe (Warb.) Markgf.			9228		
Parsonsia curvisepala K. Sch.			9211		
Aquifoliaceae					
Ilex archboldiana Merr. & Perry				SISA	
Ilex arnhemensis (F.v.M.) Loes.			9203		
Ilex scabridula Merr. and Perry				SISA	
Araliaceae					
Arthropodium proliferum Philipson		19431			
Gastonia spectabilis (Harms) Philipson		19427			
Harmsiopanax harmsii K. Sch.	19142				
Mackinlaya celebica (Harms) Philipson		19555			
Osmoxylon sessiliflorum (Laut.) Philipson		19288			
Polyscias royenii Philipson	19206, 19207				
Polyscias schultzei Harms				SISA	
'Schefflera' aff. carrii Harms	19031				
'Schefflera' dentata Frodin	19045, 19059, 19232				
'Schefflera' elliptica (Seem.) Harms			9206		
'Schefflera' ischnocarpa Harms				SISA	
'Schefflera' aff. ? megalantha Harms (section Brassaia)		19272			
'Schefflera' monimioides Frodin				SISA	
'Schefflera' setulosa Harms	19248				
'Schefflera' straminea Frodin				SISA	
'Schefflera' sp. 'ischnoacra-forbesii facies'		19280			
Aristolochiaceae					
Aristolochia engleriana Schmidt			9128		
Asteraceae					
Adenostemma lavenia (L.) Kuntze		19345			

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Ageratum conyzoides</i> L.					SR
<i>Bidens pilosa</i> L. var. <i>minor</i> (Bl.) Sherff					SR
<i>Blumea papuana</i> S. Moore	19157				
<i>Blumea riparia</i> (Bl.) DC.			9145		
<i>Crassocephalum crepidioides</i> (Benth.) S. Moore					SR
<i>Emilia sonchifolia</i> (L.) DC. var. <i>javanica</i> (Burm.) Mattfeld					SR
<i>Erigeron sumatrensis</i> Retz		19333			
<i>Gnaphalium</i> cf. <i>involucratum</i> Forst. f.	19255				
<i>Lactuca laevigata</i> (Bl.) DC. var. <i>laevigata</i>	19093				
<i>Microglossa pyrifolia</i> (Lamk) O. Ktze.		19453			
<i>Olearia platyphylla</i> Mattf. var. <i>microcephala</i> Koster	19238				
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray		19432			
<i>Vernonia cuneata</i> Less.	19124				
Begoniaceae					
<i>Begonia</i> cf. <i>pinnatifida</i> Merr. & Perry			7243		
Bignoniaceae					
<i>Pandorea pandorana</i> (Andr.) Steen.		19492			
<i>Tecomnanthe dendrophila</i> (Bl.) K. Sch.		19349	9142		
Boraginaceae					
<i>Cynoglossum hellwigii</i> Brand	19133				
BURSERACEAE					
<i>Canarium acutifolium</i> (DC.) Merr.			9204		
Campanulaceae					
<i>Peracarpa carnosus</i> (Wall.) Hook. f. & Thomson	19271				
Cannabaceae					
<i>Girardinia subaequalis</i> Planch.			9216		
Caricaceae					
<i>Carica papaya</i> L.					SR
Caryophyllaceae					
<i>Drymaria cordata</i> (L.) Willd. ex Roemer & Schult.					SR
Casuarinaceae					
<i>Casuarina</i> cf. <i>oligodon</i> L.A.S. Johnson					SR
Celastraceae					
<i>Celastrus monospermoides</i> Loes.		19291			
<i>Perrottetia alpestris</i> (Bl.) Loes. ssp. <i>moluccana</i> (Bl.) Ding Hou	19041, 19247				
<i>Siphonodon celastreus</i> Griff.			9186 (det. P. Stevens)		
Chloranthaceae					
<i>Ascarina subsessilis</i> Verdcourt	19178				
<i>Chloranthus erectus</i> (Buch.-Ham.) Verdcourt		19425			
Clusiaceae					
<i>Calophyllum</i> cf. <i>articulatum</i> P.F. Stevens				SISA	
<i>Calophyllum</i> cf. <i>gaimanum</i> P.F. Stevens				SISA	
<i>Calophyllum goniocarpum</i> P.F. Stevens			9224 (det. P. Stevens)		
<i>Garcinia archboldiana</i> A.C. Smith or aff.	19053, 19122				
<i>Garcinia assugu</i> Laut.		19434			
<i>Garcinia celebica</i> L.		19402			
<i>Garcinia hunsteinii</i> Laut.			9240		
<i>Garcinia klinkii</i> Laut.				SISA	

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Garcinia latissima</i> Miq.		19536			
<i>Garcinia</i> aff. ? <i>schraderi</i> Laut.		19379, 19449			
<i>Garcinia</i> cf. <i>warrenii</i> F.v.M.		19468			
Cornaceae					
<i>Alangium javanicum</i> (Bl.) Wangerin	19073				
* <i>Alangium ferrugineum</i> C.T. White				SISA	
Cucurbitaceae					
<i>Zehneria scabridula</i> (Merr. & Perry) de Wilde	19020				
Cunoniaceae					
* <i>Caldcluvia celebica</i> (Bl.) Hoogl. = <i>Spiraeopsis celebica</i> (Bl.) Miq.				SISA	
<i>Schizomeria serrata</i> (Hochr.) Hochr.	19220				
<i>Spiraeopsis celebica</i> (Bl.) Miq.		19393			
<i>Spiraeopsis papuana</i> (Pulle) L.M. Perry		19348			
<i>Weinmannia pullei</i> Schltr.	19162				
Daphniphyllaceae					
<i>Daphniphyllum gracile</i> Gage				SISA	
Dilleniaceae					
<i>Dillenia auriculata</i> Mart.			9136		
Elaeagnaceae					
<i>Elaeagnus triflora</i> Roxb. var. <i>triflora</i>		19499			
Elaeocarpaceae					
<i>Aceratium</i> 'ledermannii-oppositifolium' (intermediate)			9118		
<i>Aceratium pittosporoides</i> Schltr.				SISA	
<i>Dubouzetia novoguineensis</i> A.C. Smith				SISA	
<i>Elaeocarpus altigenus</i> Schltr.	19151, 19160, 19163				
<i>Elaeocarpus altisectus</i> Schltr.				SISA	
<i>Elaeocarpus angustifolius</i> Bl.				SISA	
<i>Elaeocarpus arfakensis</i> Schltr.				SISA	
<i>Elaeocarpus culminicola</i> Warb.				SISA	
<i>Elaeocarpus fuscoideus</i> Knuth or aff.		19440			
<i>Elaeocarpus ledermannii</i> Schltr.				SISA	
<i>Elaeocarpus lingualis</i> Knuth		19336, 19373			
<i>Elaeocarpus pachyanthus</i> Schltr.		19370			
<i>Elaeocarpus polydactylus</i> Schltr.	19148				
<i>Elaeocarpus sayeri</i> var. <i>altigenus</i> F.v.M.				SISA	
<i>Sericolea brassii</i> A.C. Smith				SISA	
<i>Sericolea micans</i> var. <i>micans</i> Schltr.				SISA	
<i>Sloanea forbesii</i> F.v.M.				SISA	
<i>Sloanea pulchra</i> (Schltr.) A.C. Smith (probably) ssp. <i>pulchra</i>		19469			
Ericaceae					
<i>Dimorphanthera anchorifera</i> J.J. Sm.	19165				
<i>Dimorphanthera denticulifera</i> Sleum.				SISA	
* <i>Dimorphanthera dominans</i> Sleum. (illegitimate name)				SISA	
<i>Dimorphanthera fissiflora</i> (Sleum.) Stevens or aff.	19208				
<i>Dimorphanthera keysseri</i> (Schltr. ex Diels) Stevens				SISA	
<i>Diplycosia morobeensis</i> Sleum.	19214				
<i>Diplycosia rupicola</i> Sleum.				SISA	

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Rhododendron beyerinckianum</i> Koord.	19007				
<i>Rhododendron</i> cf. <i>scabridibracteum</i> Sleum.				SISA	
<i>Rhododendron christi</i> Foerster				SISA	
<i>Rhododendron gracilentum</i> F.v.M.				SISA	
<i>Rhododendron macgregoriae</i> F.v.M.	19268				
<i>Vaccinium longiporum</i> Sleum.	19038				
<i>Vaccinium psammogenes</i> Sleum.			9153		
<i>Vaccinium quinquefidum</i> J.J. Sm.				SISA	
<i>Vaccinium reticulatovenosum</i> Sleum.	19193, 19227				
Euphorbiaceae sens. lat.					
<i>Acalypha</i> cf. <i>grandis</i> Benth.			9124		
<i>Acalypha hellwigii</i> Warb. var. <i>mollis</i> (Warb.) K. Sch. & Laut.		19358			
<i>Antidesma contractum</i> J.J. Sm.			9146		
<i>Antidesma erostre</i> F.v.M. ex Benth.				SISA	
<i>Antidesma myriocarpum</i> Airy Shaw var. <i>myriocarpum</i>		19273, 19323			
<i>Antidesma</i> aff. ' <i>rhynchophyllum-jucundum</i> group'			9175		
<i>Aporosa brassii</i> Mansf.		19278, 19335			
<i>Aporosa papuana</i> Pax & Hoffm.		19470, 19522			
<i>Bridelia cernua</i> (Poir.) Muell.-Arg.				SISA	
<i>Codiaeum variegatum</i> (L.) Bl. var. <i>moluccanum</i> (Decne.) Muell.-Arg.					SR
<i>Euphorbia hirta</i> L.					SR
<i>Glochidion</i> cf. <i>ambiguum</i> Airy Shaw				SISA	
<i>Glochidion frodinii</i> Airy Shaw				SISA	
<i>Glochidion galorii</i> Airy Shaw		19400, 19552			
<i>Glochidion macrocarpum</i> Bl. ssp. <i>orientale</i> Airy Shaw				SISA	
<i>Glochidion pachyconum</i> Airy Shaw		19482			
<i>Glochidion philippicum</i> Cav.) C.B. Rob.		19350, 19382			
<i>Macaranga carrii</i> L.M. Perry				SISA	
<i>Macaranga chrysotricha</i> Laut. & K. Schum.		19356			
<i>Macaranga pleioneura</i> Airy Shaw var. <i>pleioneura</i>		19372, 19480			
<i>Macaranga reiteriana</i> Pax & Hoffm.	19005, 19068				
<i>Omalanthus nervosus</i> J.J. Sm.	19108, 19256				
<i>Omalanthus novoguineensis</i> (Warb.) K. Sch.	19029				
<i>Phyllanthus ciccoides</i> Muell.-Arg.		19454			
<i>Spathiostemon javensis</i> Bl.			9215		
Eupomatiaceae					
<i>Eupomatia laurina</i> R. Br.		19307			
Fabaceae sens. lat.					
Caesalpiniaceae sens. str.					
<i>Cassia floribunda</i> Cav.		19300, 19380			
Fabaceae sens. str.					
<i>Crotalaria lanata</i> Beddome		19302			
<i>Desmodium sequax</i> Wall.		19461			
<i>Desmodium uncinatum</i> (Jacq.) DC.		19458			
<i>Inocarpus</i> sp. nov. ' <i>rubidus</i> ' sensu Verdcourt			9190		
<i>Mucuna albertisii</i> F.v.M.		19452			
<i>Mucuna cyanosperma</i> K. Sch.		19352			
<i>Strongylodon</i> cf. <i>archboldianus</i> Merr. & Perry			7244, 9237		
<i>Stylosanthes guianensis</i> (Aubl.) Sw.		19332			

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Mimosaceae sens. str.					
<i>Leucaena leucocephala</i> (Lam.) de Wit					SR
<i>Paraserianthes falcata</i> (L.) Nielsen ssp. <i>falcata</i>		19527			
Fagaceae					
<i>Castanopsis acuminatissima</i> (Bl.) A. DC.					SR
<i>Lithocarpus rufovillosus</i> (Markgrf.) Rehd.		19283, 19479, 19511			
<i>Nothofagus grandis</i> Steen.				SISA	
<i>Nothofagus pullei</i> Steen.	19071				
<i>Nothofagus rubra</i> Steenis	19212				
Gesneriaceae					
<i>Aeschynanthus kermesinus</i> Schltr.			9143, 9159		
<i>Agalmyla formosa</i> Hilliard & Burt		19411, 19419			
<i>Agalmyla nervosa</i> Hilliard & Burt			9157		
<i>Cyrtandra decurrens</i> DeVriese			9112 (det. B.L. Burt)		
<i>Cyrtandra</i> cf. <i>erectiloba</i> Gillett				SISA	
<i>Cyrtandra</i> cf. <i>hirta</i> Schltr.				SISA	
<i>Cyrtandra hispidissima</i> Schltr.			7249		
* <i>Cyrtandra mariana</i> (dubious name; no such binomial exists)				SISA	
<i>Rhynchochelys discolor</i> (Maxim.) B.L. Burt		19346			
Goodeniaceae					
<i>Scaevola oppositifolia</i> R. Br.	19137		7230		
Haloragaceae					
<i>Gunnera macrophylla</i> Bl.					SR
Himantandraceae					
<i>Galbulimima belgraveana</i> (F.v.M.) Sprague	19152				
Hydrangeaceae					
<i>Dichroa febrifuga</i> Lour.	19063				
Icacinaeae					
<i>Citronella suaveolens</i> (Bl.) Howard		19334			
<i>Platea excelsa</i> Bl.				SISA	
<i>Rhytidium longifolium</i> K. Sch. & Laut.		19484	7258		
Lamiaceae					
<i>Callicarpa pedunculata</i> R.Br.		19554			
<i>Geunsia pentandra</i> (Roxb.) Merr.					SR
<i>Plectranthus scutellarioides</i> (L.) R.Br.		19444, 19533			
<i>Premna serratifolia</i> L.			7228		
Lauraceae					
<i>Actinodaphne multiflora</i> Benth.				SISA	
<i>Cinnamomum</i> cf. <i>clemensii</i> Allen				SISA	
<i>Cinnamomum</i> cf. <i>frodinii</i> Kosterm.				SISA	
<i>Cryptocarya bullata</i> Kosterm.				SISA	
<i>Cryptocarya</i> cf. <i>apamaefolia</i> Gamble				SISA	
<i>Cryptocarya caloneura</i> (Scheff.) Kosterm.		19450			
<i>Cryptocarya</i> cf. <i>verrucosa</i> Teschn.				SISA	
<i>Cryptocarya fagifolia</i> Gamble				SISA	
<i>Endiandra</i> cf. <i>altissima</i> Kosterm.				SISA	
<i>Litsea areolata</i> Boerl.				SISA	
Loganiaceae					
<i>Fagraea bodenii</i> Wernh.				SISA	

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Fagraea ceilanica</i> Thunb.	19076, 19126				
<i>Geniostoma antherotrichum</i> Gilg. & Bened. var. <i>antherotrichum</i>			7213		
<i>Geniostoma antherotrichum</i> Gilg & Bened. (between vars. <i>antherotrichum</i> and <i>archboldianum</i>)	19257				
<i>Geniostoma weinlandii</i> K. Sch.			9222		
<i>Neuburgia corynocarpa</i> (A. Gray) Leenh. var. <i>corynocarpa</i>					SR
<i>Neuburgia corynocarpa</i> (A. Gray) Leenh. var. <i>sarcantha</i> (Gilg. & Bened.) Conn		19465			
<i>Strychnos axillaris</i> Colebr.			7239		
Loranthaceae					
<i>Decaisnina hollrungii</i> (K. Schum.) Barlow		19428, 19507	9182		
<i>Dendrophthoe curvata</i> (Bl.) Miq.		19491			
Magnoliaceae					
<i>Elmerrillia tsiampaca</i> (L.) Dandy ssp. <i>tsiampaca</i> var. <i>tsiampacca</i>		19285			
<i>Magnolia candollii</i> (Bl.) H. Keng var. <i>candollii</i>		19277, 19368			
Malvaceae sens. lat.					
<i>Abelmoschus moschatus</i> Medicus			7236		
<i>Commersonia bartramia</i> (L.) Merr.					SR
<i>Hibiscus archboldianus</i> Borss.			9114		
<i>Melochia odorata</i> L.f.			9212		
<i>Sida rhombifolia</i> L. ssp. <i>rhombifolia</i>		19459			
<i>Sterculia monticola</i> Mildbr.		19317, 19509			
<i>Triumfetta 'nigricans-pilosa' facies</i>		19383			
Melastomataceae					
<i>Astronia atroviridis</i> Mansf.		19513			
<i>Astronia ledermannii</i> Mansf.	19049, 19170				
<i>Astronidium acutifolia</i> Mansf.				SISA	
<i>Medinilla hollrungiana</i> Mansf.		19392			
<i>Medinilla maluensis</i> Mansf.				SISA	
<i>Medinilla novoguineensis</i> Bak.				SISA	
<i>Medinilla quadrifolia</i> Bl.		19281, 19483			
<i>Medinilla rubiginosa</i> Cogn.				SISA	
<i>Medinilla</i> cf. <i>rubrovenia</i> Bak.		19297			
<i>Medinilla tenuipedicellata</i> Bak. f.	19213				
<i>Medinilla teysmannii</i> Miq.				SISA	
<i>Medinilla</i> sp. nov. <i>pseudostipular</i> group	19025				
<i>Melastoma cyanoides</i> Sm.		19424			
<i>Melastoma malabathricum</i> L. ssp. <i>malabathricum</i>		19381	9137		
<i>Memecylon 'hepaticum' sensu Mansfeld</i>		19563			
Meliaceae					
<i>Aglaia agglomerata</i> Merr. & Perry		19540			
<i>Aglaia</i> cf. <i>cedreloides</i> Harms				SISA	
<i>Chisocheton lasiocarpus</i> (Miq.) Val. entity 'formicarum'		19341			
<i>Chisocheton novoguineensis</i> C. DC.			9180		
<i>Chisocheton pohlianus</i> Harms		19478, 19521			
<i>Dysoxylum latifolium</i> Benth.		19545			
<i>Dysoxylum variabile</i> Harms		19347			
Menispermaceae					

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Albertisia papuana Becc.			9185		
Arcangelisia tympanopoda (Laut. & K. Sch.) Diels			9188		
Stephania japonica (Thunb.) Miers var. timoriensis (DC.) Forman	19022	19498			
Monimiaceae					
Kibara laurifolia A.C. Smith				SISA	
Levieria acuminata (F.v.M.) Perkins	19150				
Levieria squarrosa Perkins				SISA	
Palmeria arfakiana Becc.	19098				
Palmeria incana A.C. Smith			9127		
Steganthra hirsula (Warb.) Perkins				SISA	
Steganthra ilicifolia A.C. Smith				SISA	
Moraceae					
Artocarpus communis J.R. & G. Forst.					SR
Artocarpus vrieseanus Miq. var. vrieseanus		19462, 19466			
Ficus arfakensis King				SISA	
Ficus bernaysii King		19539			
Ficus botryocarpa Miq.			9120		
Ficus congesta Roxb.				SISA	
Ficus convexa Corner				SISA	
Ficus dammaropsis Diels		19448			
Ficus gul Laut. & K. Sch.		19520			
Ficus gymnorhiza Summerh.		19506, 19535			
Ficus iodotricha Diels	19095				
Ficus aff. 'irritans-odoardi facies'; closest to F. irritans Summerh.		19386			
Ficus itoana Diels		19420			
Ficus lanata Bl.				SISA	
Ficus megalophylla Diels	19125				
Ficus mollior Benth.		19433, 19515			
Ficus nasuta Summerh.		19510			
Ficus odoardi King		19275			
Ficus pungens Reinw. ex Bl.					SR
Ficus aff. ?scratchleyana King	19258				
Ficus subtrinervia Laut. & K. Sch.		19547			
Ficus aff. subtrinervia Laut. & K. Sch.		19339 (disconforming coll.)			
Ficus subulata Bl.		19316			
Ficus aff. tinctoria Forst. f.	19002, 19006, 19016, 19079				
Ficus aff. ?tinctoria Forst. f.		19512 (deviant)			
Ficus variegata Bl.		19464			
Ficus cf. virens Ait.		19553			
Ficus virgata Reinw. ex Bl.		19503			
Ficus wassa Roxb.		19472			
Streblus glabra (Merr.) Corner				SISA	
Myristicaceae					
Horsfieldia subtilis (Miq.) Warb. var. subtilis			7241, 9164		
Myristica ingrata de Wilde ssp. ingrata		19422, 19447, 19538			
Myristica lancifolia Poir.			9205		

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
<i>Myristica longipes</i> Warb.		19290, 19403, 19548			
<i>Myristica</i> aff. <i>pedicellata</i> Sincl.		19362, 19408, 19548			
<i>Myristica sphaerosperma</i> A.C. Smith		19376			
<i>Myristica</i> sp. nov.		19378			
Myrsinaceae					
<i>Ardisia</i> aff. <i>myriosticta</i> K. Sch.	19136				
<i>Conandrium polyanthum</i> (K. Sch. & Laut.) Mez		19279, 19475			
<i>Discocalyx</i> cf. <i>subsinuata</i> Sleum.				SISA	
<i>Discocalyx latepetiolata</i> Mez) Sleum.				SISA	
<i>Fittingia tubiflora</i> Mez	19131, 19251, 19259				
<i>Grenacheria buxifolia</i> Mez			9139		
<i>Maesa haplobotrys</i> F.v.M.		19560			
Myrsine 'acrosticta'; <i>Rapanea acrosticta</i> Mez	19061, 19209				
Myrsine 'leucantha'; <i>Rapanea leucantha</i> K. Sch.	19102, 19215	19455			
Myrsine 'rhombata'; <i>Rapanea rhombata</i> Royen	19056				
*Myrsine 'leucantha'; <i>Rapanea leucantha</i> Sleum.				SISA	
Myrtaceae					
<i>Decaspermum exiguum</i> Merr. and Perry				SISA	
<i>Decaspermum fruticosum</i> Forst				SISA	
<i>Octamyrtus insignis</i> Diels		19488			
<i>Octamyrtus pleiopetala</i> Diels		19274, 19436			
<i>Psidium guajava</i> L.					SR
<i>Rhodomyrtus elegans</i> (Bl.) A.J. Scott		19294			
<i>Rhodomyrtus pinnatinervis</i> C.T. White	19103				
<i>Syzygium anomalum</i> Laut. or aff.	19060				
<i>Syzygium benjaminum</i> Diels				SISA	
<i>Syzygium effusum</i> (A. Gray) C. Muell.		19477			
<i>Syzygium fastigiatum</i> (Bl.) Merry & Perry		19456			
<i>Syzygium furfuraceum</i> Merr. & Perry		19319			
* <i>Syzygium 'montana'</i> ; = <i>Acmena montana</i> Hartley & Craven				SISA	
<i>Syzygium pachycladum</i> (Laut. & K. Sch.) Merr. & Perry				SISA	
<i>Syzygium pyriforme</i> Merr. & Perry	19099				
<i>Syzygium roemerii</i> (Laut.) Merr. & Perry				SISA	
<i>Syzygium</i> aff. <i>samarangense</i> (Bl.) Merr. & Perry		19423			
<i>Xanthomyrtus</i> aff. <i>bryophila</i> Diels	19064				
<i>Xanthomyrtus scolopacina</i> (Ridl.) Diels	19228				
Nepenthaceae					
<i>Nepenthes ampullaria</i> Jack			9150		
<i>Nepenthes mirabilis</i> (Lour.) Druce				SISA	
Ochnaceae					
<i>Schuurmansia henningsii</i> K. Sch.		19387			
Olacaceae					
<i>Olax</i> aff. <i>imbricata</i> Roxb.			9156 (det. P. Stevens)		
Oleaceae					
<i>Chionanthus</i> cf. <i>brassii</i> (Kobuski) Kiew (sessiflorum group)		19405, 19546			
<i>Chionanthus ramiflorus</i> Roxb.				SISA	
<i>Jasminum domatigerum</i> Lingelsh.				SISA	

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Passifloraceae					
Passiflora ligularis Juss.	19077				
Piperaceae					
Peperomia laevifolia (Bl.) Miq.				SISA	
Peperomia pellucida (L.) Kunth					SR
Peperomia purpurea Ridl.			9165		
Piper aduncum L.					SR
Piper arfakianum C. DC.				SISA	
Piper breviantherum C. DC.			9115		
Piper caninum Bl.		19295, 19519			
Piper gibbilimbum C. DC.	19017	19371			
Piper majusculum Bl.			9179		
Piper novoguineense Warb.	19074, 19176				
Piper rodatzii K. Sch. and Laut.	19013, 19119, 19217	19562			
Piper triangulare Chew	19040				
Piper versteegii C. DC.			9129		
Pittosporaceae					
Pittosporum pullifolium Burk. ssp. ledermannii (Pritzel) Schodde var. ledermannii	19033	19298, 19463, 19551			
Pittosporum pullifolium Burk. ssp. pullifolium var. pullifolium				SISA	
Pittosporum ramiflorum (Zoll. & Mor.) Miq. var. praegnans Schodde	19054	19286			
Pittosporum ramiflorum (Zoll. & Mor.) Miq. var. ramiflorum		19439			
Pittosporum sinuatum Bl.					SR
Polygalaceae					
Polygala paniculata L.		19303			
Xanthophyllum papuanum Whitm.			9225		
Polyosmaceae					
Polyosma cestroides Schltr.	19036				
Polyosma forbesii Val. ex Laut.				SISA	
Polyosma integrifolia Bl.				SISA	
Proteaceae					
Bleasdalea papuana (Diels) Domin		19391			
Helicia acutifolia Sleum.	19046, 19210, 19218, 19223				
Helicia amplifolia Sleum.		19550			
Helicia cf. longispicata Sleum.			9158		
Helicia cf. stelechantha Diels				SISA	
Ranunculaceae					
Clematis phanerophlebia Merr. and Perry				SISA	
Rhamnaceae					
Alphitonia ferruginea Merr. & Perry	19130				
Rhamnus nipalensis (Wallich) Lawson ex Hook.	19088				
Rhizophoraceae					
Carallia brachiata (Lour.) Merr.			9201		
Rosaceae					
Prunus costata (Hemsl.) Kalkm.				SISA	
Prunus dolichobotrys (Laut. & K. Sch.) Kalkm.		19354, 19435	7240, 9144		
Prunus grisea (Bl. ex C. Muell.) Kalkm.				SISA	
Rubus archboldianus Merr. & Perry				SISA	
Rubus ferdinandi-muelleri Focki	19008				

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Rubus glomeratus Bl.				SISA	
Rubus moluccanus L. var. obtusangulus Miq.	19139				
Rousseaceae					
Carpodetus arboreus (K. Sch. & Laut.) Schltr.		19293			
Rubiaceae					
Airosperma grandifolium Val.			9117		
Atractocarpus sp. (=Randia schumanniana Merr. & Perry)			9178		
Canthium cf. barbatum Seem.			7246		
Canthium longiflorum (Val.) Merr. & Perry				SISA	
Gardenia gjellerupii Val.	19032				
Gardenia lamingtonii F.M. Bail.			9202		
Hedyotis sp. nov. aff. nana Merr. and Perry	19269				
Hydnophytum cf. montiskani Val.			9210		
Hydnophytum cf. parvifolium Val.			9174		
Hydnophytum radicans Becc.				SISA	
Lucinaea cf. ledermannii Val.			9141		
Morinda umbellata L.		19389	9207		
Mussaenda ferruginea K. Sch.			7235		
Myrmecodia pendula Merr. & Perry			9246		
Myrmecodia tuberosa Jack					SR
Nauclea orientalis L.					SR
Pachystylus gulcherianus K. Sch.			9214		
Psychotria amplithyrsa Val. or aff.	19023	19437			
Psychotria leucococca Laut.	19110, 19174, 19192, 19224				
Psychotria dieniensis Merr. and Perry	19101, 19141				
Timonius avenis Val. var. avenis	19168, 19182, 19226				
Timonius belensis Merr. and Perry				SISA	
Timonius grandifolius Val.			7234		
Timonius kaniensis Val.		19282			
Timonius singularis (F.v.M.) L.S. Sm.				SISA	
Timonius trichanthus Merr. and Perry		19438, 19457			
Rutaceae					
Acronychia emarginata Laut.	19234				
Acronychia murina Ridl.				SISA	
Acronychia rugosa Hartley	19189				
Halfordia papuana Laut.	SR	photo		SISA	
Melicope brassii Hartley	19249				
Melicope denhamii (Seem.) Hartley		19304			
*Melicope elleryana (F.v.M.) Hartley				SISA	
Melicope rubra (Laut. & K. Sch.) Hartley	19028, 19159				
Melicope triphylla (Lam.) Merr.		19355			
Melicope xanthoxyloides (F.v.M.) Hartley			7255		
Melicope (between perryae Hartley and trachycarpa Laut.)	19034				
Sabiaceae					
Meliosma pinnata (Roxb.) Maxim.			9221		
Sabia pauciflora Bl.	19121		7233		
Salicaceae					
Casearia monticola Sleum.	19191				
Casearia pachyphylla Gilg.				SISA	

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Sapindaceae					
Dictyoneura obtusa Bl.		19564			
Dodonaea angustifolia L.f.		19528			
Guioa comesperma Radlk.			9138		
Guioa sp. nov. aff. molluscula Radlk.		19366			
Harpullia ramiflora Radlk.		19287, 19342, 19543	7254		
Lepisanthes senegalensis (Poir.) Leenh.			9122		
Mischocarpus largifolius Radlk.		19541			
Mischocarpus pyriformis (F.v.M.) Radlk. ssp. papuanus (Radlk.) R.W. Ham		19292			
Mischocarpus retusus Radlk.				SISA	
Sarcopteryx rigida Radlk.				SISA	
Toeckia cf. erythrocarpum Radlk.			9223 (det. K. Damas)		
Sapotaceae					
Pouteria monticola (Krause) H.J. Lam				SISA	
Scrophulariaceae					
Buddleja asiatica Lour.	19082				
Solanaceae					
Capsicum annuum L. var. annuum					SR
Nicotiana tabacum L.					SR
Physalis peruviana L.	19092				
Solanum anfractum Symon	19014				
Solanum oliverianum Laut. & K. Sch.			7232, 9181		
Sphenostemonaceae					
Quintinia ledermannii Schltr.	19062				
Sphenostemon papuana (Laut.) Steen. & Erdtman	19058, 19167, 19169				
Staphyleaceae					
Turpinia pentandra (Schltr.) v.d. Linden	19035				
Styracaceae					
Styrax argente (Lour.) G. Don			9177		
Symplocaceae					
Symplocos cochinchinensis (Lour.) S. Moore ssp. cochinchinensis var. cochinchinensis		19375, 19409			
Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. leptophylla	19140, 19186				
Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. maculata (Brand) Noot.	19047, 19161				
Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. molobros (Brand) Noot.				SISA	
Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. monticola Noot.				SISA	
Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. ovata Noot.				SISA	
Theaceae					
Eurya kanehirai Kobuski or aff.	19015, 19172				
Eurya tigang K. Sch. and Laut.	19019. 10201				
Gordonia papuana Kobuski		19429			
Ternstroemia britteniana F.v.M.	19039				
Thymelaeaceae					
Phaleria macrocarpa (Scheff.) Boerl.				SISA	

Species	Collection numbers				
	Hides 3	Benaria	Kutubu Limestone	Mt Sisa	other records
Wikstroemia androsaemifolia Decne	19107, 19197				
Trimeniaceae					
Trimenia papuana Ridl.		19558			
Urticaceae					
Cypholophus cf. ledermannii Winkl.	19004				
Cypholophus rotundifolius Winkl. or aff.	19024				
Dendrocnide morobensis Chew	19158				
Elatostema 'tridens group'	19266				
Leucosyke capitellata (Poir.) Wedd.			7229		
Nothocnide melastomatifolia (K. Sch.) Chew	19138, 19144				
Pilea melastomoides (Poir.) Bl.	19155				
Pilea microphylla (L.) Liebm.					SR
Pilea papuana Winkl.				SISA	
Pipturus argenteus (Forst. f.) Wedd.		19481			
Pipturus pullei Winkl.	19012				
Poikilospermum cf. inaequale Chew		19531, 19544			
Pouzolzia hirta (Bl.) Hassk.		19359			
Procris frutescens Bl.		19331			
Verbenaceae					
Stachytarpheta cayennensis (Rich.) M. Vahl					SR
Vitaceae					
Cayratia japonica (Thunb.) Gagn.		19301			
Cissus discolor Bl.					SR
Nothocissus penninervis (F.v.M.) Latiff				SISA	
Tetrastigma papillosum (Bl.) Planch.				SISA	
Tetrastigma pullei Laut.				SISA	
Winteraceae					
Drimys piperita Hook. f. entity macrantha	19233				
Drimys piperita Hook. f. entity montis-wilhelmii	19222				
Zygogynum calothyrsum (Diels) Vink	19037				
Species Count	159	197	116	170	56

**BOTANICAL RESULTS FROM A FLORISTIC
SURVEY OF MONTANE ENVIRONMENTS WITHIN
THE PNG GAS PROJECT CONCESSION**

FIGURES

W. Takeuchi



Figure 1. *Passiflora ligularis* Juss. The coronal segments are conspicuously marked by purple and white horizontal bands.



Figure 2. *Passiflora ligularis* Juss. Although the fruits are visually appealing and supposedly edible, the pulp has a decidedly unsavory 'mousey' odor.



Figure 3. *Nothofagus pullei* Steen. and *Nothofagus rubra* Steenis in the emergent canopy at Hides 3. The two species are the largest trees on the montane karst.



Figure 4. *Lithocarpus rufovillosus* (Markgrf.) Rehd., a dominant canopy species on crestlines and ridges around Benaria.



Figure 5. *Lithocarpus rufovillosus* (Markgrf.) Rehd. Fruit detail.



Figure 6. *Saurauia trugul* Royen. A distinctive and common species in montane environments at Hides. The leaf undersurfaces are densely covered by orange-brown tomentum.



Figure 7. *Saurauia rufa* Burkill is frequently seen as a pioneer shrub in association with *S. trugul* (white arrow).



Figure 8. *Saurauia rufa* Burkill. The fiercely armed stems and foliage are features shared by many congeners.



Figure 9. *Alphitonia ferruginea* Merr. & Perry. The species is a common component of Papuan montane forests. Shown in general aspect. The corymbose (flat-topped) inflorescence is characteristic.



Figure 10. *Alphitonia ferruginea* Merr. & Perry. Closer view of the flowering branch.



Figure 11. *Quintinia ledermannii* Schltr. A common arborescent species of the Highlands region.



Figure 12. *Sphenostemon papuana* (Laut.) Steen. & Erdtman. One of the most frequently collected trees in Papuan montane environments.



Figure 13. *Melicope rubra* (Laut. & K. Sch.) Hartley. Formerly placed in *Acronychia* or *Evodiella*, the species is distinguished by large and attractively coloured capsules with 4-angled sides.



Figure 14. *Fittingia tubiflora* Mez, a common undershrub on the limestone karst. The translucent-pink fruits are very juicy and grapelike in texture.



Figure 15. *Fittingia tubiflora* Mez. Fruit detail.



Figure 16. The showy flowers of *Agalmiella formosa* Hilliard & Burt. The species was recently described from Lake Kutubu and the adjacent districts of Tari, Porgera, and Nipa (Hilliard & Burt 2002).



Figures 17. *Agalmyla formosa* Hilliard & Burt. Long hairs on flowering peduncles (arrow) immediately distinguish this attractive vine from its closest relatives.



Figure 18. *Melodinus forbesii* Fawc. A vining species with occurrences throughout New Guinea and into the eastern islands of Indonesia (Leeuwenberg 2003). The highly fragrant flowers are marked in the center by a yellowish eye.



Figure 19. *Melodinus forbesii* Fawc. The large terminal panicles are distinctive.



Figure 20. *Mucuna albertisii* F.v.M. is a leguminous vine found throughout Papuasia and possibly into the Moluccas (Verdcourt 1979).



Figure 21. *Mucuna albertisii* F.v.M. Flower detail. The corolla is white or pale green.



Figure 22. *Ficus gymnorhiza* Summerh. An easily recognized vine distinguished by attractive nectarine-like figs and leaves with pitted undersides.



Figure 23. *Ficus megalophylla* Diels. Stems are clustered in gregarious colonies in montane understories.



Figure 24. *Ficus megalophylla* Diels. The distinctive figs are closed at the summit by prominent ostiolar bracts.



Figure 25. *Ficus* sp. nov. Showing the large spherical figs with an unusual open orifice.



Figure 26. *Myristica* sp. nov. The new species is characterized by an unusually dense and persistent tomentum of orange-brown hairs.



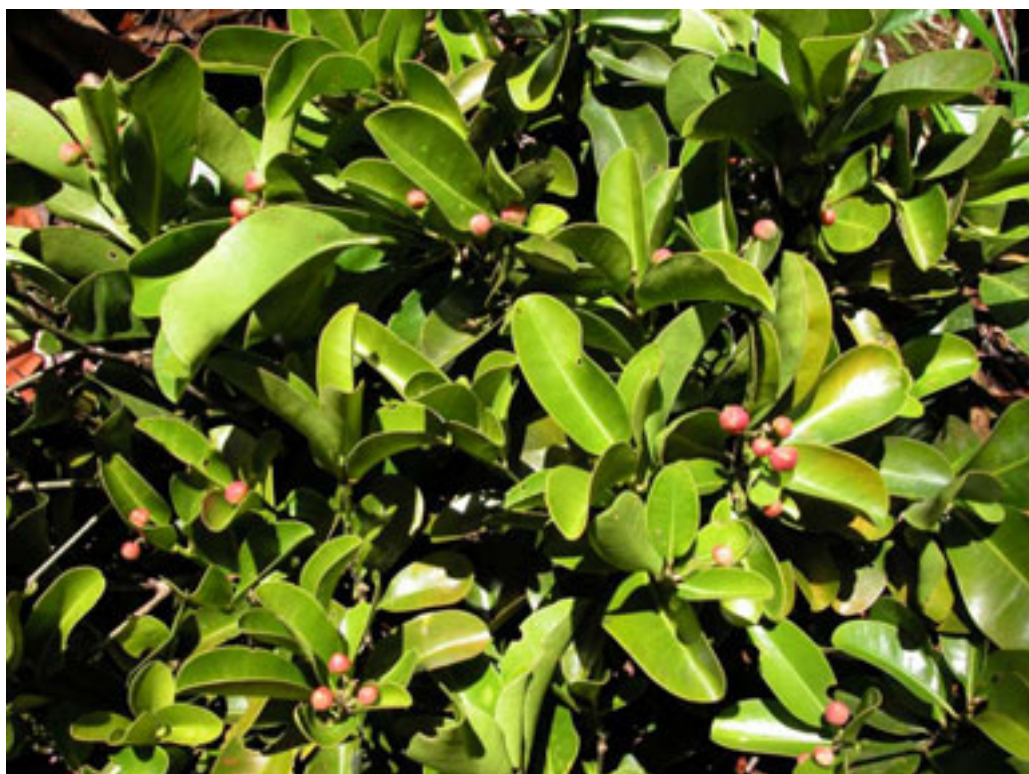
Figure 27. *Myristica* sp. nov. Fruit Detail.



Figure 28. *Myristica ingrata* de Wilde ssp. *ingrata* is part of a myrmecophilous complex recently revised by de Wilde (1998). The hollow branches are inhabited by foul-smelling ants.



Figure 29. *Myristica ingrata* de Wilde ssp. *ingrata* Fruits are globose and branchlets are prominently lined by interpetiolar ridges.



Figures 30. *Halfordia papuana* Laut. The species is probably not as rare as implied by its IUCN 'critically endangered' listing.



Figure 31. *Mischocarpus pyriformis* (F.v.M.) Radlk. ssp. *papuanus* (Radlk.) R.W. Ham. Fruits are conspicuously long-stipitate and pendulous on the living plant.

Annex 02

Biodiversity survey results:

**Flora at Juha North, Juha South, Baia River, South Karius and
Deviation Camp in 2008**

Botany of the upstream portion of the PNG LNG Project, Papua New Guinea

Wayne Takeuchi

Tropical Research Biologist, the Herbaria and Arnold Arboretum of
Harvard University

Forest Research Institute, POB 314, Lae, PNG

Report to Coffey Natural Systems

May 2008

Contents

1	EXECUTIVE SUMMARY	5
2	INTRODUCTION	6
3	MATERIALS AND METHODS	8
4	RESULTS	10
4.1	Vegetation Descriptions	10
4.1.1	Juha North survey area (Hm)	10
4.1.2	Juha South survey area (Hm, L)	12
4.1.3	Baia River survey area (Hm, HsCp, Po, Ps)	12
4.1.4	South Karius survey area (Fsw, L)	13
4.1.5	Deviation Camp survey area (LN).	14
4.2	3.2 Noteworthy Collections	14
4.2.1	Burseraceae	16
4.2.2	Elaeocarpaceae	16
4.2.3	Ericaceae	17
4.2.4	Euphorbiaceae	18
4.2.5	Fabaceae	19
4.2.6	Grammitidaceae	19
4.2.7	Lecythidaceae	19
4.2.8	Lindsaea Group	20
4.2.9	Malvaceae s.l. (Sterculiaceae)	20
4.2.10	Meliaceae	20
4.2.11	Moraceae	21
4.2.12	Myristicaceae	21
4.2.13	Myrsinaceae	22
4.2.14	Myrtaceae	22
4.2.15	Proteaceae	23
4.2.16	Rubiaceae	23
4.2.17	Rutaceae	24
4.2.18	Solanaceae	24
5	DISCUSSION	26
5.1	4.1 Elevational Anomalies	26
5.2	4.2 Floristic Diversity	26
5.3	4.3 Project Impacts	27
6	RECOMMENDATIONS	30
6.1	5.1 Ban on Plant Importation	30
6.2	5.2 Plant Quarantine on Human and Vehicular Traffic into Pristine Habitats	30
7	LITERATURE CITED	31
7.	GLOSSARY	37

Tables

Table 1 Flora listed as of conservation concern in the Project Area.

Figures

- Figure 1 Location map of the 2008 surveys, showing major geographic features, pipeline alignments and the position of camps from the 2005 and 2008 surveys.
- Figure 2 Topographic map showing location of camp and sample transects at Juha North Camp.
- Figure 3 Topographic map showing location of camp and sample transects at Juha South Camp.
- Figure 4 Topographic map showing location of camp and sample transects at Baia River Camp.
- Figure 5 Topographic map showing location of camp and sample transects at South Karius Camp.
- Figure 6 Topographic map showing location of camp and sample transects at Deviation Camp.
- Figure 7 *Aceratium pittosporoides* Schltr. Flowers. Shown with intact corollas and (center) with petals removed to reveal internal parts.
- Figure 8 *Aceratium pittosporoides* Schltr. Fruit.
- Figure 9 *Elaeocarpus lingualis* Knuth.
- Figure 10 *Sloanea gymnocarpa* A.C. Smith.
- Figure 11 *Sloanea gymnocarpa* A.C. Smith.
- Figure 12 *Sloanea* sp. nov., aff. *tieghemii* (F.v.M.) A.C. Smith.
- Figure 13 *Glochidion beehlerii* Takeuchi.
- Figure 14 *Glochidion beehlerii* Takeuchi.
- Figure 15 *Glochidion beehlerii* Takeuchi
- Figure 16 *Macaranga* sp. nov. A, aff. *salicifolia* Airy Shaw.
- Figure 17 *Macaranga* sp. nov. A, aff. *salicifolia* Airy Shaw.
- Figure 18 *Macaranga* sp. nov. B, aff. 'Dioica Group' sensu Whitmore.
- Figure 19 *Macaranga* sp. nov. B, aff. 'Dioica Group' sensu Whitmore.
- Figure 20 *Macaranga* sp. nov. B, aff. 'Dioica Group' sensu Whitmore.
- Figure 21 *Grammitis* sp. nov.
- Figure 22 *Aglaia* sp. nov., aff. *puberulanthera* C. DC. Habit.
- Figure 23 *Aglaia* sp. nov., aff. *puberulanthera* C. DC.
- Figure 24 *Aglaia* sp. nov., aff. *A. saxonii* Takeuchi. The imparipinnate leaves are similarly unusual, substantially exceeding the corresponding dimensions for any Malesian species with sessile foliage.
- Figure 25 *Aglaia* sp. nov., aff. *A. saxonii* Takeuchi.
- Figure 26 *Fittingia* sp. nov., aff. *mariae* Stone.
- Figure 27 *Fittingia* sp. nov., aff. *mariae* Stone.
- Figure 28 *Loheria reiniana* (Jacobs) Sleumer.
- Figure 29 *Syzygium ubogoensis* Takeuchi.

- Figure 30 *Syzygium ubogoensis* Takeuchi.
Figure 31 *Syzygium* sp. nov., aff. *malaccense* (L.) Merr. & Perry.
Figure 32 *Caelospermum salomoniense* (Engl.) J.T. Johansson.
Figure 33 *Psychotria matambuai* Takeuchi.
Figure 34 *Psychotria matambuai* Takeuchi.
Figure 35 *Psychotria matambuai* Takeuchi.
Figure 36 *Versteegia* sp. nov., aff. ?*minor* Val.
Figure 37 *Versteegia* sp. nov., aff. ?*minor* Val.
Figure 38 *Versteegia* sp. nov., aff. ?*minor* Val.
Figure 39 *Acronychia cartilaginea* Hartley.
Figure 40 *Acronychia reticulata* Laut. subsp. nov.
Figure 41 *Flindersia pimenteliana* F.v.M.
Figure 42 *Flindersia pimenteliana* F.v.M.
Figure 43 *Solanum memecylonoides* Bitter & Schltr.

Appendices

Appendix A Species Database

1 EXECUTIVE SUMMARY

A botanical account is presented of the principal forest environments in the Hides and Juha areas of the PNG LNG Project. The summary comprises one element in a comprehensive study represented by other biological disciplines, as discussed in the main EIS report.

Five localities were surveyed using rapid-assessment methods often employed in plant inventories. The forest formations examined by field reconnaissance have been described and categorized in terms of the Forest Inventory Mapping System.

A provisional checklist is provided for the 1502 specimens obtained during an intensive seven-week itinerary. The compilations currently consist of 783 vascular plant taxa, including 154 pteridophyte species (ferns and lycophytes), 6 gymnosperms, 102 monocots, and 521 dicots. The counts are distributed through 27 pteridophyte families, 3 gymnosperm families, 97 APG (Angiosperm Phylogeny Group) families, and a cumulative total of 345 genera. These figures do not account for families still under study.

Distributional records, rare plants, and other noteworthy taxa are discussed with particular attention to their presumed conservation significance. The survey findings are distilled into a series of proposed management actions highlighting the conservation value of the most critical botanical assets. At least 14 species and 2 subspecies previously unknown to science have been confirmed from ongoing evaluation of the collections, the largest number of new taxa ever obtained by an expedition in Papua New Guinea's post-independence period. Three of the discoveries involve plants of exceptional botanical significance and interest. Taken collectively, the findings indicate the presence of forest environments of extraordinary taxonomic composition and value within the project area.

2 INTRODUCTION

Although the true size of its inventory is unknown and subject to considerable speculation, there is no doubt that the island of New Guinea is home to one of the world's richest floras. Botanical commentators estimate at least 20,000 species are probably present in its forest environments (Johns 1993; Womersley 1978). Using orchids and ferns as biodiversity benchmarks, the most recent assessment places the upper limit of more than 25,000 vascular plants (Supriatna 1999).

For many genera, New Guinea is a regional centre for specific radiation, and the conspectus for certain groups can attain levels usually seen only on continental perspectives. Ferns for example, are represented by 3,000 species (Parris 2007) and orchids by 2,800 (Schuiteman & Vogel 2007). This extraordinary diversification is correlated with the presence of an impressive range of floristic environments rarely seen in island ecosystems. Barthlott et al. (1996, 2005) reported a tracheophytic density of 3,000 to 5,000+ species per 10,000 sq km, and determined the species richness for the area around Mt Wilhelm (05.783° S, 145.025° E) as comprising one of the world's 6 phytomaxima. Current compilations from Flora Malesiana indicate that New Guinea has the highest numbers of indigenous and endemic plant species within Malesia (Balgooy et al. 1996; Welzen 1997). Johns (1993) estimated that the overall percentage of endemics exceeds 70%.

The status of Papuan plant exploration and documentation has been reviewed in a number of general accounts (Beehler 1993; Conn 1994; Damas 1998; Frodin & Gressitt 1982; Johns 1993; Stevens 1989; Takeuchi & Golman 2001). Such evaluations consistently highlight the acutely inadequate coverage of our existing knowledge. On a regional basis, the collections density (CD) for New Guinea is one of the lowest for Malesia, with only the Celebes and Sumatra having similar density indices (Stevens 1989). Assuming a standard of 50–100 collections per 100 sq km as representing 'well-collected' areas, there are very few localities in New Guinea which can be regarded as adequately sampled (*ibid.*). The overall CD for Papuasias is only 30 collections per 100 sq km (Frodin 1990) and for most of New Guinea the CD is less than 25 (Conn 1994). The documentation coverage is so poor that a disproportionate fraction of the flora is known only from one or very few specimens, and basic floristic parameters (e.g. geographic distributions, population variation, rarity values) are uncertain or speculative. Numerous species undoubtedly remain undiscovered.

The gaps in field documentation are exacerbated by parallel deficiencies in scientific literature. At current rates of family revision, a full accounting of the Flora Malesiana (see glossary) will not be completed until the years 2135–2150 (Geesink 1990; Roos 2003). For many speciose families, there are no effective modern summaries of any kind. Plant identifications in such groups are highly contingent upon acquisition of new information.

This penurious state of affairs provides a critical backdrop for understanding the value of exploratory work in areas such as the Kikori basin. Although the collections intensity for Papua New Guinea (PNG) is now nearing the benchmark CD of 50 collections per 100 sq km, the geographic distribution of the coverage is highly uneven and many

areas remain practically unknown (Frodin 1990). At an early point in PNG's sovereign history, Prance (1977) had already identified the southern karst as an area specifically in need of investigation. This appraisal has been reaffirmed in subsequent country reviews by Stevens (1989) and Johns (1993).

The Kikori basin and adjacent uplands (as the Southern Scarp Wet Zone) is ranked among the 16 major terrestrial unknowns in PNG (Sekhran & Miller 1995) and comprises the largest of all the unknown regions. Based on a critical combination of biodiversity values and environmental threats, Takeuchi and Golman (2001) identified the Papuan Austrocraton and adjacent lowlands (encompassing all of Kikori) as the single highest-priority target for botanical survey in PNG. There is arguably no other area in PNG where responsible environmental stewardship will be as consequential for conservation of the endemic flora.

3 MATERIALS AND METHODS

The floristic reconnaissance of habitats addressed by this study was focused on five survey areas along or near the the Juha-Hides Pipeline and the LNG Project Gas Pipeline (Figure 1). Each surveyed locality consisted of a base camp with a radiating network of access tracks into surrounding, pre-targeted habitats. Botanical collections were obtained along these temporary (ca. 1 km long) footpaths on a daily basis, in accordance with the protocols outlined below.

Taken collectively, the survey tracts provide an elevationally-sequenced sample of forest environments within the LNG upstream area of interest. For logistical and reporting purposes, the individual camps were assigned the following designations by survey planners (the camp enumerations are arbitrary and not in chronological or elevation order):

Juha North survey area	05.8078° S, 142.3083° E, elev. 213 m (Figure 2)
Juha South survey area	05.90189° S, 142.436° E, elev. 953 m (Figure 3)
Baia River survey area	06.0205° S, 142.54735° E, elev. 328 m (Figure 4)
South Karius survey area	05.99112° S, 142.67063° E, elev. 1,368 m (Figure 5)
Deviation Camp survey area	06.096767° S, 143.10452° E, elev. 2,060 m (Figure 6)

The botanical study was based on procedures commonly employed by contemporary biodiversity surveys within Papuasias (cf. Balen in press; Beehler & Alonso 2001; Mack 1998; Mack & Alonso 2000; Richards 2007). Although the concept of multidisciplinary evaluations based on short-duration sampling was first developed by Conservation International for their Rapid Assessment Program (RAP), the methodology has since been adopted by numerous operators with similar requirements for site assessment. Particularly in New Guinea, RAP-style surveys are currently the principal means by which botanical data are obtained and compiled for wilderness areas. The PNG LNG Project survey is thus a continuation of contemporary trends, being patterned after the same protocols established by comparable operations elsewhere.

In conformity with rapid-format surveys, the botanical work consisted primarily of opportunistic collecting of tracheophytic plants (i.e. ferns, gymnosperms, and angiosperms). A field team composed of the writer and two assistants collected herbarium specimens during daily hikes through the study areas. Voucher specimens were obtained from all fertile taxa encountered by forest reconnaissance, using tree climbers and 15 m extensible pruning poles as required. Accessory documentation such as bottled flowers, carpological specimens, silica-dried leaf samples (for DNA sequencing), and photographs (8 megapixel digital imagery) were also taken from the more interesting collections. Specimens for exsiccatae were secured in sets of 1–5+ duplicates, then field-packed in 70% ethanol for subsequent processing at the Lae National Herbarium (LAE) and the PNG Forest Research Institute (FRI).

Whenever possible, taxonomic determinations are confirmed with keys from formally published literature and/or by comparison to authentically annotated sheets cited by

authorities. In cases where a genus or family has been revised several times, the most recent one has been selected as the basis for making the identifications. When no modern summary or treatment is available, the collections have been compared against appropriate species diagnoses. In several particularly difficult families (e.g. Melastomataceae, Urticaceae, Zingiberaceae) the most recent treatments were published in the early 1900s and have become acutely outdated. No claims for taxonomic discovery are made in relation to such groups, given the uncertainties in their nomenclature and circumscription.

The botanical results have been compiled into a provisional checklist (Appendix 1) with the reminder that definitive identifications are not always possible. Genera are assigned to families in accordance with the following sources: ferns and fern allies (Croft 1986), gymnosperms (Laubenfels 1988), and angiosperms (Angiosperm Phylogeny Group 1998, 2003). Some of the family assignments will seem odd to traditional botanists (e.g. Flacourtiaceae, Sterculiaceae, and Tiliaceae are eliminated), but the adopted system is consistent with the latest DNA-based phylogenies. The same taxonomic protocols were employed in a previous assessment of the pipeline route (see Annex 01), thus allowing for direct comparison and transference of botanical data between the respective projects.

The Forest Inventory Mapping System (FIMS; Hammermaster & Saunders 1995a, b) is the classification scheme used by nearly all floristic assessments in PNG (cf. Balen in press; Beehler & Alonso 2001; Mack 1998; Richards 2007) and has likewise been adopted for this survey. Despite some shortcomings, FIMS is the only mapping code in PNG designed specifically for electronic applications. Unlike earlier systems (Paijmans 1975; Saunders 1993a, b), FIMS is presented on the spatial scales (1: 250,000 and 1: 100,000) most often used in site assessment. The others are developed only at 1: 1,000,000 scale, a resolution inadequate for survey planning and execution.

4 RESULTS

4.1 Vegetation Descriptions

Forest structures and compositions are characterized below in terms of the Forest Inventory Mapping System, with the applicable typing codes provided in parentheses for each locality. Due to several deficiencies in FIMS methodology, the vegetation descriptions of surveyed areas are not necessarily the same ones charted on corresponding map overlays.

Many of FIMS' shortcomings are consequences of the fact that its mapping assignments were derived entirely from aerial photography, without a collateral program of ground-truthing reconnaissance. FIMS is thus a series of extrapolations and assumptions, in which aerial-photo profiles from known vegetation types were used as a basis for inferring the probable identities of similar-looking areas. Given the time and budgetary constraints of the FIMS program, this methodology was reasonable and necessary. But it was also prone to faulty approximations. As one example of the potential problems, a recent expedition to Lake Tawa (05.595° S, 142.841° E) discovered a new vegetation facies consisting of *Pandanus* savanna covering thousands of hectares, which FIMS had misconstrued as subalpine scrub (Richards 2007, Takeuchi 2007a, b, in press). The 'subalpine scrub' was at least 1,000 m below the FIMS elevational limit for that formation, and had no structural or taxonomic resemblance to such communities. Hammermaster and Saunders (1995a, b) undoubtedly made their anomalous assignment on the basis of 'closest fit', but in the absence of a truthing facility could not have known what was actually on the ground.

Aside from difficulties in interpretation, FIMS mapping decisions are area averages which may or may not give an accurate description of the forest at a specific place. Even on a 1: 250,000 mapping scale, plant communities are heterogeneous entities, and what an observer sees in the field is not necessarily what seems to be there by remote sensing. Previous RAP surveys have observed (e.g. Takeuchi 2000a) that FIMS forest units are a melange of structural types nested within the specified typing code. Owing to the limitations in FIMS methodology, the forest descriptions presented in this study have been developed primarily from actual field reconnaissance, and are not taken uncritically from the FIMS classification.

The forest types examined by this study can be given the following characterizations.

4.1.1 Juha North survey area (Hm)

At ca. 200 m elevation, the Juha North vegetation is primarily an 'Hm' formation (small crowned lowland hill forest), with areas of construction-related regrowth along the base camp periphery. The 'Hm' mapping class is believed to represent the richest forest type in PNG (Louman & Nicholls 1995), an appraisal which is probably correct if applied strictly to patterns of tree diversity. But when total enumerations (including all plants, not just trees) are considered, the highest species counts are actually in premontane/low montane forest at the 'L' class boundary (Takeuchi & Golman 2001).

These previously discerned trends in diversification are consistent with findings from the survey. The only large canopy novelty confirmed so far from the collections (*Aglaia* sp. nov.) is from Juha North, the site where the most phanerophytes (arborescent plants) were expected, based on elevation. However the most new species, all of them understorey or substage taxa, originate from Juha South, at the premontane boundary. Although the numbers may change, the patterns of discovery between the survey areas probably will not.

An anomalous feature of the Juha North vegetation is the presence of plant groups normally found only in montane environments above 1,000 m elevation. *Dimorphanthera denticulifera* from Juha North is a low elevation generic record. There are similarly unexpected occurrences for *Acmena montana* (= *Syzygium* sp.), *Acronychia*, *Argostema*, *Cyrtandra* sect. *Geodesme*, *Discocalyx latepetiolata*, *Lindsaea wernerii*, *Parsonsia sanguinea* var. *brassii*, *Rapanea* (= *Myrsine*), *Rhododendron englerianum*, *Sterculia monticola* var. *laxiflora*, *Vaccinium* sect. *Oarianthe*, and *Zygogynum*. The anomalies include representatives from the families Apocynaceae, Ericaceae, Gesneriaceae, Lindsaeaceae, Mysinaceae, Myrtaceae, Rubiaceae, Rutaceae, Sterculiaceae, and Winteraceae. These irregularities are too taxonomically diverse to be merely coincidental.

Tendencies for elevational records have been noted before in Papuan colline environments. At Lakekamu (Gulf Province) the appearance of montane plants at low altitudes was attributed to high rainfalls (Takeuchi 2000c). This is arguably also the cause for the atypical plant distributions at Juha North. Unfortunately there are no meteorological stations in the foothills of the Papuan Plateau (viz. the Papuan Fold Belt; cf. Löffler 1977) from which rainfalls can be ascertained. The nearest station with published 15-year records is Koroba (3,331 mm annual rainfall at elev. 5,500 m; McAlpine et al. 1983), but the actual precipitation is probably substantially higher for Juha North, near the base of the Plateau. Sekhran and Miller (1995) noted the presence of exceptional rainfalls in the southern foothill zone and predicted that high floristic diversity, including new plant genera, would be found there.

Without actual measurements, rainfall levels must be inferred from stand physiognomies (tree stunting, crown forms such as gnarling, epiphyte loads, bryophytic mass etc.). In this connection, forest structures at Juha North are comparable to what has been seen (pers. obs.) at Wabo (Purari River basin, Gulf Province), which is at a similar elevation of 110 m and also with the same forest type 'Hm' as Juha North (Hammermaster & Saunders 1995b: SB 55-13). Meteorological statistics from Wabo indicate annual rainfalls of 8,700 mm (McAlpine et al. 1983) a figure that is probably closer than the Koroba values, to what is actually being received at Juha North and also at Juha South.

A global sampling program (Gentry 1988) concluded that rainfall is the single most important environmental factor affecting plant diversity. Indications of perhumid climate at the two Juha localities are consistent with the outstanding taxonomic outputs from those places. The findings show that Juha north and Juha South are floristically the richest and most valuable environments examined by this study. The lowland and mid-altitude forests at the far western end of the survey itinerary are thus of particular botanical significance.

4.1.2 Juha South survey area (Hm, L)

Juha South is technically in the ecotone between traditionally defined lowland and montane zones, but due to high rainfalls the area is clearly a well-developed mossy montane forest. Based on observed local conditions, plant communities here have the attributes of FIMS typing class 'L' and are similar to the ridge vegetation found at South Karius. As would be expected from its transitional position, there are some characteristics of 'Hm' forests at Juha South, which become more strongly expressed with descending altitude (e.g. along track 3). At elevations below the base camp site, the forest apparently sheds some of its montane qualities and a less ambiguous 'Hm' formation is established, as suggested by the FIMS typing overlays.

The 'L'-coded habitats at Juha South and South Karius survey areas have essentially the same family profiles but show significant differences at the species level. The latter circumstance is presumably connected to the presence of limestone karst at Juha South. Limestone floras in the Malesian region are generally associated with increased endemism, and this appears to be the case for the Juha karst. Previous estimates regarding the likelihood of floristic discoveries from limestone (e.g. Sekhran & Miller 1995) have been corroborated by the PNG LNG Project investigations of the southern karst. When sites positioned in the premontane transition are also associated with specialized substrates, the combination can be synergistic for botanical discovery. The unusual findings from Juha South are a compelling confirmation of this expectation. However the prediction regarding new genera from the Papuan limestone (*ibid.*) has yet to be realized. All discoveries from the survey are of undescribed species or infraspecific taxa. The recent claim of a new genus from the southern plateau (i.e. '*Vinkiella*' nomen nudum) has been discounted by phytomolecular study (S. Renner, pers. comm.).

Vegetation ecotones like Juha South, or actually, any kind of transitional situation (e.g., forest edges), are preferred venues for botanical exploration and discovery. Whenever floristic environments with different taxonomic sets come into contact, the interface is enriched by the infusion of elements from either set, and the result is a powerful driver for effective collecting. The benefits of prospecting in forest margins have been experienced many times during previous surveys, such that the botanical team consciously targeted these situations for preferential attention. From a plant perspective, mature primary-growth forest is counterintuitively the worst environment for RAP work because of its oftentimes homogeneous structure.

4.1.3 Baia River survey area (Hm, HsCp, Po, Ps)

At this survey area the Baia River follows a narrow channel with vertical escarpments on either side. Due to the topographic constraints, flood surges and landslides are dominant factors affecting the structure and development of plant communities. Site instability is also reflected in the composition of forest substrates, which consisted either of colluvial rubble (mainly sedimentary spalls from surrounding cliffs) or alluvium of various consistencies ranging from silt to large boulders. Mineralized soils are not present, an indication that surface renewal and replacement is an ongoing occurrence at this location.

Vegetation mapping is particularly difficult in topographies such as those present along the Baia River. Communities tend to be abruptly delimited from each other on account of sharp topographic boundaries, such as between escarpment and flood plain, but the vegetation types are of small size and often unchartable. In particular, the alluvial zone immediately bordering the river is clearly a lowland successional facies (Po, Ps) prone to flood-induced upsets, but the occurrences are too narrow for presentation on 1:250,000 overlays (Hammermaster & Saunders 1995b). Along the transition to higher slopes immediately around the base camp, the forest has a small crowned canopy with *Casuarina papuana* [= *Gymnostoma papuana* (S. Moore) L.A.S. Johnson] even though the development (as typing code 'HsCp') is again localized and invisible to the FIMS. At least on a district-wide basis, the ridge forest is an 'Hm' formation as portrayed on SB 54-12 (Hammermaster & Saunders 1995b), but was unsurveyable by the field team because of the topographic obstacles. Adjoining tracts are mapped by FIMS with a disturbance code of '8', meaning that 20% of the forest cover has been removed. Since there is no human habitation nearby, the disturbance probably refers to canopy removal by landslides, especially as the rating applies to a terrain section where large landslips were seen during the helicopter overflights.

Baia riverine communities are mainly composed of pioneer and secondary taxa including *Ficus*, *Macaranga*, *Pimelodendron*, *Pometia*, etc., and apparently represent a flood-resistant or sciophobic subset of taxa from adjacent slopes. It is unusual to find new species in floristic contexts where the plant life is subject to recurring stresses and frequent turnover. Only two novelties were recorded from the Baia River. Significantly, these were not in the alluvial zone, but from higher slopes, suggesting that the hill forest there may be of greater significance than the survey has been able to determine.

4.1.4 South Karius survey area (Fsw, L)

South Karius is an irregular mosaic of natural-growth and anthropogenic vegetation. Most of this area was placed by FIMS mainly within typing class 'L' (small crowned lower montane forest), a facies dominated inter alia, by the families Cunoniaceae, Elaeocarpaceae, Fagaceae, Lauraceae, Myrtaceae, Podocarpaceae, Theaceae, and Winteraceae. Nearly all of the character genera cited by Hammermaster and Saunders (1995a) were recorded from habitats around the base camp. In general, the mapping decisions made by FIMS were confirmed by ground survey and correctly depict the forest status on ridges and slopes. However the swampy, alluvial vegetation is best referred to class 'Fsw' (mixed swamp forest) and is clearly distinct from the better-drained hill environments.

Due to the presence of village settlers near the base camp, there is a discernable increase in weedy species at South Karius, including some cosmopolitan plants not found at any of the other locations. The anthropogenic influences are also reflected in the higher incidence of successional stands along the margins of primary forest. In contrast, the environments at Juha South, Baia River and Deviation Camp survey areas are floristically pristine or nearly so.

4.1.5 Deviation Camp survey area (LN).

Deviation Camp was set in small-crowned *Nothofagus* forest (LN) near the Maruba River. As reported by FIMS, the *Nothofagus* zone in this area extends across a montane tract at least 20 x 15 km (fide Hammermaster & Saunders 1995b).

Nothofagus starkenborghii Steen. forms a monodominant overstorey to ca. 40 m in height at the Deviation Camp. Forest canopies are structurally complex but species-depauperate, with overlapping substrata composed mainly of the genera *Acronychia*, *Elaeocarpus*, *Garcinia*, *Sphenostemon*, and *Syzygium*. Despite the concentration of biomass in higher synusia, most of the taxonomic diversity is actually found in the height interval from 0–5 m, where bryophytes and pteridophytes are particularly well-represented. The diminutive 'tree' ferns *Cyathea microphylloides* Rosenst. and *C. perpelvigera* v.A.v.R. are the most conspicuous components of this ground assemblage.

The Deviation Camp was established near forest communities affected by a 1996-7 fire reportedly induced by El Niño disturbances of that period (pers. comm., Huli respondents). The burn areas are conspicuously marked by large numbers of standing snags and coppicing saplings. Light-demanding *Nothofagus* and successional genera such as *Macaranga*, *Melicope*, *Omalanthus*, and *Pandanus* are dominant phanerophytes in the regrowth. Paradoxically, these woody heliophytes (*Pandanus* is a monocot and thus sens. str. non-woody) are intermingled among shade-adapted plants normally associated only with old-growth understory. The unusual combination suggests either: 1) the ferny, gesnerid-rich understory recovered completely from fire in about 10 years, despite an open canopy, or 2) the former burn was primarily a crown fire which did not affect the ground flora.

A study of El Niño-induced fires at Maimafu (6°43' S, 145°00' E, elev. 1200 m; Takeuchi 1999), showed different effects from those seen at Deviation Camp. In the Maimafu burn, forest structure and post-fire regeneration bore no resemblance to the original vegetation (W. Takeuchi *pers. obs.*). The species composition of Maimafu forests experienced complete replacement in the aftermath of El Niño (as documented by Takeuchi collections 12608–12700 and adjacent number sequences).

The successional patterns documented at Maimafu are typical of forest wild fires. Forest recovery processes seen at Deviation Camp are actually anomalous and may be due to the fact that the area was not in the centre of the burn zone but on its margins. The regrowth anomalies are possibly confined to the burn interface, with different patterns prevailing in the burn centre. Due to safety concerns, observations at the Deviation Camp could not be made along a full traverse of the fire zone, so the possibility of differing edge and centre effects could not be confirmed. However the collective observations from Deviation Camp and Maimafu suggest that the spatial extension of fire and a site's position relative to a fire front will determine the subsequent succession in PNG forest environments.

4.2 Noteworthy Collections

The 1,502 collections made during the PNG LNG Project surveys are an unprecedented tally, considerably exceeding the output from other rapid-assessment

expeditions in Papuasia. Previous RAP undertakings in the post-independence period have never been able to surpass the 800 count mark, primarily due to the logistical and phenological obstacles constraining field investigations (Takeuchi 2007a, in press). Exceptional infrastructure and fortuitous phenologies enabled the botany component to achieve an exemplary level of sampling coverage. Judging from patterns of diminishing returns during the field work, the collecting apparently obtained most of the taxa flowering or fruiting during the survey.

Based on the identifications completed thus far, the expeditionary gatherings consist of at least 783 vascular plant taxa (Appendix 1). Included in the preliminary accounting are 154 pteridophyte species (ferns and lycophytes), 6 gymnosperms, 102 monocots, and 521 dicots. The counts are distributed through 27 pteridophyte families, 3 gymnosperm families, 97 APG (Angiosperm Phylogeny Group) families, and a cumulative total of 345 genera.

These figures may experience further refinement after examination of the taxonomically difficult groups (inter alia Melastomataceae, Orchidaceae, Urticaceae, and Zingiberaceae) but the possibility of additional adjustments will not affect the validity of findings already in hand. As noted in the section on 'materials and methods', no future claims will be made for putative discoveries in unrevised families, due to their taxonomic and nomenclatural instability. There are probably ca. 150 morphospecies in the unrevised groups.

Distributional records, rare plants of conservation value, species new to science, and other noteworthy findings are briefly discussed below in family sequence. **Table 1** provides a compilation of the IUCN-listed plants of conservation concern. .

Table 1 Flora listed as of conservation concern in the Project Area.

Scientific Name	IUCN ¹	PNG Fauna Act ²
<i>Halfordia papuana</i> Laut.	CR	-
<i>Bleasdalea papuana</i> (Diels) Domin	EN	-
<i>Flindersia pimenteliana</i> F.v.M	EN	-
<i>Arthrophyllum proliferum</i> Philipson	VU	-
<i>Helicia acutifolia</i> Sleum.	VU	-
<i>Pterocarpus indicus</i>	VU	-
<i>Aglaia puberulanthera</i>	VU	-
<i>Myristica globosa</i>	NT	-

* Species likely to occur but not yet recorded.

1 IUCN status CR = Critically Endangered; EN = Endangered, VU = Vulnerable, NT = Lower Risk But Near Threatened, DD = Data Deficient

2 Status under the PNG Fauna (Protection and Control) Act. P = Protected, R = Restricted (R)

4.2.1 Burseraceae

Canarium acutifolium (DC.) Merr. var. *pioriverensis* Takeuchi; 23707

Malesian *Canarium* has been treated by Leenhouts (1955a, 1955b, 1956, 1959; cf. also Steenis 1972). There are 20 species reported from New Guinea.

Canarium acutifolium var. *pioriverensis* is a canopy tree with large stipules (to 25 x 6 mm) and drupes (to 27 x 14 mm). The variety is easily distinguished from related taxa by its deciduous habit and the unusual size of the vegetative and fruiting structures (Takeuchi 2000b). Prior to the Juha North collection, var. *pioriverensis* was known only from the type specimen in Chimbu Province. The survey record represents a range disjunction of 270 km west of the original locality.

4.2.2 Elaeocarpaceae

Aceratium pittosporoides Schltr.; 23803, 23890. Figs. 7, 8

A complete suite of diagnostic structures is present on the survey gatherings, including immature buds, anthetic flowers, and ripe fruits. Extant material cited by authorities had either flowers or fruits (not both simultaneously). With a full range of essential characters now available from individual plants, the conspecific status of earlier collections has been confirmed.

Although the latest samples from Deviation Camp have pedicels 3x longer than the description in Coode (1981), the inflorescence is otherwise consistent with published accounts. The linear-acuminate sepals (15–20 x 3–5 mm, bifacially tomentose) are early-falling and were not known until the recent survey.

The survey specimens are an altitudinal record (2,080 m), surpassing the previous limit of 1,400 m.

Elaeocarpus lingualis Knuth; 22548. Fig. 9

Two PNG localities were previously known for this species (Coode 1981). With the latest record from South Karius, the range has been extended into the southern region.

The survey collection is the first to include mature fruits with open flowers, enabling critical comparisons to be made with congeners in the *sepikanus* complex. Species concepts in the *sepikanus* facies are in dire need of refinement because of a general inability to relate fruiting sheets to confirmatory flowering structures. As anticipated by Coode (ibid.) the fruits of *Elaeocarpus lingualis* are indistinguishable from *E. sarcanthus* and *E. sepikanus*.

Elaeocarpus sp. nov., aff. *sericoloides* A.C. Smith; 22581

The only known *Elaeocarpus* with opposite leaves and large fruits is the rarely collected *Elaeocarpus sericoloides* (Coode 1981). A related species with considerably larger leaves, glabrous on all parts, has been found at South Karius. Unfortunately the survey collection consists of a single fruiting specimen without flowers, an inappropriate choice for a type specimen.

Sloanea gymnocarpa A.C. Smith; 22988. Figs. 10, 11

The species is apparently rare, with just four prior collections reported by Coode (1981) and a fifth record recently obtained from Baia River survey area. Based on the presence of intergrading characters, the distinction with *Sloanea forbesii* F.v.M. may require future re-evaluation.

Sloanea sp. nov., aff. *tieghemii* (F.v.M.) A.C. Smith; 22640. Fig. 12

A new species from South Karius is closest to *S. tieghemii*, but differs on the characters given by Coode (1981) for the latter plant.

4.2.3 Ericaceae

Vaccinium sp. nov., aff. *summifaucis* Sleumer; 23199

A specimen culled from a windthrown *Nothofagus* is a new *Vaccinium* in section *Bracteata*. The unusual novelty has a globose corolla only 2 mm in diameter, the smallest flower known among sectional congeners. In size and shape the blossoms are similar to the *Oarianthe* facies, but are assembled into distinct racemes at least 2 cm in length. The leaves are also much larger than the nanophylls or microphylls characteristic of *Oarianthe*.

The Juha species will key to *Vaccinium summifaucis* in Sleumer (1967), but is easily distinguished by the presence of appendages and dorsal spurs on the anther tubules. Considering the size of the genus (ca. 155 species in New Guinea), the novelty is primarily a technical discovery of interest primarily to specialists. However the plant's unusual features still qualify as a significant addition to our knowledge of New Guinea's renowned montane flora.

4.2.4 Euphorbiaceae

Glochidion beehlerii Takeuchi; 23168. Figs. 13 - 15

Glochidion is a prominent component of Malesian forests, typically occurring in regrowth, edge situations, and other heliophytic environments. The 67 Papuan species generally flower along leafy branches or immediately below the leaves (Airy Shaw 1980). Only four species, including *Glochidion beehlerii*, produce fruits in large clusters near the ground (Takeuchi 2003a). Cassowaries are reportedly the dispersal agent for these cauliflorous congeners, a circumstance presumably correlated with the shift from heliophytic to umbrageous forest habitats (Takeuchi 1999).

Although there are some discrepancies with its fructification, the survey voucher has been conservatively placed with *G. beehlerii*, a species formerly known only from the type locality in Chimbu Province. The record from Juha South is a substantial extension in range. Field observations suggest that despite having a much wider distribution than previously supposed, the species is probably a low-density taxon.

Macaranga tsonane Whitmore; 22827

Whitmore (1980) indicated that the species is known only from its type locality. A contemporary collection (Barker 130) from the Freeport area was recently identified (by Whitmore) as *Macaranga tsonane*.

The survey voucher from the Baia River is a country record for PNG.

Macaranga sp. nov. A, aff. *salicifolia* Airy Shaw; 23153, 23161, 23221. Figs. 16, 17

With long-peduncled solitary flowers and fused stipules, the new *Macaranga* from Juha North has the essential characteristics of the '*Longistipulata*' complex, the second largest of Whitmore's (1980a, b) informal groups for New Guinea. The survey specimens have apparent similarities to *M. salicifolia*, a species known only from its Vogelkop type, but differ markedly in leaf shape/size and capsule indument.

Macaranga sp. nov. B, aff. '*Dioica* Group' sensu Whitmore; 23506 ex F. Crome, 23528-A, 23531, 23540. Figs. 18 - 20

The *Dioica* Group (20 species) is the largest complex recognized by Whitmore (1980b) among the 75 species of Papuan *Macaranga*. A new taxon from this alliance was collected at Juha South and is characterized by macrophyllous foliage and red spiny capsules.

Macaranga is a genus primarily of heliophytic environments, such as those associated with anthropogenic activities or with natural agencies (e.g., landslips, windthrows, volcanism) giving rise to similar situations. The Papuan species are usually found in closed forest only as the odd persister from earlier forest-successional events. Due to their visual prominence in open habitats, the light-demanding taxa are collectively well-represented in herbarium collections and the conspectus was thought to be at or near a complete enumeration (Takeuchi 2007b). With the surprising discovery of at least two new *Macaranga*, it is now obvious that undescribed species are still present in PNG environments.

4.2.5 Fabaceae

Pterocarpus indicus Willd.; SR Baia River, Juha North

This species is IUCN-listed as 'vulnerable', but is widely distributed throughout Malesia and eastwards to the Santa Cruz Islands (Verdcourt 1979). As one of the most common trees in New Guinea, it is not under any real threat despite the IUCN ranking.

4.2.6 Grammitidaceae

Grammitis ornatissima (Ros.) Copel.; 22731, 23253

The cited numbers belong with the '*intromissa* group' of Parris (1983), consisting of 17 species endemic to New Guinea.

Grammitis ornatissima is readily distinguished from related taxa by the presence of calcium concretions ('lime dots') on the upper leaf surface. The survey collections from Juha North and Juha South are a distributional record for the PNG Highlands and the southern region.

Grammitis sp. nov.; 23273, 23404, 23518, 23551, 23648. Fig. 21

The distinction between *Grammitis* and allied ferns such as *Ctenopteris* and *Xiphopteris*, has historically been ill-defined (Parris 1983). Past authors have relied primarily on the simple leaves of *Grammitis* (aberrant individuals can be occasionally coarsely toothed or sometimes once-furcate) as a principal criterion for discrimination against the pinnately-leaved or pinnatisect genera.

The discovery at Juha North and Juha South, of a *Grammitis* with dichotomously branching fronds, suggests that separations between grammitioid genera may require redefinition. Leaf morphology apparently cannot be used as a principal basis for identification. The isolated occurrences of forked leaves in previously described species (e.g., in the *G. sumatrana*, *G. caespitosa*, and *G. dolichosora* complexes, sensu Parris 1983) can now be retrospectively interpreted as evidence for a latent dichotomous structure, and not merely as random aberrations.

Collection 23271 has coarse toothing and once-forked leaves characteristic of related taxa such as *G. sumatrana*. It is apparently a hybrid, as suggested by the presence of aborted tetrads in the sporangia.

The new *Grammitis*, with leaves repeatedly forked through 3–4 orders, is a striking addition to the Papuan flora.

4.2.7 Lecythydaceae

Barringtonia josephstaalensis Takeuchi, or aff.; 23504

The species was first described from PNG's Mamose region (Takeuchi 2000a) and presumably recollected several years later on the Bomberai Peninsula of Irian Jaya (Takeuchi 2007d). The linear-lorate leaves and reiterative architecture uniquely distinguish this *Barringtonia* from all other congeners. Despite the biogeographic

improbability of a Mamose-Bomberai disjunction, the same species was believed to be present in both areas owing to similarities in the specimens then available for study. Unfortunately the presumed equivalence is complicated by the absence of fruits on the type gathering, and a corresponding absence of flowers on the collection from Irian Jaya.

The survey voucher from Juha North has aquamarine-blue fruits identical to the distinctive Irian material and is undoubtedly conspecific to the latter. Based on similarities in the available characters, the Mamose *Barringtonia* is apparently present at Juha, and a major range extension to the southern region is thus indicated. Definitive confirmation of this identification will require recovery of flowers and fruits (together) from any of the populations currently assigned to *B. josephstaalensis*.

4.2.8 Lindsaea Group

Lindsaea wernerii Ros.; 23460

Lindsaea wernerii is an epiphytic fern with scattered occurrences from Sumatra to the Mamose provinces of PNG (Kramer 1971). The Juha North collection is the easternmost record for the species and extends the range to New Guinea's southern region.

The fern is normally a montane plant, but has now been recorded by the survey at an unusually low elevation (200 m).

4.2.9 Malvaceae s.l. (Sterculiaceae)

Sterculia monticola Mildbr. var. *laxiflora* Tantra; 23224

Previous collections of this taxon are all from the Mamose provinces of northeast New Guinea (Tantra 1976). The latest record from Juha South extends the varietal range across the Central Divide and into the southern region.

4.2.10 Meliaceae

Aglaia sp. nov., aff. *puberulanthera* C. DC.; 23287, 23300, 23422, 23528-B, 23652, 23665, 23706. Figs. 22, 23

Of the 37 species of Papuan *Aglaia*, only three have simple leaves (Pannell 1992). The simple-leaved taxa (viz., *A. integrifolia* Pannell, *A. leucoclada* C. DC., *A. puberulanthera* C. DC.) are rarely collected and have all been IUCN-listed as 'vulnerable'.

In overall aspect the survey collections are closest to *Aglaia puberulanthera*, a species known thus far from four widely separated localities on mainland New Guinea (Pannell 1992). Within PNG, *A. puberulanthera* has been recorded only from the Waria-Kokoda district in Northern Province. Specimens obtained at the Juha survey areas are superficially similar to that species, but detailed examination of the vouchers has revealed significant differences in foliar and indument characters. In particular, the sessile leaves with spreading stellate hairs are features not found in related congeners, and are sufficient to recognize the survey plants as a newly discovered *Aglaia*.

Aglaia sp. nov., aff. *A. saxonii* Takeuchi; 23573. Figs. 24, 25

The survey specimen from Juha North is a remarkable new species with affinities to *Aglaia saxonii* Takeuchi, a species discovered in 1999 during the TNC Josephstaal RAP to Madang Province. The sessile leaves with progressively reduced leaflets along the rachis are conspicuous points of similarity with *A. saxonii*, and are also suggestive of a possible relationship to *A. subsessilis* Pannell of western Malesia.

The copiously lactiferous fruits on the new tree are of exceptional size (14 x 8.5 cm), substantially larger than any previously reported species from Papuasias. Novelty status for this plant is clearly indicated by the unusual foliage and fructification.

Dysoxylum sp., aff. *pettigrewianum* F.M. Bailey; 22900

Dysoxylum pettigrewianum is a common lowland tree with glabrous foliage. Several historical specimens appear to belong to this species, but have unusually hairy leaflets, and may represent an undescribed novelty allied to *D. pettigrewianum* sensu stricto (Mabberley et al. 1995). The anomalously hairy form has been collected from several localities in NW and NE New Guinea (ibid.) and has now been recorded for the Southern region at Baia River. Unfortunately no flowers have yet been obtained for the hairy morphotype, and its status remains unresolved.

Dysoxylum sp. nov., aff. *phaeotrichum* Harms; 22697

The new species, from South Karius, has a whiplike inflorescence recalling *Dysoxylum phaeotrichum* but is distinguished from the latter by the following characteristics (corresponding characters for *D. phaeotrichum* in parentheses): leaf-blades oblanceolate (linear-elliptic), indument velutinous (sericeous), epicarp dark red when dried (black), fruit indument mealy-papillate (pilose), staminal tube conspicuously toothed (weakly crenate). The two taxa are similarly restricted to New Guinea's central region and are probably sibling or sister species.

4.2.11 Moraceae

Ficus sp. nov., aff. *hypophaea* Schltr.; 22805

Ficus is the fifth largest genus in Papuasias, with an estimated 150 species in New Guinea (Berg & Corner 2005). A previously unknown root climber in section *Rhizocladus* has been discovered near the Baia River, the second *Ficus* novelty to be obtained from the project area in recent years [see Takeuchi 2005a (Annex 01)]. The new vine is distinguished by its large cordate leaves and by sessile figs covered with silky hairs.

4.2.12 Myristicaceae

Myristica globosa Warb.; 23428, 23602, 23623

The species is IUCN-listed as 'near threatened' due to its presumed susceptibility to commercial logging. Fertile collections of *Myristica globosa* were obtained from Juha South and South Karius.

4.2.13 Myrsinaceae

Discocalyx latepetiolata (Mez) Sleumer; 23555

An unusual low-elevation record was obtained for this species in the perhumid hill forest at Juha North. Prior to the PNG LNG Project survey, *Discocalyx latepetiolata* was regarded as a strictly montane tree from 1,065 to 2,835 m (Sleumer 1988). The unexpected occurrences at 240 m are arguably attributable to extremely high rainfalls at the base of the Papuan Fold Belt.

Fittingia sp. nov., aff. *F. mariae* Stone; 23574, 23577, 23698, 23700. Figs. 26, 27

Fittingia is a genus of seven species restricted to the New Guinea mainland (Hu Chi Ming 2001; Sleumer 1988; Stone 1994). Four of the species are either narrow endemics or known only from single specimens.

A new *Fittingia* from Juha North is immediately distinguished by large leaves gradually tapered at both ends and lacking a petiole (all the congeners are clearly petiolate). The recently described *F. mariae* (Stone 1994) and *F. grandiflora* (Hu Chi Ming 2001) have similarly shaped blades, but in addition to a clearly defined petiole, these latter species have contracted inflorescences (<7 cm) while the Juha plants have whiplike panicles among the longest recorded in the genus (>30 cm long).

Loheria reiniana (Jacobs) Sleumer; 22617, 22685. Fig. 28

Sleumer (1988) cites a total of 5 collections of *Loheria reiniana*. Most of the existing specimens have originated from the Papuan districts, but the species is apparently nowhere very common. Lae Herbarium has nearly all the *exsiccatae* studied by Sleumer, including an isotype. The mature fruits are red, spongy, and densely assembled in globose heads. Involucral bracts are deciduous.

Loheria reiniana was found at South Karius as scattered monocaules with leaves in a terminal spray. Its consistent association with mature understoreys suggests that the species is probably heliophobic. In vegetative condition the plants are very reminiscent of pachycaulous *Barringtonia* and can easily be confused for the latter.

Population-based studies have never been made of Papuan *Loheria* due to their rarity. The Karius occurrences now afford that opportunity.

4.2.14 Myrtaceae

Decaspermum bracteatum (Roxb.) A.J. Scott var. *glabrum* A.J. Scott; 22462, 22804, 22866, 23557

The var. *glabrum* is defined by glabrous calyx tubes, acute calyx lobes, and lax panicles. *Decaspermum bracteatum* was previously thought to be represented in PNG only by var. *bracteatum* (Scott 1985). The survey collections from Baia River and South Karius are a PNG distributional record for the glabrous form.

Syzygium ubogoensis Takeuchi; 23118. Figs. 29, 30

The cauliflorous *Syzygium ubogoensis* was previously known only from the type collection, made from limestone ridges in the Lake Kutubu District (Takeuchi 2002). The understory shrub has now been recorded at South Karius and Juha South. Judging from the number of sightings, *S. ubogoensis* is apparently more common than previously supposed.

Syzygium sp. nov., aff. *malaccense* (L.) Merr. & Perry; 23684. Fig. 31

A new species in the *malaccense* complex is distinguished by showy yellow flowers inserted singly on the main trunk, or clustered on old wood. The presumed novelty is thus far known only from the limestone forest at Juha North.

4.2.15 Proteaceae

Helicia acutifolia Sleum.; 22606, 22753

Until its rediscovery at the Hides 2 and 3 wellheads [Takeuchi, 2005a (Annex 01), 2007c], *Helicia acutifolia* had been known only from the type collection made in 1936 at Mt Victoria (Foreman, 1976, 1995). The species is IUCN-listed as 'vulnerable'.

Additional populations of *Helicia acutifolia* have now been confirmed from Juha South and South Karius. In light of the numerous sightings of this tree species during the recent survey, the IUCN 'vulnerable' assessment is probably spurious. Despite its former absence in the scientific record, *H. acutifolia* is very common within the project area and is not subject to any obvious threats. The plant was even seen as an invasive colonizer in anthropogenic habitats (pers. obs.), a circumstance which argues against its IUCN status as a taxon in need of conservation monitoring and possible interventions.

4.2.16 Rubiaceae

Caelospermum salomoniense (Engl.) J.T. Johansson; 22930. Fig. 32

The collection from Juha North is a distributional record for the Trans-Fly and southern region of PNG (see Johansson 1988).

Psychotria matambuai Takeuchi subsp. ?nov.; 23123, 23128, 23220, 23291. Figs. 33 - 35

The species was originally described from a population sample obtained at Crater Mt (Eastern Highlands Province) and was regarded as endemic to that general area (Takeuchi 1999). With the newly acquired specimens from Juha South, the range is extended substantially westwards.

Psychotria matambuai is common on the Juha limestone, where it is found as trees to 15 m in height. As noted in the diagnosis, the orange-red drupes (19–21 x 14–16 mm, exclusive of a prominent 4–5 mm residual calyx) are of unusual size; among the largest reported for eastern Malesia (only *P. howcroftii* Takeuchi and *P. monopedicellata* Sohmer are comparable). Juha specimens have extraordinary fruits to 35 x 28 mm, exceeding all congeneric material from New Guinea, and may require recognition as a subspecific endemic from limestone.

Versteegia sp. nov., aff. ?*minor* Val.; 23649, 23656, 23667. Figs. 36 - 38

Versteegia consists of five species endemic to the Papuan region (Ridsdale et al. 1972). Of the four taxa reported from New Guinea, only *V. cauliflora* (K. Sch. & Laut.) Val. can be considered moderately common. Although the distinctive *V. grandifolia* Val. was recently rediscovered in Madang (Takeuchi 2000a), the other mainland species are known only from their types and are poorly understood.

Given its endemic status and overall rarity, *Versteegia* is a genus of particular significance and interest. The new record from Juha North is a particularly noteworthy discovery.

4.2.17 Rutaceae

Acronychia cartilaginea Hartley; 23857. Fig. 39

The species collected at Deviation Camp was previously known from a single specimen obtained near Tari in 1966.

Acronychia reticulata Laut. subsp. nov.; 23382. Fig. 40

Acronychia reticulata was previously unrecorded from the southern region. The specimen from Juha North is a new subspecies with distinctively foveate fruits.

Flindersia pimenteliana F.v.M.; 23106. Figs. 41, 42

Flindersia is represented by five species of commercial timbers in New Guinea (Hartley 1969). Of the four IUCN-listed taxa in this genus, *F. pimenteliana* (IUCN-listed as 'endangered') is regarded as being at highest risk.

Although *Flindersia pimenteliana* is distributed from the Vogelkop Peninsula to Milne Bay Province (Hartley 1969) it was previously unrecorded from the Trans-Fly and southern region. The collection from Juha South is the first report from Western Province and adjacent districts.

4.2.18 Solanaceae

Solanum memecylonoides Bitter & Schltr.; 23895. Fig. 43

Scientific knowledge of *Solanum memecylonoides* is constrained by its scarcity and the poor data provided with existing specimens (Symon 1985). The survey's detailed observations of the plant's habitat, growth form, and coloration of diagnostic structures (documented by the photos of the species) will enable effective characterization of this rarely seen vine.

The size and habit of mature individuals have never been clearly indicated by earlier collectors. From the newest observations at Deviation Camp, it is now clear that the species is actually a frail, numerous branched, and low-growing liane starting from the ground (previously described as an epiphyte). The slender stems are horizontally clambering rather than strongly ascendant. Filaments and petals are (atypically) white.

Solanum sp. nov., subg. *Lycianthes*, aff. *S. peranomalum* Wernham; 22892

The vining *Solanum* from the Baia River is similar to *S. peranomalum* Wernham, a species known only from the type locality in south Irian Jaya. However the dense indument of stellate hairs readily distinguishes the new plant from its presumed relative (*S. peranomalum* is glabrous on all vegetative parts).

5 DISCUSSION

5.1 Elevational Anomalies

Unexpected patterns in community structure and composition were documented at Juha North and Juha South, as noted in an earlier section on results (subheadings 1a and 1b, respectively). In light of such observations, the FIMS typing system obviously will not provide a complete account of the variation in certain environments, but this does not negate the value of the existing code or of comparable elevation-based classifications. Elevation is the most influential factor determining forest development (Pajmans 1975); no author has ever proposed an alternative basis for classifying the New Guinea vegetation. Under extenuating circumstances, other forces can intervene to deflect forest development from its expected course (*ibid.*). Judging from the recent work at Juha North and South, high rainfalls may be effecting a downward depression of vegetation belts within the project area (coincidentally affording excellent opportunities for future ecological and environmental research). The elevational anomalies should not be interpreted as an argument for discarding the FIMS as a principal planning tool for the PNG LNG Project as there is nothing better.

5.2 Floristic Diversity

It is natural to inquire to what extent the survey's superior outputs are attributable to intrinsic diversity, or alternatively, to logistical and phenological advantages experienced during the study. Probably all of the preceding factors have contributed positively to the final results, but it is impossible to separate the individual contributions. Statistically significant estimates of floristic diversity require methodologies (transects and count plots) specifically designed for species-area enumeration. Such time-consuming procedures are beyond the scope of RAP-style assessment, which by definition, are oriented towards rapid, cost-effective appraisal. The botanical study has established the presence of forest communities having unusual taxonomic compositions. Although statistically-based comparisons cannot be drawn against other floristic environments, the investigation has provided documented evidence of plant occurrences with exceptional conservation and scientific significance. This sort of outcome has traditionally served as the basis for designation of protected areas or other easement interventions, and its legitimacy underpins the recommendations made by this survey. Irrespective of the numbers of species involved, there is clear evidence that project environments have many rare, unusual, or previously unknown plants. The qualitative issues regarding taxonomic values are at least as important as quantitative statistical measures relating to total diversity, and from a conservation perspective, perhaps even more so. A forest primarily composed of widely distributed taxa is not necessarily more valuable than one with lesser numbers of species but with many narrow endemics. Whether or not the surveyed habitats have higher numbers of species than other wilderness areas is quite immaterial. The evidence in hand clearly demonstrates the unique floristic status of the project areas and the need for protective interventions.

5.3 Project Impacts

The highest value assets identified by the survey are mostly forest gap species, or even pioneers adapted to disturbance. Such plants are obligate heliophytes at least at some point in their life cycle, so it is reasonable to assume that pipeline construction would actually improve their population status by creating new opportunities for establishment. However even with the heliophobic plants identified as being of taxonomic or conservation interest, it is very doubtful that the proposed project represents a serious threat. The amount of forest projected for removal is small compared to the total standing acreage. Since the most important taxa are sparsely distributed, the direct construction-related losses will be insignificant when measured against the probable size of existing populations. The diffuse distributions of the conservation assets would make any mitigation measures extremely difficult to implement anyway. Of all the surveyed areas, probably only Juha South can be regarded as having significant concentrations of notable species, and this perception may be an artefact of discontinuous spatial sampling.

In general, the investigated environments are not delimited by obvious abiotic discontinuities which would create specialized habitats within the larger forest matrix. The karst comes closest in qualifying as a specialized environment, but since the Papuan limestone is the largest formation of its kind in New Guinea (Löffler 1977) the direct effects of the Hides to Juha Pipeline RoW would be quite miniscule compared to the collective size of the affected habitats.

No special actions are believed necessary in relation to the newly discovered species. Nearly all of the novelties were seen many times and are not rare at their respective sites of discovery. The sole exception (*Aglaia* sp. nov., with a single collection) is a canopy tree, and would be difficult to detect under normal circumstances even if it were present at relatively high frequencies. The very fact that the new species are present in natural-growth environments implies the existence of unseen and viable populations through the surrounding forest. Most of the novelties are dioecious or functionally unisexual (*Aglaia*, *Fittingia*, *Macaranga*, *Versteegia*) and representatives only of one sex, or nearly so, have thus far been found. It logically follows from their reproduction requirements, that individuals from undiscovered populations must be present in the project areas, otherwise the plants could not have been discovered in the first place. While it is tempting to assume that these species have managed to evade detection because of extreme rarity, a more rational and plausible approach is to view the discoveries within their historical context. As already noted in the introduction to this section, the Papuan Plateau is a conspicuous biotic unknown within one of Malesia's most poorly documented regions. Even if the survey's findings are intriguing, they are indicative not so much of a remarkable local flora, but of a provincial level of documentation so thin that almost any exploration effort can be expected to deliver significant results. The present discoveries should be understood in that sense, against the background of a grossly inadequate level of knowledge which ranks among the world's worst. When the high diversity status of a flora is conjoined with historically low levels of exploration and documentation, discoveries of previously unknown plants are virtually inevitable. Even common plants will be determined as having novelty status under such conditions (Takeuchi 2000a, 2001, 2003a, b).

The direct effects of the Hide to Juha Pipeline RoW are likely to be botanically insignificant. The principal concerns stem primarily from the delayed, indirect impacts of development, in particular the collateral costs of improved access into the project areas.

Many of the surveyed environments are currently in a floristically pristine state. For example, no alien weeds were recorded from Deviation Camp, a status which is nowadays increasingly rare even in highly protected jurisdictions. With the exception of the inhabited areas around South Karius, the survey areas have at most, only a few benign adventives such as *Bidens pilosa* L. and *Ageratum conyzoides* L. (probably waifs brought in by working crews). These accidental introductions are low-growing annuals of limited forest-invasive capacity and are mainly a visual nuisance.

However PNG has many habitat-altering weeds capable of inflicting serious damage on indigenous ecosystems (e.g. *Piper aduncum* L.; see Leps et al. 2002; Rogers & Hartemink 2000). Although such plants are not yet present in upland forests of the study area, this could easily change with future increases in human traffic. The indirect consequences presented by this potential threat will require mitigation through access management, prohibitions on deliberate plant introductions, and quarantine inspections of vehicles moving into presently weed-free habitats.

Prohibitions on plant importation should include all species, even native ones, since intermixing of propagules from different geographic provenances can pollute the integrity of local genetic resources. Human cultivation has already been implicated in corrupting the biogeographic and taxonomic status of woody species such as *Inocarpus fagifer* (Parkinson ex Z) Fosberg and *Averrhoa bilimbi* L. In some localities it is no longer possible to separate the native elements from the introduced ones, or even to ascertain whether the plants are naturally-occurring (Adema 2007; Veldkamp 1971). Juha populations of *Psychotria matambuai* appear to be infraspecifically distinct from eastern forms, but the differences could be erased or reduced if introductions from extra-provincial sources were allowed to contaminate the gene pool.

The possibility of undesirable genetic effects would be even greater with introduction of native plants having known propensities for hybridization (e.g. the many species of montane *Rubus*). Local labourers often bring seeds and seedlings into work sites either for aesthetic purposes or in order to establish subsistence gardens. This practice is deeply ingrained in PNG culture and will be difficult to control, but the failure to do so could result in despoiling the most pristine environments within the PNG LNG Upstream Project Area.

Worst of all are the deliberate introductions of alien plants for which congeners are present in the local flora. At the Hides 3 wellhead, the 2005 survey (Annex 01) documented plantings of *Passiflora ligularis* Juss. at the drill pad [Takeuchi 2005a (Annex 010)]. This species is native to the South American Andes, occupies the same niche as local passion fruit species, and is potentially capable of physically displacing the native taxa. If hybridization were to occur, the unique identity of the local species could be lost through genetic dilution.

Floristic impacts from the PNG LNG Project can be anticipated by examining other resource-development operations in PNG, of which the Porgera Joint Venture (PJV) is

an appropriate model because of its comparable location in the Enga Highlands. During a recent RAP assessment in the PJV concession, there were clear indications of alien plants establishing on roadsides and other avenues of human entry (Takeuchi 2007a). At the Omyaka bivouac (05.527° S, 143.056° E), all the recorded aliens were found along service roads or in immediately adjoining areas, indicating that transport infrastructure was unintentionally facilitating the ingress of unwanted plants. Of particular concern was the apparently recent entry of *Passiflora mollissima* (H.B.K.) Bailey into the montane habitats. Originally from South America, *P. mollissima* has become a serious pest in many Malesian and oceanic ecosystems (de Wilde 1972; HDOA 1992). Unlike the weeds recorded in the survey areas, this vine has a proven capacity for forest destruction because of its ability to form dense thickets over native vegetation.

Irrespective of precautions which may have been adopted against the entry of noxious plants, there are clear connections between road construction and processes of floristic degradation (Conservation International 2003). In a world where the spread of aggressive species is increasingly contributing to the destruction of native floras, areas such as the Papuan karst are becoming rare ecological resources. In terms of preservation status and taxonomic content, the karst flora is an outstanding example of a speciose, intact ecosystem, and one highly deserving of enlightened corporate stewardship.

6 RECOMMENDATIONS

6.1 Ban on Plant Importation

Deliberate introductions of any propagules, to include fruits, seeds, seedlings, and cuttings, should be prohibited. The proposed controls are particularly desirable for the natural-growth environments at Juha South, Deviation Camp, and the Hides wellheads.

6.2 Plant Quarantine on Human and Vehicular Traffic into Pristine Habitats

Prohibitions on deliberate plantings could be unintentionally defeated by the accidental entry of noxious plants into protected habitats. Basic quarantine measures would be needed as a preventive adjunct to an importation ban. Examples of potential actions include pre-entry quarantine checks, removal of soil/seeds from visitors' clothing and personal gear, and establishment of vehicle hygiene stations for hosing of tires and other exposed surfaces to which disseminules might be expected to adhere.

7 LITERATURE CITED

- Adema, F. 2007. Notes on Malesian Fabaceae (Leguminosae-Papilionoideae). 13. The genus *Inocarpus*. *Blumea* 52: 401–407.
- Airy Shaw, H.K. 1980. The Euphorbiaceae of New Guinea. *Kew Bull. Addit. Series* 8. Her Majesty's Stationery Office, London.
- Angiosperm Phylogeny Group. 1998. An ordinal classification for the families of flowering plants. *Ann. Missouri Bot. Gard.* 85 (4): 531–553.
- Angiosperm Phylogeny Group. 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Linn. Soc. London, Bot. Journ. Linn. Soc.* 141: 399–436.
- Balen, van B., ed. In press. A Biodiversity Assessment for the Western Mamberamo, Papua Province, Indonesia. RAP Bulletin of Biological Assessment. Conservation International, Arlington, VA.
- Balgooy, M.M.J. van, P. Hovenkamp, and P. van Welzen. 1996. Phytogeography of the Pacific—floristic and historical distribution patterns in plants. In: A. Keast and S. Miller, eds. *The Origin and Evolution of Pacific Island Biotas: New Guinea to Eastern Polynesia: Patterns and Processes*. SPB Academic Press, Amsterdam, the Netherlands. Pp 191–214.
- Barthlott, W., W. Lauer, and A. Placke. 1996. Global distribution of species diversity in vascular plants: towards a world map of phytodiversity. *Erdkunde. Archiv fur wissenschaftliche Geographie* 50: 317–327.
- Barthlott, W., J. Mutke, D. Rafiqpoor, G. Kier, and H. Kreft. 2005. Global centers of vascular plant diversity. *Nova Acta Leopoldina NF* 92 (342): 61–83.
- Beehler, B., ed. 1993. *Papua New Guinea Conservation Needs Assessment*, Vol. 2. Corporate Press, Inc., Landover, Maryland.
- Beehler, B., and L.E. Alonso, eds. 2001. *Southern New Ireland, Papua New Guinea: a Biodiversity Assessment*. RAP Bulletin of Biological Assessment 21. Conservation International, Washington, DC.
- Berg, C.C., and E.J.H. Corner. 2005. Moraceae (*Ficus*). *Flora Malesiana ser. I*, 17 (2): 1–730.
- Conn, B.J. 1994. Documentation of the flora of New Guinea. In: C.-I Peng and C.H. Chou, eds. *Biodiversity and Terrestrial Ecosystems*. Institute of Botany, Academia Sinica Monograph 14: 123–156.
- Conservation International. 2003. Ecosystem profile: Sumatra, Sundaland. URL: http://www.cepf.net/xp/cepf/where_we_work/sundaland/full_strategy.xml. (link tested active as of May 6, 2008).
- Coode, M.J.E. 1981. Elaeocarpaceae. In: E.E. Henty, ed. *Handbooks of the flora of Papua New Guinea* 2: 38–185.
- Croft, J.R. 1986 (unpublished). Keys to the genera of pteridophytes in Papuasias.
- Damas, K. 1998. The present status of plant conservation in Papua New Guinea. In: C.-I Peng and P.P. Lowry II, eds. *Rare, Threatened, and Endangered Floras of Asia and the Pacific Rim*. Institute of Botany, Academia Sinica Monograph 16: 171–179.

- Foreman, D.B. 1976. A Taxonomic Study of the Genus *Helicia* Lour. (Proteaceae) in New Guinea and Australia with Notes on Origin, Distribution and Ecology. Armidale, New South Wales: University of New England.
- Foreman, D.B. 1995. Proteaceae. In: B.J. Conn, ed. Handbooks of the Flora of Papua New Guinea Vol. 3. Melbourne University Press, Carlton, Victoria. Pp 221–270.
- Frodin, D.G. 1990. Botanical progress in Papuasias. In: P. Baas, K. Kalkman, and R. Geesink, eds. The Plant Diversity of Malesia, Proceedings of the Flora Malesiana Symposium Commemorating Prof. Dr. C.G.G.J. van Steenis. Kluwer Academic Publishers, Dordrecht, Boston, and London. Pp 235–247.
- Frodin, D.G., and J.L. Gressitt. 1982. Biological exploration in New Guinea. In: J.L. Gressitt, ed. Biogeography and Ecology of New Guinea: 87–130. Junk (Monogr. Biol. 42), The Hague.
- Geesink, R. 1990. The general progress of Flora Malesiana. In: P. Baas, K. Kalkman, and R. Geesink, eds. The Plant Diversity of Malesia, Proceedings of the Flora Malesiana Symposium Commemorating Prof. Dr. C.G.G.J. van Steenis. Kluwer Academic Publishers, Dordrecht, Boston, and London. Pp 11–16.
- Gentry, A. 1988. Changes in plant community diversity and floristic composition on environmental and geographical gradients. Ann. Missouri Bot. Gard. 75: 1–34.
- Hammermaster, E.T., and J.C. Saunders. 1995a. Forest Resources and Vegetation Mapping of Papua New Guinea. PNGRIS Publ. 4, CSIRO and AIDAB, Canberra.
- Hammermaster, E.T., and J.C. Saunders. 1995b. Forest Resources and Vegetation Mapping of Papua New Guinea. 1: 250,000 vegetation map overlays separately issued as working copies to PNGRIS Publ. 4, CSIRO and AIDAB, Canberra.
- Hartley, T.G. 1969. A revision of the genus *Flindersia* (Rutaceae). Jour. Arn. Arb. 50 (4): 481–526.
- HDOA (Hawaii Department of Agriculture). 1992. List of plant species designated as noxious weeds for eradication or control purposes. Hawaii Department of Agriculture, Honolulu.
- Hu Chi Ming. 2001. A new species of *Fittingia* (Myrsinaceae) from New Guinea. Blumea 46 (1): 189–191.
- Johansson, J.T. 1988. Revision of the genus *Caelospermum* Blume (Rubiaceae, Rubioideae, Morindeae). Blumea 33: 265–297.
- Johns, R.J. 1993. Biodiversity and conservation of the native flora of Papua New Guinea. In: B. Beehler, ed. Papua New Guinea Conservation Needs Assessment Report, Vol. 2. PNG Dept. of Environment and Conservation, Boroko. Pp 15–75.
- Kramer, K.U. 1971. *Lindsaea*-group. Flora Malesiana ser. II, 1 (3): 177–254.
- Laubenfels, D.J. de. 1988. Coniferales. Flora Malesiana ser. I, 10 (3): 337–453.
- Leenhouts, P.W. 1955a. The genus *Canarium* in the Pacific. B.P. Bishop Museum Bulletin 216: 1–53.
- Leenhouts, P.W. 1955b. *Florae Malesianae Precursores* XI. New taxa in *Canarium*. Blumea 8: 181–194.
- Leenhouts, P.W. 1956. Burseraceae. Flora Malesiana ser. I, 5: 209–296.

- Leenhouts, P.W. 1959. Revision of the Burseraceae of the Malaysian area in a wider sense. Xa. Canarium Stickm. Blumea 9: 275–647.
- Leps, J., V. Novotny, L. Cizek, K. Molem, B. Isua, W. Boen et al. 2002. Successful invasion of the neotropical species *Piper aduncum* in rain forests in Papua New Guinea. Appl. Veg. Sci. 5: 255–262.
- Löffler, E. 1977. Geomorphology of Papua New Guinea. CSIRO and Australian National University Press, Canberra.
- Louman, B., and S. Nicholls. 1995. Forestry in Papua New Guinea. In: N. Sekhran and S. Miller, eds. Papua New Guinea Country Study on Biological Diversity. Colorcraft Ltd, Hong Kong. Pp 155–167.
- Mabberley, D.J., C.M. Pannell, and A.M. Sing. 1995. Meliaceae. Flora Malesiana ser. I, 12 (1): 1–407.
- Mack, A., ed. 1998. A Biological Assessment of the Lakekamu Basin, Papua New Guinea. Rapid Assessment Program Working Papers 9. Conservation International, Washington, DC.
- Mack, A., and L.E. Alonso, eds. 2000. A Biological Assessment of the Wapoga River Area of Northwestern Irian Jaya, Indonesia. RAP Bulletin of Biological Assessment 14. Conservation International, Washington, DC.
- McAlpine, J.R., G. Keig, and R. Falls. 1983. Climate of Papua New Guinea. CSIRO and Australian National University Press, Canberra, London, and Miami.
- Pajmans, K. 1975. Explanatory notes to the vegetation map of Papua New Guinea. Land Research Series 35. CSIRO, Melbourne.
- Pannell, C.M. 1992. A Taxonomic Monograph of the Genus *Aglaia* Lour. (Meliaceae). Kew Bull. Additional Series XVI. HMSO, London.
- Parris, B.S. 1983. A taxonomic revision of the genus *Grammitis* Swartz (Grammitidaceae: Filicales) in New Guinea. Blumea 29: 13–222.
- Parris, B.S. 2007. Chapter 3.4. Ferns and lycophytes of Papua. In: A.J. Marshall and B.M. Beehler, eds. The Ecology of Papua. The Ecology of Indonesia Volume 5. Conservation International. Periplus HK Editions, Singapore. Pp 335–343.
- Pigram, C.J., and H.L. Davies. 1987. Terranes and the accretion history of the New Guinea orogen. Bureau of Mineral Resources, J. Austr. Geol. Geoph. 10: 193–211.
- Pigram, C.J., and H. Panggabean. 1984. Rifting of the northern margin of the Australian continent and the origin of some microcontinents in eastern Indonesia. Tectonophysics 107: 331–353.
- Prance, G.T. 1977. Floristic inventory of the tropics: where do we stand? Ann. Missouri Bot. Gard. 64: 659–684.
- Richards, S., ed. 2007. A Rapid Biodiversity Assessment of the Kaijende Highlands, Enga Province, Papua New Guinea. RAP Bulletin of Biological Assessment 45. Conservation International, Arlington, VA.
- Ridsdale, C.E., R.C. Bakhuizen van den Brink, and J. Koek-Noorman. 1972. Notes on New Guinea Rubiaceae. *Versteegia* and *Maschalodesme*. Blumea 20 (2): 339–348.
- Rogers H.M., and A.E. Hartemink. 2000. Soil seed bank and growth rates of an invasive species, *Piper aduncum*, in the lowlands of Papua New Guinea. J. Trop. Ecol. 16: 243–251.

- Roos, M.C. 2003. Flora Malesiana 1991–2001. What has been achieved: revitalisation, momentum? What next? Proceedings of the 5th International Flora Malesiana Symposium 2001. *Telopea* 10 (1): 1–10.
- Saunders, J.C. 1993a. Forest Resources of Papua New Guinea. Colour maps (4) at 1: 1,000,000 scale. PNGRIS Publication 2. CSIRO, Canberra.
- Saunders, J.C. 1993b. Forest Resources of Papua New Guinea. Explanatory Notes to Map. PNGRIS Publication 2. CSIRO and Australian International Development Assistance Bureau, Canberra.
- Schuiteman, A., and E. de Vogel. 2007. Orchidaceae of Papua. In: A.J. Marshall and B.M. Beehler, eds. *The Ecology of Papua. The Ecology of Indonesia Volume 5. Conservation International. Periplus HK Editions, Singapore.* Pp 435–456.
- Scott, A.J. 1985. *Decaspermum* (Myrtaceae) in New Guinea. *Kew Bull.* 40 (1): 149–165.
- Sekhran, N., and S. Miller, eds. 1995. Papua New Guinea Country Study on Biological Diversity. Colorcraft Ltd, Hong Kong.
- Sleumer, H. 1967. Ericaceae. *Flora Malesiana ser. I*, 6 (5): 669–914.
- Sleumer, H. 1988. The genera *Discocalyx* Mez, *Fittingia* Mez, *Loheria* Merr., and *Tapeinosperma* Hook. f. (Myrsinaceae) in New Guinea. *Blumea* 33 (1): 81–107.
- Steenis, C.G.G.J. van. 1972. Addenda, corrigenda et emendanda. *Canarium. Flora Malesiana ser. I*, 6: 921–928.
- Stevens, P.F. 1989. New Guinea. In: D.G. Campbell and H.D. Hammond, eds. *Floristic Inventory of Tropical Countries: the Status of Plant Systematics, Collections, and Vegetation, Plus Recommendations for the Future.* New York Bot. Gard., New York. Pp 120–132.
- Stone, B.C. 1994. New and noteworthy Malesian Myrsinaceae, VIII. *Sida* 16 (2): 263–272.
- Supriatna, J., ed. 1999. The Irian Jaya Biodiversity Conservation Priority-Setting Workshop. Final report. Conservation International, Washington, DC.
- Symon, D.E. 1985. The Solanaceae of New Guinea. *Journ. Adelaide Bot. Gard.* 8: 1–171.
- Takeuchi, W. 1999. New plants from Crater Mt., Papua New Guinea, and an annotated checklist of the species. *Sida, Contributions to Botany* 18 (4): 961–1006.
- Takeuchi, W. 2000a. A floristic and ethnobotanical account of the Josephstaal Forest Management Agreement Area, Papua New Guinea. *Sida, Contributions to Botany* 19 (1): 1–63.
- Takeuchi, W. 2000b. Additions to the flora of Crater Mt., Papua New Guinea. *Sida, Contributions to Botany* 19 (2): 237–247.
- Takeuchi, W. 2000c. *Rhododendron loranthiflorum* (Ericaceae) from mainland New Guinea. A distributional record and new subspecies. *Edinb. J. Bot.* 57 (3): 333–337.
- Takeuchi, W. 2001. New and noteworthy plants from recent botanical surveys in Papua New Guinea, 7. *Edinb. J. Bot.* 58: 159–172.
- Takeuchi, W. 2002. Notes and new species in Papuan *Syzygium* (Myrtaceae). *Edinburgh Journal of Botany* 59 (2): 259–272.

- Takeuchi, W. 2003a. Two new species from the Bomberai Peninsula of Indonesian Papua, New Guinea. *Harvard Papers in Botany* 7 (2): 467–471.
- Takeuchi, W. 2003b. Plant discoveries from PABITRA-related exploration in Papua New Guinea. *Organisms, Diversity and Evolution* 3 (2): 77–84. Elctr. suppl.: colour pictures, pdf-format, 2.1 MB at <http://www.senckenberg.uni-frankfurt.de/odes/03-03.htm>. (link tested active as of May 6, 2008).
- Takeuchi, W. 2005a. Botanical results from a floristic survey of montane environments within the PNG Gas Project area. *Environmental Impact Statement Volume 1. Main Report Text. Report CR 790-20-Rev4. Esso Highlands Ltd., Oil Search, and Enesar Pty. Ltd. (Annex 01 to Biodiversity Appendix)*
- Takeuchi, W. 2005b (unpublished). Compilation of herbarium and literature records for IUCN-listed plants, with recommendations for delisting and database additions. Consultancy report prepared for Conservation International.
- Takeuchi, W. 2007a. Vascular plants of the Kaijende Highlands, Papua New Guinea: taxonomic and vegetation survey. In: S.J. Richards, ed. *A Rapid Biodiversity Assessment of the Kaijende Highlands, Enga Province, Papua New Guinea. RAP Bulletin of Biological Assessment* 45. Conservation International, Arlington, VA. Pp 25–39, 71–86.
- Takeuchi, W. 2007b. Additions to the flora of the Kaijende Highlands, Papua New Guinea: *Macaranga daviesii* (Euphorbiaceae), a new calciphilous species from the Paiela limestone. *Harvard Papers in Botany* 12 (2): 389–394.
- Takeuchi, W. 2007c. A new fern and two floristic records from the Karius limestone of Papua New Guinea. *Edinb. J. Bot.* 64 (1): 7–15.
- Takeuchi, W. 2007d. Chapter 3.1. Introduction to the flora of Papua. In: A.J. Marshall and B.M. Beehler, eds. *The Ecology of Papua. The Ecology of Indonesia Volume 5. Conservation International. Periplus HK Editions, Singapore.* Pp 269–302.
- Takeuchi, W. n press. Additions to the flora of the Kaijende Highlands, Papua New Guinea: *Glochidion welzenii* (Euphorbiaceae), a new species from the Paiela limestone district. *Blumea* 53.
- Takeuchi, W. In press. A synopsis of taxonomic and floristic records from the 2007 west Mamberamo Expedition to Papua Province, Indonesia. In: B. van Balen, ed. *A Biodiversity Assessment for the Western Mamberamo, Papua Province, Indonesia. RAP Bulletin of Biological Assessment. Conservation International, Arlington, VA.*
- Takeuchi, W. and M. Golman. 2001. Botanical documentation imperatives: some conclusions from contemporary surveys in Papuasia. *Sida* 19 (3): 445–468.
- Tantra, I.G.M. 1976. A revision of the genus *Sterculia* L. in Malesia. *Forest Research Institute Communication. Bogor, Indonesia.*
- Veldkamp, J.F. 1971. Oxalidaceae. *Flora Malesiana ser. I*, 7 (1): 151–178.
- Verdcourt, B. 1979. A manual of New Guinea legumes. *Botany Bull.* 11, Office of Forests, Div. of Botany, Lae.
- Welzen, P.C. van. 1997. Increased speciation in New Guinea: tectonic causes? In: J. Dransfield, M.J.E. Coode, and D.A. Simpson, eds. *Plant Diversity in Malesia III. Proceedings of the Third International Flora Malesiana Symposium 1995. Royal Botanic Gardens, Kew.* Pp 363–387.

- Whitmore, T.C. 1980a. *Macaranga* in New Guinea and the Bismarck Archipelago. Kew Bull. 34 (3): 599–606.
- Whitmore, T.C. 1980b. *Macaranga*. In H.K. Airy Shaw. The Euphorbiaceae of New Guinea. Kew Bull. Addit. Ser. 8: 123–162.
- Wilde, W.J.J.O. de. 1972. *Passifloraceae*. Flora Malesiana ser. I, 7 (2): 405–434.
- Womersley, J.S., ed. 1978. Handbooks of the Flora of Papua New Guinea. Vol. I. Melbourne University Press, Carlton, Victoria.

7. GLOSSARY

adventive	a species introduced by man and subsequently becoming naturalized.
anthetic	referring to the point in flower maturation corresponding to expansion of the perianth.
cauliflorous	flowering along the main stem.
colline	pertaining to environments with low, hilly terrain.
conspectus	content, synopsis; an enumeration of taxa comprising a particular group of plants.
crenate	scallop-shaped, referring especially to margins shallowly furnished with rounded teeth.
deciduous	falling at the end of a growing season or other period of development.
diagnosis	the formal scientific description of a new taxon.
dissepiment	partition or dividing wall, such as the septae between locules.
epicarp	the outer layer or surface of a fruit.
exsiccata(e)	a set of dried specimens with printed collection data, typically affixed to sheets and stored in herbaria.
Flora Malesiana	a series of comprehensive family revisions of the Malesian flora, published at irregular intervals by the National Herbarium Nederlands (Netherlands National Herbarium). The compendium of authoritative taxonomic summaries is currently in volume 18 for flowering plants and volume 3 for ferns and fern allies.
foveate	pitted, the pits solitary or numerous.
glabrous	lacking hairs or scales.
glaucous	covered with a bloom or whitish substance, pruinose.
heliophyte	a light-demanding plant, consisting primarily of pioneer or seral species establishing in forest gaps and newly cleared environments.
indument(um)	a hair- or scale-covering on any plant part.
involucral	pertaining to one or more whorls of reduced leaves or bracts subtending a flower or flower cluster.
lax	loose, with component parts well-separated; the opposite of congested.
lorate	strap-shaped; elongate with more or less parallel sides, often somewhat flaccid or lacking an acute apex.
monocaul	single-stemmed, generally referring to a plant without branches.
pachycaulous	possessing a thick or stout stem.
panicle	an indeterminate branching raceme; an inflorescence in which the branches of the primary axis are racemose and the flowers pedicellate.
papillate	provided with minute pimple-like protuberances (papillae).
Papuasias	the biogeographic region consisting of New Guinea, the Bismarck Archipelago, and the Solomon Islands. Due to pronounced floristic similarities between these three areas, they are usually treated as a single unit in botanical studies.
pilose	furnished with shaggy, soft hairs, usually with the hairs septate.
raceme	a simple, indeterminate inflorescence with stalked flowers.
sciophobic	literally 'shade-fearing'; referring to plants that cannot tolerate shade.
sericeous	with an indument of silky, subappressed hairs.

sessile	lacking a stalk; said of any plant part inserted directly on an axis or receptacle, as for example, a leaf without a petiole.
synusia	a vegetation stratum composed of species with similar stature and life form.
tomentose	densely woolly or pubescent, with matted soft hairs.
trifoliolate	with three leaflets.
umbrageous	shady; implying the presence of multistoried closed-canopy forest.
velutinous	with a velvety indument of erect, moderately firm, and straight hairs.

Appendix A

Species Database

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Ferns & Fern Allies	Adiantaceae	Adiantum aneitense Carr	X									X
Ferns & Fern Allies	Adiantaceae	Adiantum caudatum L.				X						
Ferns & Fern Allies	Adiantaceae	Coniogramme macrophylla (Bl.) Hieron.						X				
Ferns & Fern Allies	Adiantaceae	Hypolepis brooksiae Alderw.								X		
Ferns & Fern Allies	Adiantaceae	Pityrogramma calomelanos (L.) Link						X				
Ferns & Fern Allies	Adiantaceae	Syngamma cf. schlechteri Brause			X							
Ferns & Fern Allies	Adiantaceae	Taenitis blechnoides (Willd.) Sw.	X									
Ferns & Fern Allies	Aspleniaceae	Asplenium acrobryum Christ	X								X	X
Ferns & Fern Allies	Aspleniaceae	Asplenium adiantoides (L.) C. Chr. or aff.		X								
Ferns & Fern Allies	Aspleniaceae	Asplenium bipinnatifidum Baker							X		X	
Ferns & Fern Allies	Aspleniaceae	Asplenium aff. caudatum Forst.		X								
Ferns & Fern Allies	Aspleniaceae	Asplenium cromwellianum Ros.				X						
Ferns & Fern Allies	Aspleniaceae	Asplenium cuneatum Sw.							X			
Ferns & Fern Allies	Aspleniaceae	Asplenium decorum Kunze		X				X		X		
Ferns & Fern Allies	Aspleniaceae	Asplenium keysserianum Ros.						X	X			
Ferns & Fern Allies	Aspleniaceae	Asplenium macrophyllum Sw.		X								
Ferns & Fern Allies	Aspleniaceae	Asplenium morobense Copel.						X	X		X	X
Ferns & Fern Allies	Aspleniaceae	Asplenium nidus L. var. nidus					S					
Ferns & Fern Allies	Aspleniaceae	Asplenium pellucidum Lam. or aff.		X					X		X	
Ferns & Fern Allies	Aspleniaceae	Asplenium phyllitidis Don ssp. malesicum Holttum		X						X		
Ferns & Fern Allies	Aspleniaceae	Asplenium remotum S. Moore		X								
Ferns & Fern Allies	Aspleniaceae	Asplenium sancti-christofori Christ								X		
Ferns & Fern Allies	Aspleniaceae	Asplenium scandens J.J. Sm.			X						X	
Ferns & Fern Allies	Aspleniaceae	Asplenium steerei Harrington									X	X
Ferns & Fern Allies	Aspleniaceae	Asplenium submarginatum Ros.			X			X				
Ferns & Fern Allies	Aspleniaceae	Asplenium tenerum Forst. f.		X				X		X		
Ferns & Fern Allies	Aspleniaceae	Asplenium sp. nov.	X									
Ferns & Fern Allies	Aspleniaceae	Didymochlaena truncatula (Sw.) J.J. Sm.							X			
Ferns & Fern Allies	Aspleniaceae	Diplora aff. longifolia Presl			X							
Ferns & Fern Allies	Athyriaceae	Diplazium accedens Bl.					S			X		
Ferns & Fern Allies	Athyriaceae	Diplazium armatum (Copel.) Holtt.	X									
Ferns & Fern Allies	Athyriaceae	Diplazium asperum Bl.		X								
Ferns & Fern Allies	Athyriaceae	Diplazium cyatheifolium (Rich.) Presl	X									
Ferns & Fern Allies	Athyriaceae	Diplazium scotinum Ros.	X								X	
Ferns & Fern Allies	Athyriaceae	Diplazium sp. = Callipteris spinulosa (Blume) J. Smith		X								

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Ferns & Fern Allies	Blechnaceae	Blechnum fraseri (A. Cunn.) Luerss.										X
Ferns & Fern Allies	Blechnaceae	Blechnum hieronymi Brause	X									
Ferns & Fern Allies	Blechnaceae	*Blechnum decorum Brause (=B. hieronymi)				X						
Ferns & Fern Allies	Blechnaceae	Blechnum keysseri Ros.										X
Ferns & Fern Allies	Cyatheaceae	Cyathea aeneifolia (v.A.v.R.) Domin										X
Ferns & Fern Allies	Cyatheaceae	Cyathea auriculifera Copel.				X						
Ferns & Fern Allies	Cyatheaceae	Cyathea cf. geluensis Ros.				X						
Ferns & Fern Allies	Cyatheaceae	Cyathea cf. hornei (Bak.) Copel.				X			X			
Ferns & Fern Allies	Cyatheaceae	Cyathea foersterii Ros.				X						
Ferns & Fern Allies	Cyatheaceae	Cyathea aff. macgillivrayi (Baker) Domin						X				
Ferns & Fern Allies	Cyatheaceae	Cyathea magna Copel.										X
Ferns & Fern Allies	Cyatheaceae	Cyathea microphyloides Ros.	X									X
Ferns & Fern Allies	Cyatheaceae	Cyathea perpelvigera Holtt.				X			X			X
Ferns & Fern Allies	Cyatheaceae	Cyathea pilulifera Copel.							X			
Ferns & Fern Allies	Cyatheaceae	Cyathea wernerii Ros.						X				
Ferns & Fern Allies	Cyatheaceae	Cyathea sp. A., subg. Sphaeropteris, sect. Sphaeropteris						X				
Ferns & Fern Allies	Cyatheaceae	Cyathea sp. B, subg. Cyathea, sect. Cyathea						X	X		X	
Ferns & Fern Allies	Cyatheaceae	Cyathea sp. nov. section Gymnosphaera	X									
Ferns & Fern Allies	Davalliaceae	Davallia divaricata Bl. var. divaricata		X								
Ferns & Fern Allies	Davalliaceae	Davallia pectinata Sm.					S					
Ferns & Fern Allies	Davalliaceae	Davallia repens (L.f.) Kuhn		X	X			X	X	X	X	X
Ferns & Fern Allies	Davalliaceae	Davallia solida (Forster) Swartz					S					
Ferns & Fern Allies	Davalliaceae	Davallodes novoguineense (Rosenst.) Copel.	X									
Ferns & Fern Allies	Davalliaceae	*Humata similis Copel. (=D. repens)				X						
Ferns & Fern Allies	Davalliaceae	*Humata deltoidea Copel. (=D. repens)				X						
Ferns & Fern Allies	Davalliaceae	Leucostegia pallida (Mett.) Copel.						X	X			
Ferns & Fern Allies	Davalliaceae	Rumohra adiantiformis (Forst. f.) Ching										X
Ferns & Fern Allies	Dennstaedtiaceae	Dennstaedtia glabrata (Ces.) C. Chr.									X	
Ferns & Fern Allies	Dennstaedtiaceae	Dennstaedtia (closest to) glabrata (Ces.) C. Chr.						X				
Ferns & Fern Allies	Dennstaedtiaceae	Dennstaedtia magnifica Copel.						X				
Ferns & Fern Allies	Dennstaedtiaceae	Dennstaedtia novoguineensis (Ros.) Copel.		X								
Ferns & Fern Allies	Dennstaedtiaceae	Dennstaedtia sp., aff. resinifera (Bl.) Mett.							X			
Ferns & Fern Allies	Dennstaedtiaceae	Histiopteris caudatum (Copel.) Holttum				X						
Ferns & Fern Allies	Dennstaedtiaceae	Histiopteris incisa (Thunb.) J. Smith	X									
Ferns & Fern Allies	Dennstaedtiaceae	Hypolepis papuana Bailey				X						

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Ferns & Fern Allies	Dennstaedtiaceae	<i>Pteridium aquilinum</i> (L.) Kuhn					S					
Ferns & Fern Allies	Dipteridaceae	<i>Dipteris conjugata</i> Reinw.							X			
Ferns & Fern Allies	Dryopteridaceae	<i>Arachniodes aristata</i> (Forst. f.) Tindale		X								
Ferns & Fern Allies	Dryopteridaceae	<i>Ctenitis alpina</i> (Ros.) Copel.				X						
Ferns & Fern Allies	Dryopteridaceae	<i>Dryopteris subarborea</i> (Baker) C. Chr., sens. lato						X	X		X	
Ferns & Fern Allies	Dryopteridaceae	<i>Polystichum keysserianum</i> Ros.						X	X		X	X
Ferns & Fern Allies	Equisetaceae	<i>Equisetum ramosissimum</i> Desf. ssp. <i>debile</i> (Vauch.) Hauke					S				X	
Ferns & Fern Allies	Gleicheniaceae	<i>Dicranopteris linearis</i> (Burm. f.) Underw.					S				X	X
Ferns & Fern Allies	Gleicheniaceae	* <i>Diplopterygium sordidum</i> (= <i>Gleichenia sordida</i>)				X					X	
Ferns & Fern Allies	Gleicheniaceae	<i>Gleichenia hirta</i> Bl. var. <i>lanuginosa</i> (v.A.v.R.) Holtt.	X								X	
Ferns & Fern Allies	Gleicheniaceae	<i>Gleichenia sordida</i> Copel.	X									
Ferns & Fern Allies	Grammitidaceae	<i>Calymmodon clavifer</i> (Hook.) Moore										X
Ferns & Fern Allies	Grammitidaceae	<i>Calymmodon cucullatus</i> (Nees & Bl.) Presl										X
Ferns & Fern Allies	Grammitidaceae	<i>Ctenopteris integripaleata</i> Copel.	X						X			X
Ferns & Fern Allies	Grammitidaceae	<i>Ctenopteris stellatosetosa</i> Copel.	X								X	X
Ferns & Fern Allies	Grammitidaceae	<i>Ctenopteris subulatinna</i> (v.A.v.R.) Copel.				X						
Ferns & Fern Allies	Grammitidaceae	<i>Ctenopteris subsecundodissecta</i> (Zoll.) Copel.	X								X	
Ferns & Fern Allies	Grammitidaceae	<i>Ctenopteris taxodioides</i> (Baker) Copel.				X						
Ferns & Fern Allies	Grammitidaceae	<i>Ctenopteris tenuisecta</i> (Bl.) J. Sm.									X	
Ferns & Fern Allies	Grammitidaceae	<i>Ctenopteris yoderi</i> Copel.	X								X	X
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis adspersa</i> (Bl.) Bl.							X			
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis dolichosora</i> (Copel.) Copel.				X		X				X
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis impressa</i> Copel.							X			
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis ornatissima</i> (Ros.) Copel.							X		X	
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis padangensis</i> (Baker) Copel.				X						
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis cf. pleurogrammoides</i> (Ros.) Copel.										X
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis scabristipes</i> (Baker) Copel.				X						
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis sumatrana</i> (Baker) Copel.	X					X				
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis</i> sp. nov. (' <i>dichotoma</i> ')						X	X			
Ferns & Fern Allies	Grammitidaceae	<i>Grammitis</i> sp. nov. (' <i>dichotoma</i> ') hybrid with <i>G. sumatrana</i>							X			
Ferns & Fern Allies	Grammitidaceae	<i>Prosaptia alata</i> (Bl.) Christ		X								
Ferns & Fern Allies	Grammitidaceae	<i>Prosaptia contigua</i> (Forst.) Presl	X	X				X				
Ferns & Fern Allies	Hymenophyllaceae	<i>Hymenophyllum geluense</i> Ros.				X		X				
Ferns & Fern Allies	Hymenophyllaceae	<i>Trichomanes imbricatum</i> (Bl.) Copel.				X						

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Ferns & Fern Allies	Hymenophyllaceae	Trichomanes obscurum Bl.				X		X				
Ferns & Fern Allies	Lindsaea Group	Lindsaea azurea Christ						X				
Ferns & Fern Allies	Lindsaea Group	Lindsaea lucida Bl.						X	X			
Ferns & Fern Allies	Lindsaea Group	Lindsaea microstegia Copel.						X				
Ferns & Fern Allies	Lindsaea Group	Lindsaea obtusa J. Sm.		X				X		X	X	
Ferns & Fern Allies	Lindsaea Group	Lindsaea odorata Roxb.						X				
Ferns & Fern Allies	Lindsaea Group	Lindsaea pulchella (J.J. Sm.) ex Kuhn (closest to) var. blanda (Mett. ex Kuhn) Krame										X
Ferns & Fern Allies	Lindsaea Group	Lindsaea cf. roemeriana Ros.						X				
Ferns & Fern Allies	Lindsaea Group	Lindsaea rosenstockii Brause									X	
Ferns & Fern Allies	Lindsaea Group	Lindsaea wernerii Ros.						X				
Ferns & Fern Allies	Lindsaea Group	Sphenomeris chinensis (L.) Maxon		X						X		
Ferns & Fern Allies	Lindsaea Group	Sphenomeris retusa (Cav.) Maxon						X		X		
Ferns & Fern Allies	Lindsaea Group	Tapeinidium longipinnulum (Ces.) C. Chr.						X				
Ferns & Fern Allies	Lindsaea Group	Tapeinidium novoguineense Kramer							X			
Ferns & Fern Allies	Lomariopsis Group	Bolbitis heteroclita (Presl) Ching			X					X		
Ferns & Fern Allies	Lomariopsis Group	Elaphoglossum favigerum Holtt.	X									
Ferns & Fern Allies	Lomariopsis Group	*Elaphoglossum heterolepium v.A.v.R.				X (Dubious Record)						
Ferns & Fern Allies	Lomariopsis Group	Elaphoglossum novoguineense v.A.v.R.				X					X	
Ferns & Fern Allies	Lomariopsis Group	Elaphoglossum resiniferum Holtt. or aff.	X									
Ferns & Fern Allies	Lomariopsis Group	Lomagramma sinuata C. Chr.		X				X				
Ferns & Fern Allies	Lycopodiaceae	Huperzia phlegmaria (L.) Rothm.		X	X			X				
Ferns & Fern Allies	Lycopodiaceae	Huperzia phlegmarioides (Gaud.) Rothm.		X								
Ferns & Fern Allies	Lycopodiaceae	Hyperzia sp. ?nov.; 'phlegmaria-phlegmarioides facies'		X								
Ferns & Fern Allies	Lycopodiaceae	Lycopodium clavatum L.				X						
Ferns & Fern Allies	Marattiaceae	Marattia coronata Copel. or aff.	X									
Ferns & Fern Allies	Marattiaceae	Marattia cf. costulisora Alston				X						
Ferns & Fern Allies	Marattiaceae	Marattia tafaensis C. Chr.				X					X	
Ferns & Fern Allies	Matoniaceae	*Phanerosorus albido-squamatus' (dubious name; there is no such binomial)				X						
Ferns & Fern Allies	Oleandraceae	Nephrolepis acuminata (Houtt.) Kuhn		X								
Ferns & Fern Allies	Oleandraceae	Nephrolepis biserrata (Sw.) Schott							X		X	
Ferns & Fern Allies	Oleandraceae	Nephrolepis brownii (Desv.) Hovenkamp & Miyam.						X	X	X		
Ferns & Fern Allies	Oleandraceae	Nephrolepis davallioides (Sw.) Kunze									X	

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Ferns & Fern Allies	Oleandraceae	Nephrolepis (closest to) falcata (Cav.) C. Chr.		X								
Ferns & Fern Allies	Oleandraceae	Nephrolepis lauterbachii Christ		X				X	X		X	
Ferns & Fern Allies	Oleandraceae	Oleandra archboldii Copel.			X							
Ferns & Fern Allies	Oleandraceae	Oleandra cuspidata Baker						X			X	
Ferns & Fern Allies	Oleandraceae	Oleandra siboldii Grev.									X	
Ferns & Fern Allies	Oleandraceae	Oleandra wernerii Ros.				X				X		
Ferns & Fern Allies	Ophioglossaceae	Ophioglossum pendulum L.								X		
Ferns & Fern Allies	Osmundaceae	Leptopteris alpina (Baker) C. Chr.									X	X
Ferns & Fern Allies	Plagiogyriaceae	*Plagiogyria glauca (Bl.) Mett.				X						X
Ferns & Fern Allies	Polypodiaceae	Aglaomorpha drynarioides (Hook.) Roos			X					X		
Ferns & Fern Allies	Polypodiaceae	Aglaomorpha heraclea (Kunze) Copel.		X	X			X		X		
Ferns & Fern Allies	Polypodiaceae	Aglaomorpha hieronymi (Brause) Copel.		X								
Ferns & Fern Allies	Polypodiaceae	Aglaomorpha novoguineensis (Brause) C. Chr.						X			X	
Ferns & Fern Allies	Polypodiaceae	Belvisia mucronata (Fée) Copel. var. mucronata		X				X	X		X	
Ferns & Fern Allies	Polypodiaceae	Belvisia novoguineensis (Rosen.) Copel.	X								X	X
Ferns & Fern Allies	Polypodiaceae	Ctenopteris millefolia (Bl.) Copel.										X
Ferns & Fern Allies	Polypodiaceae	Drynaria rigidula Bedd.					S					
Ferns & Fern Allies	Polypodiaceae	Drynaria sparsisora (Desvaux) T. Moore					S	X				
Ferns & Fern Allies	Polypodiaceae	Goniophlebium demersum (Brause) Rodl-Linder						X				X
Ferns & Fern Allies	Polypodiaceae	Goniophlebium cf. demersum (Brause) Rodl-Linder						X	X			
Ferns & Fern Allies	Polypodiaceae	Goniophlebium persicifolium (Desv.) Bedd., or aff.										X
Ferns & Fern Allies	Polypodiaceae	Goniophlebium pseudoconnatum (Copel.) Copel.						X	X		X	
Ferns & Fern Allies	Polypodiaceae	Goniophlebium subauriculatum (Bl.) Presl							X			
Ferns & Fern Allies	Polypodiaceae	Goniophlebium cf. subauriculatum (Bl.) Presl				X						
Ferns & Fern Allies	Polypodiaceae	Lecanopteris deparioides (Ces.) Baker			X			X		X		
Ferns & Fern Allies	Polypodiaceae	Lemmaphyllum accedens (Bl.) Donk						X	X	X		
Ferns & Fern Allies	Polypodiaceae	Microsorium commutatum Copel.	X	X						X		
Ferns & Fern Allies	Polypodiaceae	Microsorium linguiforme (Mett.) Copel.							X	X		
Ferns & Fern Allies	Polypodiaceae	Microsorium membranifolium (R. Br.) Ching			X			X		X		
Ferns & Fern Allies	Polypodiaceae	Microsorium papuanum (Baker) Parris	X	X				X	X		X	
Ferns & Fern Allies	Polypodiaceae	Microsorium powellii (Hook. & Baker) Copel.							X			
Ferns & Fern Allies	Polypodiaceae	Microsorium pteropus (Bl.) Copel.			X							
Ferns & Fern Allies	Polypodiaceae	Microsorium punctatum (L.) Copel.					S	X		X		
Ferns & Fern Allies	Polypodiaceae	Pyrrosia cf. adnascens (Sw.) Ching				X						
Ferns & Fern Allies	Polypodiaceae	Pyrrosia foveolata (Alston) Morton var. foveolata		X								

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Ferns & Fern Allies	Polypodiaceae	<i>Pyrrosia foveolata</i> (Alston) Morton var. <i>lauterbachii</i> (Christ) Hovenkamp						X		X		
Ferns & Fern Allies	Polypodiaceae	<i>Pyrrosia longifolia</i> (N.L. Burm.) Morton				X						
Ferns & Fern Allies	Polypodiaceae	<i>Pyrrosia princeps</i> (Mett.) Morton						X		X		
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea albidosquamata</i> (Bl.) Parris	X	X	X			X		X	X	X
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea costulata</i> (Ces.) Wagner & Grether									X	
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea enervis</i> (Cav.) Ching		X	X							
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea enervis</i> (Cav.) Ching, depauperate form						X				
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea enervis</i> (Cav.) Ching, gramineous 'renifera' form							X		X	
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea enervis</i> (Cav.) Ching, typical New Guinea form						X	X	X		
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea enervis</i> (Cav.) Ching, undulatosinuatus-subundulatus form										X
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea hellwigii</i> (Diels) Hovenkamp							X		X	X
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea</i> cf. <i>hellwigii</i> (Diels) Hovenkamp, atypical form										X
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea plantaginea</i> Brack.		X								
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea</i> sp., plantaginea group							X			
Ferns & Fern Allies	Polypodiaceae	<i>Selliguea</i> sp. nov.	X									
Ferns & Fern Allies	Psilotaceae	<i>Psilotum nudum</i> (L.) Beauv.		X						X		
Ferns & Fern Allies	Pteridaceae	<i>Pteris blumeana</i> Agardh	X									
Ferns & Fern Allies	Pteridaceae	<i>Pteris</i> aff. <i>cretica</i> L								X	X	
Ferns & Fern Allies	Pteridaceae	<i>Pteris excelsa</i> Gaud.		X								
Ferns & Fern Allies	Pteridaceae	<i>Pteris moluccana</i> Bl.								X		
Ferns & Fern Allies	Pteridaceae	<i>Pteris pacifica</i> Hieron.	X		X							
Ferns & Fern Allies	Pteridaceae	<i>Pteris schlechteri</i> Brause									X	
Ferns & Fern Allies	Pteridaceae	<i>Pteris torricelliana</i> Christ									X	
Ferns & Fern Allies	Pteridaceae	<i>Pteris vittata</i> L.	X									
Ferns & Fern Allies	Pteridaceae	<i>Pteris warburgii</i> Christ						X		X		
Ferns & Fern Allies	Schizaeaceae	<i>Lygodium circinnatum</i> (Burm. f.) Sw.						X				
Ferns & Fern Allies	Selaginellaceae	<i>Selaginella</i> aff. 'angustiramea-hieronymiana group'		X							X	X
Ferns & Fern Allies	Tectaria Group	<i>Pleocnemia dahlii</i> (Hieron.) Holttum						X				
Ferns & Fern Allies	Tectaria Group	<i>Tectaria durvillei</i> (Bory) Holttum						X				
Ferns & Fern Allies	Tectaria Group	<i>Tectaria menyanthides</i> (Presl) Copel.								X		
Ferns & Fern Allies	Tectaria Group	<i>Tectaria pleiosora</i> (Alderw.) C. Chr.								X		
Ferns & Fern Allies	Tectaria Group	<i>Tectaria repanda</i> (Willd.) Holtt.		X								
Ferns & Fern Allies	Thelypteridaceae	<i>Amphineuron subattenuatum</i> (Ros.) Holtt.	X									

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Ferns & Fern Allies	Thelypteridaceae	Coryphopteris habbemensis (Copel.) Holtt.				X					X	
Ferns & Fern Allies	Thelypteridaceae	Mesophlebium sp. nov.	X									
Ferns & Fern Allies	Thelypteridaceae	Plesioneuron fulgens (Brause) Holtt.	X									
Ferns & Fern Allies	Thelypteridaceae	Pneumatopteris sogerensis (Gepp) Holtt.		X								
Ferns & Fern Allies	Thelypteridaceae	Pneumatopteris superba (Brause) Holtt.	X								X	X
Ferns & Fern Allies	Thelypteridaceae	Pronephrium womersleyi Holtt.			X							
Ferns & Fern Allies	Thelypteridaceae	Pseudophegopteris cf. padulosa (Bl.) Ching				X						
Ferns & Fern Allies	Thelypteridaceae	Pseudophegopteris cf. cyclocarpa Holtt.				X						
Ferns & Fern Allies	Thelypteridaceae	Sphaerostephanos acrostichoides (Desv.) Holtt.	X									
Ferns & Fern Allies	Thelypteridaceae	Sphaerostephanos archboldii (C. Chr.) Holtt.	X								X	
Ferns & Fern Allies	Thelypteridaceae	Sphaerostephanos confertus (Brause) Holtt.				X						
Ferns & Fern Allies	Thelypteridaceae	Sphaerostephanos hispiduliformis (C. Chr.) Holtt.	X									
Ferns & Fern Allies	Thelypteridaceae	Sphaerostephanos pilososquamatus (v.A.v.R.) Holtt.		X								
Ferns & Fern Allies	Thelypteridaceae	Sphaerostephanos unitus (L.) Holtt. var. papilliferus Holtt.	X					X		X		
Ferns & Fern Allies	Thelypteridaceae	Sphaerostephanos veitchii Holtt.		X								
Ferns & Fern Allies	Vittariaceae	Antrophyum alatum Brack.			X							
Ferns & Fern Allies	Vittariaceae	Antrophyum plantagineum (Cav.) Kaulfuss	X					X	X	X	X	
Ferns & Fern Allies	Vittariaceae	Haplopteris angustifolia (Bl.) Crane		X								
Ferns & Fern Allies	Vittariaceae	Haplopteris elongata (Sw.) Crane		X								
Ferns & Fern Allies	Vittariaceae	Loxogramme paltonioides Copel.	X						X			X
Ferns & Fern Allies	Vittariaceae	Loxogramme sp. [Colysis polysora (Brause) Copel.]							X			
Gymnosperms	Araucariaceae	Araucaria cunninghamii D. Don					S					
Gymnosperms	Cupressaceae	Libocedrus papuana F.v.M. var papuana	X									X
Gymnosperms	Gnetaceae	Gnetum gnemon L.						X		X		
Gymnosperms	Gnetaceae	Gnetum gnemonoides Brongn.								X		
Gymnosperms	Phyllocladaceae	Phyllocladus hypophyllus Hk. f.	X									
Gymnosperms	Podocarpaceae	Dacrydium cornwalliana de Laub.										X
Gymnosperms	Podocarpaceae	Podocarpus neriifolius D. Don				X						
Gymnosperms	Podocarpaceae	Podocarpus pseudobracteatus de Laub.										X
Monocotyledons	Araceae	Alocasia hollrungii Engl.				X		X				
Monocotyledons	Araceae	Alocasia nicolsonii Hay					S				X	
Monocotyledons	Araceae	Amydrium zippelianum (Schott) Nicolson		X								
Monocotyledons	Araceae	Cyrtosperma macrotum Becc. ex Engl.			X							
Monocotyledons	Araceae	Epipremnum cf. papuanum v.A.v.R.				X						
Monocotyledons	Araceae	Holochlamys beccarii Engl.					S			X		

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Monocotyledons	Araceae	Pothos ledermannii Engl. & Krause				X						
Monocotyledons	Araceae	Pothos zippelii Schott			X				X			
Monocotyledons	Araceae	Rhaphidophora conocephala v.A.v.R.				X						
Monocotyledons	Arecaceae	Areca catechu L.					S					
Monocotyledons	Arecaceae	Areca macrocalyx Zipp. ex Bl.				X					X	
Monocotyledons	Arecaceae	Calamus cuthbertsonii Becc.				X						
Monocotyledons	Arecaceae	Calamus humboldtianus Becc.			X							
Monocotyledons	Arecaceae	Caryota rumphiana Martelli					S	X				
Monocotyledons	Arecaceae	Cocos nucifera L.					S					
Monocotyledons	Arecaceae	Metroxylon sagu Rottb.					S					
Monocotyledons	Commelinaceae	Floscopa scandens Lour.		X						X		
Monocotyledons	Commelinaceae	Polia thyrsiflora (Bl.) Steud.			X					X		
Monocotyledons	Costaceae	Costus speciosus (Koen.) J.E. Sm.					S			X		
Monocotyledons	Costaceae	Tapeinochilos ananassae (Hassk.) K. Sch.		X						X		
Monocotyledons	Costaceae	Tapeinochilos brassii Gideon			X							
Monocotyledons	Costaceae	Tapeinochilos pubescens Ridl.			X							
Monocotyledons	Cyperaceae	Capitularina involucrata (Valck.) Kern						X				
Monocotyledons	Cyperaceae	Carex graeffeana Boeck							X			
Monocotyledons	Cyperaceae	Cyperus difformis L.						X				
Monocotyledons	Cyperaceae	Cyperus diffusus Vahl									X	
Monocotyledons	Cyperaceae	Cyperus kyllingia Endl.									X	
Monocotyledons	Cyperaceae	Cyperus melanospermus (Nees) Valck.									X	
Monocotyledons	Cyperaceae	Fimbristylis dichotoma (L.) Vahl						X				
Monocotyledons	Cyperaceae	Fimbristylis littoralis Gaudich.						X				
Monocotyledons	Cyperaceae	Mapania macrocephala (Gaud.) K. Sch.			X							
Monocotyledons	Cyperaceae	Mapania sumatrana (Miq.) Benth.			X							
Monocotyledons	Cyperaceae	Scirpus ternatanus Reinw. ex Miq.								X	X	
Monocotyledons	Cyperaceae	Scleria ciliaris Nees						X			X	
Monocotyledons	Cyperaceae	Scleria terrestris (L.) Fass.		X								
Monocotyledons	Flagellariaceae	Flagellaria indica L.						X				
Monocotyledons	Hemerocallidaceae	Geitonoplesium cymosum (R. Br.) Hook.				X						
Monocotyledons	Hypoxidaceae	Curculigo capitulata (Lour.) Kuntze						X				
Monocotyledons	Laxmanniaceae	Cordyline fruticosa (L.) A. Chev.					S		X			
Monocotyledons	Liliaceae sens. lat.	Dianella ensifolia (L.) DC.				X			X			X
Monocotyledons	Orchidaceae	Appendicula polystachya Schltr.			X							

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Monocotyledons	Orchidaceae	Bulbophyllum foetidum Schltr.		X								
Monocotyledons	Orchidaceae	Calanthe (Styloglossum group)			X							
Monocotyledons	Orchidaceae	Dendrobium cf. cuthbertsonii F.v.M.				X					X	X
Monocotyledons	Orchidaceae	*Dendrobium flox (dubious name; no such binomial known)				X						
Monocotyledons	Orchidaceae	Dendrobium fulgibum Schltr.			X							
Monocotyledons	Orchidaceae	Dendrobium torricellianum Krzl.			X							
Monocotyledons	Orchidaceae	Dipodium pandanum Bail.			X							
Monocotyledons	Orchidaceae	Lepidogyne sceptrum Schltr.			X							
Monocotyledons	Orchidaceae	Podochilus imitans Schltr.			X							
Monocotyledons	Pandanaceae	Freycinetia naumannii Warb.				X						
Monocotyledons	Pandanaceae	Freycinetia sp.									X	
Monocotyledons	Pandanaceae	Pandanus conoideus Lamk				X						
Monocotyledons	Pandanaceae	Pandanus englerianus Mart.				X						
Monocotyledons	Pandanaceae	Pandanus julianetti Mart.				X						
Monocotyledons	Pandanaceae	Pandanus kaernbachii Warb.				X						
Monocotyledons	Pandanaceae	Pandanus sp.						X				
Monocotyledons	Poaceae	Axonopus compressus (Swartz) Beauv.					S					
Monocotyledons	Poaceae	Bambusa vulgaris Schrad.					S					
Monocotyledons	Poaceae	Chrysopogon aciculatus (Retz.) Trin.					S					
Monocotyledons	Poaceae	Coix lachryma-jobi L.					S					
Monocotyledons	Poaceae	Cyrtococcum cf. patens (L.) A. Camus						X				
Monocotyledons	Poaceae	Eragrostis chariis (Schult) Hitchc.						X				
Monocotyledons	Poaceae	Eragrostis cumingii Steud.						X				
Monocotyledons	Poaceae	Garnotia stricta Brongn. var. longiseta Hack.						X	X		X	
Monocotyledons	Poaceae	Ichnanthus vicinus (F.M. Bailey) Merr.									X	
Monocotyledons	Poaceae	Isachne globosa (Thunb.) Kuntze							X		X	
Monocotyledons	Poaceae	Isachne pauciflora Hack.									X	
Monocotyledons	Poaceae	Isachne cf. obtecta Reeder									X	
Monocotyledons	Poaceae	Ischaemum polystachyum Presl									X	
Monocotyledons	Poaceae	Imperata conferta (Presl) Ohwi						X				
Monocotyledons	Poaceae	Leersia hexandra Sw.									X	
Monocotyledons	Poaceae	Miscanthus floridulus (Labill.) Warb.	X									
Monocotyledons	Poaceae	Nastus productus (Pilg.) Holtt.				X						
Monocotyledons	Poaceae	Paspalum conjugatum Berg.								X	X	
Monocotyledons	Poaceae	Pennisetum macrostachyum (Brogn.) Trin.									X	

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Monocotyledons	Poaceae	Pennisetum purpureum Schumach.		X							X	
Monocotyledons	Poaceae	Pogonatherum paniceum (Lam.) Hack.								X		
Monocotyledons	Poaceae	Saccharum robustum Brandes & Jeswiet ex Grassl									X	
Monocotyledons	Poaceae	Sacciolepis indica (L.) Chase									X	
Monocotyledons	Poaceae	Zea mays L.					S					
Monocotyledons	Smilacaceae	Smilax calophylla Wall.				X				X		
Monocotyledons	Smilacaceae	Smilax luzonensis Presl				X						
Monocotyledons	Zingiberaceae	Curcuma australasica Hook. f.			X							
Monocotyledons	Zingiberaceae	Hornstedtia scottiana (F.v.M.) K. Sch.					S				X	
Dicotyledons	Acanthaceae	Dicliptera papuana Warb.		X								
Dicotyledons	Acanthaceae	Rungia klossii S. Moore					S					
Dicotyledons	Actinidiaceae	Saurauia aff. bifida Warb.	X									
Dicotyledons	Actinidiaceae	Saurauia aff. calyptata Laut.	X									
Dicotyledons	Actinidiaceae	Saurauia conferta Warb.	X		X			X		X		
Dicotyledons	Actinidiaceae	Saurauia defaurii (F.v.M.) Diels				X						
Dicotyledons	Actinidiaceae	Saurauia aff. drimytiflora Diels	X									
Dicotyledons	Actinidiaceae	Saurauia aff. drimytiflora Diels (2nd morphospecies)	X									
Dicotyledons	Actinidiaceae	Saurauia naumannii Diels	X									
Dicotyledons	Actinidiaceae	Saurauia cf. nudiflora DC.				X						
Dicotyledons	Actinidiaceae	Saurauia rufa Burkill	X									
Dicotyledons	Actinidiaceae	Saurauia scaberrima Laut.				X						
Dicotyledons	Actinidiaceae	Saurauia schumanniana Diels				X		X				
Dicotyledons	Actinidiaceae	Saurauia trugul Royen	X									
Dicotyledons	Actinidiaceae	Saurauia ser. Setosae aff. ?klinkii Laut. & K. Sch.		X								
Dicotyledons	Actinidiaceae	Saurauia ser. Setosae aff. 'xiphophylla facies'	X									
Dicotyledons	Amaranthaceae	Achyranthes bidentata Bl.		X								
Dicotyledons	Amaranthaceae	Iresine herbstii Hook. f.			X						X	
Dicotyledons	Anacardiaceae	Buchanania arborescens Bl.			X							
Dicotyledons	Anacardiaceae	Dracontomelon dao (Blanco) Merr. & Rolfe					S					
Dicotyledons	Anacardiaceae	Rhus caudata Laut.				X						
Dicotyledons	Anacardiaceae	Rhus taitensis Guillemin		X	X			X		X		
Dicotyledons	Anacardiaceae	Semecarpus aruensis Engl.						X				
Dicotyledons	Anacardiaceae	Semecarpus schlechteri Laut.							X			
Dicotyledons	Annonaceae	Cyathocalyx osmanthus Diels			X							
Dicotyledons	Annonaceae	Mitrella kentii (Bl.) Miq.		X								

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Apiaceae	Centella asiatica (L.) Urb.		X								
Dicotyledons	Apocynaceae sens. lat.	Alyxia sp.									X	X
Dicotyledons	Apocynaceae sens. lat.	Asclepias physocarpa Schltr.					S					
Dicotyledons	Apocynaceae sens. lat.	Cerbera floribunda K. Sch.		X						X		
Dicotyledons	Apocynaceae sens. lat.	Melodinus forbesii Fawc.		X							X	
Dicotyledons	Apocynaceae sens. lat.	Melodinus novoguineensis (Wernh.) Pichon				X						
Dicotyledons	Apocynaceae sens. lat.	Papuechites aambe (Warb.) Markgf.			X							
Dicotyledons	Apocynaceae sens. lat.	Parsonsia curvisepala K. Sch.			X							
Dicotyledons	Aquifoliaceae	Ilex archboldiana Merr. & Perry				X						
Dicotyledons	Aquifoliaceae	Ilex arnhemensis (F.v.M.) Loes.			X							
Dicotyledons	Aquifoliaceae	Ilex scabridula Merr. and Perry				X						
Dicotyledons	Aquifoliaceae	Ilex aff. spicata Bl.										X
Dicotyledons	Araliaceae	Arthropphyllum proliferum Philipson		X								
Dicotyledons	Araliaceae	Gastonia spectabilis (Harms) Philipson		X						X		
Dicotyledons	Araliaceae	Harmsiopanax harmsii K. Sch.	X									X
Dicotyledons	Araliaceae	Mackinlaya celebica (Harms) Philipson		X								
Dicotyledons	Araliaceae	Osmoxylon sessiliflorum (Laut.) Philipson		X								
Dicotyledons	Araliaceae	Polyscias royenii Philipson	X						X			
Dicotyledons	Araliaceae	Polyscias schultzei Harms				X						
Dicotyledons	Araliaceae	'Schefflera' aff. carrii Harms	X									
Dicotyledons	Araliaceae	'Schefflera' dentata Frodin	X								X	
Dicotyledons	Araliaceae	'Schefflera' elliptica (Seem.) Harms			X							
Dicotyledons	Araliaceae	'Schefflera' ischnocarpa Harms				X						
Dicotyledons	Araliaceae	'Schefflera' aff. ? megalantha Harms (section Brassia)		X								
Dicotyledons	Araliaceae	'Schefflera' monimioides Frodin				X						
Dicotyledons	Araliaceae	'Schefflera' setulosa Harms	X									
Dicotyledons	Araliaceae	'Schefflera' straminea Frodin				X						
Dicotyledons	Araliaceae	'Schefflera' sp. 'ischnoacra-forbesii facies'		X								
Dicotyledons	Aristolochiaceae	Aristolochia engleriana Schmidt			X			X				
Dicotyledons	Asteraceae	Adenostemma lavenia (L.) Kuntze		X							X	
Dicotyledons	Asteraceae	Ageratum conyzoides L.					S				X	
Dicotyledons	Asteraceae	Bidens pilosa L. var. minor (Bl.) Sherff					S					
Dicotyledons	Asteraceae	Bidens pilosa L. (close to) var. minor (Bl.) Sherff, deviant form						X			X	
Dicotyledons	Asteraceae	Blumea arfakiana Mart.						X		X		

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Asteraceae	Blumea papuana S. Moore	X									
Dicotyledons	Asteraceae	Blumea riparia (Bl.) DC.			X							
Dicotyledons	Asteraceae	Crassocephalum crepidioides (Benth.) S. Moore					S	X			X	
Dicotyledons	Asteraceae	Emilia sonchifolia (L.) DC. var. javanica (Burm.) Mattfeld					S					
Dicotyledons	Asteraceae	Erechtites valerianifolia (Wolf) DC.								X		
Dicotyledons	Asteraceae	Erigeron sumatrensis Retz		X							X	
Dicotyledons	Asteraceae	Gnaphalium cf. involucratum Forst. f.	X									
Dicotyledons	Asteraceae	Lactuca laevigata (Bl.) DC. var. laevigata	X									
Dicotyledons	Asteraceae	Microglossa pyrifolia (Lamk) O. Ktze.		X								
Dicotyledons	Asteraceae	Mikania cordata (Burm. f.) B.L. Rob.						X			X	
Dicotyledons	Asteraceae	Olearia platyphylla Mattf. var. microcephala Koster	X									
Dicotyledons	Asteraceae	Tithonia diversifolia (Hemsl.) A. Gray		X								
Dicotyledons	Asteraceae	Vernonia arborea Ham.							X			
Dicotyledons	Asteraceae	Vernonia cuneata Less.	X					X				
Dicotyledons	Begoniaceae	Begonia cf. pinnatifida Merr. & Perry			X					X		
Dicotyledons	Bignoniaceae	Pandorea pandorana (Andr.) Steen.		X								
Dicotyledons	Bignoniaceae	Tecomanthe dendrophila (Bl.) K. Sch.		X	X							
Dicotyledons	Boraginaceae	Cynoglossum hellwigii Brand	X								X	
Dicotyledons	Boraginaceae	Tournefortia sarmentosa Lam.								X		
Dicotyledons	Brassicaceae	Rorippa nasturtium-aquaticum (L.) Hayek									X	
Dicotyledons	Burseraceae	Canarium acutifolium (DC.) Merr.			X			X				
Dicotyledons	Campanulaceae	Peracarpa carnososa (Wall.) Hook. f. & Thomson	X									
Dicotyledons	Cannabaceae	Gironniera subaequalis Planch.			X							
Dicotyledons	Caricaceae	Carica papaya L.					S					
Dicotyledons	Caryophyllaceae	Drymaria cordata (L.) Willd. ex Roemer & Schult.					S				X	
Dicotyledons	Casuarinaceae	Casuarina cf. oligodon L.A.S. Johnson					S					
Dicotyledons	Casuarinaceae	Gymnostoma papuanum (S. Moore) L. Johnson								X		
Dicotyledons	Celastraceae	Celastrus monospermoides Loes.		X								
Dicotyledons	Celastraceae	Perrottetia alpestris (Bl.) Loes. ssp. moluccana (Bl.) Ding Hou	X									
Dicotyledons	Celastraceae	Siphonodon celastrineus Griff.			X							
Dicotyledons	Chloranthaceae	Ascarina subsessilis Verdcourt	X									
Dicotyledons	Chloranthaceae	Chloranthus erectus (Buch.-Ham.) Verdcourt		X					X			
Dicotyledons	Clusiaceae	Calophyllum cf. articulatum P.F. Stevens				X						
Dicotyledons	Clusiaceae	Calophyllum cf. gaimanum P.F. Stevens				X						

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Clusiaceae	Calophyllum goniocarpum P.F. Stevens			X							
Dicotyledons	Clusiaceae	Calophyllum sp.									X	X
Dicotyledons	Clusiaceae	Garcinia archboldiana A.C. Smith or aff.	X								X	X
Dicotyledons	Clusiaceae	Garcinia assugu Laut.		X								
Dicotyledons	Clusiaceae	Garcinia celebica L.		X								
Dicotyledons	Clusiaceae	Garcinia hunsteinii Laut.			X			X	X	X		
Dicotyledons	Clusiaceae	Garcinia klinkii Laut.				X						
Dicotyledons	Clusiaceae	Garcinia latissima Miq.		X								
Dicotyledons	Clusiaceae	Garcinia aff. ?schraderi Laut.		X								
Dicotyledons	Clusiaceae	Garcinia cf. warrenii F.v.M.		X								
Dicotyledons	Cornaceae	Alangium javanicum (Bl.) Wangerin	X									
Dicotyledons	Cornaceae	*Alangium ferrugineum C.T. White				X						
Dicotyledons	Corynocarpaceae	Corynocarpus cribbianus (F.M. Bail.) L.S. Sm.										X
Dicotyledons	Cucurbitaceae	Zehneria scabridula (Merr. & Perry) de Wilde	X									
Dicotyledons	Cunoniaceae	*Caldcluvia celebica (Bl.) Hoogl. =Spiraeopsis celebica (Bl.) Miq.				X						
Dicotyledons	Cunoniaceae	Schizomeria serrata (Hochr.) Hochr.	X									X
Dicotyledons	Cunoniaceae	Spiraeopsis celebica (Bl.) Miq.		X								
Dicotyledons	Cunoniaceae	Spiraeopsis papuana (Pulle) L.M. Perry		X								
Dicotyledons	Cunoniaceae	Weinmannia fraxinea (D. Don) Miq.								X		
Dicotyledons	Cunoniaceae	Weinmannia pullei Schltr.	X									
Dicotyledons	Daphniphyllaceae	Daphniphyllum gracile Gage				X			X			
Dicotyledons	Datisceae	Octomeles sumatrana Miq.					S					
Dicotyledons	Dilleniaceae	Dillenia auriculata Mart.			X							
Dicotyledons	Dilleniaceae	Dillenia papuana Mart.									X	
Dicotyledons	Elaeagnaceae	Elaeagnus triflora Roxb. var. breviliimbata T Hart									X	
Dicotyledons	Elaeagnaceae	Elaeagnus triflora Roxb. var. triflora		X								
Dicotyledons	Elaeocarpaceae	Aceratium 'ledermannii-oppositifolium' (intermediate)			X							
Dicotyledons	Elaeocarpaceae	Aceratium muellerianum Schltr.							X			
Dicotyledons	Elaeocarpaceae	Aceratium oppositifolium C. DC.									X	
Dicotyledons	Elaeocarpaceae	Aceratium pittosporoides Schltr.				X						X
Dicotyledons	Elaeocarpaceae	Dubouzetia novoguineensis A.C. Smith				X						
Dicotyledons	Elaeocarpaceae	Elaeocarpus altigenus Schltr.	X									X
Dicotyledons	Elaeocarpaceae	Elaeocarpus altisectus Schltr.				X						
Dicotyledons	Elaeocarpaceae	Elaeocarpus angustifolius Bl.				X						

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Elaeocarpaceae	Elaeocarpus arfakensis Schltr.				X						
Dicotyledons	Elaeocarpaceae	Elaeocarpus culminicola Warb.				X						
Dicotyledons	Elaeocarpaceae	Elaeocarpus dolichodactylus Schltr.									X	
Dicotyledons	Elaeocarpaceae	Elaeocarpus dolichodactylus Schltr., glabrous form							X			
Dicotyledons	Elaeocarpaceae	Elaeocarpus dolichodactylus Schltr., hairy form							X			
Dicotyledons	Elaeocarpaceae	Elaeocarpus fuscoides Knuth or aff.		X								
Dicotyledons	Elaeocarpaceae	Elaeocarpus ledermannii Schltr.				X		X		X		
Dicotyledons	Elaeocarpaceae	Elaeocarpus lingualis Knuth		X						X		
Dicotyledons	Elaeocarpaceae	Elaeocarpus pachyanthus Schltr.		X								
Dicotyledons	Elaeocarpaceae	Elaeocarpus polydactylus Schltr.	X						X			
Dicotyledons	Elaeocarpaceae	Elaeocarpus pycnanthus A.C. Sm.										X
Dicotyledons	Elaeocarpaceae	Elaeocarpus sayeri var. altigenus F.v.M.				X						
Dicotyledons	Elaeocarpaceae	Elaeocarpus sp. nov., aff. sericoloides A.C. Smith									X	
Dicotyledons	Elaeocarpaceae	Sericolea brassii A.C. Smith				X						
Dicotyledons	Elaeocarpaceae	Sericolea micans var. micans Schltr.				X						
Dicotyledons	Elaeocarpaceae	Sloanea forbesii F.v.M.				X						
Dicotyledons	Elaeocarpaceae	Sloanea gymnocarpa A.C. Sm.								X		
Dicotyledons	Elaeocarpaceae	Sloanea (closest to) gymnocarpa A.C. Sm.								X		
Dicotyledons	Elaeocarpaceae	Sloanea ledermannii A.C. Sm.									X	
Dicotyledons	Elaeocarpaceae	Sloanea pulchra (Schltr.) A.C. Smith (probably) ssp. pulchra		X								
Dicotyledons	Elaeocarpaceae	Sloanea tieghemii (F.v.M.) A.C. Sm.										X
Dicotyledons	Elaeocarpaceae	Sloanea aff. tieghemii (F.v.M.) A.C. Sm.									X	
Dicotyledons	Ericaceae	Dimorphanthera amoena Sleumer									X	
Dicotyledons	Ericaceae	Dimorphanthera anchorifera J.J. Sm.	X									
Dicotyledons	Ericaceae	Dimorphanthera cornuta J.J. Sm. (between vars. cornuta & tenuiflora)										X
Dicotyledons	Ericaceae	Dimorphanthera decockii J.J. Sm. var. chlorocarpa (Sleumer) Sleumer							X			
Dicotyledons	Ericaceae	Dimorphanthera decockii J.J. Sm. var. pubiflora Sleumer									X	
Dicotyledons	Ericaceae	Dimorphanthera denticulifera Sleum.				X						
Dicotyledons	Ericaceae	Dimorphanthera denticulifera Sleumer var. pubens Sleumer						X				
Dicotyledons	Ericaceae	*Dimorphanthera dominans Sleum. (illegitimate name)				X						
Dicotyledons	Ericaceae	Dimorphanthera fissiflora (Sleum.) Stevens or aff.	X									
Dicotyledons	Ericaceae	Dimorphanthera inopinata Stevens							X			

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Ericaceae	Dimorphanthera keysseri (Schltr. ex Diels) Stevens				X						
Dicotyledons	Ericaceae	Dimorphanthera aff. lancifolia Sleumer									X	
Dicotyledons	Ericaceae	Diplycosia edulis Schltr.							X		X	X
Dicotyledons	Ericaceae	Diplycosia morobeensis Sleum.	X									
Dicotyledons	Ericaceae	Diplycosia morobeensis Sleumer var. morobeensis										X
Dicotyledons	Ericaceae	Diplycosia rupicola Sleum.				X						
Dicotyledons	Ericaceae	Rhododendron beyerinckianum Koord.	X								X	
Dicotyledons	Ericaceae	Rhododendron cf. scabridibracteum Sleum.				X						
Dicotyledons	Ericaceae	Rhododendron christi Foerster				X						
Dicotyledons	Ericaceae	Rhododendron englerianum Koord.						X				
Dicotyledons	Ericaceae	Rhododendron (closest to) englerianum Koord.						X				
Dicotyledons	Ericaceae	Rhododendron gracilentum F.v.M.				X						
Dicotyledons	Ericaceae	Rhododendron macgregoriae F.v.M.	X									
Dicotyledons	Ericaceae	Rhododendron macgregoriae F.v.M. var. macgregoriae									X	X
Dicotyledons	Ericaceae	Rhododendron wentianum Koord.									X	
Dicotyledons	Ericaceae	Vaccinium (close to) finisterrae Schltr.										X
Dicotyledons	Ericaceae	Vaccinium longiporum Sleum.	X									
Dicotyledons	Ericaceae	Vaccinium psammogenes Sleum.			X							
Dicotyledons	Ericaceae	Vaccinium quinquefidum J.J. Sm.				X						
Dicotyledons	Ericaceae	Vaccinium reticulatovenosum Sleum.	X									
Dicotyledons	Ericaceae	Vaccinium schoddei Sleumer										X
Dicotyledons	Ericaceae	Vaccinium stricaule Sleumer										X
Dicotyledons	Ericaceae	Vaccinium versteegii Koord.						X				
Dicotyledons	Ericaceae	Vaccinium sp. nov., aff. summifaucis Sleumer							X			
Dicotyledons	Ericaceae	Vaccinium sp., sect. Oarianthe							X			
Dicotyledons	Ericaceae	Vaccinium sp. indet									X	
Dicotyledons	Euphorbiaceae sens. lat.	Acalypha cf. grandis Benth.			X							
Dicotyledons	Euphorbiaceae sens. lat.	Acalypha hellwigii Warb. var. mollis (Warb.) K. Sch. & Laut.		X							X	
Dicotyledons	Euphorbiaceae sens. lat.	Antidesma contractum J.J. Sm.			X							
Dicotyledons	Euphorbiaceae sens. lat.	Antidesma erostre F.v.M. ex Benth.				X						
Dicotyledons	Euphorbiaceae sens. lat.	Antidesma myriocarpum Airy Shaw var. myriocarpum		X								

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Euphorbiaceae sens. lat.	Antidesma aff. 'rhynchophyllum-jucundum group'			X							
Dicotyledons	Euphorbiaceae sens. lat.	Aporosa brassii Mansf.		X								
Dicotyledons	Euphorbiaceae sens. lat.	Aporosa papuana Pax & Hoffm.		X								
Dicotyledons	Euphorbiaceae sens. lat.	Breynia cernua (Poir.) Muell. Arg.						X				
Dicotyledons	Euphorbiaceae sens. lat.	Bridelia cernua (Poir.) Muell.-Arg.				X						
Dicotyledons	Euphorbiaceae sens. lat.	Codiaeum variegatum (L.) Bl. var. moluccanum (Decne.) Muell.-Arg.					S					
Dicotyledons	Euphorbiaceae sens. lat.	Euphorbia hirta L.					S					
Dicotyledons	Euphorbiaceae sens. lat.	Galearia celebica Koord. var. celebica						X	X			
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion cf. ambiguum Airy Shaw				X						
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion beehlerii Takeuchi							X			
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion chondrocarpum Airy Shaw							X			
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion frodinii Airy Shaw				X						
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion galorii Airy Shaw		X								
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion macrocarpum Bl. ssp. orientale Airy Shaw				X						
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion novoguineense K. Sch.								X		
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion pachyconum Airy Shaw		X								
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion philippicum Cav.) C.B. Rob.		X								
Dicotyledons	Euphorbiaceae sens. lat.	Glochidion sp. A, aff. ?pachyconum Airy Shaw							X			
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga aleuritoides F.v.M.								X		
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga bifeveata J.J. Sm.						X		X		

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga carrii L.M. Perry				X						
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga chrysotricha Laut. & K. Schum.		X							X	
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga fragrans Merr. & Perry						X		X		
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga papuana J.J. Sm. var. papuana							X			
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga pleioneura Airy Shaw var. pleioneura		X								
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga reiteriana Pax & Hoffm.	X								X	X
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga strigosa Pax & Hoffm., caudata-strigosa facies										X
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga tsonane Whitmore								X		
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga sp. nov. A, aff. salicifolia Airy Shaw							X			
Dicotyledons	Euphorbiaceae sens. lat.	Macaranga sp. nov. B, Dioica Group						X				
Dicotyledons	Euphorbiaceae sens. lat.	Omalanthus nervosus J.J. Sm.	X						X		X	X
Dicotyledons	Euphorbiaceae sens. lat.	Omalanthus novoguineensis (Warb.) K. Sch.	X									
Dicotyledons	Euphorbiaceae sens. lat.	Phyllanthus ciccoides Muell.-Arg.		X							X	
Dicotyledons	Euphorbiaceae sens. lat.	Pimelodendron amboinicum Hassk.						X				
Dicotyledons	Euphorbiaceae sens. lat.	Spathiostemon javensis Bl.			X							
Dicotyledons	Eupomatiaceae	Eupomatia laurina R. Br.		X								
Dicotyledons	Caesalpiniaceae sens. str.	Cassia floribunda Cav.		X								
Dicotyledons	Fabaceae sens. str.	Crotalaria lanata Beddome		X								
Dicotyledons	Fabaceae sens. str.	Desmodium sequax Wall.		X				X		X		
Dicotyledons	Fabaceae sens. str.	Desmodium uncinatum (Jacq.) DC.		X								
Dicotyledons	Fabaceae sens. str.	Inocarpus sp. nov. 'rubidus' sensu Verdcourt			X							
Dicotyledons	Fabaceae sens. str.	Mucuna albertsii F.v.M.		X								
Dicotyledons	Fabaceae sens. str.	Mucuna cyanosperma K. Sch.		X								

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Fabaceae sens. str.	Mucuna novoguineensis Verdc.					S			X		
Dicotyledons	Fabaceae sens. str.	Pterocarpus indicus Willd.						X		X		
Dicotyledons	Fabaceae sens. str.	Strongylodon cf. archboldianus Merr. & Perry			X							
Dicotyledons	Fabaceae sens. str.	Stylosanthes guianensis (Aubl.) Sw.		X								
Dicotyledons	Mimosaceae sens. str.	Leucaena leucocephala (Lam.) de Wit					S					
Dicotyledons	Mimosaceae sens. str.	Paraserianthes falcata (L.) Nielsen ssp. falcata		X				X				
Dicotyledons	Fagaceae	Castanopsis acuminatissima (Bl.) A. DC.					S					
Dicotyledons	Fagaceae	Lithocarpus rufovillosus (Markgr.) Rehd.		X								
Dicotyledons	Fagaceae	Lithocarpus cf. schlechteri Markgraf									X	
Dicotyledons	Fagaceae	Nothofagus grandis Steen.				X						
Dicotyledons	Fagaceae	Nothofagus pullei Steen.	X									
Dicotyledons	Fagaceae	Nothofagus rubra Steenis	X									
Dicotyledons	Fagaceae	Nothofagus starkerborghii Steenis										X
Dicotyledons	Fagaceae	Nothofagus aff. starkerborghii Steenis, anthers deviant										X
Dicotyledons	Gesneriaceae	Aeschynanthus kermesinus Schltr.			X							
Dicotyledons	Gesneriaceae	Agalmyla formosa Hilliard & Burt		X					X			
Dicotyledons	Gesneriaceae	Agalmyla nervosa Hilliard & Burt			X							
Dicotyledons	Gesneriaceae	Cyrtandra decurrens DeVriese			X							
Dicotyledons	Gesneriaceae	Cyrtandra cf. erectiloba Gillett				X		X		X		
Dicotyledons	Gesneriaceae	Cyrtandra cf. hirta Schltr.				X						
Dicotyledons	Gesneriaceae	Cyrtandra hispidissima Schltr.			X			X	X			
Dicotyledons	Gesneriaceae	Rhynchochelys discolor (Maxim.) B.L. Burt		X								
Dicotyledons	Goodeniaceae	Scaevola oppositifolia R. Br.	X		X				X		X	
Dicotyledons	Haloragaceae	Gonocarpus halconensis (Merrill) Orchard									X	
Dicotyledons	Haloragaceae	Gunnera macrophylla Bl.					S				X	
Dicotyledons	Himantandraceae	Galbulimima belgraveana (F.v.M.) Sprague	X									
Dicotyledons	Hydrangeaceae	Dichroa febrifuga Lour.	X						X			X
Dicotyledons	Icacinaceae	Citronella suaveolens (Bl.) Howard		X						X		
Dicotyledons	Icacinaceae	Platea excelsa Bl.				X						
Dicotyledons	Icacinaceae	Rhyticaryum longifolium K. Sch. & Laut.		X	X				X	X	X	
Dicotyledons	Lamiaceae	Callicarpa pedunculata R.Br.		X								
Dicotyledons	Lamiaceae	Geunsia pentandra (Roxb.) Merr.					S	X		X		
Dicotyledons	Lamiaceae	Plectranthus scutellarioides (L.) R.Br.		X								
Dicotyledons	Lamiaceae	Premna serratifolia L.			X					X		
Dicotyledons	Lauraceae	Actinodaphne multiflora Benth.				X						

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Lauraceae	Actinodaphne sp.							X			
Dicotyledons	Lauraceae	Cinnamomum cf. clemensii Allen				X						
Dicotyledons	Lauraceae	Cinnamomum cf. frodinii Kosterm.				X						
Dicotyledons	Lauraceae	Cryptocarya bullata Kosterm.				X						
Dicotyledons	Lauraceae	Cryptocarya cf. apamaefolia Gamble				X						
Dicotyledons	Lauraceae	Cryptocarya caloneura (Scheff.) Kosterm.		X								
Dicotyledons	Lauraceae	Cryptocarya cf. verrucosa Teschn.				X						
Dicotyledons	Lauraceae	Cryptocarya fagifolia Gamble				X						
Dicotyledons	Lauraceae	Cryptocarya sp.									X	X
Dicotyledons	Lauraceae	Endiandra cf. altissima Kosterm.				X						
Dicotyledons	Lauraceae	Litsea areolata Boerl.				X						
Dicotyledons	Lecythidaceae	Barringtonia josephstaalensis Takeuchi						X				
Dicotyledons	Lecythidaceae	Planchonia papuana Knuth								X		
Dicotyledons	Loganiaceae	Fagraea bodenii Wernh.				X						
Dicotyledons	Loganiaceae	Fagraea ceilanica Thunb.	X					X	X			
Dicotyledons	Loganiaceae	Geniostoma antherotrichum Gilg. & Bened. var. antherotrichum			X							
Dicotyledons	Loganiaceae	Geniostoma antherotrichum Gilg & Bened. (between vars. antherotrichum and archboldianum)	X									
Dicotyledons	Loganiaceae	Geniostoma weinlandii K. Sch.			X							
Dicotyledons	Loganiaceae	Neuburgia corynocarpa (A. Gray) Leenh. var. corynocarpa					S	X	X	X		
Dicotyledons	Loganiaceae	Neuburgia corynocarpa (A. Gray) Leenh. var. sarcantha (Gilg. & Bened.) Conn		X								
Dicotyledons	Loganiaceae	Strychnos axillaris Colebr.			X							
Dicotyledons	Loranthaceae	Decaisnina hollrungii (K. Schum.) Barlow		X	X			X	X	X		
Dicotyledons	Loranthaceae	Dendrophthoe curvata (Bl.) Miq.		X								
Dicotyledons	Lythraceae	Duabanga moluccana Bl.								X		
Dicotyledons	Magnoliaceae	Elmerrillia tsiampaca (L.) Dandy ssp. tsiampaca var. tsiampacca		X								
Dicotyledons	Magnoliaceae	Magnolia candollii (Bl.) H. Keng var. candollii		X								
Dicotyledons	Malvaceae sens. lat.	Abelmoschus moschatus Medicus			X							
Dicotyledons	Malvaceae sens. lat.	Commersonia bartramia (L.) Merr.					S					
Dicotyledons	Malvaceae sens. lat.	Hibiscus archboldianus Borss.			X		S					
Dicotyledons	Malvaceae sens. lat.	Melochia odorata L.f.			X							
Dicotyledons	Malvaceae sens. lat.	Sida rhombifolia L. ssp. rhombifolia		X								
Dicotyledons	Malvaceae sens. lat.	Sterculia macrophylla Vent.						X				

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Malvaceae sens. lat.	Sterculia monticola Mildbr.		X								
Dicotyledons	Malvaceae sens. lat.	Sterculia monticola (Mildbr.) var. laxiflora Tantra							X			
Dicotyledons	Malvaceae sens. lat.	Sterculia shillinglawii F.v.M.					S					
Dicotyledons	Malvaceae sens. lat.	Sterculia schumanniana (Laut.) Mildbr.					S					
Dicotyledons	Malvaceae sens. lat.	Triumfetta 'nigricans-pilosa' facies		X								
Dicotyledons	Melastomataceae	Astronia atroviridis Mansf.		X								
Dicotyledons	Melastomataceae	Astronia ledermannii Mansf.	X									
Dicotyledons	Melastomataceae	Astronidium acutifolia Mansf.				X						
Dicotyledons	Melastomataceae	Medinilla holrungiana Mansf.		X					X			
Dicotyledons	Melastomataceae	Medinilla maluensis Mansf.				X						
Dicotyledons	Melastomataceae	Medinilla novoguineensis Bak.				X						
Dicotyledons	Melastomataceae	Medinilla quadrifolia Bl.		X								
Dicotyledons	Melastomataceae	Medinilla rubiginosa Cogn.				X						
Dicotyledons	Melastomataceae	Medinilla cf. rubrovenia Bak.		X								
Dicotyledons	Melastomataceae	Medinilla tenuipedicellata Bak. f.	X									
Dicotyledons	Melastomataceae	Medinilla teysmannii Miq.				X						
Dicotyledons	Melastomataceae	Medinilla sp. nov. pseudostipular group	X									
Dicotyledons	Melastomataceae	Melastoma cyanoides Sm.		X				X				
Dicotyledons	Melastomataceae	Melastoma malabathricum L. ssp. malabathricum		X	X							
Dicotyledons	Melastomataceae	Memecylon 'hepaticum' sensu Mansfeld		X								
Dicotyledons	Meliaceae	Aglaia agglomerata Merr. & Perry		X								
Dicotyledons	Meliaceae	Aglaia cf. cedreloides Harms				X						
Dicotyledons	Meliaceae	Aglaia aff. crenea Merr. & Perry						X		X		
Dicotyledons	Meliaceae	Aglaia lepiorrhachis Harms						X				
Dicotyledons	Meliaceae	Aglaia subcuprea Merr. & Perry										X
Dicotyledons	Meliaceae	Aglaia tomentosa Teijsm. & Binn.						X	X			
Dicotyledons	Meliaceae	Aglaia sp. nov., aff. puberulanthera C. DC.						X	X	X		
Dicotyledons	Meliaceae	Aglaia sp. nov., aff. saxonii Takeuchi						X				
Dicotyledons	Meliaceae	Aphanamixis polystachya (Wall.) R.N. Parker					S					
Dicotyledons	Meliaceae	Chisocheton lasiocarpus (Miq.) Val. entity 'formicarum'		X								
Dicotyledons	Meliaceae	Chisocheton morobeanus Harms								X		
Dicotyledons	Meliaceae	Chisocheton novoguineensis C. DC.			X							
Dicotyledons	Meliaceae	Chisocheton pohlianus Harms		X								
Dicotyledons	Meliaceae	Chisocheton cf. versteegii C. DC.						X				
Dicotyledons	Meliaceae	Chisocheton sayeri (C. DC.) Stevens						X				

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Meliaceae	Dysoxylum (close to) kaniense Harms								X		
Dicotyledons	Meliaceae	Dysoxylum latifolium Benth.		X								
Dicotyledons	Meliaceae	Dysoxylum parasiticum (Osb.) Kosterm.								X		
Dicotyledons	Meliaceae	Dysoxylum aff. pettigrewianum F.M. Bailey								X		
Dicotyledons	Meliaceae	Dysoxylum variabile Harms		X								
Dicotyledons	Meliaceae	Dysoxylum sp. nov., aff. phaeotrichum Harms									X	
Dicotyledons	Menispermaceae	Albertisia papuana Becc.			X							
Dicotyledons	Menispermaceae	Arcangelisia tympanopoda (Laut. & K. Sch.) Diels			X							
Dicotyledons	Menispermaceae	Stephania japonica (Thunb.) Miers var. timoriensis (DC.) Forman	X	X								
Dicotyledons	Monimiaceae	Kibara laurifolia A.C. Smith				X						
Dicotyledons	Monimiaceae	Levieria acuminata (F.v.M.) Perkins	X						X			
Dicotyledons	Monimiaceae	Levieria squarrosa Perkins				X					X	X
Dicotyledons	Monimiaceae	Palmeria arfakiana Becc.	X									X
Dicotyledons	Monimiaceae	Palmeria incana A.C. Smith			X							
Dicotyledons	Monimiaceae	Stegantthera hirsula (Warb.) Perkins				X		X				
Dicotyledons	Monimiaceae	Stegantthera ilicifolia A.C. Smith				X						
Dicotyledons	Moraceae	Artocarpus altilis (Parkinson) Fosb.					S					
Dicotyledons	Moraceae	Artocarpus lacucha Buch.-Ham.		X						X		
Dicotyledons	Moraceae	Ficus adenosperma Miq.								X	X	
Dicotyledons	Moraceae	Ficus arbuscula Laut. & K. Sch.						X		X		
Dicotyledons	Moraceae	Ficus arfakensis King				X						X
Dicotyledons	Moraceae	Ficus armitii King								X	X	
Dicotyledons	Moraceae	Ficus austrina Corner								X		
Dicotyledons	Moraceae	Ficus bernaysii King		X				X	X		X	
Dicotyledons	Moraceae	Ficus botryocarpa Miq.			X							
Dicotyledons	Moraceae	Ficus comitis King								X		
Dicotyledons	Moraceae	Ficus congesta Roxb.				X				X		
Dicotyledons	Moraceae	Ficus convexa Corner				X						
Dicotyledons	Moraceae	Ficus dammaropsis Diels		X						X		
Dicotyledons	Moraceae	Ficus erythrosperma Miq.										X
Dicotyledons	Moraceae	Ficus gul Laut. & K. Sch.		X						X	X	
Dicotyledons	Moraceae	Ficus gymnorygma Summerh.		X				X	X			
Dicotyledons	Moraceae	Ficus hesperidiiformis King							X	X	X	
Dicotyledons	Moraceae	Ficus insculpta Summerh.									X	

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Moraceae	<i>Ficus iodotricha</i> Diels	X									
Dicotyledons	Moraceae	<i>Ficus</i> aff. 'irritans-odoardi facies'; closest to <i>F. irritans</i> Summerh.		X								
Dicotyledons	Moraceae	<i>Ficus itoana</i> Diels		X				X				
Dicotyledons	Moraceae	<i>Ficus lanata</i> Bl.				X						
Dicotyledons	Moraceae	<i>Ficus macrorrhyncha</i> Laut. & K. Sch.									X	
Dicotyledons	Moraceae	<i>Ficus megalophylla</i> Diels	X									
Dicotyledons	Moraceae	<i>Ficus mollior</i> F.v.M. ex Benth.		X						X	X	
Dicotyledons	Moraceae	<i>Ficus</i> (close to) <i>mollior</i> F.v.M. ex Benth.									X	
Dicotyledons	Moraceae	<i>Ficus nasuta</i> Summerh.		X								
Dicotyledons	Moraceae	<i>Ficus odoardi</i> King		X				X		X		
Dicotyledons	Moraceae	<i>Ficus pantoniana</i> King									X	
Dicotyledons	Moraceae	<i>Ficus phaeosyce</i> Laut. & K. Sch.								X		
Dicotyledons	Moraceae	<i>Ficus porphyrochaete</i> Corner									X	
Dicotyledons	Moraceae	<i>Ficus pungens</i> Reinw. ex Bl.					S	X		X	X	
Dicotyledons	Moraceae	<i>Ficus</i> aff. ? <i>scratchleyana</i> King	X									
Dicotyledons	Moraceae	<i>Ficus sublimbata</i> Corner							X			
Dicotyledons	Moraceae	<i>Ficus</i> aff. <i>sublimbata</i> Corner						X	X	X		
Dicotyledons	Moraceae	<i>Ficus subtrinervia</i> Laut. & K. Sch.		X								
Dicotyledons	Moraceae	<i>Ficus</i> aff. <i>subtrinervia</i> Laut. & K. Sch.		X								
Dicotyledons	Moraceae	<i>Ficus subulata</i> Bl.		X								
Dicotyledons	Moraceae	<i>Ficus</i> aff. <i>tinctoria</i> Forst. f.	X									
Dicotyledons	Moraceae	<i>Ficus</i> aff. ? <i>tinctoria</i> Forst. f.		X								
Dicotyledons	Moraceae	<i>Ficus trichocerasa</i> Diels							X			
Dicotyledons	Moraceae	<i>Ficus variegata</i> Bl.		X								
Dicotyledons	Moraceae	<i>Ficus</i> cf. <i>virens</i> Ait.		X								
Dicotyledons	Moraceae	<i>Ficus virgata</i> Reinw. ex Bl.		X						X		
Dicotyledons	Moraceae	<i>Ficus wassa</i> Roxb.		X						X		X
Dicotyledons	Moraceae	<i>Ficus</i> cf. <i>wassa</i> Roxb.								X		
Dicotyledons	Moraceae	<i>Ficus</i> sp. nov., aff. <i>hypophaea</i> Schltr.								X		
Dicotyledons	Moraceae	<i>Ficus</i> sp., aff. <i>adenosperma</i> Miq.									X	
Dicotyledons	Moraceae	<i>Ficus</i> sp., aff. <i>bernaysii</i> King							X		X	
Dicotyledons	Moraceae	<i>Ficus</i> sp., aff. <i>ternatana</i> Miq.							X			
Dicotyledons	Moraceae	<i>Maclura cochinchinensis</i> (Lour.) Corner						X				
Dicotyledons	Moraceae	<i>Streblus glabra</i> (Merr.) Corner				X						

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Myristicaceae	Horsfieldia subtilis (Miq.) Warb. var. subtilis			X					X		
Dicotyledons	Myristicaceae	Myristica cornutiflora Warb.							X			
Dicotyledons	Myristicaceae	Myristica globosa Warb.						X			X	
Dicotyledons	Myristicaceae	Myristica hollrungii Warb.						X		X		
Dicotyledons	Myristicaceae	Myristica ingrata de Wilde ssp. ingrata		X								
Dicotyledons	Myristicaceae	Myristica lancifolia Poir.			X							
Dicotyledons	Myristicaceae	Myristica longipes Warb.		X							X	
Dicotyledons	Myristicaceae	Myristica aff. pedicellata Sincl.		X								
Dicotyledons	Myristicaceae	Myristica sphaerosperma A.C. Smith		X						X		
Dicotyledons	Myristicaceae	Myristica aff. subululata Miq.						X	X		X	
Dicotyledons	Myristicaceae	Myristica sulcata Warb.						X				
Dicotyledons	Myristicaceae	Myristica sp. nov.		X								
Dicotyledons	Myristicaceae	Myristica sp. A						X				
Dicotyledons	Myrsinaceae	Ardisia aff. myriosticta K. Sch.	X									
Dicotyledons	Myrsinaceae	Ardisia aff. dasyneura Mez										X
Dicotyledons	Myrsinaceae	Conandrium polyanthum (K. Sch. & Laut.) Mez		X				X				
Dicotyledons	Myrsinaceae	Discocalyx latepetiolata Mez) Sleum.				X		X				X
Dicotyledons	Myrsinaceae	Discocalyx cf. subsinuata Sleum.				X						
Dicotyledons	Myrsinaceae	Embelia cotinoides (S. Moore) Merr.								X		
Dicotyledons	Myrsinaceae	Embelia cf. cotinoides (S. Moore) Merr.									X	
Dicotyledons	Myrsinaceae	Fittingia tubiflora Mez	X								X	
Dicotyledons	Myrsinaceae	Fittingia sp. nov., aff. mariae Stone						X				
Dicotyledons	Myrsinaceae	Grenacheria buxifolia Mez			9139							
Dicotyledons	Myrsinaceae	Loheria reiniana (Jacobs) Sleumer									X	
Dicotyledons	Myrsinaceae	Maesa haplobotrys F.v.M.		X					X	X		
Dicotyledons	Myrsinaceae	Myrsine 'acrosticta'; Rapanea acrosticta Mez	X									X
Dicotyledons	Myrsinaceae	Myrsine 'leucantha'; Rapanea leucantha K. Sch.	X	X					X			X
Dicotyledons	Myrsinaceae	Myrsine 'rhombata'; Rapanea rhombata Royen	X									
Dicotyledons	Myrsinaceae	*Myrsine 'leucantha'; Rapanea leucantha Sleum.				X						
Dicotyledons	Myrtaceae	Decaspermum bracteatum (Roxb.) A.J. Scott var. glabrum A.J. Scott						X		X	X	
Dicotyledons	Myrtaceae	Decaspermum exiguum Merr. and Perry				X						
Dicotyledons	Myrtaceae	Decaspermum fruticosum Forst				X						
Dicotyledons	Myrtaceae	Kania eugenioides Schltr.										X
Dicotyledons	Myrtaceae	Octamyrtus behrmannii Diels									X	

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Myrtaceae	Octamyrtus insignis Diels		X								
Dicotyledons	Myrtaceae	Octamyrtus pleiopetala Diels		X								
Dicotyledons	Myrtaceae	Psidium guajava L.					S					
Dicotyledons	Myrtaceae	Rhodomyrtus elegans (Bl.) A.J. Scott		X								
Dicotyledons	Myrtaceae	Rhodomyrtus pinnatinervis C.T. White	X									
Dicotyledons	Myrtaceae	Syzygium anomalum Laut. or aff.	X									
Dicotyledons	Myrtaceae	Syzygium benjaminum Diels				X						
Dicotyledons	Myrtaceae	Syzygium effusum (A. Gray) C. Muell.		X					X			
Dicotyledons	Myrtaceae	Syzygium fastigiatum (Bl.) Merry & Perry		X						X		
Dicotyledons	Myrtaceae	Syzygium furfuraceum Merr. & Perry		X								
Dicotyledons	Myrtaceae	Syzygium hylochare (Diels) Merr. & Perry							X			
Dicotyledons	Myrtaceae	Syzygium insulare Merr. & Perry						X				
Dicotyledons	Myrtaceae	Syzygium lagerstroemioides Merr. & Perry							X			
Dicotyledons	Myrtaceae	Syzygium longipes Merr. & Perry						X		X	X	
Dicotyledons	Myrtaceae	*Syzygium 'montana'; = Acmena montana Hartley & Craven				X		X				
Dicotyledons	Myrtaceae	Syzygium nemorale Merr. & Perry							X			
Dicotyledons	Myrtaceae	Syzygium nutans (K. Sch.) Merr. & Perry						X				
Dicotyledons	Myrtaceae	Syzygium pachycladum (Laut. & K. Sch.) Merr. & Perry				X						
Dicotyledons	Myrtaceae	Syzygium puberulum Merr. & Perry						X				
Dicotyledons	Myrtaceae	Syzygium pyriforme Merr. & Perry	X									
Dicotyledons	Myrtaceae	Syzygium roemerii (Laut.) Merr. & Perry				X						
Dicotyledons	Myrtaceae	Syzygium aff. samarangense (Bl.) Merr. & Perry		X								
Dicotyledons	Myrtaceae	Syzygium trivene (Ridl.) Merr. & Perry									X	
Dicotyledons	Myrtaceae	Syzygium sp. A						X				
Dicotyledons	Myrtaceae	Syzygium sp. B									X	
Dicotyledons	Myrtaceae	Uromyrtus sp., archboldiana facies										X
Dicotyledons	Myrtaceae	Xanthomyrtus aff. bryophila Diels	X									
Dicotyledons	Myrtaceae	Xanthomyrtus scolopacina (Ridl.) Diels	X									
Dicotyledons	Nepenthaceae	Nepenthes ampullaria Jack			X							
Dicotyledons	Nepenthaceae	Nepenthes mirabilis (Lour.) Druce				X		X				
Dicotyledons	Nyctaginaceae	Pisonia longirostris Teijsm. & Binn.								X		
Dicotyledons	Ochnaceae	Schuurmansia henningsii K. Sch.		X					X			
Dicotyledons	Olacaceae	Anacolosa papuana Schellenb.						X				
Dicotyledons	Olacaceae	Olax aff. imbricata Roxb.			X							

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Oleaceae	Chionanthus cf. brassii (Kobuski) Kiew (sessiflorum group)		X								
Dicotyledons	Oleaceae	Chionanthus ramiflorus Roxb.				X					X	
Dicotyledons	Oleaceae	Jasminum domatiigerum Lingelsh.				X					X	
Dicotyledons	Onagraceae	Ludwigia octovalvis (Jacq.) Raven						X			X	
Dicotyledons	Passifloraceae	Passiflora ligularis Juss.	X									
Dicotyledons	Pentaphragmataceae	Pentaphragma grandiflorum Kurz						X				
Dicotyledons	Piperaceae	Peperomia laevifolia (Bl.) Miq.				X						
Dicotyledons	Piperaceae	Peperomia pellucida (L.) Kunth					S					
Dicotyledons	Piperaceae	Peperomia purpurea Ridl.			X							
Dicotyledons	Piperaceae	Peperomia sp. A						X		X		
Dicotyledons	Piperaceae	Peperomia sp. B									X	
Dicotyledons	Piperaceae	Piper aduncum L.					S					
Dicotyledons	Piperaceae	Piper arfakianum C. DC.				X						
Dicotyledons	Piperaceae	Piper breviantherum C. DC.			X							
Dicotyledons	Piperaceae	Piper caninum Bl.		X						X	X	X
Dicotyledons	Piperaceae	Piper decumanum (Rumph.) L.								X		
Dicotyledons	Piperaceae	Piper gibbilimbum C. DC.	X	X				X	X	X	X	
Dicotyledons	Piperaceae	Piper lessertianum (Miq.) C. DC.							X			
Dicotyledons	Piperaceae	Piper macropiper Pennant									X	X
Dicotyledons	Piperaceae	Piper majusculum Bl.			X							
Dicotyledons	Piperaceae	Piper mestonii Bailey, stenocarpum facies							X			
Dicotyledons	Piperaceae	Piper novoguineense Warb.	X									
Dicotyledons	Piperaceae	Piper pullibaccum Trelease						X				
Dicotyledons	Piperaceae	Piper rodatzii K. Sch. and Laut.	X	X								
Dicotyledons	Piperaceae	Piper subbullatum K. Sch. & Laut.						X				
Dicotyledons	Piperaceae	Piper aff. subcanirameum C. DC.									X	
Dicotyledons	Piperaceae	Piper triangulare Chew	X									
Dicotyledons	Piperaceae	Piper cf. truncatibaccum C. DC.									X	
Dicotyledons	Piperaceae	Piper versteegii C. DC.			X			X		X		
Dicotyledons	Pittosporaceae	Pittosporum pullifolium Burk.									X	
Dicotyledons	Pittosporaceae	Pittosporum pullifolium Burk. ssp. ledermannii (Pritzel) Schodde var. ledermannii	X	X								
Dicotyledons	Pittosporaceae	Pittosporum pullifolium Burk. ssp. pullifolium var. pullifolium				X						
Dicotyledons	Pittosporaceae	Pittosporum ramiflorum (Zoll. & Mor.) Miq.								X		X

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Pittosporaceae	Pittosporum ramiflorum (Zoll. & Mor.) Miq. var. praegnans Schodde	X	X								
Dicotyledons	Pittosporaceae	Pittosporum ramiflorum (Zoll. & Mor.) Miq. var. ramiflorum		X								
Dicotyledons	Pittosporaceae	Pittosporum sinuatum Bl.					S					
Dicotyledons	Polygalaceae	Epirixanthes papuana J.J. Sm.							X			
Dicotyledons	Polygalaceae	Polygala paniculata L.		X				X				
Dicotyledons	Polygalaceae	Xanthophyllum papuanum Whitm.			X							
Dicotyledons	Polygonaceae	Polygonum barbatum L.									X	
Dicotyledons	Polygonaceae	Polygonum chinense L.									X	
Dicotyledons	Polygonaceae	Polygonum nepalense Meissn.									X	
Dicotyledons	Polyosmaceae	Polyosma cestroides Schltr.	X									
Dicotyledons	Polyosmaceae	Polyosma forbesii Val. ex Laut.				X						
Dicotyledons	Polyosmaceae	Polyosma integrifolia Bl.				X						
Dicotyledons	Polyosmaceae	Polyosma sp., cestroides-induta group							X		X	X
Dicotyledons	Proteaceae	Bleasdalea papuana (Diels) Domin		X								
Dicotyledons	Proteaceae	Helicia acutifolia Sleum.	X								X	
Dicotyledons	Proteaceae	Helicia amplifolia Sleum.		X								
Dicotyledons	Proteaceae	Helicia cf. longispicata Sleum.			X							
Dicotyledons	Proteaceae	Helicia cf. stelechantha Diels				X						
Dicotyledons	Ranunculaceae	Clematis phanerophlebia Merr. and Perry				X						
Dicotyledons	Ranunculaceae	Clematis sp.								X		
Dicotyledons	Rhamnaceae	Alphitonia ferruginea Merr. & Perry	X									
Dicotyledons	Rhamnaceae	Gouania aff. javanica Miq.								X		
Dicotyledons	Rhamnaceae	Rhamnus nipalensis (Wallich) Lawson ex Hook.	X								X	
Dicotyledons	Rhizophoraceae	Carallia brachiata (Lour.) Merr.			X							
Dicotyledons	Rosaceae	Prunus costata (Hemsl.) Kalkm.				X						
Dicotyledons	Rosaceae	Prunus dolichobotrys (Laut. & K. Sch.) Kalkm.		X	X					X		
Dicotyledons	Rosaceae	Prunus grisea (Bl. ex C. Muell.) Kalkm.				X						
Dicotyledons	Rosaceae	Prunus schlechteri (Koehne) Kalkm.									X	
Dicotyledons	Rosaceae	Rubus archboldianus Merr. & Perry				X						
Dicotyledons	Rosaceae	Rubus ferdinandi-muelleri Focki	X									X
Dicotyledons	Rosaceae	Rubus glomeratus Bl.				X						
Dicotyledons	Rosaceae	Rubus moluccanus L. var. obtusangulus Miq.	X						X		X	
Dicotyledons	Rosaceae	Rubus moluccanus L. (close to) var. obtusangulus Miq.						X				
Dicotyledons	Rosaceae	Rubus rosifolius J.E. Sm.									X	

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Rousseaceae	Buddleja asiatica Lour.	X								X	
Dicotyledons	Rousseaceae	Carpodetus arboreus (K. Sch. & Laut.) Schltr.		X				X		X	X	
Dicotyledons	Rubiaceae	Airosperma grandifolium Val.			X							
Dicotyledons	Rubiaceae	Amaracarpus heteropus Val.								X		
Dicotyledons	Rubiaceae	Amaracarpus sp. A										X
Dicotyledons	Rubiaceae	Amaracarpus sp. B						X	X			
Dicotyledons	Rubiaceae	Amaracarpus sp. C								X		
Dicotyledons	Rubiaceae	Anotis papuana Laut. & K. Sch.									X	
Dicotyledons	Rubiaceae	Antirhea megacarpa Merr. & Perry						X				
Dicotyledons	Rubiaceae	Argostemma aff. bryophilum K. Sch.						X	X			
Dicotyledons	Rubiaceae	Atractocarpus decorus (Val.) Puttock								X		
Dicotyledons	Rubiaceae	Atractocarpus sp. (=Randia schumanniana Merr. & Perry)			X							
Dicotyledons	Rubiaceae	Caelospermum salomonense (Engl.) Johansson								X		
Dicotyledons	Rubiaceae	Canthium cf. barbatum Seem.			X							
Dicotyledons	Rubiaceae	Canthium longiflorum (Val.) Merr. & Perry				X						
Dicotyledons	Rubiaceae	Canthium sp.						X				
Dicotyledons	Rubiaceae	Dolianthus sp.							X			
Dicotyledons	Rubiaceae	Gardenia gjellerupii Val.	X									
Dicotyledons	Rubiaceae	Gardenia lamingtonii F.M. Bail.			X							
Dicotyledons	Rubiaceae	Gardenia pallens Merr. & Perry									X	
Dicotyledons	Rubiaceae	Hedyotis congesta R. Br., or aff.						X				
Dicotyledons	Rubiaceae	Hedyotis sp. nov. aff. nana Merr. and Perry	X									
Dicotyledons	Rubiaceae	Hedyotis sp., 'auricularia-lapeyrousii' facies						X				
Dicotyledons	Rubiaceae	Hydnophytum cf. montiskani Val.			X							
Dicotyledons	Rubiaceae	Hydnophytum cf. parvifolium Val.			X							
Dicotyledons	Rubiaceae	Hydnophytum radicans Becc.				X						
Dicotyledons	Rubiaceae	Hydnophytum sp. A							X			
Dicotyledons	Rubiaceae	Hydnophytum sp. B, 'linearifolia'							X		X	
Dicotyledons	Rubiaceae	Ixora sp. A						X	X			
Dicotyledons	Rubiaceae	Ixora sp. B						X				
Dicotyledons	Rubiaceae	Lucinaea cf. ledermannii Val.			X							
Dicotyledons	Rubiaceae	Morinda umbellata L.		X	X							
Dicotyledons	Rubiaceae	Mussaenda cylindrocarpa Burck						X		X		
Dicotyledons	Rubiaceae	Mussaenda ferruginea K. Sch.			X						X	
Dicotyledons	Rubiaceae	Mussaenda whitei S. Moore										X

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Rubiaceae	Myrmecodia pendula Merr. & Perry			X							
Dicotyledons	Rubiaceae	Myrmecodia tuberosa Jack					S					
Dicotyledons	Rubiaceae	Nauclea orientalis L.					S					
Dicotyledons	Rubiaceae	Ophiorrhiza sp. A								X		
Dicotyledons	Rubiaceae	Ophiorrhiza sp. B							X			
Dicotyledons	Rubiaceae	Ophiorrhiza sp. C						X				
Dicotyledons	Rubiaceae	Pachystylus gulcherianus K. Sch.			X						X	
Dicotyledons	Rubiaceae	Pavetta platyclada K. Sch.						X		X		
Dicotyledons	Rubiaceae	Psychotria amplithyrsa Val. or aff.	X	X					X	X	X	
Dicotyledons	Rubiaceae	Psychotria apiculata Warb.						X		X		
Dicotyledons	Rubiaceae	Psychotria chaunantha Laut. & K. Sch., or aff.						X				
Dicotyledons	Rubiaceae	Psychotria chrysantha Merr. & Perry									X	
Dicotyledons	Rubiaceae	Psychotria dieniensis Merr. and Perry	X									X
Dicotyledons	Rubiaceae	Psychotria leptothyrsa Miq. var. friabilis Sohmer									X	
Dicotyledons	Rubiaceae	Psychotria leucococca Laut.	X									
Dicotyledons	Rubiaceae	Psychotria cf. leucococca Laut.									X	
Dicotyledons	Rubiaceae	Psychotria matambuai Takeuchi							X			
Dicotyledons	Rubiaceae	Psychotria aff. membranifolia Bartl. ex C. DC.						X				
Dicotyledons	Rubiaceae	Psychotria multicostata Val.									X	
Dicotyledons	Rubiaceae	Psychotria ramadecumbens Sohmer									X	
Dicotyledons	Rubiaceae	Psychotria sp. A, aff. hebecarpa Merr. & Perry						X				
Dicotyledons	Rubiaceae	Psychotria sp. B, aff. ?hollandiae Val.						X				
Dicotyledons	Rubiaceae	Psychotria sp. C, aff. ?amplithyrsa Val.						X				
Dicotyledons	Rubiaceae	Psychotria sp. D										X
Dicotyledons	Rubiaceae	Psychotria sp. E						X				
Dicotyledons	Rubiaceae	Psychotria sp. F, leucococca group										X
Dicotyledons	Rubiaceae	'Rhadinopus' aff. kurivana Ridsd.						X				
Dicotyledons	Rubiaceae	Saprosma subrepandum (K. Sch. & Laut.) Val.						X				
Dicotyledons	Rubiaceae	Tarenna buruensis (Miq.) Val.						X				
Dicotyledons	Rubiaceae	Timonius avenis Val. var. avenis	X									
Dicotyledons	Rubiaceae	Timonius belensis Merr. and Perry				X					X	
Dicotyledons	Rubiaceae	Timonius caudatus Val.						X	X		X	
Dicotyledons	Rubiaceae	Timonius dolichophyllus (Merr. & Perry) Darwin						X		X	X	
Dicotyledons	Rubiaceae	Timonius filipes Wernh., 'caudatus group'							X			
Dicotyledons	Rubiaceae	Timonius grandifolius Val.			X				X			

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Rubiaceae	Timonius kaniensis Val.		X								
Dicotyledons	Rubiaceae	Timonius (close to) minutifolius Val., 'caudatus group'							X			
Dicotyledons	Rubiaceae	Timonius singularis (F.v.M.) L.S. Sm.				X						
Dicotyledons	Rubiaceae	Timonius trichanthus Merr. and Perry		X								
Dicotyledons	Rubiaceae	Timonius xanthocarpus Merr. & Perry, or aff.						X	X			
Dicotyledons	Rubiaceae	Timonius sp. A., rufescens facies (not the sp.)									X	
Dicotyledons	Rubiaceae	Timonius sp. B, flavescens alliance sensu Darwin										X
Dicotyledons	Rubiaceae	Uncaria lanosa Wall. var. appendiculata (Benth.) Ridsd.							X			
Dicotyledons	Rubiaceae	Versteegia sp. nov., aff. ?minor Val.						X				
Dicotyledons	Rutaceae	Acronychia cartilaginea Hartley										X
Dicotyledons	Rutaceae	Acronychia emarginata Laut.	X									
Dicotyledons	Rutaceae	Acronychia foveata Hartley										X
Dicotyledons	Rutaceae	Acronychia montana Hartley										X
Dicotyledons	Rutaceae	Acronychia murina Ridl.				X						
Dicotyledons	Rutaceae	Acronychia (closest to) murina Ridley										X
Dicotyledons	Rutaceae	Acronychia reticulata Laut.						X				
Dicotyledons	Rutaceae	Acronychia rugosa Hartley	X									
Dicotyledons	Rutaceae	Flindersia pimenteliana F.v.M.							X			
Dicotyledons	Rutaceae	Halfordia papuana Laut.	SR	photo		X						
Dicotyledons	Rutaceae	Melicope brassii Hartley	X									
Dicotyledons	Rutaceae	Melicope denhamii (Seem.) Hartley		X								
Dicotyledons	Rutaceae	*Melicope elleryana (F.v.M.) Hartley				X					X	
Dicotyledons	Rutaceae	Melicope rubra (Laut. & K. Sch.) Hartley	X									X
Dicotyledons	Rutaceae	Melicope trachycarpa Laut.										X
Dicotyledons	Rutaceae	Melicope triphylla (Lam.) Merr.		X				X				
Dicotyledons	Rutaceae	Melicope xanthoxyloides (F.v.M.) Hartley			X					X		
Dicotyledons	Rutaceae	Melicope sp. (between perryae Hartley and trachycarpa Laut.)	X									
Dicotyledons	Sabiaceae	Meliosma pinnata (Roxb.) Maxim.			X						X	
Dicotyledons	Sabiaceae	Sabia pauciflora Bl.	X		X							
Dicotyledons	Salicaceae	Casearia monticola Sleum.	X									
Dicotyledons	Salicaceae	Casearia pachyphylla Gilg.				X						
Dicotyledons	Santalaceae	Dendromyza sp.										X
Dicotyledons	Santalaceae	Scleropyrum leptostachyum Pilg.						X		X		
Dicotyledons	Sapindaceae	Dictyoneura obtusa Bl.		X					X			

Group	Family	Species	Hides 3	Benaria	Kutubu-lagifu-Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Sapindaceae	Dodonaea angustifolia L.f.		X								
Dicotyledons	Sapindaceae	Guioa comesperma Radlk.			X							
Dicotyledons	Sapindaceae	Guioa sp. nov. aff. molliuscula Radlk.		X								
Dicotyledons	Sapindaceae	Harpullia ramiflora Radlk.		X	X							
Dicotyledons	Sapindaceae	Harpullia rhachiptera Radlk.						X	X	X		
Dicotyledons	Sapindaceae	Lepidopetalum xylocarpum Radlk.								X		
Dicotyledons	Sapindaceae	Lepisanthes senegalensis (Poir.) Leenh.			X							
Dicotyledons	Sapindaceae	Mischocarpus largifolius Radlk.		X								
Dicotyledons	Sapindaceae	Mischocarpus pyriformis (F.v.M.) Radlk. ssp. papuanus (Radlk.) R.W. Ham		X								
Dicotyledons	Sapindaceae	Mischocarpus pyriformis (F.v.M.) Radlk. subsp. retusus (Radlk.) R.W. Ham									X	
Dicotyledons	Sapindaceae	Mischocarpus retusus Radlk.				X						
Dicotyledons	Sapindaceae	Pometia pinnata Forst.					S					
Dicotyledons	Sapindaceae	Sarcopteryx rigida Radlk.				X						
Dicotyledons	Sapindaceae	Toechima cf. erythrocarpum Radlk.			X							
Dicotyledons	Sapindaceae	genus indet.									X	
Dicotyledons	Sapotaceae	Pouteria monticola (Krause) H.J. Lam				X						
Dicotyledons	Solanaceae	Capsicum annuum L. var. annuum					S					
Dicotyledons	Solanaceae	Nicotiana tabacum L.					S					
Dicotyledons	Solanaceae	Physalis peruviana L.	X									
Dicotyledons	Solanaceae	Solanum anfractum Symon	X									
Dicotyledons	Solanaceae	Solanum memecylonoides Bitter & Schltr.										X
Dicotyledons	Solanaceae	Solanum oliverianum Laut. & K. Sch.			X			X		X		
Dicotyledons	Solanaceae	Solanum sp. nov., subg. Lycianthes								X		
Dicotyledons	Solanaceae	Solanum sp., 'torvum facies'						X				
Dicotyledons	Sphenostemonaceae	Quintinia ledermannii Schltr.	X									
Dicotyledons	Sphenostemonaceae	Sphenostemon papuana (Laut.) Steen. & Erdtman	X								X	X
Dicotyledons	Staphyleaceae	Turpinia pentandra (Schltr.) v.d. Linden	X									
Dicotyledons	Stemonuraceae	Gomphandra papuana (Becc.) Sleumer									X	
Dicotyledons	Stemonuraceae	Gomphandra sp., 'australiana-montana' facies						X				
Dicotyledons	Styracaceae	Styrax argrege (Lour.) G. Don			X							
Dicotyledons	Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore ssp. cochinchinensis var. cochinchinensis		X								
Dicotyledons	Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. leptophylla	X									

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. maculata (Brand) Noot	X									
Dicotyledons	Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. molobros (Brand) Noot.				X						
Dicotyledons	Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. monticola Noot.				X					X	X
Dicotyledons	Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore ssp. leptophylla (Brand) Noot. var. ovata Noot.				X						
Dicotyledons	Theaceae	Eurya kanehirai Kobuski or aff.	X									
Dicotyledons	Theaceae	Eurya tigang K. Sch. and Laut.	X									
Dicotyledons	Theaceae	Eurya tigang K. Sch. & Laut., leptantha facies							X		X	X
Dicotyledons	Theaceae	Eurya tigang K. Sch. & Laut., rehderiana-roemeri facies						X				X
Dicotyledons	Theaceae	Gordonia papuana Kobuski		X				X				
Dicotyledons	Theaceae	Ternstroemia britteniana F.v.M.	X									
Dicotyledons	Theaceae	Ternstroemia merrilliana Kobuski						X				
Dicotyledons	Thymelaeaceae	Phaleria macrocarpa (Scheff.) Boerl.				X				X		
Dicotyledons	Thymelaeaceae	Wikstroemia androsaemifolia Decne	X									X
Dicotyledons	Trimeniaceae	Trimenia papuana Ridl.		X					X			X
Dicotyledons	Urticaceae	Cypholophus cf. ledermannii Winkl.	X									
Dicotyledons	Urticaceae	Cypholophus rotundifolius Winkl. or aff.	X									
Dicotyledons	Urticaceae	Dendrocnide morobensis Chew	X									
Dicotyledons	Urticaceae	Elatostema 'tridens group'	X									
Dicotyledons	Urticaceae	Leucosyke capitellata (Poir.) Wedd.			X			X		X		
Dicotyledons	Urticaceae	Nothocnide melastomatifolia (K. Sch.) Chew	X									
Dicotyledons	Urticaceae	Pilea melastomoides (Poir.) Bl.	X						X		X	
Dicotyledons	Urticaceae	Pilea microphylla (L.) Liebm.					S					
Dicotyledons	Urticaceae	Pilea papuana Winkl.				X						
Dicotyledons	Urticaceae	Pipturus argenteus (Forst. f.) Wedd.		X				X		X	X	
Dicotyledons	Urticaceae	Pipturus pullei Winkl.	X									
Dicotyledons	Urticaceae	Poikilospermum cf. inaequale Chew		X								
Dicotyledons	Urticaceae	Pouzolzia hirta (Bl.) Hassk.		X								
Dicotyledons	Urticaceae	Procris frutescens Bl.		X				X	X			
Dicotyledons	Verbenaceae	Stachytarpheta cayennensis (Rich.) M. Vahl					S					
Dicotyledons	Vitaceae	Cayratia japonica (Thunb.) Gagn.		X								
Dicotyledons	Vitaceae	Cissus discolor Bl.					S	X		X		
Dicotyledons	Vitaceae	Nothocissus penninervis (F.v.M.) Latiff				X						

Group	Family	Species	Hides 3	Benaria	Kutubu- lagifu- Agogo	Mt Sisa	other records*	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Dicotyledons	Vitaceae	Tetrastigma papillosum (Bl.) Planch.				X		X	X			
Dicotyledons	Vitaceae	Tetrastigma pullei Laut.				X						
Dicotyledons	Winteraceae	Drimys piperita Hook. f. entity macrantha	X									X
Dicotyledons	Winteraceae	Drimys piperita Hook. f. entity montis-wilhelmii	X									
Dicotyledons	Winteraceae	Zygogynum calothyrsum (Diels) Vink	X									X
Species Count		1030	160	198	116	170	63	194	130	141	184	104

Figures

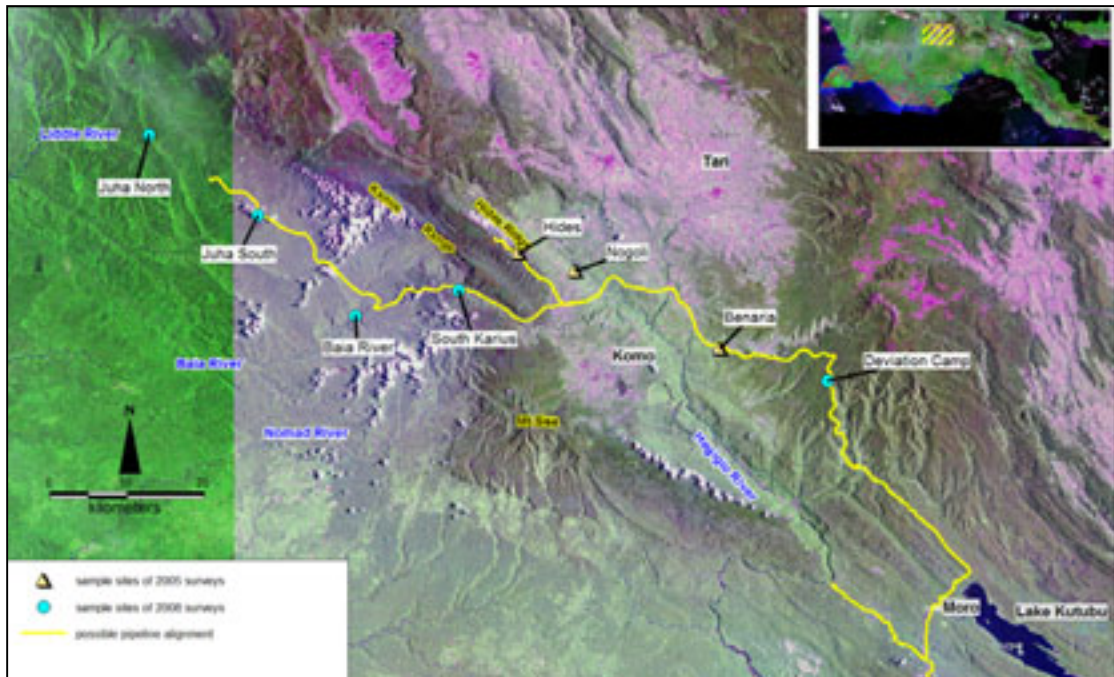


Figure 1 Location map of the 2008 surveys, showing the position of camps from the 2005 and 2008 surveys.



Figure 2 Topographic map showing location of camp and sample transects at Juha North Camp. Image from 1:100,000 topographic map displaying 1 km grid.

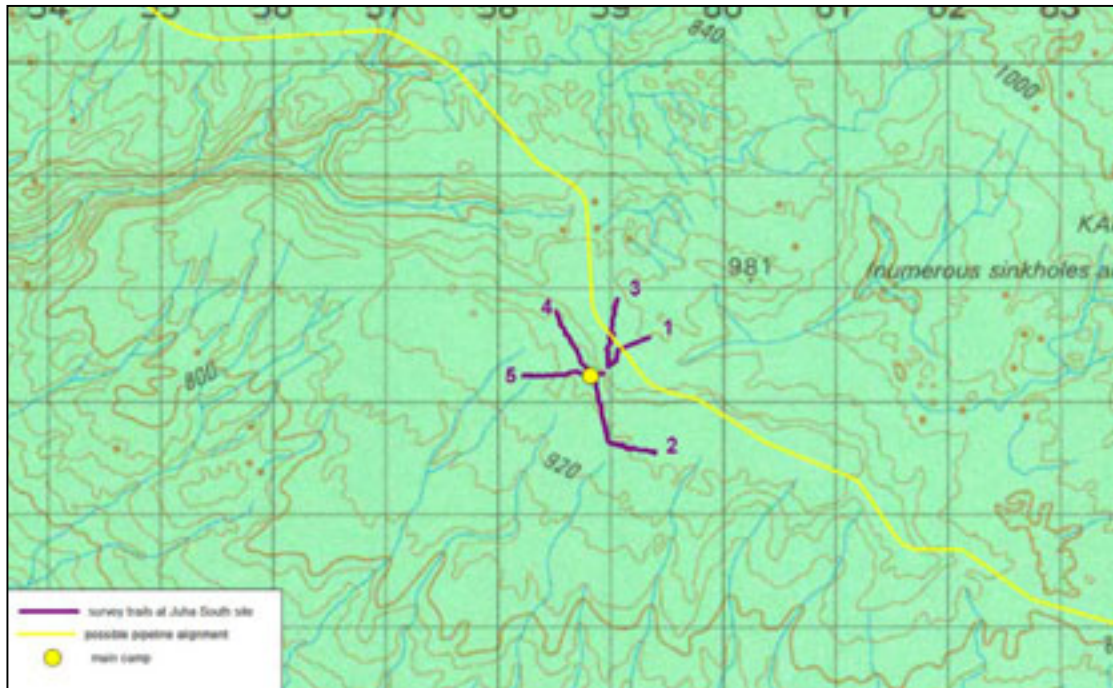


Figure 3 Topographic map showing location of camp and sample transects at Juha South Camp. Image from 1:100,000 topographic map displaying 1 km grid.

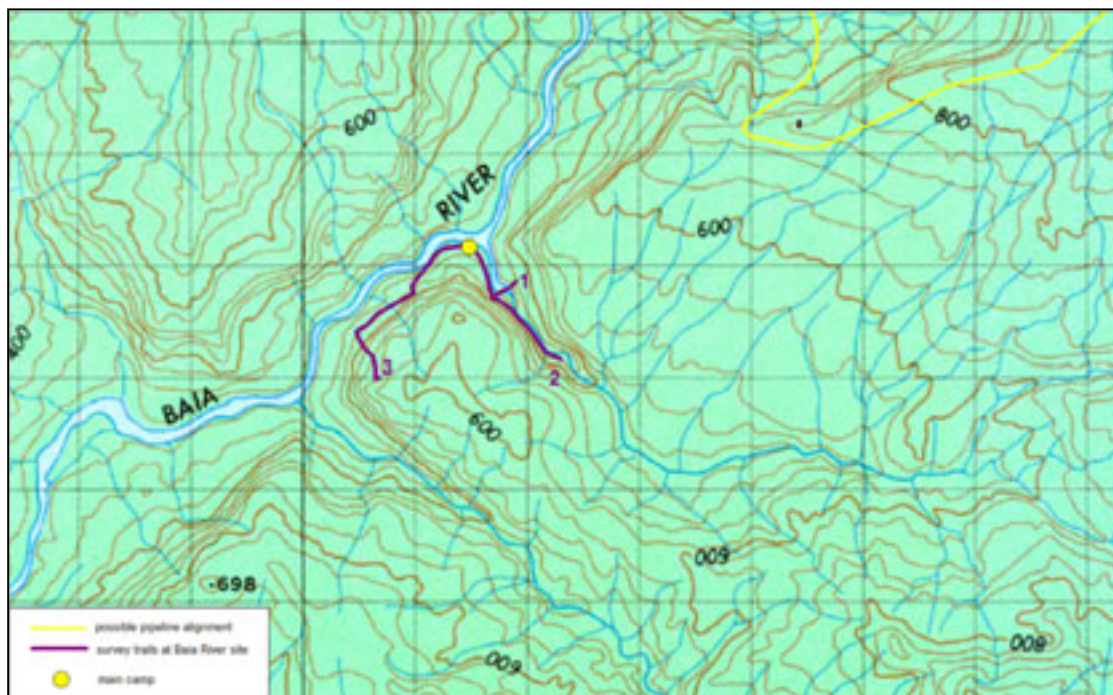


Figure 4 Topographic map showing location of camp and sample transects at Baia River Camp. Image from 1:100,000 topographic map displaying 1 km grid.

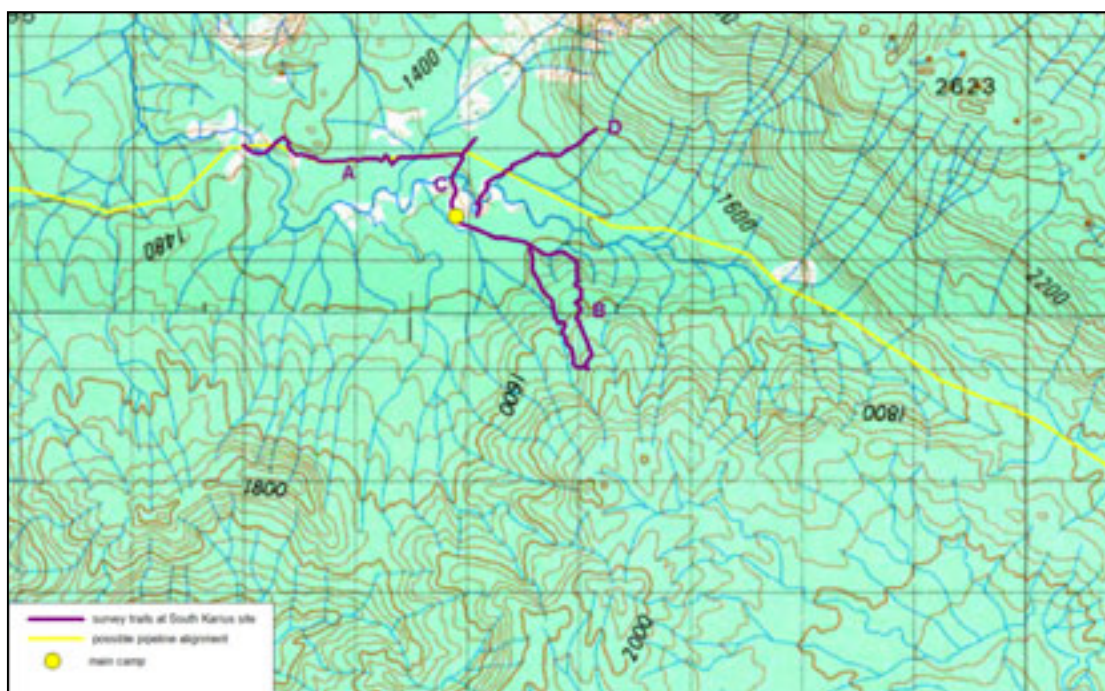


Figure 5 Topographic map showing location of camp and sample transects at South Karius Camp. Image from 1:100,000 topographic map displaying 1 km grid.

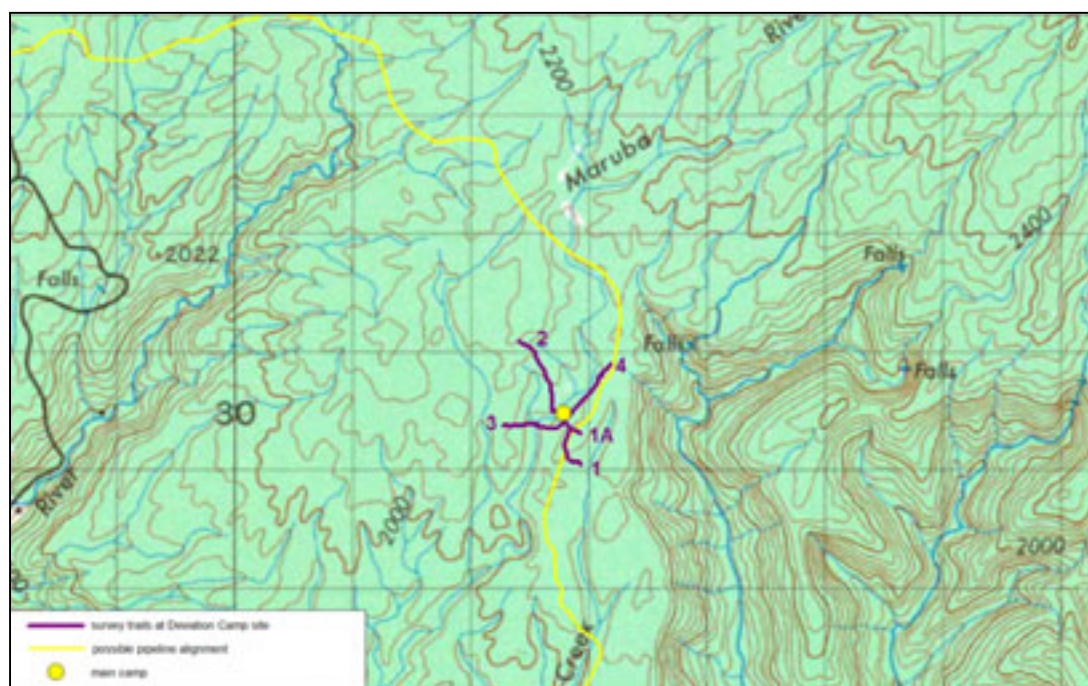


Figure 6 Topographic map showing location of camp and sample transects at Deviation Camp. Image from 1:100,000 topographic map displaying 1 km grid.



Figure 7

Aceratium pittosporoides Schltr. Flowers. Shown with intact corollas and (center) with petals removed to reveal internal parts. The tufted hairs on anther apices are characteristic of the genus.



Figure 8

Aceratium pittosporoides Schltr. Fruit. The bright red drupes are up to 5 x 4.5 cm in size.



Figure 9

Elaeocarpus lingualis Knuth. Fruiting branchlet from a 20 m tree at South Karius.



Figure 10

Sloanea gymnocarpa A.C. Smith. Flowers, side view of the contracted racemes.



Figure 11

Sloanea gymnocarpa A.C. Smith. Flowers, apical view. The multiseriate stamens inserted on an unlobed disk (visible as the fleshy orange-yellow ring) is a diagnostic generic trait.



Figure 12

Sloanea sp. nov., aff. *tieghemii* (F.v.M.) A.C. Smith. The new tree is part of a small species group with solitary flowers and tubular corollas.

Figure 13

Glochidion beehlerii Takeuchi. Copiously fruiting bole from a 15 m tree in dense forest at Juha South. The fructifications are concentrated near ground level, diminishing progressively in density upwards along the trunk.



Figure 14

Glochidion beehlerii Takeuchi. Leafy branch severed from the crown and displayed beside the stem. Intensely glaucous leaves are a principal character separating this species from the closely related *G. daviesii* Takeuchi of Irian Jaya.



Figure 15

Glochidion beehlerii Takeuchi. Fruit detail. Capsules are recessed at the summit. There are 8–9 dissepiments, but these are not clearly marked on the epicarp.

Figure 16

Macaranga sp. nov. A, aff. *salicifolia* Airy Shaw. Vegetative aspect. The closest relative to the new *Macaranga* is a species (*M. salicifolia*) restricted to the Vogelkop Peninsula, a Gondwanic microcontinent which migrated into its present position independently of the Australian austrocraton (Pigram & Panggabean 1984; Pigram & Davies 1987). Because of their occurrence on disjunct cratonic terranes, the morphological similarities between these species are suggestive of early evolutionary divergence.



Figure 17

Macaranga sp. nov. A, aff. *salicifolia* Airy Shaw. Showing the diagnostic structures: stipule, female flower, and fruits.



Figure 18

Macaranga sp. nov. B, aff. 'Dioica Group' sensu Whitmore. The cordate leaves are the largest recorded in the Dioica complex.



Figure 19

Macaranga sp. nov. *B*, aff. 'Dioica Group' *sensu* Whitmore. Female inflorescence.



Figure 20

Macaranga sp. nov. *B*, aff. 'Dioica Group' *sensu* Whitmore. Infructescence. Note the double indument consisting of flexible spines and a white granulate layer beneath.



Figure 21

Grammitis sp. nov. Individual fronds are furcately branched at least three times, an extraordinary character state.

Figure 22

Aglaia sp. nov., aff. *puberulanthera* C. DC. Habit. The sessile leaves, truncate at the base, are the most obvious characters distinguishing the new plant from *A. puberulanthera*.



Figure 23

Aglaia sp. nov., aff. *A. puberulanthera* C. DC. Closer view of the panicle. Flowers are globose.

Figure 24

Aglaia sp. nov., aff. *A. saxonii* Takeuchi. With the size and shape of cassowary eggs, the fruits are at least 3x larger than any known congener from New Guinea. The imparipinnate leaves are similarly unusual, substantially exceeding the corresponding dimensions for any Malesian species with sessile foliage.





Figure 25

Aglaia sp. nov., aff. *A. saxonii* Takeuchi. Fruits are solitary, axillary, and with surfaces obscured by a mealy tomentum.



Figure 26

Fittingia sp. nov., aff. *mariae* Stone. The new shrub is closest to *F. mariae*, a species known from a single collection made in 1940 by famed missionary Mary Clemens (Morobe Province). The novelty differs in having much longer leaves and inflorescences.



Figure 27

Fittingia sp. nov., aff. *mariae* Stone. Fruits are bright red, spongy-textured, and inserted on pendulous axes. The single seeds are conspicuously sculptured.

Figure 28

Loheria reiniana (Jacobs) Sleumer. Mature drupes were not present on earlier collections of this species.



Figure 29

Syzygium ubogoensis Takeuchi. Understory shrubs at Juha South, growing as 3 m poles.



Figure 30

Syzygium ubogoensis Takeuchi. The attractive flowers emerge singly or in small clusters from woody callosities on the stem.



Figure 31

Syzygium sp. nov., aff. *malaccense* (L.) Merr. & Perry. The conspicuous yellow flowers easily distinguish the new tree from allied species. Other congeners in the *malaccense* group have red flowers.



Figure 32

Caelospermum salomoniense (Engl.) J.T. Johansson. Formerly placed in *Morinda*, this woody vine has a wide distribution including the Moluccas, Solomons, and the Caroline Islands, but had not been recorded from PNG's southern provinces (Johansson 1988).



Figure 33

Psychotria matambuui Takeuchi. Architectural form of a 5 m treelet at Juha South.



Figure 34
Psychotria matambuai Takeuchi. Stipules
 are sheathing and early-falling.



Figure 35
Psychotria matambuai Takeuchi. The
 plants from Juha South have the largest
 fruits of any *Psychotria* in eastern Malesia.



Figure 36
Versteegia sp. nov., aff. ?*minor* Val.
 Cauliflorous habit of a 4 m treelet
 from the Juha South karst.



Figure 37

Versteegia sp. nov., aff. ?*minor* Val. Leafy branchlets. Stipules are persisting, fleshy, and thickened at the base.



Figure 38

Versteegia sp. nov., aff. ?*minor* Val. The fertile structures are the smallest known, with ripe fruits only 4 mm diameter in vivo and petals ≤ 4 mm long. There is no corolla tube.



Figure 39

Acronychia cartilaginea Hartley. Herbarium specimens have unusually angular fruits, resulting from collapse of the epicarp with drying. In vivo, the fruits are globose.

Figure 40

Acronychia reticulata Laut. subsp. nov. Leaves are trifoliate and hairy on all parts. The pitted epicarp is a novel character state for the species.



Figure 41

Flindersia pimenteliana F.v.M. Within PNG the species has been known primarily from Morobe Province and the Papuan Peninsula. There are scattered records from Irian Jaya and Northern Queensland, but none from the southern region (Hartley 1969).



Figure 42

Flindersia pimenteliana F.v.M. The yellow flowers are pleasantly aromatic and mostly bisexual.



Figure 43

Solanum memecylonoides Bitter & Schltr.
Although widely dispersed through New
Guinea, the vining plant was known to
Symon (1985) by only 10 collections.

Annex 03

Biodiversity survey results:

Non-volant mammals at Hides, Nogoli and Benaria in 2005

This report originally appeared in the PNG Gas Project EIS as:
Supporting Study 3: “Report for an Assessment Survey of Terrestrial Mammals for
PNG Gas Project, Papua New Guinea”



Report for an Assessment Survey of Terrestrial Mammals for PNG Gas Project, Papua New Guinea

By Ted Mamu, Olo Gebia, Ivan Enoch, Rex Namo, Max Kuduk and Amos Ona
*WWF Kikori Integrated Conservation and Development Project, P.O Box 8280,
Boroko, National Capital District, Papua New Guinea.*

June 08 2006



Murexia sp. recorded from Mt. Sisa
WWF KICDP Photo

Table of contents

Acknowledgements.....	7
Executive Summary	8
Introduction:	10
Site Description.....	11
Methods	13
Methods	14
Trapping.....	14
Signs	14
Spotlighting	14
Camera Trapping	15
Local Information	15
Results.....	19
Conservation Status	20
Richness and Endemism	22
Discussion	23
Potential Impacts of Gas Project on the Environment.	24
Primary impacts	24
Terrestrial systems.....	24
Impacts on River System	27
General assessment of primary impacts.....	27
Secondary impacts.	28
General assessment of secondary impacts	30
Mitigation measures	30
Recommendations	32
References	33

Figures

Figure 1. Location of the study area

Figure 2. The WWF KICDP area of study of mammals and plants

Figure 3. Map showing two sites of survey: Benaria and Hides.

Figure 4. Species composition of mammals from the Hides and Benaria sites.

Figure 5 The effects of disturbance and secondary impacts of immigration.

Tables

Table 1 Trapping effort at Hides 3 and Benaria.

Table 2 Details of camera trapping.

Table 3 Mammal records from Hides and Benaria Survey Sites

Table 4 The IUCN status of species recorded in the Kikori, Benaria and H3

Table 5 Comparison of number of species supported by PNG and Australia.

Table 6 Ecological effects of forest clearing and spoil disposal during constructions in mountain areas.

Table 7 Primary impacts of forest clearings on the environment. (Limestone mid-lower montane, swamp, and mangrove forest types).

Table 8 Potential degree of impact on mammal population from gas pipeline project

Table 9 Significance of secondary impacts on the environment.

Appendices

Appendix 1 Description of survey transects.

Appendix 2 Occurrence of non-flying mammals at survey sites in the Kikori ICDP.

Appendix 3 Conservation status and level of endemism of KICDP non-flying mammals.

List of Acronyms

B	Benaria
CITES	Convention on International Trade in Endangered Species
DEC	Department of Environment and Conservation
EIS	Environmental Impact Study
H3	Hides 3
IUCN	International Union for Conservation of Nature
NG	New Guinea
PNG	Papua New Guinea
UPNG	University of Papua New Guinea
WMA	Wildlife Management Area
WWF	World Wide Fund for Nature
WWF KICDP	World Wide Fund for Nature Kikori Integrated Conservation and Development Project

Acknowledgements

WWF Kikori Project was initially approached to provide biological survey data and reports generated over 10 years since our existence and operation in the Kikori Basin. These reports and other data sources have been cut on CDs and provided to Enesar Consulting Pty Ltd on 16 March 2005. Following discussions with the Co-leader of Science Team, Mr. Francis Crome and Enesar Consulting Pty Ltd, WWF was invited to submit a proposal to participate in undertaking the Mammal Component of the surveys that started in April 2005.

A formal brief for the Assessment of Terrestrial Mammals for PNG Gas Project was received on 17 March 2005. Further details of the requirements for this sub contract are outlined in a document titled PNG Gas Project, EIS Study B6 (WWF) circulated via email by Janet Gray on 17 March 2005

We gratefully acknowledge the recognition and confidence shown by the Science Co-leader, Mr. Francis Crome and Enesar Consulting Pty Ltd in inviting us to undertake this sub contract. We also acknowledge and thank those who provided logistical support to undertake the fieldwork including Esso Highlands staff, field contractors, and WWF staff.

While undertaking the fieldwork, WWF staff (Ted Mamu, Olo Gebia and Ivan Enoch) benefited from assistance and good company of the survey team that included Science Co-leaders (Francis Crome and Greg Richards) Steve Richards, Iain Woxvold, and Wayne Takeuchi and his field assistants.

We also acknowledge and appreciate the tireless efforts of the local field assistants from Benaria and Hides areas. They provided vital local information on the presence and existence of larger non-flying mammals (terrestrial mammals) that we would have been privy to if otherwise.

Finally but not the least, acknowledgement is due to the tireless and hard work of WWF Kikori staff including Steven Saleu, Mavia Mumuan and Aloysius Pokaraija and the rest of the staff. Teamwork has been an admirable attribute of Kikori team, and this has once again been evident in the smooth and successful execution of the tasks on hand.

Executive Summary

1. WWF Kikori Project (WWF KICDP from hereon) was engaged by Enesar Consulting Pty Ltd to conduct a survey on the non-flying mammals, which will form a supporting study to the overall Environmental Impact Assessment (EIA) study of the PNG Gas Project.
2. This report documents the findings of field surveys from 18 April to 16 May of the non-flying terrestrial mammal fauna at Hides 3 (2,163 - 2,267 m.a.s.l) and Benaria (1,230 - 1, 530 m.a.s.l) within the perimeters of the oil and gas development and the WWF KICDP areas. A total of 2 sites (5 transects at Hides 3 and 6 transects at Benaria) were surveyed covering an altitudinal range from 1,530 to 2,267 meters above sea level.
3. The mammal fauna occurring within the project area has been well documented by WWF since 1994. The data in this report is representative of other areas between Hides and Omati that will be affected by the pipeline construction.
4. A total of 44 species of mammals in 9 families comprising 30 genera were recorded from these two sites. This is about 50% of the total species of mammals recorded from the Kikori River Basin. However, more than half of the total number of species recorded was from information provided by local informants who have seen the species living in the area.
5. 50% of all species recorded belonged to the family Muridae (rats and mice), 11% each to the Dasyuridae (marsupial carnivores) and Phalangeridae (cuscuses), 11%, Macropodidae (Kangaroos), 7% each to the Petauridae (gliders) and Pseudocheiridae (possums) and 2% each to the families Acrobatidae (pygmy gliders) and Tachyglossidae (echidnas).
6. There are high levels of endemism within the KICDP area and at the two survey sites. Species include *Dasyurus albopunctatus*, *Dendrolagus goodfellowi*, *Phalanger vestitus*, *Xenuromys barbatus*, and *Zaglossus bartoni* are endemic as well as endangered or threatened.
7. The mammal fauna indicates that the forest in general is stable and intact.
8. Comparing these results with the total of 81 non-flying mammal species recorded from the Kikori River Catchment, about 50% (44) occur at Hides 3 and Benaria area.
9. Many of the species are endemic but not yet threatened by hunting pressures from local people and other predators.
10. In general, the non-flying mammal fauna appears to be intact and healthy as the habitat is relatively undisturbed and there does not appear to be any significant hunting pressure on the fauna. This is evident by the occurrence of larger mammals and some rare species as reported by local informants, though they were not captured in this survey.

11. According to the assessments based on previous biodiversity surveys in various parts of the project area by WWF KICDP, the operations of the existing oil and petroleum field developments do not appear to have had a significant or adverse impact on the native fauna.
12. The mammal species most at risk from project development are specialists to particular altitudes and ecotypes, including the higher montane species, cave dwellers and those requiring streamside vegetation. whose habitats are in the direct line of disturbance.
13. The most serious threat to the larger mammal fauna appears to be people having access to roads and resorting to hunting and clearing for gardens.
14. The success or failure in safeguarding the environment is very much dependent on how much effort the developer focuses its attention on understanding the people, and working with them and actively convincing them of the life sustaining benefits of their environment. Monitoring of fauna populations in these areas is recommended, as it is essential to assess the degree of impact on the environment.

Introduction:

The island of New Guinea is a home to a diverse non-flying mammal fauna comprising 125 species in 49 genera and 9 families (Flannery, 1995). Much of this mammal fauna is endemic and mostly composed of monotremes, carnivorous marsupials, bandicoots, possums, gliders, tree kangaroos and placental mammals. However, the distribution of mammals in Papua New Guinea is poorly known as indicated by the distribution maps of mammals in Flannery (1995). The little or poor knowledge of the distribution of the mammals is an indication of the lack of significant inventory work in much of Papua New Guinea. About 27% of PNG's mammals are considered critically endangered, endangered or vulnerable by IUCN as per the Status of 2003 IUCN Red List of Threatened Species compared to 22% of Australia's mammals. This also indicates that PNG still has forest habitats that can support a good number of species of mammals. This is evidenced by the fact that bigger mammals and some of the rare species are still encountered in many localities.

Understanding and knowing the distribution and occurrence of certain focal or indicator species of plants and animals is of the essence to assessing the degree of impact imposed by any development activity on the natural environment. Therefore, the biodiversity survey work on non-flying mammals at Hides and Benaria, reported on here, also builds upon previous biodiversity survey work conducted by WWF KICDP within the project area in the following areas: Mt. Sisa, Veiru Creek, Utiti Creek and Kopi area, Omo, Wasi Falls, Mt Kemenagi, Mt Bosavi and the Kutubu Oil Fields (Moro, Agogo and Iagifu Ridge areas) (Leary and Seri, 1997); and in Gobe (Leary, 1999 unpublished); and at Iviri, Keboi Kerowa, Dark End Lumber eco-forestry areas in the lower Kikori and lately at Darai Plateau and Libano WMA area.

Most of these mammal surveys conducted by WWF KICDP are within the perimeters of the oil and petroleum development project area and account for more than 81 non-flying mammal species and show a general trend that the non-flying mammal fauna appears to be intact as their natural habitats are relatively undisturbed by oil development activities and other human or nature induced disturbances such as hunting.

2.0 Objectives

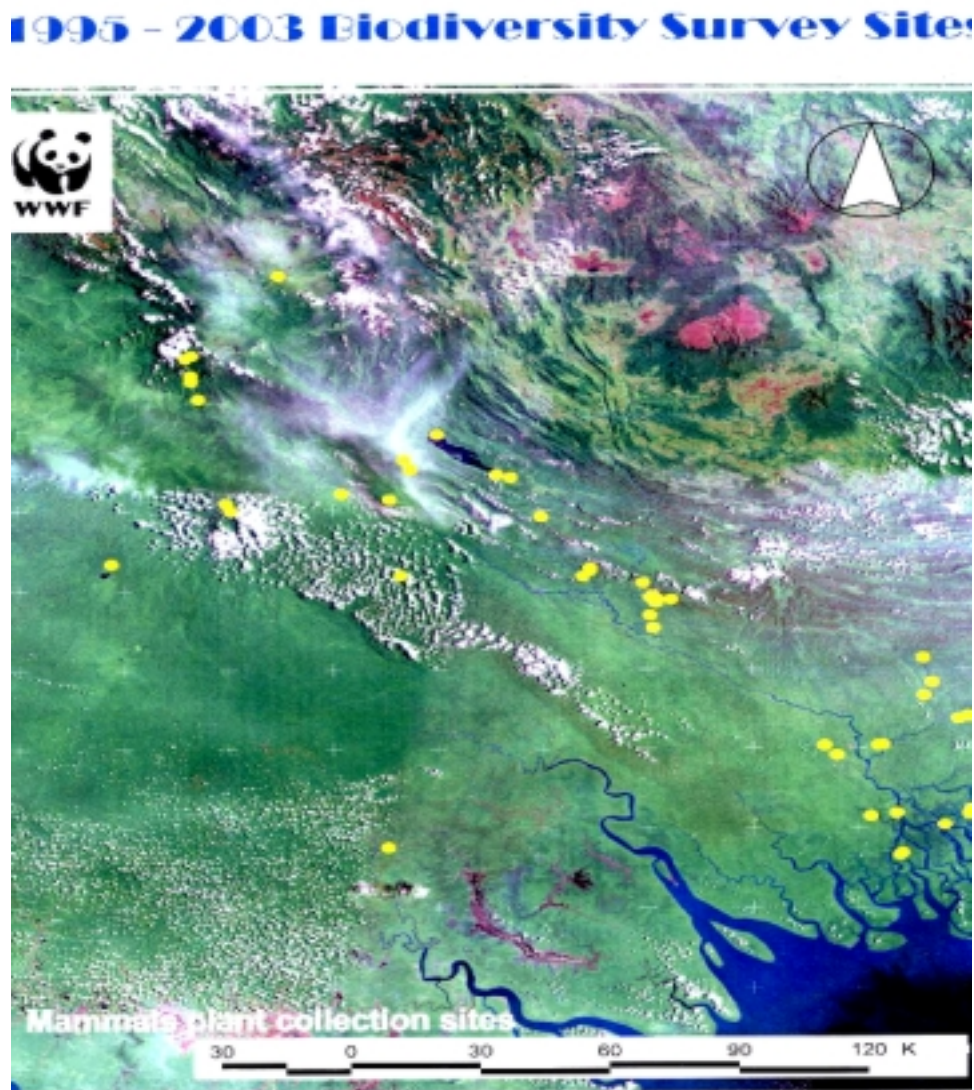
Our objective was to:

1. Assist the biodiversity survey team with inventorying non-flying mammals in the Hides to Kutubu Central Production Facility area and Kantobo and Kopi-Omati area and to assess the potential impacts of the PNG Gas Project on this group of taxa concentrating on species whose habitat needs may force adjustments of the pipeline route, and groups of species that are either in the PNG legislation or listed by IUCN.
2. Provide an overview of the non-flying mammal fauna of the KICDP area.

Site Description

The WWF KICDP area covers the entire Kikori River Catchment, whose tributaries rises in the mountainous north (up to 3,600 m) and finishes 300 km southeast in the Gulf at sea level, and includes the Great Papuan Plateau (Leary *et al.*, 1997) and (Figures 1 and 2). Topography in the area is extremely variable and is characterized by steep jagged limestone karst and volcanoes. Forest types range from mangrove to montane forest. The entire Kikori River Catchment covers an area of approximately 2.3 million hectares.

Figure 1: Location of the study area.



The map displays the study area in Papua New Guinea, specifically the Western Highlands Province and Gulf Province. The Muro and Hemo districts are highlighted in orange. Key locations marked include Tari, Mt Bosavi, and Wabunan. The map also shows the Muro River and the Hemo River. An inset map in the bottom left corner shows the location of the study area within Papua New Guinea. A north arrow is located in the bottom right corner.

Annex 03 Non volant mammals at Hides, Nogoli and Benaria in 2005

WWF have surveyed many sites in the KICDP (see Appendix 2). This survey covered areas not previously characterized by WWF – the montane karst forest in the north of the KICDP area and the montane volcanics on the western edge of the Doma Peaks area.

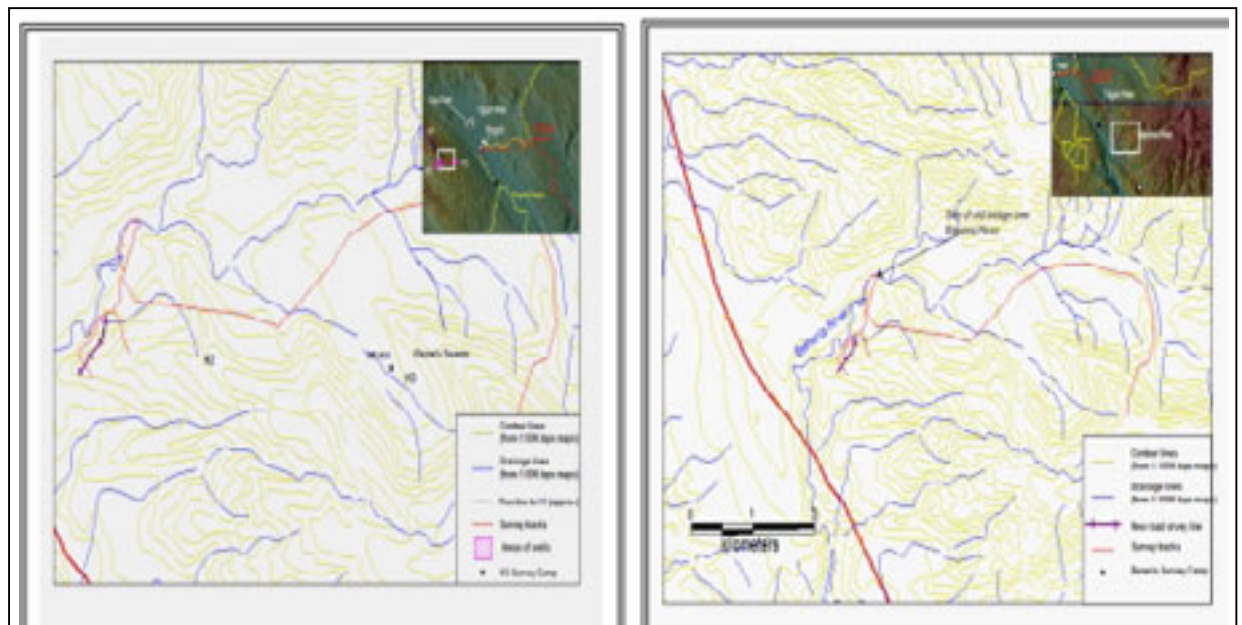
The two sites surveyed were as follows:

Hides 3 (H3) (05° 56.947 S, 142° 44.443 E altitude 2,163m) is located on upland karst dominated by mid montane forest with *Nothofagus* spp. It was surveyed between 24 – 30 April 2005.

Benaria (06° 03.553 S, 142° 58.730 E altitude 1,239 – 1, 530 m) is on volcanic outwash alluviums and volcanic ridges. The vegetation is dominated by lower montane hill forest comprising *Castanopsis acuminatissima* and *Lithocarpus* sp. It was surveyed between 1 - 8 May 2005.

The locations of the sites and the survey tracks are shown in Figure 3.

Figure 3: Map showing the two sites of survey, Hides 3 and Benaria.



Methods

Non-flying mammals were sampled by systematic trapping, spoor surveys, spotlighting along trails at night, camera trapping and interviewing local landowners about mammals they had seen or hunted.

Trapping.

Systematic small mammal trapping was done by establishing trapping transects along which three kinds of traps were placed - small and large Elliot traps and large cage traps. The traps were 10 m apart and laid either on the ground or on platforms nailed to trees at 1-2 m above the ground.

Traps were baited with a mixture of roasted coconut kernels, peanut butter, rolled oats and muesli. Appendix 1 presents the details of each transect. Table 1 presents the number of transects and trapping effort used at each site.

Table 1 Trapping effort at Hides 3 and Benaria.

Site	Small Elliots on ground	Large Elliots	Small Elliots on trees	Elliots on logs or fallen trees	Cage Traps	Nights	Total trap nights
Hides 3							
H3 - Perimeter of H3 helipad	23	15	0	0	2	1	40
H3: Transect 1 from SR Hill to flow lines near to H2	41	10	1 (small)	6 (small)	0	6	348
H3: Transect 2 - downhill to Wayne's swamp and track uphill	17	7	5 (small), 1 (large)	4 (small)	6	6	240
Benaria							
Benaria camp – perimeter of camp site	10	0	0	0	0	3	30
Benaria transect 1	30	10	3 (small)	1 (small)	0	2	88
Benaria transect 2	22	10	2 (small)	0	8	6	252
Benaria transect 3	15	10	3 (small)	0	0	4	112
Benaria transect 4	15	0	1 (small)	0	0	2	32

All animals caught were identified, measured, photographed and released back into the site of capture. Reference specimens were preserved to confirm identifications at the UPNG Biology Department Museum.

Signs

Tracks were walked every day and all spoor and droppings sighted were recorded and identified.

Spotlighting

Arboreal mammals were surveyed by spotlighting at night along tracks, forest edges and access points within 2 km of the camps.

Camera Trapping

Five "Photoscout" 35mm IR triggered camera traps were used to continuously record fauna. To operate the traps the camera would be loaded with 400 ASA 35 mm film, desiccant placed in the housing and the unit closed and sealed. The unit was then tied to a tree and aimed so that any bird or mammal crossing the ground within 15 m of the camera would trigger the IR beam and a photograph of the animal taken. Table 2 provides details of camera trap operations.

Table 2 Details of Camera trapping.

Trap serial number	Locality	Date set	Date retrieved	Nights
Hides 3				
25536	SRHill top	24/04/2005	30/04/2005	5
25539	H2 track near SRHill	24/04/2005	30/04/2005	5
25535	Wayne's swamp bottom	25/04/2005	30/04/2005	4
25537	Track out of Wayne's Swamp	25/04/2005	30/04/2005	4
Benaria				
25536	Near Benaria River	2/05/2005	8/05/2005	7
25539	Hill above swamp	2/05/2005	8/05/2005	7
25535	Survey Hill 6 03.554; 142 58.603	2/05/2005	8/05/2005	7
25537	Swamp	2/05/2005	8/05/2005	7
Rental	Above garden on Benaria River 6° 03.533; 142 ° 58.473	2/05/2005	8/05/2005	7

Local Information

Local villagers and landowners were interviewed at length over several days. They were shown pictures of mammals in Flannery (1995) and detailed conversations about behaviour, habits etc. enabled us to decide whether each local record was reliable or not. Only records we believe are reliable were included.

Table 3. Mammal records from Hides and Benaria Survey Sites

Family	Scientific name ^A	Common name	Local Name	H3 ^B	Benaria ^B
Tachyglossidae	<i>Zaglossus bartoni</i> ¹	Long-beaked Echidna	Poraga	Sighted tracks and nesting sites.	Local
Dasyuridae	<i>Dasyurus albopunctatus</i>	New Guinea Quoll	Porere	Local	Local
Dasyuridae	<i>Murexia longicaudata</i>	Short Furred Dasyure	Mali	Local	Local
Peroryctidae	<i>Echymipera kalubu</i>	Common Echymipera	Hurupuri	Local	Photographed in camera trap
Peroryctidae	<i>Microperoryctes longicauda</i>	Striped Bandicoot	Mali	Local and photographed in camera trap	Local
Peroryctidae	<i>Peroryctes raffrayana</i>	Raffray's Bandicoot	Mali	Local	Sighted one during spotlighting
Phalangeridae	<i>Phalanger carmelitae</i>	Mountain Cuscus	Tia Hakuanda	Locals caught four individuals, spotlighted one individual.	Heard calls from the forest during spotlighting.
Phalangeridae	<i>Phalanger gymnotis</i>	Ground Cuscus	Horia	Observed bones and fur in dog faeces	Local. Saw burrow under boulders near Benaria village
Phalangeridae	<i>Phalanger sericeus</i>	Silky Cuscus	Kepa	Caught one individual.	Local
Phalangeridae	<i>Phalanger vestitus</i>	Stein's Cuscus	Palana	Local	Heard, Local
Phalangeridae	<i>Spilocuscus maculatus</i>	Common Spotted Cuscus	Abai	Local, Not found at higher elevation, but at lower elevation near study area.	Common, Local
Macropodidae	<i>Dendrolagus dorianus</i>	Doria's Tree Kangaroo	Andaja	Sighted their feeding and nesting sites	Local
Macropodidae	<i>Dendrolagus goodfellowii</i>	Goodfellow's Tree Kangaroo	Timbuni Andaja	Local, Not seen often in the area	Found feeding and nesting sites
Macropodidae	<i>Dorcopsulus vanheurni</i>	Lesser Forest Wallaby	Hari	Local, Collected a specimen from Moran of similar altitude recently	Local, Collected a specimen from Mt. Moran at similar altitude recently
Burramyidae	<i>Cercartetus caudatus</i>	Long-tailed Pygmy-possum	Puri		Local
Pseudocheiridae	<i>Pseudocheirops corinnae</i>	Plush-coated Ringtail	Pajawe	Local	Local
Pseudocheiridae	<i>Pseudocheirops cupreus</i>	Coppery Ringtail	Tenagua	Local	Local
Pseudocheiridae	<i>Pseudochirulus mayeri</i>	Pygmy Ringtail	Jakbono	Local	Local
Petauridae	<i>Dactylopsila palpator</i>	Long-fingered Triok	Pogorali		Local
Petauridae	<i>Dactylopsila trivirgata</i>	Striped Possum	Pogorali		Local

Table 3. Mammal records from Hides and Benaria Survey Sites

Family	Scientific name ^A	Common name	Local Name	H3 ^B	Benaria ^B
Petauridae	<i>Petaurus breviceps</i>	Sugar Glider	Tele	Spotlighted one individual and heard a few calls from the camp.	Heard, Local
Acrobatidae	<i>Distoechurus pennatus</i>	Feather-tailed Possum	Kununu/Pogorali	Local, Build nests in hollows of tree-ferns	A villager killed one in the forest
Muridae	<i>Chiruromys vates</i>	Lesser Tree-mouse	Paragajar		Local
Muridae	<i>Crossomys moncktoni</i>	Earless Water Rat	Ibatia	Local	Local
Muridae	<i>Cocomys rummleri</i>	Rummler's Mouse	Huru		Captured in regrowth hill forest
Muridae	<i>Hydromys chrysogaster</i>	Common Water-rat	Puri		Local
Muridae	<i>Leptomys ernstmayeri</i>	Ernst Mayer's Leptomys	Lurago		Local
Muridae	<i>Mayeremys ellermani</i>	One-toothed Shrew Mouse	Pagana Habuto	Local	Local
Muridae	<i>Melomys leucogaster</i>	White-bellied Mosaic-tailed Rat	Huru		Local
Muridae	<i>Melomys lutillus</i> ^{2,3}	Grassland Melomys	Huru		Captured
Muridae	<i>Melomys rufescens</i>	Black-tailed Melomys	Huru	Captured	Captured
Muridae	<i>Parahydromys asper</i>	Waterside Rat	Hurapuri	Local	Local
Muridae	<i>Paramelomys mollis</i>	Thomas's Melomys	Huru		Local
Muridae	<i>Paramelomys platyops</i> ²	Lowland Melomys	Huru		Local
Muridae	<i>Paramelomys rubex</i>	Mountain Melomys	Huru	Captured	Local
Muridae	<i>Pogonomys loriae</i>	Large Tree-mouse	Hurupuri or Hurugiti	caught at camp near cooking place	Local
Muridae	<i>Pogonomys sylvestris</i>	Gray-bellied Tree-mouse	Iraparaja		Local
Muridae	<i>Rattus leucopus</i>	Cape York Rat	Huru		Local
Muridae	<i>Rattus sp.nov (Benaria) cf. praetor</i> ⁴	Large Spiny Rat	Mendiwali		Local
Muridae	<i>Rattus steini</i>	Stein's Rat	Huru		Local
Muridae	<i>Rattus sp.</i>	Unidentified Rat	Huru		Caught one in grassland
Muridae	<i>Stenomys niobe</i>	Moss-forest Rat	Huru	Captured	Local
Muridae	<i>Stenomys verecundus</i>	Slender Rat	Puri		Local
Muridae	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat	Pagana	Captured	
Total Recorded				25	37

A Taxonomic Notes

1. Formerly *Z. bruijnii*. *Z. bartoni* follows Flannery and Groves (1998).

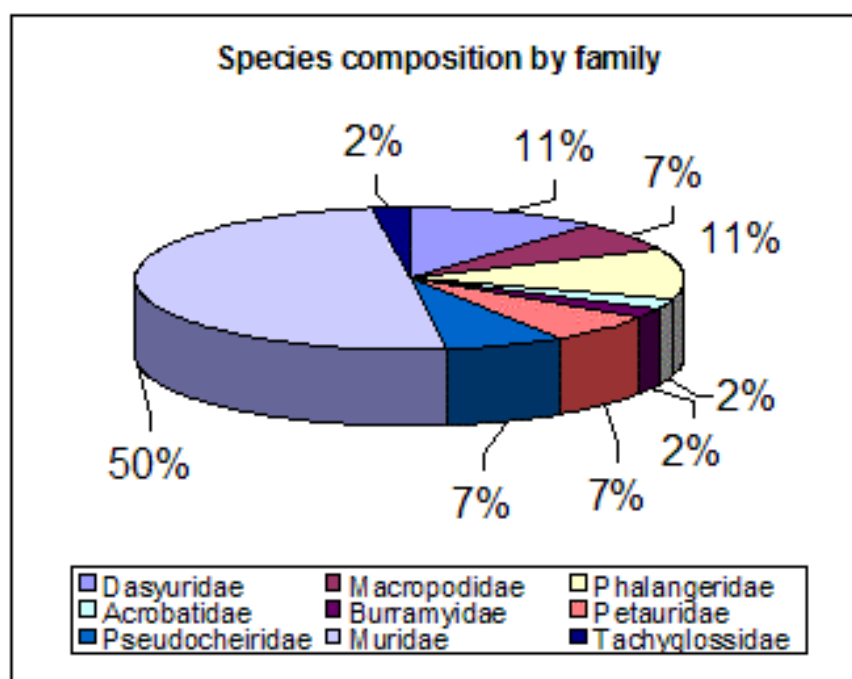
2. Generic arrangements follows Menzies (1996).
 3. Flannery (1995) suggests this is synonymous with *M. burtoni* of Australia but Tanya Leary (*in litt.* 23/06/05) says "No-one has yet revised *M. lutillus*, and I believe that it is only the subspecies *Melomys lutillus muscinus* is a synonym of *M. burtoni*. *M. lutillus muscinus* only occurs in the TransFly so *M. lutillus* for our specimens is correct. It actually appears that the insular varieties of *M. leucogaster* are a separate species"
 4. "*R. praetor* should not theoretically be in the project area. For now, I would leave it as *R. cf praetor*. I am looking at other material to decide whether this should be described as a new species – this would make a 4th undescribed *Rattus* species for the project." (Tanya Leary *in litt.* 23/06/05). In addition, *Rattus mordax* was erroneously recorded for the KICDP as a result of a misinterpretation of a museum label. (Tanya Leary *in litt.* 23/06/05).
- B. Local – confirmed present by local villagers.

Results

The species recorded at Hides 3 and Benaria are presented in Table 3. Nomenclature follows Flannery (1995) for most species, Flannery and Groves (1998) for *Zaglossus*, Norris and Musser (2001) for the *Murexia* group, and Menzies (1996) for the “*Melomys*” rodents.

A total of 44 species of mammals in 9 families and 29 genera were recorded – 25 at Hides 3 and 37 at Benaria. Rodents (*Muridae*) account for the highest species diversity with 50% (22) species while *Dasyuridae* and *Phalangeridae* makes up 11% (5) each (Figure 4).

Figure 4 Family composition of fauna from Hides 3 and Benaria.



Of particular significance was a capture of the very rare Rock-dwelling Giant Rat (*Xenuromys barbatus*) in the scree slope below the well pad at Hides 3. This is a little known and rarely seen species. The occurrence of Long-beaked Echidna (*Zaglossus bartoni*), the world's largest existing monotreme species needs mentioning here. Although it is widely distributed along the central cordillera of the New Guinea mainland, this species can be considered as flagship species in terms of natural environment condition. Its existence provides essential clue that the forest is stable and intact.

By way of comparing the two sites of survey, of the total of 44 non-flying mammals one species was recorded only at Hides 3, 17 only at Benaria and 26 were recorded at both sites.

The total Kikori non-flying mammal fauna totals 79 species to date (Appendix 2). This figure includes possibly four new species of *Rattus*, an unidentified *Rattus*, and a new species of *Murexia*.

Appendix 2 shows that the montane and mid-montane sites are far richer in non-flying mammals than the lowland sites. Hides 3 and Benaria rank among the richest sites yet sampled in the KICDP. 64 species were recorded at Mt. Sisa, 28 species were recorded at Libano-Sok, 26 at Gobe, 25 on Mt Kemenagi, and 27 on Mt Bosavi. The two sites sampled recently by WWF in the Homa-Idauwi road route, had 30 species at each site.

Benaria is the second richest site sampled to date in the Kikori drainage. It is at lower altitude than Hides 3 and the montane sites on Mts Kemenagi and Bosavi. This lower altitude has the potential to cover the ranges of most mid montane species, some lowland species with high upper altitude limits and montane species that descend to lower altitudes. Hides 3 sampled the ranges of fewer species. The two Homa-Idauwi¹ sites, in a similar altitudinal zone to Benaria also have high diversity. Two localities surveyed (Hides and Benaria) lie in the high altitudinal zones and are therefore important for mammal species diversity with a viable population size.

Two other significant factors, however, are habitat diversity and the wider range of local informants available at Benaria. Benaria has a major river, grassland and a range of secondary habitats not found at Hides 3, which is pristine montane forest. Thus, at Benaria one would expect a wider range of species. Moreover, there were more local informants at this site than at Hides 3. Only one third of the species recorded at Benaria were seen or captured by the survey team whereas the figure at Hides 3 is 12 - half the species recorded. While identification of the medium and larger mammals by local people is quite reliable, the identity of the smaller rodents is less so and there may be overestimation of the numbers of rodents at Benaria. 17 of the supposed 20 rodents species at Benaria were from local informants only. Similarly, all the records from Homa-Idauwi sites are from local informants.

Conservation Status

This survey provides baseline biodiversity information on terrestrial non-flying mammals to assist in identifying of the occurrence of the species of mammals that are protected by Papua New Guinea legislation under *Environment Act 2003*. In Papua New Guinea, man and other potential predators easily hunt the bigger mammals and destroy habitats thus causing depletion in the number of wildlife. In general, most large and medium and many small mammal species are vulnerable to hunting, because of their size, slower movements, and are found in a limited area and have a small population size (Miller, 1996).

The IUCN status of all species in the KICDP area is presented in Appendix 3. Table 4 presents those species in all categories other than "Low Risk and of least concern" (LR/lc). 18 species in the KICDP area are in IUCN endangerment categories, of which eight were recorded at Hides 3 and Benaria.

Most of the listed species are hunting targets and are endangered by this process. These include *Zaglossus*, the tree kangaroos, possums, cuscuses, and the two giant rats *Uromys* and *Xenuromys*. They are threatened by over-hunting rather than habitat loss although some possums such as *Pseudochirops corinnae* are very sensitive to disturbance as well as hunting (Flannery, 1995). The status of the five small rodents is due to rarity.

¹ The spelling follows the 1:100K PNG topo maps. Alternatively, the spelling is Irawi.

Table 4 The IUCN status of species recorded in the KICDP, Benaria and H3

Family	Scientific name	Common name	Conservation status (IUCN)	Hides 3	Benaria
TACHYGLOSSIDAE	<i>Zaglossus bartoni</i>	Long-beaked Echidna	EN A1ac ver 2.3 (1994)		
DASYURIDAE	<i>Dasyurus albopunctatus</i>	New Guinea Quoll	VU A1a ver 2.3 (1994)	X	X
DASYURIDAE	<i>Phascomurexia naso</i>	Long-nosed Murexia	DD ver 2.3 (1994)		
PHALANGERIDAE	<i>Phalanger gymnotis</i>	Ground Cuscus	DD ver 2.3 (1994)	X	X
PHALANGERIDAE	<i>Phalanger vestitus</i>	Stein's Cuscus	VU A1a, B1+2a ver 2.3 (1994)	X	X
MACROPODIDAE	<i>Dendrolagus dorianus</i>	Doria's Tree Kangaroo	VU A1a ver 2.3 (1994)	X	X
MACROPODIDAE	<i>Dendrolagus goodfellowii</i>	Goodfellow's Tree Kangaroo	EN A1a ver 2.3 (1994)	X	X
MACROPODIDAE	<i>Dendrolagus spadix</i>	Lowland Tree Kangaroo	DD ver 2.3 (1994)		
PSEUDOCHEIRIDAE	<i>Pseudochirops corinnae</i>	Plush-coated Ringtail	VU A1a ver 2.3 (1994)	X	X
PSEUDOCHEIRIDAE	<i>Pseudochirulus canescens</i>	Lowland Ringtail	DD ver 2.3 (1994)		
PETAURIDAE	<i>Dactylopsila megalura</i>	Great Tailed Triok	VU A1d, B1+2a ver 2.3 (1994)		
MURIDAE	<i>Leptomys elegans</i>	Large Leptomys	CR B1+2c ver 2.3 (1994)		
MURIDAE	<i>Leptomys signatus</i>	Fly River Leptomys	CR B1+2c ver 2.3 (1994)		
MURIDAE	<i>Macruromys major</i>	Greater Small-toothed Rat	EN C2a ver 2.3 (1994)		
MURIDAE	<i>Mayeremys ellermani</i>	One-toothed Shrew Mouse	VU C2a ver 2.3 (1994)	X	X
MURIDAE	<i>Pogonomelomys bruijni</i>	Large Pogonomelomys	CR B1+2c ver 2.3 (1994)		
MURIDAE	<i>Uromys anak</i>	Giant Naked-tailed Rat	LR/nt ver 2.3 (1994)		
MURIDAE	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat	LR/nt ver 2.3 (1994)	X	

Richness and Endemism

The project area is very rich in mammals and this reflects the richness of PNG as a faunal area. With the exception of reptiles its fauna and flora is as great as or bigger than that of Australia (Table 5).

Table 5 Comparison of number of species supported by PNG and Australia.

Taxon	Australia		PNG	
	Total species (estimate)	% Of world total	Total species (estimate)	% Of world total
Higher plants	15,638	6	15,000 – 21,000	9
Amphibians	196	5	200	5
Reptiles	755	12	305	5
Birds	751	8	762	8
Mammals	282	6	242	5
Bats	77	8	91	9
Rodents (Muridae)	55	5	74	7

Like Australia, most of the PNG species of mammals are endemic i.e. more or less restricted to the area and their losses can be of global as well as national significance.

Appendix 3 includes a score for endemism, i.e. the extent to which a species is restricted to an area, for the 73 species with binomials (new species necessarily excluded). The scoring system is as follows.

1. Endemic to PNG (+/- satellite islands)
2. Endemic to main island of New Guinea +/- satellite islands (including Waigeo, Salawati and Misool)
3. Endemic to main island of New Guinea +/- satellite islands and the Aru islands
4. Endemic to main island of New Guinea +/- satellite islands +/- New Britain +/- New Ireland +/- the Louisiades.
5. Occurs more widely through the Australia, Indonesia, the Solomon Islands or the Pacific.

10 of the Kikori species are only found in PNG and a further 43 species only on the island of New Guinea i.e. nearly 70% of the species are highly endemic. The fauna at Hides 3 and Benaria have similar levels of endemism.

Discussion

The total number of 44 species recorded from the two sites of Hides 3 and Benaria is relatively high diversity considering the length of time spent in the field. Because of the limited time spent in the field for the survey, it is difficult to make comparisons between the two sites. However, using the limited survey data the species diversity between the two sites was compared. Of the two sites surveyed most of the locally and regionally endemic species occur in lower montane forest, which also means that greater mammal species diversity is to be expected at lower altitudes while higher altitudes often harbor only restricted range mid-upper montane specialists (Leary, 1999). Although the data is not sufficient, there appears to be a trend that towards low altitudes, there were high species diversity and species diversity decreases as altitude increases. In PNG, overall mammal diversity decreases with altitude and each species has a special range of altitudes within which it occurs. A large percentage of New Guinea endemic mammals are found at mid elevations of 1, 200 – 2, 500 m. According to Flannery (1995), high elevations have high percentages of endemism but the species usually occur in fewer numbers.

Hunting pressures from local people and other predators mostly threaten the endangered species. These same species are under threat in many parts of PNG and some places no longer retain species such as *Dendrolagus goodfellowi*, *Zaglossus bartoni* and *Pseudochirops corinnae*. Most of the data collected on abundance are from local informants based on their experiences and encounters, therefore, some of the species that were said to be seen but were not encountered by the survey team itself during the survey may have actually been locally extirpated but the locals still remember their presence.

Considering the general lifestyle of the people living within the project area, they more or less practice nomadic lifestyle and are still heavily dependant on wild animals (mammals) for meat. As lifestyle of the local people improve, the population size also increases and the demand for hunting these mammals and disturbing their natural environment increases simultaneously. Another possible threat to the non-flying and flying mammals is the high prevalence and usage of shotguns and home made rifles in the local area, because many other areas where guns are often used have already lost much of their large mammal species (Leary, 1999).

Larger mammals such as tree kangaroos (*Dendrolagus* spp.), bandicoots (*Microperoryctes* spp and *Peroryctes raffrayana*), cuscuses (*Phalanger* spp), possums and echidnas are heavily hunted by locals and the survey team observed few of these animals, particularly at Benaria. Few of the species were heard calling in the night but some were confirmed from their droppings. This could mean that either these larger mammals could be living at low population densities, or that their abundance is decreasing because of growing demand and hunting pressures.

However, from the results (44 species in 9 families and 30 genera) obtained from Hides 3 and Benaria we can confidently conclude that both sites accounts for high species diversity and that the natural ecological properties are still intact and rich. If enough time was spent in the field, the results would have provided avenue for firm argument on the status and stability of the natural habitats and the general environment and also some of the endangered or vulnerable species could have been caught or recorded. Thus, there is no adverse impact on the natural biodiversity and the impact of the oil and petroleum project, as it presently exists in the area, is minimal.

Potential Impacts of PNG Gas Project on the Environment.

Large scale development regimes that demand conversion and disturbance of large amounts of forest are likely to cause the greatest negative impact by causing the conversion or alteration of critical ecosystem processes. The retention of rare species and other biological diversity as well as non-biological factors is tied to retention of their natural habitat, which in the case of the Kikori River Catchment and the oil and petroleum development project area is primarily tropical moist forest (WWF US, 1997). When the forest habitat is significantly altered, it is extremely unlikely that the current species composition will remain and therefore biological diversity will be degraded. However, developments like gas pipeline construction will not necessarily involve conversion of vast areas of natural environment thus, generally they should have minor negative impacts on ecosystem processes and biodiversity values, providing that adequate care is taken to reduce forest cleared and disturbed, regeneration is allowed, and accidents such as oil spills, bursting of gas from broken pipes and fires do not occur. One of the most important things is to make sure that people cannot take advantage of the project by clearing forest and over hunting fauna.

Some of the potential impacts the PNG Gas Project will have on the environment are;

- Loss of micro habitats of mammal species in areas to be cleared for the RoW and ancillary facilities (access roads, camp sites, etc).
- Disturbance and removal of feeding, breeding and recreational areas of animals thus imposing threats to their survival. This is because each animal is territorial and moving into other territories and adapting to new environment may be a problem. Some may die in the process.
- Exposure of ground to direct sunlight and rain in areas to be cleared for the RoW and ancillary facilities (access roads, camp sites, etc) may cause soil erosion thus affecting forest regeneration.
- Local people hunting by accessing the pipeline path and causing alterations to the environment for agricultural or settlements.
- Introduction of exotic or new species of plants and animals that will have adverse environmental impact.
- Fire and diseases affecting the forest.

Various degrees of impacts of the gas pipeline project on the environment will directly (primary impacts) and indirectly (secondary impacts) affect the mammal population along the length of the proposed gas pipeline starting from the mountains of Hides (Nogoli) and finishing off in the lowlands at Omati.

Primary impacts

Terrestrial systems

Clearing of tropical moist forest is considered as one of the world's most serious environmental problems because tropical forests are home to 50-90% of the Earth's total stock of species (Miller 1996) and most of them still unknown and unnamed. Fragmentation of a portion of forest is very detrimental to various forms of plants and animals that inhabit that site.

The construction of the PNG Gas Project will involve destruction and alteration of some forest and hence will affect ground mammals, arboreal mammals, micro-bats, birds, reptiles, frogs and plants. Mammals especially will be the most affected because of their body size, restrictiveness, and low mobility of some species.

Table 6 shows the types of impacts that can affect different fauna groups and Table 7 indicates potential primary impacts that may be caused on the general environment from forest clearings and other construction activities along the pipeline route.

Forest clearance and the removal and accumulation of soil from construction sidecast will impact mammals in the direct line of disturbance. Mammals would be the species most vulnerable to this clearing. Habitats may be fragmented, thus causing some individuals of species to be lost and others to migrate.

As well as general forest clearing there will be alterations along the ROW to specific sites for mammals including trees, epiphytes, vines, montane grass, pandanus, dead logs, rocks, cliffs and big and small caves which mammals use for breeding, feeding and leisure. However, the degree of impact from construction can be minimized to an acceptable level so that most of the species are not affected much. Those species that are in the immediate vicinity of the project sites having potential of being killed or severely impacted can colonize if secondary impacts and gas project operations allows it.

Table 6 Ecological effects of forest clearing and soil disposal during constructions in mountain areas.

Impact Type	Ecological factors affected
Habitat fragmentation	All fauna and flora species that are there
Interruption of food web	Inter and intra dependent species of fauna and flora
Loss of nesting sites	Fauna (birds, mammals-flying and non-flying)
Loss of recreational sites	Fauna – all species of animals
Loss of feeding sites	All fauna and flora species
Loss of breeding sites	All actively breeding species of fauna and flora
Loss of species	Both fauna and flora in the site
Species migration	Fauna species whose habitats are destroyed
Loss of food sources	Species dependent on certain plants for food
Loss of seed dispersal agents	Both fauna and flora species that have interdependency relationship
Soil covering up wetlands and ponds	Fauna and flora dependent on water in ponds & wetland environment
Soil affecting nutrient cycle	Fauna and flora, not enough nutrients in the soul
Siltation of streams & alterations to watercourses	Fauna and flora
Soil covering up homes for mammals and other ground animals	Mammals

Table 7 Primary impacts of forest clearings on the environment. (Limestone mid-lower montane, swamp and mangrove forest types)

ROW Construction	Road constructions	Stream crossings	Operations
Loss of forest	Loss of forest	Loss of riverine vegetation	Noise
Loss of special habitats	Loss of special habitats	Loss of special habitats	Trafficking of fauna species
Loss of wetlands	Loss of wetlands	Loss of wetlands	Continued erosion
Habitat fragmentation	Habitat fragmentation	Disturbance to stream beds	Contaminants at crossing
Disturbance to nesting fauna	Disturbance to nesting fauna	Contaminants at crossing	Downstream erosion and siltation,
Trafficking fauna	Trafficking fauna	Catastrophic gas blow	
Hunting by construction crews	Hunting by construction crews	Catastrophic gas blow	
Noise and dust disturbance	Noise and dust disturbance	Maintaining vegetation	
Soil clearance and trenching	Soil clearance and trenching	Continued erosion	
Loss of soil structure and fertility	Loss of soil structure & fertility		
Sediment input to watercourse	Sediment input to watercourse		
Contamination of ground water	Contamination of ground water		
Disposing contaminants	Disposing contaminants		
Fire risk, burning cleared vegetation	Fire risk from burning cleared vegetation		
Fire risk, burning cleared vegetation	Fire risk from burning cleared vegetation		
Hazards from discarded materials and wastes	Permanent drainage system changes to ground and surface water		
Reduction of water quality	Failure of slopes at cuttings, fill		
Downstream erosion & siltation,	Sediment input to watercourses		
Drying of wells/springs	Interruption of surface drainage and changes in the hydrology		
Trench open and fauna falling in	River, stream morphology		
Changes to ground and surface water flows	Potential contamination of groundwater resources		
Permanent changes to drainage system	Soil disposal		
Failure of slopes at cuttings, fills	Contaminants disposal (diesel, other toxic chemicals)		
Soil disposal	Burrow pits		
Waste disposal			
Long term erosion, drainage problems			
Hydro testing - contamination of water			

Although not very much is known of the impact of noise on mammals in the project area it is assumed that noise may cause mammals to move out to other places in fear of the noise from machines and helicopters.

Impacts on River System

Rivers, streams, creeks, ponds, and other wetlands provide vital services to both flying and non-flying mammals as well as other fauna and flora in the environment. Water bodies are part of the ecosystem that directly and indirectly support the livelihood of the mammals and other species of fauna and flora. The construction of roads and digging of drains for the gas pipeline could increase the rate of soil erosion in disturbed areas causing increased sediment runoff into streams. Mammals whose lives are closely associated with riverine environment may be affected by:

- Clearing of the riverine vegetation that provides feeding, breeding, and recreational, sites.
- Deposition and accumulation of soil in the riverbeds affecting water quality.
- Disposal of wastes and other environmentally hazardous substances into the stream.
- Modification of bank morphology.

Some of the rodent species such as Water Rats (*Hydromys*, *Parahydromys*, and *Uromys*) and similar species could be affected. As a result, some mammal species may migrate to other locations in search of similar natural habitats. In a new environment, intra and inter species competition between the established mammals and the migrants for territory, food, space, and mate will force some of these migrants to eventually die out. Human induced migration of species of animals (mammals) is one cause of depletion in species number.

General assessment of primary impacts

Table 8 presents an overall assessment of primary impacts on mammals within the project area. The species most at risk are those that are regarded as specialists to particular altitudes and ecotypes and this particularly includes the higher montane species, cave dwellers and those requiring streamside vegetation. The montane species are larger mammals that are often rare at times. Generally, the mammal species diversity away from the gas pipeline construction will still be stable, intact and rich if no secondary impacts occur.

Table 8 Potential degree of impact on mammal population from gas pipeline project

Potential impact	Species within the proposed pipeline path	Species outside of the pipeline path
Road construction	Significant	Insignificant
Pipeline flow path	Significant	Insignificant
Hill cutting	Significant	Moderate
Waste disposal	Moderate (long term effect)	Mild
Diesel and oil spills	Moderate	Mild
Noise – disturbance	Significant	Widespread/insignificant
Introduced species (animal)	High	Widespread
Chemical disposal	Significant	Insignificant (but can be widespread as time goes by)

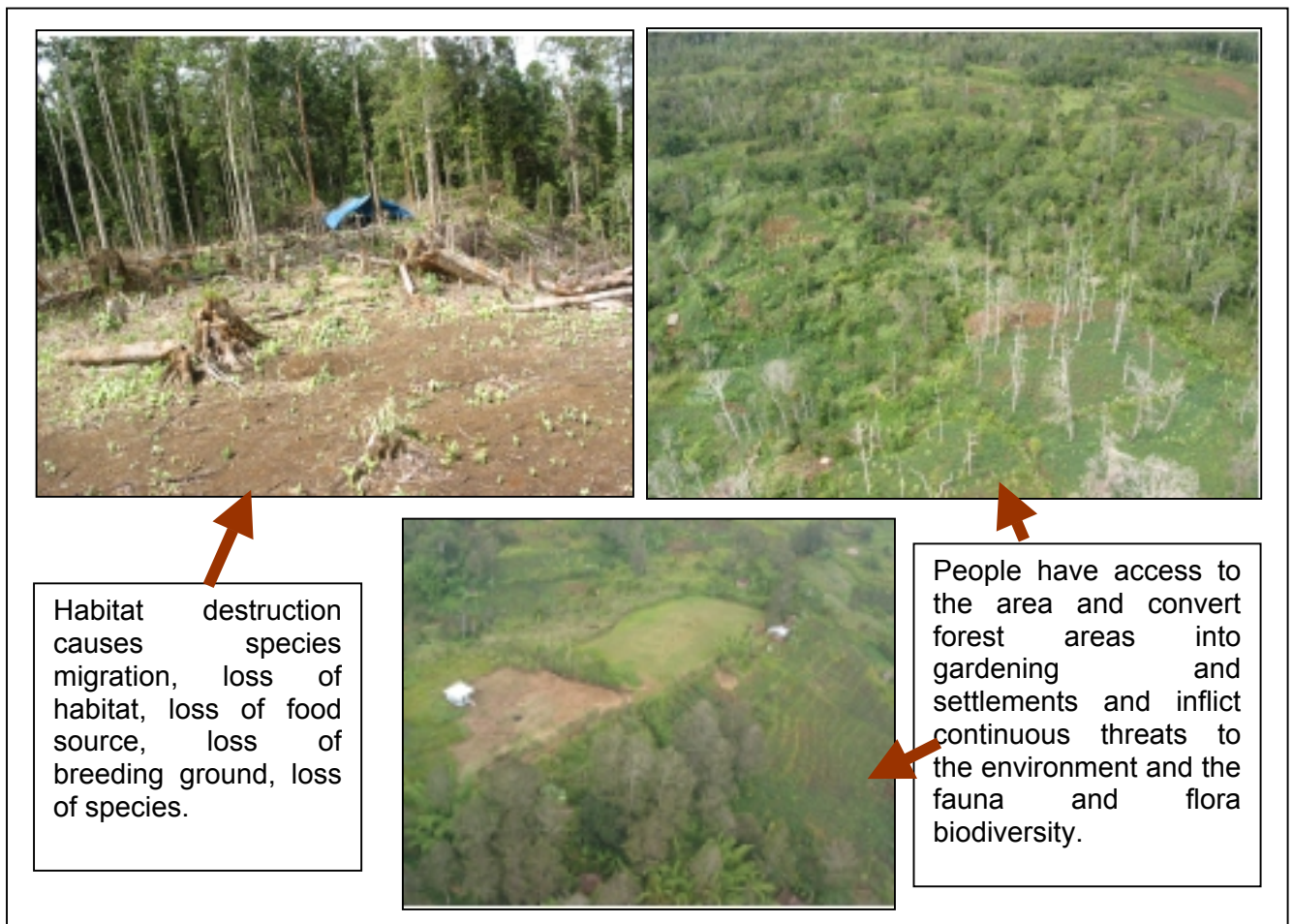
Secondary impacts.

Ecological integrity, maintaining the diversity and quality of ecosystems and enhancing their capacity to adapt to various degrees of changes, is crucial for nature to at least recreate an ecosystem that is as close as possible to the one which existed before a development. It is demonstrated that the natural environment within the project area is still intact and stable although there has been continuous disturbances and habitat destructions in the area since the development of oil and gas projects in the KICDP in the early 1990s. From an ecological perspective much of the primary impacts were done during the construction of these projects and in particular the Kutubu crude oil pipeline project, however some are still continuing in the areas where new exploration and drilling activities are conducted.

The construction of roads connecting various local villages and project sites to the Highlands Highway opens up doors for a potential influx of people from outside into the project area and the promotion of illegal logging, gardening and hunting. The impact of population growth within the project area itself is also a threat to the natural environment.

It is most likely that as road links are built for the laying of gas pipelines, many of the local people as well as migrants will have access to the roads thus having access to areas that are biologically intact. Much of the forest resources near the villages within the project area? have long been depleted and more people are moving further into areas they have never been to before to extract raw materials. This indicates that with the local population growth and the increasing number of migrants more forest areas will be cleared for settlements and agricultural purposes (Figure 5).

Figure 5 The effects of disturbance and secondary impacts of immigration.



People living in the project area have long been dependent on the natural environment before the inception of the oil and gas projects (we should try to be consistent here in the use of the terminology). Their day-to-day lives and activities were connected to the nature. They depended on the bigger mammals for meat and fur and birds for plumes. The extraction of such resources from the bush was done sustainably using traditional methods of hunting. However, with the introduction of money into the region the people tend to hunt with shotguns and slingshots rather than methods that are more traditional. The introduction of money has forced them to clear bigger forest areas for settlements or for agricultural activities. The oil and gas development projects have attracted people from outside into the project area thus increasing the population density. As the population grows the demand for usage of resources also increases. This instantaneous growth poses great threat to the environment especially the biological diversity within and around the surrounding area of the project. With this precedence set by the oil and gas development projects, it is most likely that more people will move into the region and the population of the local people will increase too.

Under the present regime of limited access to most of the project area biological diversity is likely to remain relatively high, particularly in areas where the human population is low. However, as population and the use of

cash in the region grow, the impact on the biological diversity is likely to be considerable.

Table 9 presents a summary of the likely severity and extent of secondary impacts.

Table 9 Significance of secondary impacts on the environment.

Human Impact	Degree of impact				
	<i>Severe</i>	<i>High</i>	<i>Moderate</i>	<i>Mild</i>	<i>Permanent</i>
Habitat destruction		√			√
Illegal settlements			√		√
Illegal hunting of fauna		√			
Agricultural activities				√	
Bush fire				√	
Illegal logging				√	
Additional bush tracts			√		√
Introduction of exotic species		√			√
Over harvesting of resources			√		
Trafficking of wildlife out of the site			√		√
Water and stream contamination				√	

General assessment of secondary impacts

Secondary impacts have the potential to be far worse than the primary impacts. If human intrusion and illegal clearing, hunting and logging cannot be controlled the local impacts around the project components can be severe and permanent and this may spread widely in the project area.

The oil and gas development projects in the Southern Highlands and Gulf provinces have opened up doors to modern basic services such as roads, airstrips, health centers thus improving lifestyle of the local people. Even the road links connecting to the Highlands Highway has had great impact on the lives of the local resource owners as well as those that having resource use rights. One of the significant impacts of the oil and petroleum project had is that it turned out to be one of the attracting factors. People from outside of the project area moved into the area and influenced the indigenous population with new ideas. There are always negative and positive impacts from similar large-scale development such as mining to the local population in the region.

Mitigation measures

The issue now with major developments that involve alterations of the natural ecosystems is how to maintain balanced and stable natural ecosystems. Intrusion of humans into natural environment can have multiple effects. Most of these effects are unpredictable because of our limited understanding of how nature works, and of which connections are more

important for the sustainability and survival of the ecosystems. The ecosystems can self-repair and heal the wounds inflicted by humans. In this process of rehabilitation and stabilizing of the natural environment by the nature requires our assistance. We can help in keeping the natural environment still intact and rich in biological diversity by;

- Ensuring that the minimal area of forest is cleared for the construction of the corridor in which the pipe will be laid.
- Secondary impacts need to be a particular focus of the project.
- Conducting surveys along the project area to identify, categorize and delineate critical natural habitats.
- The developer and its employees should at all times practice environmentally friendly working habit so that their activities do not impact the environment.
- Identify plants and animals that are endemic, critically endangered and vulnerable so that local people and the developer are made aware of the occurrence of the important species.
- Identify all critical natural habitats (e.g. roosting sites for bats-caves) along the project area and designate it to be a protected area so that Protected Areas Act protects it. Optionally, the corridor of the gas pipeline and adjacent environment could be declared as a protected area so that it prevents unnecessary people from having access to the pipeline path.
- Environmental monitoring is required to ensure and confirm that the habitats along the gas pipeline are intact and steady biologically.

Recommendations

World Wide Fund for Nature as an international conservation non-government organization was established in the Kikori River Catchment upon recommendations from the Papua New Guinea Conservation Needs Assessment (PNG CNA - Biodiversity Support Program 1993) to manage and provide technical support, scientific information, and other alternative resource use approaches to the resource owners and to ensure that they provide good stewardship towards their resources - one of the remaining intact biologically diverse habitats. The PNG CNA identified four areas inside the project area which the oil and petroleum project is included; Mt Bosavi, Kikori Karst/Lake Kutubu, Doma Peaks and Gulf (marine biodiversity) as areas of high conservation priority. As documented by WWF led biodiversity assessment surveys, the Kikori River Catchment (including Hides and Omati) harbors tremendous biological diversity of international significance (WWF US, 1997). It was stated clearly by Diamond and Bishop (1998) that 'the Kikori area has the potential to be managed as the large, self sustaining conservation area, covering the whole spectrum from alpine grassland at 13,000 feet down to mangrove at sea level'. It is true for this case because motor vehicles access is strictly regulated by the previous owners Chevron and now Oil Search so that the area adjacent to any roads and constructions is insulated from the usual threats to conservation (hunting, gardening, logging, settlements) that are rampant elsewhere in Papua New Guinea (Diamond & Bishop, 1998).

From the results and analysis of the information gathered on the biological diversity of mammals and other species within the project area, the following are some of the recommendations put forward in an effort to maintain the biological richness of the environment.

1. With the involvement of the landowners, National Government (DEC) and the gas and oil developer (ESSO Highlands Limited and Oil Search Limited respectively) work together and establish a protected area associated with the ROW. This will then prevent local and outside people from unnecessarily accessing the roads and other facilities within the corridor of the oil and gas pipelines and prevent them from illegal gardening, logging, hunting and settlement along the pipeline roads and flow lines.
2. Through collaborative effort between the developer and a reputable environmental specialist conduct a thorough educational awareness in villages around the project area and to the employees (of the developer and sub contractors) featuring the importance of the environment, ecological processes, functions and importance of organisms and the effect of destructive practices, IUCN and CITES status of plants and animals and their legality obligations in the country. The local people should be enlightened to practice sustainable resource harvesting, and avoid using of shotguns and other destructive weapons for hunting.
3. Establish and implement internal policies that will safeguard the fauna and flora within the project site. These policies will be closely monitored and ensure that all stakeholders and contractors comply.

References

- Balun L. (2004) An Audit on the Status of the Flora and Fauna of the Porora Forest, South East Mananda Forest, Southern Highlands Province. WWF KICDP Report.
- Balun, L. Mamu, T. and R, Namo. (2004). Supplementary report on the biodiversity survey of South-east Mananda (SEM). Unpublished report to HSES section – OSL.
- Diamond, J. and Bishop, K. D. (1998). Rivers in the Sky: The avifauna of the Kikori Pipeline, Papua New Guinea. Unpublished WWF Report
- Flannery, T. F. (1995). *Mammals of New Guinea*. Revised and Updated Edition. Robert Brown and Associates, Sydney, Australia.
- Flannery, T. F. and Groves, C. P. (1998) A revision of the genus *Zaglossus* (Monotremata, Tachyglossidae), with description of new species and subspecies. *Mammalia* **62**: 367 – 396.
- Groombridge, B. (1994). *1994 IUCN Red List of threatened animals*, IUCN. Cambridge, United Kingdom.
- Hartshorn, G. S., Burrows, I., Forney, M., Kosi, T., Mala, T. and Wiakabu, J. (1994). Preliminary biological reconnaissance of the Kikori River Basin, Papua New Guinea. Unpublished WWF Report, Washington DC.
- Hartshorn, G. S., Leary, T., Seri, L., Burrows, I., Allen, G., Polhemus, D., Balun, L., Orsak, L., Bigilale, E., Kinbag, F., Kinibel, A., Dal, C., Wasel, H., Ellis, G. and Forney, M. (1995). Field Survey of Biodiversity in the Kikori River Basin, Papua New Guinea. Unpublished WWF Report, Washington DC.
- Lamb, D, and Gilmour, D. (2003). *Issues in Conservation. Rehabilitation and restoration of degraded forests*. IUCN report. France.
- Leary T. & Seri L. (1995) Survey of Birds and Mammals at Utiti Creek. Unpublished WWF KICDP Report.
- Leary T. (1998) Mammals of the Lake Kutubu Swamp Forests. Wetlands International Report.
- Leary T. (1999) Mammal Survey of the Gobe Oil Field Area, Southern Highlands and Gulf Provinces, Papua New Guinea - December, 1998. WWF KICDP Report.
- Leary T. (2000) Rare Dolphins Found in the Kikori River Delta Area. WWF/PNG National Museum and Art Gallery Report.
- Leary T. (2001) Mammal Survey of Two Sites on the Northeast Slopes of Mt Sisa, Southern Highlands Province, PNG - October 1999. WWF KICDP Report.
- Leary T. (2002) Brief Report on Iviri Mammal Monitoring - December 2001. WWF KICDP Report.
- Leary T. (2004a) Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province, July - August, 2003. WWF KICDP Report.
- Leary T. (2004b) Brief Report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003. WWF KICDP Report.
- Leary T. (2004c) Brief Report on Keboi Kerowa Mammal Monitoring - July 2004. WWF KICDP Report.

- Leary T., Seri L. & Kinbag F. (1995) Report on the bat component of the field survey of biodiversity in the Kikori ICDP area. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (eds. G. S. Hartshorn). WWF KICDP Report.
- Leary, T. and Seri, L. (1997). An annotated checklist of mammals recorded in the Kikori River Basin, Papua New Guinea. *Science in New Guinea* **23** (2) : 79 – 100.
- Leary, T. and T, Mamu. (2004). (Second edition). *Conserving Papua New Guinea's forest fauna through community planning*. WWF Kikori Integrated Conservation and Development Project, Papua New Guinea.
- Mamu, T. and R, Sine. (2005). A preliminary fauna assessment of the forest corridor of Homa-Irawi proposed road, Tari. Southern Highlands Province. A supplementary report to HSES section - Oil Search Limited.
- Menzies, J. I. (1996) A systematic revision of *Melomys* (Rodentia: Muridae) of New Guinea. *Australian Journal of Zoology*. **44**: 367 – 426.
- Miller, G. T. Jr. (1996). *Living in the environment. Principles, connections and solutions*. Wadsworth Publishing Company. New York. USA.
- Namo R. (2004a) Annotated Checklist of Mammals of Kikori Basin. WWF KICDP Report.
- Norris, C. A. and Musser, G. G. (2001) Systematic Revision within the *Phalanger orientalis* complex (Diprotodontia, Phalangeridae): a third species of lowland grey Cuscus from New Guinea and Australia. *American Museum Novitates* 3356.
- Seri L., Leary T. & Kinbag F. (1995) Report on the non-flying mammal component of the field survey of biodiversity in the Kikori ICDP area. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (eds G. S. Hartshorn et al.). WWF KICDP Report.
- Van Dyck, S. (2002) Morphology-based revision of *Murexia* and *Antechinus* (Marsupialia: Dasyuridae). *Memoirs of the Queensland Museum* **48**: 239 – 330.
- WWF US. (1997) Regional Environmental Analysis. Prepared for the WWF Conservation and Sustainable Development and Loan Fund Program in the Kikori Basin. WWF US, USA.

Appendix 1 Description of survey transects.

Site	Nights of actual survey	Latitude in decimal minutes	Longitude in decimal minutes	Altitude (m)	Vegetation type
H 3 - Perimeter of H 3 helipad	1	05 DEG 56.921 S	142 DEG 44.723 E	2,266	Mid montane forest dominated by <i>Nothofagus</i> sp. Disturbed forest with secondary regrowth dominated by <i>Saurauia</i> spp. , with fraction of karst and limestone
H 3: Transect 1 at SR Hill near Mammal Trap # 1 (S)	6	05 DEG 56.909 S	142 DEG 44.660 E	2,262	Mid montane forest dominated by <i>Nothofagus</i> sp.
H 3: Transect 1 from SR Hill to flow lines near H 2 end of Mammal Trap # 51 (S)		05 DEG 56.947 S	142 DEG 44.443 E	2,267	Mid montane forest dominated by <i>Nothofagus</i> sp.
H 3: Transect 2 - Trap # 1 downhill to Wayne's swamp	6	05 DEG 56.874 S	142 DEG 44.720 E		Mid montane forest with dominants of re-growth secondary succession and limestone karst.
H 3: Transect 2 – track uphill out of Wayne's swamp at end of Mammal Trap # 30 (SE)		05 DEG 56.795 S	142 DEG 44.742 E		Mid montane forest dominated by <i>Nothofagus</i> sp. with dense thickets of scrambling bamboo <i>Nastus productus</i> undergrowth.
Benaria camp – perimeter of camp site	3	06 DEG 03.280 S	142 DEG 58.719 E	1,350	Disturbed lower montane forest – camp site mostly re-growth forest and grassland.
Benaria Transect 1 - near small creek beginning of Mammal traps on road survey line.	2	06 DEG 03.434 S	142 DEG 58.646 E	1,350	Lower montane forest dominated by <i>Castanopsis acuminatissima</i> and <i>Lithocarpus</i> spp.
Benaria Transect 2 - Trap # 40 (SE) end of trap line near river	6	06 DEG 03.529 S	142 DEG 58.468 E	1,343	Lower montane hill forest dominated by <i>Castanopsis acuminatissima</i> and <i>Lithocarpus</i> spp.
Benaria Transect 3 - Trap # 40 (SE) end of trap line uphill	4	06 DEG 03.560 S	142 DEG 58.710 E	1,449	Lower montane hill forest dominated by <i>Castanopsis acuminatissima</i> and <i>Lithocarpus</i> spp.
Benaria Transect 3 - ridge top		06 DEG 03.553 S	142 DEG 58.730 E	1,530	Lower montane re-growth forest on old abandoned village.
Benaria Transect 4 – near swampy area.	2			1,300	Lower montane forest on swampy area

Appendix 2 Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Aird Hills	Au Cave	Dark End Lumber	Iviri (1, 2 & 3)	Keboi Kerowa	Kikori	Kopi	Utiti Creek	Veiru Creek	Fogomaiyu	Libano Sok	Waro	Darai	Omo	Sirebi	Gobe	Kafa village/cave	Kantobo	Mt Kemenagi
Tachyglossidae	Zaglossus bartoni ¹	Long-beaked Echidna											L		L			X			X
Tachyglossidae	Tachyglossus aculeatus	Short-beaked Echidna											L		L						
Dasyuridae	Dasyurus albopunctatus	New Guinea Quoll											L		L			X			
Dasyuridae	Murexichinus melanurus ²	Black-tailed Antechinus											L								
Dasyuridae	Phascomurexia naso ²	Long-nosed Murexia											L								
Dasyuridae	Murexia longicaudata	Short-furred Dasyure											X								
Dasyuridae	Murexia sp.	Murexia																			
Dasyuridae	Myoictis melas	Three-striped Dasyure											L		L						X
Peroryctidae	Echymipera kalubu	Common Echymipera			X	T	T				X		X		X			X			X
Peroryctidae	Echymipera rufescens	Long-nosed Echymipera									X				X						X
Peroryctidae	Microperoryctes longicauda	Striped Bandicoot			L													X			L
Peroryctidae	Peroryctes raffrayana	Raffray's Bandicoot			L				R ⁸				L								L
Phalangeridae	Phalanger carmelitae	Mountain Cuscus																			
Phalangeridae	Phalanger gymnotis	Ground Cuscus			L			M		X			L		L			X			L
Phalangeridae	Phalanger intercastellanus ³	Common Cuscus								X				M				L			L
Phalangeridae	Phalanger mimicus ³	Cuscus			L	T	T						L		L						
Phalangeridae	Phalanger sericeus	Silky Cuscus																			
Phalangeridae	Phalanger vestitus	Stein's Cuscus																			
Phalangeridae	Spilocuscus maculatus	Spotted Cuscus			L	T	T						L	M	L			X			X

Appendix 2 Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Aird Hills	Au Cave	Dark End Lumber	Iviri (1, 2 & 3)	Keboi Kerowa	Kikori	Kopi	Utiti Creek	Veiru Creek	Fogomaiyu	Libano Sok	Waro	Darai	Omo	Sirebi	Gobe	Kafa village/cave	Kantobo	Mt Kemenagi
Macropodidae	<i>Dendrolagus dorianus</i>	Doria's Tree Kangaroo											L		L			X		X	X
Macropodidae	<i>Dendrolagus goodfellowii</i>	Goodfellow's Tree Kangaroo											L		L			X			
Macropodidae	<i>Dendrolagus spadix</i>	Lowland Tree Kangaroo			L				R ⁸						L						L
Macropodidae	<i>Dorcopsis hageni</i>	White-Striped Dorcopsis																			
Macropodidae	<i>Dorcopsis luctuosa</i>	Grey Dorcopsis			L				R	X			L		L						
Macropodidae	<i>Dorcopsulus vanheurni</i>	Lesser Forest Wallaby																L			X
Burramyidae	<i>Cercartetus caudatus</i>	Long-tailed Pygmy Possum																			L
Pseudocheiridae	<i>Pseudochirops corinnae</i>	Plush-coated Ringtail																			
Pseudocheiridae	<i>Pseudochirops cupreus</i>	Coppery Ringtail																			L
Pseudocheiridae	<i>Pseudochirulus canescens</i>	Lowland Ringtail					T				X							X			
Pseudocheiridae	<i>Pseudochirulus forbesi</i>	Painted Ringtail																			X
Pseudocheiridae	<i>Pseudochirulus mayeri</i>	Pygmy Ringtail																			
Petauridae	<i>Dactylopsila megalura</i>	Great Tailed Triok																			
Petauridae	<i>Dactylopsila palpator</i>	Long-fingered Triok																			
Petauridae	<i>Dactylopsila trivirgata</i>	Striped Possum			L								L	M				L			L
Petauridae	<i>Petaurus breviceps</i>	Sugar Glider			L		T			L			X	M	X			X			L
Acrobatidae	<i>Distoechurus pennatus</i>	Feather-tailed Possum			L				T				L		L						L
Muridae	<i>Anisomys imitator</i>	Uneven-toothed Rat											L								
Muridae	<i>Chiruromys vates</i>	Lesser-tree Mouse										M	X								

Appendix 2 Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Aird Hills	Au Cave	Dark End Lumber	Iviri (1, 2 & 3)	Keboi Kerowa	Kikori	Kopi	Utiti Creek	Veiru Creek	Fogomaiyu	Libano Sok	Waro	Darai	Omo	Sirebi	Gobe	Kafa village/cave	Kantobo	Mt Kemenagi
Muridae	<i>Crossomys moncktoni</i>	Earless Water Rat																			
Muridae	<i>Cocomys rummleri</i>	Rummler's Mouse																			
Muridae	<i>Hydromys chrysogaster</i>	Common Water Rat					T														
Muridae	<i>Hyomys goliath/ dammermani</i> H.	White-eared Rat																			
Muridae	<i>Leptomys elegans</i>	Large Leptomys																			
Muridae	<i>Leptomys signatus</i>	Fly River Leptomys													X						
Muridae	<i>Leptomys ernstmayeri</i>	Ernst Mayer's Leptomys													X						
Muridae	<i>Lorentzimys nouhuysi</i>	Long-footed Tree Mouse													X			X			
Muridae	<i>Macruromys major</i>	Greater Small-toothed Rat																			
Muridae	<i>Mallomys aroaensis</i>	Grey Black-eared Rat																			
Muridae	<i>Mallomys rothschildi</i>	Dusky Black-eared Rat																			
Muridae	<i>Mayeremys ellermani</i>	One-toothed Shrew Mouse																			
Muridae	<i>Melomys leucogaster</i> ⁴	White-bellied Melomys				X	X			X	X			M				X			
Muridae	<i>Melomys lutillus</i> ^{4,5}	Grassland Melomys																			
Muridae	<i>Melomys rufescens</i> ⁴	Black-tailed Melomys			X					X			X	M	X			X			
Muridae	<i>Microhydromys richardsoni</i>	Groove-toothed Shrew Mouse													X						
Muridae	<i>Parahydromys asper</i>	Waterside Rat																			
Muridae	<i>Paramelomys levipes</i> ? ⁴	Long-nosed Melomys														X		X			X
Muridae	<i>Paramelomys lorentzii</i> ⁴	Lorentz's Melomys																			

Appendix 2 Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Aird Hills	Au Cave	Dark End Lumber	Iviri (1, 2 & 3)	Keboi Kerowa	Kikori	Kopi	Utiti Creek	Veiru Creek	Fogomaiyu	Libano Sok	Waro	Darai	Omo	Sirebi	Gobe	Kafa village/cave	Kantobo	Mt Kemenagi
Muridae	<i>Paramelomys mollis</i> ⁴	Thomas's Melomys																			
Muridae	<i>Paramelomys platyops</i> ⁴	Lowland Melomys			X						X		X		X	X		X			X
Muridae	<i>Paramelomys rubex</i> ⁴	Mountain Melomys								X								X			X
Muridae	<i>Pogonomelomys bruijni</i>	Large Pogonomelomys																			
Muridae	<i>Pogonomelomys mayeri</i>	Shaw Mayer's Pogonomelomys																			
Muridae	<i>Pogonomys loriae</i>	Large Tree Mouse			X					X			X					X			
Muridae	<i>Pogonomys macrourus</i>	Chestnut Tree Mouse											X								
Muridae	<i>Pogonomys sylvestris</i>	Grey-bellied Tree-mouse																			
Muridae	<i>Rattus exulans</i>	Pacific Rat							T												
Muridae	<i>Rattus leucopus</i>	Cape York Rat	M		X			M	T	X	X		X	M	X	X		X			X
Muridae	<i>Rattus novaeguineae</i>	New Guinea Rat																			
Muridae	<i>Rattus sp.</i>	Rat																			
Muridae	<i>Rattus sp. nov. (Mt Kemenagi)</i>	Undescribed species of Rattus																			X
Muridae	<i>Rattus cf. praetor</i> ⁶	Large Spiny Rat																X			
Muridae	<i>Rattus sp. nov. (Gobe)</i>	Undescribed species of Rattus			X										X			X			
Muridae	<i>Rattus sp. nov. Darai (cf. mordax)</i>	Undescribed species of Rattus											X								
Muridae	<i>Rattus steini</i>	Stein's Rat																X			

Appendix 2 Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Aird Hills	Au Cave	Dark End Lumber	Iviri (1, 2 & 3)	Keboi Kerowa	Kikori	Kopi	Utiti Creek	Veiru Creek	Fogomaiyu	Libano Sok	Waro	Darai	Omo	Sirebi	Gobe	Kafa village/cave	Kantobo	Mt Kemenagi
Muridae	<i>Stenomys niobe</i>	Moss Forest Rat																X			
Muridae	<i>Stenomys verecundus</i>	Slender Rat											X		X						X
Muridae	<i>Uromys anak</i>	Giant Naked-tailed Rat																			
Muridae	<i>Uromys caudimaculatus</i>	Mottled-tailed Giant Rat				X	X			X			X	M				X			X
Muridae	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat																			

Appendix 2 (contd.) Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Wasi Falls	Lake Kutubu	Agogo (Henry's Trail)	Iagifu Ridge	Benaria	Homa - Idauwi (H12)	Homa - Idauwi (H5)	Hides3	Boavi-Didesa	Mt Bosavi	Mt Sisa
Tachyglossidae	Zaglossus bartoni ¹	Long-beaked Echidna					L	L	L	X			M
Tachyglossidae	Tachyglossus aculeatus	Short-beaked Echidna											
Dasyuridae	Dasyurus albopunctatus	New Guinea Quoll			R ⁷		L	L	L	L			X
Dasyuridae	Murexichinus melanurus ²	Black-tailed Antechinus	X										M
Dasyuridae	Phascomurexia naso ²	Long-nosed Murexia											X
Dasyuridae	Murexia longicaudata	Short-furred Dasyure					L	L	L	L			M
Dasyuridae	Murexia sp.	Murexia											X
Dasyuridae	Myoictis melas	Three-striped Dasyure						L	L			X	M
Peroryctidae	Echymipera kalubu	Common Echymipera	X				X	L	L	L			M
Peroryctidae	Echymipera rufescens	Long-nosed Echymipera											M
Peroryctidae	Microperoryctes longicauda	Striped Bandicoot	L				L	L	L	X			X
Peroryctidae	Peroryctes raffrayana	Raffray's Bandicoot					X			L			M
Phalangeridae	Phalanger carmelitae	Mountain Cuscus					X	L	L	X		X	X
Phalangeridae	Phalanger gymnotis	Ground Cuscus					L	L	L	X		L	X
Phalangeridae	Phalanger intercastellanus ³	Common Cuscus			R							L	M
Phalangeridae	Phalanger mimicus ³	Cuscus											
Phalangeridae	Phalanger sericeus	Silky Cuscus					L	L	L	X			X
Phalangeridae	Phalanger vestitus	Stein's Cuscus					X	L	L	L			M
Phalangeridae	Spilocuscus maculatus	Spotted Cuscus					L	L	L	L		L	M
Macropodidae	Dendrolagus dorianus	Doria's Tree Kangaroo	L				L	L	L	X		X	M

Appendix 2 (contd.) Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Wasi Falls	Lake Kutubu	Agogo (Henry's Trail)	Iagifu Ridge	Benaria	Homa - Idauwi (H12)	Homa - Idauwi (H5)	Hides3	Boavi-Didesa	Mt Bosavi	Mt Sisa
Macropodidae	<i>Dendrolagus goodfellowii</i>	Goodfellow's Tree Kangaroo					X	L	L	L			M
Macropodidae	<i>Dendrolagus spadix</i>	Lowland Tree Kangaroo	L					L	L			R	M
Macropodidae	<i>Dorcopsis hageni</i>	White-Striped Dorcopsis											L
Macropodidae	<i>Dorcopsis luctuosa</i>	Grey Dorcopsis	X										
Macropodidae	<i>Dorcopsulus vanheurni</i>	Lesser Forest Wallaby					L			L			M
Burramyidae	<i>Cercartetus caudatus</i>	Long-tailed Pygmy Possum					L	L	L				M
Pseudocheiridae	<i>Pseudochirops corinnae</i>	Plush-coated Ringtail					L	L	L	L			X
Pseudocheiridae	<i>Pseudochirops cupreus</i>	Coppery Ringtail					L	L	L	L		X	X
Pseudocheiridae	<i>Pseudochirulus canescens</i>	Lowland Ringtail						L	L			M	M
Pseudocheiridae	<i>Pseudochirulus forbesi</i>	Painted Ringtail											M
Pseudocheiridae	<i>Pseudochirulus mayeri</i>	Pygmy Ringtail					L	L	L	L			M
Petauridae	<i>Dactylopsila megalura</i>	Great Tailed Triok											L
Petauridae	<i>Dactylopsila palpator</i>	Long-fingered Triok					L						M
Petauridae	<i>Dactylopsila trivirgata</i>	Striped Possum					L	L	L			X	M
Petauridae	<i>Petaurus breviceps</i>	Sugar Glider	L				X	L	L	X		L	M
Acrobatidae	<i>Distoechurus pennatus</i>	Feather-tailed Possum		T			X	L	L	L			M
Muridae	<i>Anisomys imitator</i>	Uneven-toothed Rat	X			X		L	L				X
Muridae	<i>Chiruromys vates</i>	Lesser-tree Mouse					L					M	M
Muridae	<i>Crossomys moncktoni</i>	Earless Water Rat					L	L	L	L			M
Muridae	<i>Coccomys rummleri</i>	Rummler's Mouse					X						
Muridae	<i>Hydromys chrysogaster</i>	Common Water Rat					L						M
Muridae	<i>Hyomys goliath/ H.</i>	White-eared Rat											M

Appendix 2 (contd.) Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Wasi Falls	Lake Kutubu	Agogo (Henry's Trail)	Iagifu Ridge	Benaria	Homa - Idauwi (H12)	Homa - Idauwi (H5)	Hides3	Boavi-Didesa	Mt Bosavi	Mt Sisa
	dammermani												
Muridae	Leptomys elegans	Large Leptomys	X			X							M
Muridae	Leptomys signatus	Fly River Leptomys											
Muridae	Leptomys ernstmayeri	Ernst Mayer's Leptomys					L						
Muridae	Lorentzimys nouhuysi	Long-footed Tree Mouse	X	X								X	M
Muridae	Macruromys major	Greater Small-toothed Rat											M
Muridae	Mallomys aroaensis	Grey Black-eared Rat											M
Muridae	Mallomys rothschildi	Dusky Black-eared Rat										M	M
Muridae	Mayeremys ellermani	One-toothed Shrew Mouse					L			L			
Muridae	Melomys leucogaster ⁴	White-bellied Melomys		X			L	L	L				M
Muridae	Melomys lutillus ^{4,5}	Grassland Melomys					X						M
Muridae	Melomys rufescens ⁴	Black-tailed Melomys	X	X			X	L	L	X			X
Muridae	Microhydromys richardsoni	Groove-toothed Shrew Mouse											M
Muridae	Parahydromys asper	Waterside Rat					L			L			M
Muridae	Paramelomys levipes? ⁴	Long-nosed Melomys											M
Muridae	Paramelomys lorentzii ⁴	Lorentz's Melomys										R	
Muridae	Paramelomys mollis ⁴	Thomas's Melomys					L						X
Muridae	Paramelomys platyops ⁴	Lowland Melomys	X	X			L					M	M
Muridae	Paramelomys rubex ⁴	Mountain Melomys	X			X	L	L	L	X		X	X
Muridae	Pogonomelomys bruijini	Large Pogonomelomys										M	M
Muridae	Pogonomelomys mayeri	Shaw Mayer's Pogonomelomys											M

Appendix 2 (contd.) Occurrence of non flying mammals at survey sites in the Kikori ICDP.

Family	Scientific name	Common name	Wasi Falls	Lake Kutubu	Agogo (Henry's Trail)	Iagifu Ridge	Benaria	Homa - Idauwi (H12)	Homa - Idauwi (H5)	Hides3	Boavi-Didesa	Mt Bosavi	Mt Sisa
Muridae	<i>Pogonomys loriae</i>	Large Tree Mouse					L	L	L	X		R	M
Muridae	<i>Pogonomys macrourus</i>	Chestnut Tree Mouse										R	M
Muridae	<i>Pogonomys sylvestris</i>	Grey-bellied Tree-mouse					L					R	
Muridae	<i>Rattus exulans</i>	Pacific Rat										M	
Muridae	<i>Rattus leucopus</i>	Cape York Rat	X									M	M
Muridae	<i>Rattus mordax</i>	Eastern Rat											M
Muridae	<i>Rattus novaeguineae</i>	New Guinea Rat	X										M
Muridae	<i>Rattus</i> sp.	Rat											
Muridae	<i>Rattus</i> sp. nov. (Mt Kemenagi)	Undescribed species of <i>Rattus</i>											
Muridae	<i>Rattus</i> cf. <i>praetor</i> ⁶	Large Spiny Rat											
Muridae	<i>Rattus</i> sp. nov. (Gobe)	Undescribed species of <i>Rattus</i>											
Muridae	<i>Rattus</i> sp. nov. Darai (cf. <i>mordax</i>)	Undescribed species of <i>Rattus</i>											
Muridae	<i>Rattus steini</i>	Stein's Rat										R	M
Muridae	<i>Stenomys niobe</i>	Moss Forest Rat						L	L			X	X
Muridae	<i>Stenomys verecundus</i>	Slender Rat				X						X	M
Muridae	<i>Uromys anak</i>	Giant Naked-tailed Rat						L	L				M
Muridae	<i>Uromys caudimaculatus</i>	Mottled-tailed Giant Rat	X									X	M
Muridae	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat	X										M

X = definitively recorded on a WWF survey by WWF scientists, **T** = incidental survey record in reports in prep. (T. Leary pers. comm. to F. Crome 22/07/05); **being prepared L** = local knowledge only, **M** = museum record, **R** = reference to another paper in a WWF report. Only the highest reliability record per cell is included for brevity's sake. Thus, if only L then this implies there are no X or M or R, if R then there are no X or L, if X then may also be L and/or R, if M then may also be X and/or L and/or R).

See next table for locations of sites.

*Taxonomic Notes

1 Formerly *Z. bruijnii*. *Z. bartoni* follows Flannery and Groves (1998)

2. Generic arrangements follows Van Dyck (2002).

3. Norris and Musser (2001) raised "...a third species of lowland Cuscus *Phalanger mimicus*. The boundaries of which are somewhat fuzzy and the boundary between *P. mimicus* and *P. intercastellanus* probably lies within the Kikori Basin. Those that I have collected and examined recently from Libano, Darai and Iviri and Keboi Kerowa are all *Phalanger mimicus* as are the specimens Norris & Musser examined from Mt Bosavi. I have not re-examined earlier specimens from Utiti Creek, Wasi Falls, Mt Sisa and Gobe so cannot say which species they are. I suspect though that those at Gobe and Wasi Falls may be *P. intercastellanus*." (Tanya Leary *in litt.* 23/06/05)

4. Generic arrangements follows Menzies (1996).

5. Flannery (1995) suggest this is synonymous with *M. burtoni* of Australia but Tanya Leary (*in litt.* 23/06/05) says "No-one has yet revised *M. lutillus*, and I believe that it is only the subspecies *Melomys lutillus muscinus* is a synonym of *M. burtoni*. *M. lutillus muscinus* only occurs in the TransFly so *M. lutillus* for our specimens is correct. It actually appears that the insular varieties of *M. leucogaster* are a separate species"

6. "*R. praetor* should not theoretically be in the project area. For now I would leave it as *R. cf praetor*. I am looking at other material to decide whether this should be described as a new species – this would make a 4th undescribed *Rattus* species for the project." (Tanya Leary *in litt.* 23/06/05). Also *Rattus mordax* was erroneously recorded for the KICDP as a result of a misinterpretation of a museum label. (Tanya Leary *in litt.* 23/06/05).

7 Recorded in Hartshorn et al. 1994 but not Hartshorn et al. 1996.

8 Hartshorn et al (1994) recorded from Kopi but record may be doubtful (Leary and Seri)

Data Sources

Balun (2004), Hartshorn et al. (1995), Leary & Seri (1995), Leary (1998), Leary (1999), Leary (2000), Leary (2001), Leary (2002), Leary (2004a), Leary (2004b), Leary (2004c), Mamu & Sine, (2005), Namo (2004a), Namo (2004b), Seri, Leary & Kinbag (1995).

Appendix 2 continued Locations of sites in Appendix 2.

Site	Southing	Easting	Altitude (m)	Site of	
				WWF Survey	Museum Specimen
Au Cave	7°25'32' S	144°11'44' E	20		
Bosavi-Didesa	6° 28.00' S	142° 50.00' E			X
Bosavi	6° 32' 43' S	142° 50' 23' E	1280	X	X
Mt Bosavi	6°32'43' S	142°50'23' E	1300	X	
Dark End Lumber	6°07.547' S	142°46.019'E	20-30	X	
Fogomaiyu	6°32' S	143° 05' E	200		X
Gobe	6°49'409' S	143°44'680' E	50, 250, 600, 900 & 1300	X	
Iagifu Ridge	6°28'58' S	143°13'39' E	1330-1350	X	
Iviri (1, 2 & 3)	7°25'32' S	144°11'44' E	20	X	
Kafa village/cave	06°43'21' S	143°20.22' E	1330-1350	X	
Kantobo	6°44'53' S	143°35'23' E	400-420		
Keboi Kerowa#	7°25'32' S	144°11'44' E	20	X	
Kikori	07°25'42' S	144°14'54' E	10		X
Kopi	7°19.323 S	144°10.895' E	20-30	X	
Lake Kutubu and Gesege village	06°24.84' S	143°15.73' E	830	X	X
Mt Kemenagi	6°27'55' S	143°24'29' E	900	X	
Mt Sisa	6°12' S	142°46' E	2000 & 2500	X	X
Omo	6°58'41' S	144°18'15' E	170-200	X	
Sirebi	7°03'S	144°19'E	20-35		
Utiti Creek	7°13'33' S	144°05'54' E	35	X	
Veiru Creek	7°25'32' S	144°11'44' E	30	X	
Waro	6°32' S	143° 05' E	?		X

Appendix 2 continued Locations of sites in Appendix 2.

Site	Southing	Easting	Altitude (m)	Site of	
				WWF Survey	Museum Specimen
Wasi Falls	6°44'53' S	143°35'23' E	450	X	
Libano Sok	06°24'01.6' S	142°58'30.0' E	200-600		
Darai	07°07'50.7' S	143°36'37.8' E	300-700	X	
Hides 3	06°03'17.8' S	142°59' ²⁴ , E	2163	X	
Benaria	05°56'54' S	142°59' ^{43.8} , E	1530	X	
Aird Hills	07°26' 24' S	144°22'11' E	50		X
Agogo (Henry's Trail)	06°23'54' s	143°10'42' E	1050		
Homa-Irawi (H5)	06 10' 38'	143 04' 31'	1239		
Homa-Irawi (H12)	6 05' 24'	142 59' 24'	1239		

Appendix 3 Conservation status and level of endemism of KICDP non-flying mammals.

Family	Scientific name	Common name	Conservation status (IUCN)	* Endemism	Abundance
Tachyglossidae	<i>Zaglossus bartoni</i>	Long-beaked Echidna	EN A1ac ver 2.3 (1994)	4	rare
Tachyglossidae	<i>Tachyglossus aculeatus</i>	Short-beaked Echidna	LR/lc ver 2.3 (1994)	1	uncommon
Dasyuridae	<i>Dasyurus albopunctatus</i>	New Guinea Quoll	VU A1a ver 2.3 (1994)	4	rare
Dasyuridae	<i>Murexichinus melanurus</i>	Black-tailed Antechinus	LR/lc ver 2.3 (1994)	3	common
Dasyuridae	<i>Phascomurexia naso</i>	Long-nosed Murexia	DD ver 2.3 (1994)	4	uncommon
Dasyuridae	<i>Murexia longicaudata</i>	Short-furred Dasyure	LR/lc ver 2.3 (1994)	3	very rare
Dasyuridae	<i>Murexia sp.</i>	Undescribed species of Murexia		5	unknown
Dasyuridae	<i>Myoictis melas</i>	Three-striped Dasyure	LR/lc ver 2.3 (1994)	3	rare
Peroryctidae	<i>Echymipera kalubu</i>	Common Echymipera	LR/lc ver 2.3 (1994)	2	common
Peroryctidae	<i>Echymipera rufescens</i>	Long-nosed Echymipera	LR/lc ver 2.3 (1994)	1	common
Peroryctidae	<i>Microperoryctes longicauda</i>	Striped Bandicoot	LR/lc ver 2.3 (1994)	4	common
Peroryctidae	<i>Peroryctes raffrayana</i>	Raffray's Bandicoot	LR/lc ver 2.3 (1994)	4	common
Phalangeridae	<i>Phalanger carmelitae</i>	Mountain Cuscus	LR/lc ver 2.3 (1994)	4	common
Phalangeridae	<i>Phalanger gymnotis</i>	Ground Cuscus	DD ver 2.3 (1994)	3	common
Phalangeridae	<i>Phalanger intercastellanus</i>	Common Cuscus	LR/lc ver 2.3 (1994)	1	common
Phalangeridae	<i>Phalanger mimicus</i>	Cuscus	No classification	4	
Phalangeridae	<i>Phalanger sericeus</i>	Silky Cuscus	LR/lc ver 2.3 (1994)	4	common
Phalangeridae	<i>Phalanger vestitus</i>	Stein's Cuscus	VU A1a, B1+2a ver 2.3 (1994)	4	rare
Phalangeridae	<i>Spilocuscus maculatus</i>	Spotted Cuscus	LR/lc ver 2.3 (1994)	1	common
Macropodidae	<i>Dendrolagus dorianus</i>	Doria's Tree Kangaroo	VU A1a ver 2.3 (1994)	4	common
Macropodidae	<i>Dendrolagus goodfellowii</i>	Goodfellow's Tree Kangaroo	EN A1a ver 2.3 (1994)	4	uncommon
Macropodidae	<i>Dendrolagus spadix</i>	Lowland Tree Kangaroo	DD ver 2.3 (1994)	5	very rare

Appendix 3 Conservation status and level of endemism of KICDP non-flying mammals.

Family	Scientific name	Common name	Conservation status (IUCN)	Endemism*	Abundance
Macropodidae	<i>Dorcopsis hageni</i>	White-striped Dorcopsis	LR/lc ver 2.3 (1994)	4	common
Macropodidae	<i>Dorcopsis luctuosa</i>	Grey Dorcopsis	LR/lc ver 2.3 (1994)	4	common
Macropodidae	<i>Dorcopsulus vanheurni</i>	Lesser Forest Wallaby	LR/lc ver 2.3 (1994)	4	common
Burramyidae	<i>Cercartetus caudatus</i>	Long-tailed Pygmy Possum	LR/lc ver 2.3 (1994)	1	common
Pseudocheiridae	<i>Pseudochirops corinnae</i>	Plush-coated Ringtail	VU A1a ver 2.3 (1994)	4	
Pseudocheiridae	<i>Pseudochirops cupreus</i>	Coppery Ringtail	LR/lc ver 2.3 (1994)	4	common
Pseudocheiridae	<i>Pseudochirulus canescens</i>	Lowland Ringtail	DD ver 2.3 (1994)	4	common
Pseudocheiridae	<i>Pseudochirulus forbesi</i>	Painted Ringtail	LR/lc ver 2.3 (1994)	4	common
Pseudocheiridae	<i>Pseudochirulus mayeri</i>	Pygmy Ringtail	LR/lc ver 2.3 (1994)	4	common
Petauridae	<i>Dactylopsila megalura</i>	Great Tailed Triok	VU A1d, B1+2a ver 2.3 (1994)	4	very rare
Petauridae	<i>Dactylopsila palpator</i>	Long-fingered Triok	LR/lc ver 2.3 (1994)	4	common
Petauridae	<i>Dactylopsila trivirgata</i>	Striped Possum	LR/lc ver 2.3 (1994)	1	common
Petauridae	<i>Petaurus breviceps</i>	Sugar Glider	LR/lc ver 2.3 (1994)	1	common
Acrobatidae	<i>Distoechurus pennatus</i>	Feather-tailed Possum	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Anisomys imitator</i>	Uneven-toothed Rat	LR/lc ver 2.3 (1994)	4	uncommon
Muridae	<i>Chiruromys vates</i>	Lesser-tree Mouse	LR/lc ver 2.3 (1994)	5	common
Muridae	<i>Crossomys moncktoni</i>	Earless Water Rat	LR/lc ver 2.3 (1994)	5	common
Muridae	<i>Coccomys rummleri</i>	Rummler's Mouse	LR/lc ver 2.3 (1994)	4	very uncommon
Muridae	<i>Hydromys chrysogaster</i>	Common Water Rat	LR/lc ver 2.3 (1994)	1	common
Muridae	<i>Hyomys goliath/ H. dammermani</i>	White-eared Rat	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Leptomys elegans</i>	Large Leptomys	CR B1+2c ver 2.3 (1994)	5	uncommon

Appendix 3 Conservation status and level of endemism of KICDP non-flying mammals.

Family	Scientific name	Common name	Conservation status (IUCN)	* Endemism	Abundance
Muridae	<i>Leptomys signatus</i>	Fly River Leptomys	CR B1+2c ver 2.3 (1994)	5	very rare
Muridae	<i>Leptomys ernstmayeri</i>	Ernst Mayer's Leptomys	LR/lc ver 2.3 (1994)	5	uncommon
Muridae	<i>Lorentzimys nouhuysi</i>	Long-footed Tree Mouse	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Macruromys major</i>	Greater Small-toothed Rat	EN C2a ver 2.3 (1994)	4	uncommon
Muridae	<i>Mallomys aroaensis</i>	Grey Black-eared Rat	LR/lc ver 2.3 (1994)	4	uncommon
Muridae	<i>Mallomys rothschildi</i>	Dusky Black-eared Rat	LR/lc ver 2.3 (1994)	4	uncommon
Muridae	<i>Mayeremys ellermani</i>	One-toothed Shrew Mouse	VU C2a ver 2.3 (1994)	4	very rare
Muridae	<i>Melomys leucogaster</i>	White-bellied Melomys	LR/lc ver 2.3 (1994)	1	common
Muridae	<i>Melomys lutillus</i>	Grassland Melomys	LR/lc ver 2.3 (1994) (M. burtoni)	4	common
Muridae	<i>Melomys rufescens</i>	Black-tailed Melomys	LR/lc ver 2.3 (1994)	2	common
Muridae	<i>Microhydromys richardsoni</i>	Groove-toothed Shrew Mouse	LR/lc ver 2.3 (1994)	4	very rare
Muridae	<i>Parahydromys asper</i>	Waterside Rat	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Paramelomys levipes?</i>	Long-nosed Melomys	LR/lc ver 2.3 (1994)	5	common
Muridae	<i>Paramelomys lorentzii</i>	Lorentz's Melomys	LR/lc ver 2.3 (1994)	3	uncommon
Muridae	<i>Paramelomys mollis</i>	Thomas's Melomys	LR/lc ver 2.3 (1994)	4	
Muridae	<i>Paramelomys platyops</i>	Lowland Melomys	LR/lc ver 2.3 (1994)	2	common
Muridae	<i>Paramelomys rubex</i>	Mountain Melomys	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Pogonomelomys bruijni</i>	Large Pogonomelomys	CR B1+2c ver 2.3 (1994)	4	very rare
Muridae	<i>Pogonomelomys mayeri</i>	Shaw Mayer's Pogonomelomys	LR/lc ver 2.3 (1994)	4	very rare
Muridae	<i>Pogonomys loriae</i>	Large Tree Mouse	LR/lc ver 2.3 (1994)	1	uncommon

Appendix 3 Conservation status and level of endemism of KICDP non-flying mammals.

Family	Scientific name	Common name	Conservation status (IUCN)	Endemism*	Abundance
Muridae	<i>Pogonomys macrourus</i>	Chestnut Tree Mouse	LR/lc ver 2.3 (1994)	2	common
Muridae	<i>Pogonomys sylvestris</i>	Grey-bellied Tree-mouse	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Rattus exulans</i>	Pacific Rat	LR/lc ver 2.3 (1994)	1	rare
Muridae	<i>Rattus leucopus</i>	Cape York Rat	LR/lc ver 2.3 (1994)	1	common
Muridae	<i>Rattus novaeguineae</i>	New Guinea Rat	LR/lc ver 2.3 (1994)	5	very rare
Muridae	<i>Rattus sp.</i>	Undescribed species of Rattus		-	unknown
Muridae	<i>Rattus sp. nov. (Mt Kemenagi)</i>	Undescribed species of Rattus		-	unknown
Muridae	<i>Rattus cf. praetor</i>	Large Spiny Rat	LR/lc ver 2.3 (1994)	1	
Muridae	<i>Rattus sp. nov. Darai (cf. mordax)</i>	Undescribed species of Rattus		-	unknown
Muridae	<i>Rattus sp. nov. (Gobe)</i>	Undescribed species of Rattus		5	unknown
Muridae	<i>Rattus steini</i>	Stein's Rat	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Stenomys niobe</i>	Moss Forest Rat	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Stenomys verecundus</i>	Slender Rat	LR/lc ver 2.3 (1994)	4	common
Muridae	<i>Uromys anak</i>	Giant Naked-tailed Rat	LR/nt ver 2.3 (1994)	4	common
Muridae	<i>Uromys caudimaculatus</i>	Mottled-tailed Giant Rat	LR/lc ver 2.3 (1994)	1	common
Muridae	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat	LR/nt ver 2.3 (1994)	4	very rare

* 1 Endemic to PNG +/- satellite islands)

2 Endemic to main island of New Guinea +/- satellite islands(including Waigeo, Salawati and Missool

3. Endemic to main island of New Guinea +/- satellite islands and the Aru islands"

4. Endemic to main island of New Guinea +/- satellite islands +/- New Britain +/- New Ireland +/- the Louisiades

5. Occurs more widely through the Australia, Indonesia, the Solomon Islands or the Pacific.

Annex 04

Biodiversity survey results:

**Non-volant mammals at Juha North, Juha South, Baia River, South
Karius and Deviation Camp in 2008**

PNG LNG Project

Environmental Impact Study of Terrestrial Mammals for the PNG LNG Project, Papua New Guinea

Report to Coffey Natural Systems Ltd

Prepared by Ted Mamu

WWF PNG

P.O Box 8280, Boroko

National Capital District

Papua New Guinea

With Technical Assistance from Dr Greg Richards

May 2008

Table of Contents

Acronyms and abbreviations	4
Executive Summary	5
1 Introduction.....	7
1.1 Objectives	7
1.2 Study Area	8
1.2.1 General	8
1.2.2 Survey area descriptions	9
2 Methodology.....	14
2.1 Trapping of terrestrial mammals	14
2.2 Signs	14
2.3 Spotlighting and daytime observations	14
2.4 Camera trapping	14
2.5 Information from hunters	15
2.6 Voucher Specimens	16
3 Results	17
4 Sensitivities and conservation status of mammals	22
4.1 Habitat and resilience to disturbance	22
4.2 IUCN Red List of Threatened Species	22
5 Discussion	28
5.1 Potential Impacts.....	28
5.2 Suggested mitigation measures.....	29
7 Acknowledgement.....	30
8 References.....	31
Appendix 1A Mammal records from elevations 0 to 1000 m in the Project Area	33
Appendix 1B Mammal records from elevations 1000 to 2000 m in the Project Area	36
Appendix 2 Habitat needs and conservation notes on species recorded in the project area.	39

Tables

Table 1 Survey areas

Table 2 Trapping effort. Survey areas are listed in order of elevation above sea level.

Table 3: Terrestrial mammal species recorded by the 2008 surveys.

Table 4: Species recorded during the survey that are listed on IUCN Red List.

Figures

Figure 1 Map of all sites.

Figure 2 Sampling trails at Juha North survey area

Figure 3 Sampling trails at Juha South survey area

Figure 4 Sampling trails at Baia River survey area

Figure 5 Sampling trails at South Karius survey area

Figure 6 Sampling trails at Deviation Camp survey area

Figure 7 Sources of terrestrial mammal records obtained during the survey.

Figure 8 Number of terrestrial mammal species per family at survey areas.

Figure 9 Two Doria's Tree Kangaroos (*Dendrolagus dorianus*) that were captured by local hunters in the vicinity of the South Karius camp using trained dogs.

Figure 10 All ringtail possums, in this case a Plush-coated Ringtail (*Pseudochirus corinnae*) are procured as a food source by local landowners, as in this example from South Karius.

Acronyms and abbreviations

BR	Baia River survey area
CITES	Convention on International Trade in Endangered Species
DEV	Deviation Camp survey area
DD	Data Deficient
DEC	Department of Environment and Conservation
EIS	Environmental Impact Statement
EN	Endangered
IUCN	International Union for Conservation of Nature
JN	Juha North survey area
JS	Juha South survey area
LNG	Liquefied Natural Gas
Ltd	Limited
mm	Millimetres
NG	New Guinea
PNG	Papua New Guinea
NT	Near Threatened
SK	South Karius survey area
UPNG	University of Papua New Guinea
VU	Vulnerable
WWF	World Wide Fund for Nature
KICDP	Kikori Integrated Conservation and Development Project
HGCP	Hides Gas Conditioning Plant

Executive Summary

This report provides the findings of approximately 30 days of field survey of the non-flying terrestrial mammal fauna along the proposed Juha-Hides Pipeline ROW and on the LNG Project Gas Pipeline north-east of Homa.

Five survey areas were sampled that covered an altitudinal transect from around 200 m to over 2,000 m: South Karius, Baia River, Juha South, Juha North and Deviation Camp. Survey methods included live trapping, spotlighting and observations of the animals *per se* or their signs such as footprints or calls. Remote automated cameras were positioned along trails and photographs were taken when animals tripped an infrared beam. Local informants were also interviewed to provide information on mammals used for food and in some cases it was possible to obtain skeletal fragments from them as evidence.

Seventy species of non-flying mammals in 40 genera from 11 Families were captured, seen, heard and confirmed by landowners for the five survey areas. From the trapping, observations and local knowledge 50 species were recorded at South Karius, 27 at Baia River, 43 at Juha South, 16 at Juha North and 49 at the Deviation Camp.

The total species recorded from the 2008 survey areas by systematic survey methods (trapping, searching for signs, spotlighting) was about half of the total number of species known by several generations of local informants who have observed animals living in their land. Of these, the Muridae family accounts for high species diversity with 52%. Species belonging to the Dasyuridae, Macropodidae, and Phalangeridae families account for 9% each, Pseudocheiridae 7%, Peroryctidae 6%, Petauridae 4%, and the Acrobatidae, Burramyidae, Tachyglossidae and Suidae families 1% each. A total of 44 species were recorded from the five sites. Seven (12%) species were endemic to the Papua New Guinea island itself and 37 (88%) were New Guinea wide endemics.

Twelve species recorded during the surveys are on the IUCN Red List of Threatened Species. These include the Critically Endangered Long-Footed Water Rat (*Leptomys elegans*); the Endangered Long-beaked Echidna (*Zaglossus* sp.); Goodfellow's Tree Kangaroo (*Dendrolagus goodfellowi*); the Vulnerable New Guinea Quoll (*Dasyurus albopunctatus*), Doria's Tree Kangaroo (*Dendrolagus dorianus*), Macleay's Dorcopsis (*Dorcopsulus macleayi*), the New Guinea Pademelon (*Thylogale browni*), Stein's Cuscus (*Phalanger vestitus*), the Plush-coated Ringtail (*Pseudochirops corinnae*), One-toothed Shrew-mouse (*Mayermys ellermani*); the Near Threatened Black-tailed Giant-rat (*Uromys anak*), and the Rock-dwelling Giant-rat (*Xenuromys bartbatus*).

Of the six tree-kangaroo species known from Papua New Guinea, two were recorded at all sampling areas with the exception of the Baia River survey area. Doria's tree-kangaroo (*Dendrolagus dorianus*) tended to be abundant whereas Goodfellow's Tree-kangaroo (*D. goodfellowi*) was less common.

The world's largest existing monotreme species, Long-beaked Echidna (*Zaglossus bartoni*), which is distributed throughout the central cordillera of the New Guinea region, was also recorded during the surveys. This species is considered to be a flagship species in terms of assessing natural environment because it is one of the oldest living monotremes in the

Kikori Basin. The existence of this species indicates a stable natural habitat that is largely undisturbed by humans. Skull fragments of the endangered Long-beaked Echidna were collected at South Karius and Juha South.

The capture of the Western White-eared Giant-rat (*Hyomys dammermani*) at South Karius provided a new record for the area. Little is known of the biology of this rare species and the first capture in the region extended its distribution range to the south of Papua New Guinea. It was previously only known from the northern part of New Guinea.

The capture of a number of individuals of a native Uromyine rat (*Paramelomys sp. aff. moncktoni*) is likely to be a new species was a significant addition to the survey data. Seven individuals were captured at Juha South and another three were also captured at Juha North. It appeared to be common in these two areas.

Many parts of Papua New Guinea no longer have these threatened species. For example, the Long-Footed Water Rat now has a geographic range estimated to be less than 100 km² which is fragmented, and populations of Goodfellow's Tree Kangaroo were estimated by the IUCN to have reduced by 70% over the last decade. Hence, in the project area, to obtain records of these species emphasises the remoteness of some of the sampling areas.

The precedence set by the oil field developments is that operations do not appear to have had a significant or adverse impact on the native fauna. The most serious threat to the larger mammal fauna appears to be people having access to roads and resorting to hunting. The PNG LNG Project is not expected to have a significant impact if human access can be restricted.

1 Introduction

The Papua New Guinea Liquefied Natural Gas Project (PNG LNG Project) aims to commercialise the petroleum reserves in the Hides, Angore and Juha fields and associated gas reserves in the Kutubu, Agogo, Gobe and Moran fields in the Southern Highlands and Western provinces of Papua New Guinea. The project involves the production of gas and its transportation to an LNG facility at Portion 152 on the coast of the Gulf of Papua. The gas is to be liquefied at the facility and the LNG product shipped to international markets.

The Project proposes to utilize a similar gas pipeline alignment between Hides and the Omati River landfall as was proposed and surveyed for the PNG Gas Project in the course of 2005 and 2006. The PNG LNG Project, however, involves the following additional upstream project components: the development of gas fields and a gas production facility at Juha west of Hides, a gas conditioning facility at Hides.

This report documents the findings of five mammal surveys undertaken in these new, previously unexplored project areas and where necessary combines it with previous mammal survey data (collected during the 2005 PNG Gas Project surveys or World Wide Fund for Nature (WWF) in the Kikori Integrated Conservation and Development (KICDP) area for analysis. It covers non-volant mammals i.e. all terrestrial mammal species excluding bats and aquatic mammals.

1.1 Objectives

This study conducted an assessment of the terrestrial non-flying mammals at five locations along and in the vicinity of the proposed Juha-Hides Pipeline ROW and the LNG Project Gas Pipeline north-east of Homa. The objectives of the study were to:

- Provide an inventory of terrestrial non-flying mammals in the study areas and an assessment of the potential impacts of the project upon the mammal fauna.
- Integrate the findings of the surveys with the 2005 survey data collected for the PNG Gas Project (Mamu *et al.* 2005 see Annex 03).
- Collate and assess existing information relevant to mammals in the entire gas project area.
- Assess the potential impact of the project upon terrestrial mammal species that are protected by Papua New Guinea legislation and/or are in the IUCN Red List of Threatened Species (Red List).
- Assess the potential impacts of the project upon mammal habitats and other ecological factors that have the potential to be altered in the pipeline corridor.
- Provide suggestions on management and monitoring measures to mitigate or reduce impacts on biodiversity.

1.2 Study Area

1.2.1 General

The main island of New Guinea with its extensive forest habitats and its offshore islands is home to a diverse range of mammals comprising 242 species in 54 genera and 11 families of monotremes¹, carnivorous marsupials, bandicoots, possums, gliders, tree kangaroos and placental mammals (Flannery, 1995). Many species are endemic and about 27% of the mammals are considered critically endangered, endangered or vulnerable.

The study area encompasses the entire Kikori River catchment and the northwest corner of the Strickland River catchment in the Western Province. The Kikori's tributaries rise in the mountainous north (up to 3,600 m above sea level) and the river finishes 300 km southeast in the Gulf of Papua and includes the Great Papuan Plateau (Leary *et al*, 1996). Topography in the area is extremely variable and is characterized by steep jagged limestone karst, volcanic areas and landslide zones. Forest types range from mangrove to montane rainforest.

Five sites were selected for biodiversity surveys along the proposed Juha–Hides Rich Gas Pipeline route and the potential pipeline route deviation north-east of Homa (Homa deviation). The site names, locations and dates sampled are provided in Table 1.

Table 1 Survey areas

Survey area	Latitude	Longitude	Elevation (m)	Dates
Juha North	5.8078	142.3083	213	4th – 10th Feb 2008
Juha South	5.90189	142.436	953	11th – 16th Feb 2008
Baia River	6.0205	142.54735	328	17th – 22nd Feb 2008
South Karius	5.99112	142.67063	1368	26th March – 2nd April 2008
Deviation Camp	6.096767	143.1045167	2060	3rd –8th April 2008

¹ Primitive egg laying mammals

1.2.2 Survey area descriptions

Locations of the survey areas are shown in Figure 1

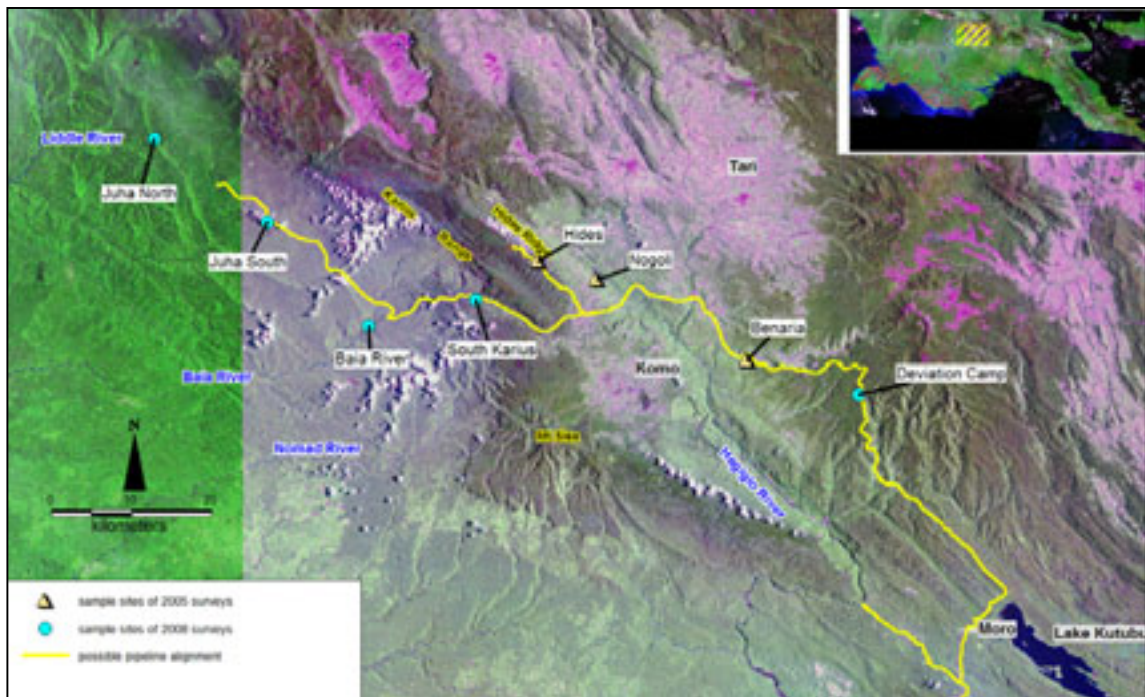


Figure 1 Map of all sites.

Juha North survey area (Figure 2) was on the Liddell River, a tributary of the Strickland River, and situated in low hills on the edge of limestone terrain. Waterfalls emanating from holes in the limestone were located close to the camp. The forest was “small crowned low altitude forest on uplands (Hm)” with evidence of disturbance and hunting. An anomalous feature of the vegetation was the presence of many plant groups normally found only in montane environments above 1,000 m elevation. Among the unusual elevational occurrences were many species in Ericaceae, Myrsinaceae, and Myrtaceae.

Juha South survey area (**Figure 3**) is technically in the transition ecotone between traditionally defined lowland and montane zones but due to local conditions of very high rainfall this area is clearly a well-developed mossy montane forest. It would classify as transitional between “small crowned lower montane forest (L)” and “very small crowned lower montane forest (Ls)” (Hammermaster & Saunders 1995a, b). As is generally the case for montane formations, the canopy is usually low (less than 20 m average height) with considerable epiphytic loads on trunks and upper branches. Forest understories are generally rich in cryptogamic² growth and in remarkably pristine condition due to the absence of wild pigs. The latter circumstance is probably attributable to low human population densities. The camp itself was located on an old well pad with an assortment of construction materials remaining from the previous drilling activities. Forest regeneration at the site was well advanced, composed for the most part of *Eurya*, *Ficus*, *Macaranga*,

² Plants having no stamens or pistils, and therefore no proper flowers (definition from Oxford Dictionary)

Timonius, and urticates. Numerous sinkholes were present on the surrounding karst terrain.

Baia River survey area (Figure 4) was located on the banks of the Baia River in an area dominated by landslides. The landscape was extremely unstable and this site was 2 to 3 km downstream from the originally designated site. This was because of the difficulty in locating a sufficiently stable stretch of stream bank that could be considered safe enough to build a camp. This section of the Baia River and the helicopter approaches to the River from South Karius survey area appears to be highly unstable sedimentary formations with numerous and large landslides. The camp area is an exclusively lowland vegetation formation with a floristically distinct alluvial and flood zone along the streams (collectively including various communities in Po, Ps, Wsw), and “small crowned low altitude forest on uplands (Hm)” (Hammermaster & Saunders 1995a, b) on higher slopes. There were numerous talus slopes and active landslides with early pioneer and secondary vegetation. The principal genera represented at the site were *Ficus*, *Gymnostoma*, *Macaranga*, *Pimelodendron*, and *Pometia*.

South Karius survey area (Figure 5) was located at the base of the Karius Range in a complex of streams and swamps that form the headwaters of the Baia River. The camp itself was located on the edge of a flat area that had been converted to gardens within the last few years. It was surrounded by swamplands with pandanus emergents (Wsw) that merged into “very small crowned lower montane forest” (Ls) (Hammermaster & Saunders 1995a, b) on the surrounding hills. The surrounding hills appeared to be karst while the camp was on the alluvial soils of the surrounding streams and swamps. The community structure of the natural-growth vegetation was similar to that at Juha South survey area, however due to the presence of human habitation near the camp, there was a discernable increase in weedy species, including some cosmopolitan plants not found at any of the other locations. The anthropogenic influences are also reflected in the higher incidence of successional stands along the margins of the primary forest.

Deviation Camp survey area (Figure 6) was located approximately 5.5 km southwest of Benaria village and close to a potential pipeline deviation. It was in pristine “mossy montane *Nothofagus* forest” (Ln) next to a fast flowing tributary of the Muruba River. The overstory was composed almost exclusively of *Nothofagus pullei* emergents up to 40 m tall. Subcanopy genera included primarily *Acronychia*, *Elaeocarpus*, *Sphenostemon*, and *Syzygium*. Understories were characterized by dense bryophyte and lycophyte growth, with particular dominance by *Cyathea microphylloides* and *C. perpelvigera*. Most of the floristic diversity was concentrated in the near-ground interval up to ca. 5 m height.

The camp bordered an area of forest burnt in the 1996-7 fires. These regenerating areas were dominated by dead stags and coppicing surviving trees, with saplings up to 15 m high. There was extensive regeneration by light-demanding *Nothofagus* and other heliophytes such as *Macaranga*, *Omalanthus*, and *Cyathea* spp. (e.g., *C. contaminans*). The understorey included many shade tolerant species, suggesting that in this area the fires had been crown fires and had not burnt the mossy ground layer.

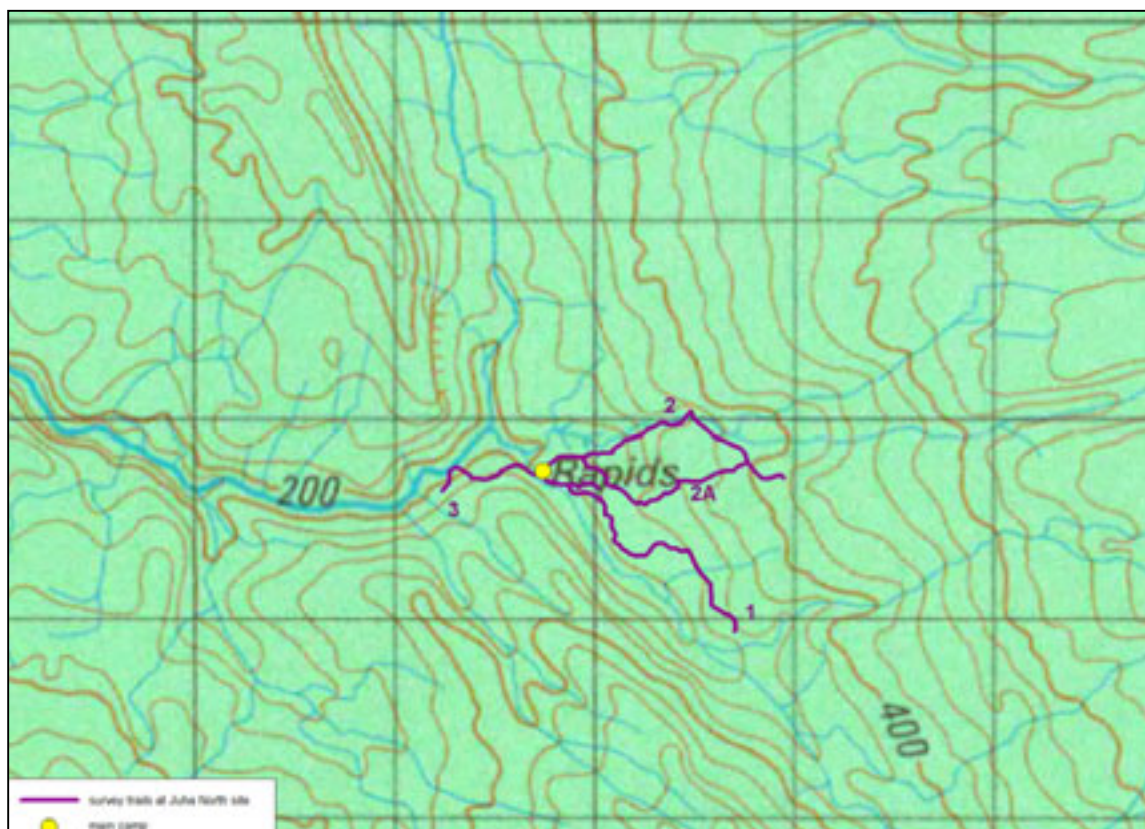


Figure 2 Sampling trails at Juha North survey area

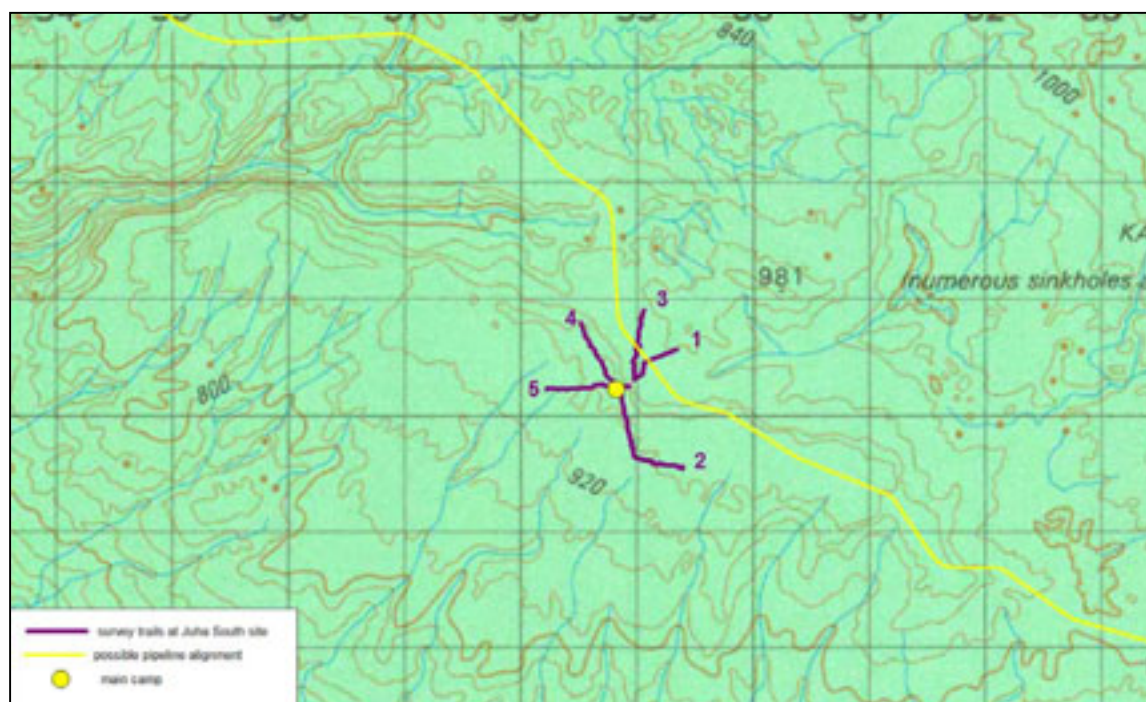


Figure 3 Sampling trails at Juha South survey area

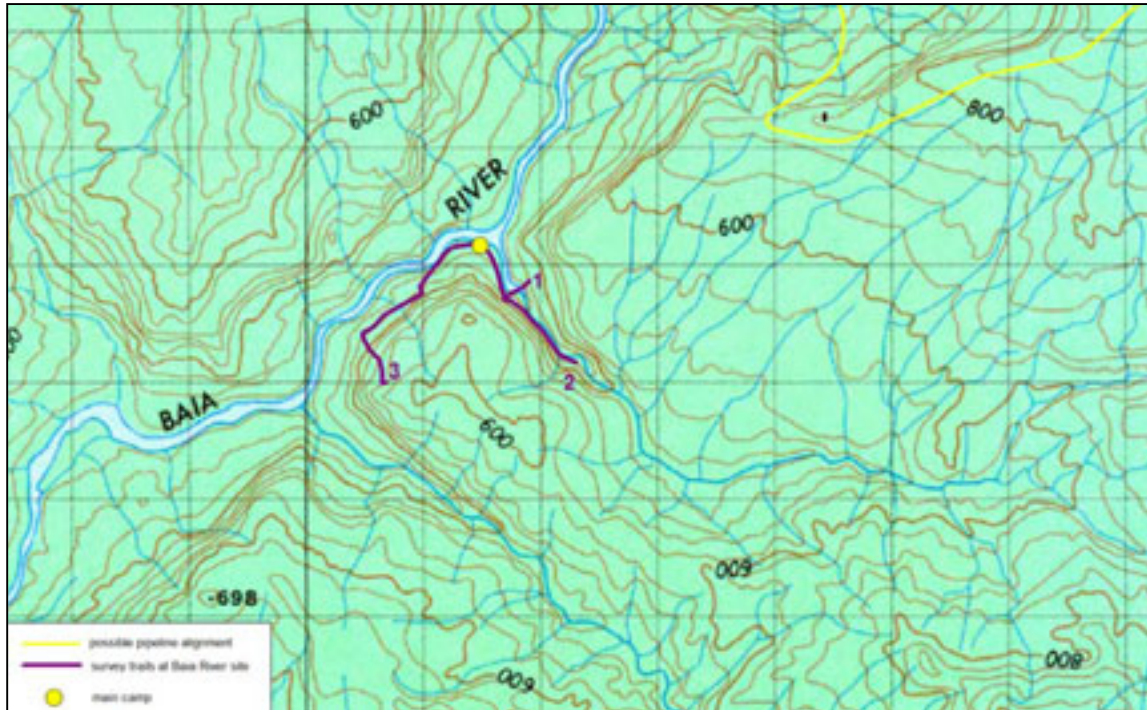


Figure 4 Sampling trails at Baia River survey area



Figure 5 Sampling trails at South Karius survey area

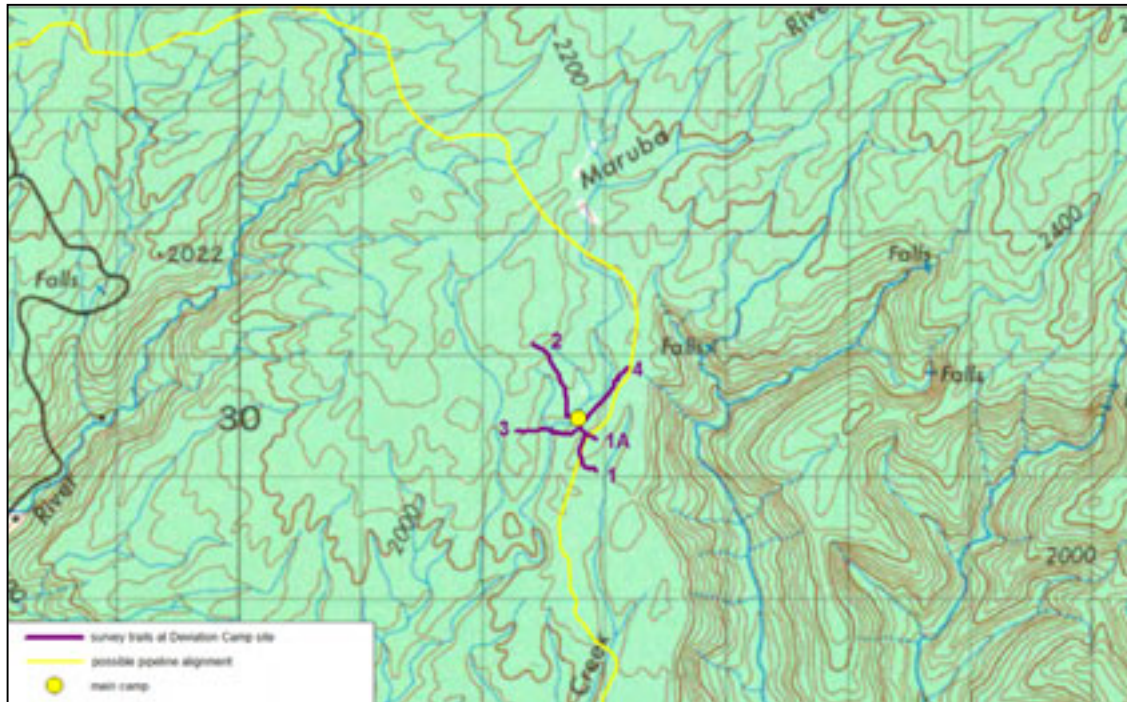


Figure 6 Sampling trails at Deviation Camp survey area

2 Methodology

Terrestrial mammals were sampled using a range of systematic and opportunistic techniques. The methods used are standard ones used in rapid biodiversity appraisals aiming to provide a cost-effective species list for a site. More intensive small mammal trapping over several seasons may produce a larger inventory of small mammals but the inventory of medium to large sized mammals, those most frequently hunted by local people, is probably close to complete.

2.1 Trapping of terrestrial mammals

Systematic small mammal trapping was carried out along narrow transects cut to access rainforest. Three types of traps were used: small aluminium Elliot traps, large Elliot traps and steel cage traps. Traps were placed approximately 10 m apart along transects and were baited with a mixture of roasted coconut kernels, rolled oats and muesli mixed with peanut butter and honey. Each transect had a total of 20 – 25 traps, some of which were placed on tree trunks or lower branches using wooden brackets. A total of 120 traps (100 small Elliots, 9 large Elliots, 1 cat trap and 10 wire cage traps) were used to capture small mammals at four transects at each survey area. The survey effort using this method is shown in **Table 2**.

Trapping was conducted for six consecutive days and bait was replenished daily when animals were collected for processing. All animals caught were identified, processed and released at the site of capture. Animals caught were earmarked and released so to distinguish the new captures from recaptures.

2.2 Signs

Transects were walked every day and all footprints, droppings or identifiable claw marks on trees were recorded and identified. Photographs were also taken and shown to local landowners for their local knowledge to verify the record.

2.3 Spotlighting and daytime observations

Arboreal mammals were surveyed by spotlighting and listening for vocalisations at night along the transects and accessible forest edges within 1 - 2 km of each camp. During the day transects would be walked and random walks taken and any mammal observed or heard would be recorded.

2.4 Camera trapping

'Photoscout' 35 mm IR triggered camera traps loaded with 400 ASA 35 mm film were used to continuously record fauna. A unit would be tied to a tree and aimed so that any animal crossing the ground within 15 m of the camera would trigger the IR beam and a photograph of the animal taken. **Table 2** provides details of camera trap effort.

2.5 Information from hunters

Hunters and local landowners were interviewed about the species present and shown photographs in Flannery (1995). Interviewing hunters and villagers is an efficient and cost-effective method for rapidly establishing what species of large and medium sized and, in the case of PNG even small mammals, are present in an area. However there are many pitfalls. Informants can be unreliable, incompetent or have faulty memories. Many informants repeat hearsay as their own facts and can be reluctant to admit this. Local taxonomies differ from western ones; different names can be given to separate sexes and age classes of the same species, and several species can be included under one local name. Localities and time periods can be vague – “around here” and “nearby” could mean anywhere; and “recently” and “last year” could mean anytime between last week and a decade ago.

The quality of information is assessed by questioning informants in depth about behaviour, calls, etc to get an appreciation as to how good a naturalist the informant is and how discriminating an observer he may be. Good observers tend to know not only the mammal they hunt but behaviour, calls and habits of many birds and reptiles as well.

Hunter information is generally more reliable in PNG than some other parts of the tropics because in PNG subsistence hunting is still a major activity for the people, particularly those in the project area and they are intimately familiar with what mammals are in their forests.

Overall the interviews returned consistent information about most species but nonetheless, records were classified into 3 types based on degree of reliability.

Category 1. Live or dead animals, bones or other animal parts collected by informants in the vicinity.

Category 2. Species definitely accepted because a range of correct ancillary biological and behavioral information was provided by the informant. Henceforth these are termed “landowner records”

Category 3. Species with a high probability of occurring because the information came with some but not sufficient biological and behavioral background, but in the professional opinion and local experience of the interviewer (the author) the record is considered to have a reasonable chance of being correct. This record type is henceforth termed a “probable”.

Hunters were present and regularly hunted at South Karius and Deviation camps sites but at the other three survey areas, hunting was rare or non-existent. In the latter three cases, camp staff had been recruited from the landowners and while many rarely or never hunted these areas, they took the opportunity to hunt during the survey and provided many records at these sites.

Table 2 Trapping effort. Survey areas are listed in order of elevation above sea level.

Survey area	Transect number	# of Small Elliots	# of Large Elliots	# of Elliots on trees	# of Elliots on logs or fallen trees	# of Cage traps	Total trap nights	# of camera traps	Hours of camera trapping
Juha North	1	25	3	0	10	2	30	6	823
	2	25	3	0	6	2	30		
	3	8	2	0	0	0	10		
	4	0	0	0	0	0	0		
	Camp*	6	0	0	0	1	7		
	Totals	64	8	0	16	5	77		
Baia River	1	25	3	1	4	3	31	6	595
	2	25	5	0	0	1	31		
	3	3	1	2	8	2	6		
	4	3	0	0	0	0	3		
	Totals	56	9	3	12	6	71		
Juha South	1	17	2	0	5	1	20	6	609
	2	15	4	0	6	1	20		
	3	8	1	0	2	1	10		
	4	8	2	0	4	1	11		
	Camp*	3	0	0	0	2	5		
	Totals	51	9	0	17	6	66		
South Karius	1	20	0	2	0	2	22	5	500
	2	25	2	1	6	0	27		
	3	19	0	1	6	2	20		
	4	0	2	0	0	1	3		
	Camp*	4	0	0	0	1	5		
	Totals	58	4	4	12	6	78		
Deviation camp	1	17	2	0	12	1	20	5	747
	2	18	3	2	13	0	21		
	3	16	2	0	15	2	20		
	4	16	2	1	9	2	20		
	Camp*	0	0	0	0	1	1		
	Totals	67	9	3	49	6	82		
Overall totals		296	39	10	106	29	374		3274

* Some traps opportunistically placed around each campsite.

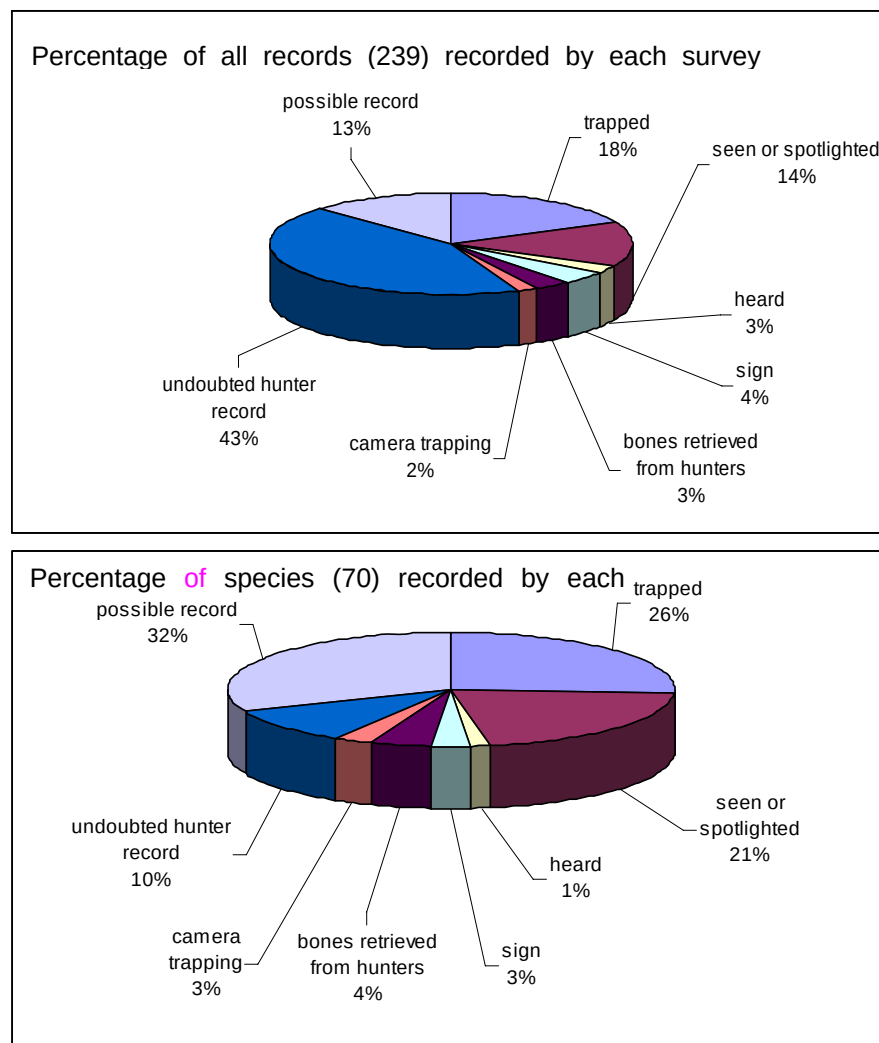
2.6 Voucher Specimens

Specimens of mammals that were of special significance, for example, extensions of distribution, were difficult to identify in the field, or were new to science were euthanased with 2 – 3 ml of chlorobutanol and then preserved in 10% formalin for identification in the laboratory. Specimens were lodged in either the PNG National Museum and Art Gallery or the University of PNG Biology Department Museum.

3 Results

The species recorded at the five survey areas are presented in **Table 3. Appendix 1** presents data on the entire non-flying mammal fauna found so far in the project area (89 species), based on data from this report, the 2005 survey (Annex 03 to Biodiversity Appendix) and the WWF surveys (Hartshorn et al. 1995, Seri et al. 1995, Leary et al. 1995, Leary and Seri 1995? 1997, Leary 1998, 1999, 2001, 2002?, 2004?a, 2004?b, 2004c, Balun 2004?, Namo 2004, Mamu and Sine 2005, and see Appendices 1 and 2 to main Biodiversity Appendix).

Nomenclature follows Flannery (1995) for most species, Flannery and Groves (1998) for *Zaglossus*, Norris and Musser (2001) for the *Phalanger* group, and Menzies (1996) for the “Melomys” rodents. **Appendix 1** includes both *Phalanger intercastellanus* and *P. mimicus* but it is likely only one species occurs.



* where a species was detected by several methods it is assigned to that method giving the most definitive record (e.g. trapping ahead of sightings etc.).

Figure 7 Sources of terrestrial mammal records obtained during the survey.

The relative contribution of the different survey methods to the records obtained is shown in **Figure 7**. Of a total of 239 records from the five sites 56% are from hunters. There were hunter records for 52 species, of which 25 were confirmed by a specimen, sighting, calls, bones or sign during the survey period indicating good reliability of informants. Of the total of 70 species, 58% were recorded by an actual trapped or photographed animal, a sighting, bones or sign from at least one of the survey areas at which it was recorded.

The number of terrestrial non-flying mammal species recorded at each sampling area ranged from 16 to 50 with a total of 70 species being recorded during the entire survey (Table 2). Fifty species were recorded at South Karius, 27 at Baia River, 43 at Juha South, 16 at Juha North and 49 at the Deviation Camp.

Eleven families were represented in the survey data, including the wild pig (Suidae) and *Rattus exulans* (Muridae), which are introduced species. Almost 50% of the species were rodents in the Family Muridae (Figure 8).

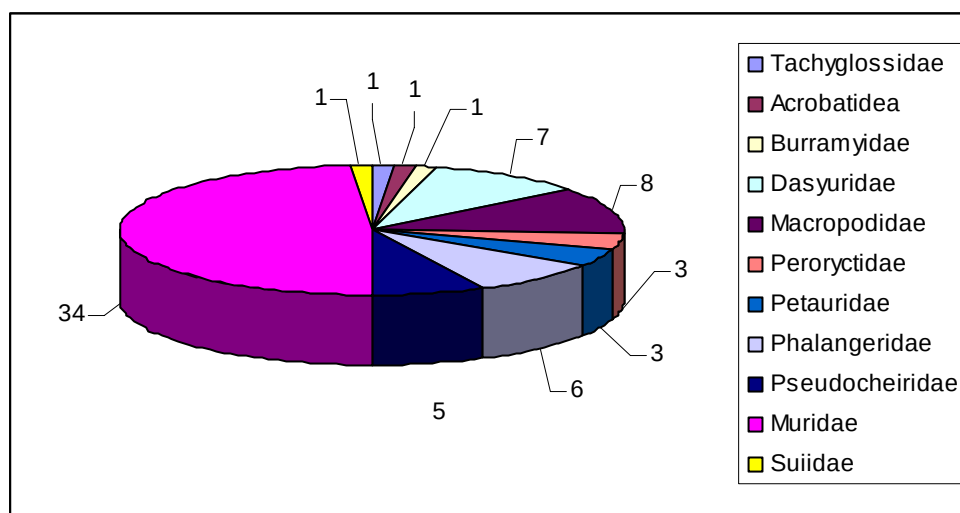


Figure 8 Number of terrestrial mammal species per family at survey areas.

There have been 87 species of non-flying mammals recorded in the project area since 1995 by WWF and the LNG surveys in 2005 and 2008 (Appendix 1), of which 47 were detected by direct survey methods and a further 23 were probable records from hunters. This represents 53% and 26% (total 79%) respectively of the non-flying mammals in the project area. Seven of the species recorded in the 2008 survey are endemic to the Papua New Guinea half of the island and 37 are endemic to the main island of New Guinea and its satellite islands. Records included six different cuscus species, three species of forest wallabies, three species of tree-kangaroos (*Dendrolagus spp*), four different bandicoots and the Long-beaked Echidna (*Zaglossus bartoni*). The tree kangaroos and the echidna are all protected species under the PNG Fauna (Protection and Control) Act and are also endemic to Papua New Guinea. These are also species of special biological consideration as they are listed in the IUCN Red List of Threatened Species (see Section 4).

Of the six tree-kangaroo species known from Papua New Guinea, two were recorded at all sampling areas with the exception of the Baia River. Doria's tree-kangaroo (*Dendrolagus dorianus*) tended to be abundant whereas Goodfellow's Tree-kangaroo (*D. goodfellowi*)

was less common. They are classified as Vulnerable and Endangered respectively under the IUCN Red List of Threatened Species (IUCN Red List)

The world's largest existing monotreme species, the Long-beaked Echidna (*Zaglossus bartoni*), which is distributed throughout the central cordillera of the New Guinea region, was also recorded during the surveys. The species is listed as threatened on the IUCN Red List and is considered to be a flagship species in terms of assessing quality of the natural environment because it is the evolutionarily oldest living mammal species in the project area. The existence of this species indicates a stable natural habitat that is largely undisturbed by humans. Skull fragments of the species were collected at South Karius and Juha South.

Also recorded was the Feather-tailed Possum (*Distoechurus pennatus*) which, while not listed under the IUCN Red List of Threatened Species is listed under the PNG Fauna (Protection and Control) Act as "Restricted" i.e. hunting is limited.

The capture of the Western White-eared Giant-rat (*Hyomys dammermani*) at South Karius provided a new record for the project area. Little is known of the biology of this rare species and the first capture in the region extended its distribution range to the south of Papua New Guinea. It was previously only known from the northern part of New Guinea.

The capture of a number of individuals of a native Uromyine rat (*Paramelomys sp. aff. moncktoni*), which is likely to be a new species, was a significant result from the survey. Seven individuals were captured at Juha South and another three were also captured at Juha North.

Table 3: Terrestrial mammal species recorded by the 2008 surveys.

Family	Scientific name	Common name	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Tachyglossidae	<i>Zaglossus bartoni</i>	Long-beaked Echidna	EP	6	L	6	L
Dasyuridae	<i>Dasyurus albopunctatus</i>	New Guinea Quoll		4	4	L	L
Dasyuridae	<i>Murexichinus melanurus</i>	Black-tailed Antechinus		EP	L	L	L
Dasyuridae	<i>Phascomurexia naso</i>	Long-nosed Murexia				L	L
Dasyuridae	<i>Phascolosorex dorsalis</i>	Narrow-striped Dasyure					L
Dasyuridae	<i>Murexia longicaudata</i>	Short-furred Dasyure		EP	3	2	L
Dasyuridae	<i>Myoictis melas</i>	Three-striped Dasyure		L	3	L	
Peroryctidae	<i>Echymipera kalubu</i>	Common Echymipera		EP	2	L	L
Peroryctidae	<i>Echymipera rufescens</i>	Long-nosed Echymipera					
Peroryctidae	<i>Microperoryctes longicauda</i>	Striped Bandicoot		L	3	L	L
Peroryctidae	<i>Peroryctes raffrayana</i>	Raffray's Bandicoot		L	L	L	7
Phalangeridae	<i>Phalanger carmelitae</i>	Mountain Cuscus		3		L	3
Phalangeridae	<i>Phalanger gymnotis</i>	Ground Cuscus		5	5	5	EP
Phalangeridae	<i>Phalanger intercastellanus</i>	Common Cuscus		L	2	5	
Phalangeridae	<i>Phalanger sericeus</i>	Silky Cuscus		3		5	EP
Phalangeridae	<i>Phalanger vestitus</i>	Stein's Cuscus		EP		L	L
Phalangeridae	<i>Spilocuscus maculatus</i>	Spotted Cuscus		3	6	L	
Macropodidae	<i>Dendrolagus dorianus</i>	Doria's Tree Kangaroo		6		6	EP
Macropodidae	<i>Dendrolagus goodfellowii</i>	Goodfellow's Tree Kangaroo		L		L	L
Macropodidae	<i>Dendrolagus spadix</i>	Lowland Tree Kangaroo	EP				
Macropodidae	<i>Dorcopsulus macleayi</i>	Macleay's Dorcopsis					7
Macropodidae	<i>Dorcopsulus vanheurni</i>	Lesser Forest Wallaby		L		L	EP
Macropodidae	<i>Thylogale browni</i>	New Guinea Pademelon		L			
Burramyidae	<i>Cercartetus caudatus</i>	Long-tailed Pygmy Possum				1	L
Pseudocheiridae	<i>Pseudocheirops corinnae</i>	Plush-coated Ringtail		EP		1	L
Pseudocheiridae	<i>Pseudocheirops cupreus</i>	Coppery Ringtail				L	L
Pseudocheiridae	<i>Pseudochirulus canescens</i>	Lowland Ringtail			L		
Pseudocheiridae	<i>Pseudochirulus forbesi</i>	Painted Ringtail		EP		2	L
Pseudocheiridae	<i>Pseudochirulus mayeri</i>	Pygmy Ringtail				L	3
Petauridae	<i>Dactylopsila palpator</i>	Long-fingered Triok				3	L
Petauridae	<i>Dactylopsila trivirgata</i>	Striped Possum		EP	3	L	L
Petauridae	<i>Petaurus breviceps</i>	Sugar Glider		4	4	4	2
Acrobatidae	<i>Distoechurus pennatus</i>	Feather-tailed Possum		EP	L	3	
Muridae	<i>Anisomys imitator</i>	Uneven-toothed Rat		L	EP	5	L
Muridae	<i>Chiruromys lamia</i>	Broad-headed Tree-mouse					3
Muridae	<i>Chiruromys vates</i>	Lesser-tree Mouse		L	EP	L	
Muridae	<i>Crossomys moncktoni</i>	Earless Water Rat				L	L
Muridae	<i>Cocomys rummieri</i>	Rummler's Mouse					EP
Muridae	<i>Hydromys chrysogaster</i>	Common Water Rat		EP	1	L	L
Muridae	<i>Hyomys dammermani</i>	Western White-eared Giant-rat				1	
Muridae	<i>Hyomys goliath</i>	Eastern White-eared giant-rat				1	
Muridae	<i>Leptomys elegans</i>	Long-Footed Water Rat		EP		EP	
Muridae	<i>Leptomys ernstmayeri</i>	Ernst Mayer's Leptomys				L	L
Muridae	<i>Lorentzimys nouhuysi</i>	Long-footed Tree Mouse		EP	L	L	L
Muridae	<i>Mallomys aroensis</i>	Grey Black-eared Rat				L	L
Muridae	<i>Mallomys rothschildi</i>	Dusky Black-eared Rat				L	L
Muridae	<i>Mayeremys ellermani</i>	One-toothed Shrew Mouse					L
Muridae	<i>Melomys leucogaster</i>	White-bellied Melomys		1	EP	1	
Muridae	<i>Melomys lutillus</i>	Grassland Melomys	1	1	L		L
Muridae	<i>Melomys rufescens</i>	Black-tailed Melomys	1	EP	1	2	L
Muridae	<i>Parahydromys asper</i>	Waterside Rat		EP		L	L
Muridae	<i>Abeomelomys sevia</i>	Menzie's Mouse					L
Muridae	<i>Paramelomys lorentzii</i>	Lorentz's Melomys	EP				
Muridae	<i>Paramelomys mollis</i>	Thomas's Melomys		1		1	1

Table 3: Terrestrial mammal species recorded by the 2008 surveys.

Family	Scientific name	Common name	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Muridae	<i>Paramelomys moncktoni</i>	Monckton's Melomys	EP				
Muridae	<i>Paramelomys sp.aff. moncktoni</i>	New Melomys species	1	1			
Muridae	<i>Paramelomys platyops</i>	Lowland Melomys	1	1	1		
Muridae	<i>Paramelomys rubex</i>	Mountain Melomys		1		1	1
Muridae	<i>Pogonomys loriae</i>	Large Tree Mouse	5	L	L	L	2
Muridae	<i>Pogonomys macrourus</i>	Chestnut Tree Mouse	EP	L	L	1	L
Muridae	<i>Pogonomys sylvestris</i>	Grey-bellied Tree-mouse				L	L
Muridae	<i>Rattus exulans</i>	Pacific Rat	1				
Muridae	<i>Rattus leucopus</i>	Cape York Rat	1	1			
Muridae	<i>Rattus mordax</i>	Eastern Rat	EP				
Muridae	<i>Rattus steini</i>	Stein's Rat	EP	1			L
Muridae	<i>Stenomys niobe</i>	Moss Forest Rat		L		1	1
Muridae	<i>Stenomys verecundus</i>	Slender Rat	EP	L		1	L
Muridae	<i>Uromys anak</i>	Giant Naked-tailed Rat				5	L
Muridae	<i>Uromys caudimaculatus</i>	Mottled-tailed Giant Rat	EP	1	EP	L	EP
Muridae	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat			EP		
Total number of species recorded per site			16	43	27	50	49

1 - trapped, 2 - spotlighted, 3 - sighted in daytime, 4 - calls heard, 5 - spoor or droppings or other sign, 6 - bones retrieved from hunters, 7 – photo from camera trap, L - undoubted hunter record, EP - probable hunter record.

4 Sensitivities and conservation status of mammals

4.1 Habitat and resilience to disturbance

Appendix 2 presents notes on the habitat requirements and status of all species recorded by the WWF surveys and the LNG surveys in 2005 and 2008, except the introduced wild pig. 36 of these 86 species (52%) have broad habitat needs or can establish populations in degraded or secondary forest and 28 species (40%) require primary forest. The requirements of five species remain unknown. Thus in general the mammal fauna is resilient to small-scale habitat disturbance. New Guinea has a very dynamic geomorphology and landslides and earthquakes, which intermittently destroy small to large tracts of forest, are common place and a natural hazard for the mammal fauna. However, the species of primary forest are unlikely to tolerate widespread habitat degradation and are likely to become locally extinct where primary forest is reduced to small remnants.

The mammal fauna has coped with the oil developments in the Kikori and rich faunas exist alongside the facilities. During the present surveys, Juha South was found to be a very rich site even though it was on an old well pad. The fauna had been maintained in the face of this local but short-lived clearing that had been allowed to regenerate. At this particular site up to four Common Spotted Cuscus (*Spiloglossus maculatus*) could be seen feeding in daytime in the vicinity of the camp, an extremely rare occurrence elsewhere in Papua New Guinea.

The main issues for mammals in relation to the project are forest degradation and excessive hunting brought about by improving access to the mammal rich, uninhabited and undisturbed regions around Juha. Many species recorded in the project area are endemic and elsewhere in Papua New Guinea threatened by hunting from local people.

4.2 IUCN Red List of Threatened Species

Table 4 shows which species identified in the surveys are on the IUCN Red List. Twelve recorded species are under threat, with three being Endangered or Critically Endangered.

Many parts of Papua New Guinea no longer have the species shown in **Table 4** particularly the larger species, hence, to find these species emphasises the remoteness of some of the sampling areas, and the value of the forests of the project area. Of particular importance are the species in the highest categories – Critically Endangered and Endangered, and the larger species classified as Vulnerable which are avidly hunted.

- **Long-Footed Water Rat** The geographic range of this critically endangered species has been predicted by the IUCN to be less than 100 km² and probably also fragmented into small areas. It has been found in the KICDP area by WWF and, based on local information, it is probable that it is at Juha South and South Karius sample areas.
- **Goodfellow's Tree Kangaroo** Classified as Endangered this tree kangaroo was determined through local information to be present at Juha South, South Karius and at the Deviation Camp survey areas. Being a large (7 – 9 kg) animal, it is sought

after by hunters as a food source, as are all of the other tree kangaroos. It has a very distinctive coat colour which increases the reliability of the hunting records. The listing of the species as Endangered is because its global population has been reduced by 70% over the last decade. This reduction would have been due to hunting and other human pressures such as rainforest habitat clearance, a problem identified by Flannery (1995).

- **Long-beaked Echidna** Amongst the endangered species we have included *Zaglossus bartoni*. This was previously part of *Z. bruijnii*, a species classified as Endangered by IUCN, but it was found to consist of three species (Flannery and Groves 1998). The genus has not been revised by IUCN but the status of its population has changed, as the species is now split into three. This taxonomic splitting may even increase the status of one or more of the *Zaglossus* species when the genus is revised by IUCN. It suffers severely from hunting. Bones were obtained from camp workers who had hunted close to camp at South Karius and Juha South, and reliable records were obtained from locals at Deviation Camp and Baia River survey areas.
- **Doria's Tree Kangaroo**, which is listed as Vulnerable is another species that has suffered severe declines in populations (by 50% or more over the last decade, according to IUCN assessors) probably through hunting with trained dogs. During the survey, records were obtained at the Juha South and South Karius survey areas from local hunters (Figure 9).
- Two other large macropods classified as Vulnerable by the IUCN, the **New Guinea Pademelon** and **Stein's Cuscus**, were identified as being present at a number of sites, with the former known only from Juha South survey area, and the latter from that area as well as South Karius and the Deviation survey areas. These records were reliably provided by local landowners because they frequently hunt them with trained dogs.
- Another Vulnerable species, **Macleay's Dorcopsis** is in the same body size range (around 3 kg) that is favoured by hunters. The IUCN assessment describes populations as being very small and restricted to being either less than 20 km² or it is only known from less than five locations, "such that it is prone to the effects of human activities". Evidence for the presence in the Deviation sample area was obtained from an automated camera trap.
- Another species that is hunted that is classified as Vulnerable by the IUCN, the **Plush-coated Ringtail** is one of many possum species hunted by landowners (Figure 70). Records of this species were obtained from South Karius, Juha South, and the Deviation survey areas.
- **The New Guinea Quoll** is a medium-sized marsupial carnivore that advertises its presence at night by a distinctive call, which was the basis of records at Juha South and the Baia River. Local knowledge of this distinctive species provided records at South Karius and the Deviation sample areas, where the calls provide a clue to hunters. IUCN assessors placed this species in the Vulnerable category on the basis that populations had reduced by 50% or more over the last decade.

- **The One-toothed Shrew-mouse** is known from just a few scattered localities in Papua New Guinea and is generally restricted to high altitude moss forest between 1300 – 2800 m (Flannery 1995). The record of this unique species from the Deviation area was based on local knowledge. The IUCN Vulnerable assessment is based upon the population being estimated to be less than 10,000 individuals. It is not clear what impacts are causing this decline, but habitat loss would be expected to be the situation.

Table 4: Species recorded during the survey that are listed on IUCN Red List.

Threat status*	Reason for listing
CRITICALLY ENDANGERED	
Long-Footed Water Rat (<i>Leptomys elegans</i>)	Geographic range is estimated to be <100 km2 and is its population is fragmented
ENDANGERED	
Long-beaked Echidna (<i>Zaglossus sp.</i>) (P)	Prior to it being split into three species <i>Zaglossus bruijini</i> was classified as endangered. The classification is kept for this discussion because the taxonomic change will not have altered the status of the populations.
Goodfellow's Tree Kangaroo (<i>Dendrolagus goodfellowi</i>) (P)	Population reduction is estimated to be >70% over the last decade
VULNERABLE	
New Guinea Quoll (<i>Dasyurus albopunctatus</i>)	Population reduction is estimated to be >50% over the last decade
Doria's Tree Kangaroo (<i>Dendrolagus dorianus</i>) (P)	
Plush-coated Ringtail (<i>Pseudochirops corinnae</i>)	
New Guinea Pademelon (<i>Thylogale browni</i>) (R)	
Macleay's Dorcopsis (<i>Dorcopsulus macleayi</i>) (R)	Population is very small and has a restricted distribution (<20 km2), or is known from few (<5) locations such that it is prone to the effects of human activities
Stein's Cuscus (<i>Phalanger vestitus</i>)	Population reduction is estimated to be >50% over the last decade, the geographic range is <20,000 km2
One-toothed Shrew-mouse (<i>Mayermys ellermani</i>)	Population size is estimated to be <10,000 individuals
NEAR THREATENED	
Black-tailed Giant-rat (<i>Uromys anak</i>)	Likely to be listed in a higher threat category if present impacts prevail
Rock-dwelling Giant-rat (<i>Xenuromys barbatus</i>)	
DATA DEFICIENT	
Lowlands tree-kangaroo (<i>Dendrolagus spadix</i>) (P)	Susceptible to hunting
Lowland Ringtail (<i>Pseudochirulus canescens</i>)	Susceptible to hunting
Ground Cuscus (<i>Phalanger gymnotis</i>)	Susceptible to hunting
NON IUCN Species listed under PNG Fauna (Priotection and Control Act 1966, 1978	
Feather-tailed possum (<i>Dostoechurus pennatus</i>)	Susceptible to hunting

* in brackets is status under PNG Fauna (Protection and Control Act 1966, 1978: P – “Protected”, R – “Restricted”.



Figure 9 Two Doria's Tree Kangaroos (*Dendrolagus dorianus*) that were captured by local hunters in the vicinity of the South Karius camp using trained dogs. Photo by G. C. Richards.

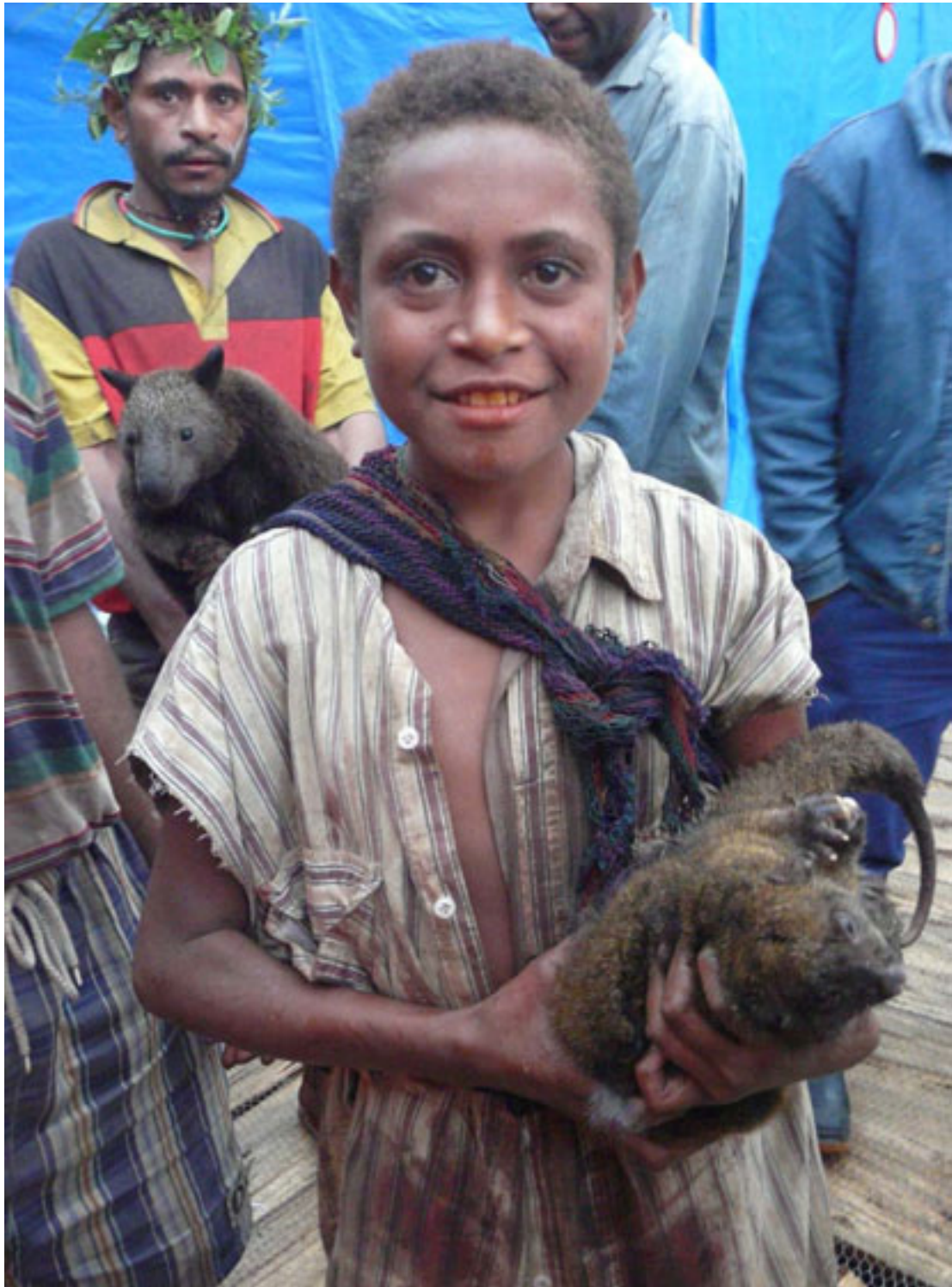


Figure 10 All ringtail possums, in this case a Plush-coated Ringtail (*Pseudochirus corinnae*) are procured as a food source by local landowners, as in this example from South Karius. Photo G. C. Richards.

5 Discussion

5.1 Potential Impacts

From the data outlined above, it is apparent that the terrestrial mammal fauna in the project area is highly diverse in most areas, with up to 50 terrestrial mammals being recorded from some of the sampling areas, particularly at higher altitudes. The fact that most of the 2008 sampling sites had previously been inaccessible to humans, and had no human settlement until the surveys commenced, resulted in a very high level of diversity of non-flying mammals being recorded during the surveys.

The study identified that the Juha area retained a fauna that provided an excellent representation of the natural environment of Papua New Guinea, one that had never been influenced by humans due to inaccessibility. In fact, for the survey team to gain access, a complex logistical operation involving many people and helicopters was required. To build the survey camps, labourers were transported to the sampling areas prior to the arrival of the survey team. This inadvertently led to short term, high hunting pressure of the mammals by the labourers and as a result, an inordinately high number of hunter species records were obtained. This was beneficial to the survey in terms of providing species records but indicated how easily certain species, especially larger ones such as tree kangaroos and ground mammals, could be found and hunted by locals. The potential hunting pressure from locals infiltrating previously inaccessible parts of their domain with modern hunting methods is a key issue for the project, but may be able to be mitigated by control of access along project roads and tracks during construction and operations.

It is unlikely any of the 70 species recorded would be directly impacted severely by the construction of a cleared pipeline corridor which would for most of its length be less than 50 m wide. All species are capable of crossing cleared areas, and almost half of the species recorded are known to occupy disturbed habitats such as secondary forest, regrowth in gardens, and areas cleared for gardens themselves. Similarly it is unlikely there will be severe direct impacts from associated infrastructure such as wells, fly roads, facilities, temporary camps etc.

The highest potential impact of the project is the influx of humans into previously inaccessible areas along project roads and tracks. This can occur in several ways:

- Hunting by project employees and contractors, which creates an immediate direct, not indirect, impact.
- Providing access to unspoiled forest and thus new hunting grounds as people not related to the project access new areas via the pipeline corridor, again providing an immediate indirect impact through hunting.
- Settlement by people along the pipeline corridor who clear wildlife habitat for gardens and business enterprises which then creates a long-term impact via habitat loss.
- Access by entrepreneurs to forest that is then illegally logged, which creates a long-term and often irreversible impact through habitat loss and the production of large areas of disturbed habitat.

5.2 Suggested mitigation measures

The suggested mode of mitigation for these potential impacts are to:

- Restrict and monitor the activities of the construction workforce, imposing appropriately severe penalties for hunting.
- Restrict human access when the pipeline easement is in operation through secure gating and imposing appropriately severe penalties upon people who otherwise gain access.
- These mitigations need to be closely monitored and all stakeholders and contractors be required to comply by imposing appropriately severe penalties.
- Some indicator species e.g. the Doria's Tree-kangaroo associated with undisturbed forests with little disturbance from humans could have specific habitat protection measures developed for them if large intact populations are located.

Adjuncts to these measures that could be considered are:

- Protecting critical natural habitats (such as feeding and breeding sites for threatened species of Doria's Tree-kangaroos in montane rainforests) along the project area and designating them to be a protected area under the PNG Protected Areas Act. As an option, the entire pipeline corridor could be considered for declaration as a protected area so that it prevents human access while allowing facilities and pipeline management. This may be achievable by continuing support for WWF activities in the Kikori.
- A program could be implemented to educate local people on the fauna laws of PNG [Fauna (Protection and Control) Act, 1976] governing certain species and traditional modes of hunting.
- Implementing educational awareness amongst employees and widely in the local community to increase awareness of the impacts of invasive or introduced animals (cats and dogs, Black rat - *Rattus rattus*) and plants (*Piper aducum*, etc).
- Ensuring that corporate policies that operate in the project area are sufficiently strong to be a powerful driver in maintaining flora and fauna. Establish and implement internal policies that will safeguard the fauna and flora within the project site.
- Establish a monitoring program that regularly assesses the population of threatened species to ensure that the biodiversity values of the forests between Hides and Juha are not diminishing.

7 Acknowledgement

This study was feasible with the financial assistance from the following operators of the PNG LNG Project: Exxon Mobil Corporation and Esso Highlands Limited in co-venture with licensees, including Oil Search Limited (OSL), Santos Limited, AGL Energy Limited, Nippon Oil Exploration Limited and Mineral Resources Development Company Limited (MRDC), on behalf of the project area landowners. In addition, the interest and support from the PNG Government on this project was significant.

I would thank Coffey Natural Systems Pty Ltd who have the confidence and expertise to conduct this exhaustive biological expedition to the remotest parts of the highlands of Papua New Guinea to the southeastern part of Central Province. I would also extend my sincere gratitude to Francis Crome (scientific team leader) and Kate Sutherland (upstream team leader) for leading this terrestrial component of the EIS.

I would like to extend special thanks to Dr Greg Richards for his patience and technical assistance in putting this report together during a difficult personal time for the author.

Lastly, I would acknowledge and appreciate the tireless efforts of the local field assistants who provided vital local information of the presence and existence of the terrestrial mammals that we would not have been privy to otherwise.

8 References

- Balun L. (2004?) An Audit on the Status of the Flora and Fauna of the Porora Forest, South East Mananda Forest, Southern Highlands Province. WWF KICDP area Report.
- Flannery, T. F. (1995). Mammals of New Guinea – Revised and Updated Edition. Robert Brown and Associates, Sydney, Australia.
- Flannery, T. F. and Groves, C. P. (1998). A revision of the genus *Zaglossus* (Monotremata, Tachyglossidae), with description of new species and subspecies. *Mammalia* **62**: 367 – 396.
- Groombridge, B. (1994). 1994 IUCN Red List of threatened animals, IUCN. Cambridge, United Kingdom.
- Hammermaster, E.T., and J.C. Saunders. (1995). Forest Resources and Vegetation Mapping of Papua New Guinea. PNGRIS Publ. 4, CSIRO and AIDAB, Canberra
- Hartshorn G. S., Burrows I., Leary T., Seri L., Allen G., Polhemus D., Balun L., Orsak L., Bigilale E., Kinbag F., Kinibel A., Dal C., Wasel H., Ellis G. & Forney M., (1995). Field survey of biodiversity in the Kikori River Basin. Papua New Guinea. WWF KICDP area Report
- Leary T. (1998) Mammals of the Lake Kutubu Swamp Forests. Wetlands International Report.
- Leary T. (1999) Mammal Survey of the Gobe Oil Field Area, Southern Highlands and Gulf Provinces, Papua New Guinea - December, 1998. WWF KICDP area Report.
- Leary T. (2001) Mammal Survey of Two Sites on the Northeast Slopes of Mt Sisa, Southern Highlands Province, PNG - October 1999. WWF KICDP area Report.
- Leary T. (2002?) Brief Report on Iviri Mammal Monitoring - December 2001. WWF KICDP area Report.
- Leary T. (2004a?) Brief Report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003. WWF KICDP area Report.
- Leary T. (2004b?) Brief Report on Keboi Kerowa Mammal Monitoring - July 2004. WWF KICDP area Report.
- Leary T. (2004c) Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province, July - August, 2003. WWF KICDP area Report.
- Leary T. & Seri L. (1995?). Survey of Birds and Mammals at Utiti Creek. Unpublished WWF KICDP area Report.
- Leary, T. and Seri, L. (1997). An annotated checklist of mammals recorded in the Kikori River Basin, Papua New Guinea. *Science in New Guinea* **23** (2): 79 – 100.

Leary, T. and T, Mamu. (2004). *Conserving Papua New Guinea's forest fauna through community planning*. (Second edition). WWF Kikori Integrated Conservation and Development Project, Papua New Guinea.

Leary T., Seri L. & Kinbag F. (1995) Report on the bat component of the field survey of biodiversity in the Kikori ICDP area. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report.

Mamu, T. and R, Sine. (2005). *A preliminary fauna assessment of the forest corridor of Homa-Irawi proposed road, Tari. Southern Highlands Province*. A supplementary report to HSES section - Oil Search Limited.

Mamu, T., Gebia, O., Enoch, I., Kuduk, M., and Ona, A. (2005). *Report for an Assessment Survey of Terrestrial Mammals for PNG Gas Project, Papua New Guinea*. Report to Enesar Consulting Pty. Ltd. (Annex 01 to Biodiversity Appendix)

Menzies, J. I. (1996) A systematic revision of *Melomys* (Rodentia: Muridae) of New Guinea. *Australian Journal of Zoology*. **44**: 367 – 426.

Namo, R. (2004). Annotated checklists of mammals of Kikori Basin. (unpublished report WWF KICDP)

Norris, C. A. and Musser G. G. 2001. Systematic Revision Within the *Phalanger orientalis* Complex (Diprotodontia, Phalangeridae): A Third Species of Lowland Gray Cuscus from New Guinea and Australia. *American Museum Novitates* 3356: 1-20.

Richards, G. C. (2005). *The Papua New Guinea Gas Project: a study of bat faunal biodiversity and an assessment of potential impacts*. Annex 05 to Biodiversity Appendix.

Richards, G. C. (2008). *The Papua New Guinea Liquefied Natural Gas Project: A study of bat faunal biodiversity and an assessment of potential impacts*. Annex 05 to Biodiversity Appendix.

Seri L., Leary T. & Kinbag F. (1995) Report on the non-flying mammal component of the field survey of biodiversity in the Kikori ICDP area. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP area Report

Appendix 1A Mammal records from elevations 0 to 1000 m in the Project Area

Subsite			Waro	Kikori1	Kopi	Aird Hills	Dark End Lumber	Iviri 3	Keboi Kerowa	Veiru Creek	Utiti Creek	Omo village	Fogomaiyu	Juha north	Baia River	Libano Sok	Darai Plateau	Wassji Falls WFL to WF4	Kantobo	Gobe G2 to G6
Altitude			?	10	20	50	30-60	30	30	30	35	40-170	200	213	328	200-600	300-700	380-600	400-420	626
Family	Scientific name	Common name																		
Tachyglossidae	Zaglossus bartoni	Long-beaked Echidna													L	L	L			X
Tachyglossidae	Tachyglossus aculeatus	Short-beaked Echidna														L	L			
Dasyuridae	Dasyurus albopunctatus	New Guinea Quoll													4	L	L			X
Dasyuridae	Murexichinus melanurus	Black-tailed Antechinus													L	L		X		
Dasyuridae	Phascomurexia naso	Long-nosed Murexia														L				
Dasyuridae	Phascolosorex dorsalis	Narrow-striped Dasyure																		
Dasyuridae	Murexia longicaudata	Short-furred Dasyure													3	X				
Dasyuridae	Murexia sp.	Undescribed species of Murexia																		
Dasyuridae	Myoictis melas	Three-striped Dasyure													3	L	L			
Peroryctidae	Echymipera kalubu	Common Echymipera					X	T	T	X					2	X	X	X		X
Peroryctidae	Echymipera rufescens	Long-nosed Echymipera								X							X			
Peroryctidae	Microperoryctes longicauda	Striped Bandicoot					L								3			L		X
Peroryctidae	Peroryctes raffrayana	Raffray's Bandicoot			R		L								L	L				
Phalangeridae	Phalanger carmelitae	Mountain Cuscus																		
Phalangeridae	Phalanger gymnotis	Ground Cuscus		M			L				X				5	L	L			X
Phalangeridae	Phalanger intercastellanus	Common Cuscus	M								X				2					L
Phalangeridae	Phalanger mimicus	Cuscus					L	T	T							L	L			
Phalangeridae	Phalanger sericeus	Silky Cuscus																		
Phalangeridae	Phalanger vestitus	Stein's Cuscus																		
Phalangeridae	Spilocuscus maculatus	Spotted Cuscus	M				L	T	T						6	L	L			X
Macropodidae	Dendrolagus dorianus	Doria's Tree Kangaroo														L	L	L	X	X
Macropodidae	Dendrolagus goodfellowii	Goodfellow's Tree Kangaroo														L	L			X
Macropodidae	Dendrolagus spadix	Lowland Tree Kangaroo			R		L							EP			L	L		
Macropodidae	Dorcopsis hageni	White-Striped Dorcopsis																		
Macropodidae	Dorcopsis luctuosa	Grey Dorcopsis			R		L				X					L	L	X		
Macropodidae	Dorcopsulus macleayi	Macleay's Dorcopsis																		
Macropodidae	Dorcopsulus vanheurni	Lesser Forest Wallaby																		L
Macropodidae	Thylogale browni	New Guinea Pademelon																		
Burramyidae	Cercartetus caudatus	Long-tailed Pygmy Possum																		
Pseudocheiridae	Pseudocheirops corinnae	Plush-coated Ringtail																		
Pseudocheiridae	Pseudocheirops cupreus	Coppery Ringtail																		
Pseudocheiridae	Pseudochirulus canescens	Lowland Ringtail							T	X					L					X

Appendix 1A Mammal records from elevations 0 to 1000 m in the Project Area

Subsite			Waro	Kikori1	Kopi	Aird Hills	Dark End Lumber	Iviri 3	Keboi Kerowa	Veiru Creek	Utiti Creek	Omo village	Fogomaiyu	Juha north	Baia River	Libano Sok	Darai Plateau	Wassji Falls WF1 to WF4	Kantobo	Gobe G2 to G6
Altitude			?	10	20	50	30-60	30	30	30	35	40-170	200	213	328	200-600	300-700	380-600	400-420	626
Pseudocheiridae	Pseudochirulus forbesi	Painted Ringtail																		
Pseudocheiridae	Pseudochirulus mayeri	Pygmy Ringtail																		
Petauridae	Dactylopsila megalura	Great Tailed Triok																		
Petauridae	Dactylopsila palpator	Long-fingered Triok																		
Petauridae	Dactylopsila trivirgata	Striped Possum	M				L								3	L				L
Petauridae	Petaurus breviceps	Sugar Glider	M				L		T		L				4	X	X	L		X
Acrobatidae	Distoechurus pennatus	Feather-tailed Possum			T		L								L	L	L			
Muridae	Anisomys imitator	Uneven-toothed Rat													EP	L		X		
Muridae	Chiruromys lamia	Broad-headed Tree-mouse																		
Muridae	Chiruromys vates	Lesser-tree Mouse										M			EP	X				
Muridae	Crossomys moncktoni	Earless Water Rat																		
Muridae	Cocomys rummleri	Rummler's Mouse																		
Muridae	Hydromys chrysogaster	Common Water Rat							T						1					
Muridae	Hyomys dammermani	Western White-eared Giant-rat																		
Muridae	Hyomys goliath	Eastern White-eared giant-rat																		
Muridae	Hyomys goliath/ H. dammermani	White-eared Rat																		
Muridae	Leptomys elegans	Long-Footed Water Rat																X		
Muridae	Leptomys signatus	Fly River Leptomys															X			
Muridae	Leptomys ernstmayeri	Ernst Mayer's Leptomys																		
Muridae	Lorentzimys nouhuysi	Long-footed Tree Mouse													L		X	X		X
Muridae	Macruromys major	Greater Small-toothed Rat																		
Muridae	Mallomys aroaensis	Grey Black-eared Rat																		
Muridae	Mallomys rothschildi	Dusky Black-eared Rat																		
Muridae	Mayeremys ellermani	One-toothed Shrew Mouse																		
Muridae	Melomys leucogaster	White-bellied Melomys	M					X	X	X	X									X
Muridae	Melomys lutillus	Grassland Melomys												1	L					
Muridae	Melomys rufescens	Black-tailed Melomys	M				X				X			1	1	X	X	X		X
Muridae	Microhydromys richardsoni	Groove-toothed Shrew Mouse															X			
Muridae	Parahydromys asper	Waterside Rat																		
Muridae	Abeomelomys sevia	Menzie's Mouse																		
Muridae	Paramelomys levipes?	Long-nosed Melomys										X								X
Muridae	Paramelomys lorentzii	Lorentz's Melomys												EP						
Muridae	Paramelomys mollis	Thomas's Melomys																		

Appendix 1A Mammal records from elevations 0 to 1000 m in the Project Area

Subsite			Waro	Kikori1	Kopi	Aird Hills	Dark End Lumber	Iviri 3	Keboi Kerowa	Veiru Creek	Utiti Creek	Omo village	Fogomaiyu	Juha north	Baia River	Libano Sok	Darai Plateau	Wassji Falls WFL to WF4	Kantobo	Gobe G2 to G6
Altitude			?	10	20	50	30-60	30	30	30	35	40-170	200	213	328	200-600	300-700	380-600	400-420	626
Muridae	Paramelomys moncktoni	Monckton's Melomys												EP						
Muridae	Paramelomys sp.aff. moncktoni	New Melomys species												1						
Muridae	Paramelomys platyops	Lowland Melomys					X			X		X		1	1	X	X	X		X
Muridae	Paramelomys rubex	Mountain Melomys									X							X		X
Muridae	Pogonomelomys bruijini	Large Pogonomelomys																		
Muridae	Pogonomelomys mayeri	Shaw Mayer's Pogonomelomys																		
Muridae	Pogonomys loriae	Large Tree Mouse					X				X			5	L	X				X
Muridae	Pogonomys macrourus	Chestnut Tree Mouse												EP	L	X				
Muridae	Pogonomys sylvestris	Grey-bellied Tree-mouse																		
Muridae	Rattus exulans	Pacific Rat			T									1						
Muridae	Rattus leucopus	Cape York Rat	M	M	T	M	X			X	X	X		1		X	X	X		X
Muridae	Rattus mordax	Eastern Rat												EP						
Muridae	Rattus novaeguineae	New Guinea Rat																X		
Muridae	Rattus sp.	Rat																		
Muridae	Rattus cf. praetor	Large Spiny Rat																		X
Muridae	Rattus sp. nov. (Mt Kemenagi)	Undescribed species of Rattus																		
Muridae	Rattus sp. nov. (Gobe)	Undescribed species of Rattus					X										X			X
Muridae	Rattus sp. nov. Darai (cf. mordax)	Undescribed species of Rattus														X				
Muridae	Rattus steini	Stein's Rat												EP						X
Muridae	Stenomys niobe	Moss Forest Rat																		X
Muridae	Stenomys verecundus	Slender Rat												EP		X	X			
Muridae	Uromys anak	Giant Naked-tailed Rat																		
Muridae	Uromys caudimaculatus	Mottled-tailed Giant Rat	M					X	X		X			EP	EP	X		X		X
Muridae	Xenuromys barbatus	Rock-dwelling Giant Rat													EP			X		
Number of species			8	2	6	1	16	5	8	6	10	3	1	15	26	28	23	17	1	26

X= record from WWF survey (Hartshorn et al. 1995, Seri et al. 1995, Leary et al. 1995, Leary and Seri 1995?, 1997, Leary 1998, 1999, 2000, 2001, 2002?, 2004?a, 2004?b, 2004c, Balun 2004?, Namo 2004, Mamu and Sine 2005, Igag 2003?, and see Appendices 1 and 2 to main Biodiversity Appendix), M - museum specimen. 2008 surveys only: 1 - trapped, 2 - spotlighted, 3 - sighted in daytime, 4 - calls heard, 5 - spoor or droppings or other sign, 6 - bones retrieved from hunters, 7 - photo from camera trap, L - undoubted hunter record, EP - highly probable hunter record

Appendix 1B Mammal records from elevations 1000 to 2000 m in the Project Area

Sample site			Benaria	Henry's Trail - Agogo Rd	Homa-Idauwi (H12)	Homa-Idauwi (H5)	Iagifu Ridge	Lake Kutubu LK1 to LK3	Mt Kemanagi MK1 and MK2	Juha South	South Karius	Hides 3	Mt Sisa MS1 and MS2	Mt Bosavi	Deviation Camp	Total records for species
Altitude (m)			1239	1050	1239	1239	1330-1350	808	900-1130	953	1368	2163	1840-2560	1250-1725	1975	
Family	Scientific name	Common name														
Tachyglossidae	<i>Zaglossus bartoni</i>	Long-beaked Echidna	L		L	L			X	6	6	X	M		L	13
Tachyglossidae	<i>Tachyglossus aculeatus</i>	Short-beaked Echidna														2
Dasyuridae	<i>Dasyurus albopunctatus</i>	New Guinea Quoll	L	R	L	L				4	L	L	X		L	13
Dasyuridae	<i>Murexichinus melanurus</i>	Black-tailed Antechinus								EP	L		M		L	7
Dasyuridae	<i>Phascomurexia naso</i>	Long-nosed Murexia									L		X		L	4
Dasyuridae	<i>Phascosorex dorsalis</i>	Narrow-striped Dasyure													L	1
Dasyuridae	<i>Murexia longicaudata</i>	Short-furred Dasyure	L		L	L				EP	2	L	M		L	10
Dasyuridae	<i>Murexia sp.</i>	undescribed species of Murexia											X			1
Dasyuridae	<i>Myoictis melas</i>	Three-striped Dasyure			L	L		X	L	L			M	X		10
Peroryctidae	<i>Echymipera kalubu</i>	Common Echymipera	X		L	L		X	EP	L	L	M	M		L	18
Peroryctidae	<i>Echymipera rufescens</i>	Long-nosed Echymipera						X					M			4
Peroryctidae	<i>Microperoryctes longicauda</i>	Striped Bandicoot	L		L	L		L	L	L	X	X	X		L	13
Peroryctidae	<i>Peroryctes raffrayana</i>	Raffray's Bandicoot	X					L	L	L	L	L	M		7	11
Phalangeridae	<i>Phalanger carmelitae</i>	Mountain Cuscus	X		L	L				3	L	X	X	X	3	9
Phalangeridae	<i>Phalanger gymnotis</i>	Ground Cuscus	L		L	L		L	5	5	X	X	X	L	EP	17
Phalangeridae	<i>Phalanger intercastellanus</i>	Common Cuscus		R				L	L	5			M	L		10
Phalangeridae	<i>Phalanger mimicus</i>	Cuscus														5
Phalangeridae	<i>Phalanger sericeus</i>	Silky Cuscus	L		L	L				3	5	X	X		EP	8
Phalangeridae	<i>Phalanger vestitus</i>	Stein's Cuscus	X		L	L				EP	L	L	M		L	8
Phalangeridae	<i>Spilocuscus maculatus</i>	Spotted Cuscus	L		L	L		X	3	L	L	L	M	L		17
Macropodidae	<i>Dendrolagus dorianus</i>	Doria's Tree Kangaroo	L		L	L		X	6	6	X	X	M	X	EP	15
Macropodidae	<i>Dendrolagus goodfellowii</i>	Goodfellow's Tree Kangaroo	X		L	L				L	L	L	M		L	11
Macropodidae	<i>Dendrolagus spadix</i>	Lowland Tree Kangaroo			L	L		L					M	R		10
Macropodidae	<i>Dorcopsis hageni</i>	White-Striped Dorcopsis											L			1
Macropodidae	<i>Dorcopsis luctuosa</i>	Grey Dorcopsis														6
Macropodidae	<i>Dorcopsulus macleayi</i>	Macleay's Dorcopsis													7	1
Macropodidae	<i>Dorcopsulus vanheurni</i>	Lesser Forest Wallaby	L					X	L	L	L	L	M		EP	8
Macropodidae	<i>Thylogale browni</i>	New Guinea Pademelon								L						1
Burramyidae	<i>Cercartetus caudatus</i>	Long-tailed Pygmy Possum	L		L	L		L			1		M		L	7
Pseudocheiridae	<i>Pseudocheirus corinnae</i>	Plush-coated Ringtail	L		L	L				EP	1	L	X		L	8

Appendix 1B Mammal records from elevations 1000 to 2000 m in the Project Area

Sample site			Benaria	Henry's Trail - Agogo Rd	Homa-Idauwi (H12)	Homa-Idauwi (H15)	Iagifu Ridge	Lake Kutubu LK1 to LK3	Mt Kemanagi MK1 and MK2	Juha South	South Karius	Hides 3	Mt Sisa MS1 and MS2	Mt Bosavi	Deviation Camp	Total records for species
Altitude (m)			1239	1050	1239	1239	1330- 1350	808	900- 1130	953	1368	2163	1840- 2560	1250- 1725	1975	
Pseudocheiridae	<i>Pseudocheirops cupreus</i>	Coppery Ringtail	L		L	L			L		L	L	X	X	L	9
Pseudocheiridae	<i>Pseudochirulus canescens</i>	Lowland Ringtail			L	L							M	M		8
Pseudocheiridae	<i>Pseudochirulus forbesi</i>	Painted Ringtail							X	EP	2		M		L	5
Pseudocheiridae	<i>Pseudochirulus mayeri</i>	Pygmy Ringtail	L		L	L					L	L	M		3	7
Petauridae	<i>Dactylopsila megalura</i>	Great Tailed Triok											L			1
Petauridae	<i>Dactylopsila palpator</i>	Long-fingered Triok	L								3		M		L	4
Petauridae	<i>Dactylopsila trivirgata</i>	Striped Possum	L		L	L			L	EP	L		M	X	L	14
Petauridae	<i>Petaurus breviceps</i>	Sugar Glider	X		L	L			L	4	4	X	M	R	2	19
Acrobatidae	<i>Distoechurus pennatus</i>	Feather-tailed Possum	X		L	L		T	L	EP	3	L	M			14
Muridae	<i>Anisomys imitator</i>	Uneven-toothed Rat			L	L	X			L	5		X		L	10
Muridae	<i>Chiruromys lamia</i>	Broad-headed Tree-mouse													3	1
Muridae	<i>Chiruromys vates</i>	Lesser-tree Mouse	L							L	L		M	M		8
Muridae	<i>Crossomys moncktoni</i>	Earless Water Rat	L		L	L					L	L	M		L	7
Muridae	<i>Coccomys rummleri</i>	Rummler's Mouse	X												EP	2
Muridae	<i>Hydromys chrysogaster</i>	Common Water Rat	L							EP	L		M		L	7
Muridae	<i>Hyomys dammermani</i>	Western White-eared Giant-rat									1					1
Muridae	<i>Hyomys goliath</i>	Eastern White-eared giant-rat									1					1
Muridae	<i>Hyomys goliath/ H. dammermani</i>	White-eared Rat											M			1
Muridae	<i>Leptomys elegans</i>	Long-Footed Water Rat					X			EP	EP		M			5
Muridae	<i>Leptomys signatus</i>	Fly River Leptomys														1
Muridae	<i>Leptomys ernstmayeri</i>	Ernst Mayer's Leptomys	L								L				L	3
Muridae	<i>Lorentzimys nouhuysi</i>	Long-footed Tree Mouse						X		EP	L		M	X	L	10
Muridae	<i>Macruromys major</i>	Greater Small-toothed Rat											M			1
Muridae	<i>Mallomys aroaensis</i>	Grey Black-eared Rat									L		M		L	3
Muridae	<i>Mallomys rothschildi</i>	Dusky Black-eared Rat									L		M	M	L	4
Muridae	<i>Mayeremys ellermani</i>	One-toothed Shrew Mouse	L									L			L	3
Muridae	<i>Melomys leucogaster</i>	White-bellied Melomys	L		L	L		X		1	1		M			13
Muridae	<i>Melomys lutilus</i>	Grassland Melomys	X							1			M		L	6
Muridae	<i>Melomys rufescens</i>	Black-tailed Melomys	X		L	L		X		EP	2	X	X		L	18
Muridae	<i>Microhydromys richardsoni</i>	Groove-toothed Shrew Mouse											M			2
Muridae	<i>Parahydromys asper</i>	Waterside Rat	L							EP	L	L	M		L	6
Muridae	<i>Abeomelomys sevia</i>	Menzie's Mouse													L	1
Muridae	<i>Paramelomys levipes?</i>	Long-nosed Melomys							X				M			4

Appendix 1B Mammal records from elevations 1000 to 2000 m in the Project Area

Sample site			Benaria	Henry's Trail - Agogo Rd	Homa-Idauwi (H12)	Homa-Idauwi (H5)	Iagifu Ridge	Lake Kutubu LK1 to LK3	Mt Kemenagi MK1 and MK2	Juha South	South Karius	Hides 3	Mt Sisa MS1 and MS2	Mt Bosavi	Deviation Camp	Total records for species
Altitude (m)			1239	1050	1239	1239	1330-1350	808	900-1130	953	1368	2163	1840-2560	1250-1725	1975	
Muridae	<i>Paramelomys lorentzii</i>	Lorentz's Melomys												R		2
Muridae	<i>Paramelomys mollis</i>	Thomas's Melomys	L							1	1		X		1	5
Muridae	<i>Paramelomys moncktoni</i>	Monckton's Melomys														1
Muridae	<i>Paramelomys sp.aff. moncktoni</i>	New Melomys species								1						2
Muridae	<i>Paramelomys platyops</i>	Lowland Melomys	L					X	X	1			M	M		15
Muridae	<i>Paramelomys rubex</i>	Mountain Melomys	L		L	L	X		X	1	1	X	X	X	1	14
Muridae	<i>Pogonomelomys bruijini</i>	Large Pogonomelomys											M	M		2
Muridae	<i>Pogonomelomys mayeri</i>	Shaw Mayer's Pogonomelomys											M			1
Muridae	<i>Pogonomys loriae</i>	Large Tree Mouse	L		L	L				L	L	X	M	R	2	15
Muridae	<i>Pogonomys macrourus</i>	Chestnut Tree Mouse								L	1		M	R	L	8
Muridae	<i>Pogonomys sylvestris</i>	Grey-bellied Tree-mouse	L								L			R	L	4
Muridae	<i>Rattus exulans</i>	Pacific Rat												M		3
Muridae	<i>Rattus leucopus</i>	Cape York Rat							X	1			M	M		17
Muridae	<i>Rattus mordax</i>	Eastern Rat														1
Muridae	<i>Rattus novaeguineae</i>	New Guinea Rat											M			3
Muridae	<i>Rattus sp.</i>	Rat	X										M			3
Muridae	<i>Rattus cf. praetor</i>	Large Spiny Rat														1
Muridae	<i>Rattus sp. nov. (Mt Kemenagi)</i>	Undescribed species of Rattus							X							1
Muridae	<i>Rattus sp. nov. (Gobe)</i>	Undescribed species of Rattus														3
Muridae	<i>Rattus sp. nov. Darai (cf. mordax)</i>	Undescribed species of Rattus														1
Muridae	<i>Rattus steini</i>	Stein's Rat								1			M	R	L	6
Muridae	<i>Stenomys niobe</i>	Moss Forest Rat			L	L				L	1		X	X	1	8
Muridae	<i>Stenomys verecundus</i>	Slender Rat					X		X	L	1		M	X	L	10
Muridae	<i>Uromys anak</i>	Giant Naked-tailed Rat			L	L					5		M		L	5
Muridae	<i>Uromys caudimaculatus</i>	Mottled-tailed Giant Rat							X	1	L		M	X	EP	15
Muridae	<i>Xenuromys barbatus</i>	Rock-dwelling Giant Rat											M			3
Number of species			38	2	30	30	6	5	25	43	50	25	65	27	49	597

X= record from WWF survey (Hartshorn et al. 1995, Seri et al. 1995, Leary et al. 1995, Leary and Seri 1995?, 1997, Leary 1998, 1999, 2000, 2001, 2002?, 2004?a, 2004?b, 2004c, Balun 2004?, Namo 2004, Mamu and Sine 2005, Igag 2003?, and see Appendices 1 and 2 to main Biodiversity Appendix), R - literature record, M - museum specimen. 2008 surveys only: 1 - trapped, 2 - spotlighted, 3 - sighted in daytime, 4 - calls heard, 5 - spoor or droppings or other sign, 6 - bones retrieved from hunters, 7 - photo from camera trap, L - undoubted hunter record, EP - highly probable hunter record

Appendix 2 Habitat needs and conservation notes on species recorded in the project area.

Scientific Name	Habitat*	Conservation related notes
<i>Zaglossus bartoni</i>	U	Actively hunted and locally extinct in many areas
<i>Tachyglossus aculeatus</i>	Y	Mostly known from southern New Guinea, known to feed on ants in gardens
<i>Dasyurus albopunctatus</i>	N	Affected by introduction of cats
<i>Murexechinus melanurus</i>	Y	Widespread throughout New Guinea, more common in regrowth than in rainforest
<i>Phascomurexia naso</i>	N	Found only in primary rainforest
<i>Phascolosorex dorsalis</i>	Y	Moderately common in montane areas. Will use old gardens. Is hunted with dogs
<i>Murexia longicauda</i>	N	Primary forest species
<i>Murexia sp.</i>	U	Known only from Mt Sisa
<i>Myoictis melas</i>	Y	Widespread and generally uncommon in lowland rainforest; also uses disturbed habitats and will come into villages for prey
<i>Echymipera kalubu</i>	Y	Hunted as are all bandicoots, broad habitat requirements and may prefer secondary forest.
<i>Echymipera rufescens</i>	Y	Uncommon, hunted.
<i>Microperoryctes longicauda</i>	Y	Hunted, may be common in secondary growth
<i>Peroryctes raffrayana</i>	N	Widespread in Papua New Guinea; prefers primary forest and is rarely found in other habitats
<i>Phalanger carmelitae</i>	Y	Common and widespread. Hunted
<i>Phalanger gymnotis</i>	N	Common at higher elevations, avoids swampy lowland areas. Because it is ground-dwelling and rests by day in burrows, hollow logs etc it is susceptible to hunting by dogs which can easily find it.
<i>Phalanger intercastellanus</i>	Y	A common species in the lowlands. Hunted
<i>Phalanger mimicus</i>	U	Recently split from <i>P. intercastellanus</i> same habits. Hunted
<i>Phalanger sericeus</i>	Y	Common in montane areas. Hunted
<i>Phalanger vestitus</i>	N	Inhabits primary oak forest and appears to tolerate only limited disturbance of its habitat. Hunted
<i>Spilocuscus maculatus</i>	Y	Common and widespread within its elevational range, inhabits primary and secondary forests. Hunted
<i>Dendrolagus dorianus</i>	N	Suffering continuous range reduction by over-hunting
<i>Dendrolagus goodfellowi</i>	N	Declined markedly through settlement of the Highlands, some populations being completely exterminated over the last 50 years
<i>Dendrolagus spadix</i>	N	Extremely rare, known only from 7 specimens. Known from upper Arawa and Strickland Rivers (type locality), Mt Sisa and Wabo area. Confined to elevated karst areas on the Papua Plateau. Hunted

Appendix 2 Habitat needs and conservation notes on species recorded in the project area.

Scientific Name	Habitat*	Conservation related notes
<i>Dorcopsis hageni</i>	Y	Previously only know from northern New Guinea. River banks and alluvial flats. Hunted.
<i>Dorcopsis luctuosa</i>	Y	Hunted. Probably abundant.
<i>Dorcopsulus macleayi</i>	N	Appears to be restricted to mid-montane rainforests; vulnerable to any forest disturbance in this zone. Southern Highlands records may be an extension of range westwards. Hunted
<i>Dorcopsulus vanheurni</i>	N	Widespread in montane forests, but in some areas has almost been eliminated in the last two generations through forest clearance and the abundance of dogs that come with human settlement
<i>Thylogale browni</i>	Y	Common and widespread, prefers disturbed habitats but is sensitive to human predation especially when dogs are used in hunting, so as a consequence has vanished from many areas of suitable habitat. Easily caught in pit traps
<i>Cercartetus caudatus</i>	Y	Appears to be common throughout its range
<i>Pseudochirops corinnae</i>	N	Widespread at middle elevations and restricted to undisturbed forest. Populations have declined in settled areas due to forest clearance
<i>Pseudochirops cupreus</i>	N	Found only in undisturbed forests and common in areas above 2500m, hence forest disturbance for gardening is rare
<i>Pseudochirulus canescens</i>	N	Widespread throughout lowland NG but rare to uncommon over this range. Known from Mt Sisa area
<i>Pseudochirulus forbesi</i>	Y	Widely but patchily distributed in montane forest, including regrowth
<i>Pseudochirulus mayeri</i>	N	Inhabits moss forests, most abundant in those above 2000m
<i>Dactylopsila megalura</i>	U	One of the rarest mammals in New Guinea but the few specimens are widely spread. One literature record from Mt Sisa (WWF).
<i>Dactylopsila palpator</i>	N	Relatively common in moss forest above 1500m
<i>Dactylopsila trivirgata</i>	Y	Widespread distribution in lowlands but patchy above 1400m, most common from 800 – 1100m, uncommon below 200m. Occupies primary and secondary forests
<i>Petaurus breviceps</i>	Y	Most widespread distribution of all the Papua New Guinea possums, inhabits primary and secondary forests, as well as regrowth in old garden areas
<i>Distoechurus pennatus</i>	Y	Inhabits regrowth and disturbed forests, gardens and villages. No records from rainforest
<i>Anisomys imitator</i>	N	Found in rainforest along the Central Cordillera, with highest abundance in the mid-montane zone
<i>Chiruromys lamia</i>	U	The record from the Deviation area is a huge extension of range as Flannery states that it is only known from the Owen Stanley Ranges in south-east New Guinea. Abundant in this area
<i>Chiruromys vates</i>	N	Found in foothill and lowland rainforests – records from this survey extend its elevational range
<i>Crossomys moncktoni</i>	N	Inhabits fast flowing cold mountain streams
<i>Coccyzus rummleri</i>	N	Restricted to montane areas along the Central Cordillera, with few records below 2400m. Appears to be common in some localities.

Appendix 2 Habitat needs and conservation notes on species recorded in the project area.

Scientific Name	Habitat*	Conservation related notes
<i>Hydromys chrysogaster</i>	Y	Widespread and common, also found in marine habitats such as mangroves
<i>Hyomys dammermani</i>	Y	Inhabits rainforest and disturbed areas – plentiful where old gardens abut forest
<i>Hyomys goliath</i>	Y	Inhabits rainforest and disturbed areas – known to raid gardens
<i>Leptomys elegans</i>	Y	Limited and disjunct distribution in PNG – POM and Mt Sisa areas. Trapped in secondary forest and regrowth at old gardens
<i>Leptomys signatus</i>	U	Prior to the WWF surveys this rat was only known from one locality in the Fly River. It has since been found on the Darai Plateau. Habitat needs unknown but probably habitat generalist like its other congeners.
<i>Leptomys ernstmayeri</i>	N	Relatively wide though patchy distribution, and can be locally common
<i>Lorentzimys nouhuysi</i>	Y	Widespread distribution with broad habitat utilisation and is very common
<i>Macruromys major</i>	U	Rare and confined to mid altitude forest. Little known.
<i>Mallomys aroaensis</i>	Y	Widely distributed and common, will invade gardens and regrowth. Hunted.
<i>Mallomys rothschildi</i>	Y	Widely distributed and is hunted, though this practice does not seem to affect populations
<i>Mayermys ellermani</i>	U	Moss forest species. Little known of ecology.
<i>Melomys leucogaster</i>	N	Inhabits rainforest, no information on relative abundance
<i>Melomys lutillus</i>	Y	Usually found in grassland habitats and at Mt Sisa was trapped in old gardens that have regrown grass
<i>Melomys rufescens</i>	Y	Common and widespread in lowland areas and probably rare in primary forest. Found in disturbed areas and has adapted to human settlements.
<i>Microhydromys richardsoni</i>	Y	Generally a rainforest species but also captured in secondary forest. Little known.
<i>Parahydromys asper</i>	Y	Widely distributed along Central Cordillera. Has been found in rainforest, riparian areas and gardens
<i>Abeomelomys sevia</i>	N	Most common at altitudes over 2000m in moss forests and its edges
<i>Paramelomys levipes?</i>	U	Little known.
<i>Paramelomys lorentzii</i>	U	Little known.
<i>Paramelomys mollis</i>	Y	Widespread but recorded from scattered localities. On Mt Sisa it invades garden regrowth 20 years after use
<i>Paramelomys moncktoni</i>	U	Low elevation species but Melomys rats poorly known because of identification difficulties.
<i>Paramelomys sp.aff. moncktoni</i>	Y	Caught at both Juha North and Juha South.
<i>Paramelomys platyops</i>	Y	Species of lowland floodplains and hill forest, abundant at 200-300m. More common in disturbed habitats (including villages) than in primary forest
<i>Paramelomys rubex</i>	Y	Widespread and common in rainforest. Invades old gardens until climax community is established.

Appendix 2 Habitat needs and conservation notes on species recorded in the project area.

Scientific Name	Habitat*	Conservation related notes
<i>Pogonomelomys bruijini</i>	U	An arboreal supposedly lowland species but little known of its biology.
<i>Pogonomelomys mayeri</i>	Y	A widespread species and probably common.
<i>Pogonomys loriae</i>	Y	Extremely widespread and is common in mature forest and regrowth
<i>Pogonomys macrourus</i>	Y	Widespread in lowland and mid-montane areas and is locally common
<i>Pogonomys sylvestris</i>	Y	Widespread montane species and can be found in disturbed areas.
<i>Rattus exulans</i>	Y	Introduced species
<i>Rattus leucopus</i>	Y	Favours primary forest but will also inhabit old garden regrowth
<i>Rattus mordax</i>	Y	Survey record is unusual as this species is only known from eastern New Guinea. Recorded from rainforest, kunai, savannah and gardens
<i>Rattus novaeguineae</i>	Y	Occupies a range of habitat. The record from Mt Sisa (WWF) is a large expansion of range.
<i>Rattus sp.</i>	Y	Unidentified rat but all species of genus are found in range of habitats
<i>Rattus cf. praetor</i>	U	New species from Gobe (WWF)
<i>Rattus sp. nov. (Mt Kemenagi)</i>	U	New species from Mt Kemenagi (WWF)
<i>Rattus steini</i>	Y	Widespread and common in gardens and disturbed areas, known from Mt Sisa
<i>Stenomys niobe</i>	N	Widespread distribution. Taxon may comprise a lowland and a montane species. Montane populations are extremely abundant
<i>Stenomys verecundus</i>	Y	Widespread, recorded from rainforest and gardens
<i>Uromys anak</i>	Y	Widely distributed and prefers primary forest but has been reported in planted stands of Pandanus
<i>Uromys caudimaculatus</i>	Y	Abundant and widespread, occurring in both primary and secondary forest and can be a pest in coconut plantations
<i>Xenuromys barbatus</i>	Y	An extremely rare species, known only from a handful of specimens, widely and patchily distributed. Known from Mt Sisa area. Favours rocky areas and is hunted with dogs

* N – primary forest only, Y - tolerates or prefers secondary areas, U - habitat need unknown.

Annex 05

Biodiversity survey results:

Bats at Hides, Nogoli and Benaria in 2005

This report originally appeared in the PNG Gas Project EIS as:
Supporting Study 4: “The Papua New Guinea gas project: a study of bat
faunal biodiversity and an assessment of potential impacts”



THE PAPUA NEW GUINEA GAS PROJECT: A STUDY OF BAT FAUNAL BIODIVERSITY AND AN ASSESSMENT OF POTENTIAL IMPACTS

**Prepared by Dr G. C. Richards
For Enesar Consulting Pty Ltd, Hawthorn East, Victoria
July 2005**

Greg Richards and Associates Pty Ltd

Postal:	P.O. Box 9, Gungahlin Town Centre, ACT 2912
Office:	23 Tanderra Crescent, Ngunnawal, ACT 2913
Phone and Fax :	02 6255 0606
Email :	batmanoz@bigpond.com
ABN	99 074 890 823

CONTENTS

EXECUTIVE SUMMARY	3
PREFACE	5
INTRODUCTION	
The Project in Brief and Purpose of Report	5
The Consultant	5
The PNG Bat Fauna – Relevant Aspects	5
METHODS	
Background information	6
Ecological niches of threatened species	13
FIELD SURVEY and BIODIVERSITY ASSESSMENT	
Sampling Sites and Methodology	13
Survey Effort	14
Species Recorded at Survey Sites	14
Validation of Techniques	16
Relative Abundance of Microchiropteran Species	18
IMPACT ASSESSMENT	
Species analysis	20
The Critically Endangered Species	22
Cave Dependent Bat Species and Cave Conservation Issues	24
Project Impacts and Mitigation	33
REFERENCES	37
APPENDIX 1: Curriculum Vitae of Consultant	39
APPENDIX 2: Description of Sampling Sites	47
APPENDIX 3: Identification of Echolocation Calls	49

STANDARD DISCLAIMER¹

The following report is explicitly the opinion of the consultant, and is based upon data available and assessments conducted according to the methods described. Greg Richards and Associates (GR&A) has had to rely on information from other sources in preparing this report (including the party for whom it is prepared) and is not in a position to, and has not, verified the accuracy or completeness of information so provided. Accordingly, GR&A takes no responsibility for and assumes no liability in respect of, any information provided by others for the purposes of preparing this report nor the consequences of using such information. This document is prepared only for the persons or company to whom it is addressed and the report and any information or conclusion in it, is not intended to be, and should not be, relied upon or used by any other person. GR&A accepts no liability where any person so uses or relies upon it contrary to the preceding sentence.

¹ This is a requirement of the consultant's insurance company.

EXECUTIVE SUMMARY

This report contributes to an Environmental Impact Statement for the PNG Gas Project, and outlines an intensive study of the bat fauna using current state-of-the-art survey methods and a rigorous assessment of potential impacts on each threatened or sensitive species.

Over 90 species of bats are known from Papua New Guinea (PNG), comprising almost 10% of the world's species. During the survey, 25 taxa were recorded, including a species found on Cape York (Australia) that was recorded for the first time in PNG. The level of survey effort included 578 hours of electronic bat call detection, which produced over 70,000 files for analysis, and extensive mist netting to target non-echolocating fruit bats.

Incorporation of records from previous surveys and a general analysis of distribution patterns suggested that 72 taxa could be expected in the pipeline corridor. Of these, 20 were listed as either Critically Endangered (2), Vulnerable (12) or Near Threatened (6) according to IUCN Red Book threat categories. Of the two species that were listed as Critically Endangered (*Pharotis imogene* and the cave-dependent *Aproteles bulmerae*), the former may now be extinct.

Aproteles bulmerae (Bulmers Fruit Bat) is a cave-dependent flying fox originally described from subfossil material and thought to have been extinct for some thousands of years. It was discovered as a living animal in 1975 in a population of thousands, most of which were subsequently shot by hunters. This colony, and another that is now 'extinct or dislocated' (Bonaccorso 1998), are the only known representatives of this species worldwide. It has not been recorded in the project area but its critically endangered conservation status singles this species out for particular attention.

One of the problems with the information base for the PNG bat fauna is that species that primarily forage above mist net or harp trap height are difficult to encounter and can only be recorded by bat detectors. This factor has resulted in the incorrect assumption that many species are rare, and any information that may reveal declines (or otherwise) and lead to IUCN listing is consequently unreliable. Before taking this into account, each threatened species was given an assessment priority according to scores for its conservation status, endemism to the PNG island, and whether its distribution within the project area was restricted or widespread. The latter was rated according to the number of five 'Assessment Sections' that each species inhabited, where restriction to one section was considered to be of greater concern than if it was widely distributed.

Once prioritized, expected threats to each species were assessed, with relevant ecological information being taken into account, as well as whether rarity may have been an artifact of previous survey using traditional methods. This analysis showed that some species (for example, those that

roost in caves) had similar issues. From this analysis, it was considered that nine of the 20 threatened species would be unaffected by the project.

Potential impacts that could directly affect individual species include:

- Cave dwelling species being subject to hunting pressure or being adversely affected by human visitation, where frequent disturbance can indirectly cause mortality, especially during the breeding season when young are unable to fly.
- Hollow roosting species being affected during tree clearance operations.

A general assessment of the project *per se* was undertaken. When the number of perceived impacts in each phase of the project was examined, it was shown that the operational phase produced the greatest potential effect, followed by issues with construction roads, and the overall construction phase of the pipeline and corridor. There appeared to be very few issues for bats with the crossing of streams.

Human disturbance to roosting fauna and disturbance to migrating/ over wintering fauna are impacts that apply to all four aspects of the project. Other impacts such as *loss of forest, riverine vegetation, or special habitats; noise and dust, especially blasting near caves and loss of wetlands*, are potential impacts that could apply to three of the four aspects of the project.

An assessment of prudent and feasible measures, by which to mitigate these potential impacts, is warranted, with a view to incorporation in environmental management plans and requirements of contractors and workforces where appropriate. Options to be considered are discussed in this report.

PREFACE

This study is part of a suite of terrestrial biodiversity investigations that have been conducted for the EIS for the proposed PNG Gas Project. This study report forms Supporting Study 4 of the EIS and the findings herein support the assessment of potential impacts on terrestrial biodiversity that are discussed in Supporting Study 1 of the EIS. A detailed description of proposed PNG Gas Project is given in Chapter 2 of the Main EIS report.

INTRODUCTION

The Project in Brief and Purpose of Report

The purpose of this report is to document the bat biodiversity within sections of the PNG Gas Project pipeline corridor, to assess the impact of the proposal upon the regional bat fauna, and to contribute information to the EIS for the project.

The bat study took the form of an intensive biodiversity study using current state-of-the-art bat fauna assessment methods, followed by a rigorous assessment of potential impacts on each threatened or sensitive species.

The Consultant

Greg Richards and Associates Pty Ltd was commissioned by Enesar Consulting Pty Ltd to conduct an assessment of the bat fauna likely to occur along the corridor selected for the PNG Gas Project. The consultant and author, Dr G.C. Richards, has over three decades of experience in Asia-Pacific region and conducted the assessment. A brief Curriculum Vitae is attached as Appendix 1.

The PNG Bat Fauna – Relevant Aspects

Over 90 species of bats are known from Papua New Guinea. This high diversity is almost 10% of the world's species, and six of the 18 extant families are represented in this country. About one-third of the PNG species belong to the suborder Megachiroptera, which comprises just the Family Pteropodidae (fruit bats). The remaining five families belong to the Microchiroptera. Of importance to the project and impact assessment are four factors:

- Evolutionary History: Huge areas of limestone are associated with the raising of the sea floor when the Australasian plate collided with the Pacific plate during the Pliocene epoch, around 5 million years ago. At this time, PNG was an island arc (Flannery 1995), separated from the open woodland Australian bat fauna, but linked to the South-east Asian rainforest bat fauna. The limestone areas provided roosts for cave dwelling microchiropteran species, highly diverse in Southeast Asia and throughout the Old World. A number of endemic species evolved, particularly in the horseshoe and leafnosed bat

families². Several megachiropteran species that roost in caves also evolved.

During the Miocene (20 million years ago), as the Australian continent dried, the rainforests that dominated the landscape retreated to refugia and eucalypts prevailed. As a consequence, the Australian bat fauna changed to occupy major niches in the eucalypt woodland (Richards 2002). Lowered sea levels during Pleistocene ice ages (10-20,000 years ago) allowed the connection of PNG with Australia, and an infiltration of the bat fauna from the south.

- Biogeography: The geological evolutionary factors outlined above have shaped a bat fauna that is a mixture of (a) PNG endemics that appear to be rainforest specialists, (b) South-east Asian or Old World taxa that have speciated over many millions of years (such as horseshoe and leafnosed bats², and Bentwing (*Miniopterus*) and Pipistrelle bats) and (c) open habitat taxa that are endemic to Australia (including vespertilionids such as *Scotorepens*, *Chalinolobus* and *Nyctophilus*).
- Habitat: The massive extent of undisturbed bat habitats, including the rainforests of the central cordillera of the PNG island, and the mangroves, swamp forests and woodlands of the Gulf region, provide a vast array of ecological niches for the bat fauna. A large number of foraging guilds are represented, and within generalist and specialist assemblages (*sensu* Richards 2002).
- Geomorphology: Of relevance to impact assessment is that the recent geological age of the island has created a terrain that is steep and rugged, making human access impossible in many areas. Human access to large tracts of montane forest is further restricted by the settlement of areas where subsistence agriculture can be carried out, where a warm climate and productive soils appears to set an altitudinal limit to the human disturbance of the bat fauna.

METHODS

Background information

Background information was obtained from several sources, including Flannery's (1995) book on New Guinea mammals, Bonaccorso's (1998) field guide, and reports from World Wide Fund for Nature activities related to the Kikori Integrated Conservation and Development Project. Localities covered by WWF KIDCP reports that include bat information are shown in Table 1.

² Families Rhinolophidae and Hipposideridae, respectively

The list of 91 bat species known from PNG that were likely to inhabit the broader region surrounding the pipeline corridor was generated from Bonaccorso (1998). Information on the altitudinal limits of species so identified were tabulated to provide a working list of the bat fauna in each Assessment Section of the corridor (Table 2).

From the working list, it was concluded that the following threatened species were potentially present in the study area, and were classified in a number of IUCN categories:

- Critically Endangered: Thomas' Big-eared Bat (*Pharotis imogene*)
Bulmer's Flying Fox (*Aproteles bulmerae*)
- Vulnerable: Moss Forest Blossom Bat (*Syconycteris hobbit*)
Small-toothed Bat (*Nyctophilus microdon*)
Papuan Sheathtailed Bat (*Saccolaimus mixtus*)
Fly River Leafnosed Bat (*Hipposideros muscinus*)
Papuan Mastiff Bat (*Otomops papuensis*)
Telefomin Leafnosed Bat (*Hipposideros corynophyllus*)
Mantled Mastiff Bat (*Otomops secundus*)
Lesser Tubenosed Bat (*Nyctimene draconilla*)
Greater Big-eared Bat (*Nyctophilus timoriensis*)
Fly River Woolly Bat (*Kerivoula muscina*)
Large-eared Sheathtail Bat (*Emballonura diana*)
New Guinea Sheathtail Bat (*Emballonura furax*)
- Near Threatened: Round-eared Tubenosed Bat (*Nyctimene cyclotis*)
Large-eared Horseshoe Bat (*Rhinolophus philippinensis*)
Greater Tubenosed Bat (*Nyctimene aello*)
Green Tubenosed Bat (*Paranyctimene raptor*)
Papuan Pipistrelle (*Pipistrellus papuanus*)
Wollaston's Leafnosed Bat (*Hipposideros wollastoni*)

Table 1: Abbreviated citations of WWF KICDP (and other) reports that were consulted for area-specific background information. General information was obtained from Flannery (1995) and Bonaccorso (1998).																									
Abbreviated Citation	Omo	Mt Bosavi	Mt Sisa	Lake Kutubu	Agogo	Mt Kemenagi	Gobe	Iviri	Keboi Kerowa	Veiru/Veiru Creek	Utiti Creek	Wassi Falls	Darai Plateau	Libano	Iacifu/Ridoe Camo	Boavi-Didesa	Koni	Au Cave	Kafa Village	Kantobo	Sirebi	Dark End Lumber	Waro	Eodomaivu	Gesege Village SE Mananda
Leary et al (1995) <i>Report on the bat component of the field survey of biodiversity in the Kikori ICDP area.</i>	•	•			•	•				•	•	•													
Leary & Seri (1995?) <i>Survey of Birds and Mammals at Utiti Creek.</i>														•											
Leary (2001) <i>Mammal Survey of Two Sites on the Northeast Slopes of Mt Sisa</i>			•																						
Leary (2002?) <i>Brief Report on Iviri Mammal Monitoring - December 2001</i>								•																	
Leary (2004?) <i>Brief report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003.</i>								•	•																
Leary (2004?) <i>Brief report on Keboi Kerowa Mammal Monitoring</i>									•																
Leary (2004) <i>Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province.</i>													•	•											
Leary (1998) <i>Mammals of the Lake Kutubu Swamp Forests.</i> (Wetlands International Report)				•																					
Leary (1999) <i>Mammal Survey of the Gobe Oil Field Area, Southern Highlands and Gulf Provinces.</i>							•																		
Balun (2004?) <i>An Audit on the Status of the Flora and Fauna of the Porora Forest, South East Mananda Forest, Southern Highlands Province.</i>																									•
Leary & Seri (nd) <i>An annotated checklist of mammals recorded in the Kikori River Basin</i>	•	•			•	•				•	•	•			•										
Namo (2004a) <i>Annotated Checklist of Mammals of Kikori Basin.</i> [Summarises many of the above reports]	•	•	•	•		•	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•

Table 2: Bat species known or predicted to occur in Assessment Sections along the PNG Gas Project pipeline corridor. Horizontal bars indicate that the species is known from this altitude in New Guinea but has not yet been recorded at this altitude in the project area (altitude ranges (bars) were taken from Bonaccorso (1998)). Where records exist at an altitude, these are shown in a cell with an alpha code to indicate the source of the information. Alpha codes are A = current survey, B = Leary (1995), C = museum and literature records, D = Leary (2003), E = Namo (2004). Dark arrows indicate extensions of range established by the current survey. Light arrows in the *Nyctimene draconilla* link the 0 – 100m altitudinal range from Bonaccorso (1998) with a record from Namo (2004), which although is of a specimen from Bosavi that is lodged in the Australian Museum, it may be spurious. Locality mnemonics are : K = Kopi, NW = Neiru Wildlife Management Area, O = Omo, UC = Utiti Creek, VC = Veiru Creek, FV = Fogomaiyu Village, WF = Wassi Falls, DP = Darai Plateau, WV = Waro Village, Mo = Moro, Mt K = Mount Kemenagi, LK = Lake Kutubu, AR = Agogo Road (Henry's Camp), IC = IDD2 Cave, MtS = Mount Sisa, IR = Iagifu Ridge, MtB = Mount Bosavi

Taxon	Altitude (x 100 metres)																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Omati-Kopi			Kopi-Moro						Moro-Benaria					Benaria-Nogoli	Nogoli-Hides							
	K,NW,O,UC,VC		FV		WF,DP	WV			Mo,Mt K, LK		AR	IC	MtS	IR,MtB	Benaria survey								Hides 3 survey
Pteropodidae																							
<i>Aproteles bulmerae</i>															—	—	—	—	—	—	—	—	—
<i>Dobsonia minor</i>	B,E		—	—	—	—	—																
<i>Dobsonia magna</i>	B,E		—	—	D	—	—	—	C	—	—	B	C	—	A	—	—	—	—	—	—	—	—
<i>Pteropus alecto</i>	—	—																					
<i>Pteropus conspicillatus</i>	—	—	—																				
<i>Pteropus hypomelanus</i>	—	—																					
<i>Pteropus macrotis</i>	C,E			—	—	—																	
<i>Pteropus neohibernicus</i>	B,C,E		—	—	B,D	—	—	—	B	—	B	—	—	—	—								
<i>Pteropus scapulatus</i>	—	—																					
<i>Rousettus amplexicaudatus</i>	—	—	—	—																			
<i>Nyctimene aello</i>	B,E		—	—	B,E	—	—	—	—	—	—												
<i>Nyctimene albiventer</i>	B,E		—	—	B,E	—	—	—	B,C	—	—	—	—	—	—	—	—	—					
<i>Nyctimene cephalotes</i>	—	—	—																				
<i>Nyctimene cyclotis</i>									C,E		—	—	—	B,E	—	—	—	—	—	—	—	—	—
<i>Nyctimene draconilla</i>	—	—	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶	E									
<i>Paranyctimene raptor</i>	B,E		—	—	B,DE	C	—	—	B,E	—	—	—	—	B	A								
<i>Macroglossus minimus</i>	B,C,E		—	—	B,D,E	—	—	—	—	—	—	—	—										
<i>Syconycteris australis</i>	B,C		—	—	B,D	—	—	—	B,C	—	B	—	C	B	A	—	—	—	—	—	—		A

Table 2 (cont):	Altitude (x 100 metres)																						
Taxon	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Omati-Kopi			Kopi-Moro						Moro-Benaria					Benaria-Nogoli	Nogoli-Hides							
	K,NW,O,UC,V C	FV		WF,DP	WV			Mo,Mt K, LK		AR	IC	MtS	IR,MtB	Benaria survey						Hides 3 survey			
<i>Syconycteris hobbit</i>																				—	—	—	
Emballonuridae																							
<i>Emballonura beccarii</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—							
<i>Emballonura diana</i>	—	—	C,E	—	—	—	—	—	—	—	—	—	E	—	A		►	►	►	►	►	A	
<i>Emballonura furax</i>	—	—	C,E	—	—	—	—	—	—	—	—	—	E	—	A		►	►	►	►	►	A	
<i>Emballonura raffrayana</i>	—	—	E	—	—	—	—	—	—	—	—	—	E	—	—	—	—						
<i>Mosia nigrescens</i>	B,E		—	—	—	—	—	—	—	—	—	—	—	—	A		—	►	►	►	►	A	
<i>Saccolaimus flaviventris</i>	—	—																					
<i>Saccolaimus mixtus</i>	—	—	—																				
<i>Saccolaimus saccolaimus</i>	—	—																					
<i>Taphozous australis</i>	—	—																					
Hipposideridae																							
<i>Aselliscus tricuspidatus</i>	B,E		—	—	—	—	—																
<i>Hipposideros ater</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—					
<i>Hipposideros calcaratus</i>	—	—	—	—	D	C	—	—															
<i>Hipposideros cervinus</i>	B,E		—	—	D	C	—	—	—	—	—	—	—	—	—								
<i>Hipposideros corynophyllus</i>															—	—	—	—	—				
<i>Hipposideros diadema</i>	—	—	—	—	D	C	—	—	—	—	—	—	—	—									
<i>Hipposideros edwardshilli</i>			—	—																			
<i>Hipposideros maggietaaylorae</i>	B,E		—	—	D	C																	
<i>Hipposideros muscinus</i>	—	—	—	—	—	—	—																
<i>Hipposideros semoni</i>							—	—	—	—	—	—	—	—	A								
<i>Hipposideros wollastoni</i>	B,E				D	—	—	-	—	—	—	—	—	—	—	—	—	—	—				

Table 2 (cont):		Altitude (x 100 metres)																					
Taxon	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Omati-Kopi			Kopi-Moro						Moro-Benaria					Benaria-Nogoli	Nogoli-Hides							
	K,NW,O,UC,V C		FV		WF,DP	WV			Mo,Mt K, LK		AR	IC	MtS	IR,MtB	Benaria survey							Hides 3 survey	
Rhinolophidae																							
<i>Rhinolophus arcuatus</i>					D	C	—	—	—	—	—	—	C,E	—	A	—	►	►	►	►		A	
<i>Rhinolophus euryotis</i>	—	—	—	—	D	—	—	—	—	—	—	—	C,E	—	A	—	—	—	—				
<i>Rhinolophus megaphyllus</i>	B,E		—	—	—	—	—	—	—	—	—	—	—	—	A	—	►	►	►	►		A	
<i>Rhinolophus philippinensis</i>				—	—	C	—	—	—	—	—	—	—	—	A								
Vespertilionidae																							
<i>Chalinolobus nigrogriseus</i>	—	—	—	—	►	►	►	►	►	►	►	►	►	►	A								
<i>Myotis moluccarum</i>	—	—	—	—	—	—	—	—	—	—	—	—	—										
<i>Philetor brachypterus</i>	—	—	—	—	—	—	—	—	—	—	—	—	C,E	—	A	—	—	—	—	—	—	A	
<i>Pipistrellus angulatus</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	A	—	—	—	—	—	—	A	
<i>Pipistrellus collinus</i>									—	—	—	—	—	—	A	—	—	—	—	—	—	A	
<i>Pipistrellus papuanus</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—									
<i>Pipistrellus wattsi</i>	—	—	—																				
<i>Scotorepens sanborni</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
<i>Murina florum</i>					—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		A	
<i>Nyctophilus bifax</i>	—	—	—	—	—																		
<i>Nyctophilus microdon</i>																				—	—	A?	
<i>Nyctophilus microtis</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	A?								
<i>Nyctophilus timoriensis</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—						
<i>Pharotis imogene</i>	—	—																					
<i>Kerivoula muscina</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—						
<i>Phoniscus papuensis</i>	B		—	—	E	—	—	—	—	—	—	—	—	—									
<i>Miniopterus australis</i>	B,E		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—						
<i>Miniopterus macrocneme</i>	—	—	—	—	—	—	—	—	A	—	—	—	—	—	—	—	—	—	—	—	—	—	
<i>Miniopterus magnator</i>	B,E		—	—	—	—	—	—	A	—	—	B	—	B	A	—	—	—	—	—		A	

Table 2 (cont):	Altitude (x 100 metres)																						
Taxon	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Omati-Kopi			Kopi-Moro						Moro-Benaria					Benaria-Nogoli		Nogoli-Hides						
	K,NW,O,UC,V C	FV		WF,DP	WV			Mo,Mt K, LK		AR	IC	MtS	IR,MtB	Benaria survey							Hides 3 survey		
<i>Miniopterus medius</i>	B,E		—	—	—	—	—	—	—	—	—	—	C	B,E	—	—	—	—	—	—	—	—	—
<i>Miniopterus propitristis</i>	—	—	—	—	—	—	—	—	—	—	—	—	E	B,E	A?		—						
<i>Miniopterus schreibersii</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Molossidae																							
<i>Chaerephon jobensis</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—								
<i>Mormopterus beccarii</i>	—	—	—	—																			
<i>Mormopterus loriae</i>	—	—																					
<i>Otomops papuensis</i>	—	—	—	—																			
<i>Otomops secundus</i>															A		►	►	—	—	—		A
<i>Tadarida kuboriensis</i>															A		►	►	►	—	—		A
New or unidentified species																							
<i>Rhinolophus maros</i>															A								
Sh-FM 22-25															A		►	►	►	►	►		A
unknown 30-20																							A
Vesp Fmin 31																							A
Sh-FM 23-25															A		►	►	►	►	►		A
CF 29															A								

Ecological niches of threatened species

To provide information for the impact assessment of the pipeline corridor, an analysis of the ecological niches of each threatened bat species was conducted. This analysis is shown in Table 3 and it is apparent that there are groups that may be affected by vegetation clearance or roost disturbance, such as cave roosting species or specialist insectivores.

Table 3: A summary of the ecological niches occupied by threatened species. Primary roost type may occasionally switch to another (for example, <i>Nyctophilus</i> spp may utilise tree hollows in habitats more open than rainforest). Whether insectivory is specialised or generalised is based on published information in most cases, or may be based on knowledge of sibling species elsewhere.			
Primary diet	Primary roost type		
	Caves	Tree hollows	Within foliage
Frugivores + Nectarivores			
	<i>Aproteles bulmerae</i>		<i>Syconycteris hobbit</i>
			<i>Nyctimene aello</i>
			<i>Nyctimene cyclotis</i>
			<i>Nyctimene draconilla</i>
			<i>Paranyctimene raptor</i>
Specialist insectivores			
Foliage gleaning		<i>Pharotis imogene</i>	<i>Nyctophilus microdon</i>
			<i>Nyctophilus timoriensis</i>
			<i>Kerivoula muscina</i>
Prey ambush	<i>Hipposideros muscinus</i>		
	<i>Hipposideros corynophyllus</i>		
	<i>Hipposideros wollastoni</i>		
	<i>Rhinolophus philippinensis</i>		
Generalist insectivores			
Prey pursuit	<i>Emballonura diana</i>	<i>Saccolaimus mixtus</i>	
	<i>Emballonura furax</i>	<i>Otomops papuensis</i>	
		<i>Otomops secundus</i>	
Prey intercept		<i>Pipistrellus papuanus</i>	

FIELD SURVEY and BIODIVERSITY ASSESSMENT

Sampling Sites and Methodology

Sampling of the bat fauna was conducted at two faunal reference areas, one at the Hides 3 gas well to the northwest of Hides Camp (2163 m ASL), and another in the vicinity of Benaria (1530 m ASL). Both reference areas were in localities where vegetation clearance will be required for the gas pipeline corridor, as well as associated road works and other infrastructure. Within the reference areas, sampling sites for bats were selected opportunistically to either accommodate different habitats or to target certain threatened species. Sampling sites are described in Appendix 2.

At the majority of sampling sites, an automated Anabat™ echolocation call detector was operated in tandem with a Zcain control module³. Up to six detectors were operated on any given night. Each detector divided the

³ Zcain = Zero Crossings Analysis Interface Module

ultrasonic frequencies of microchiropteran bats by a known factor (in this case, 16) and each sequence (bat call) was recorded onto a compact flash card in the Zcain as a computer file. Each filename, created by firmware in the Zcain using an internal computer clock, provided the time of occurrence with an accuracy of one second. After each recording session, each file was displayed via dedicated software on a field computer, and analysed. This allowed analysis of the level of site usage and activity patterns.

At the remainder of sites, mist nets were used to capture bats to obtain an inventory of non-echolocating fruit bats and microchiropteran bats for recording reference calls. Harp traps were unavailable, but apparently have limited effectiveness in PNG rainforests (T. Leary (ex-WWF Kikori Project) *pers. comm.* 17 June 2005).

Opportunistic surveys were also conducted at the Moro Village/Camp near Lake Kutubu, and the camp at Nogoli. At these sites, detectors were operated near external lights that attracted insects, and as a consequence, bats.

Survey Effort

The level of survey effort is shown in Table 4, and totalled 578 hours of electronic detection, plus extensive mist net hours which yielded little data. Over seventy thousand detector files were generated from a total of 56 sampling sites, each being individually examined in the field. The average number of files recorded at each sampling site at Hides 3 was 1071 and at Benaria was 1473, indicating a difference in altitude, climate conditions (assumedly temperature), and differences in regional biodiversity.

Table 4: Summary of survey effort during each sampling period.			
	Hides 3	Benaria	Totals
Sampling period	24 – 29 April 2005	1 – 7 May 2005	
Bat detector nights	27	29	56
Hours of recording	286.2	289.6	575.8
No. of call files generated	28926	42719	71645

It is understood that this field survey has been the most intensive ‘detector-based’ bat survey ever conducted in this country, and rates well above similar surveys for Environmental Impact Statements carried out in Australia and many other parts of the world.

Species Recorded at Survey Sites

One of the issues when analysing the number of calls recorded at a sampling site with bat detectors is how best to interpret the number of calls generated. For example, if 100 calls are detected from a single species, is this one bat passing by the microphone 100 times, or 10 bats 10 times, or 100 bats once?

For the purposes of this study, such information (*actual abundance*) is not necessary, with species presence being the most important issue for impact assessment. Hence, the concept of site records is used throughout this report, where the presence of a species at a site is the primary item of data, and the number of sites utilised is the next most important item of data as it reflects *relative abundance* within a sampling area.

During both surveys, a total of 25 taxa were recorded via the methodology utilised. A total of 16 species were recorded at the Hides 3 site, and 22 at the Benaria site (Table 5). Thirteen species overlapped their distributions at both sites.

Murina florium and an unidentified species ('Vesp Fmin 31', Table 5) were only recorded at the Hides 3 site. *Dobsonia moluccensis*, *Paranyctimene raptor*, *Hipposideros semoni*, *Rhinolophus euryotis*, *R. maros*, *R. philippinensis*, *Chalinolobus nigrogriseus* and a species tentatively identified as *Miniopterus* (cf. *propitristis*) were only recorded at the Benaria site. Further, three other species tentatively identified to genus level were only recorded at this faunal reference area, whilst an emballonurid, a rhinolophid and a vespertilionid were only recorded at Benaria.

Because horseshoe and leaf-nosed bats show a reliable inverse correlation between the constant frequency (CF) component of their echolocation call with their body size, a phenomenon that is related to the physics of sound production and reception, identities of these groups can be calculated from echolocation calls (see Appendix 3) without having the bat 'in hand'. During the field surveys, five rhinolophid (horseshoe) bats were identified, yet prior to this study only four were known from PNG. The fifth taxon has been identified as part of the Australian (Cape York) *Rhinolophus philippinensis* complex, which to date comprises two species with differing morphology and echolocation calls with CF components at 33 and 46 kHz.

In summary, the impact assessment that follows is based upon 576 hours of call detection, the analysis of over 70,000 ultrasound files and appropriate mist netting effort, as a result of which 25 bat species were recorded. With the additional information from WWF surveys and museum specimens from unsurveyed sections of the project area, a total of 72 species were identified for assessment in the impact analysis for this project.

Table 5: Species recorded at the two Fauna Reference Areas, Hides 3 and Benaria. Two Bent-wing Bat species were recorded at supplementary sites at Moro and Nogoli, but because the sampling was opportunistic and not at the scale as at sampling sites, data is not included in this Table. The allocation of species identifications are justified in Appendix 3, however, some species remain unidentified. Two *Emballonura* species were seemingly inseparable on echolocation calls, and because both are IUCN listed and have similar ecological requirements, are hence combined.

	Hides 3	Benaria
Pteropodidae		
<i>Dobsonia moluccensis</i>		•
<i>Syconycteris australis</i>	•	•
<i>Paranyctimene raptor</i>		•
Emballonuridae		
<i>Emballonura diana/furax</i> complex	•	•
<i>Mosia nigrescens</i>	•	•
Hipposideridae		
<i>Hipposideros semoni</i>		•
Rhinolophidae		
<i>Rhinolophus arcuatus</i>	•	•
<i>Rhinolophus euryotis</i>		•
<i>Rhinolophus maros</i>		•
<i>Rhinolophus megaphyllus</i>	•	•
<i>Rhinolophus philippinensis</i>		•
Vespertilionidae		
<i>Chalinolobus nigrogriseus</i>		•
<i>Miniopterus</i> (cf. <i>propitristis</i>)	•	•
<i>Miniopterus magnater</i>	•	•
<i>Murina florium</i>	•	
<i>Nyctophilus</i> spp.	•	•
<i>Pipistrellus angulatus</i>	•	•
<i>Pipistrellus collinus</i>	•	•
<i>Philetor brachypterus</i>	•	•
Molossidae		
<i>Otomops secundus</i>	•	•
<i>Tadarida kuboriensis</i>	•	•
As yet unidentified		
"Vesp Fmin 31" (unidentified vespertilionid)	•	
"CF 29" (unidentified rhinolophid or emballonurid)		•
"sh-FM 22-25" (unidentified emballonurid)		•
"FM 30-20" (unidentified vespertilionid)	•	
Total species recorded	16	22

Validation of Techniques

The value of using bat detection systems in field surveys is shown by the species accumulation curves generated from the two sites (Figure 1). The detection systems had accumulated over 90% of the species complement by the third night, and the full complement by the fourth night, with no other species being added for two nights afterwards. When data from both sites were combined, 67% of the species complement was recorded on the first night and 85% on the second. For rapid sampling purposes in any future studies, it would

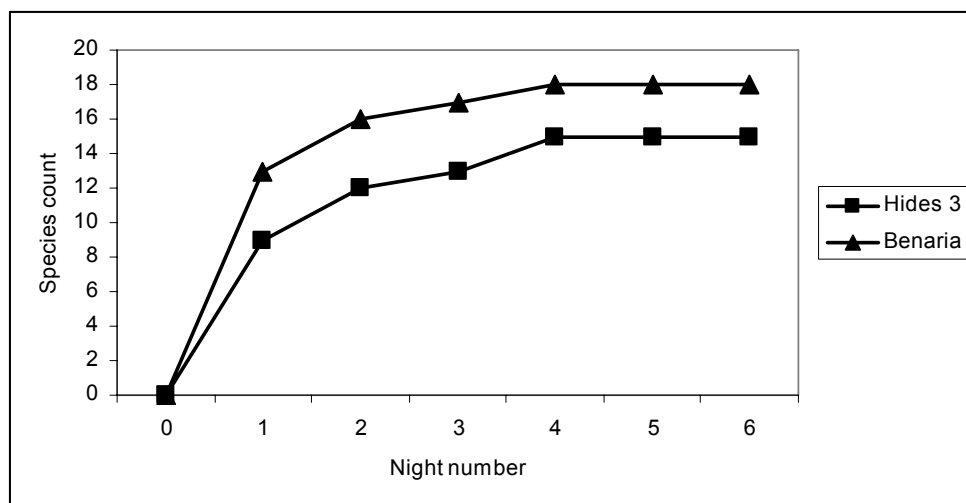
appear that three nights would provide extensive species data, with four nights being required to record rare species.

Because most species appear to fly at least several metres above ground level, many species would obviously avoid mist nets or harp traps. It is notable that considerable data was obtained via detectors for genera that are renowned to fly above the canopy or in open areas and are effectively impossible to capture, including *Tadarida*, *Otomops*, *Miniopterus*, *Pipistrellus*, *Mosia* and *Emballonura*. This group is half of the 12 microchiropteran genera that were recorded during the survey.

Although essential for recording fruit bats, mist nets were not useful for capturing microchiropteran bats. At Benaria, detectors were operated next to several mist net arrays for a number of nights in attempt to capture bats for echolocation reference calls. Some detectors recorded up to 11 species during the night, including low flying species such as *Rhinolophus*, yet no microchiropteran bats were captured. As a further example, on the night of 4 May 2005 a detector at a net recorded 33 calls from 5 species in 106 minutes after dusk and, again, no bats were captured.

Harp traps were not used due to logistical constraints, and have had limited value in extensive surveys elsewhere in the Kikori region, even when placed in the upper canopy (T. Leary pers. comm. 17 June 2005).

Figure 1: Species accumulation curves for both sampling sites. Data is only from microchiropteran bats.



Relative abundance of microchiropteran species

Analysis of the relative abundance of microchiropteran bats was conducted by comparing site records (the number of sampling sites at which each species was recorded, irrespective of the number of echolocation calls detected) from each site (Table 6). Because the number of sampling sites at each site was similar (27 at Hides 3 and 31 at Benaria), and the detection survey effort was similar (286 and 290 hours respectively), then direct comparisons can be made.

A number of species that occurred at both sites were relatively more abundant at one than the other, which perhaps indicates a preference for certain habitats or other (unknown) factors. *Mosia nigrescens*, *Nyctophilus* spp, *Pipistrellus collinus* and *Philetor brachypterus* were far more abundant at Hides 3 than at Benaria. *Rhinolophus arcuatus*, *Miniopterus* (cf. *propitristis*) and *P. angulatus* were far more abundant at Benaria than at Hides 3 (Table 7).

Table 6: Relative abundance of microchiropteran bats, based on site records (the number of sampling sites at which each species was recorded, irrespective of the number of echolocation calls detected).				
	Site records		Proportion of sites	
	Hides 3	Benaria	Hides 3	Benaria
Number of sampling sites	27	31		
<i>Emballonura dianaefurax</i> complex	9	11	0.33	0.36
<i>Mosia nigrescens</i>	22	7	0.82	0.23
<i>Hipposideros semoni</i>		4		0.13
<i>Rhinolophus arcuatus</i>	1	13	0.04	0.42
<i>Rhinolophus euryotis</i>		17		0.55
<i>Rhinolophus maros</i>		7		0.23
<i>Rhinolophus megaphyllus</i>	4	10	0.15	0.32
<i>Rhinolophus philippinensis</i>		2		0.07
<i>Chalinolobus nigrogriseus</i>		5		0.16
<i>Miniopterus</i> (cf. <i>propitristis</i>)	4	15	0.15	0.48
<i>Miniopterus magnater</i>	1	4	0.04	0.13
<i>Murina florum</i>	3		0.11	
<i>Nyctophilus</i> spp.	12	5	0.44	0.16
<i>Pipistrellus angulatus</i>	8	16	0.30	0.52
<i>Pipistrellus collinus</i>	13	4	0.48	0.13
<i>Philetor brachypterus</i>	19	7	0.70	0.23
<i>Otomops secundus</i>	12	10	0.44	0.32
<i>Tadarida kuboriensis</i>	19	18	0.70	0.58
"Vesp Fmin 31" (unidentified vespertilionid)	8		0.30	
"CF 29" (unidentified rhinolophid or emballonurid)		3		0.10
"sh-FM 22-25" (unidentified emballonurid)		8		0.26
"FM 30-20" (unidentified vespertilionid)	2		0.07	

Another group of species were recorded at only one site. *Murina florum* was only recorded at one site at Hides 3, at a dense moss forest site. Although this species is likely to be difficult to detect due to its low intensity call, given the 576 hours of recording during the survey, the conclusion that it is rare and restricted (as it is in Australia) is likely to be valid.

Five species were recorded only at Benaria: *Hipposideros semoni*, *Rhinolophus euryotis*, *R. maros*, *R. philippinensis* and *Chalinolobus nigrogriseus* (Table 7). It is significant that all but the latter species are dependent upon small humid caves.

Of note, and a likely explanation for the higher species diversity, is the difference in the habitat diversity at each site. At Hides 3, the dominant habitat was montane moss forest, and the open area surrounding the well head was also sampled. At Benaria, several types of rainforest (hill rainforest, swamp forest and riverine rainforest) were present as well as open areas and patches of regrowth. Some species appeared to utilise only one habitat; for example, *Hipposideros semoni* was only recorded in riverine rainforest.

Table 7: Species with differing distributions, assumed to be influenced by altitude (climate?) or the presence of suitable cave microclimates. The value in each cell for species recorded at both sites is the approximate extent of higher abundance, based on site records. For example, <i>Mosia nigrescens</i> is three times more abundant at Hides 3 than at Benaria. Four species without a formal name are excluded from this analysis. Cave dependent species are designated with an asterisk.		
	More abundant at Hides 3	More abundant at Benaria
Species recorded at both sites		
* <i>Mosia nigrescens</i>	3x	
* <i>Rhinolophus arcuatus</i>		10x
* <i>Rhinolophus megaphyllus</i>		2x
* <i>Miniopterus</i> (cf. <i>propitristis</i>)		4x
* <i>Miniopterus magnater</i>		4x
<i>Nyctophilus</i> spp.	2x	
<i>Pipistrellus angulatus</i>		2x
<i>Pipistrellus collinus</i>	3x	
<i>Philetor brachypterus</i>	3x	
Species recorded at only one site		
* <i>Hipposideros semoni</i>		•
* <i>Rhinolophus euryotis</i>		•
* <i>Rhinolophus maros</i>		•
* <i>Rhinolophus philippinensis</i>		•
<i>Chalinolobus nigrogriseus</i>		•
<i>Murina florum</i>	•	

IMPACT ASSESSMENT

Species analysis

The use of electronic detecting systems at the survey sites produced several species, including one new to the island of New Guinea, not previously recorded by the WWF surveys. This indicates that surveys in the past using only harp traps and mist nets undersampled the bat fauna of the Kikori basin. Electronic detection throughout the Kikori is likely to increase the known bat fauna by perhaps 20%.

Considering this, the fact that several species at the survey sites remain unidentified, and the difficulty in distinguishing some species, the list of species detected so far for the Kikori basin cannot be regarded as the total fauna that needs to be included for impact analysis. To rationalize this problem, all species with distribution ranges that overlapped the Kikori basin were taken from Bonaccorso (1998), and were included with those recorded so far into a final list of bats potentially present (Table 2). This was then altered using the IUCN categories (endangered, vulnerable) into the final species list for impact assessment, which is shown in Table 8.

Thus, twenty species that have IUCN threat status (that is, 'Red Book' listed) are expected to occupy the project area. Two species (*Pharotis imogene* and *Aproteles bulmerae*) are listed as Critically Endangered, though the former may now in fact be extinct. Twelve species are in the Vulnerable category, and the remaining six are Near Threatened (Table 8).

One of the problems with the information base for the PNG bat fauna, as revealed by the 2005 field survey, is that species that primarily forage above mist net or harp trap height are difficult to encounter and can only be recorded by bat detectors. This factor has resulted in the incorrect assumption that many species are rare, and any information that may reveal declines (or otherwise) and lead to IUCN listing is consequently unreliable. Before taking this into account, each threatened species was given an assessment priority according to scores for its conservation status, endemism to the PNG island and whether its distribution within the project area was restricted or widespread (Table 8). The latter was rated according to the number of five 'Assessment Sections' that each species inhabited, where restriction to one section was considered to be of greater concern than if it was widely distributed. The Assessment Sections were based upon altitude, whether a pipeline corridor was already present, and whether the sections were separated at known localities. The sections, graded from the coast to the highlands, are as follows:

Omati to Kopi	sea level to 100m
Kopi to Moro	100 to 800m
Moro to Benaria	800 to 1400m
Benaria to Nogoli	1400 to 1500m
Nogoli to Hides	1500 to 2400m

Each endemic species was given a score of 1, and those in the three IUCN threat categories were rated 3, 2 or 1 point depending upon the severity of the

threat classification. This method was used as a way to prioritise the list. For example, threats to a Critically Endangered endemic were considered to be of more importance and urgency to address than a Near Threatened species that ranged widely throughout the Australasian region.

Once prioritized, expected threats to each species have been assessed, with relevant ecological information being taken into account, as well as whether rarity may have been an artifact of previous surveys using traditional methods (Table 9). This analysis has shown that some species had similar issues (for example, those that roost in caves). These species have been grouped, and impacts as well as suggested mitigation procedures have then been tabulated (Table 10). From this analysis, it is considered that nine of the 20 threatened species would be unaffected by the project.

Potential impacts include:

- Cave dwelling species (particularly the Critically Endangered *Aproteles bulmerae* if present) and flying foxes in communal tree roosts being hunted;
- Roosts and maternity colonies in caves being exterminated during construction by destruction of the cave or disturbance from blasting;
- Cave dwelling species being affected by human visitation (that is, disturbance as opposed to direct killing for food), particularly horseshoe and leaf-nosed bats, most of which are Vulnerable. Frequent disturbance can cause mortality, especially during the breeding season when young are unable to fly.
- Hollow roosting species being affected during tree clearance operations, particularly the Critically Endangered (or now extinct) *Pharotis imogene*, Sheathail (*Saccolaimus mixtus*) and mastiff bats (*Otomops* spp.).

An assessment of prudent and feasible measures, by which to mitigate these potential impacts, is warranted. Options for this assessment should include:

- For *P. imogene*, either conduct an intensive harp-trapping survey in Kopi area to revise the species' status, or assume that logging in the Omati area has led to the final demise of much of the population, and consider that the far minor vegetation clearance required for the pipeline will have little further impact.
- To reduce human impact upon cave dwelling species, develop education programs to give local 'ownership' to colonies, and perhaps appoint paid caretakers of colonies
- Develop a tree clearance protocol to minimise impact on hollow roosting colonies

The Critically Endangered species

There are two species of such rarity and conservation importance in PNG that they need to be considered in any impact analysis in the country – *Pharotis*

imogene and *Aproteles bulmerae*. They have not been recorded so far in the Kikori basin, but have to be considered here.

Pharotis imogene is a member of the longeared bat group. These bats generally forage by gleaning prey from substrates such as bark or leaves, and for this purpose they have short and broad wings that allow slow and manouverable flight. The characteristic long ears allow these bats to listen for insect calls so that they can localise potential prey, and they sometimes do this without using their echolocation (Hosken *et al* 1994).

Very little is known about the biology and ecology of *P. imogene*. With regard to conservation status, prior assessments include Flannery (1995) who considered that it was “probably extinct” and Bonaccorso (1998) who believed that “the species probably still exists”. In their 1994 assessment, the IUCN classified this bat as Critically Endangered. Revision of this status is current, but becomes obvious through the chequered history of specimens attributed to *P. imogene*, which is outlined as follows:

1890	A collection of 45 specimens was made by Dr Lamberto Loria at Kamali on the Lower Kemp Welch (Wanigela) River in Central Province, which was lodged in the Museo di Storia Naturale, Genoa. Flannery (1995) states that these specimens can no longer be traced in Genoa, but some can now be found in museums in London (n=3), New York (n=1), Copenhagen (n=1) and Sydney (n=1). Swapping of specimens between museums is part of their function, and has serendipitously preserved some of the original series.
pre-1897	Bonaccorso (1998) stated that Thomas (1897) wrote about a specimen from Kapa Kapa that was collected by Dr Loria. This specimen was later lost due to flooding at the Museo di Storia Naturale (pers. comm. from Flannery to Bonaccorso, cited in Bonaccorso 1998).
1985	A specimen (PM 25374) attributed to <i>P. imogene</i> was collected by T. Anderson at Rogut Village, Tuman River, Central Province (Bonaccorso 1998) from the crown of a pandanus tree.
1988	The Rogut Village specimen was examined by Dr Harold Parnaby as part of his PhD revision of the genus <i>Nyctophilus</i> , and he confirmed that it instead represented <i>N. microdon</i> (H. Parnaby pers. comm. to IUCN).
1992	The PNG Museum catalogue shows an entry that declared the 1985 Rogut Village specimen as either lost or destroyed.

Having described *P. imogene* in 1914, Thomas would have doubtfully made an error in the identification of this species, so the pre-1897 Kapa Kapa specimen

appears to be the last one collected and identified with any accuracy. With the 1985 specimen now discounted by a long-eared bat expert as being a *Pharotis* but instead a *Nyctophilus*, and in view of *P. imogene* not being accurately recorded for more than 108 years, then the only available conclusion is that this species is extinct.

For the purposes of the PNG Gas Project, it would be prudent for several reasons to discount this species as an issue:

1. It is highly likely to be classified by IUCN as being Extinct
2. Distribution records are now only known from around Port Moresby, well away from the project area. Kamali Village is 500 km southeast of the Kikori basin, where habitats are primarily savannah and mangroves.
3. If it is (however unlikely) still extant, then the narrow corridor of the gas pipeline would doubtfully have an impact upon any local population/s (this being an animal that could easily fly across the ROW) which is much less of an impact than (for example) the land clearance/logging operations that currently take place within its potential distribution.

However, in view of 45 specimens being collected at the one site (which was likely to be a maternity colony) it is recommended that a tree clearance protocol be enacted so that big trees that may contain hollows within the 0–100 m ASL zone of the pipeline corridor be hand felled to reduce any impact upon potential colonies. This would preclude the need for the type of trapping program recommended by Bonaccorso (1998) and the IUCN during their current (2005) Global Mammal Assessment. If this species is in fact an open habitat species, then targeted trapping (which relies on the concentration of bats in flyways in dense vegetation) would not be efficient.

Aproteles bulmerae is a cave-dependent flying fox that has a fascinating and highly relevant history of discovery. It was originally described from subfossil material excavated from an archaeological dig at the Kiowa rock shelter, 2 km east of Chauve Government Station, Chimbu Province, and at an altitude of 1530 and described as a new species by Menzies 1977. The Kiowa site was a human occupation site inside a minor entrance to a large series of limestone caves, and the vertebrate remains that were excavated represented kitchen waste (Menzies *op. cit.*). The *Aproteles* material was found in layers dated between 10,000 and 11,000 years before present. Menzies described this species from 200 skulls which had been broken open at the cranium so that the brain could be extracted. Two other cave dependent species, *Dobsonia moluccensis* and *Rousettus amplexicaudatus* were also present in these layers. Menzies notes the amount of total deposit represented by *A. bulmerae* rises from <1% in the oldest layer to nearly 40% then declined rapidly to zero in the youngest layer. He concluded that at this time (10,000 ybp) this species became extinct.

It was subsequently discovered as a living animal in 1975 in the Hindenberg Wall area of Western Province by Hyndman and Menzies (1980). The doline cave where the *Aproteles* were found is known locally as Luplupwintem, at an altitude of 2400 m. Of relevance to the impact assessment is that

Luplupwintem is close to the main walking track between Tabubil, the Ok Tedi mine and Telefomin (Flannery 1995). This author mentions that in 1975 thousands of these bats were present, but on a return visit two years later only two bats were seen (Hyndman and Menzies 1977). Local informants advised that several groups of hunters entered the cave with shotguns and virtually eliminated the colony (Flannery op. cit.). The cave has a 300m drop at the entry, so hunters were keen enough to use ropes (and much bravery) to get to their prey. A small number of individuals was again resident in Luplupwintem in 1992 (Flannery and Seri 1993). This colony, and another that is now “extinct or dislocated” (Bonaccorso 1998), are the only known representatives of this species worldwide.

The key to this problem appears to be access to caves by hunters with modern equipment, an issue that will be addressed in the impact assessment.

Cave-dependent bat species and cave conservation issues

Superficially, because the project area has extensive areas of limestone, and is extensively cavernaculous, it would be easy to assume that because there are lots of caves there would be lots of bats. However, such is not the case because most cave bat species have highly specific requirements and not all caves provide everything in the matrix that suits individual species (Hall and Richards 2004). For example, in a survey of the extensive karst area at Chillagoe (Queensland, Australia), which supported nine cave dependent species, no one species occupied all caves. Cave descriptions for a selection of Chillagoe species that are also found in PNG, include:

<i>Hipposideros diadema</i>	One major colony in one cave with a high, domed ceiling, high temperatures, high humidities
<i>Hipposideros ater</i>	One colony in a cave, very small in dimensions, humid with an earth floor
<i>Rhinolophus megaphyllus</i>	Found in many caves with an earth floor and very high humidities
<i>Miniopterus schreibersii</i>	One colony in one large cave, warm but not as humid as <i>Hipposideros</i> caves, domed ceilings for rearing of young (young bats are unable to thermoregulate for the first six week of life, and females place them inside a dome to trap body heat)

Perhaps a better example of the unique requirement of cave bats – as well as the impact of humans - comes from the author’s experience at Niah Cave in Sarawak (Malaysian Borneo), which is approximately one kilometre long, and provides a niche matrix of light level, temperature, humidity and ceiling architecture. Seventeen species inhabit the cave in a combination of these niches. At the entrance of the cave, occupying a large crack, are *Taphozous melanopogon*. On the ceiling, and still just in the twilight zone, are several fruit bat species (*Eonycteris spelaea*). *Emballonura alecto* rest against the wall, individually scattered through the least humid dark section. *Miniopterus*

australis roost in circular depressions in the least humid section of the cave. Also in this area are groups of *Myotis horsfieldii* roosting in 'bell-holes' in a section of the ceiling; these are male-dominated territories with harems of females. As the cave becomes darker and the humidity increases, various species of *Hipposideros* and *Rhinolophus* occupy walls or the ceiling, and by far the most common are *H. galeritus* and *H. cervinus*, with numbers in hundreds of thousands. As the distance from the entrance passes the halfway point, various other *Hipposideros* species occupy various other niches, with species such as *H. diadema* roosting in groups but preferring to hang from low points on the ceilings of large chambers.

Of relevance though, is the demise of *Cheiromeles torquatus*, a cave-dependent freetail bat, an unfurred relative of the *Tadarida* and *Otomops* that were recorded in the pipeline project area. This species roosts on flat 'shelves' at the top of high chambers in Niah Cave, and is hunted for food by Malaysians who harvest swiftlet nests for the lucrative birds nest soup trade. In the 1950's, the Niah population of *C. torquatus* was estimated by Lord Medway to be in the order of 18,000. During surveys in 1992, less than 200 were counted and 'bird-nesters' regarded them as a luxury food item at the site. In essence, after some 40 years or so of human hunting pressure, just 1.1% of the original population survived. Further information on bats in Niah Cave is given in Hall *et al* (2002).

This narrative is intended to stress the following significant points:

- Cave bats are not generalists in their occupation of cave roosts and occupy caves with particular internal architecture and microclimates.
- In major karst areas with a myriad of caves, not all caves will provide appropriate roosts for local cave bat species.
- Some species in a local area may only find 1 in 100 caves (or any other ratio) suitable for roosting or maternity purposes.
- Human access to caves, for whatever purpose, can have a deleterious effect on resident cave bats.

Of the 18 microchiropteran species identified with confidence, 10 are cave dependent and belong to five genera. *Emballonura* and *Mosia* inhabit the twilight zone just beyond cave entrances, *Hipposideros* and *Rhinolophus* prefer very humid caves which are usually quite small, and *Miniopterus* prefer large and relatively dry caves. A fruit bat (*Dobsonia moluccensis*) recorded at Benaria, also occupies caves.

Cave-dependent species, particularly *Hipposideros* and *Rhinolophus*, are highly sensitive to disturbance, and colonies can suffer from frequent visitation. PNG landowners regard fruit bats as a source of food, and apparently do not harvest them in a sustainable manner. Flannery (1995) and Bonaccorso (1998) both describe the demise of a small colony of the Critically Endangered *Aproteles bulmerae* due to hunting, as outlined above.

However, it is apparent that landowners do not know the location of all caves in their district, especially those that are likely to be small or located in inaccessible areas. This factor is highly relevant to the importance of cave

preservation and restriction of human usage when the gas project is being constructed or is operational.

During the survey, local landowners were interviewed for information on nearby caves that may be within the pipeline corridor. No information was gained from landowners interviewed at Hides 3. Landowners interviewed at Benaria advised that the nearest cave was several hours walk away, and in another valley.

Because the computer files generated by bat detection systems are named with information from a computer clock, the time of occurrence of a bat call can be calculated with a one-second accuracy. In a serendipitous study of ambush foraging⁴ by a *Rhinolophus arcuatus*, the first of 13 bouts near a detector commenced just 7 minutes after dusk. This indicated that this individual's cave roost was only a short distance away. The flight speed of this species is not known, but would be in the order of 15–20 km per hour, or 250–333 metres per minute. In 7 minutes this individual is therefore likely to have flown 1.7–2.3 km, indicating that its cave roost was much closer than the cave known to the landowners.

This coarse analysis emphasises the problem that the extensive limestone areas in the pipeline corridor will have caves that have never been discovered, and it is expected that new ones will be located by surveyors and crews constructing the pipeline.

Cave conservation is an important issue for this project.

⁴ “Flycatcher” or “Sit and Wait” mode in birds

Table 8: Assessment of endemism and conservation status of bat species considered to be present in the project area, rated according to IUCN threat status and endemism to the island of New Guinea *per se*. For impact assessment purposes, each species was then ranked by the number of Assessment Sections it was expected to inhabit, with restriction to one section considered as being of greater concern than if distribution was widespread.

Taxon	PNG island endemic?	IUCN Threat Status (rated 1 to 5 according to threat category)			Threat + Endemicity Score	Assessment Section					Restriction within project area (= no. of Assessment Sections)	Priority for impact assessment
		Critically Endangered	Vulnerable	Near Threatened		Omati-Kopi	Kopi-Moro	Moro-Benaria	Benaria-Nogoli	Nogoli-Hides		
Critically Endangered												
<i>Pharotis imogene</i>	1	3			4	1					1	1
<i>Aproteles bulmerae</i>	1	3			4			1	1	1	3	2
Vulnerable												
<i>Syconycteris hobbit</i>	1		2		3					1	1	3
<i>Nyctophilus microdon</i>	1		2		3					1	1	3
<i>Saccolaimus mixtus</i>			2		2	1	1				1	3
<i>Hipposideros muscinus</i>	1		2		3	1	1				2	4
<i>Otomops papuensis</i>	1		2		3	1	1				2	4
<i>Hipposideros corynophyllus</i>	1		2		3			1	1	1	3	5
<i>Otomops secundus</i>	1		2		3			1	1	1	3	5
<i>Nyctimene draconilla</i>	1		2		3	1	1	1	1		4	6
<i>Nyctophilus timoriensis</i>			2		2	1	1	1	1		4	6
<i>Kerivoula muscina</i>	1		2		3	1	1	1	1	1	5	7
<i>Emballonura diana</i>			2		2	1	1	1	1	1	5	7
<i>Emballonura furax</i>			2		2		1	1	1	1	5	7
Near Threatened												
<i>Nyctimene cyclotis</i>	1			1	2			1	1	1	3	8
<i>Rhinolophus philippinensis</i>				1	1		1	1	1		3	8
<i>Nyctimene aello</i>				1	1	1	1	1	1		4	9
<i>Paranyctimene raptor</i>				1	1	1	1	1	1		4	9
<i>Pipistrellus papuanus</i>				1	1	1	1	1	1		4	9
<i>Hipposideros wollastoni</i>	1			1	2	1	1	1	1	1	5	10

Table 9: Analysis of direct threats to each prioritized species, based upon relevant ecological information and other considerations. The priority score for each species was calculated in Table 8.				
Taxon	Priority	Relevant ecological characteristics and other comments	Impact assessment considerations	Survey limitations and/or relevant data
Critically Endangered				
<i>Pharotis imogene</i>	1	The history of this enigmatic species is dealt with at length in the text. The species is most likely extinct and is only known 500 k from the project area. If it is (however unlikely) still extant, then the narrow corridor of the gas pipeline would doubtfully have an impact upon any local population/s (this being an animal that could easily fly across the ROW).	A tree clearance protocol that big trees that may contain hollows within the 0–100 m ASL zone be hand felled to reduce any impact upon potential colonies warrants investigation.	Harp traps were unavailable for the field survey
<i>Aproteles bulmerae</i>	2	A cave dwelling species, proven to be subject to hunting pressures which have caused localised demise (Flannery (1995). Living and fossil populations are all from a few high altitude localities, but strong evidence (summarised in Bonaccorso 1998) indicates that because this species (and other large cave-dwelling fruit bats) are highly localised and concentrated sources of protein, then they are subject to extreme hunting pressure if located. <i>A. bulmerae</i> was described from fossils found in food middens (Menzies 1977) shortly before extant animals were first collected (Hyman and Menzies 1980).	If human access to cave roosts is provided via the gas pipeline corridor, then further demise of any unknown local populations is likely. Local-specific on-site surveys are warrant investigation to determine the presence of cave roosts. Data from Benaria survey indicates that local human populations do not in fact know of <u>all</u> caves within their land area, especially those that may not be easily accessible.	No caves were located during the survey of the pipeline corridor and environs.

Table 9 (continued):				
Taxon	Priority	Relevant ecological characteristics and other comments	Impact assessment considerations	Survey limitations and/or relevant data
Vulnerable				
<i>Nyctophilus microdon</i>	3	Found only at high altitudes and from just a few localities. Apparent rarity may be an artifact of survey methodology which has primarily been the use of mist nets.	Most Australian <i>Nyctophilus</i> that inhabit rainforest roost in tree hollows or dense foliage such as epiphytic ferns, a resource that is unlikely to be significantly reduced by the pipeline construction.	Not recorded during survey
<i>Saccolaimus mixtus</i>	3	Appears to be strictly a coastal species, with all four known localities being below 100m. A high and fast flying species that would have an extensive foraging range.	Extensive foraging range would not be impacted by the narrow pipeline corridor, but colonies roosting in tree hollows may suffer during vegetation clearance. Likely to be already impacted by logging near the coastal section of the corridor.	Distribution range not surveyed
<i>Hipposideros muscinus</i>	4	A cave dwelling species known only from low altitudes (to approximately 600m)	Likely to be susceptible to disturbance through cave visitation <i>per se</i> (as opposed to hunting)	Not recorded during survey
<i>Otomops papuensis</i>	4	Known from only two localities. Distribution would be extended via the use of call detection as a survey method. Comments re <i>O.secundus</i> would also apply to this species.	Unlikely to be impacted by pipeline construction as it has an extensive foraging range. Habitat loss via the pipeline construction would therefore be minor. May be impacted if roosting in trees that are cleared.	Comments re <i>O.secundus</i> supposed rarity probably also apply to <i>O. papuensis</i> , though may be impacted by logging in the Gulf Province.
<i>Hipposideros corynophyllus</i>	5	A cave dwelling species known only from high altitudes	Likely to be susceptible to disturbance through cave visitation <i>per se</i> (as opposed to hunting)	Not recorded during survey
<i>Otomops secundus</i>	5	Previously known from only three localities, with the current field survey adding two more through the use of the call detection method. As discussed by Bonaccorso (1998), this species' rarity is likely to be the result of "inadequate sampling effort and techniques, rather than a true reflection of population status".	Unlikely to be impacted by pipeline construction as it has an extensive foraging range. Habitat loss via the pipeline construction would therefore be minor. May be impacted if roosting in trees that are cleared.	Frequently recorded at most sampling sites in both survey areas. Undoubtedly more common than previously thought.

Table 9 (continued):				
Taxon	Priority	Relevant ecological characteristics and other comments	Impact assessment considerations	Survey limitations and/or relevant data
<i>Nyctimene draconilla</i>	6	All records of this species are associated with freshwater swamps and rivers (Bonaccorso 1998), ranging from sea level to 100m. It is known from only 20 specimens, and because Nyctimeninae are easily caught with mist nets, its rarity is undoubtedly a reality, unless it forages primarily in the upper canopy.	Likely to be already impacted by logging in the coastal portion of the pipeline corridor. Extensive vegetation clearance is not required for the pipeline within the range of this coastal species.	Coastal portion of the pipeline corridor not surveyed
<i>Nyctophilus timoriensis</i>	6	This species utilises sclerophyl forest and woodland in Australia, and apparently also mid-montane forests to 1600m (Bonaccorso (1998) in PNG	Most Australian <i>Nyctophilus</i> that inhabit rainforest roost in tree hollows or dense foliage such as epiphytic ferns, a resource that is unlikely to be significantly reduced by the pipeline construction.	Coastal portion of the pipeline corridor not surveyed
<i>Kerivoula muscina</i>	7	Bats in the subfamily Kerivoulinae typically roost in foliage throughout their range, though occasionally utilise tree hollows. Though occasionally recorded, their low intensity echolocation calls make electronic surveys impractical.	Because this species is known to utilise disturbed habitats (Bonaccorso 1998), and has flexible roost selection, local populations are unlikely to be impacted by pipeline construction.	Not recorded during survey
<i>Emballonura diana</i>	7	Roosts in the twilight zone of caves. Considered to be a very rare species but this may be an artifact of past survey methodology because calls attributed to this species were frequently recorded during the survey and at many sampling sites.	Bonaccorso (1998) considers that the Gulf Province population is under threat from logging operations. Being small in size, it may not be attractive as a food source.	Not distinguished from <i>E. furax</i> by survey method (call detection). No caves located during survey.
<i>Emballonura furax</i>	7	See notes on <i>E. diana</i> .	Although it concentrates in caves, being small in size it may not be attractive to hunters.	See notes on <i>E. diana</i> .
Near Threatened				
<i>Nyctimene cyclotis</i>	8	This species has an extensive altitudinal range (800-2600m) and is known from many localities in montane PNG. Bonaccorso (1998) recommends that IUCN status be downgraded.	As well as primary forest, this species is common in regrowth and gardens, so is unlikely to be impacted by the pipeline construction.	Survey method appropriate for this species.
<i>Rhinolophus philippinensis</i>	8	A very rare cave dwelling species previously known only from two localities, with a third being added during the Benaria survey.	Likely to be susceptible to disturbance through cave visitation <i>per se</i> (as opposed to hunting)	Recorded once during survey, which support comments that it is very rare

Table 9 (continued):				
Taxon	Priority	Relevant ecological characteristics and other comments	Impact assessment considerations	Survey limitations and/or relevant data
<i>Nyctimene aello</i>	9	Although there are limited numbers of specimens in collections, this species is known from many localities over most of PNG, from 1000m to sea level.	Bonaccorso (1998) believes that this species conservation status was not evaluated properly, being "based on incomplete examination of distribution records", and that it should be removed from IUCN threat categories. Given this opinion, and the small amount of vegetation clearance required for construction of the pipeline from 1000m to sea level, no impacts are expected.	Not recorded during current surveys but this were conducted above the altitudinal limit of this species.
<i>Paranyctimene raptor</i>	9	This species is very common throughout PNG, and is usually recorded in any survey. Bonaccorso (1998) considers that IUCN status should be downgraded to reflect local abundance and extensive distribution. The record from Benaria increased the altitudinal range by 200-300m.	As well as primary forest, this species is common in regrowth and gardens, so is unlikely to be impacted by the pipeline construction.	Survey method appropriate.
<i>Pipistrellus papuanus</i>	9	Because it is quite common in towns and villages, Bonaccorso (1998) considers that the IUCN status of this species should be reviewed.	No impact expected	Not recorded during survey
<i>Hipposideros wollastoni</i>	10	A cave dwelling species that appears to prefer oak forest habitats (Flannery 1995)	Likely to be susceptible to disturbance through cave visitation <i>per se</i> (as opposed to hunting)	Not recorded during survey

Table 10: Summary of impact assessment and mitigation for species (or species groups) of concern, showing those that are considered to be unaffected by the pipeline construction and operation.

Taxon	Summarised impact	Impact mitigation considerations
Species of high concern		
<i>Pharotis imogene</i>	Probably extinct	Investigate tree felling protocols for the 0 – 100 m ASL section of the ROW.
<i>Aproteles bulmerae</i>	Cave dwelling, subject to hunting pressure	Clearance survey to confirm no roost caves present. If present, no disturbance to caves during construction. Prevention of human access to cave roosts. Develop education program to give local “ownership” to colonies
<i>Saccolaimus mixtus</i> <i>Otomops papuensis</i> <i>O.secundus</i>	Past survey methods not valid for this species, colonies may be affected during tree clearance operation	No practical solutions
All Hipposideridae All Rhinolophidae <i>Emballonura</i> spp.	Cave dwelling, affected by human visitation	Develop education program to give “local “ownership” to colonies
Species of least concern, unlikely to be impacted		
<i>Syconycteris hobbit</i> <i>Nyctimene draconilla</i>	Rare, but massive tracts of habitat available	None required, no major impact expected
<i>Nyctophilus microdon</i> <i>N.timoriensis</i>	Rarity an artifact of past survey methods	None required, no major impact expected
<i>Kerivoula muscina</i> <i>Nyctimene cyclotis</i> <i>N.aello</i> <i>Paranyctimene raptor</i> <i>Pipistrellus papuanus</i>	Known to utilise disturbed habitats	None required, no impact expected

Project Impacts and Mitigation

This section leads from the assessment of individual species or groups in the section above, but takes a more general view as each aspect of the project is dissected.

There are a range of global impacts that apply to all fauna and flora and relate to the construction and operational phases of the project, and also specific issues such as the crossing of streams by the pipeline and the presence of construction roads.

However, for bats three primary impacts are identified. These are hunting pressure (direct killing) upon cave species, human disturbance (indirect killing) of cave colonies (Hall and Richards 2004), and mortality of hollow roosting species when trees are felled.

The general impacts that apply to the bat fauna are shown in Table 11, where they have been given a priority ranking according to their perceived effect on local populations of threatened species. When the number of perceived impacts in each phase of the project is examined (Table 11), it can be seen that the operational phase produces the greatest potential effect, followed by issues with construction roads *per se*, and the overall construction phase of the pipeline and corridor. There appear to be very few issues for bats with the crossing of streams.

Human disturbance to roosting fauna and Disturbance to migrating/ over wintering fauna were impacts that applied to all four aspects of the project (Table 12). Other impacts such as: (i) loss of forest, riverine vegetation, or special habitats, and (ii) noise and dust, especially resulting from blasting near caves and loss of wetlands, were potential impacts that could be applied to three of the four aspects of the project.

Apart from the establishment of a vegetation clearance protocol (identified in the individual species assessment, above), an assessment of prudent and feasible measures, by which to mitigate these potential impacts, is warranted and, where feasible, inclusion in environmental management plans and requirements of contractors. Options requiring evaluation should include the following:

- Identify during the pre-construction phase (i.e., pipeline route survey) any caves and flying fox roosts, ensure that security personnel are made aware, and investigate methods to control hunting within the project area that take due and effective account of the cultural and social context, especially customary land ownership.
- Educate workers and contractors via a pre-start environmental induction of the broader adverse implications of hunting, even if it is part of traditional lifestyle.
- Consider whether gating of caves inhabited by microchiropteran bats could prevent human access and what other measures might be effective.
- Conduct education programs for villagers living near sensitive conservation areas and consider creating local ownership of sensitive conservation areas, even if this involves payment to new local custodians.

- Endeavour to prevent any blasting within 100 m of caves. Explore what scope exists within broader agreements with workers and landowners to conserve bats.

Table 12 summarises the assessed impacts and presents a series of mitigation options against each impact. The feasibility and effectiveness of these measures warrant investigation for possible inclusion in environmental management plans and requirements of contractors and workforces.

Table 11: General impacts that apply to the bat fauna, prioritized according to their perceived effect on local populations of threatened species					
Perceived priority of impact	Impact	Construction phase	Operational phase	Stream crossings	Construction roads
Very High	Cave and colony destruction	•		•	•
High	Cave disturbance by blasting	•		•	•
	Outsiders attracted to area and hunting and clearing		•		
	Human disturbance to roosting fauna in caves and flying fox camps.	•	•	•	•
Moderate	Hunting by workers and/or contractors	•	•		•
	Loss of forest, riverine vegetation, or special habitats	•		•	•
	Noise and dust, especially blasting near caves	•	•		•
	Increased access for illegal logging		•		
Low	Disturbance to migrating/ over wintering fauna	•	•	•	•
	Habitat fragmentation	•	•		•
	Gas flames (burning of excess)		•		
	Loss of wetlands	•		•	•
	Continued erosion		•		
	Maintaining cleared vegetation around wells		•		
Number of impacts		9	10	6	9

Table 12: Mitigation measures to be considered for impacts identified as “project-wide”		
Impact priority	Impact	Mitigation Options Requiring Feasibility Investigation
Very high	Cave and colony destruction	Note location of caves during initial route surveys, control access by construction crew, prevent/deter hunting and disturbance after construction via education programs and ownership (perhaps through payments to local guardians?)
High	Outsiders attracted to area and hunting and clearing	Control access to project area sites and ROW
		Ensure that security personnel are aware of caves and roosts
		Develop penalties for these impacts on company-owned land
		Consider gating of caves inhabited by microchiropteran bats to prevent human access
	Human disturbance to roosting fauna	Conduct education programs for villagers living near sensitive conservation areas
		Consider creating a local ownership of sensitive conservation areas, even if this involves payment to new local custodians
		Consider the feasibility and likely effectiveness of gating of caves inhabited by microchiropteran bats to prevent human access
Loss of forest, riverine vegetation, or special habitats	Considering the extent of intact habitat surrounding the project area, it is doubtful that this impact requires any impact mitigation procedures	
Noise and dust, especially blasting near caves	Considering that this is a highly localised ‘single-shot’ impact, endeavour to prevent any blasting within 100 m of caves	
Moderate	Hunting by workers and/or contractors	Identify caves and flying fox roosts during initial construction phase (e.g. pipeline route surveys).
		Educate workers and contractors via an environmental induction prior to commencement of work of the broader adverse implications of hunting, even if part of traditional lifestyle.
		Examine constraints on hunting (by workers) within company-owned land.
	Increased access for illegal logging	Probably impossible to mitigate, but consider constraints on company-owned land and custodian-ship by villagers of sensitive conservation areas; that is, if logging occurs, endeavour to create buffers around sensitive areas
Low	Loss of forest, riverine vegetation, or special habitats	Considering the extent of intact habitat surrounding the project area, it is doubtful that this impact requires any mitigation procedures
	Disturbance to migrating/ over wintering fauna	If cave sites are designated as sensitive conservation areas, this impact would be mitigated
	Habitat fragmentation	Considering the extent of intact habitat surrounding the project area, it is doubtful that this impact requires any mitigation procedures
	Gas flames (burning of excess)	Relates to bats flying near gas burnoff flames and becoming scorched - probably impossible to mitigate and of minor impact
	Loss of wetlands	Considering the extent of intact habitat surrounding the project area, it is doubtful that this impact requires any impact mitigation procedures
	Table 12 (continued):	
	Continued erosion	Relates to reduction of potential insect prey via stream sedimentation, but impossible to easily mitigate and of low concern to conservation of threatened species
	Maintaining cleared vegetation around wells	Considering the extent of intact habitat surrounding the project area, it is doubtful that this impact requires any mitigation procedures

REFERENCES

- Balun L. (2004?) *An Audit on the Status of the Flora and Fauna of the Porora Forest, South East Mananda Forest, Southern Highlands Province*. WWF KICDP Report.
- Bonaccorso, F.J. (1998) *Bats of Papua New Guinea*. Conservation International Tropical Field Guide Series 2, Conservation International: Washington DC.
- Flannery, T. (1995) *Mammals of New Guinea*. Reed Books: Chatswood, NSW.
- Flannery, T.F. and Seri, L. (1993) Rediscovery of *Aproteles bulmerae* (Chiroptera: Pteropodidae) . Morphology, ecology and conservation. *Mammalia* 57: 19-25
- Hall, L.S. and Richards, G. (1985) The bats of Chillagoe. *Towerkarst* 5: 13-22
- Hall, L.S., Richards, G. and Abdullah, M.T. (2002) The bats of Niah National Park, Sarawak. *Sarawak Museum Journal* 57: (78): 255-282.
- Hall, L.S. and Richards, G. (2004) Flying around underground: cave bats. Pp. 111-126 (Chapter 4) in, *Beneath the Surface. A Natural History of Australian Caves* (ed. B. Finlayson and E. Hamilton-Smith). University of NSW Press: Sydney.
- Hartshorn, G.S., Burrows, I., Leary, T., Seri, L., Allen, G., Polhemus, D., Balun, L., Orsak, L., Bigilale, E., Kinbag, F., Kinibel, A., Dal, C., Wasel, H., Ellis, G. and Forney, M. (1995). *Field survey of biodiversity in the Kikori River Basin. Papua New Guinea*. WWF KICDP report.
- Hosken, D.J., Bailey, W.J., O'Shea, J.E. and Roberts, J.D. (1994) Localisation of insect calls by the bat *Nyctophilus geoffroyi* (Chiroptera: Vespertilionidae): a laboratory study. *Australian Journal of Zoology* 42: 177-184.
- Hyndman, D. and Menzies, J.I. (1980) *Aproteles bulmerae* (Chiroptera: Pteropodidae) of New Guinea is not extinct. *Journal of Mammalogy* 61: 159-160.
- Leary, T. & Seri L. (1995?) *Survey of Birds and Mammals at Utiti Creek*. Unpublished WWF KICDP Report.
- Leary, T. (1998) *Mammals of the Lake Kutubu Swamp Forests*. Wetlands International Report.
- Leary, T. (1999) *Mammal Survey of the Gobe Oil Field Area, Southern Highlands and Gulf Provinces, Papua New Guinea - December, 1998*. WWF KICDP Report.
- Leary, T. (2001) *Mammal Survey of Two Sites on the Northeast Slopes of Mt Sisa, Southern Highlands Province, PNG - October 1999*. WWF KICDP Report.
- Leary, T. (2002?) *Brief Report on Iviri Mammal Monitoring - December 2001*. WWF KICDP Report.
- Leary, T. (2004) *Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province, July - August, 2003*. WWF KICDP Report.

- Leary, T. (2004?) *Brief Report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003*. WWF KICDP Report.
- Leary, T. (2004?) *Brief Report on Keboi Kerowa Mammal Monitoring - July 2004*. WWF KICDP Report.
- Leary, T. and Seri, S. (nd) *An annotated checklist of mammals recorded in the Kikori River Basin, Papua New Guinea*. [Probably a draft manuscript – no citation details available]
- Leary, T., Seri L. & Kinbag F. (1995) *Report on the bat component of the field survey of biodiversity in the Kikori ICDP area*. In: *Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea* (G. S. Hartshorn et al.). WWF KICDP Report.
- Menzies, J.I. (1977) *Fossil and subfossil fruit bats from the mountains of New Guinea*. *Australian Journal of Zoology* 25: 329-336.
- Namo, R. (2004a) *Annotated Checklist of Mammals of Kikori Basin*. WWF KICDP Report.
- Richards, G.C. (2002) *Ecological and Evolutionary Determinants of Bat Community Structure in South-east Australian Forests*. PhD Thesis, University of New South Wales, Sydney.
- Thomas, M.O. (1897) *On the mammals collected in British New Guinea by Dr. Lamberto Loria*. *Ann. Mus. Civico Storia Nat. Genova*, Series 2, 18: 606-622.

APPENDIX 1: CURRICULUM VITAE OF CONSULTANT

FULL NAME: Gregory Charles Richards
DATE OF BIRTH: 20 November 1949
NATIONALITY: Australian

CONTACT DETAILS

Postal address: PO Box 9, Gungahlin, ACT 2912
Home office address: 23 Tanderra Crescent, Ngunnawal, ACT 2913
Phone: (02) 6255 0606 Fax: (02) 6255 0606
Mobile: 0408 221 520 Email: batmanoz@bigpond.com

ACADEMIC QUALIFICATIONS

Doctor of Philosophy (Biological Sciences), University of NSW, 2002.
Thesis entitled "*Ecological and evolutionary determinants of bat community structure in south-east Australian forests*".

PROFESSIONAL EXPERIENCE

1996- present Director, Greg Richards & Associates Pty Ltd 8 years

The Principal Consultant provides specialist bat fauna advice to industry and government, contributing in areas such as:

- Specialist bat fauna surveys using sophisticated automated technology
- Components of Environmental Impact and Species Impact Statements
- Development of Threatened Species Management Plans
- Referrals under the Commonwealth EPBC Act
- Section 5A assessments ("Eight Part Tests") under the NSW Threatened Species Conservation Act
- The advancement of survey methods for bats, especially echolocation call monitoring, and the development of new statistical analysis methods.
- Involvement as an expert witness in legal actions includes the provision of legal advice to senior counsel, and attendance in courts including the Federal, Supreme, Magistrates (Qld) and Land & Environment (NSW) courts.

1968-1996 CSIRO Division of Wildlife & Ecology 27 years

Based at Canberra and North Queensland laboratories, research projects focused on arid zone and tropical rainforests, including Cape York and Torres Strait. Research projects included ecological (habitat based) fauna surveys and assessments, taxonomic studies, preparation of draft national Bat Conservation Plan and other natural resource management projects.

PROFESSIONAL AFFILIATIONS and AWARDS

Current positions

- Member – Environment Institute of Australia and New Zealand
- Member – ACT Natural Resources Management Committee
- Member – ACT Natural Resources Management Board (Territory Body for NHT project management)
- Member – ACT Environmental Grants Assessment Panel
- Advisor – Species Survival Commission, Chiroptera Specialist Group, IUCN (involves review of worldwide conservation action plans for bats)
- Member – Scientific Advisory Board - Bat Conservation International, Texas (representing the Australian, SE Asian and Pacific regions)
- Member – Environment Institute of Australia and New Zealand
- Member – Ecological Society of Australia
- Member – Royal Zoological Society of NSW
- Vice-president – Australasian Bat Society

Past positions

- Founder, President and Secretary – Australasian Bat Society

Awards

- 1993 CSIRO Study Award (only 6 awarded each year, visited European museums studying type specimens of Australian bats)

OVERSEAS EXPERIENCE

Malaysia - Several visits to Sarawak and Sabah (1988-1995). First visit involved surveys of several major karst systems and cave bat fauna, contributing information to the Malaysian National Parks Authority. Two subsequent visits involved training of Malaysian NPA and Sarawak Museum staff whilst conducting further surveys. Final visit was under the auspices of Bat Conservation International Inc. (USA-based) and more karst systems were surveyed, as well as rainforest areas of high biodiversity value.

Cambodia - Australian Government foreign aid consultancy (1993). Consultancy to resolve bat problem in the National Museum, Phnom Penh, involving the world's largest bat colony in a man-made structure. Issues to deter bats were turned around to change attitudes towards conservation and preservation of an "ecosystem service" cycle, which involved passive crop protection via the bat colony, and the sale of harvested guano for fertiliser which then subsidized museum operational costs.

Indonesia - Advisor to Indonesian Government Airport Corporations (2001 - current). Preliminary methods for deterring aerial wildlife (bats and birds) from Jakarta Airport with the view to preventing aircraft strike. Project suspended due to terrorism issues and travel warnings.

India, Thailand, Singapore - Various advisory roles in Southeast Asia (1995-2001) Advice to Singapore National Parks Authority on field survey methods and rapid habitat assessment for bat fauna; advice on bat fauna assessment methods within elephant reserves in India; advice to WWF on survey methods for threatened cave bats in Thailand.

USA, Costa Rica - Bat Conservation International Inc (1998) Collaboration and advisor re cave bat studies in Texas, and collaborative research on fruit bats in Costa Rica.

Europe - CSIRO Study Award project (1993). Visited major museum collections in UK, Germany, Netherlands and France to examine type specimens of Australasian bat taxa, presented an invited paper to Zoological Society of London.

PUBLICATION AND EDITORIAL EXPERIENCE:

Publications list exceeds 150 entries, and also includes significant editorial positions for major books and newsletters, and referee roles for research papers and scientific articles in international journals. Publication highlights include books such as *Flying Foxes: Fruit and Blossom Bats of Australia* (University of New South Wales Press: Sydney, 2000), *Bats of Eastern Australia* (Queensland Museum, 1979), both of which were co-authored with Dr L. S. Hall, the editing of bat chapters in the 1983 and 1995 national mammal books, and chapter consultant for the forthcoming (2005) edition.

PUBLICATIONS LIST

Scientific publications

1. Hall, L. S. and Richards, G. (2004) Flying around underground: cave bats. Pp. 111-126 (Chapter 4) in, *Beneath the Surface. A Natural History of Australian Caves* (ed. B. Finlayson and E. Hamilton-Smith). University of NSW Press.
2. Richards, G. C. (in press) Methods for analysing microbat faunal composition and community structure: case studies from Australia. In, *Functional and Evolutionary Ecology of Bats* (eds A. Zubaid, G.F. McCracken and T.H. Kunz). Oxford University Press.
3. Hall, L. S., Richards, G. and Abdullah, M.T. (2002) The bats of Niah National Park, Sarawak. *Sarawak Museum Journal* 57 (78): 255-282.
4. Richards, G. C. (2002) The development of strategies for management of the flying-fox colony at the Royal Botanic Gardens, Sydney. Pp. 196-201 in, *Managing the Grey-headed Flying-fox as a threatened species in NSW* (eds. D. Lunney and P. Eby). Royal Zoological Society of New South Wales: Sydney.
5. Richards, G. C. and Hall, L. S. (2002) A new flying-fox of the genus *Pteropus* (Chiroptera : Pteropodidae) from Torres Strait, Australia. *Australian Zoologist* 32: 69-75
6. Richards, G. and Martin, M. (2001) A note on the effect of cave entrance disturbance upon internal bat surveys: a case study from north Queensland. *Australasian Bat Society Newsletter* 17: 34-36.
7. Richards, G. C. (2001) A report on the preparation of threatened species profiles and environmental impact assessment guidelines for the bat fauna of NSW. Unpublished report to NSW National Parks and Wildlife Service, Hurstville, May 2001
8. Richards, G. C. (2001) Towards defining adequate bat survey methodology: why electronic call detection is essential throughout the night. *Australasian Bat Society Newsletter* 16: 24-27
9. Richards, G. C. (2001) Methods for analysing microbat faunal composition and community structure: case studies from Australia, abstract, 12th International Bat Research Conference, Malaysia
10. Hall, L. S. and Richards, G. C. (2000) *Flying Foxes: Fruit and Blossom Bats of Australia*. University of New South Wales Press: Sydney.
11. Richards, G. (Ed) (2000) Proceedings of a workshop to assess the status of the Grey-headed Flying-fox in New South Wales. <http://batcall.csu.edu.au/abs/ghff>
12. Richards, G. and Hall, L. S. (2000) Australia's flying foxes at a crossroad. *Bats* 18: 5-8
13. Richards, G. C. (2000) Towards defining adequate bat survey methodology: Why electronic call detection is essential throughout the night. Abstract, 9th Australasian Bat Conference, Tocal Agricultural College, NSW, April 2000.
14. Hall, L. S., Schulz, M. and Richards, G. C. (2000) Bats chapter. Pp.313-327 in, *Wildlife of Tropical North Queensland* (ed. M. Ryan). Queensland Museum, Brisbane
15. Eby, P., Richards, G., Collins, L. and Parry-Jones, K. (1999) The distribution, abundance and vulnerability to population reduction of a nomadic nectarivore, the Grey-headed Flying

- Fox *Pteropus poliocephalus* in New South Wales, during a period of resource concentration. *Australian Zoologist* 31: 240-253
16. Duncan, A., Baker, B., Hall, L., Richards, G., Tidemann, C., Clague, C. and Law, B. (1999) Threatening processes and conservation priorities. Pp. 85-95 in, *The Action Plan for Australian Bats* (Eds A. Duncan, G.B. Baker and N. Montgomery). Natural Heritage Trust: Canberra
 17. Richards, G. C. (1999) The Phoenix Bat Wailer - trials and tribulations in the first five months. *Australasian Bat Society Newsletter* 12: 27-29
 18. Richards, G. C. and Hall, L. S. (1998) The conservation biology of Australian bats. Are recent advances solving our problems? Pp. 271-281 in, *Bat biology and conservation* (Eds T.H. Kunz and P.A. Racey). Smithsonian Institution Press: Washington.
 19. Richards, G. C., Eby, P. and Parry-Jones, K. (1998) Estimating the Grey-headed Flying-fox population: an example of community involvement in bat conservation. *Australasian Bat Society Newsletter* 11: 26-28.
 20. Richards, G. C. (1998) Estimating the economic value of insect-eating bats: a case study from Cambodia. *Bats* 16: 3-5.
 21. Hall, L. S. and Richards, G. C. (1998) Issues concerning bat distribution on minesites in Australia. Pp. 125-137 in, *Fauna Habitat Reconstruction after Mining Workshop*. (Eds. C.J. Asher and L.C. Bell). Australian Centre for Mining Environmental Research: Kenmore.
 22. Richards, G. C. (1997) Bats section, *Encyclopaedia of Australian Wildlife*. Readers Digest.
 23. Hall, L. S., Richards, G. C., McKenzie, N.L. and Dunlop, N. (1997) The importance of abandoned mines as bat habitat. Chapter 62 (pp. 326-333) in, *Conservation Outside Nature Reserves* (Eds. P. Hale and D. Lamb). Centre for Conservation Biology, The University of Queensland: Brisbane.
 24. Richards, G. C. and Hall, L. S. (1996) The conservation biology of Australian bats: are recent advances solving our problems? *Bat Research News*
 25. Richards, G. C. (1996) The current conservation status of Australian bats: is there light at the end of a long tunnel? *Aust. Bat Soc. Newsl.* 7 : 59 (abstract).
 26. Kunz, T.H., Tidemann, C.R. and Richards, G. C. (1996a) Capturing mammals. Small volant mammals. Pp. 122-146 in, *Measuring and monitoring biological diversity. Standard methods for mammals*. (Eds. D. Wilson, F.R. Cole, J.D. Nicols, R. Rudran and M.S. Foster). Smithsonian Institution Press: Washington D.C.
 27. Kunz, T.H., Thomas, D.W., Richards, G. C., Tidemann, C.R., Pierson, E.D. and Racey, P.A. (1996b) Observational techniques for bats. Chapter 7, pp. 105-114 in, *Measuring and monitoring biological diversity. Standard methods for mammals*. (Eds. D. Wilson, F.R. Cole, J.D. Nicols, R. Rudran and M.S. Foster). Smithsonian Institution Press: Washington D.C.
 28. Richards, G. C. and Hall, L. S. (1996) Revision of the national species inventory. Chapter 2 in, *Action Plan for Australian Bats*. Report to the Australian Nature Conservation Agency for project 115, Canberra, 164 pp.
 29. Richards, G. C., Walker, P.A., Smyth, R.E. and Vogt, F. (1996) Survey effort and patterns of biodiversity. Chapter 3 in, *Action Plan for Australian Bats*. Report to the Australian Nature Conservation Agency for project 115, Canberra, 164 pp.
 30. Richards, G. C. and Hall, L. S. (1996) Diagnosis of rare and threatened species. Chapter 4 in, *Action Plan for Australian Bats*. Report to the Australian Nature Conservation Agency for project 115, Canberra, 164 pp.
 31. Richards, G. C. and Hall, L. S. (1996) Recovery outlines for threatened species Chapter 5 in, *Action Plan for Australian Bats*. Report to the Australian Nature Conservation Agency for project 115, Canberra, 164 pp.
 32. Richards, G. C. and Hall, L. S. (1996) National conservation and recovery research. Chapter 6 in, *Action Plan for Australian Bats*. Report to the Australian Nature Conservation Agency for project 115, Canberra, 164 pp.
 33. Richards, G. C. (1996) An assessment of two techniques for observing microchiropteran bats in fauna surveys. *Aust. Bat Soc. Newsl.* 6 : 13-16.

34. Richards, G. C. (1995) A review of ecological interactions of fruit bats in Australian ecosystems. In, *Ecology, Evolution and Behaviour of Bats* (Ed. P.A. Racey and S.M. Swift). *Symp. Zool. Soc. Lond.* 67: 79-96.
35. Pallin, N., Richards, G., Gibson, L. and Perry, A. (1995) Endangered bats in NSW. *Aust. Bat Soc. Newsl.* 4: 42-45.
36. Richards, G. C. (1994) Relationships of forest bats with habitat structure and foliage nutrients in south-eastern Australia (abstract of paper presented at the 4th Australasian Bat Research Conference, Lismore, 1994). *Australasian Bat Society Newsletter* 3 : 9.
37. Richards, G. C. and Hall, L. S. (1994) Revision of the national species inventory. Chapter 2 in, *Action Plan for Bat Conservation in Australia*. Draft report to the Endangered Species Advisory Committee, Australian Nature Conservation Agency, Canberra, 204 pp.
38. Richards, G. C., Walker, P.A., Smyth, R.E. and Hall, L. S. (1994) Survey effort and patterns of biodiversity. Chapter 3 in, *Action Plan for Bat Conservation in Australia*. Draft report to the Endangered Species Advisory Committee, Australian Nature Conservation Agency, Canberra, 204 pp.
39. Richards, G. C. and Hall, L. S. (1994) Diagnosis of rare and threatened species. Chapter 4 in, *Action Plan for Bat Conservation in Australia*. Draft report to the Endangered Species Advisory Committee, Australian Nature Conservation Agency, Canberra, 204 pp.
40. Richards, G. C. and Hall, L. S. (1994) Recovery outlines for threatened species Chapter 5 in, *Action Plan for Bat Conservation in Australia*. Draft report to the Endangered Species Advisory Committee, Australian Nature Conservation Agency, Canberra, 204 pp.
41. Richards, G. C. and Hall, L. S. (1994) National conservation and recovery research. Chapter 6 in, *Action Plan for Bat Conservation in Australia*. Draft report to the Endangered Species Advisory Committee, Australian Nature Conservation Agency, Canberra, 204 pp.
42. Richards, G. C. (1994) Critical conservation areas for preserving bat biodiversity. Chapter 7 in, *Action Plan for Bat Conservation in Australia*. Draft report to the Endangered Species Advisory Committee, Australian Nature Conservation Agency, Canberra, 204 pp.
43. Richards, G. C. (1994) Review of the Old World Fruit Bat Action Plan. Appendix 3 in, *Action Plan for Bat Conservation in Australia*. Draft report to the Endangered Species Advisory Committee, Australian Nature Conservation Agency, Canberra, 204 pp.
44. Richards, G. C. (1993) Bats. in, P.C. Catling, I.J. Mason, G. C. Richards, R. Schodde and J.C. Wombey *The Land Vertebrate Fauna of the Eastern Dunefields and Tidal Zone - Shoalwater Bay Training Area, Queensland*. A report to the Commonwealth Commission of Inquiry. CSIRO Division of Wildlife and Ecology, 48 pp.
45. Richards, G. C., Hall, L. S., Hoyer, G.A., Lumsden, L.F., Parnaby, H.E., Reardon, T.D., Strahan, R., Thomson, B.G. and Tidemann, C.R. (1993) A revision of the inventory and English names of Australian bats. *Australasian Bat Society Newsletter* 2: 8-9
46. Richards, G. C., Walker, P.A., Smyth, R.E. and Hall, L. S. (1993) A national Action Plan for bat conservation in Australia : Establishing the framework. 9th Int. Bat. Res. Conf., Madurai, India (abstract).
47. Richards, G. C. and Hall, L. S. (1993) A review of the Australian Action Plan for Bat Conservation. *Australian Bat Society Newsletter* 2: 9-12
48. Richards, G. C. (1993) A report on an inspection of a bat colony in the National Museum of Cambodia. Unpubl. rept. to OPG, Dept. Admin. Services, Canberra, 6pp.
49. Richards, G. C. (1993) NABU : a national archive of bat ultrasound. *Australasian Bat Society Newsletter* 2: 2
50. Richards, G. C., Smyth, R.E. and Walker, P.A. (1992) Patterns in the distribution of Cape York bats: results of GIS modelling and conservation implications. *Proceedings of Conservation Biology in Australia and Oceania*, Brisbane, Australia.
51. Richards, G. C. (1992) Bats. Pp. 143-162 in, R. Schodde, P.C. Catling, I.J. Mason, G. C. Richards and J.C. Wombey. *The Land Vertebrate Fauna of the Shoalwater Bay Training Area, Queensland*. Report to the Department of Defence, Commonwealth of Australia. CSIRO Division of Wildlife and Ecology, 236 pp.
52. Richards, G. C. (1992) The conservation status of the rainforest bat fauna of north Queensland. Pp.177-186 in, *The Rainforest Legacy: Australian National Rainforests Study, Vol.2 Flora and fauna of the rainforests* (eds. G.L. Werren and A.P. Kershaw). Special Australian Heritage Publications Ser.No.7(2). AGPS : Canberra.

53. Richards, G. C. (1992) *Bat fauna survey of the Gloucester and Chichester Management areas*. Supporting document no. 6, Gloucester and Chichester Management areas Environmental Impact Statement, 49 pp.
54. Richards, G. C. (1992) Fauna survey, Wingham Management Area, Port Macquarie region. Part 4. Bats. Forest Resource Series No.22, Forestry Commission of NSW. 69 pp.
55. Crome, F.H.J., Moore, L.A. and Richards, G. C. (1991) A study of logging damage in upland rainforest in north Queensland. *Forest Ecol. Manag.* 49: 1-29
56. Richards, G. C. (1991) The conservation of forest bats in Australia: Do we really know the problems and solutions? pp.81-90 in, Conservation of Australia's forest fauna, (ed. D.Lunney). Royal Zool.Soc.NSW : Mosman
57. Smyth, R.E., Richards, G. C., Walker, P.A. and Symond, J.M. (1991) Coming to grips with flighty data. AURISA 1991 Conference, Wellington, NZ (poster paper)
58. Richards, G. C. (1991) Can we predict the effect of habitat disturbance on Australia's insectivorous bat communities. 4th Aust Bat Research Conference, Brisbane (abstract)
59. Hall, L. S. and Richards, G. C. (1991) Flying fox camps. *Wildlife in Australia* 28: 19-22
60. Richards, G. C. (1990) The Spectacled flying fox, *Pteropus conspicillatus*, in north Queensland. 1. Roost site selection and distribution patterns. *Australian Mammalogy* 13: 17-24
61. Richards, G. C. (1990) The Spectacled flying fox, *Pteropus conspicillatus*, in north Queensland. 2. Diet, feeding ecology and seed dispersal. *Australian Mammalogy* 13 : 25-31
62. Richards, G. C. (1990) Rainforest bat conservation : Unique problems in a unique environment. *Australian Zoologist* 26 : 44-46
63. Richards, G. C. (1990) The conservation status of the Torresian flying fox. Unpublished report to Australian National Parks and Wildlife Service (20pp.)
64. Richards, G. C. (1989) Nocturnal activity patterns of insectivorous bats relative to temperature and prey availability in tropical Queensland. *Australian Wildlife Research* 16 : 151-158
65. Richards, G. C. (1989) A preliminary report on the ecology of bats in the Australian Capital Territory. *Unpubl. report to ACT Parks and Conservation Service*
66. Richards, G. C. (1989) VFT Coastal Route Assessment - Bat fauna. In, "The Very Fast Train. Information on potential environmental impact: Coastal route" Eds. R.G. Dickson and P.J. Fullagar. Unpubl. report, CSIRO Divn. Wildlife and Ecology, October, 1989.
67. Richards, G. C. (1989) VFT Alternative Route Assessment - Bat fauna. In, "The Very Fast Train. Information on potential environmental impact: Alternative route" Eds. R.G. Dickson and P.J. Fullagar. Unpublished report, CSIRO Divn. Wildlife and Ecology, October, 1989.
68. Crome, F.H.J. and Richards, G. C. (1988) Bats and gaps : Microchiropteran community structure in a Queensland rain forest. *Ecology* 69 :1960-1969
69. Richards, G. C. and Tidemann, C.R. (1988) Habitat : The effects of alteration and disturbance upon bat communities in Australia. *Australian Science Mag* 2 : 40-45
70. Tidemann, C.R. and Richards, G. C. (1988) Field study techniques. (Bats) *Australian Science Mag* 2 : 46-49
71. Richards, G. C. (1988) Book review: "A Guide to the Bats of South Australia". *Macroderma* 4 : 44-46
72. Richards, G. C. and Strahan, R. (1988) Bats. Pp.391-393 in, "The Australian Encyclopaedia", 5th Edition. Grolier Society, Sydney/ Australian Geographic Society, Sydney
73. Hall, L. S. and Richards, G. C. (1987) The flying fox problem in eastern Australia. Pp.279-283 in *Proceedings of the 1987 Australian Vertebrate Pest Control Conference*, Coolangatta.
74. Richards, G. C. (1987) Aspects of the ecology of Spectacled flying-foxes, *Pteropus conspicillatus* (Chiroptera : Pteropodidae), in tropical Queensland. (Abstract from First National Flying Fox Symposium, Brisbane, 1986). *Australian Mammalogy* 10 : 87-88
75. Hall, L. S. and Richards, G. C. (1987) Crop protection and management of flying foxes (Chiroptera : Pteropodidae). (Abstract from First National Flying Fox Symposium, Brisbane, 1986) *Australian Mammalogy* 10 : 137-139
76. Richards, G. C. (1986) Notes on the natural history of the Queensland tube-nosed bat, *Nyctimene robinsoni*. *Macroderma* 2 : 64-67

77. Richards, G. C. (1986) *Dobsonia* flight and ecology : more on lift at low speed. *Macroderma* 2 : 20
78. Richards, G. C. (1986) Predation on a platypus, *Ornithorhynchus anatinus* (Monotremata : Ornithorhynchidae), by a goshawk. *Australian Mammalogy* 9 : 67
79. Pettigrew, J.D., Baker, G.B., Baker-Gabb, D., Baverstock, G., Coles, R.L., Conole, L., Churchill, S., Fitzherbert, K., Guppy, A., Hall, L., Helman, P., Nelson, J., Priddel, D., Pulsford, I., Richards, G., Schulz, M. and Tidemann, C. (1986) The Australian Ghost bat, *Macroderma gigas*, at Pine Creek, Northern Territory *Macroderma* 2 : 8-19
80. Hall, L. S. and Richards, G. C. (1985) The bats of Chillagoe. *Tower Karst* 5 : 13-22
81. Richards, G. C. (1985) The effect of rainforest fragmentation on a tropical insectivorous bat community. (Abstract of paper presented at the Bat Biology Symposium, Brisbane, 1985). *Macroderma* 1 : 57
82. Richards, G. C. (1984) The conservation status of the rainforest bat fauna of north Queensland. Pp. 292-299 in G.L. Werren and A.P. Kershaw. *Australian National Rainforest Study Report*, Volume 1. Australian Conservation Foundation : Sydney.
83. Richards, G. C. and Prociv, P. (1984) Folivory in *Pteropus*. *Australian Bat Research News* 20 : 13-14
84. Richards, G. C. (1983) The Chillagoe Expedition - Part 2. *Australian Bat Research News* 19 : 5-9
85. Richards, G. C., Hall, L. S., Helman, P.M. and Churchill, S.M. (1982) First discovery of the rare Tube-nosed insectivorous bat (*Murina*) in Australia. *Australian Mammalogy* 5 : 149-151
86. Richards, G. C. (1982) Bats. pp.288-290 in *The Australian Encyclopaedia*, 4th edition, Vol.1. The Grolier Society : Sydney
87. Hall, L. S. and Richards, G. C. (1979) *The Bats of Eastern Australia*. Queensland Museum booklet 12, 66 pp.
88. Richards, G. C. (1979) Variation in water turnover in wild rabbits, *Oryctolagus cuniculus* L., in an arid environment, due to season, age and reproductive condition. *Australian Wildlife Research* 6 : 289-296
89. Richards, G. C. (1979) New information on the little pied bat, *Chalinolobus picatus*. *Australian Bat Research News* 14 : 7-8
90. Richards, G. C. (1978) Maternity sites for cave bats in New South Wales. Unpublished conservation report for National Parks and Wildlife Service, NSW, 14pp.
91. McKean, J.L., Richards, G. C. and Price, W.J. (1978) A taxonomic appraisal of *Eptesicus* (Mammalia : Chiroptera) in Australia. *Australian Journal of Zoology* 26 : 529-537
92. Carpenter, S.M., McKean, J.L. and Richards, G. C. (1978) Multivariate morphometric analysis of *Eptesicus* (Mammalia : Chiroptera) in Australia. *Australian Journal of Zoology* 26 : 629-638
93. Hall, L. S. and Richards, G. C. (1972) Notes on *Tadarida australis* (Chiroptera: Molossidae) *Australian Mammalogy* 1 : 46-47.

The Mammals of Australia (ed R. Strahan), Reed New Holland

94. Richards, G. C. (1995) Torresian Tube-nosed Bat *Nyctimene vizcaccia*. P. 429.
95. Richards, G. C. (1995) Torresian Flying-fox. Pp. 443-444.
96. Richards, G. C. (1995) Yellow-bellied Sheathtail-bat *Saccolaimus flaviventris*. Pp. 467-468.
97. Richards, G. C. (1995) Coastal Sheathtail-bat *Taphozous australis*. Pp. 471-472.
98. Richards, G. C. (1995) Northern Freetail-bat *Chaerephon jobensis*. Pp. 479-480.
99. Richards, G. C. (1995) Southern Freetail-bat *Mormopterus planiceps*. Pp. 485-486.
100. Richards, G. C. (1995) White-striped Freetail-bat *Nyctinomus australis*. Pp. 487-488.
101. Richards, G. C. (1995) Lord Howe Island Bat *Nyctophilus howensis*. P. 506-507.
102. Richards, G. C. (1995) Little Pied Bat *Chalinolobus nigrogriseus*. Pp. 517-518.
103. Richards, G. C. (1995) Large-footed Myotis *Myotis adversus*. Pp. 521-523.
104. Richards, G. C. (1995) Little Broad-nosed Bat *Scotorepens greyii*. Pp. 530-531.
105. Richards, G. C. (1995) Inland Forest Bat *Vespadelus baverstocki*. Pp. 534-535.
106. Richards, G. C. and Spencer, H.J. (1995) Spectacled Flying-fox *Pteropus conspicillatus*. Pp. 435-437.
107. Richards, G. C. and Hand, S. (1995) Ghost Bat *Macroderma gigas*. Pp. 446-447.
108. Richards, G. C. and Thomson, B.G. (1995) Papuan Sheathtail-bat *Saccolaimus mixtus*. Pp. 468-469.
109. Richards, G. C., Coles, R.B. and Spencer, H.J. (1995) Tube-nosed Insect Bat *Murina florium*. Pp. 496-497.
110. Hall, L. S. and Richards, G. C. (1995) Diadem Leafnosed-bat *Hipposideros diadema*. Pp. 459-460.
111. Hall, L. S., Richards, G. C. and Spencer, H.J. (1995) Eastern Tube-nosed Bat *Nyctimene robinsoni*. Pp. 426-428.
112. Hoyer, G.A. and Richards, G. C. (1995) Greater Broad-nosed Bat *Scoteanax rueppellii*. Pp. 527-528.

The Australian Museum Complete Book of Australian Mammals (ed R. Strahan), Angus & Robertson

113. Richards, G. C. (1983a) Grey-headed Flying-fox *Pteropus poliocephalus*. Pp. 275-276.
114. Richards, G. C. (1983b) Little Red Flying-fox *Pteropus scapulatus*. Pp. 277-279.
115. Richards, G. C. (1983c) Queensland Blossom-bat *Syconycteris australis*. Pp. 288-289.
116. Richards, G. C. (1983d) Ghost Bat *Macroderma gigas*. Pp. 292-293.
117. Richards, G. C. (1983e) Eastern Horseshoe-bat *Rhinolophus megaphyllus*. Pp. 295-296.
118. Richards, G. C. (1983f) Papuan Sheathtail-bat *Taphozous mixtus*. P. 314.
119. Richards, G. C. (1983g) Yellow-bellied Sheathtail-bat *Taphozous flaviventris*. P. 315.
120. Richards, G. C. (1983h) White-striped Mastiff-bat *Tadarida australis*. P. 319.
121. Richards, G. C. (1983i) Northern Mastiff-bat *Chaerephon jobensis*. Pp. 320-321.
122. Richards, G. C. (1983j) Little Mastiff-bat *Mormopterus norfolkensis*. Pp. 322-323.
123. Richards, G. C. (1983k) Greater Long-eared Bat *Nyctophilus timoriensis*. Pp. 328-329.
124. Richards, G. C. (1983l) Gould's Long-eared Bat *Nyctophilus gouldi*. P. 330.
125. Richards, G. C. (1983m) Chocolate Wattled Bat *Chalinolobus morio*. P. 341.
126. Richards, G. C. (1983n) Little Pied Bat *Chalinolobus picatus*. P. 342.

127. Richards, G. C. (1983o) Large-footed Mouse-eared Bat *Myotis adversus*. Pp. 346-347.
128. Richards, G. C. (1983p) Greater Broad-nosed Bat *Nycticeius rueppellii*. Pp. 348-349.
129. Richards, G. C. (1983q) Little Broad-nosed Bat *Nycticeius greyii*. Pp. 350-351.
130. Richards, G. C. (1983r) Western Broad-nosed Bat *Nycticeius balstoni*. P. 352.
131. Richards, G. C. (1983s) Golden-tipped Bat *Phoniscus papuensis*. P. 355.
132. Richards, G. C. (1983t) Little Cave Eptesicus *Eptesicus pumilus*. P. 359.
133. Richards, G. C. (1983u) King River Eptesicus *Eptesicus regulus*. P. 360.
134. Richards, G. C. (1983v) Little Forest Eptesicus *Eptesicus vulturnus*. P. 361.
135. Richards, G. C. (1983w) Large Forest Eptesicus *Eptesicus sagittula*. P. 363.
136. Richards, G. C. (1983x) Tube-nosed Insectivorous Bat *Murina florium*. P. 364.

APPENDIX 2: DESCRIPTION OF SAMPLING SITES

HIDES 3 SURVEY			
Detector night	General site description	Major habitat type	Date sampled
1	Well head area centre	Open	24-Apr
2	SR Hill bamboo thicket	Moss forest	24-Apr
3	Northwest edge of well head area	Open	25-Apr
4	Edge of well head area at Meditation Rock	Over canopy	25-Apr
5	Wayne's Swamp	Moss forest	25-Apr
6	Halfway to Wayne's Swamp	Moss forest	25-Apr
7	On SR Hill, overlooking a gully	Forest clearing	26-Apr
8	Within forest near explosives shed	Moss forest	26-Apr
9	Well head cover, pointing directly skywards	Open	26-Apr
10	Overlooking clearing near explosives shed	Forest clearing	26-Apr
11	Detector pointing into forest from open explosives shed clearing	Moss forest	26-Apr
12	Latrine site 1 overlooking forest gully and valley	Over canopy	26-Apr
13	Ted's net site on hill just W of camp	Moss forest	27-Apr
14	FC's net site just N of camp down from Med Rock (in forest)	Moss forest	27-Apr
15	Latrine site 2 facing into a large clearing to target <i>Rhinolophus arcuatus</i>	Forest clearing	27-Apr
16	Pointing into airspace over valley to east of camp	Over canopy	27-Apr
17	Small clearing just at the back of workers camp - start of SR Hill track	Forest clearing	27-Apr
18	Well head cover, pointing directly skywards (2nd night)	Open	27-Apr
19	Latrine site 1 overlooking forest gully and valley	Over canopy	28-Apr
20	Latrine site 2 facing into a large clearing to target <i>R. arcuatus</i>	Over canopy	28-Apr
21	Pointing into airspace over valley to east of camp	Over canopy	28-Apr
22	Small clearing just at the back of workers camp - start of SR Hill track	Forest clearing	28-Apr
23	Ted's Hollow – detector within small clearing	Moss forest	29-Apr
24	Ted's Hollow – detector pointing above	Moss forest	29-Apr
25	Latrine site 1 overlooking forest gully and valley	Over canopy	29-Apr
26	Latrine site 2 facing into a large clearing to target <i>R. arcuatus</i>	Over canopy	29-Apr
27	Well head - short session	Open	29-Apr

BENARIA SURVEY			
Detector site/night	General site description	Major habitat type	Date sampled
1	Detector pointing into mid canopy of riverine RF from top of river stairs	Hill rainforest	1-May
2	Ecotone between kunai and riverine rainforest near camp	Regrowth	1-May
3	Open area (kunai) behind camp	Open area	1-May
4	Halfway down river to river, pointing into subcanopy	Riverine forest	2-May
5	On riverbank overlooking water	River	2-May
6	Ecotone between kunai & riverine rainforest near camp, at net site 1	Regrowth	2-May
7	Ecotone between kunai & riverine rainforest near camp, at net site 2	Regrowth	2-May
8	Halfway down river stairs pointing into subcanopy	Riverine forest	3-May
9	At bottom of stairs to river, pointing downstream	River	3-May
10	Top of ridge up from WWF track	Hill rainforest	3-May
11	Top of ridge further up from WWF track	Hill rainforest	3-May
12	Detector pointing along a small creek along track to garden near river, at mammal point 6c	Hill rainforest	3-May
13	Ecotone between kunai and riverine rainforest nr camp	Regrowth	4-May
14	Top of ridge up from WWF track	Hill rainforest	4-May
15	Halfway up ridge up from WWF track	Hill rainforest	4-May
16	Detector pointing along a small creek along track to garden near river, at mammal point 6c	Hill rainforest	4-May
17	Ecotone between kunai and riverine rainforest near camp at net site 2	Regrowth	4-May
18	Detector pointing into open sky east of work tent	Open area	4-May
19	Top of ridge (fern and scattered trees above dry moss forest)	Ridgetop	3-May
20	Top of ridge (fern and scattered trees above dry moss forest)	Ridgetop	4-May
21	Top of ridge (fern and scattered trees above dry moss forest)	Ridgetop	5-May
22	Open area (kunai) behind camp pointing towards ridge	Open area	5-May
23	Open area in front of camp, pointing towards helipad	Open area	5-May
24	Hill rainforest (lower slopes) at bird net site 1 near camp	Hill rainforest	6-May
25	Hill rainforest (lower slopes) at bird net site 2 on creek near main track to garden	Hill rainforest	6-May
26	Riverine rainforest 100m upstream from stairs to river	Riverine forest	6-May
27	On riverbank 100m upstream from end of stairs to river	River	6-May
28	Ecotone of riverine rainforest edge and kunai approx 200m south of camp	Regrowth	7-May
29	On riverbank approx 200m north of stairs to river	River	7-May
30	Riverine rainforest opposite site 27 in small clearing	Riverine forest	7-May
31	Riverine rainforest at mist nets set approx 100m behind camp	Riverine forest	7-May

APPENDIX 3: ANALYSIS OF BAT ECHOLOCATION CALLS AND JUSTIFICATION OF SPECIES IDENTIFICATIONS.

Introduction

Prior to the current survey, there has never been any serious or extensive use of bat call detections systems for other surveys of the bat fauna of Papua New Guinea. Tanya Leary (pers. comm.) and colleagues used detectors to obtain reference calls from bats that were captured in mist nets or harp traps during surveys at the Darai Plateau and Libano River, but the technique has not been used to assess the microchiropteran bat fauna in formal ecological studies.

Experience elsewhere has shown the high value of using this technique, especially to record species that fly above the 2 – 3 metre height of mist nets and traps. For the current survey there were very few echolocation reference calls that were available to confirm identifications, but for most species a number of call characteristics (described below) could be used to gain a high probability of species identifications. The Anabat™ detection system used during the PNG Gas Project involves field recording using automated equipment that saves each burst of calls as a file, each of which is named by data from a computer clock, thus giving the date and time of the event. Files are displayed using dedicated software, and during the survey this was done in the field. An example display with three species of bats is shown in Figure 1.

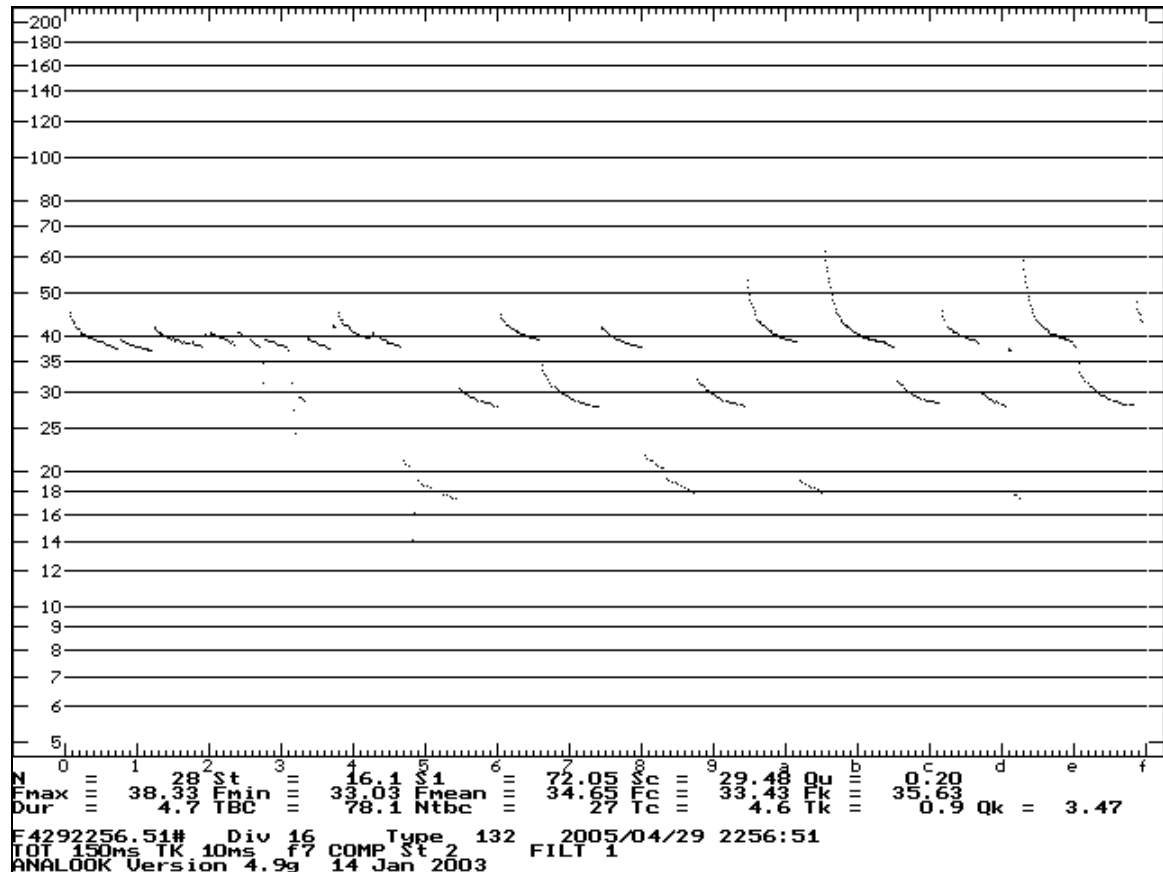
Call characteristics

Each microchiropteran bat family or subfamily has a distinctive call structure. There are two types of calls – CF and FM, and variations within, as follows:

- **CF** - those with a constant frequency component, which is a pure flat tone with descending and/or ascending parts at each end of the call, typical of horseshoe and leafnosed bats (Rhinolophidae and Hipposideridae) (Figure 2). There is an inverse relationship between the average body size of each species and the frequency of the CF component, that is, large bats have low frequencies and small bats have high frequencies. This relates to the size of the prey upon which their sonar is focused, so a small leafnosed bat with a CF component exceeding 100 kHz is likely to specialise on mosquitos and midges, whereas a large species would probably specialise on large beetles and moths. An example of this relationship is shown in Figure 3.

Because of this relationship, a regression of body size (forearm length) against CF component in known species will produce a fairly precise equation from which unknown species can be predicted, based simply on their forearm length, and without the necessity to have an echolocation reference call.

Figure 1: An example of the display produced by Anabat call analysis software. The y-axis shows frequency (kHz) and the x-axis shows time in selectable units, in this case each major tick mark is 10 milliseconds. The display has been compressed by the software to remove “spaces” between calls, which are typically around 100 milliseconds apart. Three individual species can be seen on this display, one crossing at 40 kHz, another crossing at 30 kHz, and another at 18 kHz. Data below the graph is used in the call identification process. The line ‘Fmax to Fk’ provides frequencies averaged for particular sections of the calls, and the line below it shows average duration of the call (‘Dur’) and the time between calls (TBC), both of which have diagnostic uses.



- **FM** – frequency modulated calls that are used by microchiropteran bats in all other Old World families. These can have a shallow descent in frequency (“sh-FM”) and a very long duration, typical of sheath-tail bats (Emballonuridae) and freetail or mastiff bats (Molossidae) or they can descend steeply (“st-FM”), which is typical of “ordinary” bats (Vespertilionidae).

Within the Vespertilionidae there are variations that identify subfamilies. For example, long-eared bats, woolly bats and tube-nosed bats (Nyctophilinae including *Pharotis imogene*, Kerivoulinae and Murinae respectively), have very steep calls of short duration with a large bandwidth (frequency range < 30 kHz). Others, in the subfamily Vespertilioninae, have longer duration calls with a shorter bandwidth (> 30 kHz), and their calls have various diagnostic characters at their termination. These characters can often be used to separate genera within the Vespertilioninae.

Figure 2: Two Anabat displays as examples of CF calls. *Hipposideros semoni* at around 112 kHz (above) and *Rhinolophus megaphyllus* at around 68 kHz (below). The CF component is the flat line.

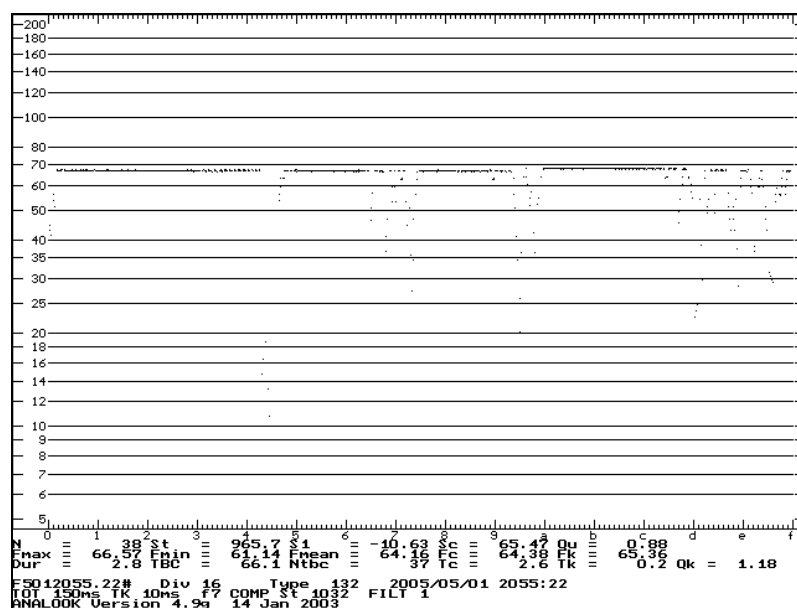
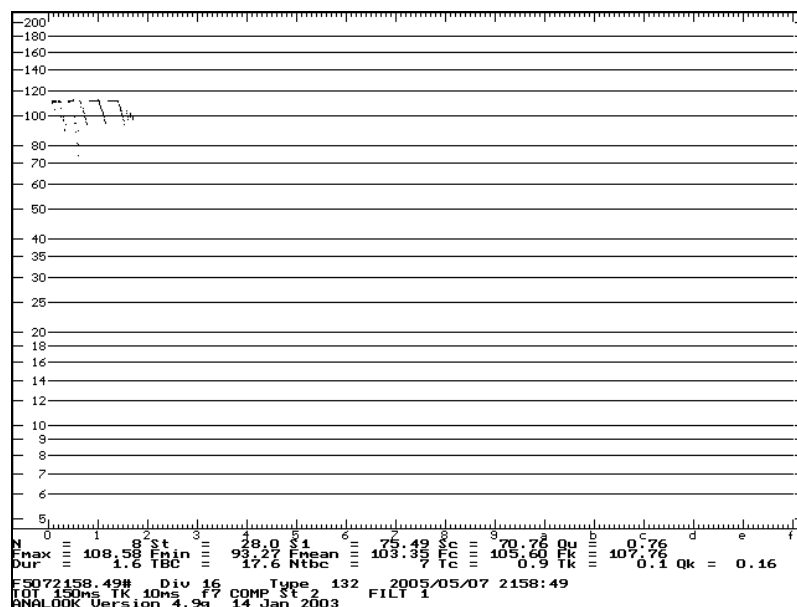
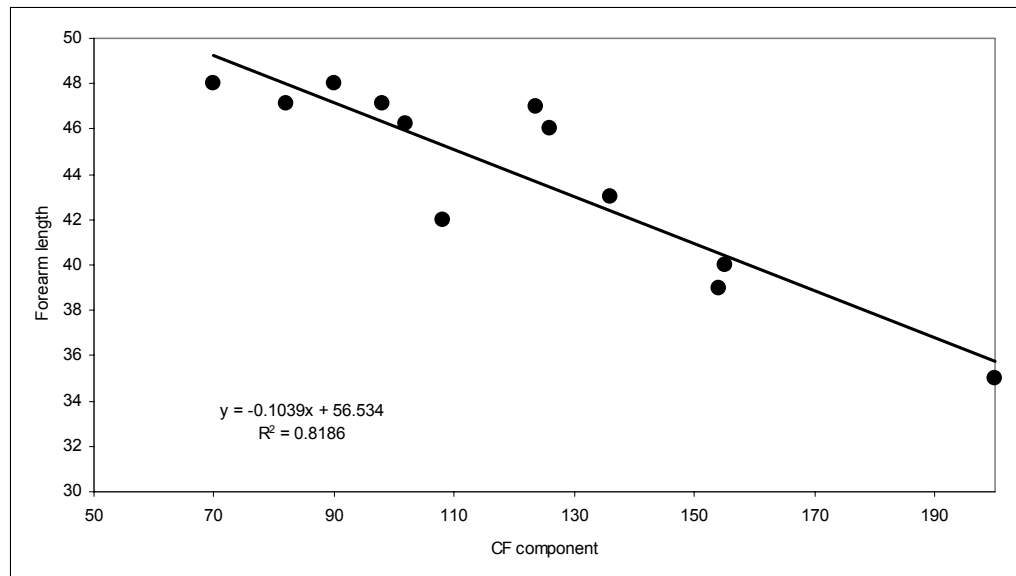


Figure 3: Plot of constant frequency (CF) component of known echolocation calls of small Australasian leafnosed bats (*Hipposideros*) with forearm lengths less than 50 mm.



Species identifications

Hipposideridae *Hipposideros semoni*

The call of *H. semoni*, with a CF component of around 112 kHz, is known from representatives on Cape York, Australia

Rhinolophidae *Rhinolophus arcuatus*, *Rhinolophus euryotis*, *Rhinolophus maros*, *Rhinolophus megaphyllus*, *Rhinolophus philippinensis*

The calls of *Rhinolophus megaphyllus*, *R. maros* and *R. philippinensis* were known from representatives recorded in Australia. *R. maros* and *R. philippinensis* were previously considered as one species but proved to be separable (primarily) on the significantly different CF components of their calls. The survey provided the first record of *R. maros* for PNG, a factor that emphasises the value of this method for ecological assessments. *R. arcuatus* and *R. euryotis* were separated by the body size – CF component relationship, with CF components predicted as 42 and 54 kHz respectively. After the survey, reference calls provided by Tanya Leary confirmed these predictions.

Emballonuridae *Emballonura dianaefurax* complex

Mosia nigrescens

The calls of two small emballonurids were recorded during the survey, each with a minimum frequency (Fmin) around 28 and 36 kHz. Using the inverse relationship between body size and Fmin, the smallest PNG emballonurid with a frequency as high as the latter could only be *Mosia nigrescens*. A plot of emballonurid body size against Fmin predicted that *M. nigrescens* should have Fmin around 33 kHz.

The calls with a Fmin of 28 kHz could be attributed to one of four *Emballonura*, all of which are found below 1600 m. Candidates include, ranked in ascending order of forearm length (brackets), *E. beccarii* (37-42 mm), *E. raffrayana* (37-42 mm), *E. diana* (45-49 mm) and *E. furax* (48-53 mm). Given their larger body size and considering the inverse relationship with call frequency, the Fmin of 28 is more likely to be applicable to the latter two species. *E. diana* and *E. furax* are both IUCN listed as Vulnerable, and for the purposes of this report and until the individual species is confirmed, they have been treated as the one conservation unit.

No large emballonurids (*Taphozous* or *Saccolaimus*), for which most calls were previously known, were recorded during the survey.

Vespertilionidae

Chalinolobus nigrogriseus, *Miniopterus (propitristis)*, *Miniopterus magnater*, *Murina florium*, *Nyctophilus* spp., *Pipistrellus angulatus*, *Pipistrellus collinus*, *Philetor brachypterus*

The characteristic call of *Chalinolobus nigrogriseus* with Fmin around 38 kHz, was previously known from Australia.

At a generic level, *Miniopterus* calls are quite distinctive from other vespertilionid calls, having a short bandwidth and a long duration. There are a number of *Miniopterus* species known from New Guinea and the calls of two, *M. schreibersii* and *M. australis*, were previously known from Australia.

Species of *Miniopterus* that were potential candidates to be recorded in the survey area are shown in Table 1 with body size range, the known Fmin of some, and the predicted Fmin of others. The range in body size was used to provide a working name for each of the *Miniopterus*-type calls recorded.

Table 1: Known and predicted [in brackets] *Miniopterus* calls recorded during the survey.

Species	Forearm range	Known or predicted Fmin (kHz)
<i>M. australis</i>	38 – 41	55
<i>M. medius</i>	40 – 48	[46-47]
<i>M. macrocneme</i>	40 – 50	
<i>M. schreibersii</i>	44 – 51	43
<i>M. magnater</i>	48 - 54	[40]
<i>M. propitristis</i>	50 – 56	[38]

Murina florum

The long sweeping call of *M. florum* was known from Australia and was only recorded on one occasion at Hides 3.

Nyctophilus spp.

Nyctophilus (and probably *Pharotis imogene* which is in the same subfamily) have a very distinctive call structure, which is almost a straight vertical line, with no terminal curvature, when plotted by the Anabat software. However, if the case is the same as it is with Australian *Nyctophilus*, then it is virtually impossible to separate these calls to species level. This is because they have very soft (low intensity) calls that do not display all of the essential characters that are shown with calls from other groups that are necessary for species identification.

Hence, as is done in Australia, *Nyctophilus* are identified only as a genus. For the purposes of the survey, the only high altitude candidates were *N. microtis* and *N. microdon* and were assessed together.

Pipistrellus spp.

Four small pipistrelles are known from PNG. *P. watti* is found only along the coast (up to 200 m) and has been ruled out of any possibility of occurring in the montane portion of the study area. Of the three other species (*P. papuanus*, *P. angulatus* and *P. collinus*) only the latter two are known to occur at altitudes above 1300 m. At Hides 3 and Benaria, two series of typical pipistrelle calls were recorded with Fmin above 50 kHz, which appeared similar in structure (very steep FM with a duration of less than 2 ms) to calls of *P. westralis* and *P. adamsi* from northern Australia.

P. collinus (altitude range 700 - 2800 m) and *P. angulatus* (altitude range 0 – 2400 m) appeared to be the only candidates to which these calls could be referred. The two species were allocated to the two call types recorded in surveys, based on the inverse relationship between body size and Fmin: the smaller of the two was attributed to *P. angulatus* (forearm range 31.1 -

34.8 mm) with the higher Fmin of 55 kHz, and the larger *P. collinus* (forearm range 33.0 - 39.1 mm) was allocated to the lower Fmin of 50-52 kHz. *P. papuanus* is much smaller than the other two species (forearm range 27 – 32 mm) and would be expected to have a much higher Fmin, probably close to 60 kHz.

Philetor brachypterus

There is no information available that could lead to the identity of this small vespertilionine species, which has a call in the range 36-50 kHz, and a duration of 1.5 milliseconds. It has a slight terminal upturn as seen in Australian *Vespadelus* calls, but no *Vespadelus* are known from PNG. Calls of the other potential candidates for this call (*Chalinolobus nigrogriseus* and *Scotorepens sanborni*) are known to the author, and both have tight coastal PNG distributions that are related to Trans-Fly habitats and Ice-Age connections with Australia.

The similarity of the shape of the 36-50 kHz calls to those of Australian *Vespadelus*, *Scotorepens* and *Chalinolobus*, the close relationship of *Philetor* to these genera, and with no other options, led to the conclusion that these calls were from *P. brachypterus*. Interestingly, Bonaccorso (1998) states that "*This species has narrow, stubby wings, unexpected for a bat that forages in forest understorey and sub-canopy...*". Notably, these days it is understood that such flight morphology characters (that is, a short stubby wing design = low wing aspect ratio) in fact suggest a highly manoeuvrable flight and occupation of niches in dense rainforest habitats (Crome and Richards 1988).

Molossidae *Otomops secundus*, *Tadarida kuboriensis*

The calls of large molossids are readily identifiable, being shallow FM at low frequencies and of long duration. These animals are large, similar in body size to large emballonurids such as *Saccolaimus* and *Taphozous*, but their calls differ in a slight downturn in the terminal portion of each one. Based on Bonaccorso (1998) two molossids were expected to occur at the Hides 3 and Benaria sites: *Tadarida kuboriensis* and *Otomops secundus*.

On past occasions *T. kuboriensis* has been considered as merely a subspecies of *T. australis* from Australia. It may in fact be a valid species that evolved during the Pliocene when the range of both taxa was split by the aggressive molossid *Chaerephon jobensis* (Richards 2002). The latitudinal distributions of these three taxa are: *T. australis* generally south of the Tropic of Capricorn, *C. jobensis* generally distributed above the Tropic and then northwards to Southeast Asia but excluding PNG, and *T. kuboriensis* distributed only in PNG.

The calls of *T. kuboriensis* in this study appear to be sh-FM and in the range of 10 - 14 kHz. There are no other PNG species that have a similar call. The calls of *T. australis* from Australia are also sh-FM and similar to *T.*

kuboriensis but are in the frequency range 12 - 16 kHz. The slightly higher frequency range for *T. kuboriensis* would fit with the inverse relationship between body size and Fmin.

Another molossid call (sh-FM ranging 19 - 21 kHz) that was recorded at both Hides 3 and Benaria was ostensibly similar to *C. jobensis* (known to the author) but was assumed to be *Otomops secundus* because in PNG *C. jobensis* has primarily a coastal lowland occurrence and is regarded as a woodland species (Crome and Richards 1988). The only remaining molossid candidates included *Mormopterus beccarii* (call known to be sh-FM around 26 kHz), *M. loriae* (call known to be sh-FM around 35 kHz) and *O. papuensis* (call is unknown but this species is restricted to the coast up to 300m). Bonaccorso (1998) states that all but one of the few records of *O. secundus* are montane (1800-2000m), with one being a road kill from the Port Moresby area. Such records, where a dead bat is removed from a car grill, should be treated with caution as the actual site of 'collection' may be distant. For the purposes of this study, because (a) no other molossids are likely to have a similar call and (b) the Fmin frequency fits the inverse body size relationship, all highland molossid calls in the range 19-21 kHz were attributed to *O. secundus*.

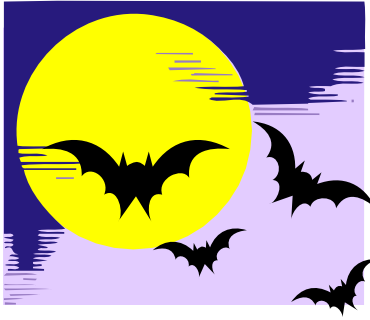
References

- Bonaccorso, F. J. (1998) *Bats of Papua New Guinea*. Conservation International Tropical Field Guide Series 2, Conservation International: Washington DC.
- Crome, F. H. J. and Richards, G. C. (1988) Bats and gaps : Microchiropteran community structure in a Queensland rain forest. *Ecology* 69 :1960-1969
- Richards, G. C. (2002) *Ecological and evolutionary determinants of bat community structure in south-east Australian forests*. Unpublished PhD Thesis, Biological Sciences, University of NSW: Sydney.

Annex 06

Biodiversity survey results:

**Bats at Juha North, Juha South, Baia River, South Karius and
Deviation Camp in 2008**



THE PAPUA NEW GUINEA LIQUEFIED NATURAL GAS PROJECT:

A STUDY OF BAT FAUNAL BIODIVERSITY AND AN ASSESSMENT OF POTENTIAL IMPACTS

*Prepared by Dr G.C. Richards
For Coffey Natural Systems, Melbourne, Victoria
July 2008*

Greg Richards and Associates Pty Ltd
Postal: P.O. Box 9, Gungahlin Town Centre, ACT 2912
Office: 23 Tanderra Crescent, Ngunnawal, ACT 2913
Phones: 02 6255 0606 0408 221 520
Email : batmangr@bigpond.net.au
ABN 99 074 890 823

STANDARD DISCLAIMER¹

The following report is explicitly the opinion of the consultant, and is based upon data available and assessments conducted according to the methods described. Greg Richards and Associates (GR&A) has had to rely on information from other sources in preparing this report (including the party for whom it is prepared) and is not in a position to, and has not, verified the accuracy or completeness of information so provided. Accordingly, GR&A takes no responsibility for and assumes no liability in respect of, any information provided by others for the purposes of preparing this report nor the consequences of using such information. This document is prepared only for the persons or company to whom it is addressed and the report and any information or conclusion in it, is not intended to be, and should not be, relied upon or used by any other person. GR&A accepts no liability where any person so uses or relies upon it contrary to the preceding sentence.

¹ This is a requirement of the consultant's insurance company.

Table of Contents

1	EXECUTIVE SUMMARY.....	6
2	PREFACE.....	9
3	INTRODUCTION	10
3.1	THE STUDY IN BRIEF AND PURPOSE OF REPORT	10
3.2	THE PNG BAT FAUNA – ASPECTS RELEVANT TO ECOLOGICAL STUDIES	10
3.2.1	EVOLUTIONARY HISTORY	10
3.2.2	BIOGEOGRAPHY	11
3.2.3	HABITAT	11
3.2.4	GEOMORPHOLOGY.....	11
3.3	BACKGROUND INFORMATION.....	11
3.4	ECOLOGICAL NICHES OF THREATENED SPECIES	21
4	FIELD SURVEY.....	22
4.1	SURVEY AREAS	22
4.2	METHODS.....	26
4.3	SURVEY EFFORT	28
4.4	SAMPLING SITES AND REPLICATION.....	28
4.5	VALIDATION OF PRIMARY SURVEY METHOD	32
5	RESULTS	33
5.1	SPECIES RECORDED AT SURVEY AREAS	33
5.2	SPECIES RICHNESS	35
5.3	RELATIVE ABUNDANCE OF MICROCHIROPTERAN BATS.....	36
5.4	MICROCHIROPTERAN BAT HABITAT UTILISATION	37
5.5	HABITAT PREFERENCES OF MICROCHIROPTERAN BATS	40
5.6	MEGACHIROPTERAN BATS	42
6	POTENTIAL PROJECT IMPACTS AND RECOMMENDATIONS	44
6.1	THE CRITICALLY ENDANGERED SPECIES.....	45
6.1.1	NEW GUINEA BIG-EARED BAT (<i>PHAROTIS</i> <i>IMOGENE</i>)	45
6.1.2	BULMER’S FLYING FOX (<i>APROTELES BULMERAE</i>)	47
6.2	CAVE-DEPENDENT BAT SPECIES AND CAVE CONSERVATION ISSUES.....	48
6.3	GENERAL IMPACT ASSESSMENT	49
7	REFERENCES	57

Tables

Table 1: Abbreviated citations of WWF KICDP (and other) reports that were consulted for area-specific background information.

Table 2 Bat species known or predicted to occur at different elevations (0 – 2200 m) along the project pipeline corridor.

Table 3 A summary of the ecological niches occupied by threatened (IUCN listed) species.

Table 4: Location, elevation and period of sampling at each of the areas surveyed in 2008.

Table 5 Summary of survey effort using bat call detection. in 2008 compared with 2005 (Annex 05 to Biodiversity Appendix)

Table 6 Replication of habitat types across survey areas in 2008 compared with 2005 (Annex 05 to Biodiversity Appendix).

Table 7 Species recorded at each survey area during the 2005 and 2008 surveys. The areas are ranked according to elevation.

Table 8 Overall relative abundance of microchiropteran bat communities based on the average number of site records (that is, occurrence at each sampling site within each survey area).

Table 9 Site records of each species at each survey area studied in 2008.

Table 10 Patterns of habitat utilisation by microchiropteran bat species recorded (●) during the 2008 field surveys.

Table 11 The proportion of the total calls recorded for each microchiropteran species during the 2008 survey in each of the habitats that they utilised.

Table 12 Summary of ecological characteristics of microchiropteran bats recorded from the 2008 surveys that are relevant to impact assessment.

Table 13 Megachiropteran bats that are expected to occur or were recorded at faunal assessment areas.

Table 14 Cave bat species known or predicted to (●) occur at different elevations in the project area

Table 15 Summary of potential impacts and mitigation measures for species (or species groups) of concern that are predicted to occur (Table 2) along the pipeline corridor, showing those that are considered to be unaffected by the pipeline construction and operation.

Table 16 General impacts that apply to the bat fauna, prioritised according to their perceived effect on local populations of threatened species

Table 17 Classification of species listed in IUCN threat categories by the potential for impact, based on scores generated from IUCN status.

Figures

Figure 1. Map of all sites.

Figure 2 Sampling trails at Juha North survey area.

Figure 3 Sampling trails at Juha South survey area.

Figure 4 Sampling trails at Baia River survey area.

Figure 5 Sampling trails at South Karius survey area.

Figure 6. Sampling trails at Deviation Camp survey area.

Figure 7 Automated bat call detector enclosed in weatherproof gear, set along a marked trail in moss forest.

Figure 8 Harp trap set in a flyway in regrowth forest.

Figure 9 Mist net set in moss forest.

Figure 10 Transmitting video camera and portable television monitor used to inspect potential roost hollows for bats.

Figure 11 Species accumulation curves for the five areas sampled during 2008, based on the number of bat detector nights.

Figure 12 The relationship between species richness and elevation at the sampling areas assessed in 2005 and 2008. The elevation of each sampling area is shown in Table 5.

1 Executive Summary

This report contributes to an Environmental Impact Statement for the Papua New Guinea Liquified Natural Gas Project (PNG LNG Project), and outlines an intensive study of the bat fauna using current state-of-the-art survey methods and an assessment of potential impacts on each threatened or sensitive species. An analysis of five sampling areas in the PNG LNG Project area surveyed in early 2008 (Juha North and South, Baia River, South Karius, and the Deviation Camp) is included in this report. Because these sites covered an elevational range of around 2000 metres above sea level, the selection of these sites provided an insight into altitudinal variation in bat community structure.

Sampling of the bat fauna was conducted at survey areas within which sampling sites for bats were selected to either accommodate different habitats or to target certain threatened species. Automated bat call detectors were used to remotely obtain records of echolocating microchiropteran bats. Bat traps and mist nets were used to capture microchiropteran bats and fruit bats (Megachiroptera). Survey effort for this and the 2005 surveys (Annex 05 to the Biodiversity appendix) using bat detectors totalled around 1300 hours over 119 detector nights, which is understood to be the largest survey conducted via this technique to date in Papua New Guinea. Almost 150,000 bat detector files were recorded, each being examined in the field. Species accumulation curves for the bat detection method showed that by the second night of survey the average percentage of the final species total approached 90%, hence justifying the minimum of five nights of survey by this method.

A total of 34 bat species were recorded during the 2008 making a total of 36 species with that from 2005 survey. This number of species equates to nearly half of the approximately 70 species that are known from the Papua New Guinea mainland.

There was a weak inverse relationship between species richness and elevation, with lower elevations having up to 26 species present, and 9 – 14 species at the highest elevations studied. The Juha North area, the lowest in elevation, had a higher relative abundance of microchiropteran bats than the other survey areas. Eleven taxa were categorized as being rare and of these two species were restricted to high elevations (> approximately 2000 m a.s.l.), and the remainder were recorded from elevations below 300 metres a.s.l.

In the assessment of relative abundance of microchiropteran bats in major habitats during the 2008 surveys a number of patterns relevant to the impact assessment were revealed, particularly that there were far less species utilising rainforest than many of the more open habitats. The edges of rivers and major clearings or open areas were primary habitats, and the highest number of species were recorded along river edges than in any other habitat. At some survey areas, only five species were recorded in rainforest compared with 13 species at river edges.

Also, activity (and relative abundance) in rainforest totaled 3680 calls compared with 25,881 recorded in edge and open habitats. The creation of edge habitat by tree clearance to construct the pipeline corridor is therefore expected to provide some overall benefit to local bat communities. Also of note is that 15 species were recorded in regrowth areas, nearly as many as in rainforest. This factor, and the heavy bias towards edges and open

areas, may indicate that the Papua New Guinea microchiropteran bat fauna may have evolved to accommodate regular broad-scale disturbance, such as landslides and volcanism.

It was apparent that there is some broad partitioning by the community into assemblages that are separated by a preferred habitat. Within families, where flight patterns and foraging styles are similar, there were some species primarily utilising either river edges or rainforest edges, and others that preferred either open areas or rainforest. To assist with the impact assessment, habitat specialisation, rarity, and foraging specialisation characteristics were assessed to identify a group of species that may have been affected by habitat loss. Ten species fell into this category, but only two of them preferred rainforest, with the others preferring edges or open areas.

Megachiropteran bats were not possible to assess with the same accuracy as microchiropteran bats because capture methods are unreliable, depending mainly upon whether the capture device was positioned in a flyway or near a food source. Hence, predicted distributions and presence or absence of species at different elevations were used in the analyses for impact assessment.

Fifteen megachiropteran species could be expected in the section of the pipeline corridor that was studied, seven of which are listed on the IUCN Red List of Threatened Species (IUCN threat list). A potential record of one of these, Bulmer's Flying Fox, which is listed as Critically Endangered, was obtained during the 2008 surveys. Information from a local villager was obtained that a colony of this species may be located near the village of Angore, south-east of Nogoli. A spinline from the Angore gas wells is planned to pass by this village therefore it is recommended that further investigations into this cave colony be conducted prior to finalization of the route of the spinline.

The potential for the project to impact upon bat species was evaluated by considering whether construction and operation of the project would allow any bat species to fall into the Critically Endangered, Vulnerable and Near Threatened categories of the IUCN Red List. For bats, the primary potential impacts identified included hunting, disturbance from blasting and human activities, and tree roost clearance. Specifically:

- Cave dwelling species being hunted, particularly the Critically Endangered Bulmer's Fruit Bat (*Aproteles bulmerae*)
- Roosts and maternity colonies in caves being exterminated during construction by destruction of the cave or disturbance from blasting
- Cave dwelling species being affected by human visitation
- Hollow roosting species being affected during tree clearance operations in lowland areas, particularly the New Guinea Big-eared Bat (*Pharotis imogene*) which is listed as Critically Endangered.

Each species was prioritised by generating a score based upon whether it was endemic to Papua New Guinea, whether it was a cave dwelling species and in particular whether it was regarded as a food item, and whether the ecological assessment determined it to be a habitat specialist, or whether it was rare or was restricted in distribution. Of the in IUCN

threat categories, only five were expected to be impacted, as long as a number of mitigation procedures were accepted. These mitigation procedures included the development of protocols for the felling of trees with hollows in lowlands (0-200m) to protect the New Guinea Big-eared Bat (*Pharotis imogene*) and the protection of caves from disturbance and from hunters. The latter action would protect any Bulmer's Flying Fox colonies and colonies of small microchiropteran bats.

2 Preface

This study is part of a suite of terrestrial biodiversity investigations that have been conducted for the EIS for the proposed PNG LNG Project. This study report forms part of the EIS and the findings herein support the assessment of potential impacts on terrestrial biodiversity that are discussed in the EIS by other consultants. A detailed description of the proposed PNG LNG Project is provided in the main Biodiversity Appendix report.

3 Introduction

3.1 The study in brief and purpose of report

The bat study took the form of an intensive biodiversity survey using current state-of-the-art bat fauna assessment methods, followed by an assessment of potential impacts on each threatened or sensitive species. Objectives of the study were:

- To provide information on bats, bat ecology, and potential impacts of the project on bats in the project area.
- To compare and integrate the findings of the 2008 survey with the 2005 survey data collected for the PNG Gas Project (Annex 05 to Biodiversity Appendix).
- To provide advice on management and monitoring methods to mitigate/reduce impacts on bats and biodiversity in general.

Greg Richards and Associates (GR&A) Pty Ltd was commissioned in 2005 to conduct an assessment of the bat fauna for the PNG Gas Project (Annex 05 to Biodiversity Appendix). In 2008 these studies were extended to cover new areas associated with the PNG LNG Project along the Juha-Hides Pipeline ROW and the LNG Project Gas Pipeline in the Homa area. The data from the 2008 surveys allowed positive identifications of four species unidentified in the 2005 study, and an update on the ecology and behaviour of many species. The data from 2005 and 2008 have been combined in several sections of this report.

3.2 The PNG bat fauna – aspects relevant to ecological studies

Over 90 species of bats are known from Papua New Guinea, 71 of which are known from the main island. The remainder are found in the Bismarck Archipelago and other offshore islands. This high diversity approaches 10% of the world's species, and six of the 18 extant families are represented in this country. About one-fifth of the total PNG species belong to the suborder Megachiroptera. The remaining five families belong to the Microchiroptera. Of importance to the project and impact assessment are four factors:

3.2.1 Evolutionary history

Large areas of limestone are associated with the raising of the sea floor when the Australasian plate collided with the Pacific plate during the Pliocene epoch, around 5 million years ago. At this time, PNG was an island arc (Flannery 1995) separated from the open woodland Australian bat fauna, but linked to the South-east Asian rainforest bat fauna. Extensive limestone areas provided roosts for cave dwelling microchiropteran species, a highly diverse suborder in Southeast Asia and throughout the Old World. A number of endemic species evolved, particularly in the horseshoe (Rhinolophidae) and leafnosed bat families (Hipposideridae). Several megachiropteran species that roost in caves also evolved.

During the Miocene (20 million years ago), as the Australian continent dried, the rainforests that dominated the landscape retreated to refugia and eucalypts prevailed. As a consequence, the Australian bat fauna changed to occupy major niches in the eucalypt woodland (Richards 2002). Lowered sea levels during Pleistocene ice ages (10-20,000 years ago) allowed the connection of PNG with Australia, and an infiltration of the bat fauna into PNG from the south. However, many of these species are restricted to coastal areas or the Trans-Fly region.

3.2.2 Biogeography

The geological evolutionary factors outlined above have shaped a bat fauna that is a mixture of:

- (a) PNG endemics that appear to be rainforest specialists,
- (b) South-east Asian or Old World taxa that have speciated over many millions of years (such as Horseshoe Bats (genus *Rhinolophus*), Leafnosed Bats (genus *Hipposideros*), Bentwing Bats (genus *Miniopterus*) and Pipistrelles (genus *Pipistrellus*) and
- (c) Open habitat taxa that are endemic to Australia (including vespertilionids such as Broad-nosed Bats (genus *Scotorepens*), Wattled Bats (genus *Chalinolobus*) and Longeared Bats (genus *Nyctophilus*).

3.2.3 Habitat

The large extent of undisturbed bat habitats, including the rainforests of the central cordillera of the PNG island itself, and the mangroves, swamp forests and woodlands of the Gulf of Papua region, provide a vast array of ecological niches for the bat fauna. A large number of foraging guilds are represented, all within generalist and specialist assemblages (*sensu* Richards 2002).

3.2.4 Geomorphology

Of relevance to impact assessment is that the recent geological age of the island has created a terrain that is steep and rugged, making human access impossible in many areas. Human access to large tracts of montane forest is further restricted by the settlement of areas where subsistence agriculture can or cannot be carried out, where a cool climate and lack of productive soils appears to set an altitudinal limit to human occupation and settlement, and consequent disturbance of the bat fauna.

3.3 Background information

Background information was obtained from several sources, including Flannery's (1995) book on New Guinea mammals, Bonaccorso's (1998) field guide, and reports from World Wide Fund for Nature activities related to the Kikori Integrated Conservation and Development Project (KICDP). Localities covered by WWF KIDCP reports, used to inform the assessment in the area south of Kutubu that included relevant bat information are shown in Table 1. Studies carried out by WWF in the KICDP area were used to inform the

assessment south of Kutubu. North of Kutubu, where there was limited existing information, seven bat surveys were undertaken at various elevations and habitat types in the project area. Two of these were carried out in 2005 and are reported in Annex 05 to the Biodiversity Appendix, and five in 2008.

The list of 91 bat species that were likely to inhabit the broader region surrounding the pipeline corridor, known from PNG *per se*, was generated from Bonaccorso (1998). Information on the altitudinal limits of species so identified were tabulated to provide a working list of the potential bat fauna at each elevation of the pipeline corridor (Table 2).

From the working list, it was concluded that the following threatened species were potentially present in the project area, and were classified in a number of IUCN categories:

Critically Endangered:	Thomas' Big-eared Bat (<i>Pharotis imogene</i>)
	Bulmer's Flying Fox (<i>Aproteles bulmerae</i>)
Vulnerable:	Moss Forest Blossom Bat (<i>Syconycteris hobbit</i>)
	Small-toothed Bat (<i>Nyctophilus microdon</i>)
	Papuan Sheath-tailed Bat (<i>Saccolaimus mixtus</i>)
	Fly River Leaf-nosed Bat (<i>Hipposideros muscinus</i>)
	Papuan Mastiff Bat (<i>Otomops papuensis</i>)
	Telefomin Leaf-nosed Bat (<i>Hipposideros corynophyllus</i>)
	Mantled Mastiff Bat (<i>Otomops secundus</i>)
	Lesser Tubenosed Bat (<i>Nyctimene draconilla</i>)
	Greater Big-eared Bat (<i>Nyctophilus timoriensis</i>)
	Fly River Woolly Bat (<i>Kerivoula muscina</i>)
	Large-eared Sheath-tail Bat (<i>Emballonura diana</i>)
	New Guinea Sheath-tail Bat (<i>Emballonura furax</i>)
Near Threatened:	Lesser Bare-backed Bat (<i>Dobsonia minor</i>)
	Greater Tube-nosed Bat (<i>Nyctimene aello</i>)
	Round-eared Tube-nosed Bat (<i>Nyctimene cyclotis</i>)
	Green Tube-nosed Bat (<i>Paranyctimene raptor</i>)
	Raffray's Sheath-tailed Bat (<i>Emballonura raffrayana</i>)
	Yellow-bellied Sheath-tailed Bat * (<i>Saccolaimus flaviventris</i>)
	Southern Sheath-tailed Bat * (<i>Taphozous australis</i>)
	Hill's Leaf-nosed Bat * (<i>Hipposideros edwardshilli</i>)
	Greater Leaf-nosed Bat (<i>Hipposideros semoni</i>)
	Wollaston's Leaf-nosed Bat (<i>Hipposideros wollastoni</i>)
	Large-eared Horseshoe Bat (<i>Rhinolophus philippinensis</i>)
	Papuan Pipistrelle (<i>Pipistrellus papuanus</i>)
	Watt's Pipistrelle * (<i>Pipistrellus wattsi</i>)

Table 1 Abbreviated citations of WWF KICDP (and other) reports that were consulted for area-specific background information. General information was obtained from Flannery (1995) and Bonaccorso (1998).

Abbreviated Citation	Omo	Mt Bosavi	Mt Sisa	Lake Kutubu	Agogo	Mt Kemenagi	Gobe	Iviri	Keboi Kerowa	Veiru/Veiru Creek	Jtiti Creek	Nassi Falls	Darai Plateau	Libano	agifu/Ridge Camp	Boavi-Didesa	Kopi	Au Cave	Kafa Village	Kantobo	Sirebi	Dark End Lumber	Naro	Fogomaiyu	Gesege Village	SE Mananda
Leary et al (1995) <i>Report on the bat component of the field survey of biodiversity in the Kikori ICDP area.</i>	•	•			•	•				•	•	•														
Leary & Seri (1995?) <i>Survey of Birds and Mammals at Utiti Creek.</i>														•												
Leary (2001) <i>Mammal Survey of Two Sites on the Northeast Slopes of Mt Sisa</i>			•																							
Leary (2002?) <i>Brief Report on Iviri Mammal Monitoring - December 2001</i>								•																		
Leary (2004?) <i>Brief report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003.</i>								•	•																	
Leary (2004?) <i>Brief report on Keboi Kerowa Mammal Monitoring</i>									•																	
Leary (2004) <i>Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province.</i>													•	•												
Leary (1998) <i>Mammals of the Lake Kutubu Swamp Forests.</i> (Wetlands International Report)				•																						
Leary (1999) <i>Mammal Survey of the Gobe Oil Field Area, Southern Highlands and Gulf Provinces.</i>							•																			

Table 1 Abbreviated citations of WWF KICDP (and other) reports that were consulted for area-specific background information. General information was obtained from Flannery (1995) and Bonaccorso (1998).

Abbreviated Citation	Omo	Vt Bosavi	Vt Sisa	_ake Kutubu	Agogo	Vt Kemenagi	Gobe	viri	Keboi Kerowa	Veiru/Veiru Creek	Jtiti Creek	Massi Falls	Darai Plateau	_ibano	agifu/Ridge Camp	Boavi-Didesa	Kopi	Au Cave	Kafa Village	Kantobo	Sirebi	Dark End Lumber	Waro	Fogomaiyu	Gesege Village	SE Mananda
Balun (2004?) <i>An Audit on the Status of the Flora and Fauna of the Porora Forest, South East Mananda Forest, Southern Highlands Province.</i>																										•
Leary & Seri (nd) An annotated checklist of mammals recorded in the Kikori River Basin	•	•			•	•				•	•	•			•											
Namo (2004a) <i>Annotated Checklist of Mammals of Kikori Basin.</i> [Summarises many of the above reports]	•	•	•	•		•	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•	

Table 2 Bat species known or predicted to occur at different elevations (0 – 2200 m) along the project pipeline corridor.*

	IUCN Status	K, NW, O, UC, VC	FV	Juha North	Baia River	WF, DP	WV			Mo, Mt K, LK	Juha South	AR	IC	Mt S	IR, MtB, South Karius	Benaria area						Homa Deviation		Hides 3
Elevation range (x 100m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Pteropodidae																								
<i>Aproteles bulmerae</i>	CR																							
<i>Dobsonia minor</i>	NT	○	○																					
<i>Dobsonia magna</i>		○	○	●		○				○	—		○	○	●	●								
<i>Pteropus alecto</i>																								
<i>Pteropus conspicillatus</i>																								
<i>Pteropus hypomelanus</i>																								
<i>Pteropus macrotis</i>		○	○																					
<i>Pteropus neohibernicus</i>		○	○			○				○		○												
<i>Pteropus scapulatus</i>																								
<i>Rousettus amplexicaudatus</i>																								
<i>Nyctimene aello</i>	NT	○	○		●	○																		
<i>Nyctimene albiventer</i>		○	○	●		○				○														

Table 2 Bat species known or predicted to occur at different elevations (0 – 2200 m) along the project pipeline corridor.*

	IUCN Status	K, NW, O, UC, VC	FV	Juha North	Baia River	WF, DP	WV			Mo, Mt K, LK	Juha South	AR	IC	Mt S	IR, MtB, South Karius	Benaria area						Homa Deviat-ion		Hides 3
Elevation range (x 100m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
<i>Nyctimene cephalotes</i>																								
<i>Nyctimene cyclotis</i>	NT									○					○									
<i>Nyctimene draconilla</i>	VU			?	?	?	?	?	?	?	?	?	?	?	○									
<i>Paranyctimene raptor</i>	NT	○	○	●		○	○			○					○	●								
<i>Paranyctimene</i> sp aff <i>raptor</i>																					●			
<i>Macroglossus minimus</i>		○	○	●		○																		
<i>Syconycteris australis</i>		○	○	●	●	○				○		○		○	●	●								●
<i>Syconycteris hobbit</i>	VU																							
Emballonuridae																								
<i>Emballonura beccarii</i>																								
<i>Emballonura diana</i>	VU			●	●									○		●								●
<i>Emballonura furax</i>	VU			●	●									○		●								●
<i>Emballonura raffrayana</i>	NT			○										○										
<i>Mosia nigrescens</i>		○	○								●				●	●						●		●
<i>Saccolaimus flaviventris</i>	NT																							

Table 2 Bat species known or predicted to occur at different elevations (0 – 2200 m) along the project pipeline corridor.*

	IUCN Status	K, NW, O, UC, VC	FV	Juha North	Baia River	WF, DP	WV			Mo, Mt K, LK	Juha South	AR	IC	Mt S	IR, MtB, South Karius	Benaria area						Homa Deviat-ion		Hides 3
Elevation range (x 100m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
<i>Saccolaimus mixtus</i>	VU																							
<i>Saccolaimus saccolaimus</i>																								
<i>Taphozous australis</i>	NT																							
Rhinolophidae																								
<i>Rhinolophus arcuatus</i>				●	●	○	○				●			○	●	●								●
<i>Rhinolophus euryotis</i>				●	●	○					●			○	●	●								
<i>Rhinolophus maros</i>				●	●						●				●	●								
<i>Rhinolophus megaphyllus</i>		○	○	●	●						●				●	●								●
<i>Rhinolophus philippinensis</i>	NT			●	●		○				●				●	●								
Hipposideridae																								
<i>Aselliscus tricuspidatus</i>		○	○	●																				
<i>Hipposideros ater</i>																								
<i>Hipposideros calcaratus</i>				●		○	○																	
<i>Hipposideros cervinus</i>		○	○	●		○	○																	
<i>Hipposideros corynophyllus</i>	VU																							

Table 2 Bat species known or predicted to occur at different elevations (0 – 2200 m) along the project pipeline corridor.*

	IUCN Status	K, NW, O, UC, VC	FV	Juha North	Baia River	WF, DP	WV			Mo, Mt K, LK	Juha South	AR	IC	Mt S	IR, MtB, South Karius	Benaria area						Homa Deviation		Hides 3
Elevation range (x 100m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
<i>Hipposideros diadema</i>				•	•	○	○				•													
<i>Hipposideros edwardshilli</i>	NT																							
<i>Hipposideros maggietaaylorae</i>		○	○	•	•	○	○				•													
<i>Hipposideros muscinus</i>	VU																							
<i>Hipposideros semoni</i>	NT			•	•						•													
<i>Hipposideros wollastoni</i>	NT	○	○			○																		
Vespertilionidae																								
<i>Chalinolobus nigrogriseus</i>																								
<i>Myotis moluccarum</i>				•																				
<i>Philetor brachypterus</i>				•	•						•			○	•	•						•		•
<i>Pipistrellus angulatus</i>				•	•										•	•						•		•
<i>Pipistrellus collinus</i>				•	•						•				•	•								•
<i>Pipistrellus papuanus</i>	NT			•																				
<i>Pipistrellus wattsi</i>	NT																							
<i>Scotorepens sanborni</i>																								

Table 2 Bat species known or predicted to occur at different elevations (0 – 2200 m) along the project pipeline corridor.*

	IUCN Status	K, NW, O, UC, VC	FV	Juha North	Baia River	WF, DP	WV			Mo, Mt K, LK	Juha South	AR	IC	Mt S	IR, MtB, South Karius	Benaria area						Homa Deviat-ion		Hides 3
Elevation range (x 100m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
<i>Murina florium</i>					•																			•
<i>Nyctophilus bifax</i>																								
<i>Nyctophilus microdon</i>	VU														•							•		•
<i>Nyctophilus microtis</i>				•	•						•				•	•						•		
<i>Nyctophilus timoriensis</i>	VU																							
<i>Pharotis Imogene</i>	CR																							
<i>Kerivoula muscina</i>	VU			•																				
<i>Phoniscus papuensis</i>		○	○			○																		
Vesp Fmin 31																								•
Miniopteridae																								
<i>Miniopterus australis</i>		○	○																			•		
<i>Miniopterus macrocneme</i>				•	•					○	•													
<i>Miniopterus magnater</i>																•								•
<i>Miniopterus medius</i>		○	○	•	•						•			○	○									
<i>Miniopterus propitristis</i>														○	•	•								

Table 2 Bat species known or predicted to occur at different elevations (0 – 2200 m) along the project pipeline corridor.*

	IUCN Status	K, NW, O, UC, VC	FV	Juha North	Baia River	WF, DP	WV			Mo, Mt K, LK	Juha South	AR	IC	Mt S	IR, MtB, South Karius	Benaria area						Homa Deviation		Hides 3
Elevation range (x 100m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
<i>Miniopterus schreibersii</i>																								
Molossidae																								
<i>Chaerephon jobensis</i>				•							•													
<i>Mormopterus beccarii</i>																								
<i>Mormopterus loriae</i>																								
<i>Otomops papuensis</i>	VU																							
<i>Otomops secundus</i>	VU			•	•						•				•	•						•		•
<i>Tadarida kuboriensis</i>															•	•						•		•

The Table was created by incorporating data from WWF studies and data recorded from the dedicated Project surveys, where Project survey records are indicated by a filled circle symbol and WWF records by an open circle. Cells filled in green indicate the span of elevations established by the total dataset and those outlined in Bonaccorso (1998), with connections indicated by a dash. A gap shown in the *Nyctimene draconilla* record separates the 0 – 100m altitudinal range suggested by Bonaccorso (1998) from a record from Namo (2004), which although is of a specimen from Mt Bosavi that is lodged in the Australian Museum, it may be spurious. Locality mnemonics in columns are : K = Kopi, NW = Neiru Wildlife Management Area, O = Omo, UC = Utiti Creek, VC = Veiru Creek, FV = Fogomaiyu Village, WF = Wassi Falls, DP = Darai Plateau, WV = Waro Village, Mo = Moro, Mt K = Mount Kemenagi, LK = Lake Kutubu, AR = Agogo Road (Henry's Camp), IC = IDD2 Cave, MtS = Mount Sisa, IR = Iagifu Ridge, MtB = Mount Bosavi. The table includes data from table 2 in Annex 05 to the Biodiversity Appendix (red figures)

3.4 Ecological niches of threatened species

To provide information for the impact assessment, an analysis of the ecological niches of each threatened bat species was conducted. This analysis is shown in Table 3 and it indicates that there are groups that may be affected by vegetation clearance or roost disturbance, such as cave roosting species or specialist insectivores.

Table 3 Summary of the ecological niches occupied by threatened (IUCN listed) species.

Primary roost type	Scientific name	Common name	Primary diet	IUCN status
Caves	<i>Aproteles bulmerae</i>	Bulmer's Flying Fox	Fruit	CR
	<i>Dobsonia minor</i>	Lesser Bare-backed Bat	Druit	NT
	<i>Hipposideros corynophyllus</i>	Telefomin Leafnosed Bat	Insects	VU
	<i>Hipposideros edwardshilli</i>	Huill's Leafnosed Bat	Insects	NT
	<i>Hipposideros muscinus</i>	Fly River Leafnosed Bat	Insects	VU
	<i>Hipposideros wollastoni</i>	Wollaston's Leafnosed Bat	Insects	NT
	<i>Hipposideros semmoni</i>	Greater Leafnosed Bat	Insects	NT
	<i>Rhinolophus philippinensis</i>	Large-eared Horseshoe Bat	Insects	NT
	<i>Emballonura diana</i>	Large-eared Sheathtail Bat	Insects	VU
	<i>Emballonura furax</i>	New Guinea Sheathtail Bat	Insects	VU
	<i>Emballonura raffrayana</i>	Raffray's Sheathtail Bat	Insects	NT
	<i>Pipistrellus papuanus</i>	Papuan Pipistrelle	Insects	NT
	<i>Pipistrellus wattsi</i>	Watt's Pipistrelle	Insects	NT
	<i>Taphazous australis</i>	Southern Sheath-tailed Bat	Insects	NT
Tree hollows	<i>Pharotis Imogene</i>	Thomas' Big-eared Bat	Insects	CR
	<i>Saccolaimus mixtus</i>	Papuan Sheathtail Bat	Insects	VU
	<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheathtail Bat	Insects	NT
	<i>Otomops papuensis</i>	Papuan Freetail bat	Insects	VU
	<i>Otomops secundus</i>	Mantled Freetail bat	Insects	VU
Within foliage	<i>Syconycteris hobbit</i>	Moss Forest Blossom Bat	Nectar & pollen	VU
	<i>Nyctimene aello</i>	Greater Tube-nosed Bat	Fruit	NT
	<i>Nyctimene cyclotis</i>	Round-eared Tube-nosed Bat	Fruit	NT
	<i>Nyctimene draconilla</i>	Lesser Tube-nosed Bat	Fruit	VU
	<i>Paranyctimene raptor</i>	Green Tube-nosed Bat	Fruit	NT
	<i>Nyctophilus microdon</i>	Small-toothed Bat	Insects	VU
	<i>Nyctophilus timoriensis</i>	Greater Big-eared Bat	Insects	VU
	<i>Kerivoula muscina</i>	Fly River Woolly Bat	Insects	VU

*Primary roost type may occasionally switch to another (for example, *Nyctophilus* spp may utilise tree hollows in habitats more open than rainforest). Whether insectivory is specialised or generalised is based on published information in most cases, or may be based on knowledge of sibling species elsewhere.

4 Field survey

4.1 Survey areas

The location, elevation and period of sampling at each of the survey areas are shown in Table 4 and Figures 1 to 6.

Table 4 Location, elevation and period of sampling at each of the areas surveyed in 2008.

Sampling Area	Latitude (°S)	Longitude (°E)	Elevation (m)	Survey period
Juha North	5.80780	142.30830	213	4th – 10th Feb 2008
Juha South	5.90189	142.43600	953	11th – 16th Feb 2008
Baia River	6.02050	142.54735	328	17th – 22nd Feb 2008
South Karius	5.99112	142.67063	1368	26th March – 2nd April 2008
Deviation Camp	6.09677	143.10452	2060	3rd – 8th April 2008

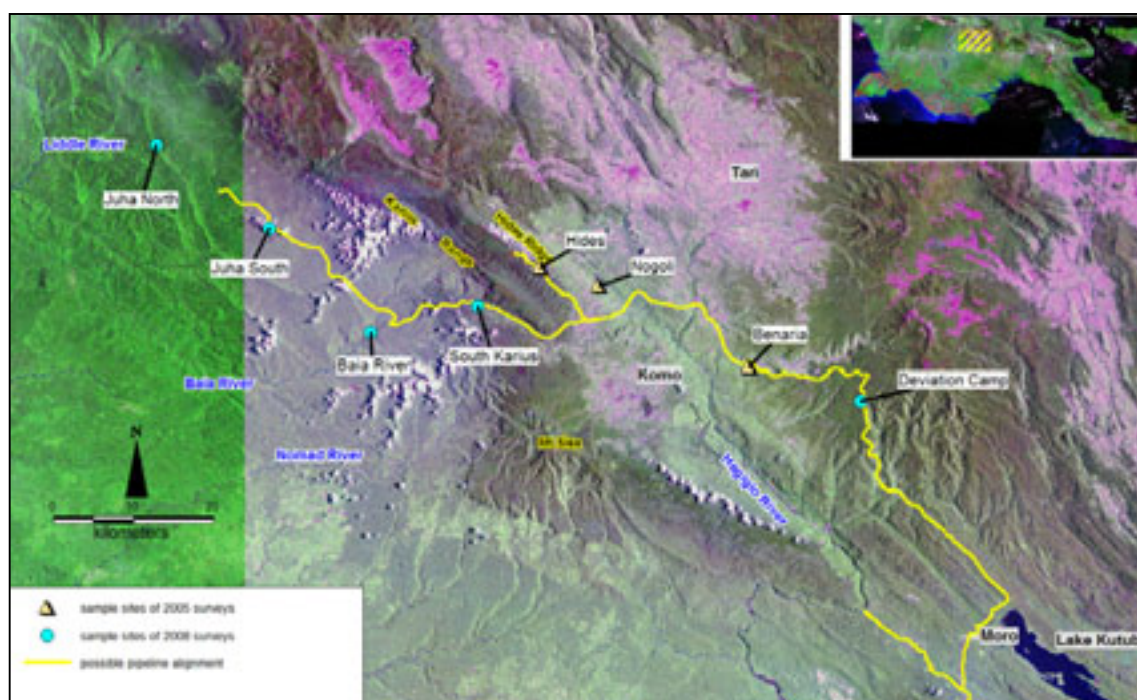


Figure 1. Map of all sites.

Juha North Survey Area (Figure 2) was located on the Liddel River, a tributary of the Strickland River, and situated in low hills on the edge of limestone terrain. Waterfalls emanating from holes in the limestone were located close to the camp. The forest was “small crowned low altitude forest on uplands (Hm)” (Hammermaster & Saunders 1995a, b) with evidence of disturbance and hunting. An anomalous feature of the vegetation was the presence of many plant groups normally found only in montane environments above 1,000

m elevation. Among the unusual elevational occurrences were many species in the families Ericaceae, Myrsinaceae, and Myrtaceae.

The Juha South Survey Area (Figure 3) was technically in the transition ecotone between traditionally defined lowland and montane zones, but due to local conditions of very high rainfall this area is clearly a well-developed mossy montane forest. It would classify as transitional between “small crowned lower montane forest (L) and “very small crowned lower montane forest (Ls)” (Hammermaster & Saunders 1995a, b). As is generally the case for montane formations, the canopy is usually low-statured (less than 20 m average height) with considerable epiphytic loads on trunks and upper branches. Forest understories are generally rich in cryptogamic growth and in remarkably pristine condition due to the absence of wild pigs. The latter circumstance is probably attributable to low human population densities. The camp itself was located on an old well pad sunk in 1983/84 and forest regeneration at the site was well advanced, composed for the most part of *Eurya*, *Ficus*, *Macaranga*, *Timonius*, and urticates. Numerous sinkholes were present on the surrounding karst terrain.

The Baia River Survey area (Figure 4) was located on the banks of the Baia River in an area dominated by landslides. The landscape was extremely unstable and this site was 2 to 3 km downstream from the originally designated site. This was because of the difficulty in locating a sufficiently stable stretch of stream bank that could be considered safe enough to build a camp. This section of the Baia River and the helicopter approaches to the river from the South Karius area appeared to be highly unstable sedimentary formations with numerous and large landslides. The survey area was an exclusively lowland vegetation formation with a floristically distinct alluvial and flood zone along the streams (collectively including various communities in Po, Ps, Wsw), and “small crowned low altitude forest on uplands (Hm)” (Hammermaster & Saunders 1995a, b) on higher slopes. There were numerous talus slopes and active landslides with early pioneer and secondary vegetation. The principal genera represented at the site were *Ficus*, *Gymnostoma*, *Macaranga*, *Pimelodendron*, and *Pometia*.

The South Karius survey area (Figure 5) was located at the base of the Karius range in a complex of streams and swamps that form the headwaters of the Baia River. The camp itself was located on the edge of a flat area that had been converted to gardens within the last few years. It was surrounded by swamplands with pandanus emergents (Wsw) that merged into “very small crowned lower montane forest” (Ls) (Hammermaster & Saunders 1995a, b) on the surrounding hills. The surrounding hills appeared to be karst whilst the camp itself was located on the alluvial soils of the surrounding streams and swamps. The community structure of the natural-growth vegetation was similar to that at the Juha South survey area. However, due to the presence of human habitation near the camp, there was a discernable increase in weedy species, including some cosmopolitan plants not found at any of the other locations. The anthropogenic influences are also reflected in the higher incidence of successional stands along the margins of the primary forest.

The “Deviation Camp” survey area was located approximately 5.5 km southwest of Benaria village and close to a potential pipeline deviation. It was in pristine “mossy montane *Nothofagus* forest” (Ln) (Hammermaster & Saunders 1995a, b) next to a fast flowing tributary of the Muruba River. The overstory was composed almost exclusively of *Nothofagus pullei* emergents up to 40 m tall. Subcanopy genera included primarily

Acronychia, *Elaeocarpus*, *Sphenostemon*, and *Syzygium*. Understories were characterized by dense bryophyte and lycophyte growth, with particular dominance by *Cyathea microphyloides* and *C. perpelvigera*. Most of the floristic diversity was concentrated in the near-ground interval up to approximately 5 m in height. The camp bordered an area of forest burnt in the 1996-7 fires. These regenerating areas were dominated by dead stags and coppicing surviving trees, with saplings up to 15m high. There was extensive regeneration by light-demanding *Nothofagus* and other heliophytes such as *Macaranga*, *Omalanthus*, and *Cyathea* spp. (e.g., *C. contaminans*). The understorey included many shade tolerant species, suggesting that in this area the fires had been crown fires and had not burnt the mossy ground layer.

The two survey areas from 2005 (Hides and Benaria) are described in Richards (Annex 05) and Crome and Woxvold (Annex 07).

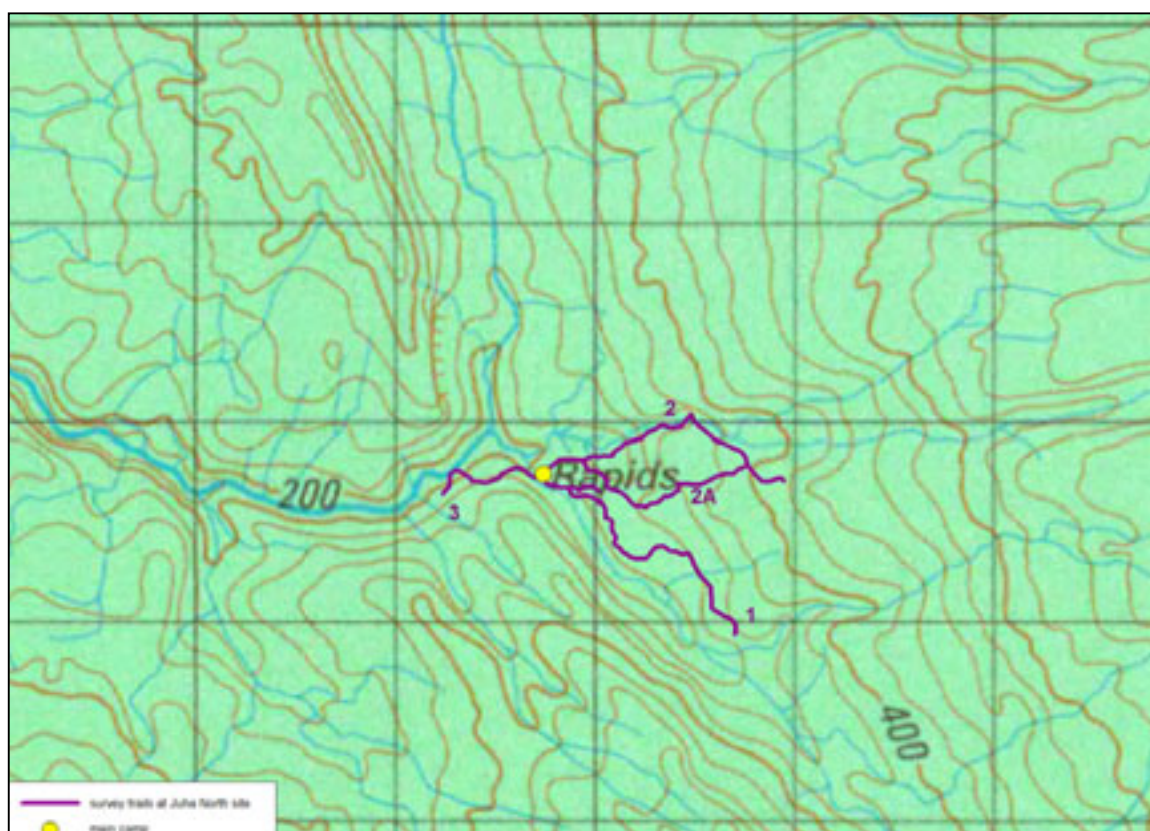


Figure 2 Sampling trails at Juha North survey area..

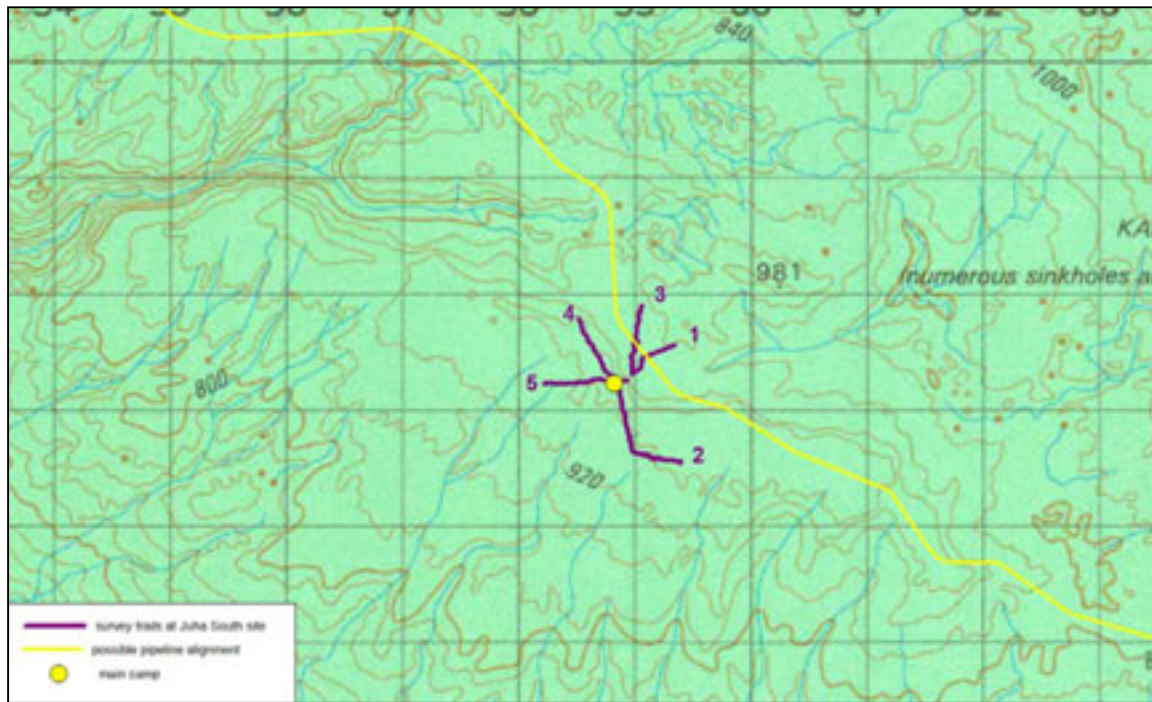


Figure 3 Sampling trails at Juha South survey area..

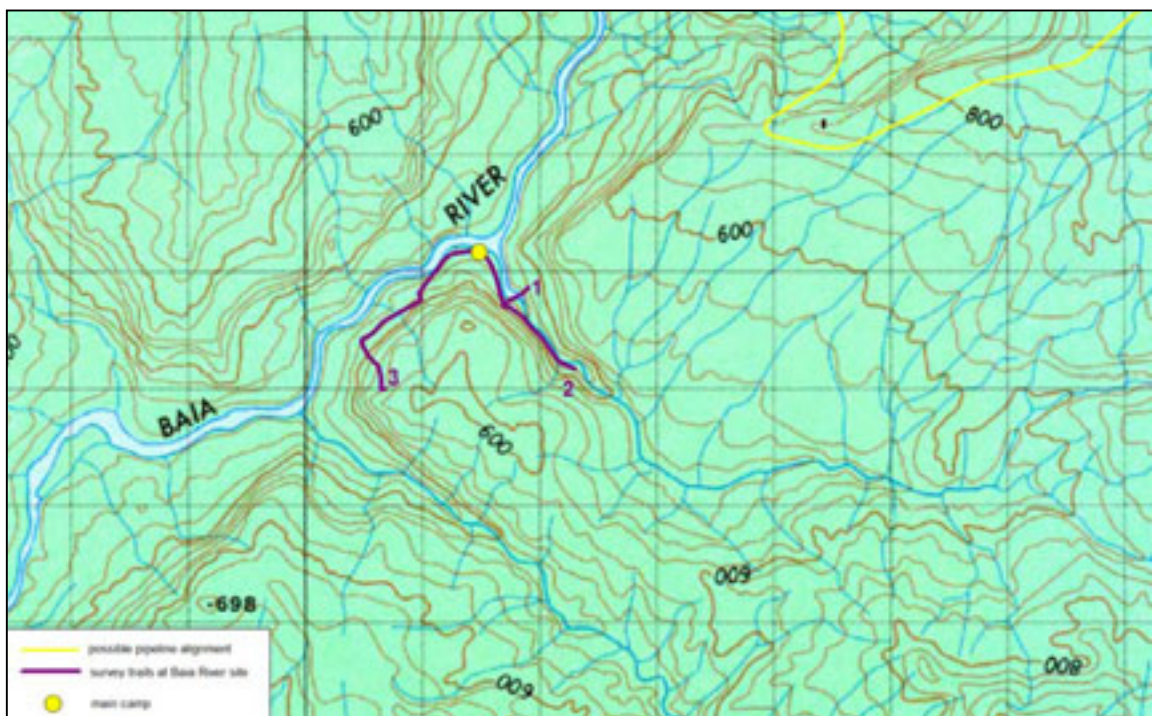


Figure 4 Sampling trails at Baia River survey area.

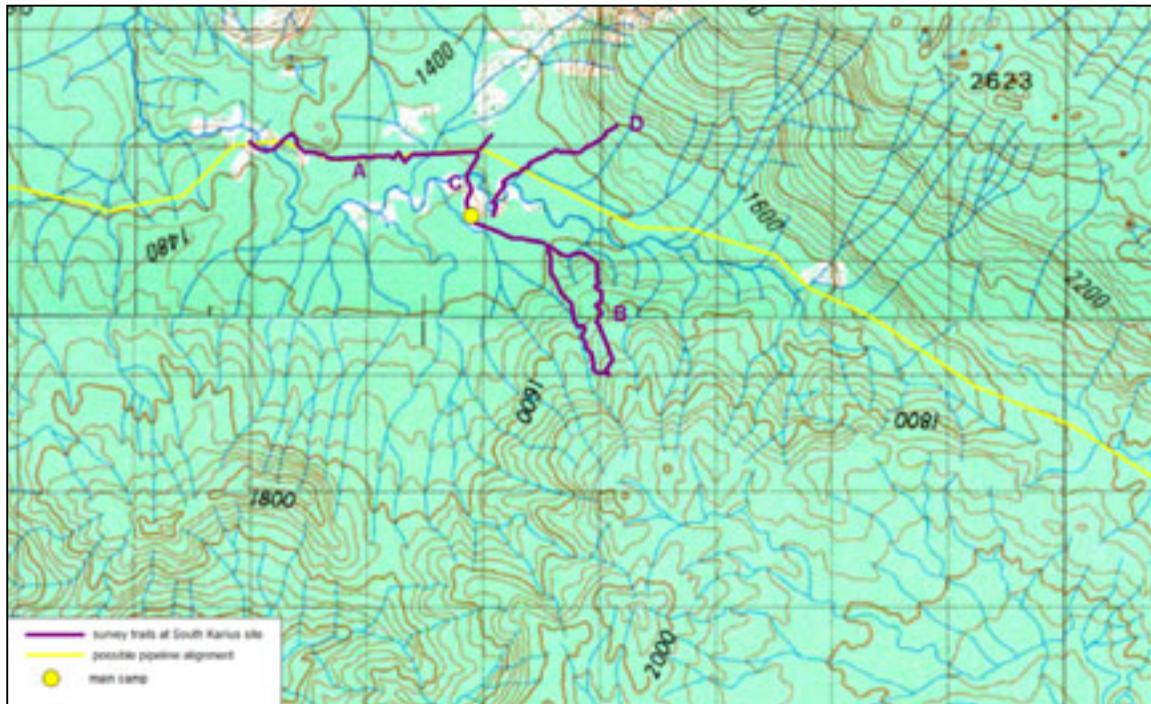
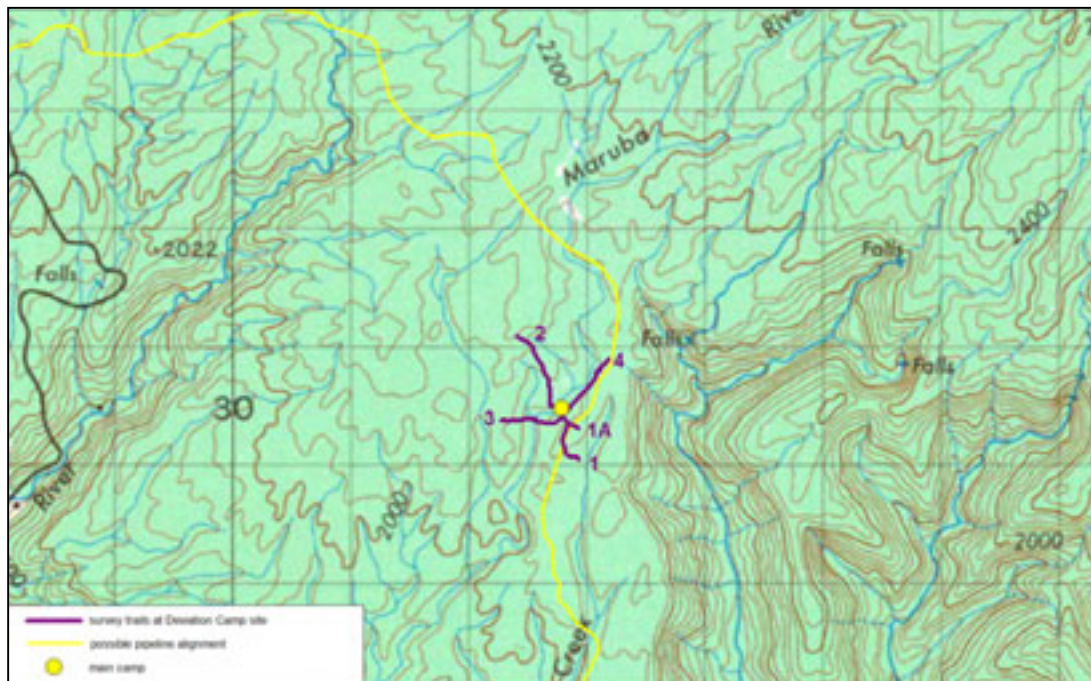


Figure 5 Sampling trails at South Karius survey area.

Figure 6. Sampling trails at Deviation Camp survey area.



4.2 Methods

Sampling of the bat fauna was conducted at the survey areas described above. The elevations covered by the transects (Figure 1) ranged from 200 to 2200 metres above sea

level (Table 5). Within the survey areas, sampling sites for bats were selected to either accommodate different habitats or to target certain threatened species.

Echolocation calls of bats, the sonar system used for navigation and prey detection, are species-specific, analogous to species-specific bird calls. The frequencies of bats that are in the ultrasound range and beyond human hearing can be detected with specialised equipment, such as the “Anabat”² system. At all of the sampling sites, an automated Anabat echolocation call detector (bat detector) was operated in tandem with a control module that turned the equipment on well before dusk, stopping its operation well after dawn. Hence, each detector operated throughout the night, which is the standard developed in Australia by Richards (2001).

Each bat detector divides the ultrasonic frequencies of microchiropteran bats by a known factor (in this case, 16) and each sequence (bat call) was recorded onto a compact flash card in the control module as a computer file. Each filename, created by firmware in the control module using an internal computer clock, provided the time of occurrence with an accuracy of one second. After each recording session, each file was displayed via dedicated software on a field computer, and analysed by visual observation. This allowed analysis of the level of site usage and activity patterns. A bat detector *in situ* is shown in Figure 7.

In each sampling area in the 2008 surveys but not in those in 2005, harp traps (Figures 8) and mist nets (Figure 9) were used to capture bats to obtain an inventory of non-echolocating fruit bats and microchiropteran bats for recording reference calls. Direct capture methods such as these have their inherent biases, where some bats can detect nets, and traps need to be placed in flyways. However, they supplement the main survey method (call detection) as far as microchiropteran bats are concerned. On the contrary, megachiropteran bats do not echolocate and for this reason direct capture methods are applicable, whatever their bias. In essence, if a bat fauna survey is to attain international standard, then as many methods as possible need to be utilised to gain the maximum amount of information about this faunal group.

Other techniques, such as the video inspection of potential bat roost hollows (Figure 10) were used when the occasion arose.

At all survey areas local informants were interviewed about bats showing pictures of bat species, particularly flying foxes that they knew of locally.

In 2005 (Annex 05 to Biodiversity Appendix), opportunistic surveys were also conducted at the Moro Village/Camp near Lake Kutubu, and the camp at Nogoli. At these sites, bat detectors were operated near external lights that attracted insects, and as a consequence, bats.

² The Anabat™ system is manufactured by Titley Electronics, Ballina, NSW, Australia.

4.3 Survey effort

The level of survey using bat detectors is shown in Table 5. Survey effort in 2005 and 2008 using this technique totalled around 1300 hours over 118 bat detector nights, which is understood to be the largest survey conducted via this technique to date in Papua New Guinea. Almost 150,000 bat detector files were recorded, each being examined in the field to gain an insight into each sampling Survey Area, and whether targeted capture was necessary, for example to obtain reference calls.

Mist netting hours were not quantified because this was conducted opportunistically, either using nets set during the day for the bird survey, or nets set specifically to capture fruit bats. Very little data was produced by this method. Two traps were used to capture bats for echolocation reference calls. Actual trapping hours were not quantified because of the expected variation in captures due to the vagaries of having to locate traps in flyways. Although around 20-30 trap nights were generated in rainforest sites, no bats were captured, explained by the low diversity and relative abundance³ that was revealed by call detection. Success was obtained when trapping was conducted in regrowth forest.

4.4 Sampling sites and replication

At the commencement of survey in each survey area, habitats were broadly categorised and bat detectors were placed accordingly. Sampling sites were selected according to broad habitat types, given the expectation that insectivorous bats would select niches appropriate to their foraging style. For example, fast flying bats with low manoeuvrability would be found in open habitat types, as opposed to slow flying highly manoeuvrable species that would tend to forage in dense forest.

Habitat types included rainforest in its varying forms (moss forest, secondary forest, dry forest on ridges (only at Benaria), lagoons or clearings in rainforest, the edges (ecotones) between open areas and forest (which includes rivers), and open areas *per se*. The distribution of the 119 sampling sites according to broad habitat types at each survey area is shown in Table 6.

³ "Relative abundance" means a comparison of the different abundances (an estimate of the quantity of particular species in a given area) between sampling sites, based primarily upon either call detection records or site records.



Figure 7 Automated bat call detector enclosed in weatherproof gear, set along a marked trail in moss forest. Bat detectors operated throughout the night and call files were analysed in the field on the following day.



Figure 8 Harp trap set in a flyway in regrowth forest. These traps consist of a frame that supports sets of taut fishing line that arrest the bat's flight, and through which they drop into an escape-proof bag. This trap caught five species in three nights.

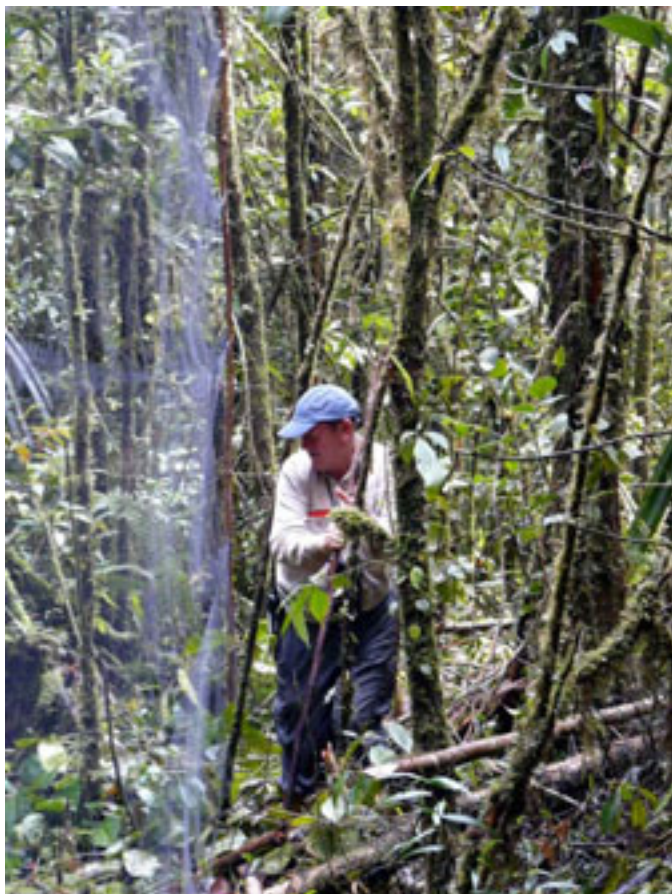


Figure 9 Mist net set in moss forest.



Figure 10 Transmitting video camera and portable television monitor used to inspect potential roost hollows for bats.

Table 5 Summary of survey effort using bat call detection. in 2008 compared with 2005 (Annex 05 to Biodiversity Appendix)

Sampling Area	Elevation (metres a.s.l.)	Field nights	Bat detector nights	Bat detector files generated
2008				
Juha North	210	7	12	20,346
Baia River	290	5	14	25,240
Juha South	950	5	12	6,851
South Karius	1370	5	12	15,408
Total 2008		22	50	67,845
2005				
Benaria*	1530	7	29	42,719
Deviation Camp	2060	5	12	7,064
Hides 3*	2160	6	27	28,926
Total 2005		18	68	78,709
Totals (both surveys)		40	118	146,554

Table 6 Replication of habitat types across survey areas in 2008 compared with 2005 (Annex 05 to Biodiversity Appendix).

Habitat type	Survey area							Totals
	Juha North	Juha South	Baia River	South Karius	Deviation Camp	Benaria	Hides 3	
Rainforest	3	6	6	4	4	8	11	42
Lagoons or clearings in rainforest		1	2	1		2	7	13
Regrowth forest	2					6		8
Dry ferny forest						3		3
Edge - rainforest	2	2	3	2	2		1	12
Edge – river	2		1	2	4	6		15
Open	2	3	1	3	2	4	11	26
Totals	11	12	13	12	12	29	30	119

4.5 Validation of primary survey method

The value of using bat detection systems in field surveys is shown by the species accumulation curves (Figure 11) for the 2008 survey. The majority of the microchiropteran species that were eventually recorded for the area was detected by the sixth bat detector night, and all species were recorded by the tenth bat detector night. When operating three to four bat detectors per night, by the second night of survey around 90% of the final species total was recorded, hence justifying the minimum of five nights of survey by this method.

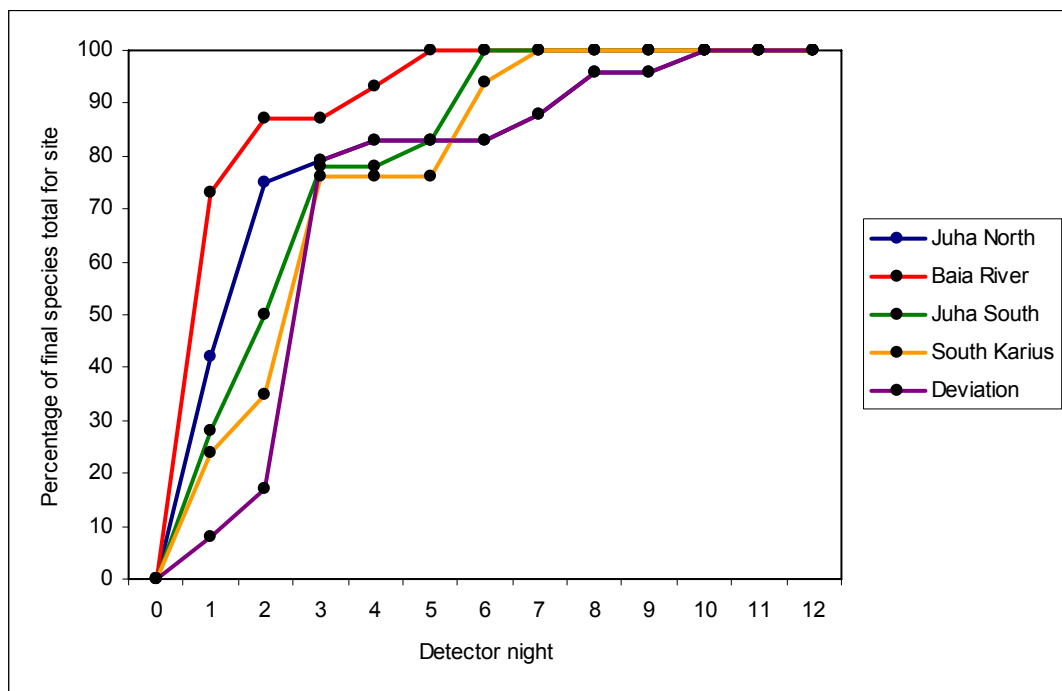


Figure 11 Species accumulation curves for the five areas sampled during 2008, based on the number of bat detector nights.

5 Results

5.1 Species recorded at survey areas

A total of 34 bat species were recorded during the 2008 surveys (Table 7). This included all but 2 of the species recorded in 2005 (Annex 05 to Biodiversity Appendix) This number of species equates to nearly half of the species that are known from the Papua New Guinea mainland (see Bonaccorso 1998), but includes several that were not known at the time of preparation of this field guide. These included:

Paranyctimene sp aff *raptor* A single individual was caught at an elevation of 2060 metres in the Deviation Camp sampling area. It is significantly different in appearance to *P. raptor* which is only found at elevations from sea level up to 1400 metres (Bonaccorso 1998), and may represent a species new to science.

Rhinolophus maros A species known from eastern Cape York discovered during the 2005 pipeline surveys (Annex 05 to Biodiversity Appendix).

“Vesp Fmin 31” A species in the family Vespertilionidae that requires identification. There are very few candidate species that could be attributable to this call, so there is the possibility that it may be an undiscovered taxon. The mnemonic refers to this species’ echolocation call having a minimum frequency of 31 kHz.

Table 7 Species recorded at each survey area during the 2005 and 2008 surveys. The areas are ranked according to elevation.

	Juha North	Baia River	Juha South	South Karius	Benaria	Deviation Camp	Hides 3
Elevation (m)	220	290	950	1360	1530	2060	2160
Pteropodidae							
<i>Dobsonia magna</i>	•			•	•		
<i>Macroglossus minimus</i>	•						
<i>Nyctimene aello</i>		•					
<i>Nyctimene albiventer</i>	•						
<i>Paranyctimene raptor</i>	•						
<i>Paranyctimene</i> sp. aff. <i>raptor</i>						•	
<i>Syconycteris australis</i>	•	•		•	•		•
Emballonuridae							
<i>Mosia nigrescens</i>			•	•	•	•	•
<i>Emballonura diana/furax</i> *		•	•		•		•
Rhinolophidae							
<i>Rhinolophus arcuatus</i>	•	•	•	•	•		•

Table 7 Species recorded at each survey area during the 2005 and 2008 surveys. The areas are ranked according to elevation.

	Juha North	Baia River	Juha South	South Karius	Benaria	Deviation Camp	Hides 3
Elevation (m)	220	290	950	1360	1530	2060	2160
<i>Rhinolophus euryotis</i>	•	•	•	•	•		
<i>Rhinolophus maros</i>	•	•	•	•	•		
<i>Rhinolophus megaphyllus</i>	•	•	•	•	•		•
<i>Rhinolophus philippinensis</i>	•	•	•	•	•		
Hipposideridae							
<i>Aselliscus tricuspidatus</i>	•						
<i>Hipposideros calcaratus</i>	•						
<i>Hipposideros cervinus</i>	•						
<i>Hipposideros diadema</i>	•	•	•				
<i>Hipposideros maggietaaylorae</i>	•	•	•				
<i>Hipposideros semoni</i>	•	•	•		•		
Miniopteridae							
<i>Miniopterus australis</i>						•	
<i>Miniopterus macrocneme/medius</i>	•	•	•				
<i>Miniopterus magnater</i>					•		•
<i>Miniopterus propitristis</i>				•	•		
Vespertilionidae							
<i>Kerivoula muscina</i>	•						
<i>Murina florium</i>		•					•
<i>Myotis moluccarum</i>	•						
<i>Nyctophilus microdon</i>				•		•	•
<i>Nyctophilus microtis</i>	•	•	•	•	•	•	
<i>Philetor brachypterus</i>	•	•	•	•	•	•	•
<i>Pipistrellus angulatus</i>	•	•		•	•	•	•
<i>Pipistrellus collinus</i>	•	•	•	•	•		•
<i>Pipistrellus papuanus</i>	•						
"Vesp Fmin 31"							•
Molossidae							
<i>Chaerephon jobensis</i>	•		•				

Table 7 Species recorded at each survey area during the 2005 and 2008 surveys. The areas are ranked according to elevation.

	Juha North	Baia River	Juha South	South Karius	Benaria	Deviation Camp	Hides 3
Elevation (m)	220	290	950	1360	1530	2060	2160
<i>Otomops secundus</i>	•	•	•	•	•	•	•
<i>Tadarida kuboriensis</i>				•	•	•	•
Total species recorded	26	18	16	16	18	9	14

*Emballonura dianaefurax and Miniopterus macrocneme/medius could not be allocated to an individual species.

5.2 Species richness

The relationship between total species richness and elevation using all the available data from 2008 and 2005 (Annex 05 to Biodiversity Appendix) is illustrated in Figure 12. There was a weak inverse relationship between species richness and elevation, with lower elevations having up to 26 species present, compared to 9 to 14 species at the highest elevations studied. The relationship was similar when only microchiropteran species were analysed. Numbers of microchiropteran bats ranged from 21 species at the lowest elevation to 8 to 13 at the highest elevations. The mean number of insectivorous bat species recorded at the seven survey areas was 15 species.

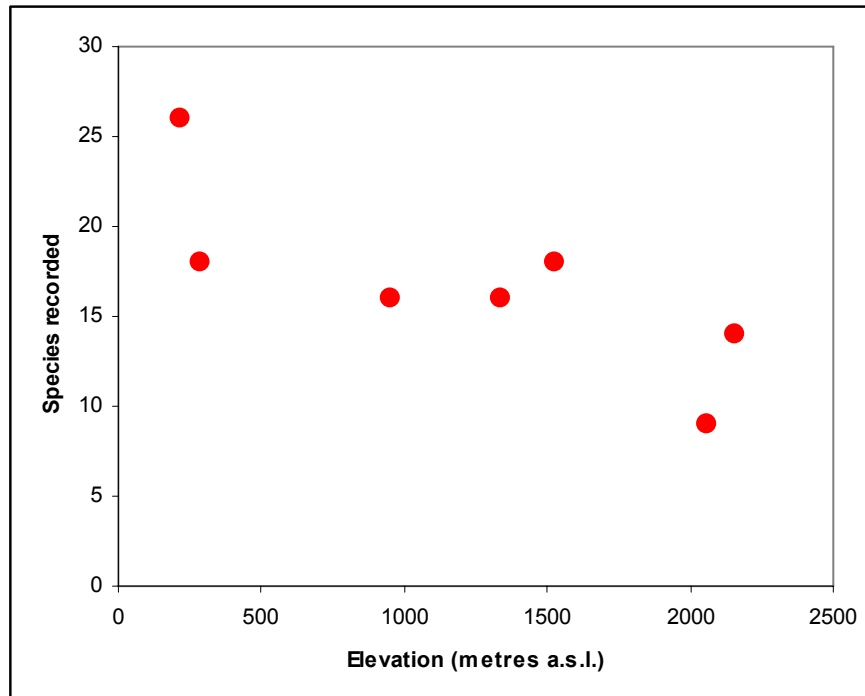


Figure 12 The relationship between species richness and elevation at the sampling areas assessed in 2005 and 2008. The elevation of each sampling area is shown in Table 5.

5.3 Relative abundance of microchiropteran bats

One of the issues when analysing the number of calls recorded at a sampling site is how best to interpret the number of calls generated. For example, if 100 calls were detected from a single species, does this indicate one bat passing by the microphone 100 times, or 10 bats 10 times, or 100 bats once? Actual abundance cannot be readily assessed but relative abundance was analysed using the frequency at which a species occurred over a survey area. The basic data unit is a site record (that is, one species recorded at one sample site), irrespective of the number of calls detected at the sample site. For example, 3 species recorded at one site equates to 3 site records, whereas 3 species recorded at each of 4 sample sites equates to 12 site records.

The number of calls were used, however, to gauge habitat preferences within a survey area. The proportion of the total number of calls recorded in a survey area that occurred in each habitat was used to indicate the relative preference for each particular habitat. For example, if a species was recorded in three different habitats but 90% of the calls were from only one of them, then that habitat would be regarded as the “primary” habitat for that species.

The total number of site records for each sampling area, using the combined data from 2005 (Annex 05 to Biodiversity Appendix) and 2008 is shown in Table 8. Juha North, the lowest in elevation, had far more site records than the other sampling areas, with one of the highest elevations (the Deviation Camp area) being significantly⁴ lower than other areas. The trend of relative abundance decreasing with elevation is a pattern similar to that of species richness. This may indicate that there are less species at higher elevations, and that they are relatively less abundant than at lower elevations.

Table 8 Overall relative abundance of microchiropteran bat communities based on the average number of site records (i.e. occurrence at each sampling site within each survey area).

	Juha North	Baia River	Juha South	South Karius	Benaria	Deviation Camp	Hides 3
Elevation	220	290	950	1360	1530	2060	2160
No of sample sites	11	13	12	12	31	12	27
Total site records	85	76	73	66	155	34	127
Average records per site	7.7	5.8	6.1	5.5	5.0	2.8	4.7

The relative abundance of each species was assessed by examining site records at each sampling area. This was only possible for the data obtained in 2008 when the sampling was relatively even (11, 12 or 13 sampling sites in each survey area) so the 2005 (Annex 05 to Biodiversity Appendix) data is not included in these analyses (Tables 10 to 12). Species abundance categories are as follows:

Abundant more than 20 site records over all survey areas

⁴ The word “significantly” is the author’s interpretation based upon experience, rather than statistical inference.

Common	12 to 19 site records
Uncommon	5 to 11 site records
Rare	less than 5 site records

Results are shown in Table 9. Nineteen species were considered to be Abundant, Common and Uncommon, and were distributed across two or more elevation zones.

The remaining 11 taxa were categorized as Rare being recorded from only one survey area from four or less site records. Of these, two species (both *Miniopterus*) were restricted to high elevations and the remainder were recorded from elevations below 300 metres a.s.l. Of relevance to the impact assessment is that a number of the low elevation species are considered to be foraging specialists. These include *Murina florium*, *Kerivoula muscina*, and the *Kerivoula/Phoniscus* taxon which are slow-flying highly maneuverable species that glean insects from substrates, and *Myotis moluccarum* which forages for aquatic prey in the backwaters of rivers. The others have specialised cave roosting requirements (very hot and humid microclimates) and include *Hipposideros cervinus*, *Aselliscus tricuspidatus* and *Hipposideros calcaratus cupidus* and (probably) *Emballonura furax*. Nothing is known about the taxon identified for the purposes of the study as “Vesp Fmin 31”.

5.4 Microchiropteran bat habitat utilisation

Patterns of habitat utilization by microchiropteran species recorded during the 2008 field surveys are shown in Table 10. In this analysis, habitat generalists are regarded as those species that utilized three or more habitat types, and habitat specialists are those that utilized just one or two.

A number of patterns relevant to the impact assessment were revealed by this analysis. In the field, it was apparent that there were far less species utilizing rainforest than many of the more open habitats. The edges of rivers and major clearings or open areas were primary habitats, and the highest number of species was recorded along river edges than in any other habitat. This pattern is attributed to the restriction of many species in accessing densely cluttered forest, where fast flying species with low maneuverability were rarely recorded. Overall, the species count in river edge habitat and open areas exceeded the number of species recorded in rainforest *per se*.

At some survey areas, only five species were recorded in rainforest compared with 13 species at river edges. This patterns is made more significant when the total number of calls recorded in rainforest (3680) is compared with the total of 25,881 recorded in edge and open habitats. Of note is that 15 species were recorded in regrowth areas, nearly as many as in rainforest. This factor, and the heavy bias towards edges and open areas, may indicate that the Papua New Guinea microchiropteran fauna may have evolved to accommodate regular broad-scale disturbance, such as landslides and volcanism.

Table 9 Site records of each species at each survey area studied in 2008. Species are ranked by overall relative abundance based on the total site records generated during the survey, and grouped into arbitrary categories to distinguish common and abundant species from those that are uncommon or rare. For each species, the cell value in bold font indicates the highest site record. This Table does not include data from the 2005 field survey.

Species	Juha North	Baia River	Juha South	South Karius	Deviation Camp	Total site records
Elevation	220 m	290m	950m	1340m	2060m	
Abundant						
<i>Philetor brachypterus</i>	6	6	5	10	6	33
<i>Rhinolophus euryotis</i>	8	12	5	5		30
<i>Rhinolophus megaphyllus</i>	8	4	10	4		26
<i>Rhinolophus maros</i>	7	6	8	3		24
<i>Pipistrellus angulatus</i>	5	4		7	6	22
<i>Rhinolophus philippinensis</i>	4	6	8	3		21
<i>Nyctophilus microtis</i>	5	3	2	4	7	21
Common						
<i>Hipposideros semoni</i>	7	9	2			18
<i>Hipposideros diadema</i>	6	7	4			17
<i>Otomops secundus</i>	3	4	3	6	1	17
<i>Pipistrellus collinus</i>	3		4	7	1	15
<i>Hipposideros maggietaaylorae</i>	4	4	5			13
Uncommon						
<i>Tadarida kuboriensis</i>				7	4	11
<i>Rhinolophus arcuatus</i>	2	2	4	1		9
<i>Miniopterus macrocneme/medius</i>	3	1	5			9
<i>Mosia nigrescens</i>			5	2	1	8
<i>Nyctophilus microdon</i>				3	4	7
<i>Pipistrellus papuanus</i>	5	1				6
<i>Chaerephon jobensis</i>	2		3			5
Rare						
<i>Miniopterus australis</i>					4	4
<i>Miniopterus propitristis</i>				4		4
<i>Murina florium</i>		3				3
<i>Hipposideros cervinus</i>	2					2
<i>Kerivoula/Phoniscus</i>		2				2
<i>Myotis moluccarum</i>	2					2
<i>Emballonura furax</i>		1				1
<i>Aselliscus tricuspidatus</i>	1					1
<i>Hipposideros calcaratus cupidus</i>	1					1
<i>Kerivoula muscina</i>	1					1
"Vesp Fmin 31"		1				1

Table 10 Patterns of habitat utilisation by microchiropteran bat species recorded (●) during the 2008 field surveys. Generalists are regarded as those species that utilised three or more habitat types, specialists are those that utilised just one or two. More species were recorded along river edges than in any other habitat. Data from the 2005 survey is not included in this analysis.

	Rain-forest	Rain-forest lagoons, clearings	Regrowth	River edges	Rain-forest edges	Open areas	Total habitats utilised
GENERALISTS							
All available habitats utilised							
<i>Hipposideros diadema</i>	●	●	●	●	●	●	6
<i>Hipposideros semoni</i>	●	●	●	●	●	●	6
<i>Otomops secundus</i>	●	●	●	●	●	●	6
<i>Philetor brachypterus</i>	●	●	●	●	●	●	6
<i>Rhinolophus euryotis</i>	●	●	●	●	●	●	6
<i>Rhinolophus maros</i>	●	●	●	●	●	●	6
<i>Rhinolophus megaphyllus</i>	●	●	●	●	●	●	6
<i>Rhinolophus philippinensis</i>	●	●	●	●	●	●	6
<i>Nyctophilus microtis</i>	●	●		●	●	●	5
<i>Pipistrellus angulatus</i>		●	●	●	●	●	5
<i>Miniopterus propitristis</i>	●			●		●	3
Most of the available habitats							
<i>Hipposideros maggietaaylorae</i>	●		●	●	●		4
<i>Pipistrellus collinus</i>	●			●	●	●	4
<i>Pipistrellus papuanus</i>	●		●	●		●	4
<i>Rhinolophus arcuatus</i>	●			●	●	●	4
<i>Nyctophilus microdon</i>	●			●		●	3
Only edges and open areas, not recorded within rainforest							
<i>Tadarida kuboriensis</i>		●	●	●		●	4
<i>Chaerephon jobensis</i>				●	●	●	3
<i>Miniopterus macrocneme/medius</i>				●	●	●	3
<i>Mosia nigrescens</i>				●	●	●	3
SPECIALISTS							
Rainforest and clearings within							
<i>Murina florium</i>	●	●					2
<i>Kerivoula/Phoniscus</i>		●					1
<i>Emballonura furax</i>	?						1
Rainforest and edges							
<i>Hipposideros cervinus</i>			●	●			2
<i>Miniopterus australis</i>	●			●			2
Regrowth							

Table 10 Patterns of habitat utilisation by microchiropteran bat species recorded (●) during the 2008 field surveys. Generalists are regarded as those species that utilised three or more habitat types, specialists are those that utilised just one or two. More species were recorded along river edges than in any other habitat. Data from the 2005 survey is not included in this analysis.

	Rain-forest	Rain-forest lagoons, clearings	Regrowth	River edges	Rain-forest edges	Open areas	Total habitats utilised
<i>Aselliscus tricuspidatus</i>			●				1
<i>Hipposideros calcaratus cupidus</i>			●				1
Edges							
<i>Myotis moluccarum</i>				●			1
Open areas							
<i>Kerivoula muscina</i>						●	1
Total species in each habitat type	17	13	15	23	16	20	

5.5 Habitat preferences of microchiropteran bats

The previous analyses defined the different levels of abundance in, and utilisation of, the major habitat types. This section further refines habitat preferences by calculating the proportion of calls of each species in each of the habitats that they utilised. This exercise was expected to reveal whether, within a family, there were any species that showed patterns of niche differentiation. Results are shown in Table 11.

It is apparent that there is some broad habitat partitioning by the species so that species assemblages can be defined that have a preferred habitat. This is notable within families where flight patterns and foraging styles are similar. For example, the Horseshoe Bats (family Rhinolophidae) have species that primarily utilise either river edges (*R. maros*) or rainforest edges (*R. megaphyllus* and *R. euryotis*), or open areas (*R. arcuatus* and *R. philippinensis*). In this group, there was no apparent preference for rainforest *per se*. The Bentwing Bats (Miniopteridae) had similar habitat separation, where each of the three that were recorded preferred a unique habitat: *M. australis* preferred rainforest, *M. propitristis* preferred river edges, and the taxon *M. macrocneme/medius* preferred rainforest edges.

In the “Ordinary” Bats (Vespertilionidae) the open habitats were preferred by the four most abundant species within the family (*Philetor brachypterus*, *Pipistrellus angulatus*, *Pipistrellus collinus* and *Kerivoula muscina*). Rainforest was preferred by the two Longeared Bats (*Nyctophilus*). The river edges were preferred by two species but they would separate by foraging styles: *Pipistrellus papuanus* foraged well above the water whereas *Myotis moluccarum* preyed upon aquatic beetles and small fish at the water surface.

Table 12 summarises the relative abundance, habitat preferences and habitat specializations of all microchiropteran bats recorded during the 2008 surveys.

Table 11 The proportion of the total calls recorded for each microchiropteran species during the 2008 survey in each of the habitats that they utilized. Data from the 2005 survey (Annex 05 to Biodiversity Appendix) is not included because fewer habitats were present in the sampling areas. The dominant habitat is shown in bold, and the species in each family are ranked by their relative abundance. The letter “c” indicates that the species was only captured and not recorded by calls.

	Rain-forest	Regrowth	Rain-forest lagoons, clearings	River edges	Rain-forest edges	Open areas	Total calls
Emballonuridae							
<i>Mosia nigrescens</i>				0.002	0.016	0.982	3985
Rhinolophidae							
<i>Rhinolophus megaphyllus</i>	0.039	0.041	0.064	0.234	0.319	0.303	2252
<i>Rhinolophus maros</i>	0.039	0.001	0.006	0.421	0.314	0.218	1241
<i>Rhinolophus euryotis</i>	0.253	0.028	0.015	0.088	0.442	0.175	890
<i>Rhinolophus arcuatus</i>	0.022			0.113	0.422	0.444	647
<i>Rhinolophus philippinensis</i>	0.211	0.094	0.078	0.234	0.086	0.297	128
Hipposideridae							
<i>Hipposideros diadema</i>	0.003	0.016	0.462	0.088	0.361	0.071	1416
<i>Hipposideros semoni</i>	0.606	0.017	0.229	0.029	0.086	0.034	175
<i>Hipposideros maggietaaylorae</i>	0.826	0.087		0.043	0.043		23
<i>Hipposideros cervinus</i>		0.500		0.500			2
<i>Hipposideros calcaratus cupidus</i>		C					
<i>Aselliscus tricuspidatus</i>		C					
Miniopteridae							
<i>Miniopterus macrocneme/medius</i>				0.030	0.774	0.197	605
<i>Miniopterus propitristis</i>	0.044			0.949		0.007	137
<i>Miniopterus australis</i>	0.643			0.357			14
Vespertilionidae							
<i>Philetor brachypterus</i>	0.010	0.080	0.045	0.244	0.267	0.354	13849
<i>Pipistrellus angulatus</i>		0.012	0.008	0.054	0.228	0.698	1906
<i>Pipistrellus collinus</i>	0.004			0.081	0.003	0.912	942
<i>Kerivoula muscina</i>						1.000	684
<i>Nyctophilus microtis</i>	0.444		0.006	0.294	0.044	0.211	180
<i>Nyctophilus microdon</i>	0.700			0.288		0.013	80
<i>Pipistrellus papuanus</i>	0.286	0.036		0.429		0.250	28
<i>Myotis moluccarum</i>				1.000			26
<i>Murina florium</i>	0.909		0.091				11
<i>Kerivoula/Phoniscus</i>			1.000				8
Molossidae							
<i>Otomops secundus</i>	0.013	0.026	0.010	0.846	0.071	0.035	311
<i>Tadarida kuboriensis</i>		0.095	0.238	0.619		0.048	21
<i>Chaerephon jobensis</i>				0.333	0.333	0.333	12

Table 12 Summary of ecological characteristics of microchiropteran bats recorded from the 2008 surveys that are relevant to impact assessment. Data from the 2005 survey (Annex 05 to Biodiversity Appendix) is not included because fewer habitats were present in the sampling areas. Habitat specialists are shown in bold.

Preferred habitats	Rare and restricted species	Abundant, Common, Uncommon species
Rainforest	<i>Miniopterus australis</i>	<i>Hipposideros semoni</i>
	<i>Murina florium</i>	<i>Hipposideros maggietaaylorae</i>
		<i>Nyctophilus microtis</i>
		<i>Nyctophilus microdon</i>
Regrowth	<i>Hipposideros c. cupidus</i>	
	<i>Aselliscus tricuspidatus</i>	
Rainforest lagoons, clearings	<i>Kerivoula/Phoniscus</i>	
River edges	<i>Miniopterus propitristis</i>	<i>Rhinolophus maros</i>
	<i>Pipistrellus papuanus</i>	<i>Myotis moluccarum</i>
		<i>Otomops secundus</i>
Rainforest edges		<i>Rhinolophus megaphyllus</i>
		<i>Rhinolophus euryotis</i>
		<i>Hipposideros diadema</i>
		<i>Miniopterus macrocneme/medius</i>
Open areas	<i>Kerivoula muscina</i>	<i>Mosia nigrescens</i>
		<i>Rhinolophus arcuatus</i>
		<i>Rhinolophus philippinensis</i>
		<i>Philetor brachypterus</i>
		<i>Pipistrellus angulatus</i>
		<i>Pipistrellus collinus</i>
Not clearly defined or unknown	<i>Hipposideros cervinus</i>	<i>Chaerephon jobensis</i>
	<i>Emballonura furax</i>	
	Vesp Fmin 31	

5.6 Megachiropteran bats

As mentioned in the Methods section, techniques that are used to record megachiropteran bats are unreliable and captures or observations depend upon chance. Hence, the predicted distributions, and presence or absence of species shown in Table 2 were used in the analyses for impact assessment.

Megachiropteran species that could be expected and those that were recorded at the seven faunal assessment areas are shown in Table 13. These records appear to follow the recognised reduction in species richness as elevation increases.

Fifteen species could be expected along the pipeline corridor, 7 of which are in various IUCN threat categories. However, the prediction that *Nyctimene draconilla* (listed as Vulnerable) would be present in the survey areas is doubtful. Records are typically from low elevations (0 - 100 m) (Bonaccorso 1998) but a record obtained during a WWF survey at the same elevation as South Karius extended its distribution into the survey area.

Table 13 Megachiropteran bats that are expected to occur or were recorded at faunal assessment areas.

	IUCN status	Juha North	Baia River	Juha South	South Karius	Benaria	Deviation Camp	Hides 3	Number of areas
Elevation (m)		220	290	950	1340	1530	2060	2160	
<i>Aproteles bulmerae</i>	CR					P	P	P	3
<i>Dobsonia minor</i>	NT	P	P						2
<i>Dobsonia magna</i>		R	P	P	R	R	P	P	7
<i>Pteropus macrotis</i>		P	P						2
<i>Pteropus neohibernicus</i>		P	P	P	P	P			5
<i>Rousettus amplexicaudatus</i>		P	P						2
<i>Nyctimene aello</i>	NT	P	R	P					3
<i>Nyctimene albiventer</i>		R	P	P	P	P			5
<i>Nyctimene cyclotis</i>	NT			P	W	P	P	P	5
<i>Nyctimene draconilla</i>	VU	D	D	D	W				?
<i>Paranyctimene raptor</i>	NT	R	P	P	W	R			5
<i>Paranyctimene</i> sp aff <i>raptor</i>	?						P		1
<i>Macroglossus minimus</i>		R	P	P					3
<i>Syconycteris australis</i>		R	R	P	R	R	P	R	7
<i>Syconycteris hobbit</i>	VU							P	1
Total species recorded		5	2	0	2	3	0	1	
Estimated species total using predicted distributions		11	11	9	7	7	5	5	

R = Recorded during field surveys, W = recorded during WWF surveys at similar elevation in the vicinity of the pipeline corridor, P = predicted from distribution patterns shown in Table 2. The 'D' in the *Nyctimene draconilla* recorded indicates that its presence is doubtful but has been predicted by extrapolating records at low elevations (0 - 100 m) and a record obtained during a WWF survey at the same elevation as South Karius. IUCN categories are CE = Critically Endangered, VU = Vulnerable, LR/nt = Lower Risk (Near Threatened). Predictions for the 2005 survey areas (Annex 05 to Biodiversity Appendix) included.

6 Potential project impacts and recommendations

The assessment of the potential for the project to impact upon bat species listed in IUCN threat categories was evaluated by considering whether construction and operation of the project would allow any to fall into the following impact categories:

Potential local impacts on bat species at individual project components:

- Low** impacts are likely to involve the loss of a few individuals or the retraction of home ranges, with no long-term lowering of the viability of local populations, i.e., those around a particular section of the project.
- Medium** impacts are likely to involve loss of a portion of the local population that will reduce the chances of long-term survival in remaining habitat around a particular section of the project.
- High** impacts are likely to involve loss of a large portion of the local population and would reduce the chance of long-term survival in remaining habitat around a particular section of the project.

Potential overall impacts for the entire project area:

- Low** impacts are likely to involve loss of a few individuals or retraction of home ranges, with no long-term lowering of viability of the species within the Project Area
- Medium** impacts are likely to involve loss of a portion of the species population within the Project Area and may reduce the chances of long-term survival in the Project Area
- High** impacts are likely to involve loss of a large portion or all of the remaining population in the Project Area.

Potential impacts include:

Cave dwelling species being hunted for food, particularly the Critically Endangered *Aproteles bulmerae*.

Roosts and maternity colonies in caves being exterminated during construction by destruction of the cave or disturbance from blasting.

Cave dwelling species being affected by human visitation (that is, disturbance as opposed to direct killing for food), particularly horseshoe and leaf-nosed bats, most of which are listed as Vulnerable on the IUCN Red List. Frequent disturbance can cause mortality, especially during the breeding season when young are unable to fly.

Hollow roosting species being affected during tree clearance operations, particularly the Critically Endangered *Pharotis imogene*.

Species were prioritised by generating a score based upon whether the species was:

- Endemic to Papua New Guinea.
- A cave dwelling species and therefore could potentially be subjected to general disturbance by human access to caves, where impacts could include loss of young in maternity clusters.
- A cave dwelling species that provides a food source and would therefore be the subject of intensive hunting.
- Whether the ecological assessment of survey data showed a species to be a habitat specialist, or was rare, or was restricted in distribution.

6.1 The Critically Endangered species

There are two species of such rarity and conservation importance in PNG that they need to be considered in any impact analysis in the country – *Pharotis imogene* and *Aproteles bulmerae*. They have not been recorded so far in the project area, though there is a possibility that the latter roosts in a cave in the Angore area as evidenced by information from local informants.

6.1.1 New Guinea Big-eared Bat (*Pharotis imogene*)

Pharotis imogene is a member of the long-eared bat group. These bats generally forage by gleaning prey from substrates such as bark or leaves, and for this purpose they have short and broad wings that allow slow and manoeuvrable flight. The characteristic long ears allow these bats to listen for insect calls so that they can localise potential prey, and they sometimes do this without using their echolocation (Hosken *et al* 1994).

Very little is known about the biology and ecology of *P. imogene*. With regard to conservation status, prior assessments include Flannery (1995) who considered that it was “probably extinct” and Bonaccorso (1998) who believed that “the species probably still exists”.

1890 A collection of 45 specimens was made by Dr Lamberto Loria at Kamali on the Lower Kemp Welch (Wanigela) River in Central Province, which was lodged in the Museo di Storia Naturale, Genoa. Flannery (1995) states that these specimens can no longer be traced in Genoa, but some can now be found in museums in London (n=3), New York (n=1), Copenhagen (n=1) and Sydney (n=1). Swapping of specimens between museums is part of their function, and has serendipitously preserved some of the original series.

pre-1897 Bonaccorso (1998) stated that Thomas (1897) wrote about a specimen from Kapa Kapa that was collected by Dr Loria. This specimen was later lost due

to flooding at the Museo di Storia Naturale (pers. comm. from Flannery to Bonaccorso, cited in Bonaccorso 1998).

1985 A specimen (PM 25374) attributed to *P. imogene* was collected by T. Anderson at Rogut Village, Tuman River, Central Province (Bonaccorso 1998) from the crown of a pandanus tree.

1988 The Rogut Village specimen was examined by Dr Harold Parnaby as part of his PhD revision of the genus *Nyctophilus*, and he confirmed that it instead represented *N. microdon* (H. Parnaby pers. comm. to IUCN).

1992 The PNG Museum catalogue shows an entry that declared the 1985 Rogut Village specimen as either lost or destroyed.

Having described *P. imogene* in 1914, Thomas would have doubtfully made an error in the identification of this species, so the pre-1897 Kapa Kapa specimen appears to be the last one collected and identified with any accuracy. With the 1985 specimen now discounted by a long-eared bat expert as being a *Pharotis* but instead a *Nyctophilus*, and in view of *P. imogene* not being accurately recorded for more than 108 years, then the only available conclusion is that this species is extinct.

For the purposes of the PNG LNG Project, it would be prudent for several reasons to discount this species as an issue:

1. It is highly likely to be classified by IUCN in the future as being Extinct
2. Distribution records are now only known from around Port Moresby, well away from the project area. Kamali Village is 500 km southeast of the Kikori basin, where habitats are primarily savannah and mangroves.
3. If it is (however unlikely) still extant, then the narrow corridor of the gas pipeline would doubtfully have an impact upon any local population/s (this being an animal that could easily fly across the ROW) which is much less of an impact than (for example) the land clearance/logging operations that currently take place within its potential distribution.

However, in view of 45 specimens being collected at the one site (which was likely to be a maternity colony) it is suggested that a tree clearance protocol be enacted so that big trees (> 50 cm dbh) within the 0–100 m a.s.l. zone of the pipeline corridor, that may contain hollows, be hand felled to reduce any impact upon potential colonies. This would preclude the need for the type of trapping program recommended by Bonaccorso (1998) and the IUCN during their 2005 Global Mammal Assessment. If this species is in fact an open

habitat species, then targeted trapping (which relies on the concentration of bats in flyways in dense vegetation) would not be efficient.

6.1.2 Bulmer's Flying Fox (*Aproteles bulmerae*)

Aproteles bulmerae is a cave-dependent flying fox that has a fascinating and highly relevant history of discovery. It was originally described from subfossil material excavated from an archaeological dig at the Kiowa rock shelter, 2 km east of Chauve Government Station, Chimbu Province, and at an altitude of 1530 metres and described as a new species by Menzies in 1977. The Kiowa site was a human occupation site inside a minor entrance to a large series of limestone caves, and the vertebrate remains that were excavated represented kitchen waste (Menzies *op. cit.*). The *Aproteles* material was found in layers dated between 10,000 and 11,000 years before present. Menzies described this species from 200 skulls which had been broken open at the cranium so that the brain could be extracted. Two other cave dependent species, *Dobsonia moluccensis* and *Rousettus amplexicaudatus* were also present in these layers. Menzies noted that the amount of total deposit represented by *A. bulmerae* rises from <1% in the oldest layer to nearly 40%, and then declined rapidly to zero in the youngest layer. He concluded that at this time (10,000 ybp) this species became extinct.

It was subsequently discovered as a living animal in 1975 in the Hindenberg Wall area of Western Province by Hyndman and Menzies (1980). The doline cave where the *Aproteles* were found is known locally as Luplupwintem, at an altitude of 2400 m. Of relevance to the impact assessment is that Luplupwintem is close to the main walking track between Tabubil, the Ok Tedi mine and Telefomin (Flannery 1995). This author mentions that in 1975 thousands of these bats were present, but on a return visit two years later only two bats were seen (Hyndman and Menzies 1977). Local informants advised that several groups of hunters entered the cave with shotguns and virtually eliminated the colony (Flannery *op. cit.*). The cave has a 300m drop at the entry, so hunters were keen enough to use ropes (and much bravery) to get to their prey. A small number of individuals was again resident in Luplupwintem in 1992 (Flannery and Seri 1993). This colony, and another that is now "extinct or dislocated" (Bonaccorso 1998), and another that was discovered several years ago in the Central Highlands, are the only known representations of this species worldwide.

A potential record of Bulmer's Flying Fox (*Aproteles bulmerae*), listed by the IUCN as Critically Endangered, was obtained during the 2008 surveys. One of the support crew⁵ who was a resident of the village of Angore, south-east of Nogoli, described a colony of cave-dwelling flying foxes that were occasionally hunted and therefore they would have seen the bats at close quarters. Several lines of enquiry, showing pictures of potential bat candidates, indicated that there was a strong possibility that the colony was Bulmer's Flying Fox. A spinline from the Angore gas wells may pass by this village therefore it is recommended that further investigations be conducted.

The potential of a colony to be in the Angore area is of great importance. It is suggested that further investigations are carried out to determine whether this colony really exists and,

⁵ The Community Affairs liaison officer at the Juha North camp.

if so, to develop and instigate a special management plan associated with the elimination of any potential impacts of the Angore development. The key to the decline in *Aproteles bulmerae* is undoubtedly the access to caves by hunters with modern equipment, and the prevention of such should be considered of the utmost importance in any such plan.

6.2 Cave-dependent bat species and cave conservation issues

Because the project area has extensive areas of limestone, and is extensively cavernaculous, it would be easy to assume that because there are lots of caves to accommodate bat colonies. However, such is not the case because most cave bat species have highly specific requirements and not all caves provide everything that suits individual species (Hall and Richards 2004). For example, in a survey of the extensive karst area at Chillagoe (Queensland, Australia), which supported nine cave dependent species, no single species occupied all caves. Cave descriptions for a selection of these species that are also found in PNG, include:

- Hipposideros diadema* - selects caves with high domed ceilings, high temperatures, and high humidities
- Hipposideros ater* - selects very small caves very humid, usually with an earth floor
- Rhinolophus megaphyllus* - selects large caves with very high humidities, usually with a wet floor with pools of water
- Miniopterus schreibersii* - selects large caves that are warm but not as humid as *Hipposideros* caves, needs domed ceilings for rearing of young (young bats are unable to thermoregulate for the first six week of life, and females place them inside a dome to trap body heat)
- Miniopterus australis* - roost in circular depressions in the least humid section of the cave
- Myotis* spp. - roost in 'bell-holes' in cave ceilings; these are male-dominated territories with harems of females
- Emballonura* sp. - rest against the wall, individually scattered through the least humid dark section
- Dobsonia* (and probably *Aproteles*) – occupy the twilight zone near cave entrances or roost on the walls of grikes or sinkholes

The number of cave bat species that can be expected to occur at various elevation intervals along the pipeline corridor is shown in Table 14. Up to 32 species are predicted to occur in lowland karst, declining to 13 species at higher elevations.

Cave-dependent species, particularly *Hipposideros* and *Rhinolophus*, are highly sensitive to disturbance, and colonies can be impacted by frequent human visitation. PNG

landowners regard fruit bats as a source of food, and apparently do not harvest them in a sustainable manner (Flannery 1995 and Bonaccorso 1998).

During the survey, local landowners were interviewed for information about nearby caves that may have been within the pipeline corridor. Very little information was gained, yet at most survey areas quite a number of cave bat species were recorded. It is apparent that landowners do not know the location of all caves in their district, especially those that are likely to be small or located in inaccessible areas, and that the extensive limestone areas in the project area will have caves that have never been discovered. This factor is highly relevant to the reduction of possible impacts upon cave bat colonies. If caves are located by surveyors and crews constructing the pipeline, the locations of these caves may need to be kept confidential so as to reduce the possibility of humans visiting and destroying any colonies of bats inside.

6.3 General impact assessment

There are a range of broad-scale impacts that apply to all fauna and flora and relate to the construction and operational phases of the project, and also specific issues such as the crossing of streams by the pipeline and the presence of construction roads.

However, for bats three primary impacts are identified. These are:

- hunting pressure (direct killing) upon cave species
- human disturbance (indirect killing) of cave colonies (Hall and Richards 2004)
- mortality of hollow roosting species when trees are felled.

Impacts and recommended general mitigation procedures are shown in Tables 15 and 16.

It is recommended that the following broad mitigation procedures be considered:

- identify during the pre-construction phase (i.e., pipeline route survey) any caves and flying fox roosts, ensure that security personnel are made aware, and investigate methods to control hunting within the project area that take due and effective account of the cultural and social context, especially customary land ownership.
- educate workers and contractors via a pre-start environmental induction of the broader adverse implications of hunting, even if it is part of traditional lifestyle.
- conduct education programs for villagers living near sensitive conservation areas advising of threats to wildlife and forest from current land clearing and hunting practices.
- consider implementing conservation programs with landowner participation in the protection of sensitive conservation areas in the project area.
- prevent blasting within 100 m of caves.

- explore what scope exists within broader agreements with workers and landowners to conserve bats.

The scores and prioritisation of each listed species is shown in Table 17. This table also provides the impact assessment based on the acceptance of recommended mitigation procedures.

Table 14 Cave bat species known or predicted to (●) occur at different elevations in the project area (modified from Table 2).

	Elevation range				
	0 – 500	600- 1000	1100- 1500	1600- 2000	<2000
Pteropodidae					
<i>Aproteles bulmerae</i>				●	●
<i>Dobsonia minor</i>	●	●			
<i>Dobsonia magna</i>	●	●	●	●	●
<i>Rousettus amplexicaudatus</i>	●				
Emballonuridae					
<i>Emballonura beccarii</i>	●	●	●	●	
<i>Emballonura diana</i>	●	●	●	●	●
<i>Emballonura furax</i>	●	●	●	●	●
<i>Emballonura raffrayana</i>	●	●	●	●	●
<i>Mosia nigrescens</i>	●	●	●	●	●
<i>Taphozous australis</i>	●				
Rhinolophidae					
<i>Rhinolophus arcuatus</i>	●	●	●	●	●
<i>Rhinolophus euryotis</i>	●	●	●	●	
<i>Rhinolophus maros</i>	●	●	●		
<i>Rhinolophus megaphyllus</i>	●	●	●	●	●
<i>Rhinolophus philippinensis</i>	●	●	●		
Hipposideridae					
<i>Aselliscus tricuspidatus</i>	●	●			
<i>Hipposideros ater</i>	●	●	●	●	
<i>Hipposideros calcaratus</i>	●	●			
<i>Hipposideros cervinus</i>	●	●	●		
<i>Hipposideros corynophyllus</i>				●	
<i>Hipposideros diadema</i>	●	●	●		
<i>Hipposideros edwardshilli</i>	●				
<i>Hipposideros maggietaaylorae</i>	●	●			
<i>Hipposideros muscinus</i>	●	●			
<i>Hipposideros semoni</i>	●	●	●		
<i>Hipposideros wollastoni</i>	●	●	●	●	●
Miniopteridae					
<i>Miniopterus australis</i>	●	●	●	●	
<i>Miniopterus macrocneme</i>	●	●	●	●	●
<i>Miniopterus magnater</i>	●	●	●	●	●
<i>Miniopterus medius</i>	●	●	●	●	●

Table 14 Cave bat species known or predicted to (●) occur at different elevations in the project area (modified from Table 2).

	Elevation range				
	0 – 500	600- 1000	1100- 1500	1600- 2000	<2000
<i>Miniopterus propitristis</i>	●	●	●	●	
<i>Miniopterus schreibersii</i>	●	●	●	●	●
<i>Vespertilionidae</i>					
<i>Myotis moluccarum</i>	●	●	●		
Total species recorded or predicted	31	28	23	19	13

Table 15 Summary of potential impacts and mitigation measures for species (or species groups) of concern that are predicted to occur (Table 2) along the pipeline corridor, showing those that are considered to be unaffected by the pipeline construction and operation.

Taxon	Summarised impact	Impact mitigation considerations
Species of high concern		
<i>Pharotis Imogene</i>	Probably extinct	Develop tree felling procedures for the 0 – 200 m a.s.l. section of the ROW to reduce potential harm to roosting bats.
<i>Aproteles bulmerae</i>	Cave dwelling, subject to hunting pressure	Pre-clearance survey to confirm that no roost caves are present. If present, prevent disturbance to caves during construction. Prevention of human access to cave roosts. Develop management plan
<i>Saccolaimus mixtus</i> <i>Otomops papuensis</i> <i>Otomops secundus</i>	Past survey methods not valid for this species, colonies may be affected during tree clearance operation	No practical solutions known for these hollow roosting species
All Hipposideridae All Rhinolophidae <i>Emballonura</i> spp.	Cave dwelling, affected by human visitation	Pre-clearance survey to confirm that no roost caves are present. If present, prevent disturbance to caves during construction. Develop education program to give “local “ownership” to colonies
Species of least concern, unlikely to be impacted		
<i>Syconycteris hobbit</i> <i>Nyctimene draconilla</i>	Rare, but massive tracts of habitat available	None required, no major impact expected
<i>Nyctophilus microdon</i> <i>Nyctophilus timoriensis</i>	Rarity an artifact of past survey methods	None required, no major impact expected
<i>Kerivoula muscina</i> <i>Nyctimene cyclotis</i> <i>Nyctimene aello</i> <i>Paranyctimene raptor</i> <i>Pipistrellus papuanus</i>	Known to utilise disturbed habitats	None required, no impact expected

Table 16 General impacts that apply to the bat fauna, prioritised according to their perceived effect on local populations of threatened species.

Perceived priority of impact	Impact	Construction phase	Operational phase	Stream crossings	Construction roads
Very High	Cave and colony destruction	•		•	•
High	Cave disturbance by blasting	•		•	•
	Outsiders attracted to area and hunting and clearing		•		
	Human disturbance to roosting fauna in caves and flying fox camps.	•	•	•	•
Moderate	Hunting by workers and/or contractors	•	•		•
	Loss of forest, riverine vegetation, or special habitats	•		•	•
	Noise and dust, especially blasting near caves	•	•		•
	Increased access for illegal logging		•		
Low	Disturbance to migrating/overwintering fauna	•	•	•	•
	Habitat fragmentation	•	•		•
	Gas flames (burning of excess)		•		
	Loss of wetlands	•		•	•
	Continued erosion		•		
	Maintaining cleared vegetation around wells		•		
Number of impacts		9	10	6	9

Table 17 Classification of species listed in IUCN threat categories by the potential for impact, based on scores generated from IUCN status. (CR = 3, VU = 2, NT = 1), endemism to PNG (or 1 or 0), roosting in caves (2 = hunted for food, 1 = subject to disturbance, 0 not cave dwelling), habitat specialisation as indicated by ecological assessment (1 or 0) and whether the surveys revealed rarity of abundance or a restriction to a particular habitat (1 or 0).

	IUCN status	IUCN score	PNG endemic	Cave dwelling	Habitat specialist	Rare, restricted	Score total	Potential for Impact		Recommendations/comments on mitigation measures
								Individual project areas	Entire project area	
<i>Aproteles bulmerae</i>	CR	3	1	2	0	1	7	Low	Low	Protection of caves from hunters
<i>Pharotis imogene</i>	CR	3	1	0	0	1	5	Low	None	Develop procedures for felling of trees with hollows in lowlands so as to reduce potential harm to roosting bats
<i>Kerivoula muscina</i>	VU	2	1	0	1	1	5	None	None	
<i>Emballonura furax/dianae</i>	VU	2	0	1	1	1	5	Low	None	Protection of caves from disturbance
<i>Nyctimene draconilla</i>	VU	2	1	0	0	1	4	None	None	
<i>Syconycteris hobbit</i>	VU	2	1	0	0	0	3	None	None	
<i>Dobsonia minor</i>	NT	1	0	2	0	0	3	None	None	Protection of caves from hunters
<i>Nyctophilus microdon</i>	VU	2	1	0	0	0	3	None	None	Species is far more common and widespread in survey areas than indicated by IUCN status
<i>Otomops secundus</i>	VU	2	1	0	0	0	3	None	None	Species is far more common and widespread in survey areas than indicated by IUCN status
<i>Nyctimene cyclotis</i>	NT	1	1	0	0	0	2	None	None	
<i>Rhinolophus philippinensis</i>	NT	1	0	1	0	0	2	Low	None	Protection of caves from disturbance but

Table 17 Classification of species listed in IUCN threat categories by the potential for impact, based on scores generated from IUCN status. (CR = 3, VU = 2, NT = 1), endemism to PNG (or 1 or 0), roosting in caves (2 = hunted for food, 1 = subject to disturbance, 0 not cave dwelling), habitat specialisation as indicated by ecological assessment (1 or 0) and whether the surveys revealed rarity of abundance or a restriction to a particular habitat (1 or 0).

	IUCN status	IUCN score	PNG endemic	Cave dwelling	Habitat specialist	Rare, restricted	Score total	Potential for Impact		Recommendations/comments on mitigation measures
								Individual project areas	Entire project area	
										species is far more common and widespread than indicated by IUCN status
<i>Pipistrellus papuanus</i>	NT	1	0	1	0	0	2	Low	None	Protection of caves from disturbance
<i>Nyctimene aello</i>	NT	1	0	0	0	0	1	None	None	
<i>Paranyctimene raptor</i>	NT	1	0	0	0	0	1	None	None	

7 REFERENCES

- Balun L. (2004?) An Audit on the Status of the Flora and Fauna of the Porora Forest, South East Mananda Forest, Southern Highlands Province. WWF KICDP Report.
- Bonaccorso, F.J. (1998) Bats of Papua New Guinea. Conservation International Tropical Field Guide Series 2, Conservation International: Washington DC.
- Flannery, T. (1995) Mammals of New Guinea. Reed Books: Chatswood, NSW.
- Flannery, T.F. and Seri, L. (1993) Rediscovery of *Aproteles bulmerae* (Chiroptera: Pteropodidae) . Morphology, ecology and conservation. *Mammalia* 57: 19-25
- Hall, L.S. and Richards, G. (1985) The bats of Chillagoe. *Towerkarst* 5: 13-22
- Hall, L.S., Richards, G. and Abdullah, M.T. (2002) The bats of Niah National Park, Sarawak. *Sarawak Museum Journal* 57: (78): 255-282.
- Hall, L.S. and Richards, G. (2004) Flying around underground: cave bats. Pp. 111-126 (Chapter 4) in, *Beneath the Surface. A Natural History of Australian Caves* (eds. B. Finlayson and E. Hamilton-Smith). University of NSW Press: Sydney.
- Hammermaster and Saunders (1995a)
- Hammermaster and Saunders (1995b)
- Hartshorn, G.S., Burrows, I., Leary, T., Seri, L., Allen, G., Polhemus, D., Balun, L., Orsak, L., Bigilale, E., Kinbag, F., Kinibel, A., Dal, C., Wasel, H., Ellis, G. and Forney, M. (1995). Field survey of biodiversity in the Kikori River Basin. Papua New Guinea. WWF KICDP report.
- Hosken, D.J., Bailey, W.J., O'Shea, J.E. and Roberts, J.D. (1994) Localisation of insect calls by the bat *Nyctophilus geoffroyi* (Chiroptera: Vespertilionidae): a laboratory study. *Australian Journal of Zoology* 42: 177-184.
- Hyndman, D. and Menzies, J.I. (1980) *Aproteles bulmerae* (Chiroptera: Pteropodidae) of New Guinea is not extinct. *Journal of Mammalogy* 61: 159-160.
- Leary, T. & Seri L. (1995?) Survey of Birds and Mammals at Utiti Creek. Unpublished WWF KICDP Report.
- Leary, T. (1998) Mammals of the Lake Kutubu Swamp Forests. Wetlands International Report.
- Leary, T. (1999) Mammal Survey of the Gobe Oil Field Area, Southern Highlands and Gulf Provinces, Papua New Guinea - December, 1998. WWF KICDP Report.
- Leary, T. (2001) Mammal Survey of Two Sites on the Northeast Slopes of Mt Sisa, Southern Highlands Province, PNG - October 1999. WWF KICDP Report.

Leary, T. (2002?) Brief Report on Iviri Mammal Monitoring - December 2001. WWF KICDP Report.

Leary, T. (2004) Mammal Survey of Darai Plateau, Gulf Province, and Libano Sok, Southern Highlands Province, July - August, 2003. WWF KICDP Report.

Leary, T. (2004?) Brief Report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003. WWF KICDP Report.

Leary, T. (2004?) Brief Report on Keboi Kerowa Mammal Monitoring - July 2004. WWF KICDP Report.

Leary, T. and Seri, S. (1997) An annotated checklist of mammals recorded in the Kikori River Basin, Papua New Guinea. [Probably a draft manuscript – no citation details available]

Leary, T., Seri L. & Kinbag F. (1995) Report on the bat component of the field survey of biodiversity in the Kikori ICDP area. In: Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea (G. S. Hartshorn et al.). WWF KICDP Report.

Menzies, J.I. (1977) Fossil and subfossil fruit bats from the mountains of New Guinea. Australian Journal of Zoology 25: 329-336.

Namo, R. (2004a) Annotated Checklist of Mammals of Kikori Basin. WWF KICDP Report.

Richards, G.C. (2001) Towards defining adequate bat survey methodology: why electronic call detection is essential throughout the night. Australasian Bat Society Newsletter 16: 24-27.

Richards, G.C. (2002) Ecological and Evolutionary Determinants of Bat Community Structure in South-east Australian Forests. PhD Thesis, University of New South Wales, Sydney.

Richards, G.C. (2005) The Papua New Guinea Gas Project: a study of bat faunal biodiversity and an assessment of project Impacts. Report to Enesar Pty Ltd, Melbourne.

Thomas, M.O. (1897) On the mammals collected in British New Guinea by Dr. Lamberto Loria. Ann. Mus. Civico Storia Nat. Genova, Series 2, 18: 606-622.

Annex 07

Biodiversity survey results:

Birds at Hides, Nogoli and Benaria in 2005

This report originally appeared in the PNG Gas Project EIS as:
Supporting Study 5: "A report on the Avifauna of the Papua New Guinea Gas
Project Area"

A report on the Avifauna of the Papua New Guinea Gas Project Area

Report to Enesar Consulting Pty Ltd

By Iain Woxvold and Francis Crome
30 September
2005

This report takes into account the particular instructions and requirements of our client(s). Francis Crome Pty Ltd has had to rely on information from other sources in preparing this report (including the party for whom it is prepared) and is not in a position to, and has not, verified the accuracy or completeness of information so provided. Accordingly, Francis Crome Pty Ltd takes no responsibility for and assumes no liability in respect of, any information provided by others for the purposes of preparing this report nor the consequences of using such information. Neither this report nor any part of it may be used by any third parties and no responsibility whatsoever is undertaken to any third parties.

Table of Contents

1	Executive Summary.....	6
2	Preface	7
3	Introduction.....	7
4	Existing Information	7
5	Study Sites for New Surveys	9
5.1	Nogoli.....	9
5.2	Hides 3.....	9
5.3	Benaria.....	9
6	Methods.....	10
6.1	General Techniques.....	10
6.1.1	Bird cruises.....	10
6.1.2	Mist-netting	10
6.1.3	Spotlighting.....	10
6.1.4	Camera trapping.....	10
6.1.5	Local information	11
6.2	Site Specific Details	11
6.2.1	Nogoli	11
6.2.2	Hides 3	11
6.2.3	Benaria	12
7	Results.....	13
7.1	Survey Sites.....	13
7.1.1	Nogoli	13
7.1.2	Hides	14
7.1.3	Benaria	18
7.2	Entire Area Summary.....	20
7.2.1	Species richness and composition	20
7.2.2	Seasonal variation	22
7.2.3	Altitudinal distribution.....	23
8	6. Conservation Significance of the Avifauna	25
8.1	IUCN-Listed Species.....	25
8.1.1	Critically endangered species.....	25
8.1.2	Vulnerable species	25
8.1.3	Near threatened species	25
8.1.4	Data deficient species	26
8.2	Endemic Bird Areas And Restricted-Range Species	27
8.3	Noteworthy areas.....	29
8.3.1	Montane Nothofagus forests	30
8.3.2	Swamp forests.....	31
9	Impact Analysis	32
9.1	Direct (Primary) Impacts During Construction.....	32
9.1.1	General considerations.....	32
9.1.2	Forest clearing.....	33
9.1.3	Noteworthy areas	35
9.1.4	River crossings	36
9.1.5	Edge effects and barriers	37
9.1.6	Fire	37
9.1.7	Open trenches.....	38
9.1.8	Pipeline construction	38
9.1.9	Materials handling	38
9.1.10	Traffic, noise and dust.....	39
9.1.11	Hunting	39
9.1.12	Impacts on migratory species.....	39

9.2	Indirect (Secondary) Impacts	40
9.3	Summary of Mitigation Measures.....	41
10	References	43

Tables

Table 1	Bird survey sites
Table 2	Details of Camera trapping
Table 3	Upland avifauna (Hides 3 and Mt Sisa
Table 4	Species of conservation concern on the IUCN red data list
Table 5	Restricted Range Species of the Central Papuan Mountains EBA recorded in or whose ranges overlap with the KICDP and the PNG Gas Project area
Table 6	Summary of mitigation measures warranting investigation

Figures

Figure 1	Study areas.
Figure 2	The Nogoli Survey site.
Figure 3	The Hides 3 survey site.
Figure 4	The Benaria survey site.
Figure 5	Altitudinal ranges of forest species – non passerines 1.
Figure 6	Altitudinal ranges of forest species – non passerines 2.
Figure 7	Altitudinal ranges of forest species – passerines 1.
Figure 8	Altitudinal ranges of forest species –passerines 2.
Figure 9	Altitudinal ranges of forest species –passerines 3.
Figure 10	Altitudinal ranges (m) of IUCN listed species.

Appendices

Appendix 1	Birds recorded from Hides 3, Nogoli and Benaria survey sites.
Appendix 2	Birds recorded from the KICDP area.
Appendix 3	Birds that may yet be recorded in the KICDP area

Plates

Plate 1	Camera trap set up at Hides3
Plate 2	Nogoli study site - regrowth next to road.
Plate 3	Nogoli study site - garden.
Plate 4	Nogoli study site - gardens, kunai, secondary and primary forest.
Plate 5	Nothofagus forest at Hides 3.
Plate 6	Nothofagus forest at Hides 3.
Plate 7	Wayne's Swamp - a sinkhole pool near Hides 3.
Plate 8	Track down into sinkhole near Hides 3.
Plate 9	Well pad at Hides 2.

- Plate 10 The Benaria River.
- Plate 11 Open grassland at the Benaria Camp.
- Plate 12 Primary forest on the ridge north of Benaria Camp.
- Plate 13 Interior of forest near Benaria River.
- Plate 14 Regrowth forest on ridge behind Benaria Camp.
- Plate 15 Orange-crowned Fairy-wren and nest.
- Plate 16 Garnet Robin.
- Plate 17 Olive Straightbill.
- Plate 18 Huli warriors with plumes and hornbill casques.
- Plate 19 Mountain cuscus captured by local hunter.

1 Executive Summary

- This report analyses the avifauna present within the Kikori Integrated Conservation and Development (KICDP) area, in which the proposed PNG Gas Project is located. The report is based on a synthesis of 47 surveys by WWF and ourselves conducted at 25 sites over a period of 11 years (1995-2005).
- Most previous WWF surveys have focused on the area between the Kikori delta and the Kutubu Central Processing Facility (CPF). Consequently, three additional surveys were conducted in April-May 2005 by Francis Crome (FC) and Iain Woxvold (IW) north of Moro at the Hides gasfield, Nogoli and Benaria.
- The Hides gasfield is characterised by entirely or almost entirely undisturbed, montane *Nothofagus* forest infrequently visited by local villagers. We recorded 65 bird species, and the area is of high conservation value, supporting at least four IUCN-listed species, including three birds-of-paradise (Yellow-breasted Bird-of-Paradise (*Loboparadisea sericea*), Black Sickbill (*Epimachus fastuosus*), Ribbon-tailed Astrapia (*Astrapia mayeri*)), and the Dwarf Cassowary (*Casuarius bennetti*).
- The proposed site for the new Hides Processing Facility (HPF) at Nogoli is heavily populated, and includes the Tagari River, subsistence agriculture and secondary forest. Forty-four bird species were observed, and the area is of low to moderate conservation value. No IUCN-listed species are expected to depend on the present habitat.
- Benaria sits halfway between Moro and close to where the pipeline right-of-way (ROW) will be constructed. The region is heavily populated, and the habitat includes the Benaria River, an adjacent swamp, cleared agricultural and grazing land, and secondary forest. We recorded 88 bird species, and conclude that the region is of moderate to high conservation value, with two IUCN-listed globally threatened species recorded (Southern Cassowary (*Casuarius casuarius*) and Blue Bird-of-paradise (*Paradisaea rudolphi*)).
- A total of 389 bird species (212 genera, 55 families) have been positively identified in the KICDP and PNG Gas Project area, accounting for 52.6% of the approximately 740 species recorded in PNG. Seventeen of these species are listed with the IUCN as globally threatened (vulnerable), near threatened or data deficient. An additional 152 species have not yet been recorded within the project area, but may be expected to occur in light of available information regarding distribution and habitat preference.
- While there may be local disruption to breeding and foraging activities close to development, the project should have little primary impact on bird populations.
- Secondary impacts from hunting and deforestation may result from greater access to areas of high conservation value.

2 Preface

This study forms Supporting Study 5 of the PNG Gas Project Environmental Impact Statement. This study provides an assessment of the potential impacts of the proposed development on birds. Aspects of the project description are discussed where relevant in the report. A detailed description of the proposed PNG Gas Project is given in Chapter 2 of the Main EIS report.

3 Introduction

The biodiversity data collected over the past 10 years by WWF is sufficient to allow impact assessment for most of the project area. However there is little data north of Kutubu. The only pre-existing bird survey that falls within the section of the project area between the Kutubu CPF and the Hides gas field was a brief survey conducted on Mt Moran in 2003 (Diamond and Bishop (2003). Consequently, additional biodiversity surveys were carried out in this area by Francis Crome (FC) and Iain Woxvold (IW) in April-May 2005.

This report presents the results of those surveys, and combines the data with the existing WWF data to provide an assessment of the avifauna of the project area and the likely impacts of the project.

4 Existing Information

The gas project area lies within the Kikori Integrated Conservation and Development Project (KICDP) area. This is an area designated by WWF to integrate conservation and development. It covers the entire Kikori drainage (Leary et al. 1996, McCall and Fleming 2000). From 1995 to 2004 WWF and its partners carried out biodiversity surveys between Kutubu and the coast. Table 1 presents the data sources and survey areas.

The majority of surveys have focused on that section of the Kikori River valley that includes the existing oil pipeline, i.e. from the Kutubu CPF to the Kikori delta. These surveys span a length of over 200 km within and on the ranges to the east and west of the Kikori valley, and cover an altitudinal range of between zero and 1,440 m ASL.

Only three surveys have been conducted at altitudes greater than 1,500 m – Mt Bosavi, Mt Sisa, and a brief survey at Mt Moran. Mounts Bosavi and Sisa are isolated 'island' peaks south of the central cordillera, and thus not likely to reflect the full diversity of bird taxa present in the northern montane parts of the KICDP and PNG Gas Project area.

Table 1 Bird survey sites

Site	Code	Latitude	Longitude	Altitude	References
Cape Blackwood	CB	7.548	144.3139	0+	Diamond & Bishop (2000)
Kikori1	KO1	7.42833	144.24833	10	Jaensch & Watkins (2000)
Veriabari	KD4	?	?	0+	Jaensch & Watkins (2000)
Kopi/Kikori	KL1	7.366	144.233	~10-20	Burrows (1995)
Kopi	KL3	7.32166	144.18139	~20	Diamond & Bishop (2003)
Pinini Creek	KP	7.187783	144.1124	20+	Diamond & Bishop (2003)
Iviri 3	I3	7.4166	144.40833	20-40	Leary (2002)
Kikori delta	KD2	7.538	144.24833	0+	Diamond & Bishop (2000)
Keboi Kerowa	KK	7.533	144.25833	55-1341	Diamond & Bishop (2003)
Veiru Creek	V	7.4256	144.1956	30	Burrows (1995)
Utiti Creek	U	7.225833	144.09833	35	Leary & Seri (1995)
Dark End Lumber	DEL	7.1572	144.393056	30-60	Diamond & Bishop (2000)
Omo village	O	6.978056	144.30417	40-170	Burrows (1995)
Libano Sok	L	6.4004	142.975	200-600	Igag (2003)
Wassi Falls 1	WF1	6.748056	143.58972	380 - 420	Burrows (1995)
Kantobo	K	6.721731	143.56652	400-420	Diamond & Bishop (2003)
Darai Plateau	D	7.13075	143.6105	300-700	Igag (2003)
Gobe	G9	6.823472	143.74472	55-1341 (643 mean)	Diamond & Bishop (2003)
Lake Kutubu	LK1	6.4166	143.33	808	Jaensch (1997)
Moro	MO3	6.3628	143.22806	740-1000	Jaensch (1997)
Moro/Kutubu/Ago go	MO1	6.367897	143.202	740-1350	Burrows (1995)
Nogoli	N	5.9648	142.8164	1200	This study
Benaria	B	6.05478	142.97845	1345	This study
Mt Bosavi	MB	6.54528	142.8397	1250-1725	Burrows (1995)
Mt Moran	MM	6.265488	143.13738	1650	Diamond & Bishop (2003)
Hides 3	H3	5.9485	142.7455	2163	This study
MS1 and MS2	MS3	6.129861	142.7606944	2200*	Diamond & Bishop (2000),

* Mean of top and bottom camps

5 Study Sites for New Surveys

The new surveys were based around three locations: Nogoli, Hides 3 and Benaria (Figure 1).

5.1 Nogoli

Surveys focused on an area approximately 5 km SE of Nogoli close to the possible new Hides Processing Facility (HPF) at approximately 1,250 m ASL (05° 58.266'S, 142° 48.828'E).

The survey site consisted of an approximately 140-ha area centred on the intersection of the road between Hides 4 and Nogoli and extending down to the Tagari River (Figure 2).

The Tagari River valley, including the area around Nogoli and the site of the proposed HPF, is heavily populated. Habitat within the study site included the river, a permanent road, subsistence gardens and secondary growth, and pre-montane rainforest with emergent *Araucaria* (Plates 2 to 4).

5.2 Hides 3

Surveys were conducted within walking distance from the base-camp situated at the Hides 3 well site at an elevation of 2,163 m (05°56.910'S, 142°44.730'E).

The study area is characterised by primary, upper montane *Nothofagus* moss forest with many epiphytes (Plates 5 to 8) overlying polygonal karst limestone with numerous sinkholes. Extensive thickets of climbing bamboo were present on the hilltops and ridges, but absent from the darker valleys. Swamps occur at the bottom of some of the larger, poorly drained sinkholes (Plate 7). Slopes surrounding the well pads are covered in scree, with emergent secondary growth. Due to the rugged terrain, this area is unsettled and rarely visited by local villagers, and apart from the existing well pads and flowlines, the habitat is pristine.

The area immediately surrounding the well site was sampled intensively because the well pad afforded an excellent view of the forest in the surrounding valleys and adjacent hills. In addition, two paths were cut through the forest by local guides and regularly traversed each day in search of birds in the forest interior. One of these paths led to Wayne's swamp in a nearby sinkhole and the other over the ridge behind H3 and on to the well at Hides 2 (05°56.857'S, 142°44.015'E, 2400 m) (Plate 9). Figure 3 shows this study area and the survey tracks.

5.3 Benaria

The study area (06°03.287'S, 142°58.707'E) was at an elevation of 1,345 m and situated half way along the proposed road between Nogoli and Moro, and about 4.6 km west of Benaria mission (06°03.503'S, 143°01.202'E, 1,546 m) along an old vehicular track now used only for walking by local residents (Figure 4). The study area includes the site where the access road will cross the Benaria River (Plate 10) and the survey route for the new access road.

This area is populated, and the surrounding habitat has been subjected to varying levels of disturbance at different times.

The camp was situated on an approximately 6-ha clearing currently used to graze cattle (Plate 11). Forested areas were characterised by mid-montane small crowned hill forest, riparian forest alongside the Benaria River, and swamp forest. Most of the habitat in the river valley and surrounding smaller hills is dominated by secondary forest in varying stages of regrowth. Primary forest is found mainly on the higher slopes surrounding the valley (Plates 12, 13 and 14), and in smaller patches on the lower slopes and in the valley.

6 Methods

6.1 General Techniques

6.1.1 Bird cruises

At all sites, birds were identified visually using binoculars (10 ×) or by their calls. Rapid survey techniques were used to maximise the opportunities to locate species. Trails and all accessible areas were walked slowly, and all birds seen and heard were recorded.

At all sites, bird calls were recorded on a Sony hiMD minidisk digital recorder using a Sennheiser ME64 cardioid microphone, and previously undetected species were later identified.

6.1.2 Mist-netting

At Hides 3 and Benaria, mist-nets were used to help confirm the presence of secretive or cryptic species. All nets were erected close to the ground on trimmed saplings, checked at least every hour, and furled during periods of rain. Most birds were released immediately at the capture site. Some individuals, particularly those in juvenile plumage, were taken to camp to confirm their identity and subsequently released at the capture site.

6.1.3 Spotlighting

Nightbirds were targeted using mist-nets, and identified by voice or visually when spotlighting.

Spotlighting was restricted to areas surrounding the bush-camps at Hides 3 and Benaria.

6.1.4 Camera trapping

Five 'Photoscout' 35 mm IR triggered camera traps were used to continuously record fauna. To operate the traps the camera would be loaded with 400 ASA 35 mm film, desiccant placed in the housing and the unit closed and sealed. The unit was then tied to a tree and aimed so that any bird or mammal crossing the ground within 15 m of the camera would trigger the IR beam and a photograph of the animal taken (Plate 1). Table 2 provides details of camera trap operations.

6.1.5 Local information

Local villagers at each site provided valuable information regarding the presence of particular species, particularly those birds commonly hunted for their meat (e.g. megapodes, cassowaries, etc.) or plumage (e.g. birds-of-paradise, hornbills, parrots and cockatoos). Villagers were interviewed by showing them pictures in Beehler et al. (1986). The identities of birds they recognised were confirmed or otherwise during discussions of behaviour, call, nesting habits etc.

Table 2 Details of Camera trapping

TRAP SERIAL NUMBER	LOCALITY	DATE SET	DATE RETRIEVED	NIGHTS
Hides 3				
25536	SRHill top	24/04/2005	30/04/2005	5
25539	H2 track near SRHill	24/04/2005	30/04/2005	5
25535	Wayne's swamp bottom	25/04/2005	30/04/2005	4
25537	Track out of Wayne's Swamp	25/04/2005	30/04/2005	4
Benaria				
25536	Near Benaria River	2/05/2005	8/05/2005	7
25539	Hill above swamp	2/05/2005	8/05/2005	7
25535	Survey Hill 6 03.554; 142 58.603	2/05/2005	8/05/2005	7
25537	Swamp	2/05/2005	8/05/2005	7
"Rental"	Above garden on Benaria River 6 03.533; 142 58.473	2/05/2005	8/05/2005	7

6.2 Site Specific Details

6.2.1 Nogoli

Surveys were conducted by IW from the afternoon of 21st April to the evening of 23rd April. Daytime weather was mostly fine, though it rained steadily for much of the afternoon of 23rd April. Due to security constraints on transport to the study site, only 16 hours of survey time were spent outside of the Nogoli camp. Much of this survey time (12 hours) fell between 1100 and 1700 h, outside the period when birds are most active. Observations were made on foot through the surrounding forest and clearings while accompanied by a local guide. Birdsong was recorded from the grounds of the Nogoli camp for 40 mins shortly after dawn on 23rd April. Recording equipment was taken on surveys to the main study site, and a total of 30 mins of birdcalls were recorded opportunistically.

6.2.2 Hides 3

Birds were sampled by FC and IW from arrival at 0830 h 24th April to departure at 1000 h 1st May. Daytime weather was fine until around midday 26th April, after which it rained steadily until departure. While in camp, birds were observed opportunistically at all times from around the well pad.

Between 0930 h and 1630 h on 26th April, FC and IW conducted a return survey between Hides 3 and Hides 2.

Six mist-nets were placed permanently within 500 m of the camp on the morning of 27th April. Trapping was opportunistic, with the nets unfurled during regular but brief respites from the rain. Two nets (6 m and 12 m) were placed in primary forest among thick undergrowth with sprawling bamboo on top of the hill behind camp. Two nets were placed on the scree to the west of the well pad, one (6 m) in enclosed, moss-covered 3-4 m secondary growth, and the other (12 m) in an adjacent open area. The final two nets (6 m and 12 m) were placed in secondary growth between the well-pad boundary and primary forest.

Birdsong was recorded for 1 hr soon after dawn on the morning of 26th April from the edge of the Hides 3 well pad. In addition, a total of 40 minutes of birdsong was recorded opportunistically during surveys on 25th, 26th, 29th and 30th April. Four camera traps were deployed along the walking trails within 1 km of the camp on 25th April, and withdrawn on 30th April.

6.2.3 Benaria

Birds were recorded by FC and IW between 1100 h 1st May and the evening of 8th May. Daytime conditions were mostly fine with brief periods of rain, though persistent rain fell on May 8th. While at camp, birds were observed opportunistically around the clearing and on the edge of the surrounding forest. Birds of riparian forest and the forest interior were surveyed on foot along pre-existing paths. In addition, one path was cut by local guides through secondary forest to the top of a nearby hill and regularly traversed by all members of the biodiversity team. At 0830 h on 5th May, IW walked with other members of the biodiversity team and a local guide to the Benaria mission and climbed to the top of an adjacent ridge (06° 03.800'S, 143° 01.008'E, 1,943 m) before returning to camp at 1730 h. The survey included agricultural areas, secondary growth and primary forest on the hilltop.

Ten mist-nets were deployed during the Benaria surveys. Six were placed permanently within 500 m of the camp on 3rd May. Two of these (6 m and 12 m) were situated in secondary forest between the clearing and a swamp, two (12 m) were placed between trees on the edge of the clearing adjacent to the riparian forest, and two (12 m) were placed in tall secondary forest across and adjacent to a small stream. A further four nets (2 × 6 m, 2 × 12 m) were deployed about 1 km from camp in secondary forest on the morning of May 7th, and withdrawn in the afternoon of the following day.

A total of 35 minutes of birdsong was recorded opportunistically during surveys on 2nd, 4th and 5th May. Five camera traps were deployed at least 6 m from the walking trails within 1 km of the camp on 2nd May, and withdrawn on 8th May.

7 Results

7.1 Survey Sites

Appendix 1 lists the bird species recorded at the three survey sites. Nomenclature and family arrangements follow the Sibley and Monroe system (Sibley and Monroe 1990, 1993a and b) for most species. Birds of Paradise follow Frith and Beehler (1998) and megapodes Jones et al. (1995).

7.1.1 Nogoli

We recorded 44 bird species (Appendix 1). The low species count was due to a number of factors:

- The survey was conducted over a short period of only 2.5 days;
- Due to logistic and security constraints placed on transport to the study site, only 16 hours of survey time were spent outside of the Nogoli base camp;
- Much of this survey time (12 hours) fell between 1100 and 1700 h, outside the period when birds are most active;
- The area is well populated, and much of the habitat we surveyed was highly modified (agriculture or secondary growth); and
- Our survey of less disturbed, mature secondary growth south of the proposed development site was conducted over four hours during which it rained steadily.

No IUCN-listed species were recorded.

The region is heavily populated and, apart from the Tagari River, the habitat within the area consists of agriculture and secondary growth well frequented by local villagers, their pigs and dogs. Consequently, there was little evidence of ground-dwelling species such as megapodes that might be expected to occur in more pristine forest. However, the secondary forest supports a variety of birds that rely on the mid- to upper-storeys of the forest. Fruiting trees attract many birds, such as fruit doves, and there is suitable breeding habitat for a number of species, such as the Slender-billed Cuckoo-dove (*Macropygia amboinensis*). Three birds-of-paradise were observed in the area - Lawes's Parotia (*Parotia lawesii*), Magnificent Riflebird (*Ptiloris magnificus*) and Raggiana Bird-of-paradise (*Paradisaea raggiana*). These are all species that cope well with forest disturbance and survive in even very heavily disturbed areas. There are no concerns regarding the conservation of these species.

The areas around Nogoli, the possible site for the HPF and the construction camp are of low to moderate conservation value, and no IUCN-listed species are expected to depend on the present habitat. Hunting pressure and habitat disturbance are considered too great for threatened species such as Salvadori's Teal (*Salvadorina waigiensis*), Pesquet's Parrot (*Psitttrichas fulgidus*), New Guinea Eagle (*Harpyopsis novaeguineae*), Gurney's Eagle (*Aquila gurneyi*), and the IUCN-listed birds-of-paradise that occupy forests of

similar altitude within the region. However, footprints of the globally threatened Dwarf Cassowary (*Casuarius bennetti*) were seen about one kilometre south of the site in less disturbed habitat.

7.1.2 Hides

Sixty-five bird species were recorded, including the following nine species not previously recorded within the KICDP:

Orange-billed Lorikeet (*Neopsittacus pullicauda*);
Mountain Eared-nightjar (*Eurostopodus archboldi*);
Bronze Ground-dove (*Gallicolumba beccarii*);
Forbes' Forest-rail (*Rallina forbesi*);
Belford's Honeyeater (*Melidectes belfordi*);
Papuan Thornbill (*Acanthiza murina*);
Wattled Ploughbill (*Eulacestoma nigropectus*);
Island Thrush (*Turdus poliocephalus*; and
Streaked Berrypecker (*Melanocharis striativentris*).

The only other formal survey at a comparable altitude within the region was one conducted on Mt Sisa in 1999, where Diamond and Bishop (2000) recorded a total of 85 species. The greater species count at Mt Sisa may be due in part to the greater attitude range sampled at Mt Sisa. Diamond and Bishop had two camps separated by more than 700 m in altitude (1840-2560m), and this exposed them to both mid-montane, montane and lowland species. The altitudinal range sampled at Hides was 2163 (H3) to 2400m (H2), which would not allow sampling of the lower midmontane and lowland species. Unfortunately an itemized list for each camp was not provided by Diamond and Bishop. Species recorded at Mt Sisa that are unlikely to be found as high as the Hides 3 well pad include:

Rainbow Lorikeet (*Trichoglossus haematodus*);
White-crowned Koel (*Caliechthrus leucolophus*);
Black-throated Honeyeater (*Lichenostomus subfrenatus*);
Black-shouldered (Cicadabird *Coracina incerta*);
Pygmy Drongo (*Chaetorhynchus papuensis*);
Black-winged Monarch (*Monarcha frater*); and
Red-capped Flowerpecker (*Dicaeum geelvinkianum*).

Despite these differences, and the disparate geomorphologies of Mt Sisa (volcanics) and the Hides range (limestone), the studies combine to create a suitable list of avifauna that are likely to be located throughout the KICDP and the gas project area at these high altitudes (2000 to 2500m). The combined species tally for Hides and Mt Sisa is 105 (Table 3). Forty species recorded on Mt Sisa were not observed at Hides 3, and 20 species recorded at Hides 3 were not observed on Mt Sisa. Forty-five species were recorded at both sites. Thirty-two of these have not been reported elsewhere in the KICDP and gas project areas, making these high altitude forests of particular significance.

The birds-of-paradise are a significant component of the avifauna at both sites. Diamond and Bishop recorded nine species on Mt Sisa, eight of which

were also seen at Hides 3, comprising 12.3% of the bird diversity recorded during the current survey. Other species not recorded in the current survey that may also be present within the Hides field include Loria's Bird-of-Paradise (*Cnemophilus loriae*), which was recorded on Mt Sisa and, though not observed at Hides 3, may also be expected to occur there. The Crested Bird-of-Paradise (*Cnemophilus macgregorii*) was not recorded at either site, but is likely to occur at elevations above 2,600 m. Finally, Stephanie's Astrapia (*Astrapia stephaniae*) may co-exist with the Ribbon-tailed Astrapia (*A. mayeri*) in the Hides ranges. Though Stephanie's Astrapia exhibits a more easterly distribution, both species are known to overlap in the Southern Highlands Province around Tari Gap, the Nipa area, and west from Mt Giluwe (Coates 1990).

We recorded four IUCN-listed species at Hides 3 (Table 4). Populations of all four species are declining due to habitat disturbance and/or hunting pressure. The Yellow-breasted Bird-of-paradise (*Loboparadisea sericea*) and the Black Sicklebill (*Epimachus fastuosus*) are among New Guinea's rarest birds-of-paradise. Due to their moderate altitudinal ranges (Yellow-breasted Bird-of-paradise 1,200–2,000 m and Black Sicklebill 1,280–2,550 m) and their distinct preference for primary forest, they are under increasing pressure from agriculture and deforestation resulting from human population growth. Furthermore, hunters target adult male Black Sicklebills for their tail plumes (the largest in the family) and their skins, which are becoming increasingly valuable.

Table 3 Upland avifauna (Hides 3 and Mt Sisa)

COMMON NAME	H3	MT	COMMON NAME	H3	MT
Dwarf Cassowary	X	X	Papuan Scrubwren	X	X
Brush Turkey species		X	Papuan Thornhill	X	
Shovel-billed Kokoihurra		X	Mountain Gerygone	X	X
Mountain Kingfisher		X	Brown-breasted	X	X
Fan-tailed Cuckoo	X	X	Lesser Ground-robin		X
Rufous-throated Bronze-Cuckoo		X	Canary Flyrobin	X	X
White-crowned Noel		X	Garnet Robin	X	X
Dusky Lory		X	Black-throated Robin		X
Rainbow Lorikeet		X	White-winged Robin	X	X
Papuan Lorikeet	X	X	Blue-grey Robin	X	X
Plum-faced Lorikeet		X	Ashy Robin		X
Yellow-billed Lorikeet	X	X	Spotted Jewel-habbler		X
Orange-billed Lorikeet	X		Ifrit	X	X
Large Fin-Parrot	X		Varied Sittella	X	X
Madagascar's Tanager-Parrot		X	Mottled Whistler		X
Papuan King-Parrot	X		Rufous-naped Whistler	X	X
Glossy Swiftlet	X	X	Brown-backed Whistler	X	X
Mountain Swiftlet		X	Sclater's Whistler	X	X
Swiftlet (Rare-bellied/Mountain)	X		Pennant Whistler		X
Greater Sooty-Owl		X	Black-headed Whistler	X	
Tropical Hawk-Owl		X	Black Pittbull		X
Feline Owllet-Nighthawk		X	Wattled Ploughhill	X	

Table 3 Upland avifauna (Hides 3 and Mt Sisa)

COMMON NAME	H3	MT	COMMON NAME	H3	MT
Mountain Owllet-Nighthar		X	Greater Melamnitia	X	
Papuan Frogmouth		X	Yellow-breasted Bird-of-	X	X
Mountain Fared-Nighthar	X		Loria's Bird-of-paradise		X
Slender-billed Cuckoo-Dove	X		Short-tailed Paradisalla	X	X
Black-billed Cuckoo-Dove		X	Black Sicklebill	X	X
Great Cuckoo-Dove	X	X	Brown Sicklebill	X	X
Bronze Ground-Dove	X		Superb Bird-of-paradise	X	X
Ornate Fruit-Dove	X	X	Lowe's Parotia	X	X
White-bibbed Fruit-Dove		X	Ribbon-tailed Astrapia	X	X
Shining Imperial-Pigeon	X	X	King-of-Saxony Bird-of-	X	X
Papuan Mountain-Pigeon	X	X	Great Woodswallow		X
Forbes's Forest-Rail	X		Mountain Peltops		X
Long-tailed Honey-buzzard	X		Hooded Cuckoo-shrike	X	X
Brahmin Kite	X	X	Black-shouldered Cuckoo-shrike		X
Black-mantled Goshawk	X		Black-bellied	X	X
Meyer's Goshawk	X		Black Fantail	X	X
New Guinea Eagle		X	Friendly Fantail	X	X
Papuan Treecreener		X	Dimorphic Fantail	X	X
Macgregor's Bowerbird		X	Pygmy Dragon		X
Orange-crowned Fairywren	X	X	Black Monarch	X	
Red-collared Myzomela		X	Black-breasted Boobill	X	X
Olive Stripedbill	X	X	Island Thrush	X	
Black-throated Honeyeater		X	New Guinea White-eye	X	
Rufous-backed Honeyeater	X	X	Mountain Leaf-Warbler		X
Black-backed Honeyeater	X	X	Red-capped		X
Relford's Melidectes	X		Fan-tailed Remyvener	X	X
Yellow-browed Melidectes		X	Streaked Remyvener	X	
Smoky Honeyeater	X	X	Tit Remyvener		X
Mountain Mouse-warbler	X	X	Crested Remyvener		X
Large Scrubwren	X	X	Blue-faced Parrotfinch		X
Rufous-faced Scrubwren	X	X			

Though occasionally found in secondary forest, the Ribbon-tailed Astrapia (*Astrapia mayeri*) has the most restricted range of any bird-of-paradise present in the central cordillera, where it is similarly threatened with localized extinctions by hunters who target males for their tail plumes.

Finally, population decline and local extinction in the dwarf cassowary (*Casuarius bennetti*) have also resulted from habitat disturbance and hunting; this bird is an important food source for local villagers.

As well as globally threatened species, we recorded a number of other birds that are less common in more populated areas where hunting is more intense. Such species include a number of other birds-of-paradise (Brown Sicklebill (*Epimachus meyeri*), Superb Bird of Paradise, King of Saxony Bird-of-paradise and Lowe's Parotia), the Papuan Lorikeet (*Charmosyna papou*), and the ground-dwelling Forbes's Forest-rail (*Rallina forbesi*).

A number of other uncommon or rare species observed at Hides 3 deserve special mention. The Greater Melampitta (*Melampitta gigantea*) is one of New Guinea's most enigmatic birds, being restricted to rugged limestone country where it roosts and nests below ground (the world's only passerine to do so). Notoriously difficult to observe, we captured an image with the camera trap of Greater Melampitta at night in Wayne's swamp. Prior to the studies within the KICDP, this species was known from only a few scattered localities in New Guinea. It has now been recorded at Gobe and Agogo (Diamond and Bishop 2003) as well as at Hides.

A number of uncommon species were mist-netted in the secondary forest near the Hides 3 well pad, including Orange-crowned Fairywren (*Clytomyias insignis*) (Plate 15), Garnet Robin (*Eugerygone rubra*) (Plate 16), Olive Straightbill (*Timeliopsis fulvigula*) (Plate 17) and Rufous-naped Whistler (*Aleadryas rufinucha*). Both Orange-crowned Fairywren and Olive Straightbill appear to be fairly common in the area and were seen on a number of occasions at separate locations. Furthermore, a nest of *C. insignis* with two eggs (Plate 15) was found at Wayne's Swamp, and an immature male *E. rubra* was captured, confirming that both these rarely seen species are breeding in the area.

Five additional IUCN-listed species not recorded in the current survey may occur within the Hides area. The most likely of these is the New Guinea Eagle, another species hunted heavily for its plumage. Blue Bird-of-paradise has suffered from hunting pressure and loss of its preferred moderate altitude habitat. Its maximum upper limit is about 2,000 m ASL, but it may occur on some of the lower hills and slopes of the Hides range. The very rare Archbold's Bowerbird (*Archboldia papuensis*) has a very limited distribution within the central cordillera, including areas in the Southern Highlands Province such as Ambua Lodge near Tari. Hides Ridge falls within its high altitudinal range preference. The few locals questioned in the current study had no knowledge of it, but there were few informants and they were infrequent visitors to the area.

The final two species are apparently very rare and known from only a handful of sightings. The Papuan whiptail (*Androphobus viridis*) has been recorded at five sites, mostly in West Papua (Indonesia), but recent sightings are reported from the highlands of PNG, including Ambua Lodge, near Tari, in the Southern Highlands Province (Eastwood and Gregory 1995). The Papuan Hawk-owl (*Uroglaux dimorpha*) is known from only nine locations, all below 1,500 m ASL (Beehler et al. 1986; Hicks 1988; Lamonthe 1993; Shany 1995)¹. However, the distinctive, rising, three-note call of an unidentified Strigid owl was heard on two nights at Hides 3 and did not fit the description of any advertising call from this group present in the literature. Unfortunately, the call was repeated few times, and we were unable to record it.

Collectively, the presence of these birds reflects the pristine condition of the primary forest and the hitherto low level of human interference in the Hides range. An aerial survey by helicopter revealed that forest of similar quality

¹ The summary for this species published on line by BirdLife International (2005) lists four additional sources with incomplete references. Nevertheless, they summarise all sightings as occurring below 1,500 m ASL.

occurs over most of the range. This, together with the range of species recorded and the fact that many are restricted to high montane forests, indicates the Hides range is of high conservation value.

7.1.3 Benaria

We recorded 88 bird species in the area between the Benaria River and Benaria Mission, including the following eight species not yet recorded within the KICDP and the PNG Gas Project area:

Brown-collared Brush-turkey (*Talegalla jobiensis*);
New Guinea Scrubfowl (*Megapodius decollatus*);
Blue-breasted Quail (*Coturnix chinensis*);
Metallic Pigeon (*Columba vitiensis*);
Brown Goshawk (*Accipiter fasciatus*);
Long-tailed Shrike (*Lanius schach*);
Blue Bird-of-paradise (*Paradisaea rudolphi*); and
Russet-tailed Thrush (*Zoothera heinei*).

Most species were observed in secondary forest, which supported a wide range of insectivores (Australian robins, flycatchers, whistlers, fantails and monarchs), as well as a number of frugivores (cassowary, fruit-doves and pigeons), nectarivores (parrots and lorikeets) and larger omnivores (cuckooshrikes, birds-of-paradise and megapodes). Notable among these was the large variety of megapodes, with three species recorded in the area. Local villagers excavated an egg from a mound on a ridge adjacent to camp during the survey.

The honeyeaters were well represented, with eight species making up nearly 10% of the total number recorded. A number of species dependent on open habitat associated with human settlement, including the Blue-breasted Quail (*Coturnix chinensis*) and Long-tailed Shrike (*Lanius schach*) were recorded.

The survey area included the Benaria River and a permanent swamp, so some river-dependent species were recorded including the Little Black Cormorant (*Phalacrocorax sulcirostris*), Little Pied Cormorant (*P. melanoleucos*) and the Torrent Robin (*Monachella muelleriana*). Other birds likely to exclusively use this habitat at this altitude include the Torrent-lark (*Grallina bruijni*) and the globally threatened Salvadori's Teal. No wetland species as such were recorded, because the swamp is a sacred area to the local Huli. Access was restricted and sampling impossible. However, the cultural significance of this habitat has resulted in minimal disturbance, and it may support a variety of resident birds such as kingfishers, rails and crakes, herons and egrets, and a number of migratory species, including snipe and Great Reed-Warblers (*Acrocephalus arundinaceus*). However, we saw no large wetland species flying over, and heard no evidence of some of the more conspicuous species such as Purple Swamphen (*Porphyrio porphyrio*) or Clamorous Reed-Warbler (*Acrocephalus stentoreus*).

Each morning we did see numerous flocks of pigeons and parrots leaving the swamp forest to search for fruiting trees in surrounding areas. Thus, such

areas of locally low disturbance become important zones for maintaining biodiversity on a broader geographical scale.

Two globally threatened species were recorded during the survey. The Southern Cassowary (*Casuarius casuarius*) was observed in secondary riparian forest within 500 m of the proposed site where the new road will cross the Benaria River, and also droppings were located on the ridge south of the camp near the new road alignment. The Blue Bird-of-paradise was confirmed by local villagers as occurring in primary forest on top of a ridge above Benaria Village (1,546 m), some 4.6 km east of the proposed river crossing. Its calls were also heard between camp and Benaria village (06° 0.016'S, 143°3.146'E, 1,450 m). Habitat loss and hunting have impacted heavily on these species throughout their ranges.

Other notable species include the Russet-tailed Thrush (*Zoothera heinei*), a ground-foraging forest species more common in Australia, but rare and difficult to observe in New Guinea (Coates 1990), and not previously reported from within the KICDP.

One other survey has been conducted within this ecological region (Eastern upland volcanics/karst) on Mt Moran in May 2003. In a much shorter visit, Diamond and Bishop (2003) recorded 44 species on Mt Moran at around 1,650 m. Despite fewer records, they observed 29 species not found by us in the current survey at Benaria. This is due largely to the higher altitude and more pristine environment of the Mt Moran survey site. Despite only a 300 m difference in altitude, many montane passerines were recorded at Mt Moran and not at Benaria. Some species are restricted to higher altitudes than the Benaria River survey site, including Yellow-browed Melidectes (*Melidectes rufocrissalis*), Mountain Mouse-warbler (*Crateroscelis robusta*), Buff-faced Scrubwren (*Sericornis perspicillatus*), Brown-breasted Gerygone (*Gerygone ruficollis*), Black-throated Robin (*Poecilodryas albonotata*), Ashy Robin (*Heteromyias albispecularis*), Ifrit (*Ifrita kowaldi*), Brown-backed Whistler (*Pachycephala modesta*), Regent Whistler (*P. schlegelii*), Short-tailed Paradigalla (*Paradigalla brevicauda*), and Black Sicklebill.

In contrast, many non-passerines observed on Mt Moran may be expected to occur at similar altitudes to Benaria, including the Mountain Kingfisher (*Syma megarhyncha*), White-crowned Koel (*Caliechthrus leucolophus*), Black-billed and Great Cuckoo-Doves (*Macropygia nigrirostris* and *Reinwardtoena reinwardtsi*) and a number of parrots - Dusky Lory (*Pseudeos fuscata*), Fairy Lorikeet (*Charmosyna pulchella*), Red-breasted Pygmy-Parrot (*Micropsitta bruijnii*) and Blue-collared Parrot (*Geoffroyus simplex*). In particular, there were conspicuously few parrots and lorikeets seen at Benaria. This may reflect seasonal availability of flowering and fruiting trees in the area. Time of year is an important determinant of avian biodiversity in the region (Diamond and Bishop 2003), and though Diamond and Bishop observed more parrots on Mt Moran at a similar time of year, a difference in altitude may interact with seasonal variation in food availability.

A number of other IUCN-listed species are found in the Southern Highlands Province at similar altitudes. However, most are dependent on primary forest and/or are specifically targeted by hunters, and the heavily populated Benaria

study area is therefore unlikely to provide important habitat for these species (Plate 18). Pesquet's Parrot and Black Sicklebill were both confirmed absent by local residents. The less conspicuous Yellow-breasted Bird-of-paradise was unknown to the locals, and if present is likely to be confined to primary forest beyond the study area. Both the New Guinea Eagle and Gurney's Eagle are likely to occur in the broader region, though ultimately dependent on less disturbed habitat. The New Guinea Eagle is particularly sought after by hunters.

However, other threatened species may be resident at the study site and may have gone undetected during the current survey. The Dwarf Cassowary occupies similar habitat to the Southern Cassowary, and is generally more common at this altitude, while the fast-flowing Benaria River provides suitable habitat for Salvadori's Teal.

We conclude that the area surveyed as the proposed pipeline route in the vicinity of the Benaria River is of moderate conservation value, given the high level of prior disturbance and current human activity coupled with the confirmed presence of the globally threatened Southern Cassowary and suitable habitat for at least two additional IUCN-listed species.

Aerial surveys by helicopter have shown that much of the pipeline ROW and road alignment between Benaria and Yarale consists of primary rainforest and rises to over 1900 m. Much of the region is subject to a lower degree of human disturbance than exists at the Benaria site. Consequently, taken as a whole, that section of the PNG Gas Project area from Benaria to Yarale is considered of high conservation value, as it includes suitable habitat for a wide range of globally threatened, moderate and high altitude species under significant pressure from hunting and habitat degradation.

7.2 Entire Area Summary

7.2.1 Species richness and composition

Appendix 2 presents the occurrence of all species within the project area and the KICDP. A total of 389² species of birds in 212 genera and 55 families have been positively identified in the project area, 52.6% of the approximately 740 species recorded in PNG (Coates 1985).

An additional 152 species have not yet been recorded within the project area, but may be expected to occur in light of available information regarding distribution and habitat preference. These species are listed in Appendix 3, together with their IUCN listings and altitudinal limits. Seventy-two of these are breeding residents within New Guinea, and 21 species are regular migrants to mainland PNG. The remaining species include 26 seabirds, which will not be impacted by the on-shore project, 26 vagrants, and seven species whose migratory/breeding status is not well known.

The KICDP and the gas project areas cover a wide variety of ecological regions, including Lake Kutubu and associated wetlands, numerous rivers

² Appendix 3 totals 394 species and includes five entries for birds only identified to genera or groups of species – *Meliphaga* sp., *Talegalla* sp. And *Aegotheles* sp and two entries for confusing swiftlets (*Aerodromas*).

and streams, coastal mudflats and mangrove forest, swamp forests, and tracts of rainforest of several types. It covers a huge altitudinal range (0–2,700 m) and varying geomorphologies and soil types. This, and the fact that much of the tracts of rainforest remains undisturbed, account for the high species richness recorded in the project area.

Forest birds comprise the majority of species recorded, particularly the passerines ('perching birds'). Many of the passerine families recorded in the area belong to a larger group with its centre of evolution based around the Australo-Papuan region. Of these, notable groups with multiple species recorded in the area include four species of fairywrens (Maluridae), 32 honeyeaters (Meliphagidae), 16 gerygones and scrubwrens (Pardalotidae) and 17 'Australian robins' (Petroicidae). Also included is the Corvidae, a large passerine family with 87 species recorded within the project area. In its current form, the Corvidae comprises a number of taxa until recently identified as separate families, and includes the jewel-babblers (three species), whistlers and allies (15 species), birds-of-paradise (20 species), cuckooshrikes (13 species), fantails (11 species) and monarch flycatchers (9 species).

Of particular note is the high diversity of birds-of-paradise recorded in the region. Excluding the taxonomically difficult Greater Melampitta (*Melampitta gigantea*), the project area supports at least half of the 40 extant species (Coates 1990), and nearly two-thirds of the 31 species recorded in PNG. Many have restricted distributions (total area and/or altitude), and a number are of significant conservation status (below).

A number of non-passerine forest-dwelling taxa are also well represented, including 29 parrots, lorries and cockatoos (Psittacidae), 28 pigeons and doves (Columbidae), raptors (15 Accipitridae and 5 Falconidae), 11 night birds (Tytonidae, Strigidae, Aegothelidae, Podargidae, Eurostopodidae and Caprimulgidae), 8 Dacelonid kingfishers (Dacelonidae), 12 cuckoos (Cuculidae and Centropodidae) and the large, ground-dwelling cassowaries (2 species - Casuaridae) and megapodes (5 species - Megapodiidae).

Like the passerines, the high species richness of many of the non-passerine forest birds reflects a long history in the region. In particular, relative to ecologically similar regions in other parts of the world, New Guinea's rainforests support a high proportion of near-obligate frugivores and nectarivores (Beehler et al. 1986). There are 16 species of fruit-doves (*Ptilonopus*) and imperial-pigeons (*Ducula*), all specialist fruit eaters and very important dispersers of seeds of hundreds of rainforest trees, and 14 species of brush-tongued lorries and lorikeets which feed almost exclusively on nectar and pollen and are significant pollinators in the rainforest ecosystem.

While the forest species are the obvious component of the avifauna, a wide range of wetland species have also been recorded in the KICDP and the PNG Gas Project area. Well-represented taxa include the 7 species of rails and crakes (Rallidae), 23 wader species (curlews, sandpipers and plovers – Scolopacidae and Charadriidae), 10 species of herons and egrets (Ardeidae), and the 11 species of the predominantly marine gulls and terns (Lariidae). Interestingly, other water birds such as ducks and geese,

alcedinid kingfishers, darters, cormorants, pelicans and ibis are neither as diverse nor abundant.

7.2.2 Seasonal variation

The number and variety of birds (species richness and composition) present at any one time within the KICDP and the PNG Gas Project area depends to some degree on the time of year. Many of the species listed in Appendices 2 and 3 occur predominantly as migrants that breed in Eurasia, Australia and New Zealand. As non-breeding visitors, birds from the northern hemisphere are present between September and April, and those from the south from May to October. In addition to the largely migrant species, the numbers of some breeding residents are also swelled at certain times of year by migratory populations of the same species from other countries and perhaps from elsewhere in New Guinea. These 'supplementary' migrants are predominantly of Australian origin, and examples include the Grey Teal (*Anas gracilis*), Great Egret (*Ardea alba*), Masked Lapwing (*Vanellus miles*), Torresian Imperial-Pigeon (*Ducula spilorrhoa*), Brush Cuckoo (*Cacomantis variolosus*), Rainbow Bee-eater (*Merops ornatus*), Spangled Drongo (*Dicrurus bracteatus*) and Metallic Starling (*Aplonis metallica*).

Most migratory species visit the coasts and wetlands. These include the large variety of migratory waders (Scolopacidae, Charadriidae) that breed in the northern hemisphere and visit tidal and coastal mudflats of the Kikori lowlands during the austral summer (September–April). These habitats in the Gulf Province have not been surveyed extensively, yet preliminary results suggest that they are important wintering grounds for many species (Diamond and Bishop 2000, Watkins 2000), including the 'Near Threatened' Asian Dowitcher (*Limnodromus semipalmatus*), the only IUCN-listed migrant recorded in the project area.

A smaller number of migrants visit the forests and clearings of the project area. Most of these breed in Australia and are therefore present from May to October. Relevant species include the Forest and Sacred Kingfishers (*Todirhamphus macleayii* and *T. sanctus*), Rainbow Bee-eater (*Merops ornatus*), Dollar-bird (*Eurystomus orientalis*), Channel-billed Cuckoo (*Scythrops novaehollandiae*), Australian Pratincole (*Stiltia isabella*), the raptors *Falco cenchroides* and *Falco longipennis*, the Black-faced Cuckooshrike (*Coracina novaehollandiae*), Satin Flycatcher (*Myiagra cyanoleuca*) and Tree Martin (*Hirundo nigricans*). Eurasian visitors to New Guinea's forests and clearings include the Oriental cuckoo (*Cuculus saturatus*) and aerial specialist White-throated Needletail (*Hirundapus caudacutus*). No forest migrants are IUCN-listed.

Seasonal changes have also been observed in the distribution of resident populations.

Diamond and Bishop (2003) presented results of a series of surveys conducted throughout the KICDP at different times of the year between 1998 and 2003. They noted that between seasons there was a significant change in the abundance and behaviour (vocalisation and flocking behaviour) of a variety of forest-dwelling birds. In particular, a number of easily detectable

species were absent from the KICDP, such as the large parrots *Cacatua galerita* and *Eclectus roratus*, the Moustached Treeswift (*Hemiprocne mystacea*), and the Yellow-eyed Starling (*Aplonis mystacea*). The comparative silence of other species e.g. Cinnamon Ground-Dove (*Gallicolumba rufigula*), Stephan's Dove (*Chalcophaps stephaniae*), Hooded Pitta (*Pitta sordida*) and Red-bellied Pitta (*Pitta erythrogaster*) was also suggestive of their absence in certain areas, though these species are harder to observe and may have been missed. Diamond and Bishop (2003) concluded that differences in abundance and detectability were not simply due to predictable seasonal changes repeated annually, but also to significant variation between years, since the greatest difference was observed between surveys conducted in April-May 1998 and April-May 2003.

Compounding this complexity is the fact that most pigeons cease calling in the wet season. Furthermore, these and other frugivores and nectarivores are nomadic to varying extents and their presence depends upon the seasonality of fruiting and flowering in the forest.

Finally, there is likely to be altitudinal and intra-country migration in many resident forest bird populations. This phenomenon has not been studied in PNG but it is well known in Asia (McClure 1974) and Australia (Crome 1993, Nix 1993). Such migrations do not necessarily involve the entire population of a species.

7.2.3 Altitudinal distribution

Most species of birds in New Guinea have a strict altitudinal range in which they occur, and this is a characteristic of the avifauna. Figures 5 to 9 show the average and extreme upper and lower altitudinal limits for individual species of 13 forest-dwelling taxonomic groups common in the KICDP and PNG Gas Project area.

In general, species richness declines with increasing altitude (Beehler et al. 1986, Coates 1985). Accordingly, most species shown in Figures 5 to 9 have a lowland to mid montane distribution of between zero and 1,000 m. There are few high altitude specialists among the non-passerine cuckoos, pigeons, doves and raptors, in which species found higher than 1,500 m usually also range down to sea-level.

A different pattern is observed in most passerine groups. Among the honeyeaters, warblers and scrubwrens, robins, whistlers, birds-of-paradise, cuckoo-shrikes, and the berrypecker complex, a significant proportion of species are upland or montane specialists, being specifically adapted to higher altitudes and rarely or never observed below 500 m. This pattern is particularly prevalent among the birds-of-paradise, which include the greatest number of restricted altitude species recorded in the project area. Among non-passerines, this pattern is also observed to a lesser extent in the parrots and lorikeets.

This general difference in the degree of altitudinal distribution between passerines and non-passerines is exacerbated when we consider wetland as well as forest species. Most birds that are specialised to exploit marine coastal and freshwater environments are non-passerines. Exceptions

include residents such as the Torrent Robin (*Monachella muelleriana*) and Torrent Lark (*Grallina bruijnii*), both passerines of fast-flowing rivers and streams at altitudes up to and exceeding 1,800 m.

8 Conservation Significance of the Avifauna

8.1 IUCN-Listed Species

Seventeen species recorded in the KICDP and gas project area (Appendix 2) are listed under the IUCN Red data list as globally threatened, near threatened or data deficient, and a further 17 species that potentially occur (Appendix 3) are listed (Table 4). Four species are seabirds, which do not nest within the KICDP and PNG Gas Project area. None of these species could be impacted by the project. Figure 10 shows the altitudinal limits of the 25 listed species recorded or likely to occur in the project area for which there is sufficient distributional data.

8.1.1 Critically endangered species

The only critically endangered species is Abbott's Booby, a seabird that is restricted to Christmas Island (Indian Ocean) and may occur as a very rare vagrant to Torres Strait. It cannot be impacted by the onshore elements of the project.

8.1.2 Vulnerable species

Within mainland PNG, 14 species are listed as vulnerable. Six of these have been recorded in the KICDP and PNG Gas Project area - Southern Cassowary, Pesquet's Parrot, Southern Crowned-Pigeon, New Guinea Eagle, Black Sickbill, and Blue Bird-of-paradise. A further two species could well occur – Salvadori's Teal and the Long-bearded Melidectes (*Melidectes principis*), a honeyeater.

All but the honeyeater, which is a very poorly known species, are more immediately threatened by hunting than habitat loss in the lower reaches of the PNG Gas Project area. Indeed, the KICDP is well known as a refuge for these species, which are declining steadily in other areas of PNG where human population is expanding (Diamond 2005).

8.1.3 Near threatened species

Sixteen species in Table 4 are listed as near threatened. Dwarf Cassowary, New Guinea Flightless Rail (*Megacrex inepta*), Gurney's Eagle, Yellow-breasted Bird-of Paradise, Ribbon-tailed Astrapia and Doria's Goshawk (*Megatriorchis doriae*) are fundamentally threatened by hunting. Asian Dowitcher, Beach Thick-knee (*Esacus giganteus*), Buff-breasted Sandpiper, Tahiti Petrel and Black-necked Stork are listed because of threats outside PNG. The remaining five species are all very rare, though the reasons for this are less clear. The KICDP and PNG Gas Project area is likely to provide important habitat for three species already recorded there (Striated Lorikeet, Olive-yellow Robin and Yellow-eyed Starling (*Aplonis mystacea*)) and the Forest Bittern (*Zonerodius heliosylus*). Though listed as a possible resident, Archbold's Bowerbird has a very restricted distribution and may prove to be absent from the region.

8.1.4 Data deficient species

The remaining seven species are data deficient, being poorly known, and only one has been recorded from the KICDP and PNG Gas Project area. The Starry Owlet-Nightjar (*Aegotheles tatei*) is a recently described species (Pratt 2000), and it and the other night birds can be easily overlooked.

Table 4 Species of conservation concern on the IUCN red data list

Common name	Scientific name	IUCN status*	# of KICDP sites at which recorded		Altitude range (m)			
			Lowland	Upland	Min	Normal range		Max
						Lower	Upper	
Species recorded in the KICDP								
Southern Cassowary	<i>Casuarius casuarius</i>	VU	5	3		0	1100	
Dwarf Cassowary	<i>Casuarius bennetti</i>	Lr/nt	0	8		0	3620	
Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>	DD	1	0		0	600	
Striated Lorikeet	<i>Charmosyna multistriata</i>	Lr/nt	0	2		80	1800	
Pesquet's Parrot	<i>Psittichas fulgidus</i>	VU	6	9		600	1200	2000
Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>	VU	7	2		0	500	
New Guinea Flightless Rail	<i>Megacrex inepta</i>	Lr/nt	2	1		0	400	
Asian Dowitcher	<i>Limnodromus semipalmatus</i>	Lr/nt	1	0		0	10	
Beach Thick-knee	<i>Esacus giganteus</i>	Lr/nt	1	0		0	10	
New Guinea Eagle	<i>Harpyopsis novaeguineae</i>	VU	2	5		0	3200	
Gurney's Eagle	<i>Aquila gurneyi</i>	Lr/nt	0	2		0	1300	2970
Olive-yellow Robin	<i>Poecilodryas placens</i>	Lr/nt	0	3		100	1450	
Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>	Lr/nt	0	2	600	1200	2000	
Black Sicklebill	<i>Epimachus fastuosus</i>	VU	0	4	1280	1800	2150	2550
Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>	Lr/nt	0	2	1800	3440	2450	
Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>	VU	0	1	1100	1400	1800	2000
Yellow-eyed Starling	<i>Aplonis mystacea</i>	Lr/nt	3	2				
Species not recorded but whose ranges overlap with the KICDP area								
Salvadori's Teal	<i>Salvadorina waigiensis</i>	VU			350	500	3700	4100
Papuan Hawk-Owl	<i>Uroglaux dimorpha</i>	DD				0	1500	
Starry Owlet-Nightjar	<i>Aegotheles tatei</i>	DD						
Wallace's Owlet-	<i>Aegotheles wallacii</i>	DD				100	1100	

Table 4 Species of conservation concern on the IUCN red data list

Common name	Scientific name	IUCN status*	# of KICDP sites at which recorded		Altitude range (m)			
			Lowland	Upland	Min	Normal range		Max
						Lower	Upper	
Nightjar								
Buff-breasted Sandpiper	<i>Tryngites subruficollis</i>	Lr/nt				0	10	
Chestnut-shouldered Goshawk	<i>Erythrotriorchis buergersi</i>	DD				450	1580	
Doria's Goshawk	<i>Megatriorchis doriae</i>	Lr/nt				0	1070	1650
Abbott's Booby	<i>Papasula abbotti</i>	CR			0	0	0	0
Forest Bittern	<i>Zonerodius heliosylus</i>	Lr/nt				0	1430	
Black-necked Stork	<i>Ephippiorhynchus asiaticus</i>	Lr/nt				0		
Antarctic Giant-Petrel	<i>Macronectes giganteus</i>	VU			0	0	0	0
Tahiti Petrel	<i>Pseudobulweria rostrata</i>	Lr/nt			0	0	0	0
Heinroth's Shearwater	<i>Puffinus heinrothi</i>	VU			0	0	0	0
Archbold's Bowerbird	<i>Archboldia papuensis</i>	Lr/nt			1750	2600	2900	3660
Long-bearded Melidectes	<i>Melidectes princeps</i>	VU			2750	3000	3800	
Papuan Whipbird	<i>Androphobus viridis</i>	DD				1400	2700	
Obscure Berrypecker	<i>Melanocharis arfakiana</i>	DD				950	950	

8.2 Endemic Bird Areas And Restricted-Range Species

Birdlife International has developed a system to identify the most important global areas for bird conservation (Stattersfield *et al.* 1998). They define Endemic Bird Areas (EBAs) as areas of the globe with a very high concentration of 'Restricted Range Species' which are those with a global range of <50,000 km², i.e. their entire population is restricted to a very small area, and many are restricted to a much smaller region still. The KICDP and PNG Gas Project area includes two EBAs – the 'South Papuan Lowlands' and the 'Central Papuan Mountains'. While knowledge of both regions is defined as 'poor', the Central Papuan Mountains have the second highest number of restricted-range species of all EBAs in the South-east Asian island region. Furthermore, the avifauna of this region is highly distinct, and includes nine endemic genera (BirdLife International 2003). Table 5 presents the 42 restricted range species of the Central Papuan Mountains EBA that

have been recorded or could occur in the KICDP and PNG Gas Project area. All but five of them are high mountain specialists.

There are far fewer Restricted Range Species within the South Papuan Lowlands. Two have been recorded in the KICDP and PNG Gas Project area (Striated Lorikeet and Olive-yellow Robin) and three more could occur (Painted Quail-thrush (*Cinclosoma ajax*), White-bellied Pitohui (*Pitohui incertus*) and Greater Bird-of-paradise (*Paradisaea apoda*)).

On a global comparison the Central Papuan Mountains ranks seventh in the world (out of 128 EBAs) in terms of numbers of Restricted Range Species. PNG as a whole is fourth highest in the world in terms of numbers of Restricted Range Species and third in the world in terms of the numbers of Restricted Range Species endemic to the country.

Conversely, PNG and EBAs within the KICDP and PNG Gas Project area are not highly ranked in terms of threat status. Overall threats to both EBAs are low.

Table 5 Restricted Range Species of the Central Papuan Mountains EBA recorded in or whose ranges overlap with the KICDP and the PNG Gas Project area.

Common name	Scientific name	Normal altitude range (m)		Status
		Lower	Upper	
MID MONTANE (MOST OF DISTRIBUTION < 1500M)				
Streaked Bowerbird	<i>Amblyornis subalaris</i>	670	1200	P
Cinnamon-browed Melidectes	<i>Melidectes ochromelas</i>	2000	1100	P
Green-backed Robin	<i>Pachycephalopsis hattamensis</i>	760	1650	P
Greater Melampitta	<i>Melampitta gigantea</i>	650	1400	X
Obscure Berrypecker	<i>Melanocharis arfakiana</i>	950	950	P
HIGH MONTANE (MOST OF DISTRIBUTION >1500M)				
Painted Tiger-Parrot	<i>Psittacella picta</i>	2450	3680	P
Modest Tiger-Parrot	<i>Psittacella modesta</i>	1700	2800	P
Bare-legged Swiftlet	<i>Aerodramus nuditarsus</i>	?	?	X
Archbold's Owlet-Nightjar	<i>Aegotheles archboldi</i>	1350	3600	P
Mountain Eared-Nightjar	<i>Eurostopodus archboldi</i>	2200	3200	X
Forbes's Forest-Rail	<i>Rallina forbesi</i>	1100	3000	X
Archbold's Bowerbird	<i>Archboldia papuensis</i>	2600	2900	P
Leaden Honeyeater	<i>Ptiloprora plumbea</i>	1100	1900	P
Olive-streaked Honeyeater	<i>Ptiloprora meekiana</i>	1300	2440	P
Rufous-backed Honeyeater	<i>Ptiloprora guisei</i>	1340	2900	X
Black-backed Honeyeater	<i>Ptiloprora perstriata</i>	2500	3750	X
Sooty Melidectes	<i>Melidectes fuscus</i>	2200	3700	P
Long-bearded Melidectes	<i>Melidectes princeps</i>	3000	3800	P
Belford's Melidectes	<i>Melidectes belfordi</i>	1600	3350	X
Yellow-browed Melidectes	<i>Melidectes rufocrissalis</i>	1400	2400	X
Papuan Thornbill	<i>Acanthiza murina</i>	3000	3700	X

**Table 5 Restricted Range Species of the Central Papuan Mountains
EBA recorded in or whose ranges overlap with the KICDP and the PNG
Gas Project area.**

Common name	Scientific name	Normal altitude range (m)		Status
		Lower	Upper	
Greater Ground-robin	<i>Amalocichla sclateriana</i>	2800	3900	P
Alpine Robin	<i>Petroica bivittata</i>	2750	3900	P
Black Sittella	<i>Daphoenositta miranda</i>	2000	3700	P
Lorentz's Whistler	<i>Pachycephala lorentzi</i>	1600	3800	P
Sooty Shrike-thrush	<i>Colluricincla umbrina</i>	1450	2150	P
Wattled Ploughbill	<i>Eulacestoma nigropectus</i>	1950	2850	X
Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>	1200	2000	X
Crested Bird-of-paradise	<i>Cnemophilus macgregorii</i>	2600	3500	P
Loria's Bird-of-paradise	<i>Cnemophilus loriae</i>	2000	2400	X
Macgregor's Bird-of-paradise	<i>Macgregoria pulchra</i>	3200	3500	P
Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>	1570	2400	X
Brown Sicklebill	<i>Epimachus meyeri</i>	1900	2900	X
Lawes's Parotia	<i>Parotia lawesii</i>	1200	1900	X
Splendid Astrapia	<i>Astrapia splendidissima</i>	2100	2700	P
Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>	3440	2450	X
King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>	1800	2500	X
Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>	1400	1800	X
Mountain Firetail	<i>Oreostruthus fuliginosus</i>	2700	3700	P
Snow Mountain Munia	<i>Lonchura montana</i>	3200	3800	P
Alpine Munia	<i>Lonchura monticola</i>	2750	3900	P
Papuan Whipbird	<i>Androphobus viridis</i>	1400	2700	P

* X – recorded in KICDP; P – Range overlaps with KICDP and gas project area

8.3 Noteworthy areas

Over the last decade, a cooperative effort by Chevron Niugini (subsequently Oil Search) and WWF in the Kikori River basin has ensured that biodiversity in the Kikori catchment remains unaffected by petroleum developments, and that hunting and habitat use by local residents remains at a sustainable level of low impact (Hartshorn et al 1995, McCall and Flemming 2000). Consequently, following extensive surveys throughout the KICDP area, Diamond and Bishop (2003) concluded that the region effectively acts as a surrogate national park, in which numerous rare and endangered species are thriving relative to populations in surrounding areas. Ensuring that the Kutubu Petroleum Development facilities (particularly roads) has not resulted in secondary habitat destruction has also meant that the Kikori basin continues to support a number of rare and enigmatic species other than those targeted by hunters, such as Blue-black Kingfisher (*Todirhamphus nigrocyaneus*), Striated Lorikeet, Gurney's Eagle, Asian Dowitcher, Beach Thick-knee, Olive-yellow Robin and the Yellow-eyed Starling. Other rare species likely still to occur south of Moro include the Forest Bittern (unconfirmed sighting at Gobe 1999, Diamond and Bishop 2003), Doria's

Goshawk, Papuan Hawk-Owl and the Obscure Berrypecker. Clearly the KICDP and the entire PNG Gas Project area remain of very high conservation value.

Finally, in contrast to the status of avian biodiversity within most of the Kikori River basin below Moro, Diamond and Bishop (2003) suggested that water birds of Lake Kutubu may not have enjoyed the surrogate protection of the KICDP, as they continue to present an obvious target for local villagers, and were conspicuously absent during their surveys of the lake between 1998 and 2003. Many of these species are still common in the Kikori lowlands (e.g. egrets and herons) or are present in rivers and streams above the Kutubu CPF (e.g. Little-pied and Little-black Cormorants at Benaria).

Within KICDP and PNG Gas Project area two habitat types stand out as particularly significant – the montane *Nothofagus* forests on karst, and the Swamp Forests.

8.3.1 Montane *Nothofagus* forests

The high altitude forests in the Hides range are rich in upland Restricted Range Species and the forests are in entirely or almost entirely undisturbed condition. The existing infrastructure has had minimal to no impact on birds; the area is free of human settlement and only occasionally visited by local hunters. These forests support a number of sensitive species observed lower in the KICDP and PNG Gas Project area such as Dwarf Cassowary, Shining Imperial-Pigeon (*Ducula chalconota*), Long-tailed Honey-buzzard (*Henicopernis pongicauda*) and Black Sicklebill as well as a number of rare or threatened birds restricted to higher altitudes such as Yellow-breasted Bird-of-paradise, Ribbon-tailed Astrapia, Orange-crowned Fairywren, Garnet Robin and Forbes' Forest-rail.

The upper storey of these areas is characterised by mature *Nothofagus* with abundant mosses and epiphytes in the upper layers. Seventy-five percent of the plant diversity within these forests is comprised of epiphytes rather than trees (*pers. comm.* W. Takeuchi to F. Crome 20/6/05), and these provide special foraging areas for much of the mid and upper canopy bird species.

Hilltops within these forests typically support undergrowth thick with sprawling bamboo, a preferred habitat for some birds such as the Wattled Ploughbill and parrotfinches (*Erythrura trichroa*, *E. papuana*). These bamboo sites are also preferred lecking sites for the very rare Archbold's bowerbird. This species was not recorded at Hides 3 but could occur in other parts of the Hides area.

Pools and small swamps at the bottom of karst sinkholes are also special habitats. At Hides 3 the sinkhole habitats are important for little known species such as Greater Melampitta, Orange-crowned Fairywren, and Ifrit. Ornithologically this habitat is poorly known.

These forests are particularly sensitive to fires, which can occur in El Niño years, and the fauna depends upon the maintenance of a closed humid microclimate. Drying out of the forests not only makes them fire-prone, but reduces their suitability for forest interior specialists.

The section of the ROW between the Benaria River and Yarale may also contain small sections of this forest type where the peaks extend over 1800 m.

8.3.2 Swamp forests

The swamp forests support a range of specialist birds, including the New Guinea Flightless Rail and Twelve-wired Bird-of-Paradise (*Seleucides melanoleucos*). Both were thought to be restricted to the coastal lowlands below 100 m altitude, but the latter has now been recorded at Kantobo and in the swamp forests to the north of Lake Kutubu at 800 m. This is a major extension of altitudinal range for this species, and these upland swamp forests must be considered of some significance. It has not yet been established whether the rail exists in these upland sites or not. The Gobe record (Diamond and Bishop 2003) is for the lowland Gobe site (55 m).

Swamp forests regenerate well and are difficult to access. The major issue is fire risk during dry years. This would eliminate the generally shallow organic soils over limestone pavements on which they grow.

9 Impact Analysis

9.1 Direct (Primary) Impacts During Construction

9.1.1 General considerations

Previous construction of the export oil pipeline and associated oil facilities involved more or less the same procedures and construction methods that will be used for the gas pipeline – the drilling of wells, clearing and construction of flow lines, clearing of a ROW, stringing pipe, digging a trench in the ROW, welding pipe, lowering it into the trench and backfilling the trench, constructing access roads and tracks, crossing rivers, locating and developing borrow pits, building bridges, constructing temporary camps and lay down and parking areas, dealing with waste, fuel handling, hydrotesting the pipe, and building permanent facilities.

The present excellent condition of the KICDP and PNG Gas Project area, and the presence of so many sensitive species within the area, indicates that the avifauna has coped well with the oil development and collateral activities to date and that there has been no long-term deleterious impact on the avifauna by the previous construction. This was achieved by:

- Limiting construction footprints.
- Helicopter construction of wells, and hand construction of flowlines in some areas.
- Limiting access roads.
- Maintaining control on access to the sites, thus eliminating most indirect impacts.
- Strict control of the behaviour of project personnel during construction and operation.

As far as direct impacts are concerned, the PNG Gas Project itself will be constructed and operated in a similar manner as the Kutubu and Gobe petroleum development projects: ground access to construct engineered pipeline RoWs and install and bury the pipe³. Therefore, the direct impacts on avifauna should be broadly similar to the localised effects observed to date at Kutubu, Gobe and along the crude oil export pipeline down past Kopi. Many of the new PNG Gas Project pipelines and other facilities will be within or adjacent to the oil development footprint, while greenfield elements mainly around Hides and between Kopi and Omati break new ground but are similar in nature to the oil facilities already been built.

In overall biodiversity terms, this means impacts on individual species but not on entire communities or on the species diversity of the bird fauna of the KICDP.

³ The existing gas production wells and flowlines at Hides were installed by ultra-low impact manual methods, with helicopter support. Low gas production flows and correspondingly small- scale pipelines made it possible for these methods to be used.

Indirect impacts are another matter—see “Indirect (Secondary) Impacts below.

9.1.2 Forest clearing

Forest will be cleared to construct well pads and flowlines, the ROW, access roads, the new HPF at Nogoli, temporary camps, temporary storage areas, vehicle parks and borrow pits.

Forest clearing will negatively impact on

- Birds that are forest interior specialists, which are common at higher altitudes.
- Ground-foraging birds.
- Birds-of-paradise and bowerbirds, through loss of traditional terrestrial and arboreal mating areas (display trees, playgrounds and bowers).

9.1.2.1 ROW AND ACCESS ROADS

If clearings for the ROW and access roads are kept narrow, the impacts on birds will be minimal. Due to the linear nature of the development, loss of habitat will be relatively minor within any one area. Most birds are territorial and the impact of clearing is to destroy territories, which results in them being forced to move into adjoining habitat. This usually results in death, since available habitat is normally saturated with territory owners. While a 12-21 m ROW will reduce the size of those territories intersected by the ROW, it is unlikely to entirely destroy a bird's territory.

Existing flow lines in the region and the oil export pipeline ROW are skirted by lush secondary growth and primary forest. With time, and if allowed, the canopy on either side of the road and flowline may close over in many places, with habitat loss eventually restricted to the lower storeys.

If the width of the ROW and access roads is kept below 30 m and regeneration is allowed over some part of it then impacts will be minimal in the short term.

Impacts will increase where the total width of clearing is 40m or more, and will become permanent though localised if no regeneration is allowed.

Birds-of-paradise and Bowerbirds are lekking species, i.e. males display communally in special display areas and compete for the attention of females. These display areas may be trees or specially prepared sites on the ground. Lekking areas are often traditional and form the breeding epicentres for local subpopulations of the species (Frith and Beehler 1998). The loss of lekking sites needs to be limited and any display trees found along the ROW by clearance surveys should be marked for retention.

Forest clearing would impact most severely on high altitude *Nothofagus* forest where regeneration rates are slower.

Overall, we predict a low level of primary direct impact on birds, with individuals locally displaced by loss of their habitat. These individuals will face competition in similar habitat nearby, with a net loss of individual birds in rough proportion to the area of cleared. In addition, the flowlines present little

impediment to the passing of ground-birds, all of which are expected to pass easily below the pipes raised some distance off the ground.

9.1.2.2 THE HIDES PRODUCTION FACILITY (HPF), CONSTRUCTION CAMPS AND OTHER CLEARINGS

The habitat where the new Hides Production Facility (HPF) at Nogoli may be located is mostly kunai, gardens and secondary forest and is unlikely to contain important habitat for IUCN-listed species. If the HPF is kept within these habitats and does not encroach on primary forest patches, e.g. along the Tagari River, it will have little impact on birds or on avian biodiversity generally within the region, including populations of globally threatened species.

Similarly, construction camps, borrow pits, lay down areas etc. will have minimal impact if located in comparable disturbed habitats. If located in primary forest the impacts will be higher and may be of moderate severity and last for the medium or long term depending upon the size of the clearing. Clearings for these camps should be kept below 1 ha and ideally below 0.5 ha.

9.1.2.3 WELL PADS

The preparation of well pads in the Hides gas field will involve removal of habitat by bulldozer and ripping or blasting to create a small (≤ 1 ha) flat area on a hilltop. Because the well pads are in a noteworthy area (see next section) extra care needs to be taken. While the well pad itself is kept clear of regrowth, natural reforestation is left to occur on the scree-covered slopes. During our biodiversity survey, secondary growth around the Hides 3 well pad was utilized by a variety of species, including some uncommon birds such as Orange-crowned Fairy-wren and Garnet Robin. Furthermore, three of the four IUCN-listed species recorded during the survey (Brown Sicklebill, Yellow-breasted Bird-of-paradise and Ribbon-tailed Astrapia) were observed within 500 m of existing well pads, despite a strong preference for primary forest. Thus, with time and low levels of human activity, the area of impact will be largely restricted to the well pad proper. Consequently, due to their small size and low level of maintenance required, well pads are predicted to have a low impact on local bird populations.

9.1.2.4 MITIGATION

Measures to limit the impacts of clearing that warrant investigation include:

- Reducing the width of the ROW and access roads as far as practical, ideally keeping them to 25 m or less.
- Limiting the combined width of the oil export pipeline ROW and the gas ROW where they coincide to 30 m or less.
- Locating facilities, camps, lay down areas, borrow pits etc. within secondary forest and cleared areas.
- Restricting clearing for facilities, camps, laydown areas, borrow pits etc. to less than 1 ha and ideally less than 0.5 ha.

- Identifying display grounds and trees of birds-of-paradise and bowerbirds during pre-construction clearance surveys and retaining these trees.
- Allowing regeneration.

9.1.3 Noteworthy areas

A combination of regionally restricted occurrence and relatively low levels of disturbance single out two vegetation communities for mitigation planning and the investigation of feasible measures to pre-empt impact or speed recovery.

9.1.3.1 MONTANE NOTHOFAGUS FOREST ON KARST

The wells and pipelines on Hides will require small areas to be cleared, much of which will stay cleared (no or partial canopy closure) for at least the life of the project. This is important upper-storey foraging habitat for many high-altitude species, and display grounds for numerous birds-of-paradise such as Black Sicklebill, Brown Sicklebill, Ribbon-tailed Astrapia, King-of-Saxony Bird-of-paradise and Superb Bird-of-paradise.

Construction in this steep terrain generates large volumes of spoil which, when sidecast, typically destroys much of the forest immediately down slope. Thus the area of forest loss is magnified compared to construction in gentler terrain.

Some sinkholes support small swamps at their base, and these unusual and restricted microhabitats are susceptible to infilling by sidecast material (although the considerable size of some sinkholes can mean that the sidecast material might not reach the base).

Well pads, construction access ways and the pipeline RoW will typically be located in ridge hilltop forest with bamboo understorey. This community is a recurring feature of the numerous ridges and cones of the polygonal karst on Hides and the impact from well pads will reflect their small area. However, clearing for construction access and the pipeline RoW will translate into a linear impact on this community.

Growth rates of plants are slow at these high altitudes, and the forest edge along access roads and the ROW will take longer to seal over than edges in forest at lower altitudes. This will expose the forest interior to longer periods of 'edge effect', the extent and duration of which will depend on the width of the original clearing and whether the canopy is able to close over thereafter.

These forests are sensitive to dieback, and to fire during dry years, where permanent loss of large areas can occur. The drier edges of clearings present both more flammable vegetation and a potential ignition source from traffic (see also 'Edge Effects and Barriers' and 'Fire' below).

Mitigation

Avoiding or substantially reducing clearing in montane Nothofagus forest warrants investigation, including the feasibility of helicopter-based construction of the field facilities or avoiding the Hides ridge altogether by drilling wells from an adjacent valley. If a conventional wellfield layout and

road-based well completions and pipeline installation are required, then the following mitigation measures should be evaluated:

- Limiting construction footprint.
- Limiting ROW and access road widths to 15m or less.
- Ideally having no permanent access roads, and ripping and allowing construction roads to regenerate.
- Limiting clearing by having no camps in this type of noteworthy area.
- Careful control of cuts and spoil disposal.

9.1.3.2 SWAMP FOREST

Swamp forests regenerate readily provided soils and the drainage regime are maintained. However, they are susceptible to fire, especially on limestone pavement, where burning in dry years can damage or destroy the shallow organic soil and root zone. If bulk earthworks from construction access and the pipeline RoW reduce water run-on, the swamp forest soils will dry and the forest will change permanently to communities adapted to drier conditions.

Mitigation

The feasibility of the following mitigation measures warrants investigation:

- Strictly controlling fire.
- Allowing the ROW to regenerate, and having no permanent access through swamp forests.
- Ensuring the ROW and essential access roads are constructed so as not to alter hydrology of these areas.

9.1.4 River crossings

The KICDP and PNG Gas Project area does not host a specialised bird fauna restricted to riverine forest (in the manner of gallery forests in dry woodlands). However, the range of species is particularly abundant in these habitats, including some kingfishers and Shining Flycatcher (*Myiagra alecto*). Riverine forest is most important in the lowlands where it supports a variety of large fruiting trees. Consequently lowland riverine forest is particularly rich in pigeons and parrots, although no species are restricted to this habitat. Many birds will move into these habitats in the drier parts of the year and at hot times of the day, particularly in the lowlands. At such times the riverine forests act as refuges. At higher altitudes two specialist species are restricted to rivers - the Torrent-lark and the Torrent Robin.

Watercourses to be crossed by horizontal directional drilling (HDD) will require small areas (less than 0.25 ha) to be cleared on either side for the equipment to drill, ream and line the hole and pull through the welded pipestring.

The narrowness of the ROW and small area temporarily cleared for HDD make it unlikely that river crossings will have any more than a local impact on the avifauna, unless large areas of riverbank are permanently cleared and/or the upland rivers are seriously physically or chemically impacted.

9.1.5 Edge effects and barriers

Linear clearings for the ROW and access roads can impact habitat through the process of edge effects and barrier formation (see e.g. Laurence and Bierregaard 1997 for an introduction to the topic).

Edge effects include changes to forest microclimate next to the clearing (the forest interior will be windier, dryer, hotter and lighter next to the forest edge), increased wind throws of trees close to the edge, the invasion of weeds and exotic species along the edge, and invasion of the forest next to the edge by bird species adapted to drier habitats and secondary forest. Edge effects may penetrate several hundred metres into the forest.

Barrier effects occur where a strip of open habitat provides a barrier of hostile habitat that discourages or prevents some species from moving across the gap, thus splitting or fragmenting populations.

Through most of the KICDP and PNG Gas Project area, regrowth and sealing of the forest edge will be rapid and thus edge effects will be short lived. However, at higher altitudes the process will be slower and edge effects will last longer.

It is unlikely that the ROW and access roads will provide a serious barrier to any bird species unless the clearing is very wide. For clearings more than 40-50 m wide, some upland interior specialists and terrestrial species (e.g. Greater Melampitta) may be discouraged from crossing the gap, but this is unlikely to result in a permanent fragmentation of a population.

Mitigation

Measures to reduce the impacts of barrier and edge effects that warrant investigation include:

- Limiting widths of ROW and access roads.
- Reducing lengths of linear clearings in montane forests.
- Allowing the ROW and access roads to regenerate and the canopy to close over the gap wherever practical.

9.1.6 Fire

Fire is a potent ecological factor in tropical forest dynamics. During drier periods even very wet forests can burn. Recent experience in the PNG Highlands and Indonesia shows how powerful fire can be in reducing forest cover (Budowski 1966, Horn and Sanford 1992, Bassini and Becker 1990, Hopkins 1983, Wade and McVean 1969, Pajmans and Löffler 1972, Pajmans 1976).

Fire only becomes a threatening process in dry years (e.g. El Niño), when its effects can be widespread and often involve permanent deforestation. Large areas of forest within the KICDP and PNG Gas Project area overlie limestone pavements and karst and the soils are shallow – often just a thin root mat over solid limestone. Fire in these forests and also the swamp forests can burn away the organic soil layer and root mat leaving bare rock or subsoil,

upon which regeneration may take many decades or centuries if it is able to occur at all.

Mitigation

Measures to limit the impacts of fire that warrant investigation include:

- Developing a fire management plan.
- Controlling the use of fire by project personnel.

9.1.7 Open trenches

Fauna may fall into open trenches, be unable to get out, and perish. The only bird species that might be affected in this way would be the New Guinea Flightless Rail in swamp forests running south from Kopi to the Omati landfall. The risk depends on the construction RoW design: a trench in a causeway may have steep enough sides to act as a trap, while an in-situ trench with shallow batters may not.

Mitigation

- The risk to rails should be assessed in light of the pipeline installation method and in particular, the design of the pie trench.
- If the trench is capable of forming a trap, measures to remove alive and release trapped rails should be investigated.

9.1.8 Pipeline construction

There would be no impacts on birds from the procedures of pipeline construction itself.

9.1.9 Materials handling

Fuels and oils, chemicals, silt spoil and overburden entering rivers, streams and sinkhole swamps during construction have the potential to impact on species dependent upon these habitats. Stream alteration and pollution has contributed to the population decline of the globally threatened Salvadori's Teal, a rare inhabitant of fast flowing montane rivers and streams (Murray 1988; Callaghan, *in prep.*; BirdLife International 2005).

Mitigation

Measures to prevent materials entering streams and sinkholes should be investigated, including the following:

- Appropriate handling of materials.
- Ensuring that fuels and oils do not enter streams.
- Ensuring that there is no vehicle washdown in or near streams.
- Keeping silt and spoil out of streams and sink holes where practicable.

9.1.10 Traffic, noise and dust

Impacts from traffic hazards and dust will be minimal if procedures to calm and control traffic are adequate. Noise from construction will temporarily drive birds away from the site - a low and temporary impact.

9.1.11 Hunting

Many birds in PNG suffer greatly from hunting pressure. In particular, those species that are specifically targeted for food and/or decorative plumage are often locally extinct or exist in very low numbers in suitable habitat near human occupation. Taxa of particular interest to hunters include cassowaries (*Casuarus casuarus* and *C. bennetti*), megapodes (*Aepyodius arfakianus*, *Talegalla* and *Megapodius* species), Blyth's Hornbill (*Aceros plicatus*), larger lorikeets (*Trichoglossus haematodus*, *Charmosyna papou*), parrots (*Probosciger aterrimus*, *Cacatua galerita*, *Eclectus roratus*, *Psitttrichas fulgidus*), pigeons (*Ducula* species, and the Crowned Pigeons (*Goura* spp.), raptors, the New Guinea Flightless Rail, and numerous, well-plumed birds-of-paradise Black Sicklebill, Brown Sicklebill, Black-billed Sicklebill, Carola's Parotia, Lawes's Parotia, Magnificent Riflebird, Ribbon-tailed Astrapia, King-of-Saxony Bird-of-paradise, Twelve-wired Bird-of-paradise, Raggiana Bird-of-paradise and Blue Bird-of-paradise. Mack and Wright (1998) show how hunting has seriously impacted on Pesquet's Parrot.

Hunting pressure can be directly increased by the PNG Gas Project through a large influx of personnel possibly hunting and purchasing wildlife products and by the use of the transport feet of vehicles and helicopters allowing easy and swift access to forest for both locals and outsiders.

Mitigation

The direct impacts can be mitigated by the PNG Gas Project proscribing hunting on company time and on company property and the possession of wildlife products on site as a condition of employment and of contracts for the supply of services and should be investigated.

However, hunting is embedded in the system of customary landownership in PNG and the PNG Gas Project has no authority over landowners who are entitled to hunt and may still wish to do so. Ways and means of obtaining the cooperation of landowners to maintain hunting at current sustainable levels require investigation.

9.1.12 Impacts on migratory species

The Kikori River delta offers important habitat for migratory waders from September to April. Similar habitat at the mouth of the Omati River has not been surveyed, but areas of open mud at low tide could be used by these birds. Construction of the pipeline at this time will disturb these birds on a local scale. However, these species do not breed in the area and ample habitat exists in the region to accommodate small-scale, temporary and localised displacement during the short period of pipeline installation.

The near-threatened Beach Thicknee does breed in the area, but the landfall in the Omati River does not cross or go close to this bird's beach habitat.

Resident and migratory species will similarly experience the localised effects of forest clearing inland. Migrant waders and waterbirds are likely to remain undisturbed as the PNG Gas Project will be avoiding by intent their open wetland or large tidal flat habitat.

9.2 Indirect (Secondary) Impacts

Indirect impacts are potentially significant but they are difficult to quantify, because they involve the activities of parties other than those involved directly in the PNG Gas Project.

The major indirect impact will be increased accessibility to people along the access roads. If these are to be public roads, and therefore uncontrollable, then there is a strong likelihood of permanent, long-term, high-level impacts on the avifauna.

The global experience with roads in tropical forests is that long term uncontrolled access will result in long term and permanent diminution of the avifauna by a combination of:

- Settlement.
- Clearing along roads for gardens and small agricultural plots.
- Illegal logging.
- Acceleration of legal logging.
- Changing the economics of logging to make unprofitable areas profitable by saving costs of building access roads.
- Over hunting.
- Ingress of weeds and pathogens brought in on vehicles.
- Fire.

Impacts of roading in tropical forests are discussed at length in numerous articles on web sites of conservation organisations. Scholarly approaches to the topic can be found in Laurance et al. (2004), Trombulak and Frissell (2000) and Forman and Alexander (1998).

The potential for this problem to occur at any altitude, from the Kikori River lowlands to the Hides gas field, is primarily determined by two factors:

- Public accessibility to previously little disturbed areas
- The level of in-migration that this induces.

Hunting pressure will be felt by the attractive prey species, whose abundance and proximity to existing oil and gas facilities is one of the defining characteristics of the KICDP and PNG Gas Project area. The public road linking the Highlands to the Gulf will be the new element in the post-PNG Gas Project environment that introduces in-migration, clearing and hunting pressures on birds not experienced in the KICDP area to date. If this occurs, then the **potential exists for a high level of impact on local populations** of many species, including a number of globally threatened birds.

Mitigation

It is recommended that ways and means of mitigating the indirect impacts of a public road on birds be investigated. It is understood that national and provincial government policy requires the PNG Gas Project to complete its construction access ways as a public road. Other measures worthy of investigation include:

- Maximising the length of company-owned roads and gating them.
- Using the present relationship with WWF (Kikori) to develop and implement a conservation and protection plan that would aim at reducing forest loss, logging and hunting along the roads.

9.3 Summary of Mitigation Measures

The mitigating measures warranting investigation as to feasibility, utility and adequacy are summarised in Table 5.

Table 5 Summary of mitigation measures warranting investigation

Activity	Mitigating measures
Forest clearing generally	• Reducing the width of the ROW and access roads as far as practical, ideally keeping them to 25 m or less. • Limiting the combined width of the oil export pipeline ROW and the gas ROW where they coincide to 30 m or less. • Locating facilities, camps, laydown areas, borrow pits etc. within secondary forest and cleared areas. • Restricting clearing for facilities, camps, laydown areas, borrow pits etc. to less than 1 ha and ideally less than 0.5 ha. • Identifying display grounds and trees of birds-of-paradise and bowerbirds during pre-construction clearance surveys and retaining these trees. • Allowing regeneration.
Forest clearing in montane areas on karst	• Limiting construction in these forests where practicable. • Limiting the construction footprint. • Limiting ROW and access road widths to 15m or less. • Ideally having no permanent access roads, and ripping and allowing construction roads to regenerate. • Limiting clearing by having no camps in this type of noteworthy area. • Careful control of cuts and spoil disposal.
Swamp forest	• Strictly controlling fire. • Allowing the ROW to regenerate, and having no permanent access through swamp forests. • Ensuring the ROW and essential access roads are constructed so as not to alter hydrology of these areas.
Barrier and edge effects	• Limiting widths of ROW and access roads. • Reducing lengths of linear clearings in montane forests. • Allowing the ROW and access roads to regenerate and the canopy to close over the gap wherever practical.
Fire	• Developing a fire management plan. • Controlling the use of fire by project personnel.
Open trenches	• Any rails found in the trench should be removed and released alive.
Materials handling	• Appropriate handling of materials. • Ensuring that fuels and oils do not enter streams. • Ensuring that there is no vehicle washdown in or near streams. • Keeping silt and spoil out of streams and sink holes where practicable.
Indirect (secondary) impacts	• Not making construction access ways public. • Maximising the length of company-owned roads and gating them. • Using the present relationship with WWF (Kikori) to develop and implement a conservation and protection plan that would aim at reducing forest loss, logging and hunting along the roads.

10References

- Bassini, F. and Becker, P. (1990). Charcoal's occurrence in soil depends on topography in tierra firme forest near Manaus, Brazil. *Biotropica* 22: 420-422.
- Beehler B. M., Pratt T. K., and Zimmerman D. A. (1986). *Birds of New Guinea*. Princeton University Press, Princeton, NJ.
- BirdLife International (2003). *BirdLife's online World Bird Database: the site for bird conservation*. Version 2.0. Cambridge, UK: BirdLife International. Available: <http://www.birdlife.org> (accessed 25/5/2005).
- BirdLife International (2005). Species factsheet: *Salvadorina waigiensis*. (Accessed 21/6/2005).
- Budowski, G. (1966). Fire in tropical lowland areas. *Proceedings of the Annual Tall Timbers Fire Ecology Conference*. 5: 5-22.
- Burrows, I. (1995). A field survey of the avifauna of the Kikori River Basin. In: *Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea* (G. S. Hartshorn et al.). WWF KICDP Report.
- Callaghan, D. A. (in prep.). *Global action plan for the conservation of Anseriformes (Ducks, Geese, Swans and Screamers)*. IUCN, Gland, Switzerland.
- Coates, B. J. (1985). *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville. Volume I, Non-Passerines*. Dove Publications, Alderley, Queensland.
- Coates B. J. (1990). *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville. Volume II, Passerines*. Dove Publications, Alderley, Queensland.
- Crome, F. H. J. (1993). Post World Heritage Bird Conservation Problems in North East Queensland. Pp. 93 - 104 in Catterall, C. P., Driscoll, P. V., Hulsman, K., Muir, D. and Taplin (A. (eds.). *Birds and their Habitats: Status and Conservation in Queensland*. Queensland ornithological Society Inc., Brisbane.
- Diamond, J. and Bishop, K. D. (2000). *Birds of Mt. Sisa*. WWF KICDP Report.
- Diamond, J. and Bishop, K. D. (2000). *Local Avifauna of the Kikori River Catchment Surveyed in 1999*. WWF KICDP Report.
- Diamond, J. and Bishop, K. D. (2003). *Seasonality in Birds in the Kikori River Catchment: Year-2003 Studies*. WWF KICDP Report.
- Diamond, J. (2005). *Collapse How Societies Choose to Fail or Survive*. Viking Books, New York.
- Eastwood, C. and Gregory, P. (1995). Interesting sightings during 1993 and 1994. *Muruk* 7: 128-142.
- Forman, R. T. and Alexander, L. E. (1998). Roads and their major ecological effects *Annual Review of Ecology and Systematics* 29: 207-231.

- Frith, C. B. and Beehler, B. M. (1998). *The Birds of Paradise Paradisaeidae*. Oxford University Press, Oxford.
- Hartshorn, G. S., Burrows, I., Leary, T., Seri, L., Allen, G., Polhemus, D., Balun, L., Orsak, L., Bigilale, E., Kinbag, F., Kinibel, A., Dal, C., Wasel, H., Ellis, G. and Forney, M. (1995). *Field survey of biodiversity in the Kikori River Basin. Papua New Guinea*. WWF KICDP Area Report.
- Hicks, R. (1988). Recent observations April to June 1987. Muruk 3: 32-38.
- Hopkins, B. (1983). Successional processes. Pp. 605-616 in Bourliere, F. (ed.). *Tropical Savannas*. Elsevier, New York.
- Horn, S. P. and Sanford, R. L. (1992). Holocene fires in Costa Rica. *Biotropica* 24: 354-361.
- Igag, P. (2003). *Report on Bird Survey for the Darai and Libano Sites of Kikori ICDP, 2003*. WWF KICDP Report.
- Jaensch, R. and Kulmoi, P. (1998). *Birds Recorded at Tubo Lodge, Lake Kutubu, August 1997 and February 1998*. Wetlands International Report.
- Jaensch, R. and Watkins, D. (2000). *Birds Recorded in the Lower Kikori River and Kikori Delta Areas Papua New Guinea (First Draft)*. Wetlands International Report.
- Jaensch, R. (1997). *Birds Recorded at Lake Kutubu, Moro and Agogo Range, Papua New Guinea, 30 July to 2 August 1997*. Wetlands International Report.
- Jaensch, R. (1999). *Birds of the Lake Kutubu Swamp Forest Papua New Guinea (Summary Report)*. Wetlands International Report.
- Jones, D. N. and Dekker, R. W. R. J. (1995). *The Megapodes Megapodiidae*. Oxford University Press, Oxford.
- Lamonthe, L. (1993). Papuan Hawk-owl *Uroglaux dimorpha* in the Lae-Bulolo area. Muruk 6: 14.
- Laurance, S. G. W., Stouffer, P. C. and Laurance, W. F. (2004). Effects of Road Clearings on Movement Patterns of Understory Rainforest Birds in Central Amazonia. *Conservation Biology* 18 1099-1109
- Laurence, W. F. and Bierregaard, R. O. Jr. (1997). *Tropical Forest Remnants. Ecology, Management, and Conservation of Fragmented Communities*. University of Chicago Press, Chicago.
- Leary, T. and Seri, L. (1995). *Survey of Birds and Mammals at Utiti Creek*. WWF KICDP Report.
- Leary, T. (2002). *Brief Report on Iviri Mammal Monitoring - December 2001*. WWF KICDP Report.
- Leary, T. (2004a). *Brief Report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003*. WWF KICDP Report.
- Leary, T. (2004b). *Brief Report on Keboi Kerowa Mammal Monitoring - July 2004*. WWF KICDP Report.

- Leary, T., Naug, R. and Price, J. (1996). *Kikori Integrated Conservational and Development Project* pp. 805 – 814 in Buchanan, P. G. (ed.). "Petroleum Exploration, Development and Production in Papua New Guinea: Proceedings of the third PNG Petroleum Convention, Port Moresby, 9th – 11th September 1996.
- Mack, A. L. and Wright, D. B. (1998). The Vulturine Parrot, *Psitttrichas fulgidus*, a threatened New Guinea endemic: notes on its biology and conservation. *Bird Conservation International* 8: 158 – 194.
- McCall, D. and Flemming, D. (2000). *Chevron and WWF: Lessons Learned from Six Years of Collaboration in Biodiversity Protection*. WWF/Chevron Niugini Report.
- McClure, H. E. (1973). *Migration and Survival of the Birds of Asia*. US Army Medical Component, S. E. A. T. O, Bangkok.
- Murray, A. (1988). A study of the birds of the Tabubil region, Western Province, Papua New Guinea. *Muruk* 3: 3.
- Nix, H. E. (1993). Bird distributions in relation to imperatives for habitat conservation in Queensland. Pp. 12 – 22 in Catterall, C. P., Driscoll, P. V., Hulsman, K., Muir, D. and Taplin (A. (eds.). *Birds and their Habitats: Status and Conservation in Queensland*. Queensland ornithological Society Inc., Brisbane.
- Pajmans, K. (1976). *New Guinea Vegetation*. CSIRO, Canberra.
- Pajmans, K. and Löffler, E. (1972). High-altitude forests and grassland of Mt. Albert Edward, New Guinea. *Journal of Tropical Geography* 34: 58 - 64.
- Pratt, T. K. (2000). Evidence for a previously unrecognized species of Owlet-Nightjar. *Auk* 117: 1-11.
- Shany, N. (1995). Juvenile Papuan Hawk-Owl *Uroglauux dimorpha* near Vanimo. *Muruk* 7: 74.
- Sibley, C. G., and Munroe, B. L. Jr. (1990). *Distribution and Taxonomy of Birds of the World*. Yale University Press, New Haven and London.
- Sibley, C. G., and Munroe, B. L. Jr. (1993a). *Supplement to Distribution and Taxonomy of Birds of the World*. Yale University Press, New Haven and London.
- Sibley, C. G., and Munroe, B. L. Jr. (1993b). *A World Checklist of Birds*. Yale University Press, New Haven and London.
- Stattersfield, A. J., Crosby, M. J., Long, A. J. and Wege, D. C. (1998). *Endemic Bird Areas of the World. Priorities for Bird Conservation*. Birdlife International, Cambridge, UK.
- Trombulak, S. C. and Frissell, C. A. (2000). Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conservation Biology* 14:18 – 30.
- Wade, L. K. and McVean, D. N. (1969). *Mt Wilhelm studies 1: The alpine and subalpine vegetation*. Publication BG/1 Australian National University, Canberra.

Watkins D. (2000). *Kikori Delta of Gulf Province, Papua New Guinea, Recently Identified as Internationally Important Area for Migratory Shorebirds along the East Asian-Australasian Flyway*. Wetlands International Report.

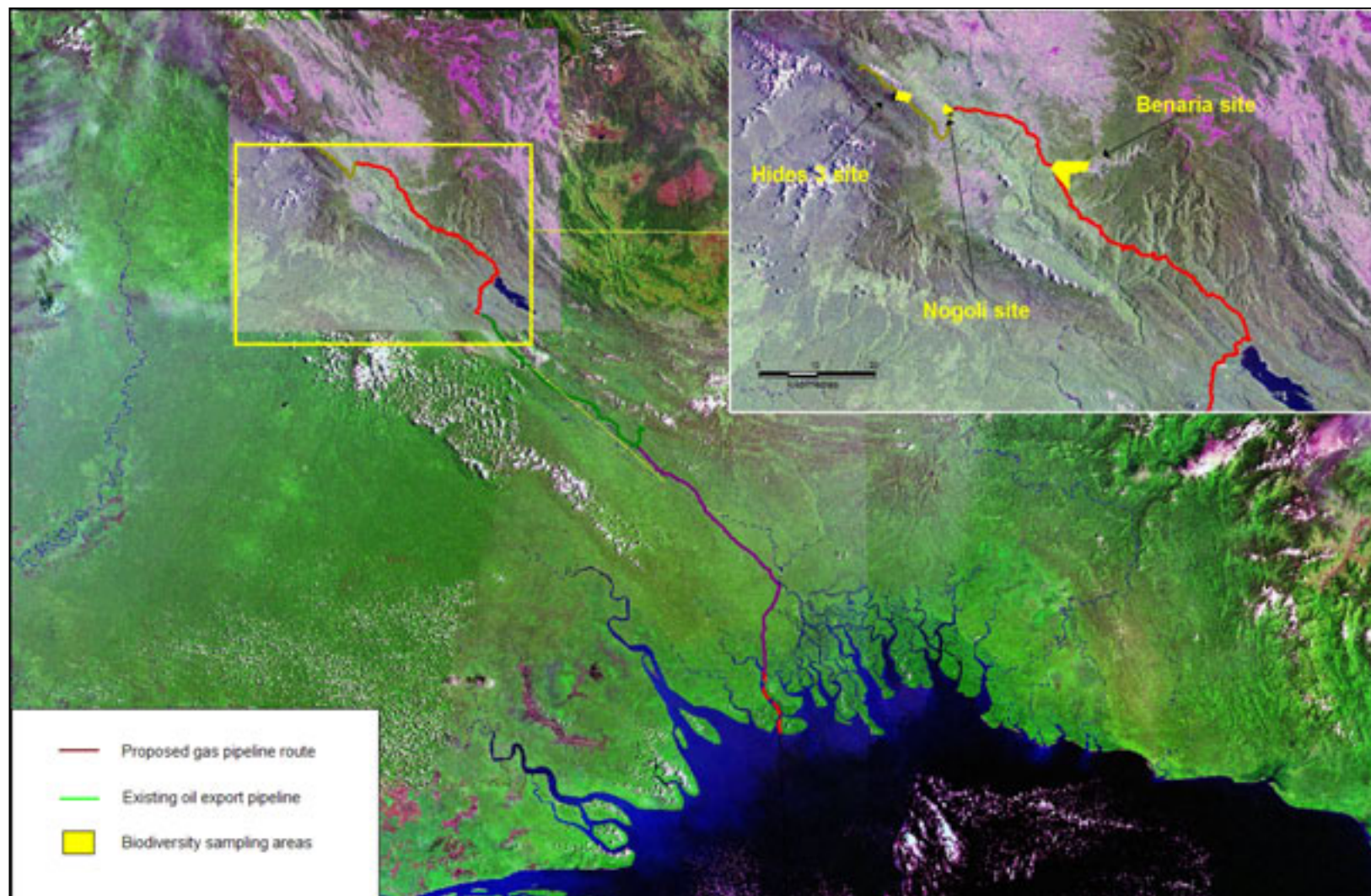


Figure 1 Study areas.

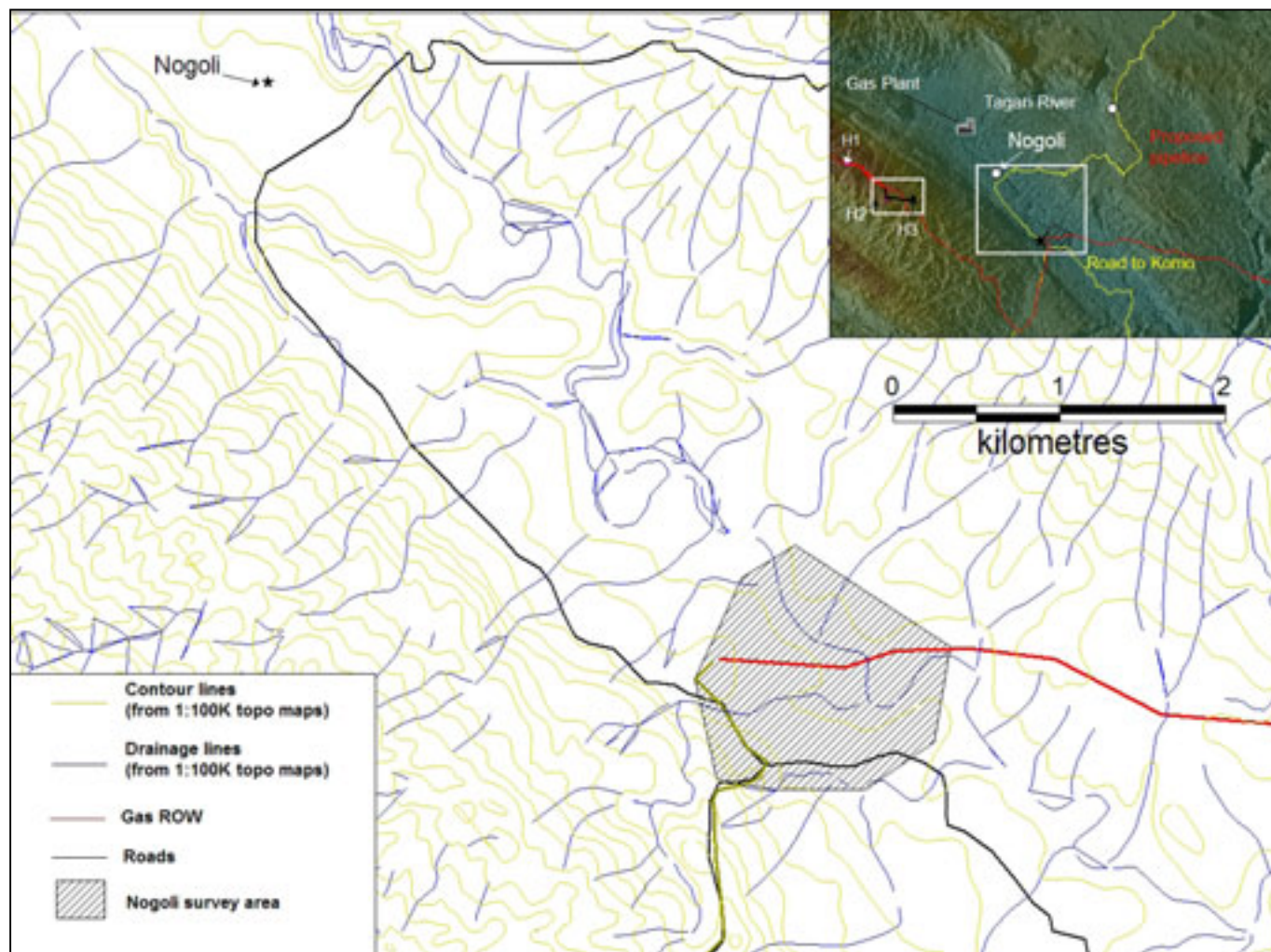


Figure 2 The Nogoli Survey site.

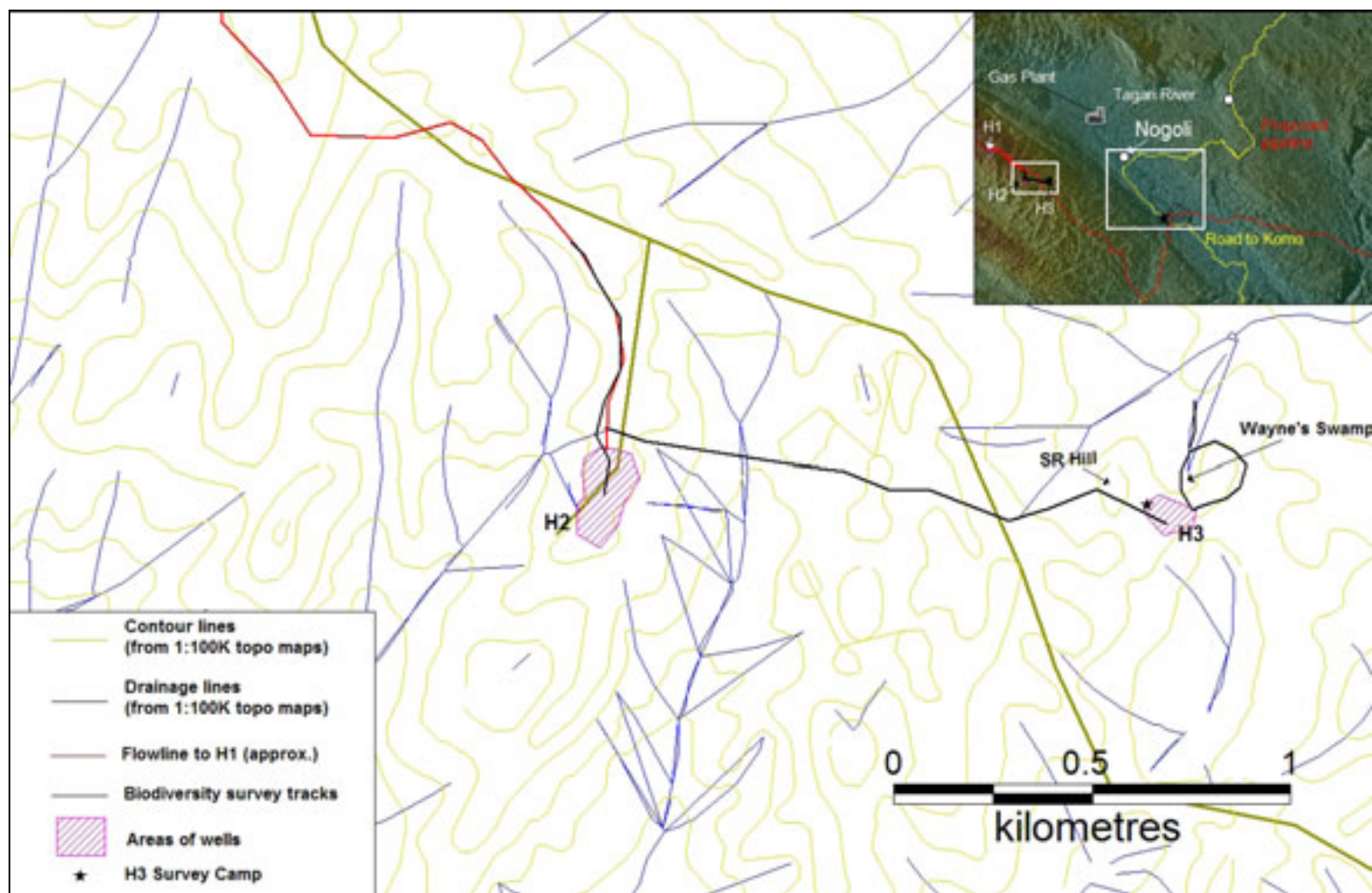


Figure 3 The Hides 3 survey site.

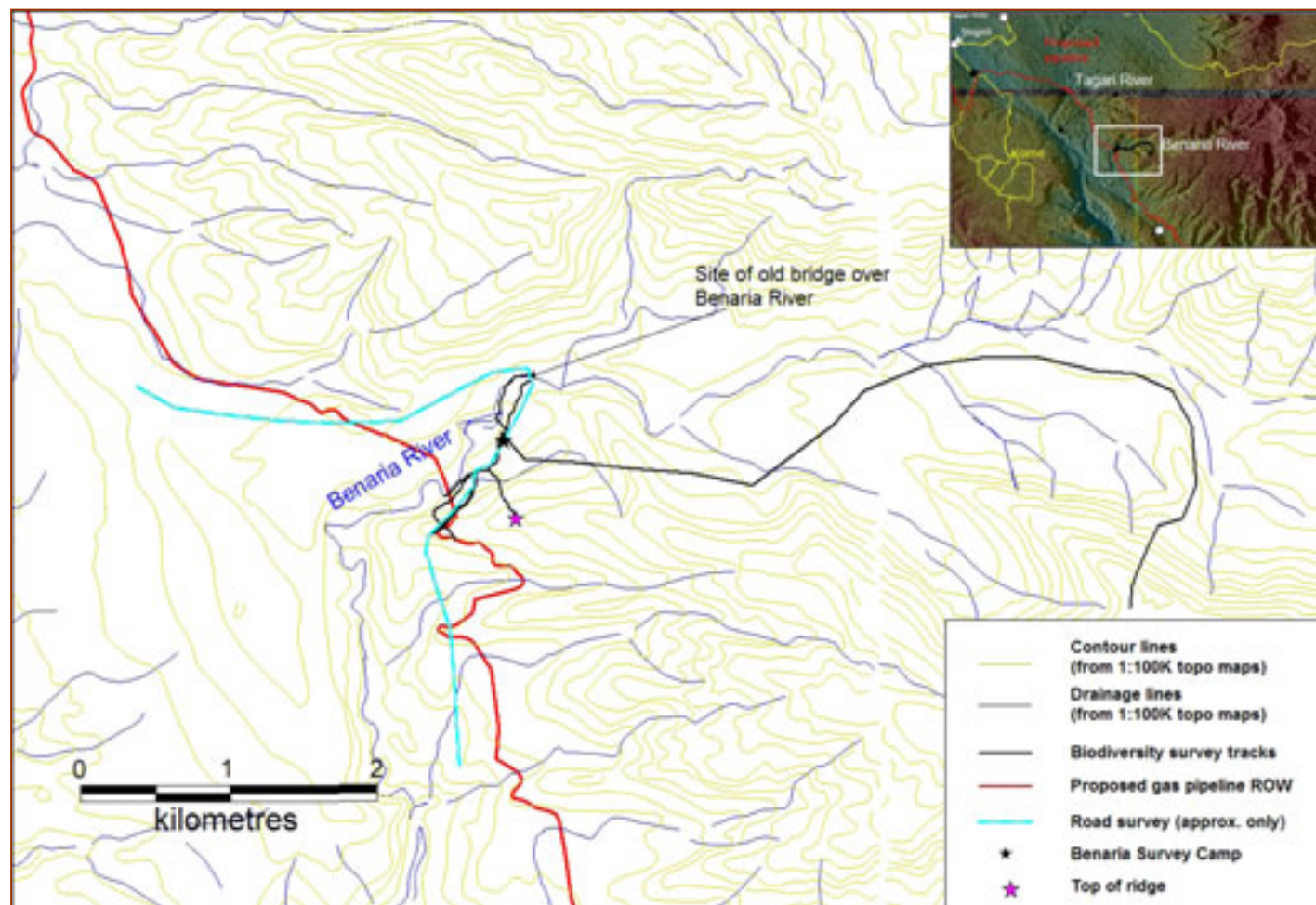
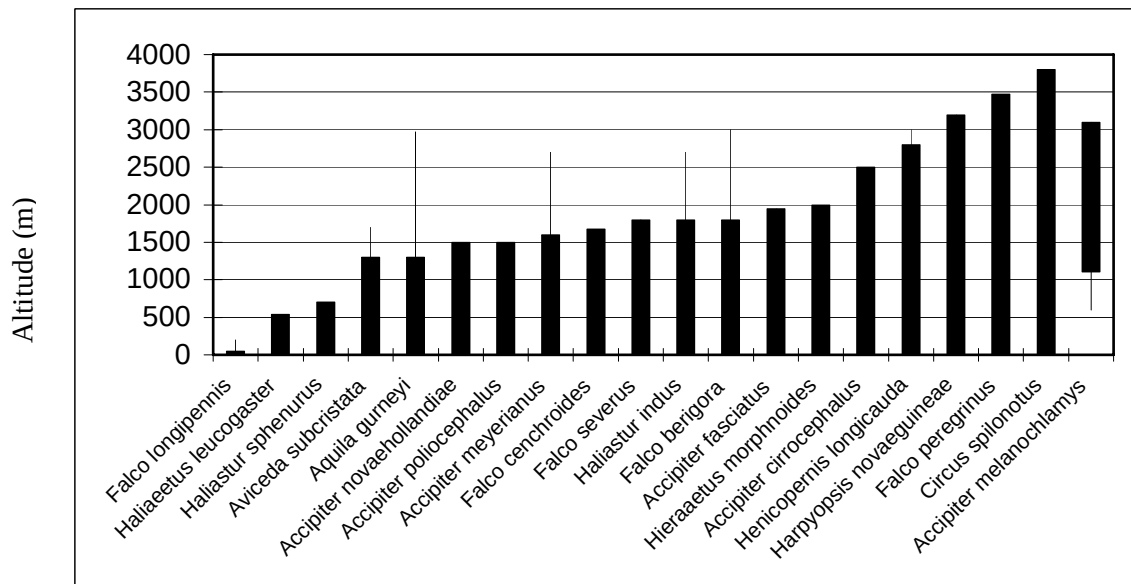


Figure 4 The Benaria survey site.

Raptors



Pigeons

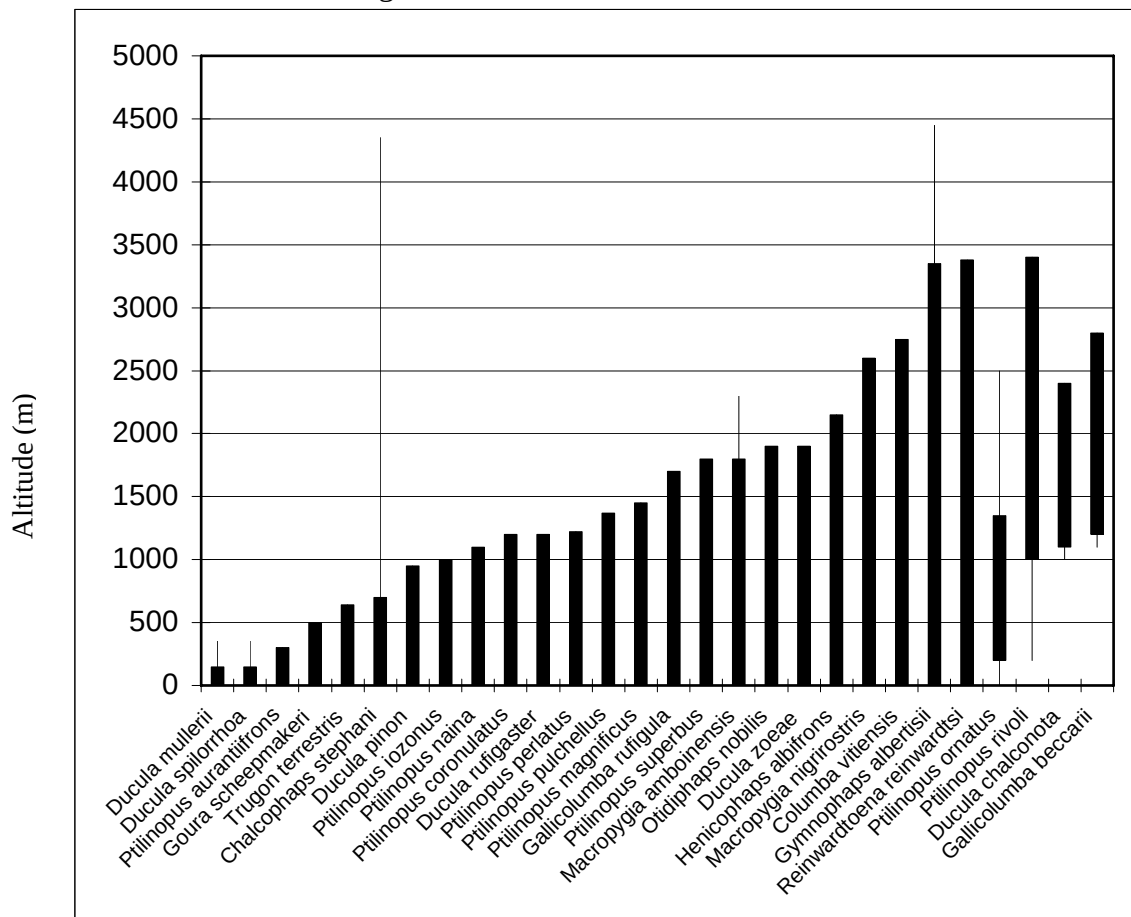
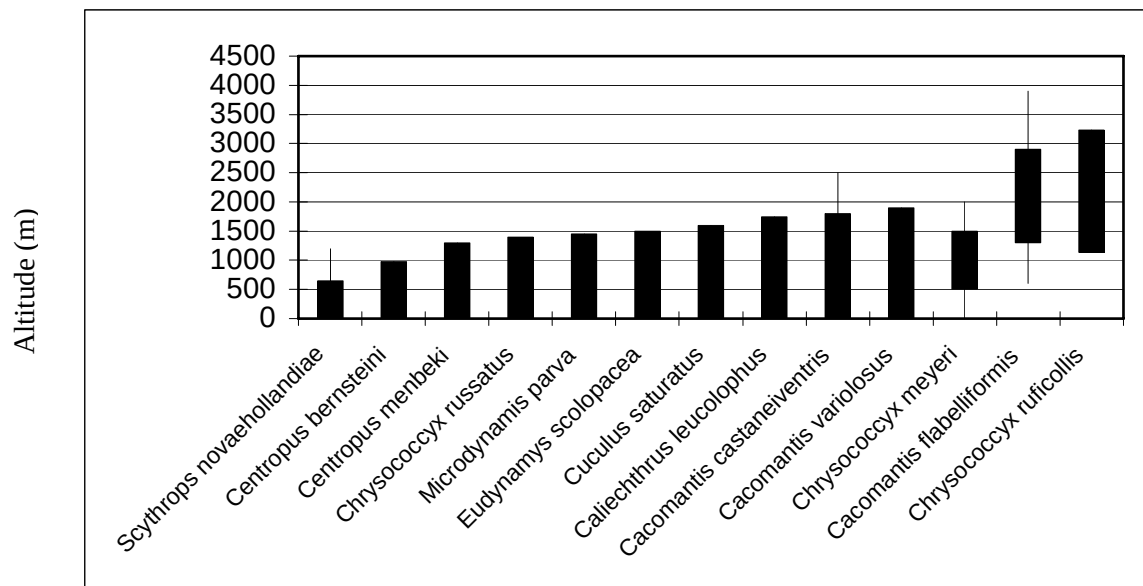


Figure 5 Altitudinal ranges of forest species – non passerines 1.



Parrots

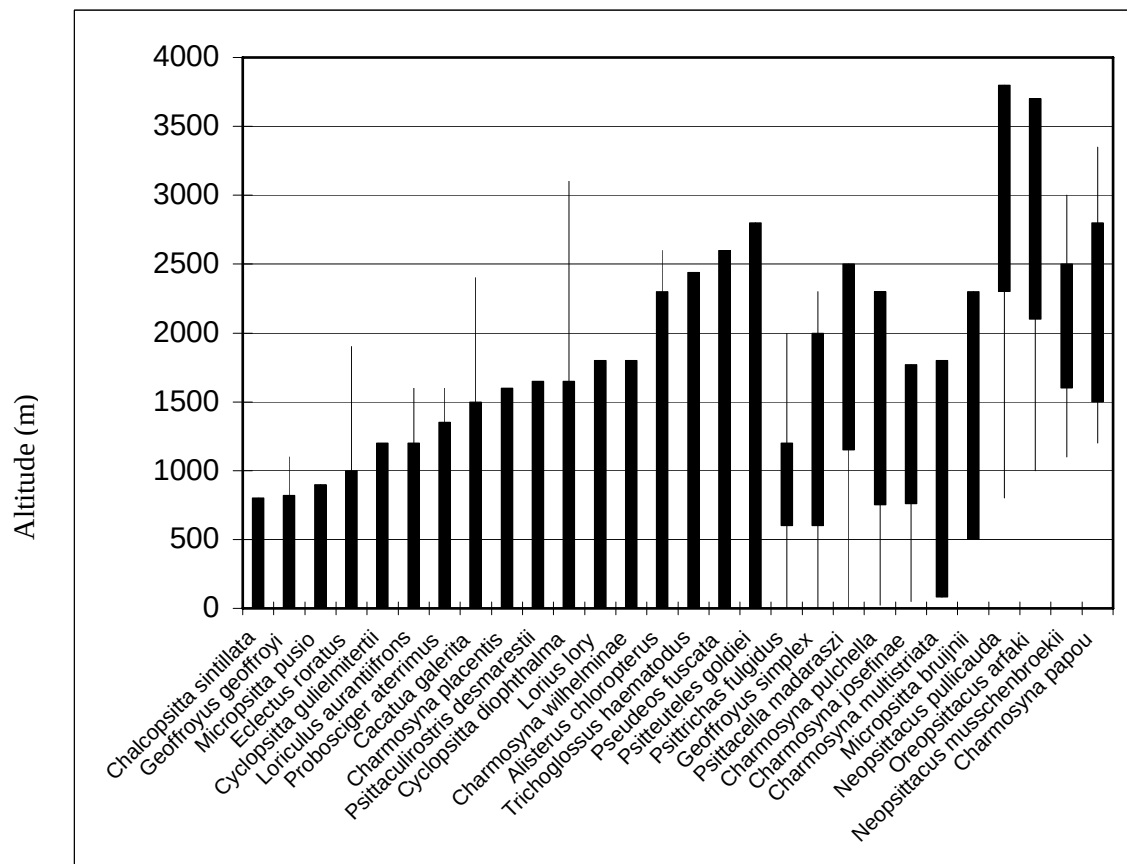
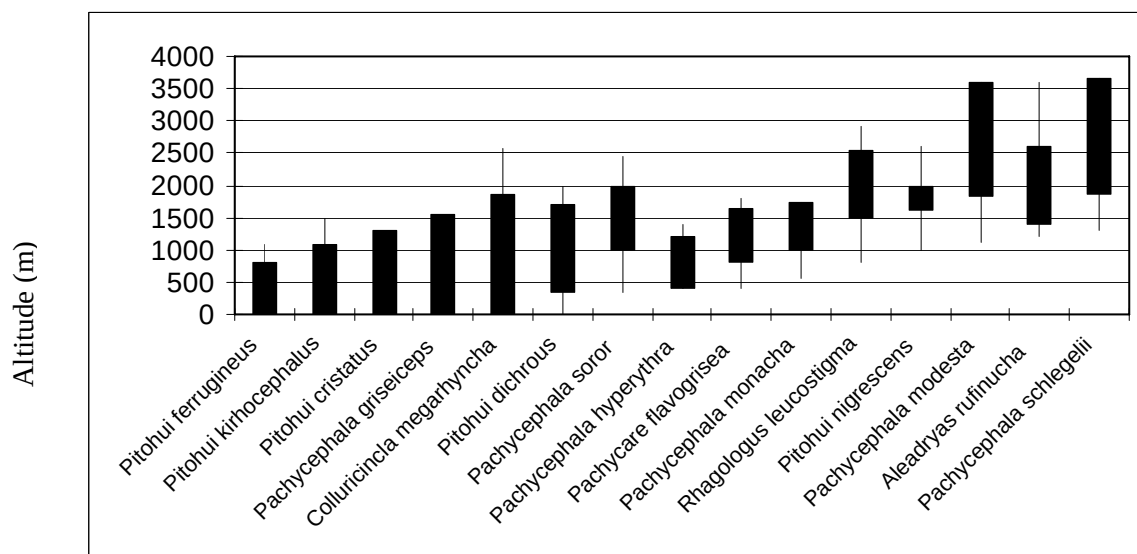
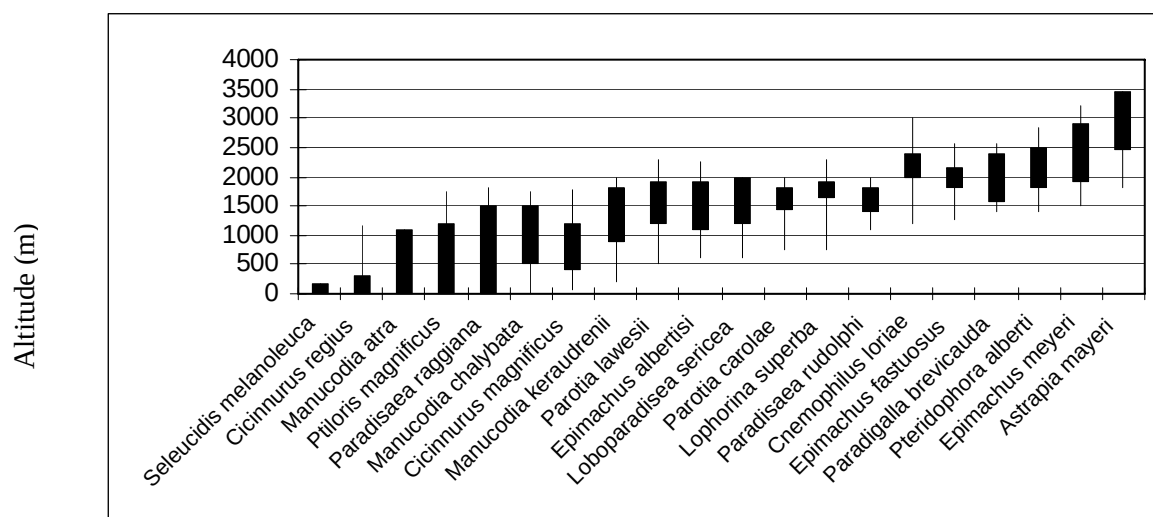


Figure 6 Altitudinal ranges of forest species – non passerines 2.

Whistlers



Birds of Paradise



Honeyeaters

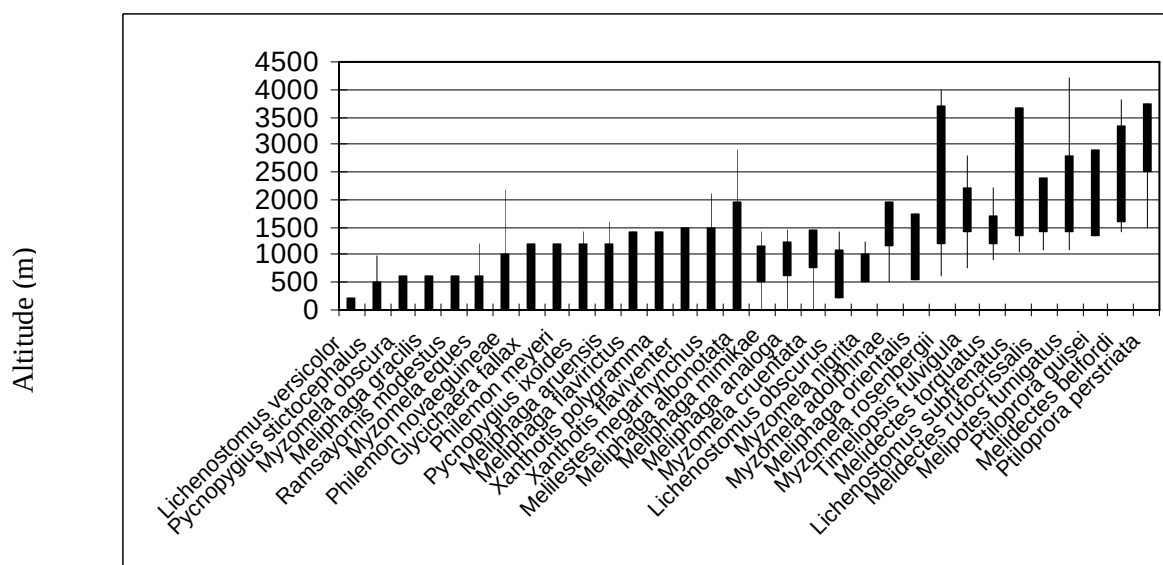


Figure 7 Altitudinal ranges of forest species –passerines part 1.



Figure 8 Altitudinal ranges of forest species – passerines 2.

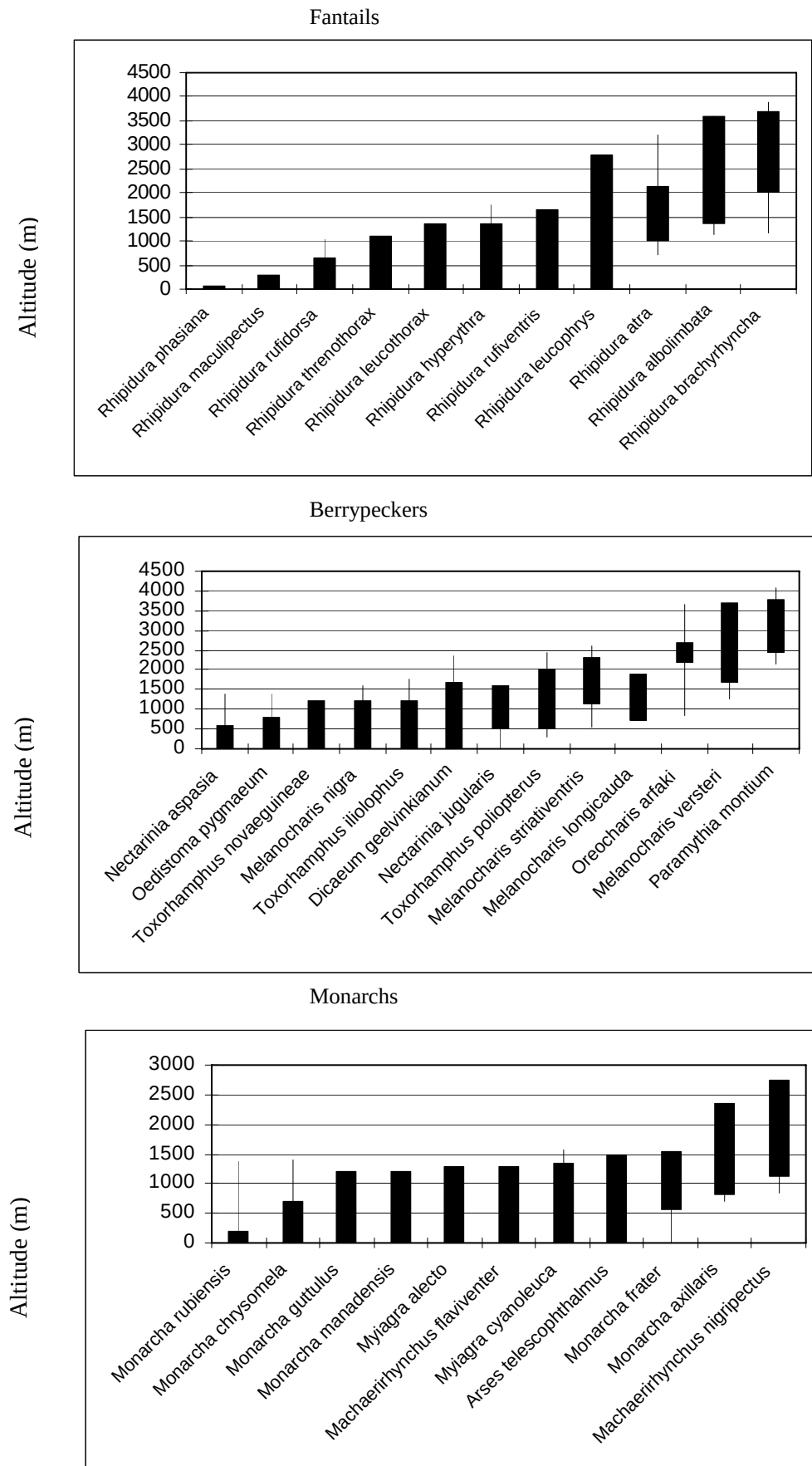


Figure 9 Altitudinal ranges of forest species –passerines 3.

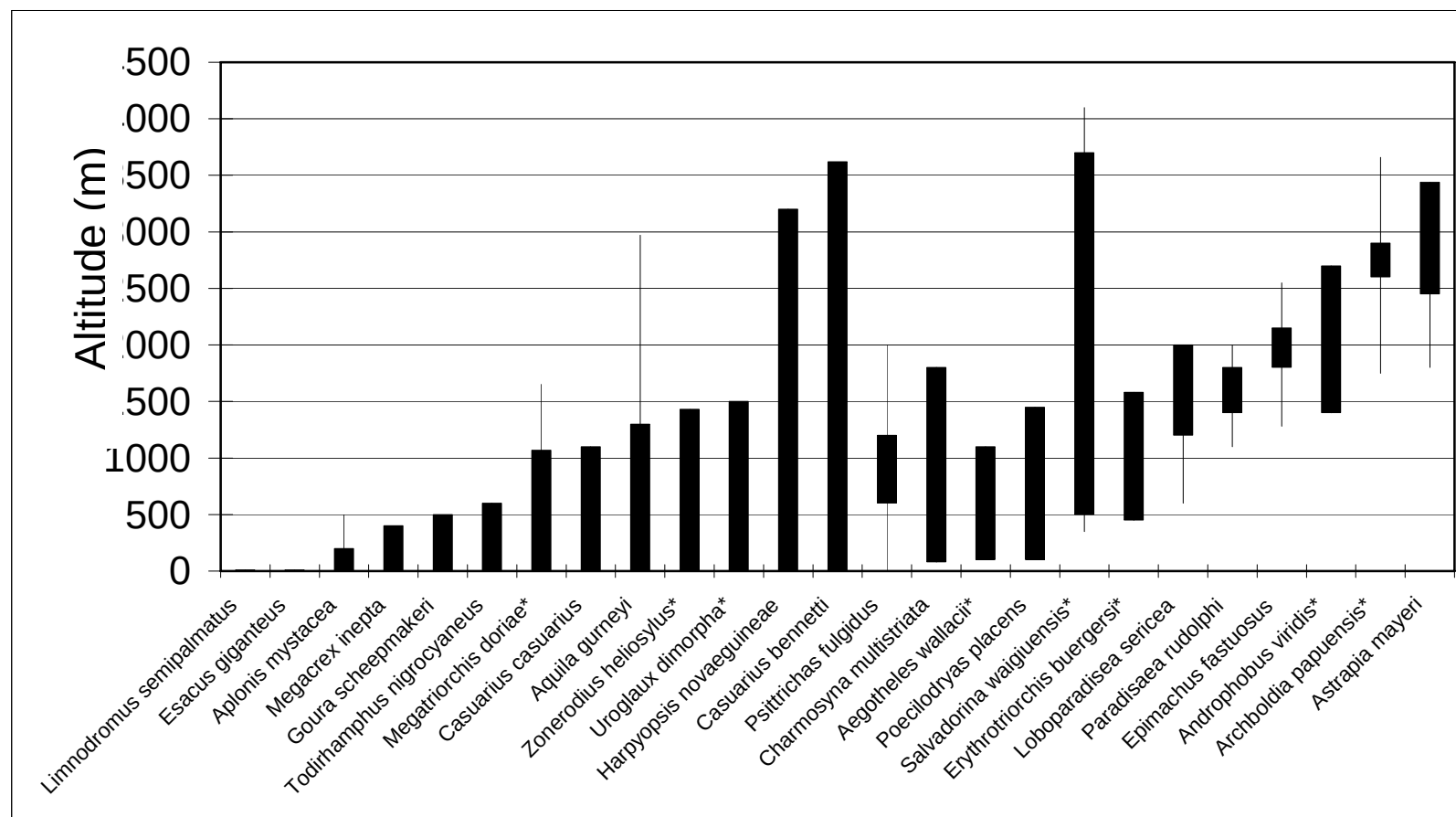


Figure 10 Altitudinal Ranges (m) of IUCN Listed species (* not recorded in KICDP and Gas Project area yet but could occur)

Appendix 1 Birds recorded from Hides 3, Nogoli and Benaria survey sites.

Family	Common Name	Scientific Name	H3	B	N
Casuariidae	Southern Cassowary	<i>Casuarius casuarius</i>		X	
Casuariidae	Dwarf Cassowary	<i>Casuarius bennetti</i>	X		X
Megapodiidae:	Black-billed Brush-turkey	<i>Talegalla fuscirostris</i>		X	
Megapodiidae:	Brown-collared Brush-turkey	<i>Talegalla jobiensis</i>		X	
Megapodiidae:	New Guinea Scrubfowl	<i>Megapodius decollatus</i>		X	
Phasianidae	Blue-breasted Quail	<i>Coturnix chinensis</i>		X	
Bucerotidae	Blyth's Hornbill	<i>Aceros plicatus</i>		X	X
Coraciidae	Dollarbird	<i>Eurystomus orientalis</i>			X
Dacelonidae	Forest Kingfisher	<i>Todirhamphus macleayii</i>		X	
Meropidae	Rainbow Bee-eater	<i>Merops ornatus</i>		X	
Cuculidae	Chestnut-breasted Cuckoo	<i>Cacomantis castaneiventris</i>		X	
Cuculidae	Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>	X	X	
Cuculidae	Dwarf Koel	<i>Microdynamis parva</i>		X	
Cuculidae	Asian Koel	<i>Eudynamis scolopacea</i>		X	X
Psittacidae	Rainbow Lorikeet	<i>Trichoglossus haematodus</i>		X	X
Psittacidae	Fairy Lorikeet	<i>Charmosyna pulchella</i>		X	
Psittacidae	Papuan Lorikeet	<i>Charmosyna papou</i>	X	X	
Psittacidae	Yellow-billed Lorikeet	<i>Neopsittacus musschenbroekii</i>	X	X	
Psittacidae	Orange-billed Lorikeet	<i>Neopsittacus pullicauda</i>	X		
Psittacidae	Sulphur-crested cockatoo	<i>Cacatua galerita</i>		X	X
Psittacidae	Double-eyed Fig-Parrot	<i>Cyclopsitta diophthalma</i>		X	
Psittacidae	Large Fig-Parrot	<i>Psittaculirostris desmarestii</i>	X		
Psittacidae	Papuan King-Parrot	<i>Alisterus chloropterus</i>	X	X	X
Apodidae	Glossy Swiftlet	<i>Collocalia esculenta</i>	X	X	X
Apodidae	Swiftlet (Mountain/ Uniform)	<i>Aerodramus hirundinaceus/ vanikorensis</i>		X	X
Apodidae	Swiftlet (Bare-legged/ Mountain)	<i>Aerodramus nuditaris/ hirundinaceus</i>	X		
Apodidae	White-throated Needletail	<i>Hirundapus caudacutus</i>		X	
Hemiprocidae	Moustached Treeswift	<i>Hemiprocne mystacea</i>		X	X
Podargidae	Papuan Frogmouth	<i>Podargus papuensis</i>		X	
Eurostopodidae	Mountain Eared-Nightjar	<i>Eurostopodus archboldi</i>	X		
Caprimulgidae	Large-tailed Nightjar	<i>Caprimulgus macrurus</i>		X	
Columbidae	Metallic Pigeon	<i>Columba vitiensis</i>		X	
Columbidae	Slender-billed Cuckoo-Dove	<i>Macropygia amboinensis</i>	X	X	X
Columbidae	Great Cuckoo-Dove	<i>Reinwardtoena reinwardtsi</i>	X		
Columbidae	Bronze Ground-Dove	<i>Gallicolumba beccarii</i>	X		
Columbidae	Ornate Fruit-Dove	<i>Ptilinopus ornatus</i>	X	X	X
Columbidae	Superb Fruit-Dove	<i>Ptilinopus superbus</i>		X	X
Columbidae	White-bibbed Fruit-Dove	<i>Ptilinopus rivoli</i>		X	
Columbidae	Shining Imperial-Pigeon	<i>Ducula chalconota</i>	X		
Columbidae	Banded Imperial-Pigeon	<i>Ducula zoeae</i>		X	X
Columbidae	Papuan Mountain-Pigeon	<i>Gymnophaps albertisii</i>	X	X	X
Rallidae	Forbes Forest-rail	<i>Rallina forbesi</i>	X		
Acciptridae	Long-tailed Honey-buzzard	<i>Henicopernis longicauda</i>	X		
Acciptridae	Brahminy Kite	<i>Haliastur indus</i>	X		X
Acciptridae	Grey Goshawk	<i>Accipiter novaehollandiae</i>			X
Acciptridae	Brown Goshawk	<i>Accipiter fasciatus</i>		X	
Acciptridae	Black-mantled Goshawk	<i>Accipiter melanochlamys</i>	X	X	
Acciptridae	Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>		X	

Appendix 1 Birds recorded from Hides 3, Nogoli and Benaria survey sites.

Family	Common Name	Scientific Name	H3	B	N
Acciptridae	Meyer's Goshawk	<i>Accipiter meyerianus</i>	X		
Phalacrocoracidae	Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>		X	
Phalacrocoracidae	Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>		X	
Ptilonorhynchidae	Spotted Catbird	<i>Ailuroedus melanotis</i>		X	
Maluridae	Orange-crowned Fairywren	<i>Clytomyias insignis</i>	X		
Maluridae	White-shouldered Fairywren	<i>Malurus alboscapulatus</i>		X	X
Meliphagidae	Olive Straightbill	<i>Timeliopsis fulvigula</i>	X		
Meliphagidae	Long-billed Honeyeater	<i>Melilestes megarhynchus</i>		X	X
Meliphagidae	Hill-forest Honeyeater	<i>Meliphaga orientalis</i>		X	
Meliphagidae	Scrub Honeyeater	<i>Meliphaga albonotata</i>		X	X
Meliphagidae	Mimic Honeyeater	<i>Meliphaga analoga</i>		X	
Meliphagidae	Honeyeater	<i>Meliphaga sp.</i>		X	
Meliphagidae	Tawny-breasted Honeyeater	<i>Xanthotis flaviventer</i>		X	X
Meliphagidae	Spotted Honeyeater	<i>Xanthotis polygramma</i>		X	
Meliphagidae	New Guinea Friarbird	<i>Philemon novaeguineae</i>		X	
Meliphagidae	Rufous-backed Honeyeater	<i>Ptiloprora guisei</i>	X		
Meliphagidae	Black-backed Honeyeater	<i>Ptiloprora perstriata</i>	X		
Meliphagidae	Belford's Melidectes	<i>Melidectes belfordi</i>	X		
Meliphagidae	Ornate Melidectes	<i>Melidectes torquatus</i>		X	
Meliphagidae	Smoky Honeyeater	<i>Melipotes fumigatus</i>	X		
Pardalotidae	Rusty Mouse-warbler	<i>Crateroscelis murina</i>		X	
Pardalotidae	Mountain Mouse-warbler	<i>Crateroscelis robusta</i>	X		
Pardalotidae	Large Scrubwren	<i>Sericornis nouhuysi</i>	X		
Pardalotidae	Buff-faced Scrubwren	<i>Sericornis perspicillatus</i>	X		
Pardalotidae	Papuan Scrubwren	<i>Sericornis papuensis</i>	X		
Pardalotidae	Papuan Thornbill	<i>Acanthiza murina</i>	X		
Pardalotidae	Mountain Gerygone	<i>Gerygone cinerea</i>	X		
Pardalotidae	Green-backed Gerygone	<i>Gerygone chloronotus</i>		X	
Pardalotidae	Brown-breasted Gerygone	<i>Gerygone ruficollis</i>	X		
Petroicidae	Torrent Robin	<i>Monachella muelleriana</i>		X	X
Petroicidae	Olive Flyrobin	<i>Microeca flavovirescens</i>		X	X
Petroicidae	Canary Flyrobin	<i>Microeca papuana</i>	X		
Petroicidae	Garnet Robin	<i>Eugerygone rubra</i>	X		
Petroicidae	White-faced Robin	<i>Tregellasia leucops</i>		X	
Petroicidae	White-winged Robin	<i>Peneothello sigillatus</i>	X		
Petroicidae	Blue-grey Robin	<i>Peneothello cyanus</i>	X		
Petroicidae	White-eyed Robin	<i>Pachycephalopsis poliosoma</i>		X	
Laniidae	Long-tailed Shrike	<i>Lanius schach</i>		X	
Corvidae (Cinclosomatinae): Quail-Thrushes, Whipbirds	Ifrit	<i>Ifrita kowaldi</i>	X		
Corvidae (Pachycephalinae, Neosittini): Sittellas	Varied Sittella	<i>Daphoenositta chrysoptera</i>	X		
Corvidae: (Pachycephalinae/ Falculculini): Shrike-Tits	Goldenface	<i>Pachycare flavogrisea</i>		X	X
Corvidae: (Pachycephalinae/ Falculculini): Shrike-Tits	Rufous-naped Whistler	<i>Aleadryas rufinucha</i>	X		
Corvidae: (Pachycephalinae/ Falculculini): Shrike-Tits	Brown-backed Whistler	<i>Pachycephala modesta</i>	X		
Corvidae: (Pachycephalinae/ Falculculini): Shrike-Tits	Grey-headed Whistler	<i>Pachycephala griseiceps</i>		X	X
Corvidae: (Pachycephalinae/ Falculculini): Shrike-Tits	Sclater's Whistler	<i>Pachycephala soror</i>	X	X	

Appendix 1 Birds recorded from Hides 3, Nogoli and Benaria survey sites.

Family	Common Name	Scientific Name	H3	B	N
Corvidae: (Pachycephalinae/ Falconidae): Shrike-Tits	Black-headed Whistler	<i>Pachycephala monacha</i>	X		X
Corvidae: (Pachycephalinae/ Falconidae): Shrike-Tits	Little Shrike-thrush	<i>Colluricincla megarhyncha</i>		X	X
Corvidae: (Pachycephalinae/ Falconidae): Shrike-Tits	Hooded Pitohui	<i>Pitohui dichrous</i>		X	X
Corvidae: (Pachycephalinae/ Falconidae): Shrike-Tits	Wattled Ploughbill	<i>Eulacestoma nigropectus</i>	X		
Corvidae: crows, magpies, jays	Grey Crow	<i>Corvus tristis</i>			X
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Greater Melampitta	<i>Melampitta gigantea</i>	X		
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>	X		
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>	X		
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Black Sickbill	<i>Epimachus fastuosus</i>	X		
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Brown Sickbill	<i>Epimachus meyeri</i>	X		
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Superb Bird-of-paradise	<i>Lophorina superba</i>	X	X	
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Lawes's Parotia	<i>Parotia lawesii</i>	X	X	X
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Magnificent Riflebird	<i>Ptiloris magnificus</i>		X	X
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>		X	
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>	X		
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>	X		
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>		X	X
Corvidae: (Corvinae, Paradisaeini): Birds-of-paradise	Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>		X	
Corvidae: (Corvinae, Artimini): Currawongs, Woodswallows	Great Woodswallow	<i>Artamus maximus</i>		X	X
Corvidae: (Corvinae, Artimini): Currawongs, Woodswallows	Mountain Peltops	<i>Peltops montanus</i>		X	
Corvidae: (Corvinae, Oriolini): Orioles, Cuckooshrikes	Brown Oriole	<i>Oriolus szalayi</i>		X	X
Corvidae: (Corvinae, Oriolini): Orioles, Cuckooshrikes	Stout-billed Cuckooshrike	<i>Coracina caeruleogrisea</i>		X	
Corvidae: (Corvinae, Oriolini): Orioles, Cuckooshrikes	Hooded Cuckooshrike	<i>Coracina longicauda</i>	X		
Corvidae: (Corvinae, Oriolini): Orioles, Cuckooshrikes	Black-shouldered Cicadabird	<i>Coracina incerta</i>		X	X
Corvidae: (Corvinae, Oriolini): Orioles, Cuckooshrikes	Black-bellied Cuckooshrike	<i>Coracina montana</i>	X	X	
Corvidae: (Corvinae, Oriolini): Orioles, Cuckooshrikes	Varied Triller	<i>Lalage leucomela</i>		X	X
Corvidae: (Dicrurinae, Rhipidurini): Fantails	Willie-wagtail	<i>Rhipidura leucophrys</i>		X	X
Corvidae: (Dicrurinae, Rhipidurini): Fantails	Northern Fantail	<i>Rhipidura rufiventris</i>		X	
Corvidae: (Dicrurinae, Rhipidurini): Fantails	Black Fantail	<i>Rhipidura atra</i>	X	X	

Appendix 1 Birds recorded from Hides 3, Nogoli and Benaria survey sites.

Family	Common Name	Scientific Name	H3	B	N
Rhipidurini): Fantails					
Corvidae: (Dicurinae, Rhipidurini): Fantails	Chestnut-bellied Fantail	<i>Rhipidura hyperythra</i>		X	X
Corvidae: (Dicurinae, Rhipidurini): Fantails	Friendly Fantail	<i>Rhipidura albolimbata</i>	X		
Corvidae: (Dicurinae, Rhipidurini): Fantails	Dimorphic Fantail	<i>Rhipidura brachyrhyncha</i>	X		
Corvidae: (Dicurinae, Monarchini): Monarchs, Magpie-larks	Black Monarch	<i>Monarcha axillaris</i>	X	X	
Corvidae: (Dicurinae, Monarchini): Monarchs, Magpie-larks	Black-winged Monarch	<i>Monarcha frater</i>		X	X
Corvidae: (Dicurinae, Monarchini): Monarchs, Magpie-larks	Spot-winged Monarch	<i>Monarcha guttulus</i>		X	
Corvidae: (Dicurinae, Monarchini): Monarchs, Magpie-larks	Friilled Monarch	<i>Arses telescopthalmus</i>		X	
Corvidae: (Malaconotinae, Malaconotini): Bush-Shrikes	Black-breasted Boatbill	<i>Machaerirhynchus nigriceps</i>	X	X	
Muscicapidae	Russet-tailed Thrush	<i>Zosterops lateralis</i>		X	
Muscicapidae	Island Thrush	<i>Turdus poliocephalus</i>	X		
Muscicapidae	Pied Bushchat	<i>Saxicola caprata</i>		X	X
Hirundinidae	Pacific Swallow	<i>Hirundo tahitica</i>			X
Zosteropidae	Black-fronted White-eye	<i>Zosterops minor</i>		X	X
Zosteropidae	New Guinea White-eye	<i>Zosterops novaeguineae</i>	X		
Sylviidae	Mountain Leaf-Warbler	<i>Phylloscopus trivirgatus</i>		X	
Nectariniidae	Red-capped Flowerpecker	<i>Dicaeum geelvinkianum</i>		X	
Melanocharitidae	Black Berrypecker	<i>Melanocharis nigra</i>		X	
Melanocharitidae	Fan-tailed Berrypecker	<i>Melanocharis versteri</i>	X		
Melanocharitidae	Streaked Berrypecker	<i>Melanocharis striativentris</i>	X		
Melanocharitidae	Grey-winged Longbill	<i>Toxorhamphus poliopterus</i>		X	
Melanocharitidae	Plumed Longbill	<i>Toxorhamphus iliolophus</i>			X
Passeridae	Hooded Munia	<i>Lonchura spectabilis</i>		X	X
Total Species			65	89	44

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Casuariidae	Southern Cassowary	<i>Casuarius casuarius</i>				X	X				X		X	X
Casuariidae	Dwarf Cassowary	<i>Casuarius bennetti</i>												
Megapodiidae	Wattled Brush-turkey	<i>Aepyodius arfakianus</i>												
Megapodiidae	Black-billed Brush-turkey	<i>Talegalla fuscirostris</i>				X	X	X			X			X
Megapodiidae	Brown-collared Brush-turkey	<i>Talegalla jobiensis</i>												
Megapodiidae	Brush-turkey	<i>Talegalla sp.</i>		X									X	
Megapodiidae	Orange-footed Scrubfowl	<i>Megapodius reinwardt</i>		X			X	X			X		X	
Megapodiidae	New Guinea Scrubfowl	<i>Megapodius decollatus</i>												
Phasianidae	Blue-breasted Quail	<i>Coturnix chinensis</i>												
Dendrocygnidae	Spotted Whistling-Duck	<i>Dendrocygna guttata</i>				X					X	X		
Dendrocygnidae	Wandering Whistling-Duck	<i>Dendrocygna arcuata</i>					X							
Anatidae	Green Pygmy-goose	<i>Nettapus pulchellus</i>												
Anatidae	Pacific Black Duck	<i>Anas superciliosa</i>												
Anatidae	Grey Teal	<i>Anas gracilis</i>												
Bucerotidae	Blyth's Hornbill	<i>Aceros plicatus</i>		X		X	X	X			X	X	X	X
Coraciidae	Dollarbird	<i>Eurystomus orientalis</i>		X		X	X	X					X	X
Alcedinidae	Azure Kingfisher	<i>Alcedo azurea</i>		X			X	X		X		X		X

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Alcedinidae	Little Kingfisher	<i>Alcedo pusilla</i>		X			X	X	X	X			X	
Alcedinidae	Variable Kingfisher	<i>Ceyx lepidus</i>					X	X				X	X	
Dacelonidae	Rufous-bellied Kookaburra	<i>Dacelo gaudichaud</i>	X	X		X	X	X	X		X	X	X	X
Dacelonidae	Shovel-billed Kookaburra	<i>Clytoceyx rex</i>												
Dacelonidae	Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>		X										
Dacelonidae	Forest Kingfisher	<i>Todirhamphus macleayi</i>				X	X				X			X
Dacelonidae	Sacred Kingfisher	<i>Todirhamphus sanctus</i>		X	X	X	X					X	X	
Dacelonidae	Hook-billed Kingfisher	<i>Melidora macrorrhina</i>					X	X			X		X	X
Dacelonidae	Yellow-billed Kingfisher	<i>Syma torotoro</i>					X	X					X	
Dacelonidae	Mountain Kingfisher	<i>Syma megarhyncha</i>												
Meropidae	Rainbow Bee-eater	<i>Merops ornatus</i>		X	X	X	X						X	
Cuculidae	Oriental Cuckoo	<i>Cuculus saturatus</i>		X									X	
Cuculidae	Brush Cuckoo	<i>Cacomantis variolosus</i>		X	X	X	X	X			X		X	X
Cuculidae	Chestnut-breasted Cuckoo	<i>Cacomantis castaneiventris</i>				X	X	X						
Cuculidae	Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>												
Cuculidae	Long-billed Cuckoo	<i>Rhamphomantis megarhynchus</i>					X							
Cuculidae	Gould's Bronze-Cuckoo	<i>Chrysococcyx russatus</i>		X			X	X					X	X

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Cuculidae	Rufous-throated Bronze-Cuckoo	<i>Chrysococcyx ruficollis</i>												
Cuculidae	White-eared Bronze-Cuckoo	<i>Chrysococcyx meyeri</i>												
Cuculidae	White-crowned Koel	<i>Caliechthrus leucolophus</i>					X	X					X	
Cuculidae	Dwarf Koel	<i>Microdynamis parva</i>					X	X					X	
Cuculidae	Asian Koel	<i>Eudynamis scolopacea</i>		X		X	X	X			X		X	X
Cuculidae	Channel-billed Cuckoo	<i>Scythrops novaehollandiae</i>		X		X	X	X						
Centropodidae	Greater Black Coucal	<i>Centropus menbeki</i>		X		X	X	X			X		X	X
Centropodidae	Lesser Black Coucal	<i>Centropus bernsteini</i>		X		X	X						X	
Psittacidae	Yellow-streaked Lory	<i>Chalcopsitta sintillata</i>		X		X	X	X			X		X	X
Psittacidae	Dusky Lory	<i>Pseudeos fuscata</i>		X		X	X						X	
Psittacidae	Rainbow Lorikeet	<i>Trichoglossus haematodus</i>		X		X	X	X			X		X	X
Psittacidae	Goldie's Lorikeet	<i>Psitteuteles goldiei</i>												
Psittacidae	Black-capped Lory	<i>Lorius lory</i>		X		X	X	X			X		X	X
Psittacidae	Striated Lorikeet	<i>Charmosyna multistriata</i>												
Psittacidae	Pygmy Lorikeet	<i>Charmosyna wilhelminae</i>												
Psittacidae	Red-flanked Lorikeet	<i>Charmosyna placensis</i>		X		X	X	X			X		X	X
Psittacidae	Fairy Lorikeet	<i>Charmosyna pulchella</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Psittacidae	Josephine's Lorikeet	<i>Charmosyna josefinae</i>												
Psittacidae	Papuan Lorikeet	<i>Charmosyna papou</i>												
Psittacidae	Plum-faced Lorikeet	<i>Oreopsittacus arfaki</i>												
Psittacidae	Yellow-billed Lorikeet	<i>Neopsittacus musschenbroekii</i>												
Psittacidae	Orange-billed Lorikeet	<i>Neopsittacus pullicauda</i>												
Psittacidae	Palm Cockatoo	<i>Probosciger aterrimus</i>		X		X	X	X			X	X	X	X
Psittacidae	Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	X	X	X	X	X	X			X		X	X
Psittacidae	Yellow-capped Pygmy-Parrot	<i>Micropsitta keiensis</i>							X	X				
Psittacidae	Buff-faced Pygmy-Parrot	<i>Micropsitta pusio</i>		X			X	X					X	
Psittacidae	Red-breasted Pygmy-Parrot	<i>Micropsitta bruijnii</i>												
Psittacidae	Orange-breasted Fig-Parrot	<i>Cyclopsitta gulelmitertii</i>		X		X	X	X			X		X	X
Psittacidae	Double-eyed Fig-Parrot	<i>Cyclopsitta diophthalma</i>					X	X						
Psittacidae	Large Fig-Parrot	<i>Psittaculirostris desmarestii</i>					X	X						
Psittacidae	Madarasz's Tiger-Parrot	<i>Psittacella madaraszii</i>												
Psittacidae	Red-cheeked Parrot	<i>Geoffroyus geoffroyi</i>	X	X		X	X	X			X		X	X
Psittacidae	Blue-collared Parrot	<i>Geoffroyus simplex</i>												
Psittacidae	Eclectus Parrot	<i>Eclectus roratus</i>		X		X	X	X			X		X	X

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Psittacidae	Pesquet's Parrot	<i>Psittirichas fulgidus</i>				X	X	X			X		X	X
Psittacidae	Papuan King-Parrot	<i>Alisterus chloropterus</i>												X
Psittacidae	Orange-fronted Hanging-Parrot	<i>Loriculus aurantiifrons</i>					X	X					X	
Apodidae	Glossy Swiftlet	<i>Collocalia esculenta</i>				X	X	X			X	X	X	X
Apodidae	Mountain Swiftlet	<i>Aerodramus hirundinaceus</i>												
Apodidae	Swiftlet (Mountain/Uniform)	<i>Aerodramus hirundinaceus/vanikorensis</i>					X	X						
Apodidae	Swiftlet (Bare-legged/Mountain)	<i>Aerodramus nudatarsus/hirundinaceus</i>												
Apodidae	Uniform Swiftlet	<i>Aerodramus vanikorensis</i>		X	X	X	X				X	X	X	X
Apodidae	Papuan Needletail	<i>Mearnsia novaeguineae</i>		X	X	X	X	X			X			
Apodidae	White-throated Needletail	<i>Hirundapus caudacutus</i>					X						X	
Hemiprocidae	Moustached Treeswift	<i>Hemiprocne mystacea</i>				X	X				X			
Tytonidae	Greater Sooty-Owl	<i>Tyto tenebricosa</i>												
Strigidae	Rufous Owl	<i>Ninox rufa</i>												
Strigidae	Jungle Hawk-Owl	<i>Ninox theomacha</i>				X								
Aegothelidae	Feline Owlet-Nightjar	<i>Aegotheles insignis</i>												
Aegothelidae	Barred Owlet-Nightjar	<i>Aegotheles bennettii</i>												
Aegothelidae	Mountain Owlet-Nightjar	<i>Aegotheles albertisi</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Aegothelidae	Owlet-Nightjar	<i>Aegotheles sp.</i>												
Podargidae	Papuan Frogmouth	<i>Podargus papuensis</i>		X			X				X		X	
Podargidae	Marbled Frogmouth	<i>Podargus ocellatus</i>					X				X		X	X
Eurostopodidae	Papuan Eared-Nightjar	<i>Eurostopodus papuensis</i>												
Eurostopodidae	Mountain Eared-Nightjar	<i>Eurostopodus archboldi</i>												
Caprimulgidae	Large-tailed Nightjar	<i>Caprimulgus macrurus</i>												
Columbidae	Metallic Pigeon	<i>Columba vitiensis</i>												
Columbidae	Slender-billed Cuckoo-Dove	<i>Macropygia amboinensis</i>				X	X	X					X	X
Columbidae	Black-billed Cuckoo-Dove	<i>Macropygia nigrirostris</i>					X						X	
Columbidae	Great Cuckoo-Dove	<i>Reinwardtoena reinwardtsi</i>					X	X			X		X	X
Columbidae	Stephan's Dove	<i>Chalcophaps stephani</i>				X	X					X		
Columbidae	New Guinea Bronzewing	<i>Henicophaps albifrons</i>					X	X						
Columbidae	Cinnamon Ground-Dove	<i>Gallicolumba rufigula</i>												
Columbidae	Bronze Ground-Dove	<i>Gallicolumba beccarii</i>												
Columbidae	Thick-billed Ground-Pigeon	<i>Trugon terrestris</i>					X	X					X	
Columbidae	Pheasant Pigeon	<i>Otidiphaps nobilis</i>					X	X					X	
Columbidae	Wompoo Fruit-Dove	<i>Ptilinopus magnificus</i>				X	X	X			X		X	X

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Columbidae	Pink-spotted Fruit-Dove	<i>Ptilinopus perlatus</i>				X	X	X			X		X	X
Columbidae	Ornate Fruit-Dove	<i>Ptilinopus ornatus</i>												
Columbidae	Orange-fronted Fruit-Dove	<i>Ptilinopus aurantiifrons</i>		X										
Columbidae	Superb Fruit-Dove	<i>Ptilinopus superbus</i>					X	X					X	
Columbidae	Coroneted Fruit-Dove	<i>Ptilinopus coronulatus</i>					X							
Columbidae	Beautiful Fruit-Dove	<i>Ptilinopus pulchellus</i>		X			X	X					X	
Columbidae	White-bibbed Fruit-Dove	<i>Ptilinopus rivoli</i>												
Columbidae	Orange-bellied Fruit-Dove	<i>Ptilinopus iozonus</i>	X	X		X	X	X			X		X	X
Columbidae	Dwarf Fruit-Dove	<i>Ptilinopus naina</i>					X	X					X	
Columbidae	Purple-tailed Imperial-Pigeon	<i>Ducula rufigaster</i>				X	X	X			X		X	X
Columbidae	Shining Imperial-Pigeon	<i>Ducula chalconota</i>												
Columbidae	Pinon Imperial-Pigeon	<i>Ducula pinon</i>		X		X	X	X			X		X	X
Columbidae	Collared Imperial-Pigeon	<i>Ducula mullerii</i>	X											X
Columbidae	Banded Imperial-Pigeon	<i>Ducula zoeae</i>		X		X	X	X			X		X	X
Columbidae	Torresian Imperial-Pigeon	<i>Ducula spilorrhoa</i>	X				X							
Columbidae	Papuan Mountain-Pigeon	<i>Gymnophaps albertisii</i>				X	X						X	
Columbidae	Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>		X		X	X	X			X		X	X

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Rallidae	Forbes's Forest-Rail	<i>Rallina forbesi</i>												
Rallidae	Red-necked Crake	<i>Rallina tricolor</i>		X			X							
Rallidae	Buff-banded Rail	<i>Gallirallus philippensis</i>					X							
Rallidae	Rufous-tailed Waterhen	<i>Amaurornis moluccana</i>					X							
Rallidae	White-browed Crake	<i>Porzana cinerea</i>												
Rallidae	New Guinea Flightless Rail	<i>Megacrex inepta</i>					X				X			
Rallidae	Dusky Moorhen	<i>Gallinula tenebrosa</i>												
Scolopacidae	Black-tailed Godwit	<i>Limosa limosa</i>	X	X										
Scolopacidae	Bar-tailed Godwit	<i>Limosa lapponica</i>	X											
Scolopacidae	Whimbrel	<i>Numenius phaeopus</i>	X	X	X									
Scolopacidae	Far Eastern Curlew	<i>Numenius madagascariensis</i>	X	X										
Scolopacidae	Marsh Sandpiper	<i>Tringa stagnatilis</i>	X	X										
Scolopacidae	Common Greenshank	<i>Tringa nebularia</i>	X	X										
Scolopacidae	Terek Sandpiper	<i>Xenus cinereus</i>	X	X										
Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	X	X	X		X				X		X	X
Scolopacidae	Grey-tailed Tattler	<i>Heteroscelus brevipes</i>	X	X										
Scolopacidae	Ruddy Turnstone	<i>Arenaria interpres</i>	X											

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Scolopacidae	Asian Dowitcher	<i>Limnodromus semipalmatus</i>	X											
Scolopacidae	Great Knot	<i>Calidris tenuirostris</i>	X	X										
Scolopacidae	Red Knot	<i>Calidris canutus</i>	X											
Scolopacidae	Sanderling	<i>Calidris alba</i>	X	X										
Scolopacidae	Red-necked Stint	<i>Calidris ruficollis</i>	X	X										
Scolopacidae	Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	X											
Scolopacidae	Curlew Sandpiper	<i>Calidris ferruginea</i>	X											
Burhinidae	Beach Thick-knee	<i>Esacus giganteus</i>	X											
Charadriidae	Pacific Golden-Plover	<i>Pluvialis fulva</i>	X	X										
Charadriidae	Grey Plover	<i>Pluvialis squatarola</i>	X											
Charadriidae	Little Ringed Plover	<i>Charadrius dubius</i>					X							
Charadriidae	Mongolian Plover	<i>Charadrius mongolus</i>	X	X										
Charadriidae	Greater Sand Plover	<i>Charadrius leschenaultii</i>	X	X										
Charadriidae	Masked Lapwing	<i>Vanellus miles</i>												
Glareolidae	Australian Pratincole	<i>Stiltia isabella</i>		X										
Laridae	Silver Gull	<i>Larus novaehollandiae</i>		X										
Laridae	Gull-billed Tern	<i>Gelochelidon nilotica</i>	X	X										

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Laridae	Caspian Tern	<i>Sterna caspia</i>	X											
Laridae	Lesser Crested-Tern	<i>Sterna bengalensis</i>		X										
Laridae	Great Crested-Tern	<i>Sterna bergii</i>	X	X										
Laridae	Black-naped Tern	<i>Sterna sumatrana</i>		X										
Laridae	Common Tern	<i>Sterna hirundo</i>			X									
Laridae	Little Tern	<i>Sterna albifrons</i>	X	X	X						X			
Laridae	Whiskered Tern	<i>Chlidonias hybridus</i>		X										
Laridae	White-winged Tern	<i>Chlidonias leucopterus</i>	X											
Laridae	Black Noddy	<i>Anous minutus</i>		X										
Accipitridae	Pacific Baza	<i>Aviceda subcristata</i>				X	X	X					X	
Accipitridae	Long-tailed Honey-buzzard	<i>Henicopernis longicauda</i>		X			X							X
Accipitridae	Whistling Kite	<i>Haliastur sphenurus</i>					X							
Accipitridae	Brahminy Kite	<i>Haliastur indus</i>		X		X	X	X			X		X	X
Accipitridae	White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>	X	X										
Accipitridae	Eastern Marsh-Harrier	<i>Circus spilonotus</i>												
Accipitridae	Grey Goshawk	<i>Accipiter novaehollandiae</i>	X	X		X	X	X					X	
Accipitridae	Brown Goshawk	<i>Accipiter fasciatus</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Accipitridae	Black-mantled Goshawk	<i>Accipiter melanochlamys</i>												
Accipitridae	Grey-headed Goshawk	<i>Accipiter poliocephalus</i>					X							
Accipitridae	Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>					X							
Accipitridae	Meyer's Goshawk	<i>Accipiter meyerianus</i>												
Accipitridae	New Guinea Eagle	<i>Harpyopsis novaeguineae</i>					X						X	
Accipitridae	Gurney's Eagle	<i>Aquila gurneyi</i>												
Accipitridae	Little Eagle	<i>Hieraaetus morphnoides</i>				X								
Falconidae	Brown Falcon	<i>Falco berigora</i>												
FalconidaeS	Australian Kestrel	<i>Falco cenchroides</i>		X			X							
Falconidae	Oriental Hobby	<i>Falco severus</i>												
Falconidae	Australian Hobby	<i>Falco longipennis</i>					X							
Falconidae	Peregrine Falcon	<i>Falco peregrinus</i>					X							
Anhingidae	Australian Darter	<i>Anhinga novaehollandiae</i>				X	X				X		X	
Phalacrocoracidae	Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>		X		X	X						X	X
Phalacrocoracidae	Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>				X								
Ardeidae	Little Egret	<i>Egretta garzetta</i>	X	X			X							
Ardeidae	Pacific Reef-Egret	<i>Egretta sacra</i>	X								X			

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Ardeidae	Great-billed Heron	<i>Ardea sumatrana</i>		X										
Ardeidae	Pied Heron	<i>Ardea picata</i>												
Ardeidae	Great Egret	<i>Ardea alba</i>	X	X		X	X						X	
Ardeidae	Intermediate Egret	<i>Mesophoyx intermedia</i>												
Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>												
Ardeidae	Striated Heron	<i>Butorides striatus</i>	X	X	X	X								
Ardeidae	Rufous Night-Heron	<i>Nycticorax caledonicus</i>				X	X							
Ardeidae	Black Bittern	<i>Dupetor flavicollis</i>												X
Threskiornithidae	Straw-necked Ibis	<i>Threskiornis spinicollis</i>												
Pelecanidae	Australian Pelican	<i>Pelecanus conspicillatus</i>	X	X										
Fregatidae	Lesser Frigatebird	<i>Fregata ariel</i>		X										
Pittidae	Hooded Pitta	<i>Pitta sordida</i>				X	X	X			X		X	X
Pittidae	Red-bellied Pitta	<i>Pitta erythrogaster</i>				X	X	X					X	
Climacteridae	Papuan Treecreeper	<i>Cormobates placens</i>												
Ptilonorhynchidae	White-eared Catbird	<i>Ailuroedus buccoides</i>				X						X	X	
Ptilonorhynchidae	Spotted Catbird	<i>Ailuroedus melanotis</i>												
Ptilonorhynchidae	Macgregor's Bowerbird	<i>Amblyornis macgregoriae</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Maluridae	Orange-crowned Fairywren	<i>Clytomyias insignis</i>												
Maluridae	Wallace's Fairywren	<i>Sipodotus wallacii</i>												
Maluridae	White-shouldered Fairywren	<i>Malurus alboscapulatus</i>												
Maluridae	Emperor Fairywren	<i>Malurus cyanocephalus</i>		X		X	X	X		X				
Meliphagidae	Red-throated Myzomela	<i>Myzomela eques</i>					X							
Meliphagidae	Dusky Myzomela	<i>Myzomela obscura</i>	X			X			X					
Meliphagidae	Red Myzomela	<i>Myzomela cruentata</i>												
Meliphagidae	Black Myzomela	<i>Myzomela nigrita</i>					X							
Meliphagidae	Mountain Myzomela	<i>Myzomela adolphinae</i>												
Meliphagidae	Red-collared Myzomela	<i>Myzomela rosenbergii</i>												
Meliphagidae	Olive Straightbill	<i>Timeliopsis fulvigula</i>												
Meliphagidae	Long-billed Honeyeater	<i>Melilestes mearnsi</i>					X	X			X	X	X	X
Meliphagidae	Green-backed Honeyeater	<i>Glycichaera fallax</i>		X			X							
Meliphagidae	Mottle-breasted Honeyeater	<i>Meliphaga mimikae</i>												
Meliphagidae	Hill-forest Honeyeater	<i>Meliphaga orientalis</i>												
Meliphagidae	Scrub Honeyeater	<i>Meliphaga albonotata</i>		X			X							
Meliphagidae	Puff-backed Honeyeater	<i>Meliphaga aruensis</i>					X	X	X				X	

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Meliphagidae	Mimic Honeyeater	<i>Meliphaga analoga</i>					X	X				X		X
Meliphagidae	Graceful Honeyeater	<i>Meliphaga gracilis</i>		X										
Meliphagidae	Yellow-gaped Honeyeater	<i>Meliphaga flavirictus</i>							X					
Meliphagidae	Honeyeater	<i>Meliphaga sp.</i>					X	X						
Meliphagidae	Black-throated Honeyeater	<i>Lichenostomus subfrenatus</i>												
Meliphagidae	Obscure Honeyeater	<i>Lichenostomus obscurus</i>											X	
Meliphagidae	Varied Honeyeater	<i>Lichenostomus versicolor</i>	X			X								
Meliphagidae	Tawny-breasted Honeyeater	<i>Xanthotis flaviventer</i>		X		X	X	X			X		X	X
Meliphagidae	Spotted Honeyeater	<i>Xanthotis polygramma</i>												
Meliphagidae	Plain Honeyeater	<i>Pycnopygius ixoides</i>					X							
Meliphagidae	Streak-headed Honeyeater	<i>Pycnopygius stictocephalus</i>					X						X	
Meliphagidae	Meyer's Friarbird	<i>Philemon meyeri</i>												
Meliphagidae	New Guinea Friarbird	<i>Philemon novaeguineae</i>		X	X	X	X	X			X		X	X
Meliphagidae	Rufous-backed Honeyeater	<i>Ptiloprora guisei</i>												
Meliphagidae	Black-backed Honeyeater	<i>Ptiloprora perstriata</i>												
Meliphagidae	Belford's Melidectes	<i>Melidectes belfordi</i>												
Meliphagidae	Yellow-browed Melidectes	<i>Melidectes rufocrissalis</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Meliphagidae	Ornate Melidectes	<i>Melidectes torquatus</i>												
Meliphagidae	Smoky Honeyeater	<i>Melipotes fumigatus</i>												
Meliphagidae	Brown-backed Honeyeater	<i>Ramsayornis modestus</i>		X										
Pardalotidae	Rusty Mouse-warbler	<i>Crateroscelis murina</i>				X	X	X			X		X	X
Pardalotidae	Mountain Mouse-warbler	<i>Crateroscelis robusta</i>												
Pardalotidae	Tropical/Beccari's Scrubwren	<i>Sericornis beccarii</i>												
Pardalotidae	Large Scrubwren	<i>Sericornis nouhuysi</i>												
Pardalotidae	Buff-faced Scrubwren	<i>Sericornis perspicillatus</i>												
Pardalotidae	Grey-green Scrubwren	<i>Sericornis arfakianus</i>												
Pardalotidae	Papuan Scrubwren	<i>Sericornis papuensis</i>												
Pardalotidae	Pale-billed Scrubwren	<i>Sericornis spilodera</i>					X					X		X
Pardalotidae	Papuan Thornbill	<i>Acanthiza murina</i>												
Pardalotidae	Mountain Gerygone	<i>Gerygone cinerea</i>												
Pardalotidae	Green-backed Gerygone	<i>Gerygone chloronotus</i>					X	X					X	
Pardalotidae	Fairy Gerygone	<i>Gerygone palpebrosa</i>					X				X	X		
Pardalotidae	Yellow-bellied Gerygone	<i>Gerygone chrysogaster</i>				X	X	X			X		X	X
Pardalotidae	Large-billed Gerygone	<i>Gerygone magnirostris</i>		X			X	X	X					

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Pardalotidae	Brown-breasted Gerygone	<i>Gerygone ruficollis</i>												
Pardalotidae	Mangrove Gerygone	<i>Gerygone levigaster</i>	X											
Petroicidae	Lesser Ground-robin	<i>Amalocichla incerta</i>												
Petroicidae	Torrent Robin	<i>Monachella muelleriana</i>											X	X
Petroicidae	Yellow-legged Flyrobin	<i>Microeca griseocephala</i>												
Petroicidae	Olive Flyrobin	<i>Microeca flavovirescens</i>												
Petroicidae	Canary Flyrobin	<i>Microeca papuana</i>												
Petroicidae	Garnet Robin	<i>Eugerygone rubra</i>												
Petroicidae	White-faced Robin	<i>Tregellasia leucops</i>												
Petroicidae	Mangrove Robin	<i>Eopsaltria pulverulenta</i>	X											
Petroicidae	Black-sided Robin	<i>Poecilodryas hypoleuca</i>		X		X	X	X				X	X	
Petroicidae	Olive-yellow Robin	<i>Poecilodryas placens</i>												
Petroicidae	Black-throated Robin	<i>Poecilodryas albonotata</i>												
Petroicidae	White-winged Robin	<i>Peneothello sigillatus</i>												
Petroicidae	Blue-grey Robin	<i>Peneothello cyanus</i>												
Petroicidae	White-rumped Robin	<i>Peneothello bimaculatus</i>												
Petroicidae	Ashy Robin	<i>Heteromyias albispecularis</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Petroicidae	White-eyed Robin	<i>Pachycephalopsis poliosoma</i>												
Petroicidae	Northern Scrub-Robin	<i>Drymodes superciliaris</i>												
Pomatostomidae	New Guinea Babbler	<i>Pomatostomus isidorei</i>					X	X					X	
Laniidae	Long-tailed Shrike	<i>Lanius schach</i>												
Corvidae (<i>Cinclosomatinae</i>)	Spotted Jewel-babbler	<i>Ptilorrhoa leucosticta</i>												
Corvidae (<i>Cinclosomatinae</i>)	Blue Jewel-babbler	<i>Ptilorrhoa caerulescens</i>				X	X	X			X		X	X
Corvidae (<i>Cinclosomatinae</i>)	Chestnut-backed Jewel-babbler	<i>Ptilorrhoa castanonota</i>												
Corvidae (<i>Cinclosomatinae</i>)	Ifrit	<i>Ifrita kowaldi</i>												
Corvidae (<i>Pachycephalinae, Neosittini</i>)	Varied Sittella	<i>Daphoenositta chrysoptera</i>												
Corvidae (<i>Pachycephalinae, Falculculini</i>)	Mottled Whistler	<i>Rhagologus leucostigma</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Goldenface	<i>Pachycare flavogrisea</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Rufous-naped Whistler	<i>Aleadryas rufinucha</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Rusty Whistler	<i>Pachycephala hyperythra</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Brown-backed Whistler	<i>Pachycephala modesta</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Grey-headed Whistler	<i>Pachycephala griseiceps</i>					X	X					X	
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Sclater's Whistler	<i>Pachycephala soror</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Regent Whistler	<i>Pachycephala schlegelii</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Black-headed Whistler	<i>Pachycephala monacha</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Little Shrike-thrush	<i>Colluricincla megarhyncha</i>				X	X	X			X		X	X
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Variable Pitohui	<i>Pitohui kirhocephalus</i>		X		X	X	X			X	X	X	X
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Hooded Pitohui	<i>Pitohui dichrous</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Rusty Pitohui	<i>Pitohui ferrugineus</i>		X			X	X			X		X	
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Crested Pitohui	<i>Pitohui cristatus</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Black Pitohui	<i>Pitohui nigrescens</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Wattled Ploughbill	<i>Eulacestoma nigropectus</i>												
Corvidae (<i>Corvinae</i> , <i>Corvini</i>)	Grey Crow	<i>Corvus tristis</i>				X	X	X					X	X
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Greater Melampitta	<i>Melampitta gigantea</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Loria's Bird-of-paradise	<i>Cnemophilus loriae</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Glossy-mantled Manucode	<i>Manucodia atra</i>		X			X	X			X		X	
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Crinkle-collared Manucode	<i>Manucodia chalybata</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Trumpet Manucode	<i>Manucodia keraudrenii</i>				X	X	X			X		X	
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Black Sickbill	<i>Epimachus fastuosus</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Brown Sicklebill	<i>Epimachus meyeri</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Black-billed Sicklebill	<i>Epimachus albertisi</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Superb Bird-of-paradise	<i>Lophorina superba</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Carola's Parotia	<i>Parotia carolae</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Lawes's Parotia	<i>Parotia lawesii</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Magnificent Riflebird	<i>Ptiloris magnificus</i>				X	X						X	
Corvidae (<i>Corvinae,Paradisaeini</i>)	Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	King Bird-of-paradise	<i>Cicinnurus regius</i>				X	X	X			X		X	X
Corvidae (<i>Corvinae,Paradisaeini</i>)	Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Twelve-wired Bird-of-paradise	<i>Seleucidis melanoleuca</i>		X		X	X	X			X			
Corvidae (<i>Corvinae,Paradisaeini</i>)	Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>				X	X	X					X	X
Corvidae (<i>Corvinae,Paradisaeini</i>)	Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>												
Corvidae (<i>Corvinae,Artimini</i>)	Hooded Butcherbird	<i>Cracticus cassicus</i>				X	X	X			X		X	X
Corvidae (<i>Corvinae,Artimini</i>)	Black Butcherbird	<i>Cracticus quoyi</i>					X	X			X		X	
Corvidae (<i>Corvinae,Artimini</i>)	White-breasted Woodswallow	<i>Artamus leucorhynchus</i>	X			X								
Corvidae (<i>Corvinae,Artimini</i>)	Great Woodswallow	<i>Artamus maximus</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Corvidae (Corvinae, Artimini)	Lowland Peltops	<i>Peltops blainvillii</i>				X	X	X					X	
Corvidae (Corvinae, Artimini)	Mountain Peltops	<i>Peltops montanus</i>												
Corvidae (Corvinae, Oriolini)	Brown Oriole	<i>Oriolus szalayi</i>				X	X	X			X		X	
Corvidae (Corvinae, Oriolini)	Black-faced Cuckooshrike	<i>Coracina novaehollandiae</i>		X			X							
Corvidae (Corvinae, Oriolini)	Stout-billed Cuckooshrike	<i>Coracina caeruleo-grisea</i>												
Corvidae (Corvinae, Oriolini)	Yellow-eyed Cuckooshrike	<i>Coracina lineata</i>												
Corvidae (Corvinae, Oriolini)	Boyer's Cuckooshrike	<i>Coracina boyeri</i>				X	X	X					X	
Corvidae (Corvinae, Oriolini)	White-bellied Cuckooshrike	<i>Coracina papuensis</i>	X			X								
Corvidae (Corvinae, Oriolini)	Hooded Cuckooshrike	<i>Coracina longicauda</i>												
Corvidae (Corvinae, Oriolini)	Slender-billed Cicadabird	<i>Coracina tenuirostris</i>												
Corvidae (Corvinae, Oriolini)	Black-shouldered Cicadabird	<i>Coracina incerta</i>				X	X						X	
Corvidae (Corvinae, Oriolini)	Grey-headed Cuckooshrike	<i>Coracina schisticeps</i>				X	X	X			X		X	X
Corvidae (Corvinae, Oriolini)	New Guinea Cuckooshrike	<i>Coracina melas</i>		X			X	X					X	
Corvidae (Corvinae, Oriolini)	Black-bellied Cuckooshrike	<i>Coracina montana</i>												
Corvidae (Corvinae, Oriolini)	Golden Cuckooshrike	<i>Campochaera sloetii</i>				X	X	X			X		X	X
Corvidae (Corvinae, Oriolini)	Varied Triller	<i>Lalage leucomela</i>		X		X	X	X			X		X	X
Corvidae (Dicrurinae, Rhipidurini)	Willie-wagtail	<i>Rhipidura leucophrys</i>		X		X	X						X	X

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Northern Fantail	<i>Rhipidura rufiventris</i>		X			X						X	
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Sooty Thicket-Fantail	<i>Rhipidura threnothorax</i>					X	X					X	X
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Black Thicket-Fantail	<i>Rhipidura maculipectus</i>				X	X			X			X	
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	White-bellied Thicket-Fantail	<i>Rhipidura leucothorax</i>		X		X	X				X		X	X
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Black Fantail	<i>Rhipidura atra</i>												
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Chestnut-bellied Fantail	<i>Rhipidura hyperythra</i>												
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Friendly Fantail	<i>Rhipidura albolimbata</i>												
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Mangrove Fantail	<i>Rhipidura phasiana</i>	X											
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Dimorphic Fantail	<i>Rhipidura brachyrhyncha</i>												
Corvidae (<i>Dicrurinae, Rhipidurini</i>)	Rufous-backed Fantail	<i>Rhipidura rufidorsa</i>					X						X	
Corvidae (<i>Dicrurinae, Dicrurini</i>)	Pygmy Drongo	<i>Chaetorhynchus papuensis</i>												
Corvidae (<i>Dicrurinae, Dicrurini</i>)	Spangled Drongo	<i>Dicrurus bracteatus</i>		X		X	X	X			X		X	X
Corvidae (<i>Dicrurinae, Monarchini</i>)	Black Monarch	<i>Monarcha axillaris</i>												
Corvidae (<i>Dicrurinae, Monarchini</i>)	Rufous Monarch	<i>Monarcha rubiensis</i>												
Corvidae (<i>Dicrurinae, Monarchini</i>)	Black-winged Monarch	<i>Monarcha frater</i>												
Corvidae (<i>Dicrurinae, Monarchini</i>)	Spot-winged Monarch	<i>Monarcha guttulus</i>				X	X	X			X	X	X	X
Corvidae (<i>Dicrurinae, Monarchini</i>)	Hooded Monarch	<i>Monarcha manadensis</i>					X	X				X	X	

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Golden Monarch	<i>Monarcha chrysomela</i>				X	X	X					X	
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Friiled Monarch	<i>Arses telescopthalmus</i>				X	X	X			X	X	X	X
Corvidae (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Satin Flycatcher	<i>Myiagra cyanoleuca</i>					X							
Corvidae (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Shining Flycatcher	<i>Myiagra alecto</i>		X		X	X	X	X		X		X	X
Corvidae (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Yellow-breasted Boatbill	<i>Machaerirhynchus flaviventer</i>												
Corvidae (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Black-breasted Boatbill	<i>Machaerirhynchus nigriceps</i>												
Muscicapidae	Russet-tailed Thrush	<i>Zosterops heinei</i>												
Muscicapidae	Island Thrush	<i>Turdus poliocephalus</i>												
Muscicapidae	Pied Bushchat	<i>Saxicola caprata</i>												
Sturnidae	Metallic Starling	<i>Aplonis metallica</i>		X		X	X	X			X		X	X
Sturnidae	Yellow-eyed Starling	<i>Aplonis mystacea</i>				X	X	X						
Sturnidae	Golden Myna	<i>Mino anais</i>					X							X
Sturnidae	Yellow-faced Myna	<i>Mino dumontii</i>		X		X	X	X			X		X	X
Hirundinidae	Pacific Swallow	<i>Hirundo tahitica</i>		X		X	X	X					X	
Hirundinidae	Tree Martin	<i>Hirundo nigricans</i>			X									
Zosteropidae	Black-fronted White-eye	<i>Zosterops minor</i>												X
Zosteropidae	New Guinea White-eye	<i>Zosterops novaeguineae</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Sylviidae	Gray's Grasshopper-Warbler	<i>Locustella fasciolata</i>												
Sylviidae	Clamorous Reed-Warbler	<i>Acrocephalus stentoreus</i>												
Sylviidae	Mountain Leaf-Warbler	<i>Phylloscopus trivirgatus</i>												
Nectariniidae	Red-capped Flowerpecker	<i>Dicaeum geelvinkianum</i>		X		X	X	X	X				X	X
Nectariniidae	Black Sunbird	<i>Nectarinia aspasia</i>		X		X	X	X	X		X		X	X
Nectariniidae	Olive-backed Sunbird	<i>Nectarinia jugularis</i>		X										
Melanocharitidae	Black Berrypecker	<i>Melanocharis nigra</i>				X	X				X		X	
Melanocharitidae	Lemon-breasted Berrypecker	<i>Melanocharis longicauda</i>												
Melanocharitidae	Fan-tailed Berrypecker	<i>Melanocharis versteri</i>												
Melanocharitidae	Streaked Berrypecker	<i>Melanocharis striativentris</i>												
Melanocharitidae	Grey-winged Longbill	<i>Toxorhamphus poliopterus</i>												
Melanocharitidae	Green-crowned Longbill	<i>Toxorhamphus novaeguineae</i>					X	X			X	X	X	X
Melanocharitidae	Plumed Longbill	<i>Toxorhamphus iliolophus</i>				X	X				X			X
Melanocharitidae	Pygmy Longbill	<i>Oedistoma pygmaeum</i>					X							
Paramythiidae	Tit Berrypecker	<i>Oreocharis arfaki</i>												
Paramythiidae	Crested Berrypecker	<i>Paramythia montium</i>												
Passeridae	Grey Wagtail	<i>Motacilla cinerea</i>												

Appendix 2 Birds recorded from the KICDP area – lowland sites (<400 m)

Site			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utiti Creek	Dark End Lumber	Omo
Code			CB	KO1	KD4	KL1	KL3	KP	I3	KK	V	U	DEL	O
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common name	Scientific name												
Passeridae	Blue-faced Parrotfinch	<i>Erythrura trichroa</i>												
Passeridae	White-spotted Munia	<i>Lonchura leucosticta</i>				X	X					X		
Passeridae	Hooded Munia	<i>Lonchura spectabilis</i>												
Total Species			47	100	13	98	161	102	10	5	73	22	117	75

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Casuariidae	Southern Cassowary	<i>Casuarus casuarus</i>	X				X						X				
Casuariidae	Dwarf Cassowary	<i>Casuarus bennetti</i>	X	X			X				X	X		X		X	X
Megapodiidae	Wattled Brush-turkey	<i>Aepyodius arfakianus</i>									X			X			
Megapodiidae	Black-billed Brush-turkey	<i>Talegalla fuscirostris</i>		X	X	X	X				X		X				
Megapodiidae	Brown-collared Brush-turkey	<i>Talegalla jobiensis</i>											X				
Megapodiidae	Brush-turkey	<i>Talegalla sp.</i>															X
Megapodiidae	Orange-footed Scrubfowl	<i>Megapodius reinwardt</i>			X		X				X						
Megapodiidae	New Guinea Scrubfowl	<i>Megapodius decollatus</i>											X				
Phasianidae	Blue-breasted Quail	<i>Coturnix chinensis</i>											X				
Dendrocygnidae	Spotted Whistling-Duck	<i>Dendrocygna guttata</i>					X										
Dendrocygnidae	Wandering Whistling-Duck	<i>Dendrocygna arcuata</i>															
Anatidae	Green Pygmy-goose	<i>Nettapus pulchellus</i>					X	X									
Anatidae	Pacific Black Duck	<i>Anas superciliosa</i>						X			X						
Anatidae	Grey Teal	<i>Anas gracilis</i>					X										
Bucerotidae	Blyth's Hornbill	<i>Aceros plicatus</i>	X	X	X	X	X	X	X		X	X	X				
Coraciidae	Dollarbird	<i>Eurystomus orientalis</i>	X	X	X		X	X	X		X	X					
Alcedinidae	Azure Kingfisher	<i>Alcedo azurea</i>			X		X	X	X		X						
Alcedinidae	Little Kingfisher	<i>Alcedo pusilla</i>					X										

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Alcedinidae	Variable Kingfisher	<i>Ceyx lepidus</i>	X	X	X	X	X				X						
Dacelonidae	Rufous-bellied Kookaburra	<i>Dacelo gaudichaud</i>		X	X		X	X			X						
Dacelonidae	Shovel-billed Kookaburra	<i>Clytoceyx rex</i>					X										X
Dacelonidae	Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>															
Dacelonidae	Forest Kingfisher	<i>Todirhamphus macleayii</i>		X			X						X				
Dacelonidae	Sacred Kingfisher	<i>Todirhamphus sanctus</i>					X	X	X	X	X						
Dacelonidae	Hook-billed Kingfisher	<i>Melidora macrorrhina</i>	X		X	X	X				X						
Dacelonidae	Yellow-billed Kingfisher	<i>Syma torotoro</i>			X	X	X	X			X						
Dacelonidae	Mountain Kingfisher	<i>Syma megarhyncha</i>									X			X	X		X
Meropidae	Rainbow Bee-eater	<i>Merops ornatus</i>					X	X	X		X		X				
Cuculidae	Oriental Cuckoo	<i>Cuculus saturatus</i>			X		X				X						
Cuculidae	Brush Cuckoo	<i>Cacomantis variolosus</i>		X	X		X	X	X		X						
Cuculidae	Chestnut-breasted Cuckoo	<i>Cacomantis castaneiventris</i>	X		X	X	X				X		X				
Cuculidae	Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>											X	X		X	X
Cuculidae	Long-billed Cuckoo	<i>Rhamphomantis megarhynchus</i>			X		X										
Cuculidae	Gould's Bronze-Cuckoo	<i>Chrysococcyx russatus</i>			X		X	X			X						
Cuculidae	Rufous-throated Bronze-Cuckoo	<i>Chrysococcyx ruficollis</i>															X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/ Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Cuculidae	White-eared Bronze-Cuckoo	<i>Chrysococcyx meyeri</i>			X		X	X			X						
Cuculidae	White-crowned Koel	<i>Caliechthrus leucolophus</i>			X		X	X			X			X	X		X
Cuculidae	Dwarf Koel	<i>Microdynamis parva</i>			X		X	X			X		X				
Cuculidae	Asian Koel	<i>Eudynamis scolopacea</i>	X	X	X		X	X			X	X	X	X			
Cuculidae	Channel-billed Cuckoo	<i>Scythrops novaehollandiae</i>	X				X										
Centropodidae	Greater Black Coucal	<i>Centropus menbeki</i>	X		X		X	X			X						
Centropodidae	Lesser Black Coucal	<i>Centropus bernsteini</i>					X										
Psittacidae	Yellow-streaked Lory	<i>Chalcopsitta sintillata</i>		X	X		X	X			X						
Psittacidae	Dusky Lory	<i>Pseudeos fuscata</i>		X	X		X	X			X			X	X		X
Psittacidae	Rainbow Lorikeet	<i>Trichoglossus haematodus</i>	X	X	X	X	X	X	X		X	X	X	X			X
Psittacidae	Goldie's Lorikeet	<i>Psitteuteles goldiei</i>					X				X			X			
Psittacidae	Black-capped Lory	<i>Lorius lory</i>	X	X	X	X	X	X	X		X			X			
Psittacidae	Striated Lorikeet	<i>Charmosyna multistriata</i>					X				X						
Psittacidae	Pygmy Lorikeet	<i>Charmosyna wilhelminae</i>					X				X						
Psittacidae	Red-flanked Lorikeet	<i>Charmosyna placentis</i>		X	X		X				X						
Psittacidae	Fairy Lorikeet	<i>Charmosyna pulchella</i>					X				X		X	X	X		
Psittacidae	Josephine's Lorikeet	<i>Charmosyna josefinae</i>					X				X						
Psittacidae	Papuan Lorikeet	<i>Charmosyna papou</i>											X	X		X	X
Psittacidae	Plum-faced Lorikeet	<i>Oreopsittacus arfaki</i>															X
Psittacidae	Yellow-billed Lorikeet	<i>Neopsittacus musschenbroekii</i>											X		X	X	X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Psittacidae	Orange-billed Lorikeet	<i>Neopsittacus pullicauda</i>														X	
Psittacidae	Palm Cockatoo	<i>Probosciger aterrimus</i>	X	X	X	X	X	X	X		X			X			
Psittacidae	Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	X	X	X		X	X	X		X	X	X	X			
Psittacidae	Yellow-capped Pygmy-Parrot	<i>Micropsitta keiensis</i>				X											
Psittacidae	Buff-faced Pygmy-Parrot	<i>Micropsitta pusio</i>			X		X	X			X						
Psittacidae	Red-breasted Pygmy-Parrot	<i>Micropsitta bruijnii</i>					X	X			X				X		
Psittacidae	Orange-breasted Fig-Parrot	<i>Cyclopsitta guliemitertii</i>			X		X	X	X		X						
Psittacidae	Double-eyed Fig-Parrot	<i>Cyclopsitta diophthalma</i>			X		X				X		X				
Psittacidae	Large Fig-Parrot	<i>Psittaculirostris desmarestii</i>			X		X	X			X					X	
Psittacidae	Madarasz's Tiger-Parrot	<i>Psittacella madaraszii</i>															X
Psittacidae	Red-cheeked Parrot	<i>Geoffroyus geoffroyi</i>		X	X		X	X			X						
Psittacidae	Blue-collared Parrot	<i>Geoffroyus simplex</i>			X		X				X			X	X		
Psittacidae	Eclectus Parrot	<i>Eclectus roratus</i>	X	X	X	X	X	X	X		X						
Psittacidae	Pesquet's Parrot	<i>Psittichas fulgidus</i>	X	X	X	X	X	X		X	X			X			
Psittacidae	Papuan King-Parrot	<i>Alisterus chloropterus</i>			X		X				X	X	X	X		X	
Psittacidae	Orange-fronted Hanging-Parrot	<i>Loriculus aurantiifrons</i>			X		X	X			X						
Apodidae	Glossy Swiftlet	<i>Collocalia esculenta</i>		X	X	X	X	X	X		X	X	X	X	X	X	X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Apodidae	Mountain Swiftlet	<i>Aerodramus hirundinaceus</i>						X			X			X			X
Apodidae	Swiftlet (Mountain/Uniform)	<i>Aerodramus hirundinaceus</i> , <i>vanikorensis</i>			X		X				X	X	X		X		
Apodidae	Swiftlet, (Bare-legged/Mountain)	<i>Aerodramus nuditarus/hirundinaceus</i>														X	
Apodidae	Uniform Swiftlet	<i>Aerodramus vanikorensis</i>		X													
Apodidae	Papuan Needletail	<i>Mearnsia novaeguineae</i>			X		X										
Apodidae	White-throated Needletail	<i>Hirundapus caudacutus</i>											X				
Hemiprocidae	Moustached Treeswift	<i>Hemiprocne mystacea</i>		X	X	X	X	X	X		X	X	X				
Tytonidae	Greater Sooty-Owl	<i>Tyto tenebricosa</i>			X						X			X			X
Strigidae	Rufous Owl	<i>Ninox rufa</i>			X		X										
Strigidae	Jungle Hawk-Owl	<i>Ninox theomacha</i>				X	X				X			X	X		X
Aegothelidae	Feline Owlet-Nightjar	<i>Aegotheles insignis</i>					X				X						X
Aegothelidae	Barred Owlet-Nightjar	<i>Aegotheles bennettii</i>									X						
Aegothelidae	Mountain Owlet-Nightjar	<i>Aegotheles albertsi</i>												X			X
Aegothelidae	Owlet-Nightjar	<i>Aegotheles sp.</i>			X		X				X						
Podargidae	Papuan Frogmouth	<i>Podargus papuensis</i>	X	X	X	X	X				X		X		X		X
Podargidae	Marbled Frogmouth	<i>Podargus ocellatus</i>	X		X	X	X				X			X	X		
Eurostopodidae	Papuan Eared-Nightjar	<i>Eurostopodus papuensis</i>				X	X										
Eurostopodidae	Mountain Eared-Nightjar	<i>Eurostopodus archboldi</i>														X	
Caprimulgidae	Large-tailed Nightjar	<i>Caprimulgus macrurus</i>	X								X		X				

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Columbidae	Metallic Pigeon	<i>Columba vitiensis</i>											X				
Columbidae	Slender-billed Cuckoo-Dove	<i>Macropygia amboinensis</i>	X	X	X	X	X	X	X		X	X	X		X	X	
Columbidae	Black-billed Cuckoo-Dove	<i>Macropygia nigrirostris</i>			X		X				X			X	X		X
Columbidae	Great Cuckoo-Dove	<i>Reinwardtoena reinwardtsi</i>		X	X	X	X	X			X			X	X	X	X
Columbidae	Stephan's Dove	<i>Chalcophaps stephani</i>	X		X	X	X										
Columbidae	New Guinea Bronzewing	<i>Henicophaps albifrons</i>			X		X				X						
Columbidae	Cinnamon Ground-Dove	<i>Gallicolumba rufigula</i>			X		X				X						
Columbidae	Bronze Ground-Dove	<i>Gallicolumba beccarii</i>														X	
Columbidae	Thick-billed Ground-Pigeon	<i>Trugon terrestris</i>				X	X										
Columbidae	Pheasant Pigeon	<i>Otidiphaps nobilis</i>		X			X				X			X			
Columbidae	Wompoo Fruit-Dove	<i>Ptilinopus magnificus</i>		X	X	X	X	X	X		X			X			
Columbidae	Pink-spotted Fruit-Dove	<i>Ptilinopus perlatus</i>			X		X	X			X			X			
Columbidae	Ornate Fruit-Dove	<i>Ptilinopus ornatus</i>					X	X			X	X	X	X	X	X	X
Columbidae	Orange-fronted Fruit-Dove	<i>Ptilinopus aurantiifrons</i>															
Columbidae	Superb Fruit-Dove	<i>Ptilinopus superbus</i>		X	X		X	X			X	X	X				
Columbidae	Coroneted Fruit-Dove	<i>Ptilinopus coronulatus</i>	X			X	X										
Columbidae	Beautiful Fruit-Dove	<i>Ptilinopus pulchellus</i>	X	X	X	X	X	X	X		X						
Columbidae	White-bibbed Fruit-Dove	<i>Ptilinopus rivoli</i>					X				X		X	X			X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Columbidae	Orange-bellied Fruit-Dove	<i>Ptilinopus iozonus</i>		X	X		X				X						
Columbidae	Dwarf Fruit-Dove	<i>Ptilinopus naina</i>			X		X				X						
Columbidae	Purple-tailed Imperial-Pigeon	<i>Ducula rufigaster</i>			X	X	X	X			X						
Columbidae	Shining Imperial-Pigeon	<i>Ducula chalconota</i>						X	X		X			X		X	X
Columbidae	Pinon Imperial-Pigeon	<i>Ducula pinon</i>	X	X	X	X	X	X			X						
Columbidae	Collared Imperial-Pigeon	<i>Ducula mullerii</i>															
Columbidae	Banded Imperial-Pigeon	<i>Ducula zoeae</i>	X	X	X	X	X	X	X		X	X	X				
Columbidae	Torresian Imperial-Pigeon	<i>Ducula spilorrhoa</i>															
Columbidae	Papuan Mountain-Pigeon	<i>Gymnophaps albertisii</i>			X		X	X	X		X	X	X	X	X	X	X
Columbidae	Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>	X				X										
Rallidae	Forbes's Forest-Rail	<i>Rallina forbesi</i>														X	
Rallidae	Red-necked Crane	<i>Rallina tricolor</i>					X	X			X						
Rallidae	Buff-banded Rail	<i>Gallirallus philippensis</i>															
Rallidae	Rufous-tailed Waterhen	<i>Amaurornis moluccana</i>	X		X		X				X						
Rallidae	White-browed Crane	<i>Porzana cinerea</i>									X						
Rallidae	New Guinea Flightless Rail	<i>Megacrex inepta</i>					X										
Rallidae	Dusky Moorhen	<i>Gallinula tenebrosa</i>						X									
Scolopacidae	Black-tailed Godwit	<i>Limosa limosa</i>															

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/ Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Scolopacidae	Bar-tailed Godwit	<i>Limosa lapponica</i>															
Scolopacidae	Whimbrel	<i>Numenius phaeopus</i>															
Scolopacidae	Far Eastern Curlew	<i>Numenius madagascariensis</i>															
Scolopacidae	Marsh Sandpiper	<i>Tringa stagnatilis</i>															
Scolopacidae	Common Greenshank	<i>Tringa nebularia</i>															
Scolopacidae	Terek Sandpiper	<i>Xenus cinereus</i>															
Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>		X			X										
Scolopacidae	Grey-tailed Tattler	<i>Heteroscelus brevipes</i>															
Scolopacidae	Ruddy Turnstone	<i>Arenaria interpres</i>															
Scolopacidae	Asian Dowitcher	<i>Limnodromus semipalmatus</i>															
Scolopacidae	Great Knot	<i>Calidris tenuirostris</i>															
Scolopacidae	Red Knot	<i>Calidris canutus</i>															
Scolopacidae	Sanderling	<i>Calidris alba</i>															
Scolopacidae	Red-necked Stint	<i>Calidris ruficollis</i>															
Scolopacidae	Sharp-tailed Sandpiper	<i>Calidris acuminata</i>															
Scolopacidae	Curlew Sandpiper	<i>Calidris ferruginea</i>															
Burhinidae	Beach Thick-knee	<i>Esacus giganteus</i>															
Charadriidae	Pacific Golden-Plover	<i>Pluvialis fulva</i>															
Charadriidae	Grey Plover	<i>Pluvialis squatarola</i>															
Charadriidae	Little Ringed Plover	<i>Charadrius dubius</i>	X				X				X						

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Charadriidae	Mongolian Plover	<i>Charadrius mongolus</i>															
Charadriidae	Greater Sand Plover	<i>Charadrius leschenaultii</i>															
Charadriidae	Masked Lapwing	<i>Vanellus miles</i>					X										
Glareolidae	Australian Pratincole	<i>Stiltia isabellae</i>															
Laridae	Silver Gull	<i>Larus novaehollandiae</i>															
Laridae	Gull-billed Tern	<i>Gelochelidon nilotica</i>															
Laridae	Caspian Tern	<i>Sterna caspia</i>															
Laridae	Lesser Crested-Tern	<i>Sterna bengalensis</i>															
Laridae	Great Crested-Tern	<i>Sterna bergii</i>															
Laridae	Black-naped Tern	<i>Sterna sumatrana</i>															
Laridae	Common Tern	<i>Sterna hirundo</i>															
Laridae	Little Tern	<i>Sterna albifrons</i>															
Laridae	Whiskered Tern	<i>Chlidonias hybridus</i>															
Laridae	White-winged Tern	<i>Chlidonias leucopterus</i>															
Laridae	Black Noddy	<i>Anous minutus</i>															
Accipitridae	Pacific Baza	<i>Aviceda subcristata</i>			X		X	X	X		X						
Accipitridae	Long-tailed Honey-buzzard	<i>Henicopernis longicauda</i>			X		X	X			X					X	
Accipitridae	Whistling Kite	<i>Haliastur sphenurus</i>															
Accipitridae	Brahminy Kite	<i>Haliastur indus</i>	X	X			X	X			X	X				X	X
Accipitridae	White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>									X						
Accipitridae	Eastern Marsh-Harrier	<i>Circus spilonotus</i>									X						

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Accipitridae	Grey Goshawk	<i>Accipiter novaehollandiae</i>		X	X		X	X			X	X					
Accipitridae	Brown Goshawk	<i>Accipiter fasciatus</i>											X				
Accipitridae	Black-mantled Goshawk	<i>Accipiter melanochlamys</i>											X			X	
Accipitridae	Grey-headed Goshawk	<i>Accipiter poliocephalus</i>					X				X						
Accipitridae	Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>					X				X		X				
Accipitridae	Meyer's Goshawk	<i>Accipiter meyerianus</i>									X					X	
Accipitridae	New Guinea Eagle	<i>Harpyopsis novaeguineae</i>	X				X				X			X			X
Accipitridae	Gurney's Eagle	<i>Aquila gurneyi</i>									X			X			
Accipitridae	Little Eagle	<i>Hieraaetus morphnoides</i>		X	X		X				X						
Falconidae	Brown Falcon	<i>Falco berigora</i>					X				X				X		
Falconidae	Australian Kestrel	<i>Falco cenchroides</i>															
Falconidae	Oriental Hobby	<i>Falco severus</i>									X						
Falconidae	Australian Hobby	<i>Falco longipennis</i>															
Falconidae	Peregrine Falcon	<i>Falco peregrinus</i>					X	X		X	X						
Anhingidae	Australian Darter	<i>Anhinga novaehollandiae</i>									X						
Phalacrocoracidae	Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>						X					X				
Phalacrocoracidae	Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>											X				
Ardeidae	Little Egret	<i>Egretta garzetta</i>					X	X									
Ardeidae	Pacific Reef-Egret	<i>Egretta sacra</i>															
Ardeidae	Great-billed Heron	<i>Ardea sumatrana</i>															
Ardeidae	Pied Heron	<i>Ardea picata</i>						X	X								

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Ardeidae	Great Egret	<i>Ardea alba</i>	X				X	X									
Ardeidae	Intermediate Egret	<i>Mesophoyx intermedia</i>						X	X								
Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>							X								
Ardeidae	Striated Heron	<i>Butorides striatus</i>															
Ardeidae	Rufous Night-Heron	<i>Nycticorax caledonicus</i>	X														
Ardeidae	Black Bittern	<i>Dupetor flavicollis</i>															
Threskiornithidae	Straw-necked Ibis	<i>Threskiornis spinicollis</i>					X										
Pelecanidae	Australian Pelican	<i>Pelecanus conspicillatus</i>															
Fregatidae	Lesser Frigatebird	<i>Fregata ariel</i>					X										
Pittidae	Hooded Pitta	<i>Pitta sordida</i>		X			X				X			X			
Pittidae	Red-bellied Pitta	<i>Pitta erythrogaster</i>		X	X	X	X				X						
Climacteridae	Papuan Treecreeper	<i>Cormobates placens</i>															X
Ptilonorhynchidae	White-eared Catbird	<i>Ailuroedus buccoides</i>	X	X	X	X	X				X						
Ptilonorhynchidae	Spotted Catbird	<i>Ailuroedus melanotis</i>					X				X		X	X			
Ptilonorhynchidae	Macgregor's Bowerbird	<i>Amblyornis macgregoriae</i>												X			X
Maluridae	Orange-crowned Fairywren	<i>Clytomyias insignis</i>														X	X
Maluridae	Wallace's Fairywren	<i>Sipodotus wallacii</i>						X									
Maluridae	White-shouldered Fairywren	<i>Malurus alboscapulatus</i>	X		X		X	X	X	X	X	X	X				
Maluridae	Emperor Fairywren	<i>Malurus cyanocephalus</i>			X		X	X			X						
Meliphagidae	Red-throated Myzomela	<i>Myzomela eques</i>			X		X				X						

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Meliphagidae	Dusky Myzomela	<i>Myzomela obscura</i>															
Meliphagidae	Red Myzomela	<i>Myzomela cruentata</i>					X				X			X			
Meliphagidae	Black Myzomela	<i>Myzomela nigrita</i>					X				X						
Meliphagidae	Mountain Myzomela	<i>Myzomela adolphinae</i>									X						
Meliphagidae	Red-collared Myzomela	<i>Myzomela rosenbergii</i>												X			X
Meliphagidae	Olive Straightbill	<i>Timeliopsis fulvigula</i>														X	X
Meliphagidae	Long-billed Honeyeater	<i>Melilestes megarhynchus</i>	X		X	X	X	X	X		X	X	X	X			
Meliphagidae	Green-backed Honeyeater	<i>Glycichaera fallax</i>					X				X						
Meliphagidae	Mottle-breasted Honeyeater	<i>Meliphaga mimikae</i>			X		X				X			X			
Meliphagidae	Hill-forest Honeyeater	<i>Meliphaga orientalis</i>					X				X		X	X			
Meliphagidae	Scrub Honeyeater	<i>Meliphaga albonotata</i>		X	X		X	X	X		X	X	X	X			
Meliphagidae	Puff-backed Honeyeater	<i>Meliphaga aruensis</i>	X		X	X	X				X						
Meliphagidae	Mimic Honeyeater	<i>Meliphaga analoga</i>	X	X		X	X				X		X				
Meliphagidae	Graceful Honeyeater	<i>Meliphaga gracilis</i>															
Meliphagidae	Yellow-gaped Honeyeater	<i>Meliphaga flavirictus</i>															
Meliphagidae	Honeyeater	<i>Meliphaga sp.</i>			X		X				X		X				
Meliphagidae	Black-throated Honeyeater	<i>Lichenostomus subfrenatus</i>												X			X
Meliphagidae	Obscure Honeyeater	<i>Lichenostomus obscurus</i>			X	X	X				X						
Meliphagidae	Varied Honeyeater	<i>Lichenostomus versicolor</i>															

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Meliphagidae	Tawny-breasted Honeyeater	<i>Xanthotis flaviventer</i>	X	X	X	X	X	X	X		X	X	X	X			
Meliphagidae	Spotted Honeyeater	<i>Xanthotis polygramma</i>					X				X		X	X			
Meliphagidae	Plain Honeyeater	<i>Pycnopygius ixoides</i>									X			X			
Meliphagidae	Streak-headed Honeyeater	<i>Pycnopygius stictocephalus</i>			X		X	X			X						
Meliphagidae	Meyer's Friarbird	<i>Philemon meyeri</i>			X		X	X			X						
Meliphagidae	New Guinea Friarbird	<i>Philemon novaeguineae</i>	X	X	X	X	X	X	X		X		X				
Meliphagidae	Rufous-backed Honeyeater	<i>Ptiloprora guisei</i>												X		X	X
Meliphagidae	Black-backed Honeyeater	<i>Ptiloprora perstriata</i>														X	X
Meliphagidae	Belford's Melidectes	<i>Melidectes belfordi</i>														X	
Meliphagidae	Yellow-browed Melidectes	<i>Melidectes rufocrissalis</i>												X	X		X
Meliphagidae	Ornate Melidectes	<i>Melidectes torquatus</i>											X	X			
Meliphagidae	Smoky Honeyeater	<i>Melipotes fumigatus</i>												X	X	X	X
Meliphagidae	Brown-backed Honeyeater	<i>Ramsayornis modestus</i>															
Pardalotidae	Rusty Mouse-warbler	<i>Crateroscelis murina</i>	X	X	X	X	X	X	X		X		X				
Pardalotidae	Mountain Mouse-warbler	<i>Crateroscelis robusta</i>												X	X	X	X
Pardalotidae	Tropical / Beccari's Scrubwren	<i>Sericornis beccarii</i>					X				X			X			

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Pardalotidae	Large Scrubwren	<i>Sericornis nouhuysi</i>												X		X	X
Pardalotidae	Buff-faced Scrubwren	<i>Sericornis perspicillatus</i>												X	X	X	X
Pardalotidae	Grey-green Scrubwren	<i>Sericornis arfakianus</i>												X			
Pardalotidae	Papuan Scrubwren	<i>Sericornis papuensis</i>														X	X
Pardalotidae	Pale-billed Scrubwren	<i>Sericornis spilodera</i>	X	X		X	X				X			X			
Pardalotidae	Papuan Thornbill	<i>Acanthiza murina</i>														X	
Pardalotidae	Mountain Gerygone	<i>Gerygone cinerea</i>														X	X
Pardalotidae	Green-backed Gerygone	<i>Gerygone chloronotus</i>			X		X	X			X		X		X		
Pardalotidae	Fairy Gerygone	<i>Gerygone palpebrosa</i>		X	X		X	X			X			X			
Pardalotidae	Yellow-bellied Gerygone	<i>Gerygone chrysogaster</i>	X	X	X	X	X	X			X						
Pardalotidae	Large-billed Gerygone	<i>Gerygone magnirostris</i>					X				X						
Pardalotidae	Brown-breasted Gerygone	<i>Gerygone ruficollis</i>												X	X	X	X
Pardalotidae	Mangrove Gerygone	<i>Gerygone levigaster</i>															
Petroicidae	Lesser Ground-robin	<i>Amalocichla incerta</i>													X		X
Petroicidae	Torrent Robin	<i>Monachella muelleriana</i>	X	X			X				X	X	X				
Petroicidae	Yellow-legged Flyrobin	<i>Microeca griseocephala</i>					X				X			X			
Petroicidae	Olive Flyrobin	<i>Microeca flavovirescens</i>			X	X	X				X	X	X				
Petroicidae	Canary Flyrobin	<i>Microeca papuana</i>														X	X
Petroicidae	Garnet Robin	<i>Eugerygone rubra</i>														X	X
Petroicidae	White-faced Robin	<i>Tregellasia leucops</i>					X				X		X	X			
Petroicidae	Mangrove Robin	<i>Eopsaltria pulverulenta</i>															

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/ Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Petroicidae	Black-sided Robin	<i>Poecilodryas hypoleuca</i>		X	X	X	X	X			X						
Petroicidae	Olive-yellow Robin	<i>Poecilodryas placens</i>			X	X					X						
Petroicidae	Black-throated Robin	<i>Poecilodryas albonotata</i>												X	X		X
Petroicidae	White-winged Robin	<i>Peneothello sigillatus</i>														X	X
Petroicidae	Blue-grey Robin	<i>Peneothello cyanus</i>												X	X	X	X
Petroicidae	White-rumped Robin	<i>Peneothello bimaculatus</i>			X	X	X				X						
Petroicidae	Ashy Robin	<i>Heteromyias albispectus</i>													X		X
Petroicidae	White-eyed Robin	<i>Pachycephalopsis poliosoma</i>					X				X		X	X			
Petroicidae	Northern Scrub-Robin	<i>Drymodes superciliaris</i>					X				X			X			
Pomatostomidae	New Guinea Babbler	<i>Pomatostomus isidorei</i>					X										
Laniidae	Long-tailed Shrike	<i>Lanius schach</i>											X				
Corvidae, (<i>Cinclosomatinae</i>)	Spotted Jewel-babbler	<i>Ptilorhoa leucosticta</i>												X	X		X
Corvidae, (<i>Cinclosomatinae</i>)	Blue Jewel-babbler	<i>Ptilorhoa caerulescens</i>	X	X	X	X	X										
Corvidae, (<i>Cinclosomatinae</i>)	Chestnut-backed Jewel-babbler	<i>Ptilorhoa castanonota</i>				X	X	X			X						
Corvidae, (<i>Cinclosomatinae</i>)	Ifrit	<i>Ifrita kowaldi</i>												X	X	X	X
Corvidae, (<i>Pachycephalinae</i> , <i>Neosittini</i>)	Varied Sittella	<i>Daphoenositta chrysoptera</i>														X	X
Corvidae, (<i>Pachycephalinae</i> , <i>Falculculini</i>)	Mottled Whistler	<i>Rhagologus leucostigma</i>												X			X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/ Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Goldenface	<i>Pachycare flavogrisea</i>					X				X	X	X	X			
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Rufous-naped Whistler	<i>Aleadryas rufinucha</i>												X	X	X	X
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Rusty Whistler	<i>Pachycephala hyperythra</i>		X	X	X	X				X						
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Brown-backed Whistler	<i>Pachycephala modesta</i>													X	X	X
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Grey-headed Whistler	<i>Pachycephala griseiceps</i>			X		X				X	X	X	X			
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Sclater's Whistler	<i>Pachycephala soror</i>			X								X	X	X	X	X
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Regent Whistler	<i>Pachycephala schlegelii</i>												X	X		X
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Black-headed Whistler	<i>Pachycephala monacha</i>										X				X	
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Little Shrike-thrush	<i>Colluricincla megarhyncha</i>	X	X	X	X	X	X			X	X	X	X	X		
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Variable Pitohui	<i>Pitohui kirhocephalus</i>			X		X	X			X			X			
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Hooded Pitohui	<i>Pitohui dichrous</i>				X	X	X			X	X	X				
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Rusty Pitohui	<i>Pitohui ferrugineus</i>	X	X	X	X	X	X			X						

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Crested Pitohui	<i>Pitohui cristatus</i>			X	X	X				X			X			
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Black Pitohui	<i>Pitohui nigrescens</i>															X
Corvidae, (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Wattled Ploughbill	<i>Eulacestoma nigropectus</i>														X	
Corvidae, (<i>Corvinae</i> , <i>Corvini</i>)	Grey Crow	<i>Corvus tristis</i>	X	X	X	X	X	X	X		X	X					
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Greater Melampitta	<i>Melampitta gigantea</i>					X				X					X	
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>														X	X
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Loria's Bird-of-paradise	<i>Cnemophilus loriae</i>															X
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Glossy-mantled Manucode	<i>Manucodia atra</i>			X		X										
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Crinkle-collared Manucode	<i>Manucodia chalybata</i>		X	X	X	X	X			X						
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Trumpet Manucode	<i>Manucodia keraudrenii</i>			X		X										
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>													X	X	X
Corvidae, (<i>Corvinae</i> , <i>Paradisaeini</i>)	Black Sickbill	<i>Epimachus fastuosus</i>												X	X	X	X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Corvidae, (Corvinae,Paradisaeini)	Brown Sicklebill	<i>Epimachus meyeri</i>														X	X
Corvidae, (Corvinae,Paradisaeini)	Black-billed Sicklebill	<i>Epimachus albertisi</i>									X						
Corvidae, (Corvinae,Paradisaeini)	Superb Bird-of-paradise	<i>Lophorina superba</i>									X		X	X	X	X	X
Corvidae, (Corvinae,Paradisaeini)	Carola's Parotia	<i>Parotia carolae</i>					X				X			X			
Corvidae, (Corvinae,Paradisaeini)	Lawes's Parotia	<i>Parotia lawesii</i>										X	X			X	X
Corvidae, (Corvinae,Paradisaeini)	Magnificent Riflebird	<i>Ptiloris magnificus</i>		X	X		X	X			X	X	X				
Corvidae, (Corvinae,Paradisaeini)	Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>			X	X	X	X			X		X	X			
Corvidae, (Corvinae,Paradisaeini)	King Bird-of-paradise	<i>Cicinnurus regius</i>	X	X	X	X	X	X	X		X						
Corvidae, (Corvinae,Paradisaeini)	Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>														X	X
Corvidae, (Corvinae,Paradisaeini)	King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>														X	X
Corvidae, (Corvinae,Paradisaeini)	Twelve-wired Bird-of-paradise	<i>Seleucidis melanoleuca</i>			X						X						
Corvidae, (Corvinae,Paradisaeini)	Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>	X	X	X	X	X	X	X		X	X	X	X			

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/ Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Corvidae, (Corvinae,Paradisaeini)	Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>											X				
Corvidae, (Corvinae,Artimini)	Hooded Butcherbird	<i>Cracticus cassicus</i>	X	X	X	X	X	X	X		X						
Corvidae, (Corvinae,Artimini)	Black Butcherbird	<i>Cracticus quoyi</i>	X	X	X	X	X				X			X			
Corvidae, (Corvinae,Artimini)	White-breasted Woodswallow	<i>Artamus leucorhynchus</i>															
Corvidae, (Corvinae,Artimini)	Great Woodswallow	<i>Artamus maximus</i>						X	X		X	X	X				X
Corvidae, (Corvinae,Artimini)	Lowland Peltops	<i>Peltops blainvillii</i>		X	X		X	X			X						
Corvidae, (Corvinae,Artimini)	Mountain Peltops	<i>Peltops montanus</i>					X		X		X		X	X	X		X
Corvidae, (Corvinae,Oriolini)	Brown Oriole	<i>Oriolus szalayii</i>		X	X	X	X				X	X	X				
Corvidae, (Corvinae,Oriolini)	Black-faced Cuckooshrike	<i>Coracina novaehollandiae</i>															
Corvidae, (Corvinae,Oriolini)	Stout-billed Cuckooshrike	<i>Coracina caeruleogrisea</i>					X	X	X		X		X	X			
Corvidae, (Corvinae,Oriolini)	Yellow-eyed Cuckooshrike	<i>Coracina lineata</i>			X						X						
Corvidae, (Corvinae,Oriolini)	Boyer's Cuckooshrike	<i>Coracina boyeri</i>			X		X	X			X						
Corvidae, (Corvinae,Oriolini)	White-bellied Cuckooshrike	<i>Coracina papuensis</i>															
Corvidae, (Corvinae,Oriolini)	Hooded Cuckooshrike	<i>Coracina longicauda</i>														X	X
Corvidae, (Corvinae,Oriolini)	Slender-billed Cicadabird	<i>Coracina tenuirostris</i>									X						
Corvidae, (Corvinae,Oriolini)	Black-shouldered Cicadabird	<i>Coracina incerta</i>			X		X				X	X	X				X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Corvidae, (<i>Corvinae</i> , <i>Oriolini</i>)	Grey-headed Cuckooshrike	<i>Coracina schisticeps</i>		X	X		X	X	X		X						
Corvidae, (<i>Corvinae</i> , <i>Oriolini</i>)	New Guinea Cuckooshrike	<i>Coracina melas</i>			X		X	X	X		X						
Corvidae, (<i>Corvinae</i> , <i>Oriolini</i>)	Black-bellied Cuckooshrike	<i>Coracina montana</i>					X				X		X	X	X	X	X
Corvidae, (<i>Corvinae</i> , <i>Oriolini</i>)	Golden Cuckooshrike	<i>Campochaera sloetii</i>		X	X		X	X	X		X						
Corvidae, (<i>Corvinae</i> , <i>Oriolini</i>)	Varied Triller	<i>Lalage leucomela</i>			X		X	X			X	X	X	X			
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Willie-wagtail	<i>Rhipidura leucophrys</i>	X				X	X	X	X	X	X	X				
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Northern Fantail	<i>Rhipidura rufiventris</i>		X	X	X	X	X			X		X				
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Sooty Thicket-Fantail	<i>Rhipidura threnothorax</i>	X	X	X	X	X				X						
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Black Thicket-Fantail	<i>Rhipidura maculipectus</i>															
Corvidae, (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	White-bellied Thicket-Fantail	<i>Rhipidura leucothorax</i>	X				X	X			X						
Corvidae, (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Black Fantail	<i>Rhipidura atra</i>									X		X	X	X	X	X
Corvidae, (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Chestnut-bellied Fantail	<i>Rhipidura hyperythra</i>		X	X		X				X	X	X				
Corvidae, (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Friendly Fantail	<i>Rhipidura albolimbata</i>												X	X	X	X

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Corvidae, (Dicurinae,Rhipidurini)	Mangrove Fantail	<i>Rhipidura phasiana</i>															
Corvidae, (Dicurinae,Rhipidurini)	Dimorphic Fantail	<i>Rhipidura brachyrhyncha</i>														X	X
Corvidae, (Dicurinae,Rhipidurini)	Rufous-backed Fantail	<i>Rhipidura rufidorsa</i>	X		X	X	X				X						
Corvidae, (Dicurinae,Dicurini)	Pygmy Drongo	<i>Chaetorhynchus papuensis</i>					X				X			X			X
Corvidae, (Dicurinae,Dicurini)	Spangled Drongo	<i>Dicrurus bracteatus</i>	X	X	X	X	X	X	X		X						
Corvidae, (Dicurinae,Monarchini)	Black Monarch	<i>Monarcha axillaris</i>					X				X		X	X	X	X	
Corvidae, (Dicurinae,Monarchini)	Rufous Monarch	<i>Monarcha rubiensis</i>									X						
Corvidae, (Dicurinae,Monarchini)	Black-winged Monarch	<i>Monarcha frater</i>					X				X	X	X	X			
Corvidae, (Dicurinae,Monarchini)	Spot-winged Monarch	<i>Monarcha guttulus</i>	X	X	X	X	X	X	X		X		X				
Corvidae, (Dicurinae,Monarchini)	Hooded Monarch	<i>Monarcha manadensis</i>		X	X		X										
Corvidae, (Dicurinae,Monarchini)	Golden Monarch	<i>Monarcha chrysomela</i>			X		X	X			X						
Corvidae, (Dicurinae,Monarchini)	Friiled Monarch	<i>Arses telescopthalmus</i>	X	X	X		X	X			X		X				

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/ Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Corvidae, (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Satin Flycatcher	<i>Myiagra cyanoleuca</i>															
Corvidae, (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Shining Flycatcher	<i>Myiagra alecto</i>	X			X	X										
Corvidae, (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Yellow-breasted Boatbill	<i>Machaerirhynchus flaviventer</i>			X		X				X			X			
Corvidae, (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Black-breasted Boatbill	<i>Machaerirhynchus nigrippectus</i>											X	X	X	X	X
Muscicapidae	Russet-tailed Thrush	<i>Zoothera heinei</i>											X				
Muscicapidae	Island Thrush	<i>Turdus poliocephalus</i>														X	
Muscicapidae	Pied Bushchat	<i>Saxicola caprata</i>							X		X	X	X				
Sturnidae	Metallic Starling	<i>Aplonis metallica</i>			X		X				X						
Sturnidae	Yellow-eyed Starling	<i>Aplonis mystacea</i>	X				X										
Sturnidae	Golden Myna	<i>Mino anais</i>		X	X	X	X										
Sturnidae	Yellow-faced Myna	<i>Mino dumontii</i>	X	X	X	X	X	X	X		X						
Hirundinidae	Pacific Swallow	<i>Hirundo tahitica</i>	X	X			X		X	X	X	X					
Hirundinidae	Tree Martin	<i>Hirundo nigricans</i>					X				X						
Zosteropidae	Black-fronted White-eye	<i>Zosterops minor</i>					X	X			X	X	X	X			
Zosteropidae	New Guinea White-eye	<i>Zosterops novaeguineae</i>														X	
Sylviidae	Gray's Grasshopper-Warbler	<i>Locustella fasciolata</i>									X						
Sylviidae	Clamorous Reed-Warbler	<i>Acrocephalus stentoreus</i>						X			X						

Appendix 3 Birds that may yet be recorded in the KICDP area

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	Hides 3	Mt Sisa
Code			L	WF1	K	D	G8	LK1	MO3	Ig1	MO1	N	B	MB	MM	H3	MS3
Altitude (M)			400	400	410	500	643	808	870	1000	1050	1200	1345	1500	1650	2163	2200
Family	Common name	Scientific name															
Sylviidae	Mountain Leaf-Warbler	<i>Phylloscopus trivirgatus</i>					X				X		X	X	X		X
Nectariniidae	Red-capped Flowerpecker	<i>Dicaeum geelvinkianum</i>		X	X	X	X	X	X		X		X	X			X
Nectariniidae	Black Sunbird	<i>Nectarinia aspasia</i>			X		X	X			X						
Nectariniidae	Olive-backed Sunbird	<i>Nectarinia jugularis</i>															
Melanocharitidae	Black Berrypecker	<i>Melanocharis nigra</i>	X	X	X	X	X				X		X	X			
Melanocharitidae	Lemon-breasted Berrypecker	<i>Melanocharis longicauda</i>									X						
Melanocharitidae	Fan-tailed Berrypecker	<i>Melanocharis versteri</i>												X		X	X
Melanocharitidae	Streaked Berrypecker	<i>Melanocharis striativentris</i>														X	
Melanocharitidae	Grey-winged Longbill	<i>Toxorhamphus poliopterus</i>				X	X		X		X		X	X			
Melanocharitidae	Green-crowned Longbill	<i>Toxorhamphus novaeguineae</i>		X	X		X										
Melanocharitidae	Plumed Longbill	<i>Toxorhamphus iliolophus</i>		X	X	X	X				X	X		X			
Melanocharitidae	Pygmy Longbill	<i>Oedistoma pygmaeum</i>			X		X				X						
Paramythiidae	Tit Berrypecker	<i>Oreocharis arfaki</i>												X			X
Paramythiidae	Crested Berrypecker	<i>Paramythia montium</i>															X
Passeridae	Grey Wagtail	<i>Motacilla cinerea</i>			X												
Passeridae	Blue-faced Parrotfinch	<i>Erythrura trichroa</i>					X				X			X	X		X
Passeridae	White-spotted Munia	<i>Lonchura leucosticta</i>									X						
Passeridae	Hooded Munia	<i>Lonchura spectabilis</i>										X	X				
Total Species			63	78	137	70	211	103	48	6	209	44	90	102	46	65	85

Appendix 3 Birds that may yet be recorded in the KICDP area

Family	Common name	Scientific name	IUCN listing	Notes*	Altitude range (m)			
					Min	Normal range		Max
						Lower	Upper	
Phasianidae	Brown Quail	<i>Coturnix ypsilophora</i>		BR		0	2600	3600
Dendrocygnidae	Plumed Whistling-Duck	<i>Dendrocygna eytoni</i>		V		0		
Anatidae	Radjah Shelduck	<i>Tadorna radjah</i>		BR		0		
Anatidae	Cotton Pygmy-goose	<i>Nettapus coromandelianus</i>		V		0	2255	
Anatidae	Salvadori's Teal	<i>Salvadorina waigiensis</i>	VU	BR	350	500	3700	4100
Anatidae	Eurasian Wigeon	<i>Mareca penelope</i>		V		0		
Anatidae	Northern Pintail	<i>Anas acuta</i>		V		0		
Anatidae	Garganey	<i>Anas querquedula</i>		V		0		
Anatidae	Hardhead	<i>Aythya australis</i>		?		0		
Turnicidae	Red-backed Buttonquail	<i>Turnix maculosa</i>		BR		0	2500	
Dacelonidae	Collared Kingfisher	<i>Todirhamphus chloris</i>		BR		0	1500	
Dacelonidae	Common Paradise-Kingfisher	<i>Tanysiptera galatea</i>		BR		0	600	820
Cuculidae	Pallid Cuckoo	<i>Cuculus pallidus</i>		V		0	0	
Cuculidae	Shining Bronze-Cuckoo	<i>Chrysococcyx lucidus</i>		M		0	1920	
Cuculidae	Horsfield's Bronze-Cuckoo	<i>Chrysococcyx basalis</i>		V		0		
Centropodidae	Pheasant Coucal	<i>Centropus phasianinus</i>		BR		0	1800	
Psittacidae	Brehm's Tiger-Parrot	<i>Psittacella brehmii</i>		BR	1100	1600	2800	3200
Psittacidae	Painted Tiger-Parrot	<i>Psittacella picta</i>		BR	1370	2450	3680	4000
Psittacidae	Modest Tiger-Parrot	<i>Psittacella modesta</i>		BR		1700	2800	
Tytonidae	African Grass-Owl	<i>Tyto capensis</i>		BR		1000	2500	
Strigidae	Barking Owl	<i>Ninox connivens</i>		BR		0	1040	
Strigidae	Papuan Hawk-Owl	<i>Uroglaux dimorpha</i>	DD	BR		0	1500	

Appendix 3 Birds that may yet be recorded in the KICDP area

Family	Common name	Scientific name	IUCN listing	Notes*	Altitude range (m)			
					Min	Normal range		Max
						Lower	Upper	
Aegothelidae	Starry Owlet-Nightjar	Aegotheles tatei	DD	BR				
Aegothelidae	Wallace's Owlet-Nightjar	Aegotheles wallacii	DD	BR		100	1100	
Aegothelidae	Archbold's Owlet-Nightjar	Aegotheles archboldi		BR		1350	3600	
Eurostopodidae	White-throated Eared-Nightjar	Eurostopodus mystacalis		M		0	1650	
Columbidae	Emerald Dove	Chalcophaps indica		BR		0	1300	
Columbidae	Zebra Dove	Geopelia striata		BR		0	550	
Columbidae	Bar-shouldered Dove	Geopelia humeralis		BR		0		
Columbidae	White-bibbed Ground-Dove	Gallinolumba jobiensis		BR		0	2400	2400
Rallidae	Lewin's Rail	Lewinia pectoralis		BR	1040	1040	2600	2600
Rallidae	Bare-eyed Rail	Gymnocyrex plumbeiventris		BR		0	2100	2100
Rallidae	Baillon's Crake	Porzana pusilla		BR		0	2450	2450
Rallidae	Spotless Crake	Porzana tabuensis		BR		0	3300	3300
Rallidae	Purple Swampphen	Porphyrio porphyrio		BR		0	1800	
Rallidae	Common Coot	Fulica atra		BR		0	2320	2320
Scolopacidae	Rufous Woodcock	Scolopax saturata		BR	2400	2400	3800	1500
Scolopacidae	Latham's Snipe	Gallinago hardwickii		M		0	3350	3350
Scolopacidae	Swinhoe's Snipe	Gallinago megala		M		0	3720	3720
Scolopacidae	Little Curlew	Numenius minutus		M		0	1100	4500
Scolopacidae	Common Redshank	Tringa totanus		V		0	100	
Scolopacidae	Wood Sandpiper	Tringa glareola		M		0	1735	
Scolopacidae	Wandering Tattler	Heteroscelus incanus		M		0	10	
Scolopacidae	Long-billed Dowitcher	Limnodromus scolopaceus		V		0	10	
Scolopacidae	Little Stint	Calidris minuta		V		0	10	

Appendix 3 Birds that may yet be recorded in the KICDP area

Family	Common name	Scientific name	IUCN listing	Notes*	Altitude range (m)			
					Min	Normal range		Max
						Lower	Upper	
Scolopacidae	Long-toed Stint	<i>Calidris subminuta</i>		V		0	10	
Scolopacidae	Baird's Sandpiper	<i>Calidris bairdii</i>		M		0	10	
Scolopacidae	Pectoral Sandpiper	<i>Calidris melanotos</i>		M		0	10	
Scolopacidae	Buff-breasted Sandpiper	<i>Tryngites subruficollis</i>	NT	V		0	10	
Scolopacidae	Broad-billed Sandpiper	<i>Limicola falcinellus</i>		M		0	10	
Scolopacidae	Ruff	<i>Philomachus pugnax</i>		V		0	10	
Scolopacidae	Red-necked Phalarope	<i>Phalaropus lobatus</i>		V		0	4500	4500
Jacanidae	Comb-crested Jacana	<i>Irediparra gallinacea</i>		BR		0	600	600
Charadriidae	Pied Oystercatcher	<i>Haematopus longirostris</i>		V		0	10	
Charadriidae	White-headed Stilt	<i>Himantopus leucocephalus</i>		BR		0	1670	1670
Charadriidae	Oriental Plover	<i>Charadrius veredus</i>		M		0	10	
Charadriidae	Red-kneed Dotterel	<i>Erythronyx cinctus</i>		?		0	10	
Glareolidae	Oriental Pratincole	<i>Glareola maldivarum</i>		M		0	1500	1500
Laridae	Pomarine Jaeger	<i>Stercorarius pomarinus</i>		S		0	10	10
Laridae	Parasitic Jaeger	<i>Stercorarius parasiticus</i>		S		0	10	10
Laridae	Long-tailed Jaeger	<i>Stercorarius longicaudus</i>		S		0	10	10
Laridae	Black-headed Gull	<i>Larus ridibundus</i>		S		0	10	10
Laridae	Roseate Tern	<i>Sterna dougallii</i>		S		0	10	10
Laridae	Bridled Tern	<i>Sterna anaethetus</i>		S		0	0	0
Laridae	Sooty Tern	<i>Sterna fuscata</i>		S		0	0	0
Laridae	Black Tern	<i>Chlidonias niger</i>		V		0	10	10
Laridae	Brown Noddy	<i>Anous stolidus</i>		S		0	10	10
Laridae	Common White-Tern	<i>Gygis alba</i>		S		0	10	10

Appendix 3 Birds that may yet be recorded in the KICDP area

Family	Common name	Scientific name	IUCN listing	Notes*	Altitude range (m)			
					Min	Normal range		Max
						Lower	Upper	
Accipitridae	Osprey	Pandion haliaetus		BR		0	540	540
Accipitridae	Bat Hawk	Macheiramphus alcinus		BR		0	975	
Accipitridae	Black-winged Kite	Elanus caeruleus		BR		0	1830	
Accipitridae	Black Kite	Milvus migrans		BR		0	2200	
Accipitridae	Swamp Harrier	Circus approximans		?				
Accipitridae	Chestnut-shouldered Goshawk	Erythrotriorchis buergersi	DD	BR		450	1580	
Accipitridae	Doria's Goshawk	Megatriorchis doriae	NT	BR		0	1070	1650
Podicipedidae	Little Grebe	Tachybaptus ruficollis		BR		0	1520	
Phaethontidae	Red-tailed Tropicbird	Phaethon rubricauda		S		0	0	0
Phaethontidae	White-tailed Tropicbird	Phaethon lepturus		S		0	0	0
Sulidae	Abbott's Booby	Papasula abbotti	CR	S		0	0	0
Sulidae	Masked Booby	Sula dactylatra		S		0	0	0
Sulidae	Red-footed Booby	Sula sula		S		0	0	0
Sulidae	Brown Booby	Sula leucogaster		S		0	0	0
Phalacrocoracidae	Pied Cormorant	Phalacrocorax varius		V				
Phalacrocoracidae	Great Cormorant	Phalacrocorax carbo		V		0		
Ardeidae	White-faced Heron	Egretta novaehollandiae		BR+M		0	1500	1700
Ardeidae	Pacific Heron	Ardea pacifica		V		0		
Ardeidae	Forest Bittern	Zonerodius heliosylus	NT	BR		0	1430	
Ardeidae	Little Bittern	Ixobrychus minutus		?		0		
Ardeidae	Yellow Bittern	Ixobrychus sinensis		?		0		
Threskiornithidae	Glossy Ibis	Plegadis falcinellus		M		0		
Threskiornithidae	Australian Ibis	Threskiornis molucca		M		0		

Appendix 3 Birds that may yet be recorded in the KICDP area

Family	Common name	Scientific name	IUCN listing	Notes*	Altitude range (m)			
					Min	Normal range		Max
						Lower	Upper	
Threskiornithidae	Royal Spoonbill	Platalea regia		?		0		
Ciconiidae	Black-necked Stork	Ephippiorhynchus asiaticus	NT	V		0		
Fregatidae	Great Frigatebird	Fregata minor		S		0	0	0
Procellariidae	Antarctic Giant-Petrel	Macronectes giganteus	VU	S		0	0	0
Procellariidae	Tahiti Petrel	Pseudobulweria rostrata	NT	S		0	0	0
Procellariidae	Fairy Prion	Pachyptila turtur		S		0	0	0
Procellariidae	Streaked Shearwater	Calonectris leucomelas		S		0	0	0
Procellariidae	Wedge-tailed Shearwater	Puffinus pacificus		S		0	0	0
Procellariidae	Flesh-footed Shearwater	Puffinus carneipes		S		0	0	0
Procellariidae	Short-tailed Shearwater	Puffinus tenuirostris		S		0	0	0
Procellariidae	Heinroth's Shearwater	Puffinus heinrothi	VU	S		0	0	0
Procellariidae	Wilson's Storm-Petrel	Oceanites oceanicus		S		0	0	0
Procellariidae	White-bellied Storm-Petrel	Fregetta grallaria		S		0	0	0
Ptilonorhynchidae	Archbold's Bowerbird	Archboldia papuensis	NT	BR	1750	2600	2900	3660
Ptilonorhynchidae	Flame Bowerbird	Sericulus aureus		BR		0	1400	
Maluridae	Broad-billed Fairywren	Malurus grayi		BR		0	1600	
Meliphagidae	Red-headed Myzomela	Myzomela erythrocephala		BR				
Meliphagidae	Tawny Straightbill	Timeliopsis griseigula		BR		0	800	
Meliphagidae	Graceful Honeyeater	Meliphaga gracilis		BR		0	600	
Meliphagidae	Marbled Honeyeater	Pycnopygius cinereus		BR	500	1000	2000	
Meliphagidae	Leaden Honeyeater	Ptiloprora plumbea		BR		1100	1900	
Meliphagidae	Olive-streaked Honeyeater	Ptiloprora meekiana		BR		1300	2440	
Meliphagidae	Sooty Melidectes	Melidectes fuscus		BR	1700	2200	3700	

Appendix 3 Birds that may yet be recorded in the KICDP area

Family	Common name	Scientific name	IUCN listing	Notes*	Altitude range (m)			
					Min	Normal range		Max
						Lower	Upper	
Meliphagidae	Long-bearded Melidectes	Melidectes princeps	VU	BR	2750	3000	3800	
Meliphagidae	Rufous-banded Honeyeater	Conopophila albogularis		BR		0	600	
Pardalotidae	Bicolored Mouse-warbler	Crateroscelis nigrorufa		BR		1220	2500	
Petroicidae	Greater Ground-robin	Amalocichla sclateriana		BR		2800	3900	
Petroicidae	Lemon-bellied Flyrobin	Microeca flavigaster		BR	0	0	670	1460
Petroicidae	Green-backed Robin	Pachycephalopsis hattamensis		BR		0	1650	2000
Orthonycidae	Logrunner	Orthonyx temminckii		BR	1200	1980	2840	3450
Corvidae (Cinclosomatinae)	Painted Quail-thrush	Cinclosoma ajax		BR		0	800	
Corvidae (Cinclosomatinae)	Papuan Whipbird	Androphobus viridis	DD	BR		1400	2700	
Corvidae (Pachycephalinae, Neosittini)	Black Sittella	Daphoenositta miranda		BR	2000	2450	3700	
Corvidae Pachycephalinae, Pachycephalini)	Black-tailed Whistler	Pachycephala melanura		BR		0	10	
Corvidae (Pachycephalinae, Pachycephalini)	Golden-backed Whistler	Pachycephala aurea		BR		0	700	1460
Corvidae (Pachycephalinae, Pachycephalini)	White-bellied Whistler	Pachycephala leucogastra		BR		0	1200	
Corvidae (Corvinae, Paradisaeini)	Lesser Melampitta	Melampitta lugubris		BR	1150	2000	2800	3500
Corvidae (Corvinae, Paradisaeini)	Crested Bird-of-paradise	Cnemophilus macgregorii		BR	2100	2600	3500	3650
Corvidae (Corvinae, Paradisaeini)	Stephanie's Astropia	Astropia stephaniae		BR	1280	1500	2800	3500
Corvidae (Corvinae, Oriolini)	Green Figbird	Sphecotheres viridis		BR		0	500	
Corvidae (Dicrurinae, Rhipidurini)	Rufous Fantail	Rhipidura rufifrons		?		0	100	1600
Corvidae (Dicrurinae, Monarchini)	Black-faced Monarch	Monarcha melanopsis		M		0	800	
Corvidae (Malaconotinae, Malaconotini)	Leaden Flycatcher	Myiagra rubecula		M		0	650	
Corvidae (Malaconotinae, Malaconotini)	Torrent-lark	Grallina bruijni		BR	400	450	2300	2800

Appendix 3 Birds that may yet be recorded in the KICDP area

Family	Common name	Scientific name	IUCN listing	Notes*	Altitude range (m)			
					Min	Normal range		Max
						Lower	Upper	
Muscicapidae	Blue Rock-Thrush	Monticola solitarius		V				
Muscicapidae	Grey-streaked Flycatcher	Muscicapa griseisticta		V		0	1460	
Muscicapidae	Siberian Rubythroat	Luscinia calliope		V				
Sturnidae	Singing Starling	Aplonis cantoroides		BR	0	0	1740	1980
Hirundinidae	Sand Martin	Riparia riparia		V				
Hirundinidae	Barn Swallow	Hirundo rustica		M		0	1740	
Hirundinidae	Welcome Swallow	Hirundo neoxena		V				
Hirundinidae	Red-rumped Swallow	Hirundo daurica		M		0	600	1650
Hirundinidae	Fairy Martin	Hirundo ariel		V				
Cisticolidae	Golden-headed Cisticola	Cisticola exilis		BR		0	1250	2225
Zosteropidae	Capped White-eye	Zosterops fuscicapillus		BR	750	1200	1850	2200
Sylviidae	Great Reed-Warbler	Acrocephalus arundinaceus		M		0		
Sylviidae	Tawny Grassbird	Megalurus timoriensis		BR		0	4000	
Melanocharitidae	Obscure Berrypecker	Melanocharis arfakiana	DD	BR		950	950	
Melanocharitidae	Spotted Berrypecker	Melanocharis crassirostris		BR	850	1150	2300	2700
Passeridae	Yellow Wagtail	Motacilla flava		M		0	3980	
Passeridae	Mountain Firetail	Oreostruthus fuliginosus		BR	2200	2700	3700	
Passeridae	Papuan Parrotfinch	Erythrura papuana		BR	500	1200	2600	

* BR – Breeding Resident, M –Migrant, S – Seabird, V – vagrant, ? – Migratory/breeding status unsure, BR+M – Breeding Resident and non-breeding Migrant.

A report on the Avifauna of the Papua New Guinea Gas Project Area

Plates



Plate 1 Camera trap set up at Hides3



Plate 2 Nogoli study site - regrowth next to road.



Plate 3 Nogoli study site - garden.



Plate 4 Nogoli study site - gardens, kunai, secondary and primary forest.



Plate 5 Nothofagus forest at Hides 3.



Plate 6 Nothofagus forest at Hides 3.



Plate 7 Wayne's Swamp - a sinkhole pool near Hides 3.



Plate 8 Track down into sinkhole near Hides 3.



Plate 9 Well pad at Hides 2.



Plate 10 The Benaria River.



Plate 11 Open grassland at the Benaria Camp.



Plate 12 Primary forest on the ridge north of Benaria Camp.



Plate 13 Interior of forest near Benaria River.



Plate 14 Regrowth forest on ridge behind Benaria Camp.



Plate 15 Orange-crowned Fairy-wren and nest.



Plate 16 Garnet Robin.



Plate 17 Olive Straightbill.

Plate 18 Huli warriors with plumes and hornbill casques. (Photo S. Richards)



Plate 19 Mountain cuscus captured by local hunter.



Annex 08

Biodiversity survey results:

**Birds at Juha North, Juha South, Baia River, South Karius and Deviation
Camp in 2008**

Avifauna of the upstream
portion of the PNG LNG
Project, Southern Highlands
and Western Provinces,
Papua New Guinea

Report to Coffey Natural Systems

May 2008

Dr Iain A. Woxvold

Table of Contents

1.	ACRONYMS, ABBREVIATIONS AND DEFINITIONS	5
1.1.	Acronyms & abbreviations	5
1.2.	Definitions	5
2.	EXECUTIVE SUMMARY	6
3.	INTRODUCTION	8
3.1.	Background.....	8
3.2.	Data	11
4.	METHODS	13
4.1.	Survey sites, timing and habitat.....	13
4.1.1.	South Karius	13
4.1.2.	Baia River	13
4.1.3.	Juha South.....	16
4.1.4.	Juha North	17
4.1.5.	Deviation Camp	17
4.2.	Survey methods	17
4.2.1.	Transects	18
4.2.2.	Mist-nets and snares	18
4.2.3.	Sound recordings and playbacks	19
4.2.4.	Camera traps	19
4.2.5.	Informal observations	19
4.2.6.	Interviews.....	19
4.2.7.	Identification, taxonomy and conservation status.....	19
4.2.8.	Statistical methods	20
5.	RESULTS OF THE 2008 SURVEYS	21
5.1.	Totals	21
5.2.	Mist-netting	21
5.3.	Interviews.....	22
5.4.	Species effort curves	22
5.5.	Migratory and resident species.....	22
5.6.	Habitat preferences	25
5.7.	Endemic species.....	25
5.8.	Threatened and protected species	25
5.9.	Inventory completeness.....	25
6.	SPECIES RICHNESS AND COMMUNITY COMPOSITION – OVERALL PNG LNG PROJECT UPSTREAM PROJECT AREA	28
6.1.	Species recorded in the overall project area	28
6.2.	Additional species not yet recorded.....	28
6.3.	Overall community composition.....	29
7.	2008 SURVEY AREA SUMMARIES	31
7.1.	Relationship of avifauna at the 2008 Survey Areas and other sites in the PNG-LNG Project Upstream Project Area	31
7.2.	Lowland sites - Baia River and Juha North	31
7.2.1.	Baia River	32
7.2.2.	Juha North	33
7.3.	Upland sites: South Karius, Juha South and the Deviation Camp	35
7.3.1.	South Karius	35
7.3.2.	Juha South.....	36
7.3.3.	Deviation Camp	37
8.	THREATENED AND PROTECTED SPECIES	38
8.1.	Cassowaries (Casuariidae).....	38
8.2.	Hornbills (Bucerotidae)	39
8.3.	Kingfishers (Alcedinidae & Dacelonidae)	39
8.4.	Parrots and Lorikeets (Psittacidae).....	40
8.5.	Nightbirds (Owls, Frogmouths, Nightjars, Owlet-nightjars)	40
8.6.	Pigeons (Columbidae)	40
8.7.	Coastal and wetland species	41
8.8.	Diurnal raptors (Accipitridae)	42
8.9.	Bowerbirds (Ptilonorhynchidae).....	42

8.10.	Whipbirds and Quail-thrush (Corvidae: Cinclosomatinae).....	43
8.11.	Birds-of-paradise (Corvidae: Corvinae, Paradisaeini)	43
8.12.	Mynas and Starlings (Sturnidae).....	45
9.	OTHER NOTABLE RECORDS	46
9.1.	Megapodes (Megapodiidae).....	46
9.2.	Owls	47
9.3.	Scrubwrens and Gerygones (Pardalotidae) and Robins (Petroicidae).....	47
9.4.	Whistlers and allies (Corvidae: Pachycephalinae)	48
9.5.	Swallows and Martins (Hirundinidae)	48
10.	DISCUSSION, IMPACTS AND RECOMMENDATIONS	49
10.1.	Conservation value and habitat quality	49
10.2.	General considerations	49
10.3.	Direct impacts.....	50
10.3.1.	Forest clearing.....	50
10.3.1.1	Non-linear developments: processing facilities, camps, storage areas and well pads	50
10.3.1.2.	Well pads.....	51
10.3.1.2	Linear developments and edge effects: ROW and access roads.....	51
10.3.2.	Contamination of rivers and wetlands	52
10.4.	Indirect (SECONDARY) impacts.....	52
10.4.1.	Overview.....	52
10.4.2.	Hunting	52
10.4.3.	Fire.....	53
10.5.	Recommendations.....	53
10.5.1.	Direct impacts.....	53
10.5.1.2.	Forest clearance.....	53
10.5.1.3.	Contamination of rivers and wetlands	55
10.5.2.	Indirect impacts	55
10.6.	Conclusions	56
11.	REFERENCES	57

Tables

Table 1 Bird surveys conducted within the PNG LNG Project Upstream Project Area prior to 2008.

Table 2 Survey dates, base co-ordinates and survey effort summaries (overall and per-site) for bird surveys conducted at each of five sites within the PNG LNG Project Upstream Project Area from February to April 2008.

Table 3 Numbers of birds mist-netted or captured by local hunters (h) at each survey area. Totals are number of species and, in brackets, the number of individuals caught at each site.

Table 4 Species of global and/or national conservation significance recorded during the 2008 surveys.

Table 5 IUCN-listed bird species recorded within PNG LNG Project Upstream Project Area between 1995 and 2005 but not recorded in 2008.

Table 6 Magnitude of impact on individual taxa associated with development of the PNG LNG Project.

Table 7 Bird species occurring in the PNG LNG Project Upstream Project Area that are commonly hunted in New Guinea by local people for meat and/or plumes, their global conservation status and their occurrence at sites surveyed in 2008.

Figures

Figure 2 Topographic map showing location of camp and sample transects at South Karius survey area.

Figure 3 Topographic map showing location of camp and sample transects at Baia River survey area.

Figure 4 Topographic map showing location of camp and sample transects at Juha South survey area.

Figure 5 Topographic map showing location of camp and sample transects at Juha North survey area.

Figure 6 Topographic map showing location of camp and sample transects at Deviation Camp survey area.

Figure 7 Species discovery curves at the five survey areas. Data include detection of species during active formal surveys (transects), mist-netting and informal observations.

Figure 8 Dendrogram showing similarity between all 32 sites surveyed in the PNG LNG Project Upstream Project Area between 1995 and 2008 based on bird species composition. Arrowheads show those sites surveyed in 2008.

Appendices

Appendix 1 Birds recorded in the PNG LNG Project Upstream Project Area in 2008

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Appendix 4 Species that may occur but have not been recorded in the PNG LNG Project Upstream Project Area.

Plates

Plate 1. Juvenile Dwarf Cassowary (NT) at South Karius. This bird was captured locally and being raised as a pet.

Plate 2. Local residents at South Karius.

Plate 3. This Salvadori's Teal (VU; P) was captured in the small creek next to the camp at South Karius.

Plate 4. Skins of three Fairy and one Papuan Lorikeet captured by locals at South Karius.

Plate 5. Cuscus and juvenile Wattled Brush-turkey captured by a local hunter at South Karius.

Plate 6. The blue facial skin identifies this bird as a juvenile Wattled Brush-turkey.

Plate 7. Brown-collared Brush-turkey snared by locals at Juha North.

1. Acronyms, abbreviations and definitions

1.1. Acronyms & abbreviations

asl	above sea-level
CPF	Central Processing Facility
CPM	The Central Papuan Mountains EBA
DD	Species classified as Data Deficient by the IUCN
DEC	Department of Environment and Conservation
EBA	Endemic Bird Area
Esso	Esso Highlands Limited
EN	Species classified as Endangered by the IUCN
IUCN	International Union for Conservation of Nature and Natural Resources
KICDP	Kikori Integrated Conservational and Development Project
LNG	Liquefied Natural Gas
LR/nt	Species classified as Near-threatened by the IUCN
P	Species protected under PNG law
PNG	Papua New Guinea
ROW	Right-of-Way
RR	Restricted Range species
Sp.	Species
VU	Species classified as Vulnerable by the IUCN
WWF	World Wide Fund for Nature

1.2. Definitions

Allopatric – Species or populations that are geographically separated without overlap

New Guinea – the large island of New Guinea (PNG + Indonesia)

New Guinea and satellite islands – the Large island of New Guinea plus it's offshore islands including the Eastern Papuan Islands (Lousiades)

PNG – the country of Papua New Guinea

PNG (mainland) – the mainland portion of the country of PNG.

2. Executive summary

- As part of an impact assessment of the Papua New Guinea Liquefied Natural Gas Project (PNG LNG Project) this report details the results of bird surveys conducted in the Southern Highlands and Western Provinces of PNG in February to April 2008. Surveys were conducted in areas between Hides and Juha along the proposed route of the Juha-Hides Pipeline ROW and the LNG Project Gas Pipeline northeast of Homa. Avian biodiversity within these areas is discussed in light of these results and those of previous surveys conducted within the PNG LNG Project Upstream Project Area (Project Area) from 1995 to 2008.
- The 2008 surveys were conducted in two stages. Phase I surveys were carried out between February 4 and 23 from three camps located along the proposed Juha-Hides Pipeline ROW: 'South Karius', 'Baia River' and 'Juha South'. Phase II surveys were conducted between March 25 and April 9 from the 'Juha North' camp northwest of the current limit of the proposed pipeline route, and from the 'Deviation Camp' northeast of Homa.
- A total of 220 bird species from 38 families were recorded during the 2008 surveys, including 10 species not previously recorded in the Project Area. The highest number of species was recorded from Juha North (91), South Karius (85), Juha South (83) and Baia River (82), and the fewest at the Deviation Camp (65).
- Twenty-eight species recorded in 2008 are of global and/or national conservation significance. Twelve species (5.5%) are listed by the IUCN as globally Threatened or Near-threatened, while 24 species (10.9%) are protected under PNG law. A further 13 species (5.9%) are listed by BirdLife International as restricted to the Central Papuan Mountains EBA (Restricted Range species).
- Excluding migrants, waterbirds and coastal species, the combined records for the 2008 surveys includes nearly half of New Guinea's resident bird species.
- A total of 409 bird species have now been recorded for the Project Area as a whole, more than 55% of all 740 or so bird species recorded in New Guinea.
- Seventeen of these species are listed by the IUCN as globally Threatened, Near-threatened or Data Deficient, seven of which were not recorded in 2008. Species of global conservation significance are discussed individually.
- The overall Project Area covers a wide variety of ecological regions, including Lake Kutubu and associated wetlands, numerous rivers and streams, coastal mudflats and mangrove forest, swamp forests and tracts of rainforest of several types. It covers a wide elevational range (0–2,700 m asl) and varying geomorphologies and soil types. This, and the fact that much of the tracts of rainforest remain undisturbed, account for the high species richness recorded in the Project Area.
- A cluster analysis comparing species composition among all 32 sites surveyed within the Project Area placed the bird communities documented at Baia River and Juha North closer to one another than to the avifauna at any other lowland sites. 125

species were recorded at these sites, and a further 95 species recorded at other lowland sites within the Project Area may occur in the lowlands of the Juha gas fields.

- Hunting pressure appeared low at Baia River and Juha North, with a variety of commonly targeted species found in good numbers. These included numerous ground-dwelling pigeons, the Dwarf Cassowary, Brown-collared Brush-turkey and New Guinea Scrubfowl. Six IUCN-listed species were recorded at these sites: Dwarf Cassowary, Pesquet's Parrot, Southern-Crowned Pigeon, Gurney's Eagle, Forest Bittern and Yellow-Eyed Starling.
- The cluster analysis placed the three upland sites (lower and mid montane) surveyed in 2008 with the four sites above 1,500 m asl surveyed between 1995 and 2005: Mt Bosavi, Mt Sisa, Mt Moran and Hides 3. Within this cluster, the avifaunas recorded at the Deviation Camp and Mt Sisa were most similar, while the bird community at Juha South was closest to that on Mt Bosavi. A total of 156 species was recorded at the three upland sites in 2008, while the 205 species recorded at all seven high-altitude sites provide a reasonably thorough inventory of the montane species likely to be encountered in the Project Area.
- As with the lowland sites, hunting pressure appeared to be low at Juha South and the Deviation Camp. Hunters were very active at South Karius, though this activity appeared recent in the area. Accordingly, a number of sensitive species were present at these sites, including Salvadori's Teal, Wattled Brush-turkey, New Guinea Scrubfowl, Pesquet's Parrot, Palm and Sulphur-crested Cockatoos, Long-tailed Honey-buzzard, New Guinea Eagle, and 17 species of Bird-of-paradise.
- Eight IUCN-listed species were recorded at these upland sites: Dwarf Cassowary, Salvadori's Teal, Pesquet's Parrot, New Guinea Eagle, Yellow-breasted Bird-of-paradise, Black Sicklebill, Ribbon-tailed Astrapia and Blue Bird-of-paradise.
- Overall, the region constitutes an increasingly rare example of a large expanse of intact and well connected tropical lowland, hill and montane forests. The area is of extremely high conservation value due to its large size, remoteness, connectivity with undisturbed habitat in surrounding areas, and the persistence of a variety of intact habitats covering a range of topographies and soil types. Notably, the region includes large areas of intact and remote habitat that support large and viable populations of a range of bird (and mammal) species that are commonly targeted by hunters and prone to local extinction in the vicinity of human settlement.
- Developments are not expected to directly result in a significant impact on regional or local bird communities. However, without mitigation these developments may produce significant indirect impacts on these communities by increasing human access to previously remote areas.

3. Introduction

3.1. Background

New Guinea is among the most biologically diverse regions on earth. The world's second largest island, it supports the third largest block of unbroken tropical rainforest on the planet and the largest remaining tract of primary rainforest in the Asia Pacific region. New Guinea's rich biota includes more than five percent of the world's plant and animal species on less than one percent of its land surface.

Moreover, New Guinea's isolation and distinct biogeographic history have ensured the evolution of a unique biota some two thirds of which are found nowhere else on earth (endemic). Of more than 700 bird species recorded in New Guinea and its satellite islands some 330 are endemic (Coates 1985; Beehler et al. 1986). The region includes eight distinct Endemic Bird Areas, each of which supports a high concentration of 'Restricted Range Species' found nowhere else (BirdLife International; Stattersfield et al. 1998). New Guinea is the centre of diversity for a wide range of avian families and supports most of the world's species of bird-of-paradise, bowerbird, cassowary and owl-nightjar. The island's unique avifauna also includes the world's largest pigeon and the smallest parrot.

Despite the diversity and high public profile of much of New Guinea's unique birdlife, and the high global conservation value of its tropical forests, relatively little is known of the distribution and ecology of avifauna across much of the island. Largely under the colonial expansion of The Netherlands, Germany and Britain, naturalists initiated the first of a series of excursions across the island in the mid-1800s that have continued for over a century. However, since the annexation of Irian Jaya by Indonesia in 1961 and the independence of Papua New Guinea (PNG) in 1975, detailed information on the island's birds has become increasingly difficult to acquire. Indeed, relatively few data are available from detailed scientific investigations into New Guinea's birdlife, and much of what we know is gleaned from collections and anecdotal information rather than long-term, peer-reviewed studies of status, distribution and behaviour. Moreover, many regions have not been surveyed for the better part of a century or remain entirely unexplored, with new bird species being discovered on the island as recently as 2006.

The Papua New Guinea Liquefied Natural Gas Project (PNG LNG Project) aims to commercialise reserves from multiple gas fields present in the Southern Highlands and Western Provinces of PNG. Project infrastructure will largely follow the same pipeline alignment between Hides, the Kutubu Central Processing Facility (CPF) and the Omati River that has been the subject of numerous biodiversity surveys conducted since 1995. However, the PNG LNG Project is planning to expand these operations to extract gas from the Juha gas fields west of Hides, in a previously unsurveyed area.

There are few formal inventories of the avifauna present within the region of the proposed developments at Juha and the associated pipeline to Hides. The most thorough survey of birds in the vicinity of Juha was conducted by A. L. Rand in 1936-37 on the Fly and lower Strickland Rivers, more than 50 km west of the present Project Area at its closest, as part of the Archbold Expeditions organised by the American Museum of Natural History (Rand 1942; Rand and Brass 1940). Therefore, as part of an impact assessment of the PNG LNG Project this report provides information on the bird communities present in the region of the Juha gas fields, between Juha and Hides, and in the vicinity of the potential deviation route east and south of Benaria. The objectives of the present study are to:

- Collate and assess existing information relevant to bird communities in the PNG LNG Project Upstream Project Area (Project Area).
- Survey bird communities present in the Hides to Juha area.
- Determine the status of rare, threatened and/or protected species likely to be present within the Project Area, and report on their habitat requirements and the viability and importance of existing populations in a local, regional, national and global context.
- Discuss the sensitivity of rare, threatened and/or protected species to possible development of the PNG LNG Project.
- Assist in the development of recommendations relevant to the mitigation of possible impacts on rare, threatened and protected taxa and/or bird communities.

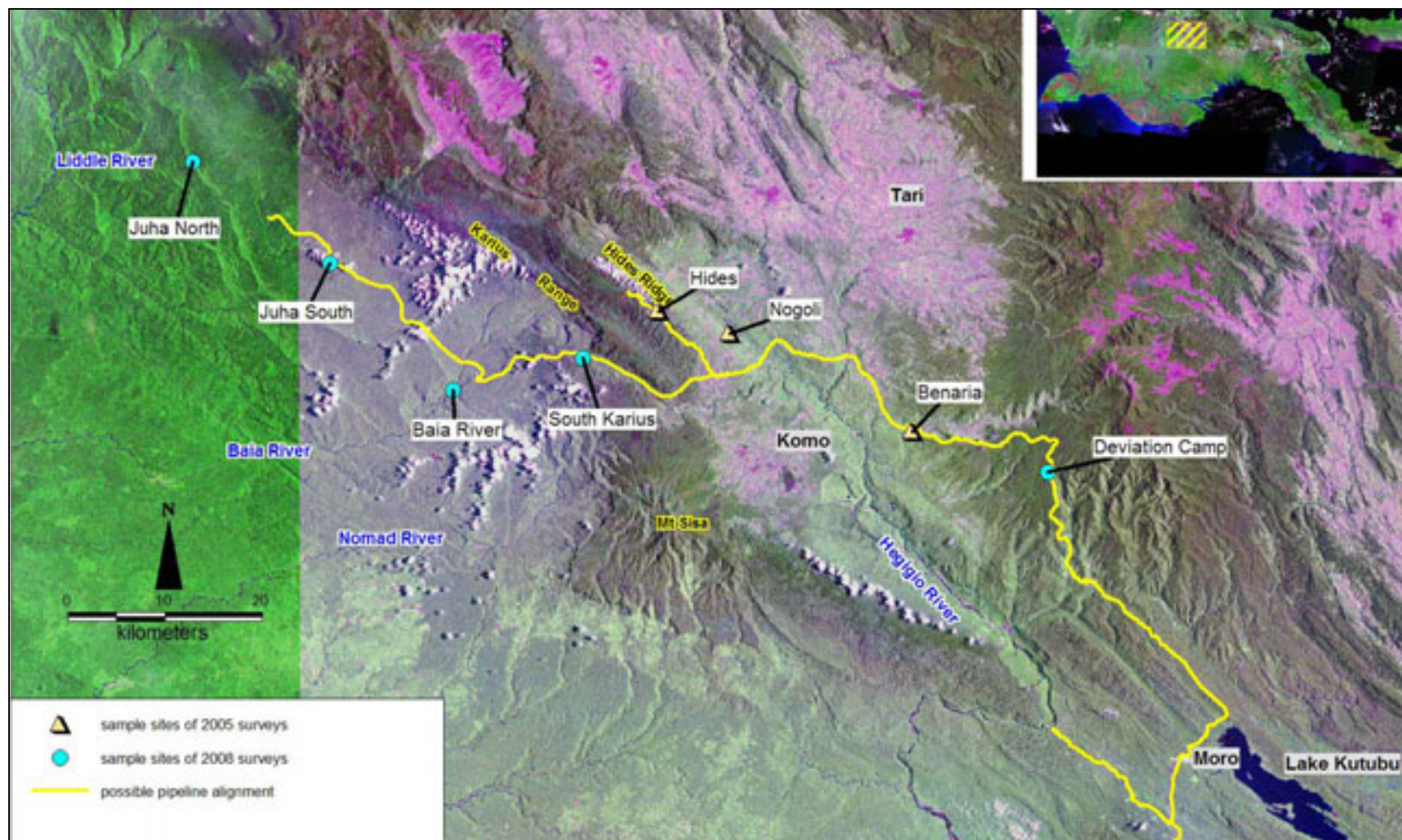


Figure 1 Location map of the 2008 surveys, showing major geographic features, pipeline alignments and the position of camps from the 2005 and 2008 surveys.

3.2. Data

In 1993, a large region of the Western and Gulf Provinces running northwest from the Kikori delta to the border with Indonesia at the headwaters of the Fly River was defined as an area of high priority for biodiversity surveys due to the paucity of scientific information available (Biodiversity Support Program 1993). Indeed, much of what was known of the region was taken from data gathered during the Archbold expeditions conducted in the 1930s. Since then, much of the Kikori drainage and parts of the central highlands to the north and west have been the subject of numerous, intensive biodiversity surveys as part of the Kikori Integrated Conservation and Development Project (KICDP).

The PNG LNG Project lies largely within the KICDP boundary, which encompasses an area designated by the World Wide Fund for Nature (WWF) for the integration of conservation and the development of natural resources (e.g. oil and gas developments) within the entire Kikori drainage (Leary et al. 1996; McCall and Fleming 2000).

As part of the KICDP, **Table 1** summarises the sources of biodiversity data and areas surveyed within the Project Area during this period. Most surveys have focused on that section of the Kikori River valley between the Kutubu CPF and the Kikori delta. These surveys span a length of over 200 km within the Kikori River valley and surrounding ranges, and cover altitudes from sea-level to over 1,400 m asl (above sea-level). In addition, mid and upper montane surveys (>1,500 m asl) were conducted by WWF on Mt Bosavi, Mt Sisa and Mt Moran. Mounts Bosavi and Sisa are isolated 'island' peaks south of the central cordillera, and thus not likely to reflect the full diversity of bird taxa present along the southern slopes of New Guinea's central ranges.

In April and May (see Iain Woxvold and Francis Crome conducted additional bird surveys at the following three sites north of the Kutubu CPF (see Annex 07 to Biodiversity Appendix):

- The site of a previously proposed gas processing facility (for the PNG Gas Project) on the Tagari River ~5 km south-east of Nogoli.
- The region of the Hides Range around the Hides 3 well pad.
- A site ~5 km west of Benaria mission approximately half way along the proposed route of the pipe-line between Nogoli and Moro.

Taken together, the studies listed in **Table 1** are sufficient to allow impact assessment for most of the Project Area. However, our current knowledge of bird communities present west of the Hides range and southeast of Benaria is still extremely limited. Consequently, additional bird surveys were carried out in these areas by Iain Woxvold and Francis Crome during February to April 2008. This report presents the results of these surveys and combines the new data with those of prior surveys to provide an assessment of the avifauna within the Project Area and the likely impacts of the project.

Table 1 Bird surveys conducted within the PNG LNG Project Upstream Project Area prior to 2008.

Site	Code	Latitude	Longitude	Altitude	References
Cape Blackwood	CB	7.54777778	144.313889	0+	Diamond & Bishop (2000)
Kikori1	KO1	7.42833333	144.248333	10	Jaensch & Watkins (2000)
Veriabari	KD4	?	?	0+	Jaensch & Watkins (2000)
Kopi/Kikori	KL1	7.36666667	144.233333	~10-20	Burrows (1995)
Kopi	KL3	7.32166667	144.181389	~20	Diamond & Bishop (2003)
Pinini Creek	KP	7.187783	144.11244	20+	Diamond & Bishop (2003)
Iviri 3	I3	7.41666667	144.408333	20-40	Leary (2002)
Kikori delta	KD2	7.53777778	144.248333	0+	Diamond & Bishop (2000)
Keboi Kerowa	KK	7.53333333	144.258333	55-1341	Diamond & Bishop (2003)
Veiru Creek	V	7.42555556	144.195556	30	Burrows (1995)
Utiti Creek	U	7.22583333	144.098333	35	Leary & Seri (1995)
Dark End Lumber	DEL	7.15722222	144.393056	30-60	Diamond & Bishop (2000)
Omo village	O	6.97805556	144.304167	40-170	Burrows(1995)
Libano Sok	L	6.40044444	142.975	200-600	Igag (2003)
Wassi Falls 1	WF1	6.74805556	143.589722	380 - 420	Burrows(1995)
Kantobo	K	6.721731	143.56652	400-420	Diamond & Bishop (2003)
Darai Plateau	D	7.13075	143.6105	300-700	Igag (2003)
Gobe	G9	6.823472	143.74472	55-1341 (643 mean)	Diamond & Bishop (2003)
Lake Kutubu	LK1	6.41666667	143.333333	808	Jaensch (1997)
Moro	MO3	6.36277778	143.228056	740-1000	Jaensch (1997)
Moro/Kutubu/Agogo	MO1	6.367897	143.202006	740-1350	Burrows (1995)
Nogoli	N	5.9648	142.8164	1200	Woxvold & Crome (2005)*
Benaria	B	6.05478	142.97845	1239	Woxvold & Crome (2005)*
Mt Bosavi	MB	6.54527778	142.839722	1250-1725	Burrows (1995)
Mt Moran	MM	6.265488	143.13738	1650	Diamond & Bishop (2003)
Hides 3	H3	5.9485	142.7455	2163	Woxvold & Crome (2005)*
Mount Sisa	MS3	6.12986111	142.760694	2200*	Diamond & Bishop (2000)

* Annex 07 to Biodiversity Appendix

4. Methods

4.1. Survey sites, timing and habitat

The 2008 bird surveys were conducted over two stages from five locations within the PNG LNG Project Upstream Project Area. Phase I surveys were carried out between February 4 and 23 from three survey areas located along the proposed Juha–Hides Gas Pipeline: ‘South Karius’, ‘Baia River’ and ‘Juha South’. Phase II surveys were conducted between March 25 and April 9 from the ‘Juha North’ survey area northwest of the current limit of the proposed pipeline route, and from the ‘Deviation Camp’ survey area along a possible realignment option for the previous PNG Gas Project pipeline alignment between Hides and the Kutubu CPF.

Figure 1 shows the location of each of the 2005 and 2008 survey sites and the possible pipeline alignments. **Table 2** lists the survey dates, base co-ordinates, altitude and total survey effort for each site.

A brief description of each study site (chronological order) and the habitats surveyed for birds is given below. Transects surveyed from each camp are shown in **Figures 2 to 6**.

4.1.1. South Karius

The South Karius survey area was situated at the base of the Karius range in a complex of streams and swamps that form the headwaters of the Baia River. Of all sites surveyed in 2008 South Karius was the most heavily settled. Habitat in the immediate vicinity of the camp included large areas cleared for subsistence agriculture. The camp itself was located on the edge of a flat area that had been converted to gardens within the last few years. It was surrounded by swamplands with *Pandanus* emergents that merged into “very small crowned lower montane forest” (Hammermaster & Saunders 1995a, b) on the surrounding hills. Geology of the surrounding hills appeared to be dominated by karst, while the camp was situated on alluvial soils derived from the surrounding streams and swamps. **Figure 2** shows the location of the camp-site and transects traversed during the study.

Based on the habitat definitions and elevation limits of Johns (1976, 1977), South Karius lies in the transition zone between lower and mid montane forest. The community structure of the natural-growth vegetation was similar to that found at Juha South (see 4.1.3 below). However, due to the presence of human habitation near the camp there was a discernable increase in weed species, including some cosmopolitan plants not found at any of the other locations. These anthropogenic influences were also reflected in a higher incidence of successional stands along the margins of the primary forest.

4.1.2. Baia River

The geomorphology of the Baia River valley in the vicinity of this camp and along the helicopter approaches to the river from South Karius appears to be comprised of highly unstable sedimentary formations subject to frequent landslides. The camp was located on the banks of the Baia River. **Figure 3** shows the location of the camp-site and transects traversed during the study.

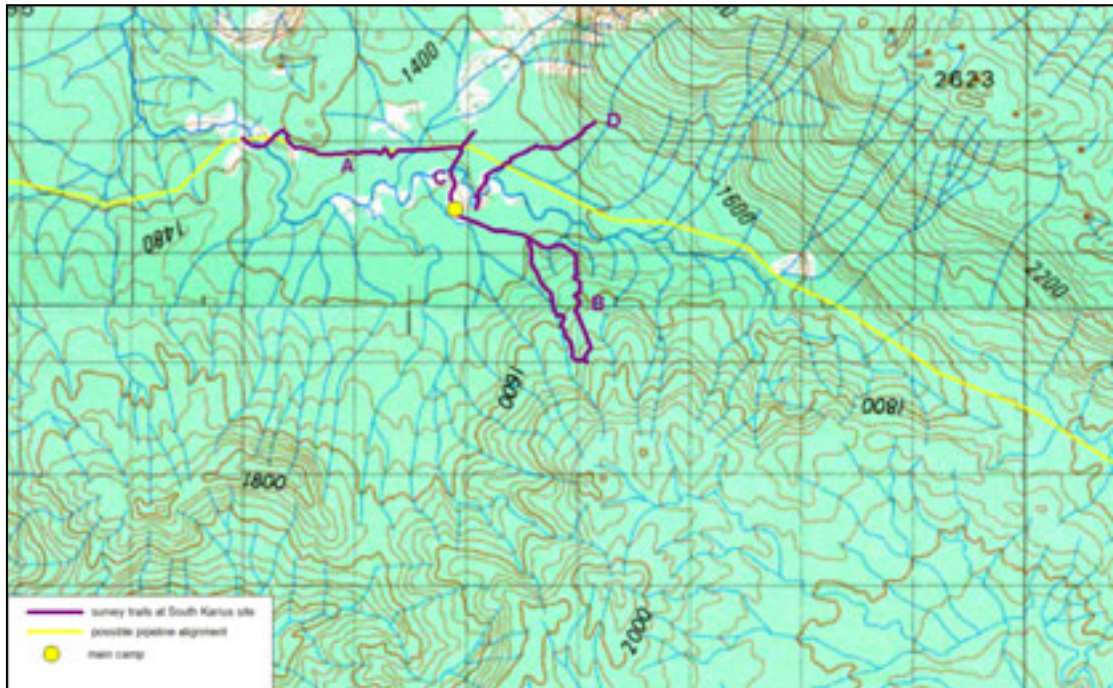


Figure 2 Topographic map showing location of camp and sample transects at South Karius survey area. Image from 1:100,000 topographic map displaying 1 km grid.

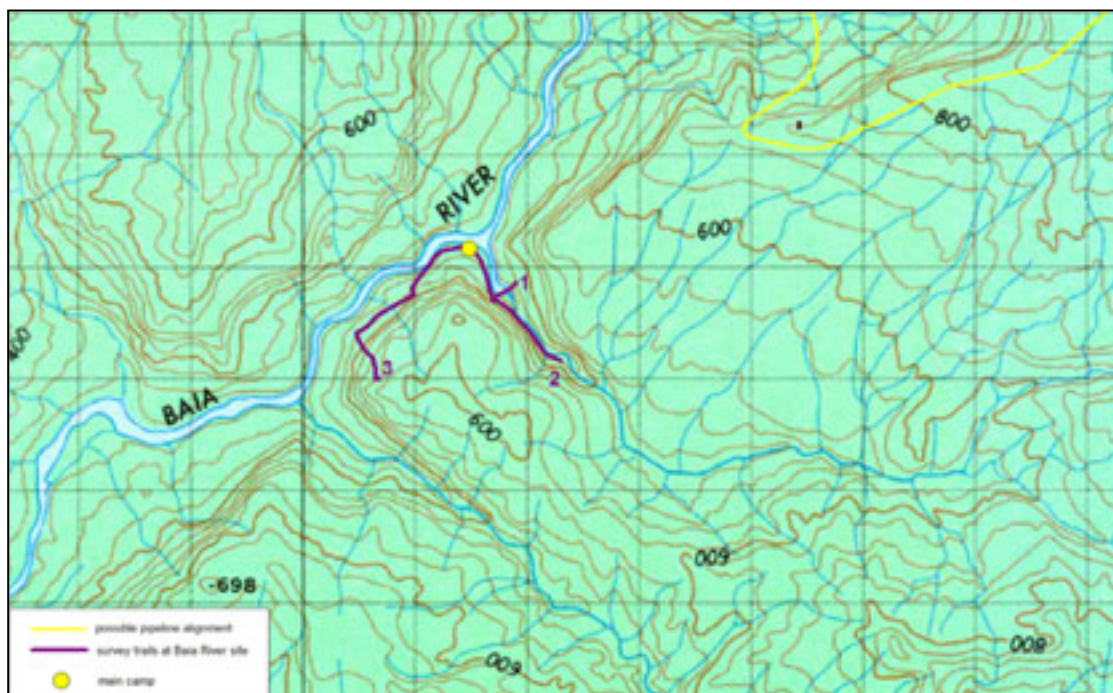


Figure 3 Topographic map showing location of camp and sample transects at Baia River survey area. Image from 1:100,000 topographic map displaying 1 km grid.

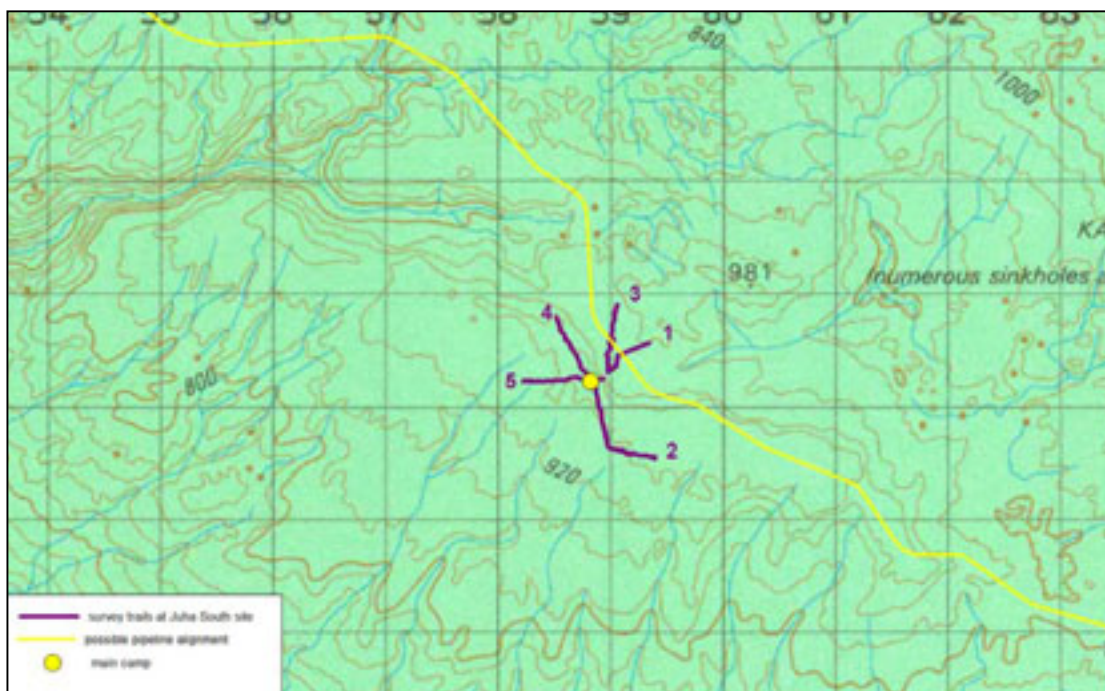


Figure 4 Topographic map showing location of camp and sample transects at Juha South survey area. Image from 1:100,000 topographic map displaying 1 km grid.

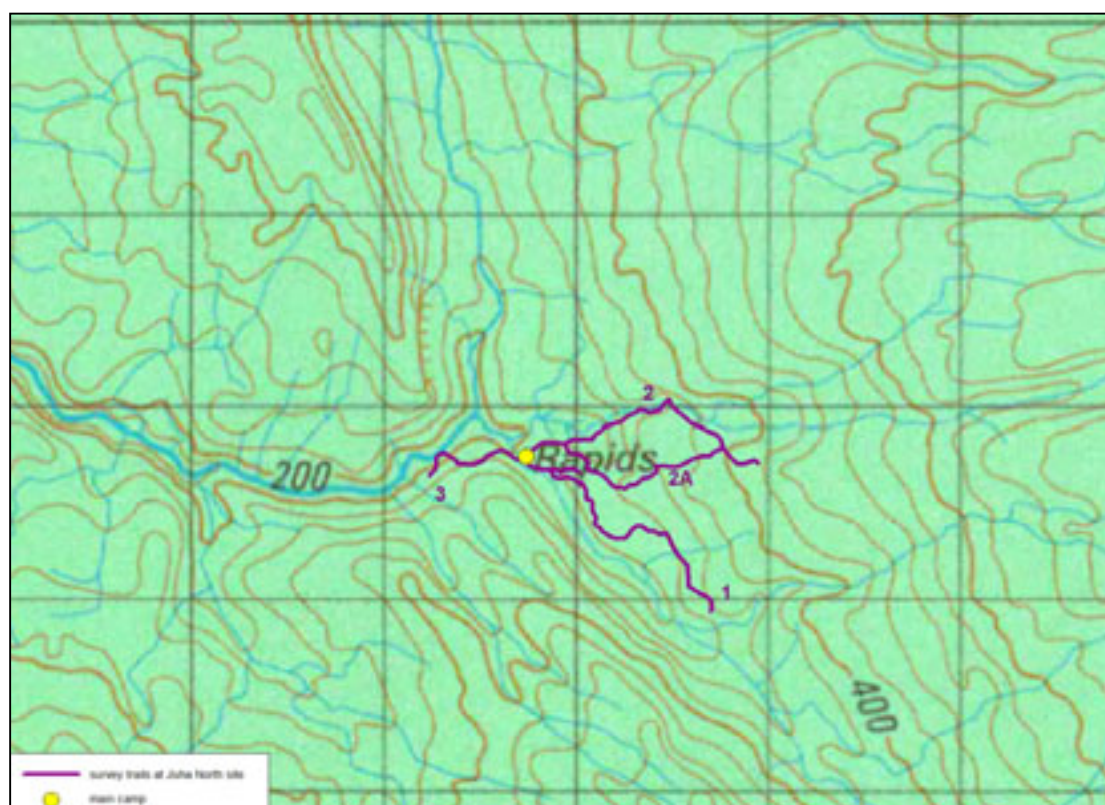


Figure 5 Topographic map showing location of camp and sample transects at Juha North survey area. Image from 1:100,000 topographic map displaying 1 km grid.

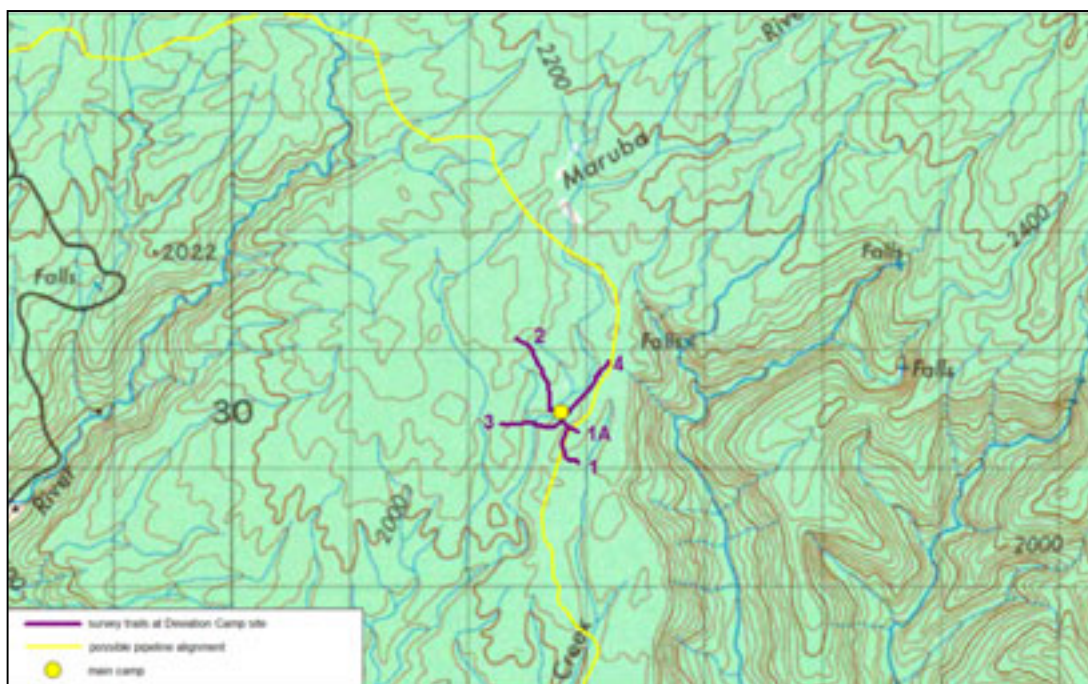


Figure 6 Topographic map showing location of camp and sample transects at Deviation Camp survey area. Image from 1:100,000 topographic map displaying 1 km grid.

Habitat around the Baia River survey area comprised exclusively lowland vegetation formations. A floristically distinct alluvial and flood zone occurred along the rivers and streams. “Small crowned low altitude forest on uplands (Hm)” (Hammermaster & Saunders 1995a, b) occurred on the higher slopes. There were numerous talus slopes and active landslides with early pioneer and secondary vegetation. The principal genera represented at the site were *Ficus*, *Gymnostoma*, *Macaranga*, *Pimelodendron*, and *Pometia* (Takeuchi 2008 Annex 02 to Biodiversity Appendix).

4.1.3. Juha South

Technically, habitat at Juha South lies in the transition ecotone between traditionally defined lowland and montane zones (lowland tropical and lower montane forest). However, due to local conditions including very high rainfall this area is clearly characterised by a well-developed mossy montane forest. Specifically, the habitat classifies as transitional between “small crowned” (L) and “very small crowned lower montane forest (Ls)” (Hammermaster & Saunders 1995a, b). As is generally the case for montane formations, the canopy was low stature (average height <20 m) with considerable epiphytic loads on trunks and upper branches.

The camp itself was located next to an old well pad sunk by Gulf Oil in 1983/84, and the immediate area was contaminated with waste remaining from drilling activities. Apart from this the area displayed a number of characteristics evident of low human population densities. Forest understoreys were generally rich in cryptogamic growth and in remarkably pristine condition due to the absence of wild pigs. Forest regeneration at the site was well advanced, composed for the most part of *Eurya*, *Ficus*, *Macaranga*, *Timonius* and urticates. Numerous sinkholes were present on the surrounding karst terrain. **Figure 4** shows the location of the camp-site and transects traversed during the study.

4.1.4. Juha North

Juha North lies beyond the end of the proposed Juha to Hides Gas Pipeline. However, this area was surveyed as an example of the lowland habitat present in the region of the pipeline's extremity.

The camp at Juha North was situated on the Liddle River, a tributary of the upper Strickland River. Topography was characterised by steep hills and valleys with areas of limestone. A large waterfall close to camp emanates from a subterranean drainage system in the limestone. **Figure 5** shows the location of the camp-site and transects traversed during the study.

Habitat comprised "small crowned low altitude forest on uplands (Hm)" with evidence of disturbance and hunting. An anomalous feature of the vegetation was the presence of many plant groups normally found only in montane environments above 1,000 m asl. Among the unusual elevational occurrences were numerous species of Ericaceae, Myrsinaceae and Myrtaceae.

4.1.5. Deviation Camp

The Deviation Camp was located approximately 5.5 km southeast of Benaria village next to a fast flowing tributary of the Muruba River. The topography included steep slopes leading from the river valley to flat and gently undulating plateau terrain. **Figure 6** shows the location of the camp-site and transects traversed during the study.

Intact habitat was characterised by pristine "mossy montane *Nothofagus* forest" (Ln). The overstory was composed almost exclusively of *Nothofagus pullei* emergents up to 40 m tall. Sub-canopy genera were dominated by *Acronychia*, *Elaeocarpus*, *Sphenostemon*, and *Syzygium*. Understoreys were characterised by dense bryophyte and lycophyte growth, with dominants including *Cyathea microphyloides* and *C. perpelvigera*. Most of the floristic diversity was concentrated in the near-ground interval up to ca. 5 m height.

The camp bordered an area of forest burnt in the 1996–97 fires. These regenerating areas were dominated by dead stags and coppicing surviving trees, with saplings up to 15 m high. There was extensive regeneration by light-demanding *Nothofagus* and other heliophytes such as *Macaranga*, *Omalanthus*, and *Cyathea* spp. (e.g. *C. contaminans*). The understorey included many shade tolerant species, suggesting that in this area the fires had been largely restricted to the upper layers (crown fires) and had not burnt the mossy ground layer. Transects 1a and 4 (Fig. 6) traversed areas disturbed by fire.

4.2. Survey methods

Survey methods included 'active' transect searches, mist-netting, call playbacks and interviews with local hunters. These techniques were combined to maximise completeness of the bird species inventory and the likelihood of locating rare and threatened taxa in the time available.

Table 2 Survey dates, base co-ordinates and survey effort summaries (overall and per-site) for bird surveys conducted at each of five sites within the PNG LNG Project Upstream Project Area from February to April 2008.

Site	Juha North	Juha South	Baia River	South Karius	Deviation Camp	Total
Dates	25 Mar–3 Apr	17–23 Feb	11–17 Feb	4–11 Feb	3–9 Apr	
Locations ¹						
Lat. (S)	5.8078	5.9018	6.0205	5.9911	6.0967	
Long. (E)	142.3083	142.436	142.5473	142.6706	143.1045	
Elevation (m)						
Camp	213	953	328	1368	2060	
Range ²	200–450	820–1,030	285–445	1,200–1,800	1,990–2,180	
Transect time (hrs) ³	29.25	21.75	31	25.75	27.5	135.25
Mist -nets (net hours)	281	92	80	80	35	316
Camera Traps						
# of cameras	6	6	6	5	7	24
Total hours	823	609	595	500	747	3274
Sound recordings						
No.	29	34	49	24	19	155
Total time (h:m:s)	1:00:59	2:21:38	1:22:41	0:46:20	0:31:24	6:03:02

¹ Base co-ordinates list the position of each base camp (WGS 84).

² Elevation range refers to the variation in altitudes surveyed at each survey area.

³ 'Transect time' includes formal census time only (transect surveys) and excludes periods of opportunistic birding (e.g. sightings from camp, deploying and retrieving mist-nets and camera traps, etc.)

4.2.1. Transects

Each morning and afternoon birds were surveyed along well-marked walking trails cut mostly through areas of closed forest. During active searches birds were identified either visually using binoculars (10×) or by their calls. Most surveys were conducted early to mid morning (0600–1100h) and from late afternoon to shortly after dusk (1500–1830h) to cover active periods of both diurnal and nocturnal birds. The active survey effort for each site is summarised in **Table 2**. **Figures 2 to 6** show the location of transects traversed during the study.

4.2.2. Mist-nets and snares

Three to five mist-nets ranging in size from 9 to 12 m (31 mm mesh) were deployed at each site in a variety of habitats, including unlogged, disturbed and secondary forest on slopes, ridges and flats. The total mist-netting effort for each survey site is summarised in **Table 2**. Nets were opened after dawn and furled during periods of heavy rain, before or a few hours after nightfall. All nets were erected close to the ground (< 5 m high) on trimmed saplings and checked at least every 1.5 hours. Most birds were identified and released immediately at the capture site. Some birds were brought back to camp and stored in the shade in calico bags

for subsequent processing including photography and measurement. No bird specimens were collected during the 2008 surveys, and all birds were released unharmed.

4.2.3. Sound recordings and playbacks

Unfamiliar calls were routinely recorded while walking transects and during informal survey periods. Calls were recorded digitally on a Sony HiMD minidisc recorder using a Sennheiser ME66 cardioid microphone. Recorded calls were later matched against an extensive database of PNG bird calls. Selected calls were played aloud using a Toa 15-watt megaphone in an effort to elucidate a response from cryptic, rare and threatened species that may be present (e.g. pigeons, pittas, jewel-babblers, scrub-robins).

4.2.4. Camera traps

Up to seven 'Photoscout' 35 mm infrared-triggered camera traps were used to continuously record fauna. To operate the trap each camera was loaded with 400 ASA 35 mm film, desiccant placed in the housing and the unit closed and sealed. The unit was then tied to a tree and aimed so that any bird or mammal crossing the ground within 15 m of the camera would trigger the infrared beam and a photograph of the animal taken. **Table 2** provides details of camera trap operations.

4.2.5. Informal observations

Outside formal survey periods (active transect surveys), opportunistic observations were recorded from camps, while tending mist-nets or releasing birds in their natural habitat.

4.2.6. Interviews

Throughout much of New Guinea the hunting of mammals and birds provides a major source of protein for local people, as well as a range of trophies important for ceremonial purposes that are still widely practiced (Coates 1985; Flannery 1995; Jones et al. 1995; Swadling 1996). Consequently, local residents are often a valuable source of information regarding the presence of certain taxa.

Direct observational data were supplemented with records provided by local residents working in the camps who hunted in the survey areas (hereafter, local 'hunters'). During interviews, individuals that displayed a particular knowledge of local avifauna were shown images of birds in Beehler et al. (1986).

Interviews were conducted at South Karius, Juha North and the Deviation Camp, but not at Juha South or Baia River. Staff at the remote Juha South survey area lived too far from the site to hunt in that area. Similarly, of the locals assisting our team at Baia River, those with sufficient knowledge of birds were from the South Karius area and so were not questioned about the Baia River fauna.

4.2.7. Identification, taxonomy and conservation status

Information on the distribution and natural history of species within New Guinea and surrounding regions was obtained from Diamond (1972), Coates (1985, 1990), Beehler et al. (1986), Gregory (1995), Jones et al. (1995), Frith and Beehler (1998), Chantler and Driessens (2000), Frith and Frith (2004), Ferguson-Lees & Christie (2005), Payne (2005) and a variety of primary sources. Nomenclature (common and scientific names) and family arrangements follow the Sibley and Monroe system (Sibley and Monroe 1990, 1993a, b) for most species.

Birds-of-paradise follow Frith and Beehler (1998), megapodes Jones et al. (1995) and cuckoos Payne (2005).

Habitat definitions and altitudes are based on Johns (1976, 1977).

The global conservation status of all species was taken from the 2007 IUCN (International Union for Conservation of Nature and Natural Resources) Red List of Threatened Species. IUCN categories rank the relative risk of individual taxa becoming extinct in the wild based on a set of standardised criteria. The following categories and their abbreviated codes appear subsequently in the text. Species classified as **Threatened** are considered to face:

- An extremely high risk of extinction (**Critically Endangered - CR**) in the wild.
- A very high risk of extinction (**Endangered - EN**) in the wild.
- Or a high risk of extinction (**Vulnerable - VU**) in the wild.

Species at lower risk though close to qualifying or likely to qualify for a threatened category in the near future are classified as **Near-threatened (NT)**.

Finally, a species is considered **Data Deficient (DD)** when there is insufficient information to assess its risk of extinction. Such species are often extremely rare with few confirmed records.

The list of species that are **Nationally Protected (P)** under Papua New Guinea's Fauna (Protection & Control) Act of 1976 was obtained from Kula and George (1996).

Restricted Range (RR) species recorded during the surveys include a number of birds found only in the Central Papuan Mountains (CPM) Endemic Bird Area (EBA).

4.2.8. Statistical methods

Sites were clustered according to species composition (presence/absence) using the Classic Jaccard similarity index. Cluster analyses and dendrograms were generated in SPSS version 12.0 using data from all WWF KICDP surveys and surveys conducted by Iain Woxvold and Francis Crome in 2005 (Annex 07 to Biodiversity Appendix) and 2008. An agglomerative (hierarchical) clustering method was used with between-groups linkage. For this analysis the swiftlet complex *Aerodramus hirundinaceus*, *A. vanikorensis* and *A. nuditarus* was combined as a single entity (*A. hirundinaceus/vanikorensis/nuditarus*) due to the similar ecological requirements and the difficulty in identifying these birds to the species level in the field. By contrast, goshawks (*Accipiter* sp.), *Meliphaga* honeyeaters and the manucodes *Manucodia atra* and *M. chalybata* not identified to species level were removed from the data set prior to performing cluster analysis.

5. Results of the 2008 surveys

All species recorded during the 2008 surveys are presented in **Appendix 1** together with their conservation and residency/migratory status, degree of endemism and habitat preference. In the text below only common names are used; scientific names can be found in **Appendices 1, 2, 3 and 4**.

5.1. Totals

220 bird species from 38 families were recorded during the 2008 surveys.¹ The highest number of species was recorded from Juha North (91) and the fewest at the Deviation Camp (65). 82 to 85 species were recorded at each of the South Karius, Juha South and Baia River camps.

5.2. Mist-netting

A total of 83 birds from 38 species were captured during the study (**Table 3**). Well represented taxonomic groups include the honeyeaters (Meliphagidae: 6 species), mouse-warblers and scrubwrens (Pardalotidae: 6 species), berrypeckers and longbills (Melanocharitidae: 4 species) and the whistlers and allies (Pachycephaline Corvids: 3 species). The most commonly captured species were the Mottle-breasted Honeyeater (9 individuals, 3 sites) and the Buff-faced Scrubwren (8 individuals, 2 sites). The high capture rate of the latter species was due in part to its group-living habits, which led to multiple individuals (up to 4) being caught on some occasions.

The six bird species captured by locals are all targeted by hunters for food and/or decoration. The Dwarf Cassowary chick at South Karius (**Plates 1 & 2**) was being raised as a pet by a family living close to the camp. Among the many other animals captured by local hunters during our survey at South Karius was a specimen of the globally Threatened (VU) Salvadori's Teal (**Plate 3**), a number of Fairy Lorikeets and a Papuan Lorikeet (**Plate 4**) and a Wattled Brush-turkey chick identified to species by its blue facial skin (**Plates 5 & 6**). The Brown-collared Brush-turkey snared at Juha North (**Plates 7 & 8**) represents a significant range extension for this species (see section 9. Species of Particular Interest).

¹ In addition there were hunter reports from Juha North of a frogmouth that may have been a Papuan frogmouth (*Podargus papuensis*) and a manucode (either Crinkle-collared *Manucodia chalybata* or Glossy-mantled *M. atra*) that may or may not represent species already encountered during the surveys. Mixed flocks of starlings ranging in size from pairs to more than 20 birds were commonly observed at Juha North and may have included Metallic Starling (*Aplonis metallica*). Only the Singing and Yellow-eyed Starling were identified with certainty, so that the Metallic Starling has not been included in the survey totals. However, the Metallic Starling is the most common of the three species in the region and was therefore likely to be present in some flocks. The very similar Mountain, Uniform and Bare-legged Swiftlets have here been listed under a single species complex. However, at least two of these species were almost certainly encountered across the wide range of altitudes covered during these surveys. A Uniform Swiftlet was positively identified from morphometric measurements at Juha North. The upper altitudinal limit of this species in New Guinea is quoted at 1,400 m asl (Coates 1990; Chantler and Driessens 2000), so that swiftlets observed at the Deviation Camp were likely Mountain and/or Bare-legged Swiftlets.

At all sites some species were captured that were not recorded by other survey methods (sight or sound). Overall, eight species were confirmed present during the 2008 surveys by mist-netting or trapping only: Wattled Brush-turkey, Emerald Dove, Red-bellied Pitta, Beccari's Scrubwren, Wattled Ploughbill, Russet-tailed Thrush, Fan-tailed Berrypecker and Grey-winged Longbill. In addition, mist-netting enabled the identification of three *Meliphaga* honeyeaters to the species level (Mottle-breasted, Hill-forest and Mimic Honeyeaters) (**Plate 9**). Members of the *Meliphaga* honeyeater complex are notoriously difficult to identify in the field as morphological variation among individuals within a species is often greater than that exhibited between species, and members of separate species often have similar calls (Diamond 1972).

5.3. Interviews

Local hunters recognised at least eight additional species not directly recorded during the 2008 bird surveys: Papuan King-Parrot, White-bibbed Ground-Dove, Orange-bellied Fruit-Dove, Collared Imperial-Pigeon, Long-tailed Shrike, Brown Sicklebill, Ribbon-tailed Astrapia, and Blue Bird-of-paradise.

5.4. Species effort curves

Species discovery curves for each of the five survey sites are shown in **Figure 7**. Variation in survey time influenced the completeness of inventories among sites, with the shorter survey period at the Deviation Camp producing records that fall well short of a full census. However, despite more extensive surveys at other locations, none of the curves approach an asymptote towards the end of the survey period, indicating that a complete inventory was not obtained at any of the sites.

5.5. Migratory and resident species

New Guinea's avifauna includes some 60 migrant species that breed in the northern hemisphere (Eurasia) and around 30 species that breed to the south in Australia and New Zealand. Most migratory species visit New Guinea's coasts and wetlands, including a large number of Eurasian migratory waders (Scolopacidae, Charadriidae) that visit tidal and coastal mudflats during the austral summer (September–April). A smaller number of migrants visit New Guinea's forests and clearings. Most of these breed in Australia and are therefore present from May to October. Such species include the Forest and Sacred Kingfishers, Rainbow Bee-eater, Dollar-bird, Channel-billed Cuckoo, Australian Pratincole, the raptors Australian Kestrel and Australian Hobby, the Black-faced Cuckooshrike, Satin Flycatcher and Tree Martin. Eurasian visitors to New Guinea's forests and clearings include the Oriental/Himalayan Cuckoo and the aerial specialist White-throated Needletail. No forest migrants are IUCN-listed.

Birds recorded in 2008 include 209 breeding resident species, six species with resident populations augmented by seasonal migrants (Slender-billed Cicadabird, Black-winged Monarch, Brush Cuckoo, Spangled Drongo, Rainbow Bee-eater, Dollar-bird) and five species that occur in New Guinea only as non-breeding migrants. All species with both resident and migrant populations in PNG are of Australo-Papuan origin with migrant populations arriving in New Guinea as non-breeding visitors from Australia. Of the five wholly migratory species recorded, the Red-rumped Swallow, Oriental/Himalayan Cuckoo, Common Sandpiper and Grey Wagtail breed in the northern hemisphere and arrive as non-breeding visitors during the austral summer. The Channel-billed Cuckoo breeds in Australia and occurs in New Guinea

mostly during the non-breeding season from April to October. However, Channel-billed Cuckoos have been recorded in New Guinea in all months and though there are no breeding records the species may breed there in small numbers (Coates 1985; Payne 2005).

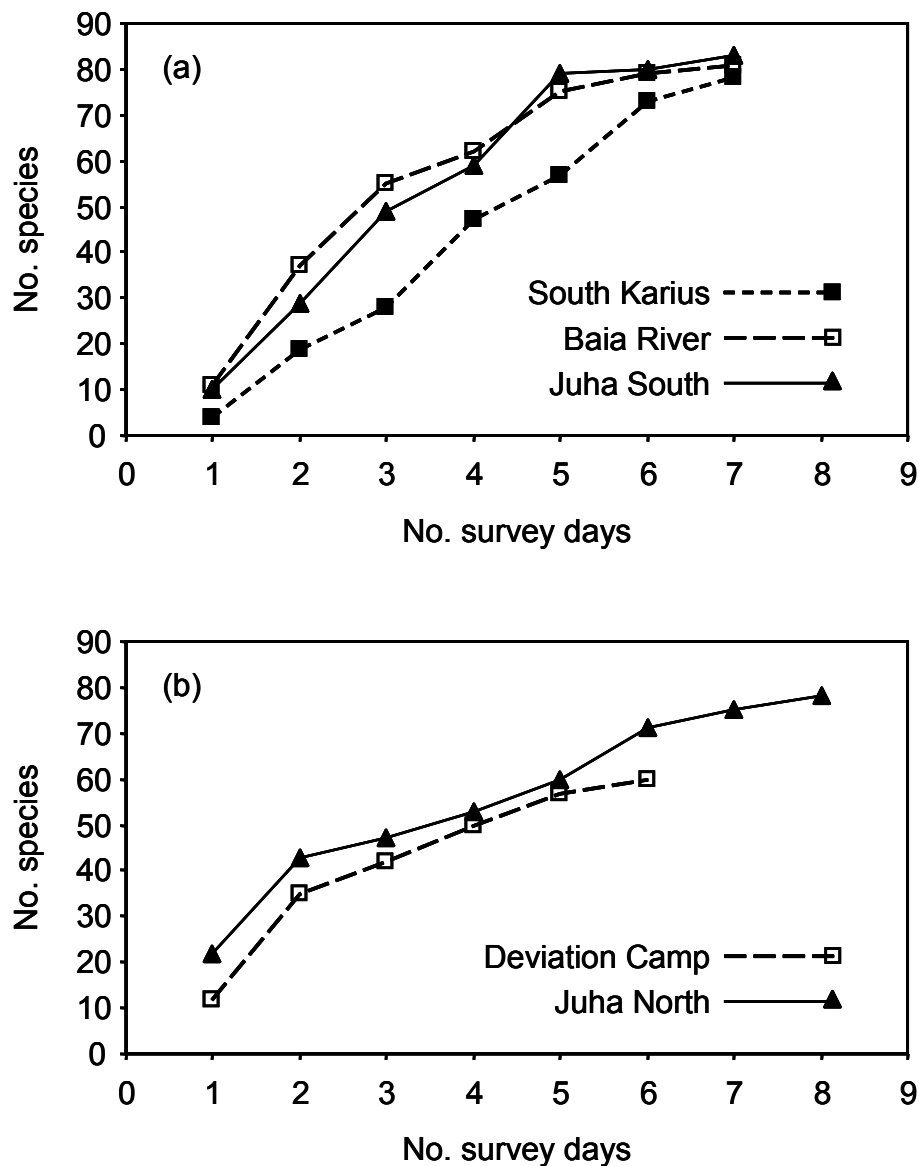


Figure 7 Species discovery curves at the five survey areas. Data include detection of species during active formal surveys (transects), mist-netting and informal observations. Data from hunter interviews excluded.

Table 3 Numbers of birds mist-netted or captured by local hunters (h) at each survey area. Totals are number of species and, in brackets, the number of individuals caught at each site.

Species	Juha Nth	Juha Sth	Baia R.	Sth Karius	Deviation
Dwarf Cassowary				1 (h)	
Wattled Brush-turkey				1 (h)	
Brown-collared Brush-turkey	1 (h)				
Salvadori's Teal				1 (h)	
Fairy Lorikeet				5 (h)	
Papuan Lorikeet				1 (h)	
Uniform Swiftlet	1 (h)				
Stephan's Dove			1		
Superb Fruit-Dove	1				
Red-bellied Pitta		1			
Long-billed Honeyeater	2	2			
Mottle-breasted Honeyeater	3	4	2		
Hill-forest Honeyeater		2			
Mimic Honeyeater	1				
Rufous-backed Honeyeater				1	1
Smoky Honeyeater				1	
Bicolored Mouse-warbler				1	
Mountain Mouse-warbler					1
Tropical / Beccari's Scrubwren				1	
Buff-faced Scrubwren				4	4
Grey-green Scrubwren		3		1	
Papuan Scrubwren					3
Torrent Robin			2		
Blue-grey Robin				1	1
White-rumped Robin		1			
Sclater's Whistler					3
Little Shrike-thrush		1	2		
Wattled Ploughbill					1
Magnificent Bird-of-paradise	1	1			
Black Fantail				1	1
Friendly Fantail					1
Black Monarch				2	
Russet-tailed Thrush		1			
Lemon-breasted Berrypecker		2			1
Fan-tailed Berrypecker					1
Grey-winged Longbill		2		2	
Plumed Longbill		2			
Blue-faced Parrotfinch				1	1
Total	7 (10)	12 (22)	4 (7)	16 (25)	12 (19)

5.6. Habitat preferences

Forest birds comprise the majority of species recorded in 2008 (**Appendix 1**), reflecting the high proportion of forest habitat covered during these surveys. Non-riverine wetlands were not surveyed in 2008. However, all study sites were traversed by permanent rivers or streams, with medium to large rivers present at South Karius, Baia River and Juha North. Only six recorded species were associated with these waterways, including four resident birds (Salvadori's Teal, Forest Bittern, Torrent Robin and Torrent-lark) and two northern hemisphere migrants (Common Sandpiper and Grey Wagtail). Four other non-forest species were dependent on grassland and other disturbed areas (Blue-breasted Quail, Buff-banded Rail, White-shouldered Fairywren and Willie-wagtail).

5.7. Endemic species

PNG (mainland) supports some 18 endemic bird species, six of which were recorded during the 2008 surveys. These include the Rufous-backed Honeyeater and five species of bird-of-paradise: Lawes' Parotia, Ribbon-tailed and Stephanie's Astrapia, Raggiana Bird and Blue Bird-of-paradise. 105 of the 240 or so species endemic to New Guinea and its satellite islands were also recorded in 2008 (**Appendix 1**).

5.8. Threatened and protected species

Twenty-eight species recorded in 2008 are considered to be of global and/or national conservation significance (**Appendix 1**). Twelve species (5.5%) are listed by the IUCN as globally Threatened or Near-threatened, while 24 species (10.9%) are protected under PNG law (**Table 4**). A further 13 species (5.9%) are listed by BirdLife International as restricted to the Central Papuan Mountains EBA (Restricted Range species). Of the five species restricted to the South Papuan Lowlands EBA none were recorded in 2008.

5.9. Inventory completeness

By the end of each survey new bird species were still being recorded daily and species discovery curves had not reached a final asymptote (**Figure 7**). This is a common occurrence in time-restricted rainforest bird surveys, where the elusive nature of many species, heavy rain, seasonal effects and timing all contribute to survey difficulties.

Migratory birds from the northern hemisphere are present mostly between September and April and those from the south from May to October. Thus our April-May surveys coincided with a period of low migrant activity, when most Eurasian visitors had already departed and most southern visitors were yet to arrive. Some migratory species were recorded, though only in small numbers.

In addition, many of New Guinea's resident bird species are to some degree nomadic and/or less detectable at certain times of year. Many resident populations undergo altitudinal and horizontal movements within New Guinea. For instance, frugivores and nectarivores are nomadic to varying degrees and their presence depends upon the seasonality of fruiting and flowering plants. Moreover, some species that may be present all year round are harder to detect at certain times of year, such as many pigeon species that typically cease calling during the wet season.

Table 4 Species of global and/or national conservation significance recorded during the 2008 surveys.

Species	PNG ¹	IUCN ¹	RR ¹
Dwarf Cassowary		NT	
Salvadori's Teal	P	VU	
Blyth's Hornbill	P		
Pesquet's Parrot	P	VU	
Palm Cockatoo	P		
Southern Crowned-Pigeon	P	VU	
New Guinea Eagle	P	VU	
Gurney's Eagle		NT	
Forest Bittern		NT	
Rufous-backed Honeyeater			CPM
Yellow-browed Melidectes			CPM
Wattled Ploughbill			CPM
Yellow-breasted Bird-of-paradise	P	NT	CPM
Loria's Bird-of-paradise	P		CPM
Crinkle-collared Manucode	P		
Trumpet Manucode	P		
Short-tailed Paradigalla	P		CPM
Black Sicklebill	P	VU	
Brown Sicklebill	P		CPM
Superb Bird-of-paradise	P		
Carola's Parotia	P		
Lawes' Parotia	P		CPM
Magnificent Riflebird	P		
Magnificent Bird-of-paradise	P		CPM
King Bird-of-paradise	P		
Ribbon-tailed Astrapia	P	NT	CPM
Stephanie's Astrapia	P		CPM
King-of-Saxony Bird-of-paradise	P		CPM
Raggiana Bird-of-paradise	P		
Blue Bird-of-paradise	P	VU	CPM
Yellow-eyed Starling		NT	

¹ Species are listed as protected (P) under PNG law, IUCN-listed as Vulnerable (VU) or Near-threatened (NT) and/or Restricted Range (RR) species restricted to the Central Papuan Mountains Endemic Bird Area. (See section 4.2.7 for further information on these classifications.)

These phenomena are relatively well understood in Asia (McClure 1974) and Australia (Crome 1993; Nix 1993), though they have not been studied to the same extent in PNG. Nevertheless, repeated surveys at single locations have consistently shown that the number and variety of resident birds detected varies strongly both within and between years (e.g. Beehler et al. 1995; Diamond and Bishop 2003). Between 1998 and 2003, Diamond and

Bishop (2003) conducted a series of surveys at the same locations within the KICDP at different times of the year. They observed significant seasonal changes in the number and behaviour (calls and flocking) of a variety of forest-dwelling birds. They concluded that differences in abundance and detectability were not simply due to predictable seasonal changes repeated annually, but also to significant variation between years, since the greatest difference was observed between surveys conducted in April-May 1998 and April-May 2003.

Despite these issues, which are characteristic of all rainforest bird censuses, the data generated during the surveys was of sufficient intensity and quality to provide an excellent basis for impact assessment of the PNG LNG Project. This is evidenced by the fact that the survey recorded nearly half (45.6%) of PNG's resident avifauna (i.e. excluding migrants, waterbirds and coastal species). Although some species will have been missed this report also includes in the impact assessment species that, while not detected on the survey, could occur based on the knowledge of the distribution and habitat preferences of PNG's birds, thus providing an exhaustive analysis.

6. Species richness and community composition – overall PNG LNG Project Upstream Project Area

6.1. Species recorded in the overall project area

Appendices 2 and 3 list all species observed at various sites within the upstream portion of the Project Area since 1995 and prior to the 2008 surveys using the data contained in the references in Table 1. **Appendix 2** lists those species recorded at lowland sites (below 300 m asl) and **Appendix 3** those species recorded in hill-forest or montane sites (≥ 400 m asl).

A total of 389 species of birds from 212 genera and 55 families were recorded in the Project Area between 1995 and 2008, 52.6% of the approximately 740 species recorded in PNG (Coates 1985). Seventeen of these species are listed by the IUCN as globally Threatened, Near-threatened or Data Deficient, seven of which were not recorded in 2008 (**Table 5**).

Ten species recorded in 2008 were not recorded in the Project Area between 1995 and 2005: Salvadori's Teal (VU), Emerald Dove, White-bibbed Ground-dove, Forest Bittern (NT), Bicolored Mouse-warbler, Singing Starling, Red-rumped Swallow, Tawny Grassbird, Torrent Lark and Spotted Berrypecker.²

Table 5 IUCN-listed bird species recorded within PNG LNG Project Upstream Project Area between 1995 and 2005 but not recorded in 2008.

Species	IUCN status	# of sites at which recorded		Altitude range (m)	
		Lowland	Upland	Lower	Upper
Southern Cassowary	VU	5	3	0	1100
Blue-black Kingfisher	DD	1	0	0	600
Striated Lorikeet	NT	0	2	80	1800
New Guinea Flightless Rail	NT	2	1	0	400
Asian Dowitcher	NT	1	0	0	10
Beach Thick-knee	NT	1	0	0	10
Olive-yellow Robin	NT	0	3	100	1450

6.2. Additional species not yet recorded

Excluding rare migrants, an additional 62 species that have not yet been recorded within the Project Area may be expected to occur in light of available information regarding distribution and habitat preference. These species are listed in **Appendix 4** together with their IUCN status and altitudinal limits.

² At least one of these, the White-bibbed Ground-dove, was recorded previously in the Lake Kutubu area by Richard Schodde in 1961 (Schodde and Hitchcock 1968, in Diamond and Bishop 2003).

Eleven species in **Appendix 4** are of global or national conservation significance, with nine listed by the IUCN as Data Deficient (six species) or Near-threatened, and two species protected under PNG law (Crested and Greater Bird-of-paradise). Sixteen species are restricted to the Central Papuan Mountains EBA, and three are endemic to the South Papuan Lowlands. Fifty-six species (90.3%) are New Guinea residents, 38 of which (61.3%) rely on forest habitat. Nine species occur in New Guinea only as regular non-breeding migrants and 24 species utilise wetland and/or open and disturbed habitats.

More than 50 seabirds and other species restricted to coastal wetland and wooded habitats have not yet been recorded in the Project Area but may occur in the southern parts of the Project Area. These are not included in **Appendix 4** as none of these habitats will be impacted by developments.

6.3. Overall community composition

The overall Project Area covers a wide variety of ecological regions, including Lake Kutubu and associated wetlands, numerous rivers and streams, coastal mudflats and mangrove forest, swamp forests and large tracts of rainforest of several types. It covers a wide elevational range (0–2,700 m asl) and varying geomorphologies and soil types. This and the fact that much of the rainforest remains undisturbed accounts for the high species richness recorded in the Project Area.

Forest birds comprise the majority of species recorded, particularly the passerines ('perching birds'). Many of the passerine families recorded in the area belong to a larger group with its centre of evolution based around the Australo-Papuan region. Of these, notable families with several species recorded in the area include four species of fairywrens (Maluridae), 32 honeyeaters (Meliphagidae), 17 gerygones and scrubwrens (Pardalotidae) and 17 'Australian robins' (Petroicidae). Also included is the Corvidae, a large passerine family with 88 species recorded within the Project Area. In its current form, the Corvidae comprises a number of taxa until recently identified as separate families, and includes the jewel-babblers (three species), whistlers and allies (15 species), birds-of-paradise (20 species), cuckooshrikes (13 species), fantails (11 species) and monarch flycatchers (9 species).

Of particular note is the high diversity of birds-of-paradise recorded in the region. Excluding the taxonomically difficult Greater Melampitta (*Melampitta gigantea*), the Project Area supports at least half of the 40 extant species (Coates 1990), and nearly two-thirds of the 31 species recorded in PNG. Many have restricted distributions (total area and/or altitude), and a number are of international conservation significance (Appendix 1). All birds-of-paradise are protected under PNG law.

A number of non-passerine forest-dwelling taxa are also well represented, including 29 parrots, lorries and cockatoos (Psittacidae), 30 pigeons and doves (Columbidae), raptors (15 Accipitridae and 5 Falconidae), 11 night birds (Tytonidae, Strigidae, Aegothelidae, Podargidae, Eurostopodidae and Caprimulgidae), 8 Dacelonid kingfishers (Dacelonidae), 12 cuckoos (Cuculidae and Centropodidae) and the large, ground-dwelling cassowaries (Casuariidae - 2 species) and megapodes (Megapodiidae - 5 species).

Like the passerines, the high species richness of many of the non-passerine forest birds reflects a long history in the region. In particular, relative to ecologically similar regions in other parts of the world, New Guinea's rainforests support a high proportion of near-obligate frugivores and nectarivores (Beehler et al. 1986). There are 16 species of fruit-doves

(*Ptilonopus*) and imperial-pigeons (*Ducula*), all specialist fruit eaters and important dispersers of seeds from a large number of rainforest tree species, and 14 species of brush-tongued lorries and lorikeets which feed almost exclusively on nectar and pollen and are significant pollinators in the rainforest ecosystem.

While the forest species are the most obvious component of the avifauna, a wide range of wetland species have also been recorded in the Project Area. Well-represented taxa include the 7 species of rails and crakes (Rallidae), 23 shorebird species (curlews, sandpipers and plovers - Scolopacidae and Charadriidae), 12 species of herons and egrets (Ardeidae), and 11 species of the predominantly marine gulls and terns (Lariidae). Interestingly, other water birds such as ducks and geese, alcedinid kingfishers, darters, cormorants, pelicans and ibis are not so diverse or abundant.

7. 2008 Survey Area Summaries

7.1. Relationship of avifauna at the 2008 Survey Areas and other sites in the PNG-LNG Project Upstream Project Area.

Figure 8 shows how the various sites surveyed within the Project Area cluster according to the degree of similarity in their bird community structure. This cluster analysis provides a useful tool with which to discuss the nature of the bird communities recorded at each site surveyed in 2008, and to construct a more complete picture of the bird communities likely to be supported in the Project Area.

For purposes of discussion, survey sites displayed in the dendrogram in **Figure 8** can be divided into the following three important groups:

- 'Upland sites' - the cluster of seven sites from Mt Bosavi to South Karius, all of which are low to mid montane sites at altitudes ranging from 950 to more than 2,200 m asl;
- The 20 sites displayed above Mt Bosavi in **Figure 8**, from Gobe to Utiti Creek;
- The out-group of five sites shown at the bottom of **Figure 8**, from Agogo to Keboi Kerowa. These sites placed separately because their results comprised lists of less than 15 bird species (Agogo, Veriabari, Iviri, Keboi Kerowa) or because a heavy focus on shorebirds and oceanic species produced a strongly distinct species composition (Cape Blackwood). These sites are excluded from the following discussion.

7.2. Lowland sites - Baia River and Juha North

Baia River and Juha North were the only two lowland sites surveyed in 2008. The range of altitudes covered at each site was very similar, with all surveys taking place between 200 and 450 m asl. Accordingly, lowland vegetation was a dominant component of the habitat at these sites. However, while Baia River was characterised exclusively by lowland flora, a number of plant groups present at Juha North are normally found only in montane areas above 1,000 m asl, including many species of Ericaceae, Myrsinaceae and Myrtaceae.

Despite these floristic differences, the cluster analysis grouped the bird communities documented at Baia River and Juha North closer to one another than to the avifauna at any other sites within the greater PNG LNG Project Upstream Project Area. Of the 125 species recorded at these sites 40% were found at both.

Of the group of 20 sites displayed above the montane cluster in **Figure 8**, 13 other sites included habitat surveyed below 500 m asl. Eight species recorded at Baia River and Juha North were not found at these other lowland sites: Forest Bittern, Gurney's Eagle, Brown-collared Brush-turkey, New Guinea Scrubfowl, White-bibbed Ground-Dove, Slender-billed Cicadabird, Red-rumped Swallow and Singing Starling. Some of these are uncommon or rarely observed (e.g. Forest Bittern, Red-rumped Swallow), while records of the Brown-collared Brush-turkey and New Guinea Scrubfowl at these sites represent significant range extensions for these species.

By contrast, some 158 species found at the other lowland sites were not recorded at Baia River or Juha North. Forty of these (25.3%) are wetland or marine coastal species not likely to be found in the interior forests of the Project Area. Another 23 (14.6%) normally have a low

altitudinal limit that is above 500 m asl. These species are only occasionally found in the lowlands, and most were recorded at higher altitudes during these surveys³. Many of the remaining 95 species may be found in the lowlands of the Juha gas fields. These include six kingfisher species, seven cuckoos, 10 parrots and lorikeets, five pigeons and doves, nine diurnal birds of prey and 43 passerines including 10 honeyeaters and seven fantails and monarch flycatchers.

7.2.1. Baia River

Of the 82 species recorded at Baia River, 12 (14.6%) are of global and/or national conservation significance, including five listed by the IUCN as Vulnerable (Pesquet's Parrot, Southern-Crowned Pigeon) or Near-threatened (Dwarf Cassowary, Gurney's Eagle and Forest Bittern), nine species protected under PNG law and one species endemic to the CPM EBA (Magnificent Bird-of-paradise). Two species, the Emerald Dove and Forest Bittern, have not been recorded elsewhere in the Project Area.

The Baia River camp was situated some distance from human settlement, with residents of the nearest village taking two days to arrive at camp by foot. Accordingly, a number of commonly hunted taxa prone to local extinction in settled areas were found in good numbers at Baia River. Notably, a variety of large ground-foraging pigeon species were recorded, including Thick-billed Ground-Pigeon, Pheasant Pigeon and the Southern Crowned-Pigeon (VU). The latter species, the world's largest pigeon, is highly sought after and vulnerable to hunting.

Despite this apparent lack of hunting pressure, bird species richness was low at Baia River with fewer species recorded there than at the lower montane sites of South Karius and Juha South. This result was unexpected given that tropical bird diversity is typically highest at low elevations. In addition to low species counts from direct observations, Baia River yielded the lowest mist-net capture rate of all sites in 2008, with only seven individuals from four species netted. Low species richness was also recorded among other taxa at Baia River, including mammals, reptiles, amphibians, fish and plants.

It seems likely that the unexpectedly low bird species richness and abundance at Baia River represents another example of the well-documented patchiness of bird distributions in New Guinea that may have been driven by survey timing (seasonality) and/or the characteristics of the specific habitats surveyed at these sites. For example, forest structure and floristic diversity around the Baia River camp were apparently greatly affected by natural, high-level disturbance from periodic flooding and frequent landslides from the adjacent escarpment. Bird diversity is expected to be higher in the immediate vicinity, though many additional species may be largely restricted to more stable (and floristically diverse) habitats that were difficult to access from the riverside campsite, including the plateaus on top of the escarpment.

³ Surveys at Darai Plateau, Libano Sok and Gobe all covered habitat above 500 m asl. Surveys at Darai Plateau reached as high as 700 m asl.

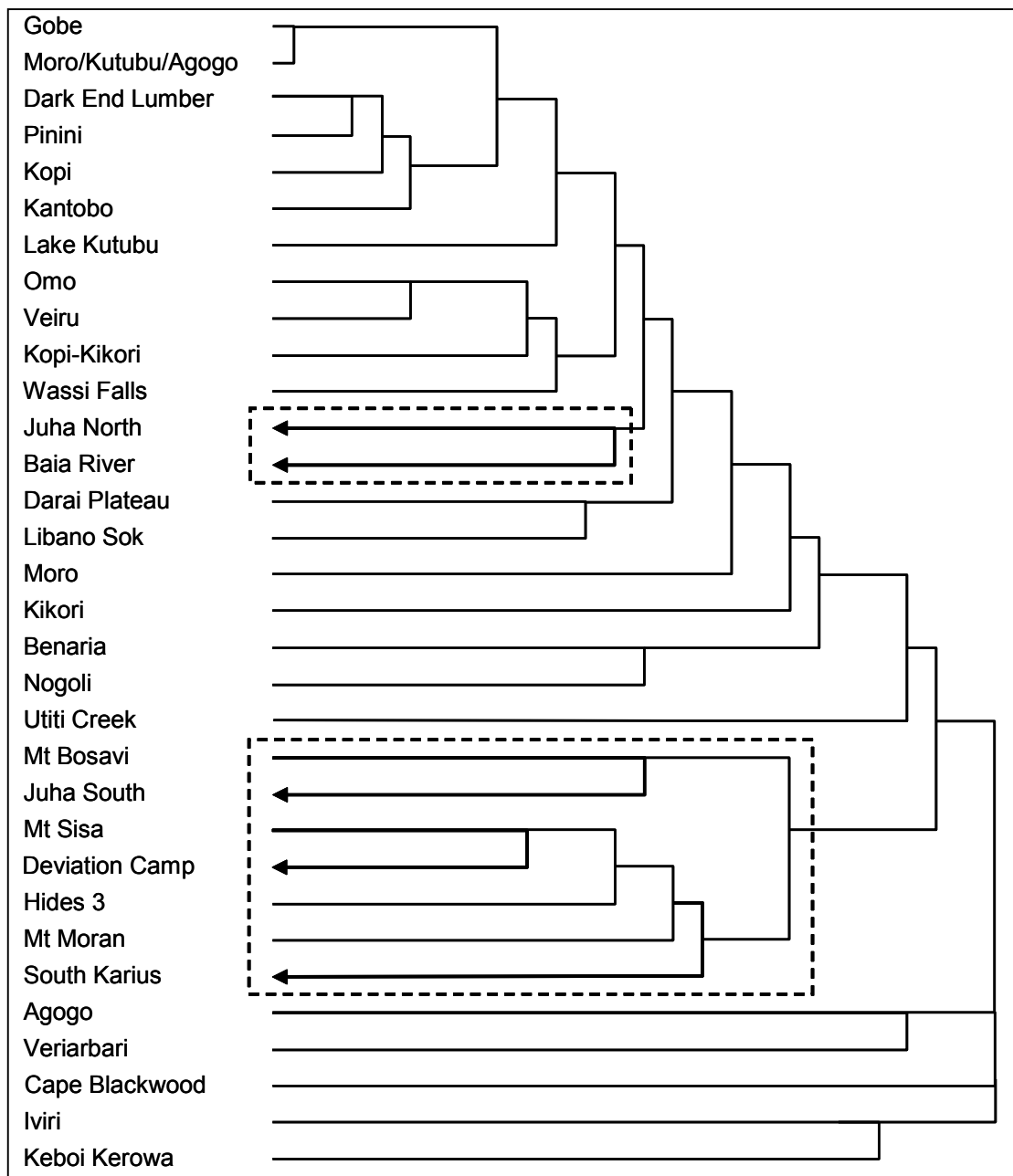


Figure 8 Dendrogram showing similarity between all 32 sites surveyed in the PNG LNG Project Upstream Project Area between 1995 and 2008 based on bird species composition. Arrowheads show those sites surveyed in 2008. Dashed boxes show the major clusters containing the 2008 survey sites. The dendrogram was produced using an agglomerative (hierarchical) clustering method with between-groups linkage. The depth of branching between adjacent sites/clusters is inversely related to their degree of similarity.

7.2.2. Juha North

Of the 91 species recorded at Juha North, 11 (12.1%) are of global and/or national conservation significance, including four listed by the IUCN as Vulnerable (Pesquet's parrot, Southern-Crowned Pigeon) or Near-threatened (Dwarf Cassowary, Yellow-Eyed Starling), nine species protected under PNG law and one species endemic to the CPM EBA (Magnificent Bird-of-paradise). Three species recorded at Juha North have not been recorded elsewhere in the Project Area (White-bibbed Ground-Dove, Singing Starling and Red-rumped Swallow).

The area around Juha North is lightly populated, with some local residents able to reach the camp on foot within a few hours. However, population density in this area is still very low, and though the forests around the camp are actively hunted they still include good numbers of a variety of commonly targeted bird species, including Dwarf Cassowary, Brown-collared Brush-turkey, a variety of imperial-pigeon species, Raggiana, Magnificent and King Birds-of-paradise.

An interesting representation of birds from different guilds was recorded at Juha North, with species richness and abundance notably high for some guilds and poor for others.

The timing of the survey at Juha North coincided with the presence of a variety of pigeons and parrots. Many of these species are subject to seasonal nomadic movements and may be present at some times and not at others, following seasonal patterns of flowering and fruiting trees. During the surveys understorey trees were fruiting more than canopy trees, though figs (*Ficus* spp.) do not follow strong seasonal patterns, with some trees in fruit within an area at most or all times of year.

Numerous species of pigeons were seen and heard, some of which were clearly present in good numbers. Communal gathering trees near a drinking area at the base of the large waterfall were used by pigeons throughout each day and provided excellent views of a variety of pigeons, with more than 120 Pinon Imperial Pigeons and Ornate Fruit-Doves seen together on some occasions. Despite these numbers, Pinon Imperial Pigeons were not seen or heard in the surrounding forest, suggesting the drinking area may attract birds from some distance and/or that this species calls infrequently at this time of year. A number of columbids are known to be less vocal at certain times of year (Diamond and Bishop 2003). However, Great Cuckoo-Doves and Beautiful and Superb Fruit-Doves were commonly heard in the forest. An active nest of the Superb Fruit-Dove was located on transect 2 (Fig. 5), and a single bird was mist-netted in ridge forest on track 1 (**Plate 10**).

Ten species of parrots (parrots, lorries, lorikeets, etc.) and cockatoos were also recorded, with a number of others no doubt remaining undetected. Smaller species such as the fig-parrots and pygmy-parrots can be difficult to detect and/or identify in the field unless feeding or roosting trees are located in an accessible area. An experienced local hunter indicated that a number of these species were common in the area.

Interesting was the absence of many insectivorous passerines common in lowland forests of New Guinea. Moreover, those that were recorded appeared either to be inconspicuous or present in very low numbers. A single monarch (Spot-winged) was observed and one fantail (Sooty Thicket-Fantail) heard on one occasion. No robins or smaller cuckoos (*Chrysococcyx*) were found. One pair of Pale-billed Scrubwrens was seen at 400 m asl at the end of track 2a (Fig. 5). Pitohuis and whistlers common and vocal at Baia River were heard and observed infrequently and in restricted areas.

As observed at Baia River, mist-netting results were consistent with these observations, with only eight individuals from five species captured in mist-nets. Of these, two species (Superb Fruit-Dove and Magnificent Bird-of-paradise) include a significant proportion of fruit in their diet.

Interestingly, the large waterfall may have contributed to an unusual habitat for this elevation. Vegetation in the valley around this large waterfall was covered in large amounts of moss normally seen only at much higher altitudes. Moreover, a number of montane plant species

normally found only above 1,000 m asl were recorded (W. Takeuchi, pers. comm.). The cool montane waters bursting straight from the limestone directly above the waterfall may have helped create a microclimate conducive to this habitat.

The structure of the local bird community reflected this pattern to some degree, with a number of bird species being recorded that are normally found at higher elevations. For example, the Brown-collared Brush-turkey and New Guinea Scrubfowl are largely restricted to northern New Guinea, with previous records of these species on the southern slopes of the central range restricted to three or four localities above 750 m asl (Jones et al. 1995). Other birds of Juha North normally found at higher elevations include the Blue-collared Parrot, Mottled-breasted Honeyeater, Magnificent Bird-of-paradise and Blue-faced Parrotfinch.

7.3. Upland sites: South Karius, Juha South and the Deviation Camp

Figure 8 shows that, in terms of bird community structure, all three lower and mid montane sites surveyed in 2008 are most similar to the four sites above 1,500 m asl surveyed between 1995 and 2005: Mt Bosavi, Mt Sisa, Mt Moran and Hides 3. Within this cluster, the avifaunas recorded at the Deviation Camp survey area and Mt Sisa were most similar, with 50% of their bird species found at both sites. The bird community at Juha South was most similar to that found on Mt Bosavi; 38% of their combined species list was found at both sites.

Forty-two species recorded at the three upland sites in 2008 were not recorded at the other four high altitude sites. Similarly, 49 species previously recorded at the other upland sites have not been recorded but may occur in upland areas along the Juha to Hides Gas Pipeline and Homa Deviation, including five parrots and lorikeets, four pigeons and doves, eight honeyeaters, four robins and five whistlers and pitohuis. Taken together, the 205 species recorded at the seven high altitude sites provide a reasonably thorough inventory of high altitude species (lower to mid montane) likely to be encountered throughout the upstream portion of the Project Area.

7.3.1. South Karius

Of the 85 species recorded at South Karius, 16 (18.8%) are of global and/or national conservation significance, including seven listed by the IUCN as Vulnerable (Salvadori's Teal, Pesquet's parrot, Black Sicklebill and Blue Bird-of-paradise) or Near-threatened (Dwarf Cassowary, Yellow-breasted Bird-of-paradise and Ribbon-tailed Astrapia), 13 species protected under PNG law and nine species endemic to the CPM EBA. Five species recorded at South Karius had not been previously recorded in the Project Area (Salvadori's Teal, Bicolored Mouse-warbler, Tawny Grassbird, Torrent-lark and Spotted Berrypecker).

Mammals and birds are being heavily hunted around South Karius. During our surveys a variety of animals were being held or brought into camp, captured by hunters and hired assistants for both food and decorative purposes. These included tree kangaroos, cuscus, Dwarf Cassowary (**Plates 1 & 2**), Wattled Brush-turkey (**Plates 5 & 6**), Papuan and Fairy Lorikeets (**Plate 4**) and the globally Threatened Salvadori's Teal (VU) (**Plate 3**). Not surprisingly, discussion with local hunters revealed that birds-of-paradise, scrubfowl and the eggs of a variety of megapode species are also harvested in the area.

Despite this heavy local hunting pressure, a number of commonly targeted bird species were frequently encountered, including Pesquet's Parrot (VU), Sulphur-crested Cockatoo and many birds-of-paradise. Of all sites surveyed in 2008, the abundance and species richness of birds-

of-paradise was highest at South Karius with nine species recorded in good numbers and two additional species claimed by local hunters to be present in the area. These include the Yellow-breasted (NT), Loria's, Superb and King-of-Saxony Birds-of-paradise, the Ribbon-tailed Astrapia (NT), Short-tailed Paradigalla, Carola's and Lawes' Parotias and two Vulnerable species, the Blue Bird-of-paradise and Black Sicklebill. Most of these species are actively hunted for their plumage.

The persistence of these species under the present degree of hunting pressure, and the ease with which many were observed, is considered due to the area being only recently settled. An experienced local hunter assisting our team was apparently the first to settle in the area with his family (**Plate 2**). If the current level of hunting is maintained, as seems likely, then many of these species may eventually be extirpated from the local area. Their current diversity serves as an indicator of what may be found at similar altitudes throughout the Project Area in the absence of hunting and human settlement.

7.3.2. Juha South

Of the 83 species recorded at Juha South, 9 (10.8%) are of global and/or national conservation significance, including three listed by the IUCN as Vulnerable (Pesquet's parrot and New Guinea Eagle) or Near-threatened (Dwarf Cassowary), eight species protected under PNG law and one species endemic to the CPM EBA (Magnificent Bird-of-paradise). All species recorded at Juha South have been recorded previously within the Project Area.

Juha South yielded among the highest number of bird species directly encountered during the 2008 surveys; local residents stated they did not come to the area to hunt, and thus were not interviewed about the presence of additional species at this site. Moreover, this level of diversity was recorded despite heavy rain preventing surveys on all but one morning, the most profitable time in which to survey birds. Overall species richness is therefore expected to be higher at this site with some species remaining undetected due to restricted sampling time.

A variety of cuscus and tree kangaroo were seen daily within 500 m of the Juha South survey area, consistent with the remoteness and apparent lack of hunting at this site. The ease with which these commonly hunted species were observed is rarely experienced in PNG forests. Accordingly, a number of birds highly sought after for their meat and plumes were also seen at Juha South, including the Dwarf Cassowary, New Guinea Scrubfowl, New Guinea Eagle, Long-tailed Honey-buzzard, Pesquet's Parrot, Palm and Sulphur-crested Cockatoos.

A wide variety of terrestrial bird species was also recorded at Juha South. In addition to the cassowary and scrubfowl mentioned above, these included the Cinnamon Ground-Dove, Forbes' Forest-Rail, Red-bellied Pitta, Northern Scrub-Robin, Chestnut-backed Jewel-babbler and Russet-tailed Thrush. As well as being susceptible to hunting (snare, dogs, etc.), terrestrial bird species, particularly insectivores such as rails, pittas, scrub-robins, jewel-babblers and thrushes, are often intolerant of disturbance to their forest habitat through processes such as logging. Thus the large number of terrestrial species recorded at Juha South further indicates the intact nature of this site's remote forests.

Despite the low hunting pressure and undisturbed nature of the forests at Juha South, the richness and diversity of birds-of-paradise was relatively low at this site, with only five species recorded (Crinkle-collared Manucode, Carola's Parotia, Magnificent Riflebird, Magnificent and Raggiana Birds-of-paradise).

The higher bird diversity at this site may be explained by the presence of both lowland and montane species in these intact mid-altitude forests. This pattern was mirrored in the high plant species richness recorded at Juha South, with both lowland and montane elements contributing to the floristic diversity (W. Takeuchi, pers. comm.).

7.3.3. Deviation Camp

Of the 65 species recorded at the Deviation Camp survey area, 10 (15.4%) are of global and/or national conservation significance, including one Near-threatened species (Dwarf Cassowary), six species protected under PNG law and eight species endemic to the CPM EBA. All species recorded at the Deviation Camp survey area have been recorded previously at other sites in the Project Area.

Surveys at the Deviation Camp survey area were conducted at higher altitudes than all other sites in 2008. Only two other surveys have been conducted at comparable altitudes within the Project Area, on Mt Sisa in 1999 and the Hides range in 2005. Consistent with the restricted elevation ranges of many montane bird species, **Figure 8** shows that the bird community recorded at the Deviation Camp was most similar to those recorded at Mt Sisa and Hides 3.

Woxvold and Crome (2005 Annex 07 to Biodiversity Appendix) also recorded 65 species at Hides 3, while Diamond and Bishop (2000) recorded a total of 85 species on Mt Sisa. The higher species count at Mt Sisa is likely to be partly due to the greater altitude range sampled there. Diamond and Bishop surveyed from two camps separated by more than 700 m elevation (1840-2560 m), exposing them to a wider variety of montane species than were encountered either at Hides 3 (2,163–2,400 m asl) or the Deviation Camp survey area (1,990–2,180 m asl).

The combined total number of species for the Deviation Camp, Hides 3 and Mt Sisa is 114. Eleven of these were only recorded at the Deviation Camp, 19 only on Mt Sisa and 16 only at Hides 3. Twenty-six of these species have not been reported elsewhere in the Project Area, demonstrating the significance of the unique avifaunal communities present in these high altitude forests.

The birds-of-paradise are a significant component of upland bird communities. Diamond and Bishop recorded nine species on Mt Sisa, eight of which were also seen at Hides 3, comprising 12.3% of the avian biodiversity recorded there in 2005 (Woxvold and Crome 2005 Annex 07 to Biodiversity Appendix). By contrast, only four species were directly encountered at the Deviation Camp in 2008: Loria's Bird-of-paradise, Short-tailed Paradigalla, Superb Bird-of-paradise and Stephanie's Astrapia. Another two species, the Brown Sicklebill and King-of-Saxony Bird-of-paradise, were well known to local hunters who stated they do occur at the site. Other species recorded at Mt Sisa and at Hides 3 may also be expected to occur along the currently proposed route of the pipeline deviation, including the Yellow-breasted Bird-of-paradise, Black Sicklebill, Lawes' Parotia and the Ribbon-tailed Astrapia. Local hunters stated that the latter species is not present in the immediate vicinity of the Deviation Camp, but is found further north near Ambua Lodge in the Tari Gap area. One female-plumaged astrapia observed at the Deviation Camp had noticeably white ventral tail feathers, suggesting the possibility of a Ribbon-tailed x Stephanie's Astrapia hybrid (= 'Barnes' Astrapia'). These species are known to interbreed in their limited area of overlap, with hybrid offspring successfully reproducing and back-crossing with parental forms, resulting in considerable variation of hybrid morphologies in the field (Frith and Beehler 1998).

8. Threatened and protected species

The species discussed below include those IUCN-listed (Threatened, Near-threatened or Data Deficient) or nationally protected birds already recorded or that are likely to occur in the Project Area. The accounts covers all listed species presented in **Table 4** and in **Appendices 2 and 3** i.e. all listed species recorded from 1995 to 2008.

The accounts include current knowledge on habitat requirements, status and distribution, and likely impacts on populations associated with development of the PNG LNG Project. The categories of impact magnitude follow those criteria and definitions set out below in **Table 6**. Mitigation measures and management practices recommended to help maintain their populations within the Project Area are discussed separately. Rare species or otherwise unusual sightings (range extensions, etc.) are also discussed separately (9. Other Notable Records). The species are treated in taxonomic order.

Table 6 Magnitude of impact on individual taxa associated with development of the PNG LNG Project.

Category	Description
Very High (VH)	Impact likely to have severe impact on population, community or ecosystem survival and health, possibly even leading to extinction or system collapse. Impact is widespread effecting > 10% of KICDP area up to national scale. Recovery, if possible, is likely to take more than 25 years.
High (H)	Likely to have large negative impact on population, community or ecosystem survival or health. Impact is regional effecting up to 10% of KICDP area. Recovery, if possible is likely to take up to 25 years.
Medium (M)	Effect will be detectable but not severe; populations or the areal extent of communities may be reduced but unlikely to lead to major changes to population, community or ecosystem survival to population, community or ecosystem survival or health. Generally occurring within 10 km of impact site. Recovery is likely to take up to 7 years.
Low (L)	Effect may be detectable but is small and highly unlikely to have any significance. Effects immediate surrounds of impact and extends for up to 2 km radius. Recovery short term up to 3 years.
Positive (P)	Change is likely to benefit the population, community or ecosystem.

8.1. Cassowaries (Casuariidae)

The **Southern Cassowary (VU)** is a solitary and sedentary lowland rainforest inhabitant. It was not recorded in 2008, but is known from a number of lowland sites in the Project Area (Appendix 2), and may occur at lower elevations in the Juha gas fields. It is listed as Threatened largely because of a severe decline in the Australian population caused predominantly by forest clearance in recent decades. In New Guinea cassowaries are of great cultural importance and constitute a major source of protein for subsistence communities throughout the island. As a result they have been locally extirpated from many settled areas (Coates 1985; Beehler et al. 1986). Increased hunting may occur as a result of indirect impacts through increased public access to the area. Indirect impacts on this species could

thus be high. By contrast, this species is tolerant of moderate habitat disturbance. It is unlikely to be impacted by forest disturbance associated with the project.

As with the previous species, the **Dwarf Cassowary (NT)** is also of important cultural and food value for local inhabitants throughout much of the Project Area. It has a much broader elevation range than the Southern Cassowary, and is found from the lowlands to montane areas over 3,000 m asl. It is therefore a favoured target of local hunters throughout most of the Project Area. It was recorded at all sites in 2008, with individuals observed at South Karius and Juha North, and footprints and or scats found at all other sites. At South Karius a chick was being raised as a family pet (**Plates 1 & 2**), to be sold as an adult for around 250 PNG Kina. It is also known from a wide range of other localities surveyed previously in the Project Area. Threats and impacts are the same as those described for the Southern Cassowary.

8.2. Hornbills (Bucerotidae)

Blyth's Hornbill (P) is the only hornbill species in New Guinea. Hornbills are sensitive to a wide range of threats. They require large areas of habitat with ample supply of fruiting trees and trees with large nesting holes, and most species occur in low densities and reproduce slowly (Kemp 1995; Bennett et al. 1997; Kinnaird and O'Brien 2007). This suite of requirements makes hornbills particularly sensitive to habitat degradation and fragmentation through logging, shifting cultivation and clearance for agriculture. In addition, as with many species in Southeast Asia, Blyth's Hornbills are hunted for food and ornamental use or to be kept as pets. Blyth's Hornbill is protected under PNG law.

Blyth's Hornbill singles and pairs were seen at both lowland sites in 2008 (Baia River and Juha North), and have been recorded at 18 other sites during previous surveys. They are not listed under the IUCN Red-list of threatened species, and their status in PNG is secure, particularly given that the island boasts the largest contiguous area of forest in the Asian hornbill realm (Kinnaird and O'Brien 2007). The ecology and threats facing Blyth's Hornbill are similar in character to those of Pesquet's Parrot (8.4. Parrots and Lorikeets), although the impacts of the project are expected to be lower on Blyth's Hornbill.

8.3. Kingfishers (Alcedinidae & Dacelonidae)

The **Blue-black Kingfisher (DD)** is a rare and little-known species endemic to New Guinea and some satellite islands. It is known from only a few widely scattered lowland locations (<600 m asl) where it inhabits forest near streams and ponds. This species was observed by Diamond and Bishop in the Project Area in mangrove forest of the Kikori River delta in 1999 (Diamond and Bishop 2000). There is no evidence of hunting of this species with the main threat likely to be habitat loss. Considering the species is broadly (though sparsely) distributed, and that the linear construction of the pipeline is unlikely to eliminate whole territories of individuals, the direct impact of the project on populations of these species is likely to be low.

If project development increases human accessibility to remote lowland forest indirect impacts through clearance for settlement and/or logging, both legitimate and illegal, may prove a significant threat.

8.4. Parrots and Lorikeets (Psittacidae)

The **Striated Lorikeet (NT)** is a rare New Guinea endemic. It is primarily an Indonesian species, being restricted to western New Guinea, and in PNG it is known from only a few sites including the upper Fly River area near Ok Tedi (Gregory 1995). In the Project Area it has been recorded at Moro and Gobe (Diamond and Bishop 2003). Though it appears to have a small and nomadic population, it is likely to be tolerant of moderate habitat disturbance, though it may be susceptible to hunting by villagers who often target lorikeets for their plumes (**Plate 4**).

The unusual **Pesquet's Parrot (VU)** is a New Guinea endemic that inhabits hill and montane forest where it is a nomadic and specialist frugivore feeding on a select variety of figs (Mack and Wright 1998). Pesquet's Parrot is heavily hunted for its plumes which are used for traditional ceremonial ornamentation. As with a number of larger parrots and cockatoos, large trees with nest hollows are cut down to access nestlings, restricting the availability of nesting habitat in settled areas. Mack and Wright (1998) show how hunting has seriously impacted on Pesquet's Parrot which has been historically and recently extirpated from large areas, particularly in PNG (Coates 1985; Mack and Wright 1998).

The Project Area appears to represent a stronghold for this species. In 2008 it was recorded at all sites except the Deviation Camp, and it has been recorded in at least 15 sites surveyed previously. In the absence of hunting, this species is tolerant of moderate habitat disturbance as evidenced by its abundance around the oil project facilities. Impacts from forest disturbance during project development are likely to be low. Increased hunting may occur as the result of indirect impacts through increased public access to the area. Indirect impacts on this species could be high, potentially resulting in local extinctions.

8.5. Nightbirds (Owls, Frogmouths, Nightjars, Owlet-nightjars)

The **Papuan Hawk-Owl (DD)** is a rare and little known endemic to New Guinea and Yapen Island, inhabiting rainforest and gallery forest in savanna. It is known from only nine locations, all below 1,500 m (Beehler et al. 1986; Hicks 1988; Lamonthe 1993; Shany 1995). It has not been recorded in the Project Area but may occur. The ecology of this species is poorly known, including susceptibility to disturbance of its forest habitat. Rarely observed, it is not likely to be commonly hunted. As a result of project developments it may be impacted by loss of habitat, but considering the linear nature of most of the construction it is unlikely that entire territories will be eliminated, and the direct and indirect impacts on this species are likely to be low to negligible.

Like the previous species, **Wallace's and Starry Owlet-Nightjars (DD)** are scarce and rarely seen night-birds. The Starry Owlet-Nightjar was only recently described and is known from three localities in southern PNG (mainland), including the upper Fly River catchment (Pratt 2000). Neither is hunted, and the most threatening process of project development will be loss of habitat. The direct and indirect impacts on these species are likely to be low.

8.6. Pigeons (Columbidae)

The **Southern Crowned-Pigeon (VU; P)** is a large terrestrial pigeon of New Guinea's southern lowland forests. It is very susceptible to hunting, being highly prized for its meat, and is easily captured, often landing on a close perch not far from where it was flushed from the ground. As a result it has been extirpated or is very rare anywhere in the vicinity of human settlement (Coates 1985; King and Nijboer 1994). However, it remains common in some

lowland areas where tracts of remote forest remain away from settled areas. Pairs of Southern Crowned-Pigeons were observed on two occasions at Baia River, and at Juha North an experienced local hunter who displayed considerable knowledge of the local avifauna and their calls said that the species was present and hunted in the area. Southern Crowned-Pigeons have also been recorded at nine other sites within the Project Area.

The species is tolerant of habitat disturbance (F. Crome, pers. comm.). Impacts from forest disturbance associated with the project will be low and localised. Increased hunting is likely to occur as a result of indirect impacts through increased public access to the area. Indirect impacts on this species could be high.

8.7. Coastal and wetland species

Salvadori's Teal (VU; P) is an elusive inhabitant of montane streams and lakes to over 3,500 m asl, but is uncommon below 600 m asl (Coates 1985; Beehler et al. 1986). It was recorded in the Project Area for the first time in 2008. Two birds were seen in the small, two metre wide stream running alongside the South Karius survey area through cleared and forested habitats. One of these was captured by a local boy (**Plate 3**) and later eaten with members of his family. Hunting by dogs and people has been implicated in local extinctions and population declines (Bishop 1987). In addition, this species is threatened by hydrological changes to the mountain torrents it inhabits through processes such as logging and mining (Murray 1988). The species could be impacted directly by changes to upland stream hydrology but the wide range of the species suggests impacts would be low. Increased public access to the area may impart a high indirect impact through hunting.

The **New Guinea Flightless Rail (NT)** is a New Guinea endemic inhabiting mangroves, lowland swamp forest and riverside thickets. Recorded at Gobe, Kopi and Veiru in the Project Area. This species is unlikely to be affected by project development.

The **Forest Bittern (NT)** is a reclusive and rarely seen inhabitant of forest swamps, streams and pools from the lowlands to 1,430 m asl. So poorly known is this species that its voice is yet to be described (Coates 1985; Coates and Peckover 2001). In 2008 two birds believed to be this species were seen at Baia River. They were observed at night perched high (~30m) in a tree on the opposite riverbank. Their continual calling, a single drawn out growling note that rises then falls in pitch, gave their position away and the birds were subsequently observed from a distance of ~75m with the aid of a spotlight. The call was recorded by S. Richards. Though not seen well, their plumage pattern was clearly noted and showed an evenly dark heron with pale belly. Confusion with immature Nankeen Night-heron seemed possible but was deemed unlikely due to the lack of vertical markings on the bird and the unusual and persistent call. Elsewhere in the Project Area, this species was possibly though inconclusively recorded at Gobe in 1999 (Diamond and Bishop 2003). It is not hunted though it is likely to be sensitive to disturbance of its forest habitat.

The shorebirds **Asian Dowitcher (NT)** and **Beach Thick-knee (NT)** have been recorded in the Project Area at Cape Blackwood. **Great, Intermediate and Little Egrets**, all protected under PNG law, have been recorded in wetlands at a number of lowland sites and at Lake Kutubu. The project development will not affect coastal areas and will result in negligible loss of or impacts on wetland habitats where these and other wetland species could occur; any impacts on them are likely to be low. There is no evidence that these species are hunted so indirect impacts are also likely to be low.

8.8. Diurnal raptors (Accipitridae)

The endemic **New Guinea Eagle (VU; P)** inhabits mostly undisturbed forest from sea-level to over 3,000 m asl. It is not a soaring raptor, but hunts mammals and birds on the ground, in trees or from tree hollows by flying through or low over the canopy. Its population density is very low and it is sensitive to habitat disturbance and actively targeted by hunters for its plumes which are used for ceremonial purposes. As a result it is very rare or extirpated from areas near human settlement (Coates 1985).

During the 2008 surveys a New Guinea Eagle was observed preening in the canopy at Juha South, where its call was also heard persistently for long periods on a number of days. It has also been recorded at Gobe, Kopi and Veiru within the Project Area.

Territories are very large so the narrow linear disturbance from the pipeline is unlikely to eliminate or seriously deplete any territories. Increased public access to the area may result in a high indirect impact through increased hunting.

Gurney's Eagle (NT) is a large, sparsely distributed raptor inhabiting lowland and hill forests throughout New Guinea and many satellite islands. A raptor soaring high over forest at Baia River was likely this species. Elsewhere in the Project Area Gurney's Eagles have been recorded on Mt Bosavi and at Moro (Diamond and Bishop 2003). The threats facing Gurney's Eagle in the Project Area are similar in character to those facing the New Guinea Eagle, though they are less sought after by hunters.

The **Chestnut-shouldered Goshawk (DD)** and **Doria's Goshawk (NT)** are sparsely distributed and rarely encountered forest inhabitants. Neither has been recorded in the Project Area but both may occur in undisturbed forests from the lowlands to over 1,000 m asl. Management recommendations are the same as those indicated for other diurnal raptors above.

8.9. Bowerbirds (Ptilonorhynchidae)

Archbold's Bowerbird (NT) is a rare species with a limited and patchy distribution within the central cordillera, occurring in frost-prone mossy montane forest, especially *Nothofagus* forest, above about 2,200 m asl (sometimes as low as 1,750 m asl) (Frith and Frith 2004). In PNG its highly restricted range of only ~800 km² includes populations at Mt Giluwe, the southern slopes of Mt Hagen, Tari Gap (including Ambua Lodge near the Deviation Camp) and the southern slopes of the Karius Range. It has not been recorded in the Project Area, though surveys conducted on the Hides Range, at the foot of the Karius Range and in montane areas around the Deviation Camp, are very close to sites where this species has been recorded. For example, the recorded locality from the southern slopes of the Karius Range (G. Clapp 1997, pers. comm. to Frith and Frith 2004) is located approximately 6.2 km from the 2008 South Karius camp-site and 3.7 km from the 2005 camp at the Hides 3 wellpad (Annex 07 to Biodiversity Appendix). Habitat surveyed at South Karius in 2008 was probably below the elevational limit of this species. However, it is considered very likely that planned developments will traverse habitat occupied by this species. The linear nature of these developments at higher elevations is unlikely to directly remove entire territories. However, habitat degradation associated with increased human activity, including fire and firewood collection, has been implicated in the abandonment of bowers (Frith and Frith 2004). Indirect impacts from increased access to local inhabitants may prove moderate to high for this species.

8.10. Whipbirds and Quail-thrush (Corvidae: Cinclosomatinae)

The **Papuan whipbird (DD)** is a rare, little known bird of the understorey of montane forests (1,450–2,800 m asl). It has been recorded at five sites, mostly in Papua (Indonesia), but recent sightings are reported from the highlands of PNG (mainland), including Ambua Lodge, near Tari, in the Southern Highlands Province (Eastwood and Gregory 1995). Though not recorded in the Project Area, it may be present in suitable habitat on the Hides or Karius range or in the vicinity of the Homa Deviation route near Ambua Lodge.

8.11. Birds-of-paradise (Corvidae: Corvinae, Paradisaeini)

Most birds-of-paradise are sedentary forest dwellers that remain within small home ranges. Many species exhibit highly restricted distributions. The family as a whole exhibits a high degree of endemism with numerous species restricted to particular island groups, mountain ranges, nations (Indonesia and PNG) and provinces (Heads 2001). Birds-of-paradise and Bowerbirds are lekking species, with males displaying individually or communally in special display areas to compete for the attention of females. These display areas may be trees or specially prepared sites on the ground. Lekking areas are often traditional and form the breeding epicentres for local subpopulations of the species (Frith and Beehler 1998).

Though generally tolerant of moderate habitat disturbance, many are actively targeted by local hunters for plumes that are still used for deeply historical and culturally significant ceremonial purposes (Coates 1990; Swadling 1996). Hunting for plumes is still an active pursuit throughout much of New Guinea, including much of the Project Area, and frequently results in significant population declines or local extirpation from areas of human settlement. A number of birds-of-paradise are therefore listed by the IUCN as species of international conservation concern (**Table 4**). All are protected under PNG law.

Twenty-one species of bird-of-paradise have been recorded in the Project Area, 18 of which were also recorded in 2008 (**Appendix 1**). Ten species recorded in 2008 are Restricted Range species found only in the CPM EBA, and four are listed by the IUCN as Threatened or Near-threatened with global extinction.

The **Yellow-breasted Bird-of-paradise (NT; P)** is uncommon and patchily distributed along New Guinea's central range, mainly in low to mid montane forest between 1,200 and 2,000 m asl. Within PNG it is apparently scarce and patchiest in the west of the mainland. Within the Project Area it has been recorded at Mt Sisa (Diamond and Bishop 2000), Mt Bosavi (Frith and Beehler 1998), the Hides Range (Woxvold and Crome 2005 Annex 07 to Biodiversity Appendix) and at South Karius in 2008 (this report). This species may be fairly common at South Karius, where a juvenile was seen in undisturbed slope forest on transect B (Fig. 2) and an adult male on the edge of recently cleared forest behind camp. This latter record is unusual as the Yellow-breasted Bird-of-paradise is reportedly more a species of the forest interior than its closest relatives The Crested Bird and Loria's Bird-of-paradise (Frith and Beehler 1998). However, this area had been recently cleared to supply timber for camp construction, and may have cut into a pre-existing territory. This is consistent with observations of the Bicolored Mouse-warbler at this site (see section 9.3. Scrubwrens and Gerygones and Robins).

The Yellow-breasted Bird-of-paradise is not heavily hunted, and little is known of its behaviour and ecology due to its patchy distribution and secretive habits. However, it seems reasonable to conclude that due to its preference for forest interior it is susceptible to habitat degradation through a variety of processes associated with human settlement, including general

disturbance and hunting with dogs, harvesting of forest resources such as timber, and clearing of forest for agriculture. The greatest threat facing this bird is therefore habitat loss and conversion. Considering the linear nature of the pipeline development it is unlikely that entire territories will be eliminated, and the direct impact of the project on resident populations is likely to be low. However, indirect impacts may result from increases in forest disturbance due to greater accessibility to local residents.

The **Black Sicklebill (VU; P)** inhabits forests of western and central New Guinea in a narrow mid-montane elevational zone between 1,280 and 2,550 m asl. It is common in places but mostly uncommon or rare. Black Sicklebills were observed and heard on multiple occasions at South Karius in 2008, including an immature male that frequently perched and called in the open on the edge of secondary forest adjacent to the camp-site and local gardens.

Black sicklebills are moderately tolerant of habitat disturbance, being found in forest edge and occasionally secondary growth as well as primary formations (Frith and Beehler 1998; pers. obs.). However, its favoured altitude range is heavily settled by highland populations, and male Black Sicklebills are heavily hunted for their tail plumes, the largest in the family, and for their skins, which are becoming increasingly valuable (Coates 1990; Swadling 1996; Frith and Beehler 1998). Populations within the Project Area are unlikely to be heavily impacted by forest disturbance associated with planned developments. However, increased public access to the area may result in a high indirect impact through increased hunting.

The **Ribbon-tailed Astrapia (NT; P)** is endemic to PNG (mainland) and has the most restricted range of any bird-of-paradise in the central range, where it occupies upper montane and subalpine moss forest mostly above 2,450 m, but occasionally as low as 1,800. In the Project Area it has been recorded on Mt Sisa (Diamond and Bishop 2000) and the Hides Range (Woxvold and Crome 2005 Annex 07 to Biodiversity Appendix). This species was not directly recorded in 2008, though local informants indicated it occurs on the Karius Range above South Karius survey area. It is also found to the north of the Deviation Camp survey area in the Tari Gap (e.g. Ambua Lodge), and there was some evidence of a Ribbon-tailed x Stephanie's *Astrapia* hybrid (= 'Barnes' *Astrapia*) at the Deviation Camp (See above: 7.3.3 Deviation Camp).

The Ribbon-tailed *Astrapia* is tolerant of some habitat disturbance, being occasionally found in fragmented and secondary forest. However, like the Black Sicklebill, male Ribbon-tailed *Astrapias* are heavily targeted by hunters for their tail plumes. Threats are the same as for the previous species.

The **Blue Bird-of-paradise (VU; P)** is a rare endemic of eastern and central PNG (mainland) west at least as far as Mt Hagen and the Tari area where it inhabits lower montane forest from 1,100 to 2,000 m asl. There is strong evidence to suggest this species is present in the vicinity of Benaria. In 2005 residents at Benaria indicated the species was present on top of a ridge above Benaria Village (1,546 m), and calls believed to be of this species were heard between the camp and Benaria village (Woxvold and Crome 2005 Annex 07 to Biodiversity Appendix). In 2008, local hunters interviewed at the Deviation Camp also indicated this species is present at Benaria. Local informants also indicated the Blue Bird-of-paradise is present near South Karius.

Like all species of *Paradisaea* the Blue Bird-of-paradise is tolerant of some habitat disturbance, being found in edge forest and old secondary growth as well as primary forest. However, it has been locally extirpated from some areas due to the clearance of forest, and it

is threatened by forest fire and hunted for its plumage. Increased hunting may occur as a result of indirect impacts through increased public access to the area and may result in local declines. Indirect impacts on this species could be high.

8.12. Mynas and Starlings (Sturnidae)

The **Yellow-eyed Starling (NT)** is a little known species largely restricted to New Guinea's western lowland forests. Until 1990 it was known in PNG only from the upper reaches of the Fly River and its upper tributaries (Coates 1990). Since then the species has proved more widespread, though sparse and difficult to distinguish from the more common and ecologically similar Metallic Starling. In 2008 small numbers of Yellow-eyed Starlings were encountered from a distance amongst other starlings close to the campsite at Juha North. Subsequently, a group of nine birds, including one juvenile, was seen well from about 30 m along transect 2 (Fig. 5). Elsewhere in the Project Area this species has been recorded at Gobe, the Kopi area, Pinini and Libano Sok. The species is not heavily hunted and likely tolerant of moderate habitat disturbance. Direct impacts are predicted to be low.

9. Other Notable Records

The following species records are of particular ornithological interest.

9.1. Megapodes (Megapodiidae)

Within the order Galliformes, the family Megapodiidae consists of a number of medium to large ground-dwelling birds that all share the unique trait of forgoing typical incubation and active care for live young, instead incubating their eggs in large mounds of soil and rotting leaf-litter. Taxonomic affinities within the group, which is largely restricted to the Australasian region, have been the subject of debate for centuries. A recent appraisal by Jones et al. (1995) recognizes 22 species from seven genera, with five species occurring in PNG (mainland).

As with many other large, ground-dwelling bird taxa, many megapode species are susceptible to disturbance and other forms of human interference and a number are now rare or threatened. The New Guinea megapodes are well known to indigenous inhabitants as they are actively targeted by hunters. Megapodes lay large eggs, large numbers of which are often easily gathered from active nest mounds. In addition, birds of all ages, from fledglings to adults, are sought after as food and regularly trapped in snares (**Plates 5–8**). Together with the fact that many species are heavily reliant on their forest habitat, these traits make New Guinea's megapodes susceptible to local extinction in well-populated areas.

Despite these concerns at the family level, the large tracts of relatively undisturbed forest remaining in many parts of PNG (mainland) mean that all five species appear to be secure. However, little is still known of the precise status and distribution of each species, and a number of observations made during the 2008 surveys are of interest.

Within PNG, the **Brown-collared** and **Black-billed Brush-turkeys** are assumed to be largely allopatric, with the latter species occupying forest south of the central cordillera generally below 800 m asl, and the former restricted mostly to forests of the island's north up to at least 850 m asl. However, a number of records also exist for Brown-collared Brush-turkeys south of the central cordillera. In eastern New Guinea (mainland) their ranges appear to overlap for at least 90 km in the Aroa River area above Port Moresby (Jones et al. 1995). An area of overlap is also assumed to occur further west over a distance of some 700 km between 142° and 148°E along the southern slopes of the Central Range, including areas of the Southern Highlands Province near Lake Kutubu and on Mount Sisa. It has been postulated that competition between these species is avoided in this area of overlap by an increase in the size difference between the species and the tendency for the Brown-collared Brush-turkey to occupy higher altitudes (Diamond 1972; Jones et al. 1995).

However, our observations of this species, particularly at low altitudes at Juha North, suggest a different story. This species appears to be common between 200 and 400 m asl in the area around the Juha North survey area. One adult was snared by locals on the banks of the Liddle River at ~200 m asl and brought into camp (**Plate 7**), another was photographed on transect 2a by a camera trap at 270 m asl (**Plate 8**), and calls of multiple *Talegalla* individuals believed to be of this species were recorded on transects 1 and 2a (Fig. 5). These birds were encountered at altitudes significantly lower than those of other Brown-collared Brush-turkeys recorded south of the Central Range; birds possibly of this species were noted from 900–1,200 m asl northeast of Lake Kutubu and between 750 and 1,500 m at Mt Sisa

(Diamond 1972; Coates 1985; Jones et al. 1995). In contrast to an already postulated altitudinal separation, an experienced hunter who lives near the Juha North campsite indicated that the brush-turkey with the “red legs” (Brown-collared) occurs at low altitudes west of Suabi village, while the species with “yellow legs” (Black-billed) is found east of Suabi. The occurrence of this species at lower altitudes than normal at Juha North is consistent with observations of a number of other floristic and faunistic observations from this site.

Recent taxonomic reappraisal has seen scrubfowl taxa previously regarded as subspecies elevated to full species, with the **New Guinea** and **Orange-footed Scrubfowls** sharing similar distributional patterns to the Brown-collared and Black-billed Brush-turkeys north and south of the Central Range respectively (Jones et al. 1995). As with the Brown-collared Brush-turkey, the New Guinea Scrubfowl has also been observed south of the Central Range at upland locations northeast of Lake Kutubu and on Mt Sisa (Jones et al. 1995). The experienced hunter at Juha North indicated that the scrubfowl with the “black legs” (New Guinea Scrubfowl) is also present in the lowland forests around the Juha North survey area. No scrubfowls were encountered directly or indirectly (e.g. camera traps) at Juha North during the 2008 surveys.

Two images of a scrubfowl with dark legs were taken at higher altitude in moss forest along transect 4 at Juha South (**Plate 11**). Although the image quality is not sufficient to identify the individual to species based on plumage characters alone, the dark legs on this animal suggest the bird is likely to be a New Guinea Scrubfowl.

9.2. Owls

It is possible that a species of owl new to science is present in the Project Area’s montane forests. In 2005, a distinctive, rising, three-note call of an unidentified Strigid owl was heard over two nights at the Hides 3 wellpad. The call was heard well and did not fit the description of any advertising call known from this group. On hearing the description and an accurate imitation of this call, David Bishop agreed that the call of the Hides 3 bird was distinct from other calls known from New Guinea owls (K. D. Bishop 2005, pers. comm.). David Bishop has worked extensively as a professional ornithologist in New Guinea for more than 20 years and is recognised as an international expert on the island’s avifauna and one of the foremost authorities on bird calls in the region. Should further conservation work be conducted in the KICDP and surrounding areas it would be of interest to conduct additional surveys for this potentially new species in the Hides Range, particularly during the period of April-May when the bird was heard calling.

9.3. Scrubwrens and Gerygones (Pardalotidae) and Robins (Petroicidae)

The **Bicolored Mouse-warbler** is a rare and patchily distributed endemic of New Guinea’s montane forests. It is generally believed to occupy a narrow elevational band of 50 to 370 m that separates the distributions of the Rusty Mouse-warbler (lower and mid montane forest) and the Mountain Mouse-warbler (mid to upper montane forest). The elevation of this zone varies geographically so that this species has been recorded from 1,220 to 2,500 m asl. At other locations the Bicolored Mouse-warbler may be absent, being ‘squeezed out’ by the other two species (Coates 1990). In 2008 this bird was locally common at South Karius. One bird was mist-netted, and others seen regularly at forest edge in a recently cleared area behind camp (1,365 m asl). Another was seen at 1,390 m in forest interior on alluvial flats on transect B, some 50 m away from a Mountain Mouse-warbler seen at the same elevation.

This part of transect B is close to the foot of a small range that rises to over 2,000 m asl near camp (**Fig. 2**). This is the first time this species has been recorded in the Project Area.

The **Olive-yellow Robin** is a patchily distributed New Guinea endemic inhabiting primary forest from the hills to 1,450 m asl. It was not recorded in 2008, but is known in the Project Area from the Darai Plateau, Moro, Kantobo and Mt Bosavi (Coates 1990; Diamond and Bishop 2003; Igag 2003). This inconspicuous bird may occur in suitable habitat anywhere in the Project Area. The greatest threat facing this bird is habitat loss and conversion. However, considering the linear nature of the pipeline development it is unlikely that entire territories will be eliminated, and the direct impact of the project on resident populations is likely to be low. There is no evidence that this species is hunted, though indirect impacts may result from increases in forest disturbance due to greater accessibility to local residents; Olive-yellow robins typically occupy habitat within 2 m of the ground.

9.4. Whistlers and allies (Corvidae: Pachycephalinae)

The **White-bellied Pitohui (LR/nt)** is known from two restricted sites in New Guinea - the Noord River in Papua (Indonesia) and 320 km to the east between Kiunga and the Palmer Junction on the Fly River. It is not known from the Project Area, though it may prove to be more widespread across the northern Trans-Fly region, perhaps including the upper Strickland, in seasonally flooded lowland forest in high rainfall areas (Diamond and Raga 1978).

9.5. Swallows and Martins (Hirundinidae)

A Red-rumped Swallow was seen feeding around camp at Juha North survey area over two consecutive days. This northern hemisphere migrant occurs as a regular but scarce visitor to New Guinea. It is the first time it has been recorded in the Project Area.

10. Discussion, impacts and recommendations

10.1. Conservation value and habitat quality

The results of the 2008 surveys expand the findings of previous avifauna surveys which indicate that the PNG LNG Project Upstream Project Area supports a highly rich and diverse bird community. Considering all surveys conducted in the Project Area since 1995, more than half of all species recorded in New Guinea and satellite islands, including migrants and seabirds, have now been recorded. As well as supporting a high level of species richness, the Project Area's forests are of high conservation value. More than 12% of the bird species observed in 2008 are of global and/or national conservation significance, with 5.5% listed by the IUCN as Threatened or Near-threatened with global extinction.

PNG's forests are under increasing pressure from a variety of threats, including both legal and illegal logging, increasing agricultural practices, plantations, road building and forest fires. Consistent with patterns of development in other tropical regions, PNG's coastal forests have been placed under the highest pressure. Consequently, the relatively remote forests of the interior play an important role in maintaining the diversity of local biota. As well as the unique montane biota, the vast interior lowlands of the Fly and Strickland River catchments represent among the Papuan region's most significant areas of intact lowland rainforest.

In terms of habitat for birds, the conservation value of a particular site or area depends on a range of factors, including:

- The size and integrity of available habitat;
- Connectivity with and quality of surrounding habitat;
- Soil type.

The Southern Highlands Province has and is undergoing a population expansion resulting in a concomitant increase in the area of forest cleared or otherwise converted for agriculture and the degree of hunting pressure imposed on the region's biota. However, many of the areas surveyed in 2008 are still relatively remote. Apart from recently established settlements around South Karius and Juha North, most camps were located some distance from areas of human settlement.

Overall, the region constitutes an increasingly rare example of a large expanse of relatively intact and well connected tropical lowland, hill and montane forests. This area is of extremely high conservation value due to its large size, remoteness, connectivity with pristine habitat in surrounding areas, and the persistence of a variety of intact habitats covering a range of topographies and soil types.

10.2. General considerations

Previous construction of the export oil pipeline and associated facilities involved more-or-less the same procedures and construction methods that will be used for the PNG LNG Project – the drilling of wells, clearing and construction of flow lines, clearing of a ROW, stringing pipe, digging a trench in the ROW, welding pipe, lowering it into the trench and backfilling the

trench, constructing access roads and tracks, crossing rivers, locating and developing borrow pits, building bridges, constructing temporary camps and lay down and parking areas, dealing with waste, fuel handling, hydrotesting the pipe and building permanent facilities.

The present excellent condition of the Project Area and the presence of so many sensitive species indicate that the avifauna has coped well with these developments and that there have been no long-term deleterious impacts on the avifauna from previous construction protocols. This was achieved by:

- Minimising construction footprints.
- Helicopter construction of wells and hand building flowlines where feasible.
- Minimising access roads.
- Maintaining control on access to the sites, thereby eliminating most indirect impacts.
- Controlling the behaviour of project personnel during construction and operation.

Given a continuation of these practices there is no reason to expect that the avifauna will not cope with construction and operation of the PNG LNG Project, especially as much of its length will be in or adjoin the existing oil export pipeline ROW, and there are few additional permanent facilities to be constructed.

10.3. Direct impacts

10.3.1. Forest clearing

Forest will be cleared to construct well pads and flowlines, the ROW, access roads, the new gas facilities at Juha and Hides, temporary camps, temporary storage areas, vehicle parks and borrow pits.

Forest clearing may negatively impact on:

- Forest interior specialists.
- Ground-foraging birds.
- Birds-of-paradise and bowerbirds through loss of traditional terrestrial and arboreal mating and display areas (display trees, playgrounds and bowers).

10.3.1.1 Non-linear developments: processing facilities, camps, storage areas and well pads

The construction of facilities, temporary camps and stockpile facilities may result in multiple patches of forest being cleared. Most resident species are territorial and the impact of clearing is to destroy territories or alter their boundaries, resulting in forced migration of the previous inhabitants. This usually results in death since remaining habitat is often saturated with territory owners. Clearing for these facilities will displace a range of territorial birds, and may result in a large reduction or total loss of individual territories of a variety of sensitive, protected or IUCN-listed species in areas directly impacted by the project.

Of particular relevance in this respect is the great variety of birds-of-paradise known to occur in the Project Area, most of which are sedentary forest dwellers that remain within small home ranges, and many of which exhibit highly restricted distributions. In addition, Birds-of-paradise

and Bowerbirds are lekking species, with males displaying communally in special display areas to compete for the attention of females. These display areas may be trees or specially prepared sites on the ground. Lekking areas are often traditional and form the breeding epicentres for local subpopulations of the species (Frith and Beehler 1998). Forest clearance may result in the loss of multiple display areas and trees.

Despite these concerns, large numbers of territories or display areas are not predicted to be lost, and given the extent of high quality habitat remaining throughout much of the Project Area, the overall impact of forest clearing for these species is expected to be low.

10.3.1.2. Well pads

The preparation of well pads will involve removal of habitat to create small (≤ 1 ha) clearings. While the well pad itself is kept clear of regrowth, natural reforestation is left to occur in surrounding areas. With time and low levels of human activity, the area of impact will be largely restricted to the well pad proper. Consequently, due to their small size and low level of maintenance required, well pads are predicted to have a low impact on local bird populations.

10.3.1.2 Linear developments and edge effects: ROW and access roads

The total area of forest cleared for the ROW and access roads is likely to be large. However, due to the linear nature of these developments the loss of habitat within any one area may be relatively minor. Ground-foraging birds and other forest interior specialists will be most affected by linear clearings.

Linear clearings for the ROW and access roads impact habitat through the process of edge effects and barrier formation (Laurence and Bierregaard 1997).

Edge effects include changes to forest microclimate next to the clearing (the forest interior will be windier, dryer, hotter and lighter next to the forest edge), increased wind throws of trees close to the edge, the invasion of weeds and exotic species along the edge, and invasion of the forest next to the edge by bird species adapted to drier habitats and secondary forest. Edge effects may penetrate several hundred metres into the forest.

Barrier effects occur where a strip of open habitat provides a barrier of hostile habitat that discourages or prevents some species from moving across the gap, thus splitting or fragmenting populations.

Throughout most of the Project Area regrowth and sealing of the forest edge is rapid so edge effects are expected to be short-lived. However, at higher altitudes the process will be slower and edge effects will last longer.

It is unlikely the ROW and access roads will provide a serious barrier to any bird species unless the width of the clearing is very high. For clearings more than 40 to 50 m some upland interior specialists and terrestrial species (e.g. Greater Melampitta) may be discouraged from crossing the gap but it is unlikely to permanently fragment a population.

Overall, there is likely to be a low level of direct impact on bird diversity at the local level due to habitat loss associated with linear infrastructure development. In addition, the flowlines present little impediment to the passing of ground-birds, all of which are expected to pass easily below the elevated pipes.

10.3.2. Contamination of rivers and wetlands

The upstream portions of the Project Area surveyed in 2008 do not include significant wetland areas, though most habitats are traversed by multiple permanent waterways including a number of large rivers (e.g. Baia River). The region does not support an extensive specialised bird fauna restricted to riverine forest, such as exists in gallery forests in dry woodlands. Nevertheless, a range of species are particularly abundant in these habitats, including some kingfishers and the Shining Flycatcher, and waterways of the Project Area's hill and montane forests do support some specialist species, such as the Torrent-lark, Torrent Robin and the IUCN-listed Salvadori's Teal (VU) (**Plate 3**) and Forest Bittern (NT). Stream alteration and contamination has contributed to the population decline of the Salvadori's Teal (Murray 1988).

Riverine forest is most important in the lowlands where it supports a variety of large fruiting trees. Consequently, lowland riverine forest is particularly rich in pigeons and parrots. Although no species is restricted to this habitat, many birds will move into these areas during the drier parts of the year and at hot times of the day. At such times the riverine forests act as refuges.

Considering the narrowness of the ROW it is unlikely that river crossings will seriously impact on the avifauna, unless large areas of riverbank are permanently cleared and /or the upland rivers are seriously physically or chemically impacted. Nevertheless, the potential exists for planned developments to result in some physical and/or chemical impacts on the Project Area's rivers and wetlands.

10.4. Indirect (secondary) impacts

10.4.1. Overview

A potentially serious range of secondary impacts may result from development of the Project Area. Many of these are associated with road construction. The impacts of road building in tropical forest are well documented (e.g. Trombulak and Frissell 2000; Laurance et al. 2004) and occur as a result of increased accessibility and human activity in areas of high conservation value. A wide range of destructive impacts have been recorded, including:

- Deforestation, forest degradation and loss of wildlife via settlement processes.
- Clearing along roads for gardens and small agricultural plots.
- Commencement/acceleration of legal and illegal logging.
- Over-hunting.
- Ingress of weeds and pathogens on vehicles.
- Increased occurrence of controlled and uncontrolled fires.

If project-constructed roads are to be made public, and therefore access is uncontrolled, then there is a strong likelihood of permanent or long-term, high-level impacts on a large proportion of bird species that currently rely on forest and riverine habitats in the Project Area.

10.4.2. Hunting

Many birds in New Guinea suffer greatly from hunting pressure. In particular, those species that are specifically targeted for food and/or decorative plumage are often locally extinct or

exist in very low numbers in suitable habitat near settled areas. The presence and relative abundance of such species therefore serves as a sensitive indicator of the local degree of hunting pressure (Diamond and Bishop 2003). Commonly hunted species known to occur within the Project Area are listed in **Table 7**. Should regular hunting become a by-product of road construction, there exists the potential for a high level impact on local populations of many species, including a number of globally threatened birds.

The overall PNG LNG Project infrastructure will span large tracts of forest in the Southern Highlands and Western Provinces, much of which is presently remote and intact. Should the project result in a significant rise in human influence throughout much of this area, there exists the potential for the project to indirectly result in a high level impact on regional and national populations of numerous rare and threatened birds.

10.4.3. Fire

Fire is a potent ecological factor in tropical forest dynamics. During drier periods even very wet forests can burn. Extensive experience in the PNG highlands and Indonesia shows how powerful fire can be in reducing forest cover (Budowski 1966; Wade and McVean 1969; Paijmans and Löffler 1972; Paijmans 1976; Hopkins 1983; Bassini and Becker 1990; Horn and Sanford 1992).

The problem of fire is likely to occur only in dry years (e.g. during El Niño events) but its effects can be widespread and often involve permanent deforestation. Large areas of forest within the Project Area overlie limestone pavements and karst and the soils are shallow – often just a thin root mat over solid limestone. Fire in these forests and the swamp forests can burn away the organic soil layer and root mat leaving bare rock or subsoil, upon which regeneration is impossible or takes many decades or centuries to occur.

10.5. Recommendations

10.5.1. Direct impacts

10.5.1.2. Forest clearance

The following mitigations are suggested to reduce impacts of clearing:

- Locate facilities, camps, lay down areas, borrow pits etc. within secondary forest and other previously cleared/disturbed areas. Wherever possible these facilities should be situated on already disturbed land so as to minimise encroachment on surrounding forest. This may prove most feasible when selecting sites for temporary developments such as construction camps, which will rely less on the quality of substrate for long-term stability than the larger, permanent production facilities. Careful selection of these sites will minimise their impact on bird communities.
- Minimise clearing for facilities, camps, lay down areas, borrow pits etc.
- Minimise the width of the clearings for the ROWs and access roads as far as possible. If the width of these clearings is kept to a minimum then with time the upper storey may regenerate to form a continuous canopy, reducing the impact of habitat loss and edge effects on species that forage at these levels. Impacts will increase where the total width of clearing is 40 m or more, and will become permanent though localised if no regeneration is allowed. Clearance widths should ideally be kept to 25 m or less during construction where terrain considerations allow.

Table 7 Bird species occurring in the PNG LNG Project Upstream Project Area that are commonly hunted in New Guinea by local people for meat and/or plumes, their global conservation status and their occurrence at sites surveyed in 2008.

Species	IUCN status	South Karius	Baia River	Juha South	Juha North	Deviation Camp
Southern Cassowary	VU					
Dwarf Cassowary	LR/nt	X	X	X	X	X
Salvadori's Teal	VU	X				
Blyth's Hornbill			X		X	
Rainbow Lorikeet			X	X	X	
Fairy Lorikeet		X	X	X		
Papuan Lorikeet		X				X
Pesquet's Parrot	VU	X	X	X	X	
Eclectus Parrot			X	X	X	
Palm Cockatoo				X	X	
Sulphur-crested Cockatoo		X	X	X	X	
Thick-billed Ground-Pigeon			X			
Pheasant Pigeon			X		X	
Purple-tailed Imperial-Pigeon					X	
Shining Imperial-Pigeon						
Pinon Imperial-Pigeon					X	
Collared Imperial-Pigeon					X	
Banded Imperial-Pigeon			X	X	X	
Torresian Imperial-Pigeon						
Southern Crowned-Pigeon	VU		X		X	
Long-tailed Honey-buzzard				X	X	
New Guinea Eagle				X		
Black Sicklebill	VU	X				
Brown Sicklebill						X
Superb Bird-of-paradise		X				X
Carola's Parotia		X		X		
Lawes's Parotia		X				
Magnificent Riflebird			X	X	X	
Magnificent Bird-of-paradise			X	X	X	
King Bird-of-paradise			X		X	
Ribbon-tailed Astrapia	LR/nt	X				
Stephanie's Astrapia						X
King-of-Saxony Bird-of-paradise		X				X
Twelve-wired Bird-of-paradise						
Raggiana Bird-of-paradise			X	X	X	

- Allow as much of the ROWs and access roads to regenerate and the canopy to close over the gap wherever possible.
- Reduce lengths of linear clearings in montane forests.
- Identify display grounds and display trees of birds-of-paradise and bowerbirds during pre-construction clearance surveys and avoid/retain these trees/sites where possible. The loss of lekking sites needs to be minimised and any display trees or display grounds found along the ROW or facility locations by clearance surveys should be marked for retention. Where possible these should be protected by a forest buffer of at least 25 m.

10.5.1.3. Contamination of rivers and wetlands

Care should be taken to prevent contaminants (including sediment) from entering rivers and streams during construction and operation of the infrastructure components.

- Wherever possible, existing riparian forest and wetlands should remain intact and previously cleared areas adjacent to waterways should be allowed to regenerate to protect river and stream systems from sediment run-off.
- Forest cover should remain on steep slopes.
- All chemical contaminants should be handled and stored securely and away from waterways.
- Roads and ROWs should be constructed to minimise sediment run-off and the clearing of riparian forest at river crossings.

10.5.2. Indirect impacts

The following mitigations are suggested to minimise indirect impacts associated with project development:

- Hunting by all employees during construction, operation and maintenance of all project components should be strictly banned. Bans should extend to contractors and their staff and to locals employed as temporary labourers.
- Apart from employees, road construction will also afford local residents greater access to potentially fruitful hunting grounds. It is recommended that settlement and hunting along project infrastructure in previously undeveloped areas be discouraged as far as industry-community relations allow. If successful limitations are set in place, previously disturbed habitats surrounding new developments may become increasingly important for a variety of significant species, such as has been previously observed in the KICDP. However, if settlement encroaches on developed areas avifauna presently using adjacent habitats are likely to be largely displaced.
- Minimise impacts from fire by developing an appropriate management plan and controlling the use of fire by project personnel in dry years.
- Restricting public access to the Project Area will greatly reduce the risk of fire. Timber extraction results in a significant increase in the amount of sunlight reaching the lower levels of the rainforest, and contributes to drying the forest and increasing its susceptibility to fire during the dry season and particularly in dry years.

- Maximise the length of company-owned roads and limit access by gating.
- Co-operate with government (provincial or national), local communities and non-government organisations to develop and implement a conservation and protection plan that would aim at reducing forest loss, logging and hunting along the roads and in surrounding forest.

10.6. Conclusions

The 2008 surveys indicate that the upstream portion of the Project Area supports a rich biota that includes a number of taxa of global and/or national conservation significance. Notably the region includes large areas of intact and remote habitat that support large and viable populations of a range of bird (and mammal) species that are commonly hunted by local villagers and prone to local extinction in the vicinity of human settlement. The proposed developments are not expected to directly result in a significant impact on regional or local bird communities. However, they may lead to significant indirect impacts on bird communities by increasing human access to previously remote areas. Increased human activity will adversely affect bird (and other biotic) communities through hunting, clearance of forest for agriculture, timber extraction and increasing susceptibility to fire. Managing these indirect impacts will be the most important aspect of the project in relation to maintaining avian biodiversity and populations of threatened, rare and endemic species known to occur within the Project Area.

11. References

- Bassini, F. and Becker, P. (1990) Charcoal's occurrence in soil depends on topography in tierra firme forest near Manaus, Brazil. *Biotropica* 22: 420-422.
- Beehler, B. M., Pratt T. K., and Zimmerman D. A. (1986) *Birds of New Guinea*. Princeton University Press, Princeton, NJ.
- Beehler, B. M., Sengo, J. B., Filardi, C. and Merg K. (1995) Documenting the lowland rainforest avifauna in Papua New Guinea – effects of patchy distributions, survey effort and methodology. *Emu* 95: 149-161.
- Bennett, E. L., Nyaoi, A. J. and Sompud, J. (1997) Hornbills *Buceros* spp. and culture in northern Borneo: can they continue to co-exist? *Biological Conservation* 82, 41-46.
- Biodiversity Support Program (1993) *Papua Niugini Ripot Bilong Luksave Long Kamap Bilong Konsevesen*. Corporate Press, Maryland.
- Bishop, K. D. (1987) Interesting bird observations in Papua New Guinea. *Muruk* 2: 52-57.
- Budowski, G. (1966) Fire in tropical lowland areas. *Proceedings of the Annual Tall Timbers Fire Ecology Conference* 5: 5-22.
- Burrows, I. (1995) A field survey of the avifauna of the Kikori River Basin. In: *Field Survey of Biodiversity in the Kikori River Basin Papua New Guinea* (G. S. Hartshorn et al.). WWF KICDP Report.
- Chantler, P. and Driessens, G. (2000) *Swifts: A Guide to the Swifts and Treeswifts of the World*. Pica Press, Sussex, UK.
- Coates, B. J. (1985) *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville. Volume I, Non-Passerines*. Dove Publications, Alderley, Queensland.
- Coates, B. J. (1990) *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville. Volume II, Passerines*. Dove Publications, Alderley, Queensland.
- Coates, B. J. and Peckover, W. S. (2001) *Birds of New Guinea and the Bismarck Archipelago, a Photographic Guide*. Dove Publications, Alderley, Queensland.
- Crome, F. H. J. (1993) Post World Heritage Bird Conservation Problems in North East Queensland. In: Catterall, C. P., Driscoll, P. V., Hulsman, K., Muir, D. and Taplin, A. (eds.) *Birds and their Habitats: Status and Conservation in Queensland*. Pp. 93 -104. Queensland ornithological Society Inc., Brisbane.
- Diamond, J. M. (1972) *Avifauna of the Eastern Highlands of New Guinea*. Nuttall Ornithological Club, Cambridge, Massachusetts, USA.
- Diamond J. M. and Bishop K. D. (2000) *Birds of Mt. Sisa*. WWF KICDP Report.
- Diamond J. M. and Bishop K. D. (2000) *Local Avifauna of the Kikori River Catchment Surveyed in 1999*. WWF KICDP Report.

- Diamond J. M. and Bishop K. D. (2003) *Seasonality in Birds in the Kikori River Catchment: Year-2003 Studies*. WWF KICDP Report.
- Diamond, J. M. and Raga, M. N. (1978) The Mottled-breasted Pitohui *Pitohui incertus*. *Emu* 78: 49-53.
- Eastwood, C. and Gregory, P. (1995) Interesting sightings during 1993 and 1994. *Muruk* 7: 128-142.
- Ferguson-Lees, J. and Christie, D. (2005) *Raptors of the World: A Field Guide*. Christopher Helm, London.
- Flannery, T. F. (1995) *Mammals of New Guinea*. Reed Books, Chatswood, NSW.
- Frith, C. B. and Beehler, B. M. (1998) *The Birds of Paradise: Paradisaeidae*. Oxford University Press, Oxford.
- Frith, C. B. and Frith, D. W. (2004) *The Bowerbirds: Ptilonorhynchidae*. Oxford University Press, Oxford.
- Gregory, P. (1995) *The Birds of the Ok Tedi Area*. National Library of PNG.
- Heads, M. (2001) Birds of paradise, biogeography and ecology in New Guinea: a review. *Journal of Biogeography* 28: 1-33.
- Hicks, R. (1988) Recent observations April to June 1987. *Muruk* 3: 32-38.
- Hopkins, B. (1983). Successional processes. In: Bourliere, F. (ed.). *Tropical Savannas*. Pp. 605-616. Elsevier, New York.
- Horn, S. P. and Sanford, R. L. (1992) Holocene fires in Costa Rica. *Biotropica* 24: 354-361.
- Igag, P. (2003) *Report on Bird Survey for the Darai and Libano Sites of Kikori ICDP, 2003*. WWF KICDP Report.
- Jaensch, R. (1997) *Birds Recorded at Lake Kutubu, Moro and Agogo Range, Papua New Guinea, 30 July to 2 August 1997*. Wetlands International Report.
- Jaensch, R. (1999) *Birds of the Lake Kutubu Swamp Forest Papua New Guinea (Summary Report)*. Wetlands International Report.
- Jaensch, R. and Kulmoi, P. (1998) *Birds Recorded at Tubo Lodge, Lake Kutubu, August 1997 and February 1998*. Wetlands International Report.
- Jaensch, R. and Watkins, D. (2000) *Birds Recorded in the Lower Kikori River and Kikori Delta Areas Papua New Guinea (First Draft)*. Wetlands International Report.
- Johns, R. J. (1976) A provisional classification of the montane vegetation of Papua New Guinea. *S. I. N. G.* 4: 105-107.
- Johns, R. J. (1977) *The Vegetation of Papua New Guinea*. Training Manual No. 10. PNG Forestry College, Bulolo.
- Jones, D. N., Dekker, R. W. R. J. and Roselaar, C. S. (1995) *The Megapodes: Megapodiidae*. Oxford University Press, Oxford.

- Kemp, A. (1995) *The Hornbills*. Oxford University Press, Oxford.
- King, C.E. and Nijboer, J. (1994) Conservation considerations for crowned pigeons, genus *Goura*. *Oryx* 28: 22-30.
- Kinnaird, M. F. and O'Brien T. G. (2007) *The Ecology and Conservation of Asian Hornbills, Farmers of the Forest*. University of Chicago Press, Chicago.
- Kula, G. R. and George, I. (1996) *Protected Fauna of Papua New Guinea*. Department of Environment and conservation, National Capital District, PNG.
- Lamonthe, L. (1993) Papuan Hawk-owl *Uroglaux dimorpha* in the Lae-Bulolo area. *Muruk* 6: 14.
- Laurance, S. G. W., Stouffer, P. C. and Laurance, W. F. (2004) Effects of Road Clearings on Movement Patterns of Understory Rainforest Birds in Central Amazonia. *Conservation Biology* 18: 1099-1109.
- Laurence, W. F. and Bierregaard, R. O. Jr. (1997) *Tropical Foorest Remnants. Ecology, Management, and Conservation of Fragmented Communities*. University of Chicago Press, Chicago.
- Leary, T. (2002) *Brief Report on Iviri Mammal Monitoring - December 2001*. WWF KICDP Report.
- Leary, T. (2004a) *Brief Report on Iviri and Keboi Kerowa Mammal Monitoring - December 2003*. WWF KICDP Report.
- Leary, T. (2004b) *Brief Report on Keboi Kerowa Mammal Monitoring - July 2004*. WWF KICDP Report.
- Leary, T. and Seri, L. (1995) *Survey of Birds and Mammals at Utiti Creek*. WWF KICDP Report.
- Leary, T., Naug, R. and Price, J. (1996) *Kikori Integrated Conservational and Development Project* In Buchanan, P. G. (ed.) *Petroleum Exploration, Development and Production in Papua New Guinea: Proceedings of the third PNG Petroleum Convention, Port Moresby, 9th – 11th September 1996*. Pp. 805-814
- Mack, A.L. and Wright, D.D. (1998) The Vulturine Parrot, *Psitttrichas fulgidus*, a threatened New Guinea endemic: notes on its biology and conservation. *Bird Conserv. Int.* 8: 185-194.
- McCall, D. and Flemming, D. (2000) *Chevron and WWF: Lessons Learned from Six Years of Collaboration in Biodiversity Protection*. WWF/Chevron Niugini Report.
- McClure, H. E. (1974) *Migration and Survival of the Birds of Asia*. US Army Medical Component, S. E. A. T. O, Bangkok.
- Murray, A. (1988) A study of the birds of the Tabubil region, Western Province, Papua New Guinea. *Muruk* 3: 89-117.
- Nix, H. E. (1993) Bird distributions in relation to imperatives for habitat conservation in Queensland. In Catterall, C. P., Driscoll, P. V., Hulsman, K., Muir, D. and Taplin, A. (eds.)

Birds and their Habitats: Status and Conservation in Queensland. Pp. 12-22. Queensland Ornithological Society Inc., Brisbane.

Paijmans, K. (1976). *New Guinea Vegetation*. CSIRO, Canberra.

Paijmans, K. and Löffler, E. (1972). High-altitude forests and grassland of Mt. Albert Edward, New Guinea. *Journal of Tropical Geography* 34: 58 - 64.

Payne, R. B. (2005) *The Cuckoos*. Oxford University Press, Oxford.

Pratt, T. K. (2000) Evidence for a previously unrecognized species of Owlet-Nightjar. *Auk* 117: 1-11.

Rand, A. L. (1942) Results of the Archbold Expeditions. No. 42. Birds of the 1936–1937 New Guinea Expedition. *Bulletin of the American Museum of Natural History* 79, 289-366.

Rand, A. L. and Brass, L. J. (1940) Results of the Archbold Expeditions. No. 29. Summary of the 1936–1937 New Guinea Expedition. *Bulletin of the American Museum of Natural History* 77, 341-380.

Shany, N. (1995) Juvenile Papuan Hawk-Owl *Uroglauis dimorpha* near Vanimo. *Muruk* 7: 74.

Sibley, C. G., and Monroe, B. L. Jr. (1990) *Distribution and Taxonomy of Birds of the World*. Yale University Press, New Haven and London.

Sibley, C. G., and Monroe, B. L. Jr. (1993a) *Supplement to Distribution and Taxonomy of Birds of the World*. Yale University Press, New Haven and London.

Sibley, C. G., and Monroe, B. L. Jr. (1993b) *A World Checklist of Birds*. Yale University Press, New Haven and London.

Stattersfield, A. J., Crosby, M. J., Long, A. J. and Wege, D. C. (1998) *Endemic Bird Areas of the World. Priorities for Bird Conservation*. Birdlife International, Cambridge, UK.

Swadling, P. (1996) *Plumes from Paradise. Trade Cycles in Outer Southeast Asia and their Impact on New Guinea and Nearby Islands until 1920*. PNG National Museum, Boroko.

Takeuchi, W. (2008) Flora of the upstream portion of the PNG LNG Project, Southern Highlands and Western Provinces, Papua New Guinea. Report to Coffey Natural Systems.

Trombulak, S. C. and Frissell, C. A. (2000) Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conservation Biology* 14:18 – 30.

Wade, L. K. and McVean, D. N. (1969) *Mt Wilhelm studies 1: The alpine and subalpine vegetation*. Publication BG/1 Australian National University, Canberra.

Watkins, D. (2000) *Kikori Delta of Gulf Province, Papua New Guinea, Recently Identified as Internationally Important Area for Migratory Shorebirds along the East Asian-Australasian Flyway*. Wetlands International Report.

Woxvold, I. A. and Crome, F. H. J. (2005) *A Report on the Avifauna of the Papua New Guinea Gas Project Area*. Enesar/Coffey Natural Systems Report. Reproduced as Annex 07 to Biodiversity Appendix.

Appendices

Appendix 1

Birds recorded in the PNG LNG Project Upstream Project Area in 2008

					Present ³				
Family	Scientific Name	Common Name	migratory status ¹	IUCN status ²	South Karius	Baia River	Juha South	Juha North	Deviation Camp
Casuariidae	Casuarus bennetti	Dwarf Cassowary	BR	NT	X	X	X	X	X
Megapodiidae:	Aepyodius arfakianus	Wattled Brush-turkey	BR		X				h
Megapodiidae:	Talegalla jobiensis	Brown-collared Brush-turkey	BR					X	h
Megapodiidae:	Megapodius decollatus	New Guinea Scrubfowl	BR		?		X	h	h
Phasianidae	Coturnix chinensis	Blue-breasted Quail	BR		X				
Anatidae	Salvadorina waigiensis	Salvadori's Teal	BR	VU	X				
Bucerotidae	Aceros plicatus	Blyth's Hornbill	BR			X		X	
Coraciidae	Eurystomus orientalis	Dollarbird	M				X		
Dacelonidae	Dacelo gaudichaud	Rufous-bellied Kookaburra	BR			X		X	
Dacelonidae	Clytoceyx rex	Shovel-billed Kookaburra	BR			X			
Dacelonidae	Melidora macrorrhina	Hook-billed Kingfisher	BR			X		X	
Dacelonidae	Syma torotoro	Yellow-billed Kingfisher	BR			X		X	
Dacelonidae	Syma megarhyncha	Mountain Kingfisher	BR		X		X		X
Meropidae	Merops ornatus	Rainbow Bee-eater	BR+M				X	X	X
Cuculidae	Oriental/Himalayan Cuckoo	Cuculus saturatus/optatus	M		X				
Cuculidae	Cacomantis variolosus	Brush Cuckoo	BR+M				X		
Cuculidae	Cacomantis castaneiventris	Chestnut-breasted Cuckoo	BR		X	X			
Cuculidae	Cacomantis flabelliformis	Fan-tailed Cuckoo	BR				X		X
Cuculidae	Rhamphomantis megarhynchus	Long-billed Cuckoo	BR			X			
Cuculidae	Chrysococcyx meyeri	White-eared Bronze-Cuckoo	BR		X	X	X		
Cuculidae	Caliechthrus leucolophus	White-crowned Koel	BR				X	X	
Cuculidae	Microdynamis parva	Dwarf Koel	BR			X			
Cuculidae	Eudynamis scolopacea	Asian Koel	BR				X		
Cuculidae	Scythrops novaehollandiae	Channel-billed Cuckoo	M		X				
Psittacidae	Chalcopsitta sintillata	Yellow-streaked Lory	BR			X	X		
Psittacidae	Pseudeos fuscata	Dusky Lory	BR		X	X	X	X	
Psittacidae	Trichoglossus haematodus	Rainbow Lorikeet	BR			X	X	X	
Psittacidae	Lorius lory	Black-capped Lory	BR		X	X	X	X	
Psittacidae	Charmosyna placentis	Red-flanked Lorikeet	BR					X	
Psittacidae	Charmosyna pulchella	Fairy Lorikeet	BR		X	X	X		X
Psittacidae	Charmosyna papou	Papuan Lorikeet	BR		X				X
Psittacidae	Neopsittacus musschenbroekii	Yellow-billed Lorikeet	BR						X
Psittacidae	Psittichas fulgidus	Pesquet's Parrot	BR	VU	X	X	X	X	
Psittacidae	Micropsitta keiensis	Yellow-capped Pygmy-Parrot	BR					X	
Psittacidae	Micropsitta bruijnii	Red-breasted Pygmy-Parrot	BR		X	X			X
Psittacidae	Cyclopsitta diophthalma	Double-eyed Fig-Parrot	BR		X				
Psittacidae	Geoffroyus simplex	Blue-collared Parrot	BR		X		X	X	X

Appendix 1

Birds recorded in the PNG LNG Project Upstream Project Area in 2008

					Present ³				
Family	Scientific Name	Common Name	migratory status ¹	IUCN status ²	South Karius	Baia River	Juha South	Juha North	Deviation Camp
Psittacidae	<i>Eclectus roratus</i>	Eclectus Parrot	BR			X	X	X	
Psittacidae	<i>Alisterus chloropterus</i>	Papuan King-Parrot	BR		h				
Psittacidae	<i>Probosciger aterrimus</i>	Palm Cockatoo	BR				X	X	
Psittacidae	<i>Cacatua galerita</i>	Sulphur-crested Cockatoo	BR		X	X	X	X	
Apodidae	<i>Collocalia esculenta</i>	Glossy Swiftlet	BR		X	X		X	X
Apodidae	<i>Aerodramus hirundinaceus/vanikorensis/nuditarsus</i>	Swiftlet (Mountain/Uniform/Bare-legged)	BR		X	X	X	X	X
Hemiprocidae	<i>Hemiprocne mystacea</i>	Moustached Treeswift	BR					h	
Tytonidae	<i>Tyto tenebricosa</i>	Greater Sooty-Owl	BR				X	X	X
Strigidae	<i>Ninox theomacha</i>	Jungle Hawk-Owl	BR		X		X	X	
Podargidae	<i>Podargus ocellatus</i>	Marbled Frogmouth	BR				X		
Caprimulgidae	<i>Caprimulgus macrurus</i>	Large-tailed Nightjar	BR				X		
Columbidae	<i>Columba vitiensis</i>	Metallic Pigeon	BR					X	
Columbidae	<i>Macropygia amboinensis</i>	Slender-billed Cuckoo-Dove	BR		X	X	X	X	
Columbidae	<i>Macropygia nigrirostris</i>	Black-billed Cuckoo-Dove	BR						X
Columbidae	<i>Reinwardtoena reinwardtsi</i>	Great Cuckoo-Dove	BR		X	X	X	X	
Columbidae	<i>Chalcophaps indica</i>	Emerald Dove	BR			X			
Columbidae	<i>Henicophaps albifrons</i>	New Guinea Bronzewing	BR			X		X	
Columbidae	<i>Gallicolumba rufigula</i>	Cinnamon Ground-Dove	BR				X	h	
Columbidae	<i>Gallicolumba jobiensis</i>	White-bibbed Ground-Dove	BR					h	
Columbidae	<i>Gallicolumba beccarii</i>	Bronze Ground-Dove	BR						X
Columbidae	<i>Trugon terrestris</i>	Thick-billed Ground-Pigeon	BR			X			
Columbidae	<i>Otidiphaps nobilis</i>	Pheasant Pigeon	BR			X		h	
Columbidae	<i>Ptilinopus magnificus</i>	Wompoo Fruit-Dove	BR			X		X	
Columbidae	<i>Ptilinopus ornatus</i>	Ornate Fruit-Dove	BR		X		X	X	X
Columbidae	<i>Ptilinopus superbus</i>	Superb Fruit-Dove	BR			X	X	X	
Columbidae	<i>Ptilinopus coronatus</i>	Coronated Fruit-Dove	BR			?			
Columbidae	<i>Ptilinopus pulchellus</i>	Beautiful Fruit-Dove	BR			X		X	
Columbidae	<i>Ptilinopus rivoli</i>	White-bibbed Fruit-Dove	BR						X
Columbidae	<i>Ptilinopus iozonus</i>	Orange-bellied Fruit-Dove	BR					h	
Columbidae	<i>Ducula rufigaster</i>	Purple-tailed Imperial-Pigeon	BR					X	
Columbidae	<i>Ducula pinon</i>	Pinon Imperial-Pigeon	BR					X	
Columbidae	<i>Ducula mullerii</i>	Collared Imperial-Pigeon	BR					h	
Columbidae	<i>Ducula zoeae</i>	Banded Imperial-Pigeon	BR			X	X	X	
Columbidae	<i>Gymnophaps albertsii</i>	Papuan Mountain-Pigeon	BR		X	X	X		X
Columbidae	<i>Goura scheepmakeri</i>	Southern Crowned-Pigeon	BR	VU		X		h	
Rallidae	<i>Rallina forbesi</i>	Forbes's Forest-Rail	BR				X		
Rallidae	<i>Rallina tricolor</i>	Red-necked Crane	BR			X			

Appendix 1

Birds recorded in the PNG LNG Project Upstream Project Area in 2008

					Present ³				
Family	Scientific Name	Common Name	migratory status ¹	IUCN status ²	South Karius	Baia River	Juha South	Juha North	Deviation Camp
Rallidae	Gallirallus philippensis	Buff-banded Rail	BR		X				
Scolopacidae	Actitis hypoleucos	Common Sandpiper	M			X			
Accipitridae	Aviceda subcristata	Pacific Baza	BR					X	
Accipitridae	Henicopernis longicauda	Long-tailed Honey-buzzard	BR				X	X	
Accipitridae	Accipiter novaehollandiae	Grey Goshawk	BR					X	
Accipitridae	Accipiter melanochlamys	Black-mantled Goshawk	BR		h				X
Accipitridae	Accipiter meyerianus	Meyer's Goshawk	BR				?		
Accipitridae	Harpyopsis novaeguineae	New Guinea Eagle	BR	VU			X		
Accipitridae	Aquila gurneyi	Gurney's Eagle	BR	NT		?			
Accipitridae	Hieraaetus morphnoides	Little Eagle	BR			X		X	
Ardeidae	Zonerodius heliosylus	Forest Bittern	BR	NT		X			
Pittidae	Pitta erythrogaster	Red-bellied Pitta	BR				X	h	
Ptilonorhynchidae	Ailuroedus buccoides	White-eared Catbird	BR				X	X	
Ptilonorhynchidae	Ailuroedus melanotis	Spotted Catbird	BR		X		X		
Ptilonorhynchidae	Amblyornis macgregoriae	Macgregor's Bowerbird	BR		X				X
Maluridae	Malurus alboscapulatus	White-shouldered Fairywren	BR		X	X			
Meliphagidae	Myzomela eques	Red-throated Myzomela	BR			X			
Meliphagidae	Myzomela cruentata	Red Myzomela	BR		X		X		
Meliphagidae	Myzomela nigrita	Black Myzomela	BR				X		
Meliphagidae	Myzomela rosenbergii	Red-collared Myzomela	BR		X				X
Meliphagidae	Melilestes mearnsianus	Long-billed Honeyeater	BR			X	X	X	
Meliphagidae	Meliphaga mimikae	Mottle-breasted Honeyeater	BR			X	X	X	
Meliphagidae	Meliphaga orientalis	Hill-forest Honeyeater	BR				X		
Meliphagidae	Meliphaga albonotata	Scrub Honeyeater	BR			X			
Meliphagidae	Meliphaga analoga	Mimic Honeyeater	BR					X	
Meliphagidae	Xanthotis flaviventer	Tawny-breasted Honeyeater	BR			X	X	X	
Meliphagidae	Pycnopygius stictocephalus	Streak-headed Honeyeater	BR			X			
Meliphagidae	Philemon meyeri	Meyer's Friarbird	BR			X			
Meliphagidae	Philemon novaeguineae	New Guinea Friarbird	BR			X		X	
Meliphagidae	Ptiloprora guisei	Rufous-backed Honeyeater	BR		X				X
Meliphagidae	Melidectes rufocrissalis	Yellow-browed Melidectes	BR		X				X
Meliphagidae	Melipotus fumigatus	Smoky Honeyeater	BR		X				X
Pardalotidae	Crateroscelis murina	Rusty Mouse-warbler	BR			X	X	X	
Pardalotidae	Crateroscelis nigrorufa	Bicolored Mouse-warbler	BR		X				
Pardalotidae	Crateroscelis robusta	Mountain Mouse-warbler	BR		X				X
Pardalotidae	Sericornis beccarii	Tropical / Beccari's Scrubwren	BR		X				
Pardalotidae	Sericornis nouhuysi	Large Scrubwren	BR		X				X

Appendix 1

Birds recorded in the PNG LNG Project Upstream Project Area in 2008

					Present ³				
Family	Scientific Name	Common Name	migratory status ¹	IUCN status ²	South Karius	Baia River	Juha South	Juha North	Deviation Camp
Pardalotidae	<i>Sericornis perspicillatus</i>	Buff-faced Scrubwren	BR		X				X
Pardalotidae	<i>Sericornis arfakianus</i>	Grey-green Scrubwren	BR		X		X		
Pardalotidae	<i>Sericornis papuensis</i>	Papuan Scrubwren	BR						X
Pardalotidae	<i>Sericornis spilodera</i>	Pale-billed Scrubwren	BR				X	X	
Pardalotidae	<i>Gerygone cinerea</i>	Mountain Gerygone	BR						X
Pardalotidae	<i>Gerygone chloronotus</i>	Green-backed Gerygone	BR			X	X	X	
Pardalotidae	<i>Gerygone palpebrosa</i>	Fairy Gerygone	BR		X				
Pardalotidae	<i>Gerygone chrysogaster</i>	Yellow-bellied Gerygone	BR					X	
Pardalotidae	<i>Gerygone ruficollis</i>	Brown-breasted Gerygone	BR		X				X
Petroicidae	<i>Amalocichla incerta</i>	Lesser Ground-robin	BR		X				X
Petroicidae	<i>Monachella muelleriana</i>	Torrent Robin	BR			X		X	
Petroicidae	<i>Microeca flavovirescens</i>	Olive Flyrobin	BR					X	
Petroicidae	<i>Microeca papuana</i>	Canary Flyrobin	BR		X				X
Petroicidae	<i>Poecilodryas albonotata</i>	Black-throated Robin	BR						X
Petroicidae	<i>Peneothello cyanus</i>	Blue-grey Robin	BR		X				X
Petroicidae	<i>Peneothello bimaculatus</i>	White-rumped Robin	BR				X		
Petroicidae	<i>Pachycephalopsis poliosoma</i>	White-eyed Robin	BR				X		
Petroicidae	<i>Drymodes superciliaris</i>	Northern Scrub-Robin	BR				X	h	
Laniidae	<i>Lanius schach</i>	Long-tailed Shrike	BR		h				
Corvidae	<i>Ptilorhoa leucosticta</i>	Spotted Jewel-babbler	BR						X
Corvidae	<i>Ptilorhoa caerulescens</i>	Blue Jewel-babbler	BR					X	
Corvidae	<i>Ptilorhoa castanonota</i>	Chestnut-backed Jewel-babbler	BR		h	X	X		
Corvidae	<i>Ifrita kowaldi</i>	Ifrit	BR						X
Corvidae	<i>Rhagologus leucostigma</i>	Mottled Whistler	BR						X
Corvidae	<i>Pachycare flavogrisea</i>	Goldenface	BR				X		?
Corvidae	<i>Aleadryas rufinucha</i>	Rufous-naped Whistler	BR		X				X
Corvidae	<i>Pachycephala hyperythra</i>	Rusty Whistler	BR			X	X		
Corvidae	<i>Pachycephala modesta</i>	Brown-backed Whistler	BR						X
Corvidae	<i>Pachycephala soror</i>	Sclater's Whistler	BR		X		X		X
Corvidae	<i>Colluricincla megarrhyncha</i>	Little Shrike-thrush	BR		X	X	X	X	
Corvidae	<i>Pitohui kirhocephalus</i>	Variable Pitohui	BR			X		X	
Corvidae	<i>Pitohui ferrugineus</i>	Rusty Pitohui	BR			X		X	
Corvidae	<i>Pitohui cristatus</i>	Crested Pitohui	BR				X	h	
Corvidae	<i>Pitohui nigrescens</i>	Black Pitohui	BR						X
Corvidae	<i>Eulacestoma nigropectus</i>	Wattled Ploughbill	BR						X
Corvidae	<i>Corvus tristis</i>	Grey Crow	BR			X		X	
Corvidae	<i>Loboparadisea sericea</i>	Yellow-breasted Bird-of-paradise	BR	NT	X				
Corvidae	<i>Cnemophilus loriae</i>	Loria's Bird-of-paradise	BR		X				X
Corvidae	<i>Manucodia chalybata</i>	Crinkle-collared	BR			X	X		

Appendix 1

Birds recorded in the PNG LNG Project Upstream Project Area in 2008

					Present ³				
Family	Scientific Name	Common Name	migratory status ¹	IUCN status ²	South Karius	Baia River	Juha South	Juha North	Deviation Camp
		Manucode							
Corvidae	Manucodia keraudrenii	Trumpet Manucode	BR		X	X			
Corvidae	Paradigalla brevicauda	Short-tailed Paradigalla	BR		X				X
Corvidae	Epimachus fastuosus	Black Sicklebill	BR	VU	X				
Corvidae	Epimachus meyeri	Brown Sicklebill	BR						h
Corvidae	Lophorina superba	Superb Bird-of-paradise	BR		X				X
Corvidae	Parotia carolae	Carola's Parotia	BR		X		X		
Corvidae	Parotia lawesii	Lawes' Parotia	BR		X				
Corvidae	Ptiloris magnificus	Magnificent Riflebird	BR			X	X	X	
Corvidae	Cicinnurus magnificus	Magnificent Bird-of-paradise	BR			X	X	X	
Corvidae	Cicinnurus regius	King Bird-of-paradise	BR			X		X	
Corvidae	Astrapia mayeri	Ribbon-tailed Astrapia	BR	NT	h				
Corvidae	Astrapia stephaniae	Stephanie's Astrapia	BR						X
Corvidae	Pteridophora alberti	King-of-Saxony Bird-of-paradise	BR		X				h
Corvidae	Paradisaea raggiana	Raggiana Bird-of-paradise	BR			X	X	X	
Corvidae	Paradisaea rudolphi	Blue Bird-of-paradise	BR	VU	h				
Corvidae	Cracticus cassicus	Hooded Butcherbird	BR			X		X	
Corvidae	Cracticus quoyi	Black Butcherbird	BR			X	X		
Corvidae	Artamus maximus	Great Woodswallow	BR						X
Corvidae	Peltops montanus	Mountain Peltops	BR		X		X		X
Corvidae	Oriolus szalayi	Brown Oriole	BR			X		X	
Corvidae	Coracina caeruleogrisea	Stout-billed Cuckooshrike	BR				X		
Corvidae	Coracina longicauda	Hooded Cuckooshrike	BR						X
Corvidae	Coracina tenuirostris	Slender-billed Cicadabird	BR+M					X	
Corvidae	Coracina incerta	Black-shouldered Cicadabird	BR				X		
Corvidae	Coracina schisticeps	Grey-headed Cuckooshrike	BR			X	X	X	
Corvidae	Coracina melas	New Guinea Cuckooshrike	BR			X	X	X	
Corvidae	Coracina montana	Black-bellied Cuckooshrike	BR		X				X
Corvidae	Campochaera sloetii	Golden Cuckooshrike	BR			X			
Corvidae	Lalage leucomela	Varied Triller	BR					X	
Corvidae	Rhipidura leucophrys	Willie-wagtail	BR		X	X			
Corvidae	Rhipidura threnothorax	Sooty Thicket-Fantail	BR			X		X	
Corvidae	Rhipidura leucothorax	White-bellied Thicket-Fantail	BR			X			
Corvidae	Rhipidura atra	Black Fantail	BR		X		X		X
Corvidae	Rhipidura hyperythra	Chestnut-bellied Fantail	BR				X		
Corvidae	Rhipidura albolimbata	Friendly Fantail	BR		X				X
Corvidae	Chaetorhynchus papuensis	Pygmy Drongo	BR		X		X		
Corvidae	Dicrurus bracteatus	Spangled Drongo	BR+M			X		X	
Corvidae	Monarcha axillaris	Black Monarch	BR		X		X		

Appendix 1

Birds recorded in the PNG LNG Project Upstream Project Area in 2008

					Present ³				
Family	Scientific Name	Common Name	migratory status ¹	IUCN status ²	South Karius	Baia River	Juha South	Juha North	Deviation Camp
Corvidae	<i>Monarcha frater</i>	Black-winged Monarch	BR+M				X		
Corvidae	<i>Monarcha guttulus</i>	Spot-winged Monarch	BR					X	
Corvidae	<i>Monarcha chrysomela</i>	Golden Monarch	BR			X	X		
Corvidae	<i>Arses telescopthalmus</i>	Friiled Monarch	BR		X	X			
Corvidae	<i>Machaerirhynchus flaviventer</i>	Yellow-breasted Boatbill	BR				X		
Corvidae	<i>Machaerirhynchus nigripetector</i>	Black-breasted Boatbill	BR		X				
Corvidae	<i>Grallina bruijini</i>	Torrent-lark	BR		X				X
Muscicapidae	<i>Zosterops heinei</i>	Russet-tailed Thrush	BR				X		
Muscicapidae	<i>Turdus poliocephalus</i>	Island Thrush	BR						X
Sturnidae	<i>Aplonis cantoroides</i>	Singing Starling	BR			X		X	
Sturnidae	<i>Aplonis mystacea</i>	Yellow-eyed Starling	BR	NT				X	
Sturnidae	<i>Mino anais</i>	Golden Myna	BR			X		X	
Sturnidae	<i>Mino dumontii</i>	Yellow-faced Myna	BR			X		X	
Hirundinidae	<i>Hirundo tahitica</i>	Pacific Swallow	BR			X			
Hirundinidae	<i>Hirundo daurica</i>	Red-rumped Swallow	M					X	
Zosteropidae	<i>Zosterops minor</i>	Black-fronted White-eye	BR		X				
Sylviidae	<i>Phylloscopus trivirgatus</i>	Mountain Leaf-Warbler	BR		X		X		X
Sylviidae	<i>Megalurus timoriensis</i>	Tawny Grassbird	BR		X				
Nectariniidae	<i>Dicaeum geelvinkianum</i>	Red-capped Flowerpecker	BR		X	X	X	X	X
Nectariniidae	<i>Nectarinia aspasia</i>	Black Sunbird	BR			X		X	
Melanocharitidae	<i>Melanocharis nigra</i>	Black Berrypecker	BR				X		
Melanocharitidae	<i>Melanocharis longicauda</i>	Lemon-breasted Berrypecker	BR		X		X		X
Melanocharitidae	<i>Melanocharis versteri</i>	Fan-tailed Berrypecker	BR						X
Melanocharitidae	Spotted Berrypecker	Spotted Berrypecker	BR		X				
Melanocharitidae	<i>Toxorhamphus poliopterus</i>	Grey-winged Longbill	BR		X		X		
Melanocharitidae	<i>Toxorhamphus novaeguineae</i>	Green-crowned Longbill	BR					X	
Melanocharitidae	<i>Toxorhamphus iliophus</i>	Plumed Longbill	BR				X	X	
Paramythiidae	<i>Oreocharis arfaki</i>	Tit Berrypecker	BR		X				
Paramythiidae	<i>Paramythia montium</i>	Crested Berrypecker	BR						X
Passeridae	<i>Motacilla cinerea</i>	Grey Wagtail	M			X		X	
Passeridae	<i>Erythrura trichroa</i>	Blue-faced Parrotfinch	BR		X			X	X
Passeridae	<i>Lonchura spectabilis</i>	Hooded Munia	BR		X				
Total					85	82	83	91	65

¹ BR – breeding residents; M – migrants; BR+M – species with resident and migratory populations

² VU – Vulnerable; NT – Near-threatened

³ X – recorded by survey team; h – hunter record; ? – specific identification uncertain.

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Casuariidae	Southern Cassowary	<i>Casuarius casuarius</i>				x	x				x		x	x
Casuariidae	Dwarf Cassowary	<i>Casuarius bennetti</i>												
Megapodiidae	Wattled Brush-turkey	<i>Aepypodius arfakianus</i>												
Megapodiidae	Black-billed Brush-turkey	<i>Talegalla fuscirostris</i>				x	x	x			x			x
Megapodiidae	Brown-collared Brush-turkey	<i>Talegalla jobiensis</i>												
Megapodiidae	Brush-turkey	<i>Talegalla sp.</i>		x									x	
Megapodiidae	Orange-footed Scrubfowl	<i>Megapodius reinwardt</i>		x			x	x			x		x	
Megapodiidae	New Guinea Scrubfowl	<i>Megapodius decollatus</i>												
Phasianidae	Blue-breasted Quail	<i>Coturnix chinensis</i>												
Dendrocygnidae	Spotted Whistling-Duck	<i>Dendrocygna guttata</i>				x					x	x		
Dendrocygnidae	Wandering Whistling-Duck	<i>Dendrocygna arcuata</i>					x							
Anatidae	Green Pygmy-goose	<i>Nettapus pulchellus</i>												
Anatidae	Pacific Black Duck	<i>Anas superciliosa</i>												
Anatidae	Grey Teal	<i>Anas gracilis</i>												
Bucerotidae	Blyth's Hornbill	<i>Aceros plicatus</i>		x		x	x	x			x	x	x	x
Coraciidae	Dollarbird	<i>Eurystomus orientalis</i>		x		x	x	x					x	x
Alcedinidae	Azure Kingfisher	<i>Alcedo azurea</i>		x			x	x		x		x		x
Alcedinidae	Little Kingfisher	<i>Alcedo pusilla</i>		x			x	x	x	x			x	
Alcedinidae	Variable Kingfisher	<i>Ceyx lepidus</i>					x	x				x	x	

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Dacelonidae	Rufous-bellied Kookaburra	<i>Dacelo gaudichaud</i>	x	x		x	x	x	x		x	x	x	x
Dacelonidae	Shovel-billed Kookaburra	<i>Clytoceyx rex</i>												
Dacelonidae	Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>		x										
Dacelonidae	Forest Kingfisher	<i>Todirhamphus macleayi</i>				x	x				x			x
Dacelonidae	Sacred Kingfisher	<i>Todirhamphus sanctus</i>		x	x	x	x					x	x	
Dacelonidae	Hook-billed Kingfisher	<i>Melidora macrorrhina</i>					x	x			x		x	x
Dacelonidae	Yellow-billed Kingfisher	<i>Syma torotoro</i>					x	x					x	
Dacelonidae	Mountain Kingfisher	<i>Syma megarhyncha</i>												
Meropidae	Rainbow Bee-eater	<i>Merops ornatus</i>		x	x	x	x						x	
Cuculidae	Oriental Cuckoo	<i>Cuculus saturatus</i>		x									x	
Cuculidae	Brush Cuckoo	<i>Cacomantis variolosus</i>		x	x	x	x	x			x		x	x
Cuculidae	Chestnut-breasted Cuckoo	<i>Cacomantis castaneiventris</i>				x	x	x						
Cuculidae	Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>												
Cuculidae	Long-billed Cuckoo	<i>Rhamphomantis megarhynchus</i>					x							
Cuculidae	Gould's Bronze-Cuckoo	<i>Chrysococcyx russatus</i>		x			x	x					x	x
Cuculidae	Rufous-throated Bronze-Cuckoo	<i>Chrysococcyx ruficollis</i>												
Cuculidae	White-eared Bronze-Cuckoo	<i>Chrysococcyx meyeri</i>												
Cuculidae	White-crowned Koel	<i>Caliechthrus leucolophus</i>					x	x					x	
Cuculidae	Dwarf Koel	<i>Microdynamis parva</i>					x	x					x	

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Cuculidae	Asian Koel	<i>Eudynamys scolopacea</i>		x		x	x	x			x		x	x
Cuculidae	Channel-billed Cuckoo	<i>Scythrops novaehollandiae</i>		x		x	x	x						
Centropodidae	Greater Black Coucal	<i>Centropus menbeki</i>		x		x	x	x			x		x	x
Centropodidae	Lesser Black Coucal	<i>Centropus bernsteini</i>		x		x	x						x	
Psittacidae	Yellow-streaked Lory	<i>Chalcopsitta sintillata</i>		x		x	x	x			x		x	x
Psittacidae	Dusky Lory	<i>Pseudeos fuscata</i>		x		x	x						x	
Psittacidae	Rainbow Lorikeet	<i>Trichoglossus haematodus</i>		x		x	x	x			x		x	x
Psittacidae	Goldie's Lorikeet	<i>Psitteuteles goldiei</i>												
Psittacidae	Black-capped Lory	<i>Lorius lory</i>		x		x	x	x			x		x	x
Psittacidae	Striated Lorikeet	<i>Charmosyna multistriata</i>												
Psittacidae	Pygmy Lorikeet	<i>Charmosyna wilhelminae</i>												
Psittacidae	Red-flanked Lorikeet	<i>Charmosyna placensis</i>		x		x	x	x			x		x	x
Psittacidae	Fairy Lorikeet	<i>Charmosyna pulchella</i>												
Psittacidae	Josephine's Lorikeet	<i>Charmosyna josephinae</i>												
Psittacidae	Papuan Lorikeet	<i>Charmosyna papou</i>												
Psittacidae	Plum-faced Lorikeet	<i>Oreopsittacus arfaki</i>												
Psittacidae	Yellow-billed Lorikeet	<i>Neopsittacus musschenbroekii</i>												
Psittacidae	Orange-billed Lorikeet	<i>Neopsittacus pullicauda</i>												
Psittacidae	Palm Cockatoo	<i>Probosciger aterrimus</i>		x		x	x	x			x	x	x	x

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Psittacidae	Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	x	x	x	x	x	x			x		x	x
Psittacidae	Yellow-capped Pygmy-Parrot	<i>Micropsitta keiensis</i>							x	x				
Psittacidae	Buff-faced Pygmy-Parrot	<i>Micropsitta pusio</i>		x			x	x					x	
Psittacidae	Red-breasted Pygmy-Parrot	<i>Micropsitta bruijnii</i>												
Psittacidae	Orange-breasted Fig-Parrot	<i>Cyclopsitta gulelmitertii</i>		x		x	x	x			x		x	x
Psittacidae	Double-eyed Fig-Parrot	<i>Cyclopsitta diophthalma</i>					x	x						
Psittacidae	Large Fig-Parrot	<i>Psittaculirostris desmarestii</i>					x	x						
Psittacidae	Madarasz's Tiger-Parrot	<i>Psittacella madaraszii</i>												
Psittacidae	Red-cheeked Parrot	<i>Geoffroyus geoffroyi</i>	x	x		x	x	x			x		x	x
Psittacidae	Blue-collared Parrot	<i>Geoffroyus simplex</i>												
Psittacidae	Eclectus Parrot	<i>Eclectus roratus</i>		x		x	x	x			x		x	x
Psittacidae	Pesquet's Parrot	<i>Psittarchas fulgidus</i>				x	x	x			x		x	x
Psittacidae	Papuan King-Parrot	<i>Alisterus chloropterus</i>												x
Psittacidae	Orange-fronted Hanging-Parrot	<i>Loriculus aurantiifrons</i>					x	x					x	
Apodidae	Glossy Swiftlet	<i>Collocalia esculenta</i>				x	x	x			x	x	x	x
Apodidae	Mountain Swiftlet	<i>Aerodramus hirundinaceus</i>												
Apodidae	Swiftlet (Mountain/Uniform)	<i>Aerodramus hirundinaceus/vanikorensis</i>					x	x						
Apodidae	Swiftlet (Bare-legged/Mountain)	<i>Aerodramus nuditarisus/hirundinaceus</i>												
Apodidae	Uniform Swiftlet	<i>Aerodramus vanikorensis</i>		x	x	x	x				x	x	x	x

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Apodidae	Papuan Needletail	<i>Mearnsia novaeguineae</i>		x	x	x	x	x			x			
Apodidae	White-throated Needletail	<i>Hirundapus caudacutus</i>					x						x	
Hemiprocnidae	Moustached Treeswift	<i>Hemiprocne mystacea</i>				x	x				x			
Tytonidae	Greater Sooty-Owl	<i>Tyto tenebricosa</i>												
Strigidae	Rufous Owl	<i>Ninox rufa</i>												
Strigidae	Jungle Hawk-Owl	<i>Ninox theomacha</i>				x								
Aegothelidae	Feline Owlet-Nightjar	<i>Aegotheles insignis</i>												
Aegothelidae	Barred Owlet-Nightjar	<i>Aegotheles bennettii</i>												
Aegothelidae	Mountain Owlet-Nightjar	<i>Aegotheles albertisi</i>												
Aegothelidae	Owlet-Nightjar	<i>Aegotheles sp.</i>												
Podargidae	Papuan Frogmouth	<i>Podargus papuensis</i>		x			x				x		x	
Podargidae	Marbled Frogmouth	<i>Podargus ocellatus</i>					x				x		x	x
Eurostopodidae	Papuan Eared-Nightjar	<i>Eurostopodus papuensis</i>												
Eurostopodidae	Mountain Eared-Nightjar	<i>Eurostopodus archboldi</i>												
Caprimulgidae	Large-tailed Nightjar	<i>Caprimulgus macrurus</i>												
Columbidae	Metallic Pigeon	<i>Columba vitiensis</i>												
Columbidae	Slender-billed Cuckoo-Dove	<i>Macropygia amboinensis</i>				x	x	x					x	x
Columbidae	Black-billed Cuckoo-Dove	<i>Macropygia nigrirostris</i>					x						x	
Columbidae	Great Cuckoo-Dove	<i>Reinwardtoena reinwardtsi</i>					x	x			x		x	x

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Columbidae	Stephan's Dove	<i>Chalcophaps stephani</i>				x	x					x		
Columbidae	New Guinea Bronzewing	<i>Henicophaps albifrons</i>					x	x						
Columbidae	Cinnamon Ground-Dove	<i>Gallicolumba rufigula</i>												
Columbidae	Bronze Ground-Dove	<i>Gallicolumba beccarii</i>												
Columbidae	Thick-billed Ground-Pigeon	<i>Trugon terrestris</i>					x	x					x	
Columbidae	Pheasant Pigeon	<i>Otidiphaps nobilis</i>					x	x					x	
Columbidae	Wompoo Fruit-Dove	<i>Ptilinopus magnificus</i>				x	x	x			x		x	x
Columbidae	Pink-spotted Fruit-Dove	<i>Ptilinopus perlatus</i>				x	x	x			x		x	x
Columbidae	Ornate Fruit-Dove	<i>Ptilinopus ornatus</i>												
Columbidae	Orange-fronted Fruit-Dove	<i>Ptilinopus aurantiifrons</i>		x										
Columbidae	Superb Fruit-Dove	<i>Ptilinopus superbus</i>					x	x					x	
Columbidae	Coroneted Fruit-Dove	<i>Ptilinopus coronulatus</i>					x							
Columbidae	Beautiful Fruit-Dove	<i>Ptilinopus pulchellus</i>		x			x	x					x	
Columbidae	White-bibbed Fruit-Dove	<i>Ptilinopus rivoli</i>												
Columbidae	Orange-bellied Fruit-Dove	<i>Ptilinopus iozonus</i>	x	x		x	x	x			x		x	x
Columbidae	Dwarf Fruit-Dove	<i>Ptilinopus naina</i>					x	x					x	
Columbidae	Purple-tailed Imperial-Pigeon	<i>Ducula rufigaster</i>				x	x	x			x		x	x
Columbidae	Shining Imperial-Pigeon	<i>Ducula chalconota</i>												
Columbidae	Pinon Imperial-Pigeon	<i>Ducula pinon</i>		x		x	x	x			x		x	x

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Columbidae	Collared Imperial-Pigeon	<i>Ducula mullerii</i>	x											x
Columbidae	Banded Imperial-Pigeon	<i>Ducula zoeae</i>		x		x	x	x			x		x	x
Columbidae	Torresian Imperial-Pigeon	<i>Ducula spilorrhoa</i>	x				x							
Columbidae	Papuan Mountain-Pigeon	<i>Gymnophaps albertisii</i>				x	x						x	
Columbidae	Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>		x		x	x	x			x		x	x
Rallidae	Forbes's Forest-Rail	<i>Rallina forbesi</i>												
Rallidae	Red-necked Crake	<i>Rallina tricolor</i>		x			x							
Rallidae	Buff-banded Rail	<i>Gallirallus philippensis</i>					x							
Rallidae	Rufous-tailed Waterhen	<i>Amaurornis moluccana</i>					x							
Rallidae	White-browed Crake	<i>Porzana cinerea</i>												
Rallidae	New Guinea Flightless Rail	<i>Megacrex inepta</i>					x				x			
Rallidae	Dusky Moorhen	<i>Gallinula tenebrosa</i>												
Scolopacidae	Black-tailed Godwit	<i>Limosa limosa</i>	x	x										
Scolopacidae	Bar-tailed Godwit	<i>Limosa lapponica</i>	x											
Scolopacidae	Whimbrel	<i>Numenius phaeopus</i>	x	x	x									
Scolopacidae	Far Eastern Curlew	<i>Numenius madagascariensis</i>	x	x										
Scolopacidae	Marsh Sandpiper	<i>Tringa stagnatilis</i>	x	x										
Scolopacidae	Common Greenshank	<i>Tringa nebularia</i>	x	x										
Scolopacidae	Terek Sandpiper	<i>Xenus cinereus</i>	x	x										

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	x	x	x		x				x		x	x
Scolopacidae	Grey-tailed Tattler	<i>Heteroscelus brevipes</i>	x	x										
Scolopacidae	Ruddy Turnstone	<i>Arenaria interpres</i>	x											
Scolopacidae	Asian Dowitcher	<i>Limnodromus semipalmatus</i>	x											
Scolopacidae	Great Knot	<i>Calidris tenuirostris</i>	x	x										
Scolopacidae	Red Knot	<i>Calidris canutus</i>	x											
Scolopacidae	Sanderling	<i>Calidris alba</i>	x	x										
Scolopacidae	Red-necked Stint	<i>Calidris ruficollis</i>	x	x										
Scolopacidae	Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	x											
Scolopacidae	Curlew Sandpiper	<i>Calidris ferruginea</i>	x											
Burhinidae	Beach Thick-knee	<i>Esacus giganteus</i>	x											
Charadriidae	Pacific Golden-Plover	<i>Pluvialis fulva</i>	x	x										
Charadriidae	Grey Plover	<i>Pluvialis squatarola</i>	x											
Charadriidae	Little Ringed Plover	<i>Charadrius dubius</i>					x							
Charadriidae	Mongolian Plover	<i>Charadrius mongolus</i>	x	x										
Charadriidae	Greater Sand Plover	<i>Charadrius leschenaultii</i>	x	x										
Charadriidae	Masked Lapwing	<i>Vanellus miles</i>												
Glareolidae	Australian Pratincole	<i>Stiltia isabella</i>		x										
Laridae	Silver Gull	<i>Larus novaehollandiae</i>		x										

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Laridae	Gull-billed Tern	<i>Gelochelidon nilotica</i>	x	x										
Laridae	Caspian Tern	<i>Sterna caspia</i>	x											
Laridae	Lesser Crested-Tern	<i>Sterna bengalensis</i>		x										
Laridae	Great Crested-Tern	<i>Sterna bergii</i>	x	x										
Laridae	Black-naped Tern	<i>Sterna sumatrana</i>		x										
Laridae	Common Tern	<i>Sterna hirundo</i>			x									
Laridae	Little Tern	<i>Sterna albifrons</i>	x	x	x						x			
Laridae	Whiskered Tern	<i>Chlidonias hybridus</i>		x										
Laridae	White-winged Tern	<i>Chlidonias leucopterus</i>	x											
Laridae	Black Noddy	<i>Anous minutus</i>		x										
Accipitridae	Pacific Baza	<i>Aviceda subcristata</i>				x	x	x					x	
Accipitridae	Long-tailed Honey-buzzard	<i>Henicopernis longicauda</i>		x			x							x
Accipitridae	Whistling Kite	<i>Haliastur sphenurus</i>					x							
Accipitridae	Brahminy Kite	<i>Haliastur indus</i>		x		x	x	x			x		x	x
Accipitridae	White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>	x	x										
Accipitridae	Eastern Marsh-Harrier	<i>Circus spilonotus</i>												
Accipitridae	Grey Goshawk	<i>Accipiter novaehollandiae</i>	x	x		x	x	x					x	
Accipitridae	Brown Goshawk	<i>Accipiter fasciatus</i>												
Accipitridae	Black-mantled Goshawk	<i>Accipiter melanochlamys</i>												

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Accipitridae	Grey-headed Goshawk	<i>Accipiter poliocephalus</i>					x							
Accipitridae	Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>					x							
Accipitridae	Meyer's Goshawk	<i>Accipiter meyerianus</i>												
Accipitridae	New Guinea Eagle	<i>Harpyopsis novaeguineae</i>					x						x	
Accipitridae	Gurney's Eagle	<i>Aquila gurneyi</i>												
Accipitridae	Little Eagle	<i>Hieraaetus morphnoides</i>				x								
Falconidae	Brown Falcon	<i>Falco berigora</i>												
Falconidae	Australian Kestrel	<i>Falco cenchroides</i>		x			x							
Falconidae	Oriental Hobby	<i>Falco severus</i>												
Falconidae	Australian Hobby	<i>Falco longipennis</i>					x							
Falconidae	Peregrine Falcon	<i>Falco peregrinus</i>					x							
Anhingidae	Australian Darter	<i>Anhinga novaehollandiae</i>				x	x				x		x	
Phalacrocoracidae	Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>		x		x	x						x	x
Phalacrocoracidae	Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>				x								
Ardeidae	Little Egret	<i>Egretta garzetta</i>	x	x			x							
Ardeidae	Pacific Reef-Egret	<i>Egretta sacra</i>	x								x			
Ardeidae	Great-billed Heron	<i>Ardea sumatrana</i>		x										
Ardeidae	Pied Heron	<i>Ardea picata</i>												
Ardeidae	Great Egret	<i>Ardea alba</i>	x	x		x	x						x	

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Ardeidae	Intermediate Egret	<i>Mesophoyx intermedia</i>												
Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>												
Ardeidae	Striated Heron	<i>Butorides striatus</i>	x	x	x	x								
Ardeidae	Rufous Night-Heron	<i>Nycticorax caledonicus</i>				x	x							
Ardeidae	Black Bittern	<i>Dupetor flavicollis</i>												x
Threskiornithidae	Straw-necked Ibis	<i>Threskiornis spinicollis</i>												
Pelecanidae	Australian Pelican	<i>Pelecanus conspicillatus</i>	x	x										
Fregatidae	Lesser Frigatebird	<i>Fregata ariel</i>		x										
Pittidae	Hooded Pitta	<i>Pitta sordida</i>				x	x	x			x		x	x
Pittidae	Red-bellied Pitta	<i>Pitta erythrogaster</i>				x	x	x					x	
Climacteridae	Papuan Treecreeper	<i>Cormobates placens</i>												
Ptilonorhynchidae	White-eared Catbird	<i>Ailuroedus buccoides</i>				x						x	x	
Ptilonorhynchidae	Spotted Catbird	<i>Ailuroedus melanotis</i>												
Ptilonorhynchidae	Macgregor's Bowerbird	<i>Amblyornis macgregoriae</i>												
Maluridae	Orange-crowned Fairywren	<i>Clytomyias insignis</i>												
Maluridae	Wallace's Fairywren	<i>Sipodotus wallacii</i>												
Maluridae	White-shouldered Fairywren	<i>Malurus alboscapulatus</i>												
Maluridae	Emperor Fairywren	<i>Malurus cyanocephalus</i>		x		x	x	x		x				
Meliphagidae	Red-throated Myzomela	<i>Myzomela eques</i>					x							

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Meliphagidae	Dusky Myzomela	<i>Myzomela obscura</i>	x			x			x					
Meliphagidae	Red Myzomela	<i>Myzomela cruentata</i>												
Meliphagidae	Black Myzomela	<i>Myzomela nigrita</i>					x							
Meliphagidae	Mountain Myzomela	<i>Myzomela adolphinae</i>												
Meliphagidae	Red-collared Myzomela	<i>Myzomela rosenbergii</i>												
Meliphagidae	Olive Straightbill	<i>Timeliopsis fulvigula</i>												
Meliphagidae	Long-billed Honeyeater	<i>Melilestes megarrhynchus</i>					x	x			x	x	x	x
Meliphagidae	Green-backed Honeyeater	<i>Glycichaera fallax</i>		x			x							
Meliphagidae	Mottle-breasted Honeyeater	<i>Meliphaga mimikae</i>												
Meliphagidae	Hill-forest Honeyeater	<i>Meliphaga orientalis</i>												
Meliphagidae	Scrub Honeyeater	<i>Meliphaga albonotata</i>		x			x							
Meliphagidae	Puff-backed Honeyeater	<i>Meliphaga aruensis</i>					x	x	x				x	
Meliphagidae	Mimic Honeyeater	<i>Meliphaga analoga</i>					x	x				x		x
Meliphagidae	Graceful Honeyeater	<i>Meliphaga gracilis</i>		x										
Meliphagidae	Yellow-gaped Honeyeater	<i>Meliphaga flavirictus</i>							x					
Meliphagidae	Honeyeater	<i>Meliphaga sp.</i>					x	x						
Meliphagidae	Black-throated Honeyeater	<i>Lichenostomus subfrenatus</i>												
Meliphagidae	Obscure Honeyeater	<i>Lichenostomus obscurus</i>											x	
Meliphagidae	Varied Honeyeater	<i>Lichenostomus versicolor</i>	x			x								

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Meliphagidae	Tawny-breasted Honeyeater	<i>Xanthotis flaviventer</i>		x		x	x	x			x		x	x
Meliphagidae	Spotted Honeyeater	<i>Xanthotis polygramma</i>												
Meliphagidae	Plain Honeyeater	<i>Pycnopygius ixoides</i>					x							
Meliphagidae	Streak-headed Honeyeater	<i>Pycnopygius stictocephalus</i>					x						x	
Meliphagidae	Meyer's Friarbird	<i>Philemon meyeri</i>												
Meliphagidae	New Guinea Friarbird	<i>Philemon novaeguineae</i>		x	x	x	x	x			x		x	x
Meliphagidae	Rufous-backed Honeyeater	<i>Ptiloprora guisei</i>												
Meliphagidae	Black-backed Honeyeater	<i>Ptiloprora perstriata</i>												
Meliphagidae	Belford's Melidectes	<i>Melidectes belfordi</i>												
Meliphagidae	Yellow-browed Melidectes	<i>Melidectes rufocrissalis</i>												
Meliphagidae	Ornate Melidectes	<i>Melidectes torquatus</i>												
Meliphagidae	Smoky Honeyeater	<i>Melipotes fumigatus</i>												
Meliphagidae	Brown-backed Honeyeater	<i>Ramsayornis modestus</i>		x										
Pardalotidae	Rusty Mouse-warbler	<i>Crateroscelis murina</i>				x	x	x			x		x	x
Pardalotidae	Mountain Mouse-warbler	<i>Crateroscelis robusta</i>												
Pardalotidae	Tropical/Beccari's Scrubwren	<i>Sericornis beccarii</i>												
Pardalotidae	Large Scrubwren	<i>Sericornis nouhuysi</i>												
Pardalotidae	Buff-faced Scrubwren	<i>Sericornis perspicillatus</i>												
Pardalotidae	Grey-green Scrubwren	<i>Sericornis arfakianus</i>												

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Pardalotidae	Papuan Scrubwren	<i>Sericornis papuensis</i>												
Pardalotidae	Pale-billed Scrubwren	<i>Sericornis spilodera</i>					x					x		x
Pardalotidae	Papuan Thornbill	<i>Acanthiza murina</i>												
Pardalotidae	Mountain Gerygone	<i>Gerygone cinerea</i>												
Pardalotidae	Green-backed Gerygone	<i>Gerygone chloronotus</i>					x	x					x	
Pardalotidae	Fairy Gerygone	<i>Gerygone palpebrosa</i>					x				x	x		
Pardalotidae	Yellow-bellied Gerygone	<i>Gerygone chrysogaster</i>				x	x	x			x		x	x
Pardalotidae	Large-billed Gerygone	<i>Gerygone magnirostris</i>		x			x	x	x					
Pardalotidae	Brown-breasted Gerygone	<i>Gerygone ruficollis</i>												
Pardalotidae	Mangrove Gerygone	<i>Gerygone levigaster</i>	x											
Petroicidae	Lesser Ground-robin	<i>Amalocichla incerta</i>												
Petroicidae	Torrent Robin	<i>Monachella muelleriana</i>											x	x
Petroicidae	Yellow-legged Flyrobin	<i>Microeca griseiceps</i>												
Petroicidae	Olive Flyrobin	<i>Microeca flavovirescens</i>												
Petroicidae	Canary Flyrobin	<i>Microeca papuana</i>												
Petroicidae	Garnet Robin	<i>Eugerygone rubra</i>												
Petroicidae	White-faced Robin	<i>Tregellasia leucops</i>												
Petroicidae	Mangrove Robin	<i>Eopsaltria pulverulenta</i>	x											
Petroicidae	Black-sided Robin	<i>Poecilodryas hypoleuca</i>		x		x	x	x				x	x	

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Petroicidae	Olive-yellow Robin	<i>Poecilodryas placens</i>												
Petroicidae	Black-throated Robin	<i>Poecilodryas albonotata</i>												
Petroicidae	White-winged Robin	<i>Peneothello sigillatus</i>												
Petroicidae	Blue-grey Robin	<i>Peneothello cyanus</i>												
Petroicidae	White-rumped Robin	<i>Peneothello bimaculatus</i>												
Petroicidae	Ashy Robin	<i>Heteromyias albispectus</i>												
Petroicidae	White-eyed Robin	<i>Pachycephalopsis poliosoma</i>												
Petroicidae	Northern Scrub-Robin	<i>Drymodes superciliaris</i>												
Pomatostomidae	New Guinea Babbler	<i>Pomatostomus isidorei</i>					x	x					x	
Laniidae	Long-tailed Shrike	<i>Lanius schach</i>												
Corvidae (<i>Cinclosomatinae</i>)	Spotted Jewel-babbler	<i>Ptilorrhoa leucosticta</i>												
Corvidae (<i>Cinclosomatinae</i>)	Blue Jewel-babbler	<i>Ptilorrhoa caerulescens</i>				x	x	x			x		x	x
Corvidae (<i>Cinclosomatinae</i>)	Chestnut-backed Jewel-babbler	<i>Ptilorrhoa castanonota</i>												
Corvidae (<i>Cinclosomatinae</i>)	Ifrit	<i>Ifrita kowaldi</i>												
Corvidae (<i>Pachycephalinae, Neosittini</i>)	Varied Sittella	<i>Daphoenositta chrysoptera</i>												
Corvidae (<i>Pachycephalinae, Falculculini</i>)	Mottled Whistler	<i>Rhagologus leucostigma</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Goldenface	<i>Pachycare flavogrisea</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Rufous-naped Whistler	<i>Aleadryas rufinucha</i>												
Corvidae (<i>Pachycephalinae, Pachycephalini</i>)	Rusty Whistler	<i>Pachycephala hyperythra</i>												

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Brown-backed Whistler	<i>Pachycephala modesta</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Grey-headed Whistler	<i>Pachycephala griseiceps</i>					x	x					x	
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Sclater's Whistler	<i>Pachycephala soror</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Regent Whistler	<i>Pachycephala schlegelii</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Black-headed Whistler	<i>Pachycephala monacha</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Little Shrike-thrush	<i>Colluricincla megarhyncha</i>				x	x	x			x		x	x
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Variable Pitohui	<i>Pitohui kirhocephalus</i>		x		x	x	x			x	x	x	x
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Hooded Pitohui	<i>Pitohui dichrous</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Rusty Pitohui	<i>Pitohui ferrugineus</i>		x			x	x			x		x	
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Crested Pitohui	<i>Pitohui cristatus</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Black Pitohui	<i>Pitohui nigrescens</i>												
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Wattled Ploughbill	<i>Eulacestoma nigropectus</i>												
Corvidae (<i>Corvinae</i> , <i>Corvini</i>)	Grey Crow	<i>Corvus tristis</i>				x	x	x					x	x
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Greater Melampitta	<i>Melampitta gigantea</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Loria's Bird-of-paradise	<i>Cnemophilus loriae</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Glossy-mantled Manucode	<i>Manucodia atra</i>		x			x	x			x		x	
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Crinkle-collared Manucode	<i>Manucodia chalybata</i>												
Corvidae (<i>Corvinae</i> , <i>Paradisaeini</i>)	Trumpet Manucode	<i>Manucodia keraudrenii</i>				x	x	x			x		x	

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Black Sickiebill	<i>Epimachus fastuosus</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Brown Sickiebill	<i>Epimachus meyeri</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Black-billed Sickiebill	<i>Epimachus albertisi</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Superb Bird-of-paradise	<i>Lophorina superba</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Carola's Parotia	<i>Parotia carolae</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Lawes's Parotia	<i>Parotia lawesii</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Magnificent Riflebird	<i>Ptiloris magnificus</i>				x	x						x	
Corvidae (<i>Corvinae,Paradisaeini</i>)	Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	King Bird-of-paradise	<i>Cicinnurus regius</i>				x	x	x			x		x	x
Corvidae (<i>Corvinae,Paradisaeini</i>)	Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>												
Corvidae (<i>Corvinae,Paradisaeini</i>)	Twelve-wired Bird-of-paradise	<i>Seleucidis melanoleuca</i>		x		x	x	x			x			
Corvidae (<i>Corvinae,Paradisaeini</i>)	Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>				x	x	x					x	x
Corvidae (<i>Corvinae,Paradisaeini</i>)	Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>												
Corvidae (<i>Corvinae,Artimini</i>)	Hooded Butcherbird	<i>Cracticus cassicus</i>				x	x	x			x		x	x
Corvidae (<i>Corvinae,Artimini</i>)	Black Butcherbird	<i>Cracticus quoyi</i>					x	x			x		x	
Corvidae (<i>Corvinae,Artimini</i>)	White-breasted Woodswallow	<i>Artamus leucorhynchus</i>	x			x								
Corvidae (<i>Corvinae,Artimini</i>)	Great Woodswallow	<i>Artamus maximus</i>												

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Corvidae (<i>Corvinae</i> , <i>Artimini</i>)	Lowland Peltops	<i>Peltops blainvillii</i>				x	x	x					x	
Corvidae (<i>Corvinae</i> , <i>Artimini</i>)	Mountain Peltops	<i>Peltops montanus</i>												
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Brown Oriole	<i>Oriolus szalayi</i>				x	x	x			x		x	
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Black-faced Cuckooshrike	<i>Coracina novaehollandiae</i>		x			x							
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Stout-billed Cuckooshrike	<i>Coracina caeruleogrisea</i>												
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Yellow-eyed Cuckooshrike	<i>Coracina lineata</i>												
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Boyer's Cuckooshrike	<i>Coracina boyeri</i>				x	x	x					x	
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	White-bellied Cuckooshrike	<i>Coracina papuensis</i>	x			x								
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Hooded Cuckooshrike	<i>Coracina longicauda</i>												
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Slender-billed Cicadabird	<i>Coracina tenuirostris</i>												
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Black-shouldered Cicadabird	<i>Coracina incerta</i>				x	x						x	
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Grey-headed Cuckooshrike	<i>Coracina schisticeps</i>				x	x	x			x		x	x
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	New Guinea Cuckooshrike	<i>Coracina melas</i>		x			x	x					x	
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Black-bellied Cuckooshrike	<i>Coracina montana</i>												
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Golden Cuckooshrike	<i>Campochaera sloetii</i>				x	x	x			x		x	x
Corvidae (<i>Corvinae</i> , <i>Oriolini</i>)	Varied Triller	<i>Lalage leucomela</i>		x		x	x	x			x		x	x
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Willie-wagtail	<i>Rhipidura leucophrys</i>		x		x	x						x	x
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Northern Fantail	<i>Rhipidura rufiventris</i>		x			x						x	
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Sooty Thicket-Fantail	<i>Rhipidura threnothorax</i>					x	x					x	x

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Black Thicket-Fantail	<i>Rhipidura maculipectus</i>				x	x			x			x	
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	White-bellied Thicket-Fantail	<i>Rhipidura leucothorax</i>		x		x	x				x		x	x
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Black Fantail	<i>Rhipidura atra</i>												
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Chestnut-bellied Fantail	<i>Rhipidura hypertythra</i>												
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Friendly Fantail	<i>Rhipidura albolimbata</i>												
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Mangrove Fantail	<i>Rhipidura phasiana</i>	x											
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Dimorphic Fantail	<i>Rhipidura brachyrhyncha</i>												
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Rufous-backed Fantail	<i>Rhipidura rufidorsa</i>					x						x	
Corvidae (<i>Dicrurinae</i> , <i>Dicrurini</i>)	Pygmy Drongo	<i>Chaetorhynchus papuensis</i>												
Corvidae (<i>Dicrurinae</i> , <i>Dicrurini</i>)	Spangled Drongo	<i>Dicrurus bracteatus</i>		x		x	x	x			x		x	x
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Black Monarch	<i>Monarcha axillaris</i>												
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Rufous Monarch	<i>Monarcha rubiensis</i>												
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Black-winged Monarch	<i>Monarcha frater</i>												
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Spot-winged Monarch	<i>Monarcha guttulus</i>				x	x	x			x	x	x	x
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Hooded Monarch	<i>Monarcha manadensis</i>					x	x				x	x	
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Golden Monarch	<i>Monarcha chrysomela</i>				x	x	x					x	
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Friilled Monarch	<i>Arses telescopthalmus</i>				x	x	x			x	x	x	x
Corvidae (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Satin Flycatcher	<i>Myiagra cyanoleuca</i>					x							
Corvidae (<i>Malaconotinae</i> , <i>Malaconotini</i>)	Shining Flycatcher	<i>Myiagra alecto</i>		x		x	x	x	x		x		x	x

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Corvidae (<i>Malaconotinae, Malaconotini</i>)	Yellow-breasted Boatbill	<i>Machaerirhynchus flaviventer</i>												
Corvidae (<i>Malaconotinae, Malaconotini</i>)	Black-breasted Boatbill	<i>Machaerirhynchus nigrippectus</i>												
Muscicapidae	Russet-tailed Thrush	<i>Zoothera heinei</i>												
Muscicapidae	Island Thrush	<i>Turdus poliocephalus</i>												
Muscicapidae	Pied Bushchat	<i>Saxicola caprata</i>												
Sturnidae	Metallic Starling	<i>Aplonis metallica</i>		x		x	x	x			x		x	x
Sturnidae	Yellow-eyed Starling	<i>Aplonis mystacea</i>				x	x	x						
Sturnidae	Golden Myna	<i>Mino anais</i>					x							x
Sturnidae	Yellow-faced Myna	<i>Mino dumontii</i>		x		x	x	x			x		x	x
Hirundinidae	Pacific Swallow	<i>Hirundo tahitica</i>		x		x	x	x					x	
Hirundinidae	Tree Martin	<i>Hirundo nigricans</i>			x									
Zosteropidae	Black-fronted White-eye	<i>Zosterops minor</i>												x
Zosteropidae	New Guinea White-eye	<i>Zosterops novaeguineae</i>												
Sylviidae	Gray's Grasshopper-Warbler	<i>Locustella fasciolata</i>												
Sylviidae	Clamorous Reed-Warbler	<i>Acrocephalus stentoreus</i>												
Sylviidae	Mountain Leaf-Warbler	<i>Phylloscopus trivirgatus</i>												
Nectariniidae	Red-capped Flowerpecker	<i>Dicaeum geelvinkianum</i>		x		x	x	x	x				x	x
Nectariniidae	Black Sunbird	<i>Nectarinia aspasia</i>		x		x	x	x	x		x		x	x
Nectariniidae	Olive-backed Sunbird	<i>Nectarinia jugularis</i>		x										

Appendix 2 Birds in the PNG LNG Project Upstream Project Area in 1995 – 2005. Lowland sites (<300 m). Data compiled from all sources in Table 1.

			Cape Blackwood	Kikori	Veriabari	Kopi/Kikori	Kopi	Pinini	Iviri	Keboi Kerowa	Veiru	Utti Creek	Dark End Lumber	Omo
Altitude (m)			10	10	10	15	20	20	30	30	30	35	45	110
Family	Common Name	Scientific Name												
Melanocharitidae	Black Berrypecker	<i>Melanocharis nigra</i>				x	x				x		x	
Melanocharitidae	Lemon-breasted Berrypecker	<i>Melanocharis longicauda</i>												
Melanocharitidae	Fan-tailed Berrypecker	<i>Melanocharis versteri</i>												
Melanocharitidae	Streaked Berrypecker	<i>Melanocharis striativentris</i>												
Melanocharitidae	Grey-winged Longbill	<i>Toxorhamphus poliopterus</i>												
Melanocharitidae	Green-crowned Longbill	<i>Toxorhamphus novaeguineae</i>					x	x			x	x	x	x
Melanocharitidae	Plumed Longbill	<i>Toxorhamphus iliolophus</i>				x	x				x			x
Melanocharitidae	Pygmy Longbill	<i>Oedistoma pygmaeum</i>					x							
Paramythiidae	Tit Berrypecker	<i>Oreocharis arfaki</i>												
Paramythiidae	Crested Berrypecker	<i>Paramythia montium</i>												
Passeridae	Grey Wagtail	<i>Motacilla cinerea</i>												
Passeridae	Blue-faced Parrotfinch	<i>Erythrura trichroa</i>												
Passeridae	White-spotted Munia	<i>Lonchura leucosticta</i>				x	x					x		
Passeridae	Hooded Munia	<i>Lonchura spectabilis</i>												
Total Species			47	100	13	98	160	102	10	5	73	22	117	75

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Casuariidae	Southern Cassowary	<i>Casuarius casuarius</i>	x				x						x				
Casuariidae	Dwarf Cassowary	<i>Casuarius bennetti</i>	x	x			x				x	x		x		x	x
Megapodiidae	Wattled Brush-turkey	<i>Aepyodius arfakianus</i>									x			x			
Megapodiidae	Black-billed Brush-turkey	<i>Talegalla fuscirostris</i>		x	x	x	x				x		x				
Megapodiidae	Brown-collared Brush-turkey	<i>Talegalla jobiensis</i>											x				
Megapodiidae	Brush-turkey	<i>Talegalla sp.</i>															x
Megapodiidae	Orange-footed Scrubfowl	<i>Megapodius reinwardt</i>			x		x				x						
Megapodiidae	New Guinea Scrubfowl	<i>Megapodius decollatus</i>											x				
Phasianidae	Blue-breasted Quail	<i>Coturnix chinensis</i>											x				
Dendrocygnidae	Spotted Whistling-Duck	<i>Dendrocygna guttata</i>					x										
Dendrocygnidae	Wandering Whistling-Duck	<i>Dendrocygna arcuata</i>															
Anatidae	Green Pygmy-goose	<i>Nettapus pulchellus</i>					x	x									
Anatidae	Pacific Black Duck	<i>Anas superciliosa</i>						x			x						
Anatidae	Grey Teal	<i>Anas gracilis</i>					x										
Bucerotidae	Blyth's Hornbill	<i>Aceros plicatus</i>	x	x	x	x	x	x	x		x	x	x				
Coraciidae	Dollarbird	<i>Eurystomus orientalis</i>	x	x	x		x	x	x		x	x					
Alcedinidae	Azure Kingfisher	<i>Alcedo azurea</i>			x		x	x	x		x						
Alcedinidae	Little Kingfisher	<i>Alcedo pusilla</i>					x										
Alcedinidae	Variable Kingfisher	<i>Ceyx lepidus</i>	x	x	x	x	x				x						
Dacelonidae	Rufous-bellied Kookaburra	<i>Dacelo gaudichaud</i>		x	x		x	x			x						
Dacelonidae	Shovel-billed Kookaburra	<i>Clytoceyx rex</i>					x										x
Dacelonidae	Blue-black Kingfisher	<i>Todirhamphus nigrocyaneus</i>															

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Dacelonidae	Forest Kingfisher	<i>Todirhamphus macleayii</i>		x			x						x				
Dacelonidae	Sacred Kingfisher	<i>Todirhamphus sanctus</i>					x	x	x	x	x						
Dacelonidae	Hook-billed Kingfisher	<i>Melidora macrorrhina</i>	x		x	x	x				x						
Dacelonidae	Yellow-billed Kingfisher	<i>Syma torotoro</i>			x	x	x	x			x						
Dacelonidae	Mountain Kingfisher	<i>Syma megarhyncha</i>									x			x	x		x
Meropidae	Rainbow Bee-eater	<i>Merops ornatus</i>					x	x	x		x		x				
Cuculidae	Oriental Cuckoo	<i>Cuculus saturatus</i>			x		x				x						
Cuculidae	Brush Cuckoo	<i>Cacomantis variolosus</i>		x	x		x	x	x		x						
Cuculidae	Chestnut-breasted Cuckoo	<i>Cacomantis castaneiventris</i>	x		x	x	x				x		x				
Cuculidae	Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>											x	x		x	x
Cuculidae	Long-billed Cuckoo	<i>Rhamphomantis megarhynchus</i>			x		x										
Cuculidae	Gould's Bronze-Cuckoo	<i>Chrysococcyx russatus</i>			x		x	x			x						
Cuculidae	Rufous-throated Bronze-Cuckoo	<i>Chrysococcyx ruficollis</i>															x
Cuculidae	White-eared Bronze-Cuckoo	<i>Chrysococcyx meyeri</i>			x		x	x			x						
Cuculidae	White-crowned Koel	<i>Caliechthrus leucolophus</i>			x		x	x			x			x	x		x
Cuculidae	Dwarf Koel	<i>Microdynamis parva</i>			x		x	x			x		x				
Cuculidae	Asian Koel	<i>Eudynamis scolopacea</i>	x	x	x		x	x			x	x	x	x			
Cuculidae	Channel-billed Cuckoo	<i>Scythrops novaehollandiae</i>	x				x										
Centropodidae	Greater Black Coucal	<i>Centropus menbeki</i>	x		x		x	x			x						
Centropodidae	Lesser Black Coucal	<i>Centropus bernsteini</i>					x										
Psittacidae	Yellow-streaked Lory	<i>Chalcopsitta sintillata</i>		x	x		x	x			x						

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Psittacidae	Dusky Lory	<i>Pseudeos fuscata</i>		x	x		x	x			x			x	x		x
Psittacidae	Rainbow Lorikeet	<i>Trichoglossus haematodus</i>	x	x	x	x	x	x	x		x	x	x	x			x
Psittacidae	Goldie's Lorikeet	<i>Psitteuteles goldiei</i>					x				x			x			
Psittacidae	Black-capped Lory	<i>Lorius lory</i>	x	x	x	x	x	x	x		x			x			
Psittacidae	Striated Lorikeet	<i>Charmosyna multistriata</i>					x				x						
Psittacidae	Pygmy Lorikeet	<i>Charmosyna wilhelminae</i>					x				x						
Psittacidae	Red-flanked Lorikeet	<i>Charmosyna placensis</i>		x	x		x				x						
Psittacidae	Fairy Lorikeet	<i>Charmosyna pulchella</i>					x				x		x	x	x		
Psittacidae	Josephine's Lorikeet	<i>Charmosyna josephinae</i>					x				x						
Psittacidae	Papuan Lorikeet	<i>Charmosyna papou</i>											x	x		x	x
Psittacidae	Plum-faced Lorikeet	<i>Oreopsittacus arfaki</i>															x
Psittacidae	Yellow-billed Lorikeet	<i>Neopsittacus musschenbroekii</i>											x		x	x	x
Psittacidae	Orange-billed Lorikeet	<i>Neopsittacus pullicauda</i>														x	
Psittacidae	Palm Cockatoo	<i>Probosciger aterrimus</i>	x	x	x	x	x	x	x		x			x			
Psittacidae	Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	x	x	x		x	x	x		x	x	x	x			
Psittacidae	Yellow-capped Pygmy-Parrot	<i>Micropsitta keiensis</i>				x											
Psittacidae	Buff-faced Pygmy-Parrot	<i>Micropsitta pusio</i>			x		x	x			x						
Psittacidae	Red-breasted Pygmy-Parrot	<i>Micropsitta bruijnii</i>					x	x			x				x		
Psittacidae	Orange-breasted Fig-Parrot	<i>Cyclopsitta gulelmitertii</i>			x		x	x	x		x						
Psittacidae	Double-eyed Fig-Parrot	<i>Cyclopsitta diophthalma</i>			x		x				x		x				

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Psittacidae	Large Fig-Parrot	<i>Psittaculirostris desmarestii</i>			x		x	x			x					x	
Psittacidae	Madarasz's Tiger-Parrot	<i>Psittacella madaraszii</i>															x
Psittacidae	Red-cheeked Parrot	<i>Geoffroyus geoffroyi</i>		x	x		x	x			x						
Psittacidae	Blue-collared Parrot	<i>Geoffroyus simplex</i>			x		x				x			x	x		
Psittacidae	Eclectus Parrot	<i>Eclectus roratus</i>	x	x	x	x	x	x	x		x						
Psittacidae	Pesquet's Parrot	<i>Psittichas fulgidus</i>	x	x	x	x	x	x		x	x			x			
Psittacidae	Papuan King-Parrot	<i>Alisterus chloropterus</i>			x		x				x	x	x	x		x	
Psittacidae	Orange-fronted Hanging-Parrot	<i>Loriculus aurantiifrons</i>			x		x	x			x						
Apodidae	Glossy Swiftlet	<i>Collocalia esculenta</i>		x	x	x	x	x	x		x	x	x	x	x	x	x
Apodidae	Mountain Swiftlet	<i>Aerodramus hirundinaceus</i>						x			x			x			x
Apodidae	Swiftlet (Mountain/Uniform)	<i>Aerodramus hirundinaceus/vanikorensis</i>			x		x				x	x	x		x		
Apodidae	Swiftlet (Bare-legged/Mountain)	<i>Aerodramus nuditarus/hirundinaceus</i>														x	
Apodidae	Uniform Swiftlet	<i>Aerodramus vanikorensis</i>		x													
Apodidae	Papuan Needletail	<i>Mearnsia novaeguineae</i>			x		x										
Apodidae	White-throated Needletail	<i>Hirundapus caudacutus</i>											x				
Hemiprocidae	Moustached Treeswift	<i>Hemiprocne mystacea</i>		x	x	x	x	x	x		x	x	x				
Tytonidae	Greater Sooty-Owl	<i>Tyto tenebricosa</i>			x						x			x			x
Strigidae	Rufous Owl	<i>Ninox rufa</i>			x		x										
Strigidae	Jungle Hawk-Owl	<i>Ninox theomacha</i>				x	x				x			x	x		x
Aegothelidae	Feline Owlet-Nightjar	<i>Aegotheles insignis</i>					x				x						x

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Aegothelidae	Barred Owlet-Nightjar	<i>Aegotheles bennettii</i>									x						
Aegothelidae	Mountain Owlet-Nightjar	<i>Aegotheles albertsi</i>												x			x
Aegothelidae	Owlet-Nightjar	<i>Aegotheles sp.</i>			x		x				x						
Podargidae	Papuan Frogmouth	<i>Podargus papuensis</i>	x	x	x	x	x				x		x		x		x
Podargidae	Marbled Frogmouth	<i>Podargus ocellatus</i>	x		x	x	x				x			x	x		
Eurostopodidae	Papuan Eared-Nightjar	<i>Eurostopodus papuensis</i>				x	x										
Eurostopodidae	Mountain Eared-Nightjar	<i>Eurostopodus archboldi</i>														x	
Caprimulgidae	Large-tailed Nightjar	<i>Caprimulgus macrurus</i>	x								x		x				
Columbidae	Metallic Pigeon	<i>Columba vitiensis</i>											x				
Columbidae	Slender-billed Cuckoo-Dove	<i>Macropygia amboinensis</i>	x	x	x	x	x	x	x		x	x	x		x	x	
Columbidae	Black-billed Cuckoo-Dove	<i>Macropygia nigrirostris</i>			x		x				x			x	x		x
Columbidae	Great Cuckoo-Dove	<i>Reinwardtoena reinwardtsi</i>		x	x	x	x	x			x			x	x	x	x
Columbidae	Stephan's Dove	<i>Chalcophaps stephani</i>	x		x	x	x										
Columbidae	New Guinea Bronzewing	<i>Henicophaps albifrons</i>			x		x				x						
Columbidae	Cinnamon Ground-Dove	<i>Gallicolumba rufigula</i>			x		x				x						
Columbidae	Bronze Ground-Dove	<i>Gallicolumba beccarii</i>														x	
Columbidae	Thick-billed Ground-Pigeon	<i>Trugon terrestris</i>				x	x										
Columbidae	Pheasant Pigeon	<i>Otidiphaps nobilis</i>		x			x				x			x			
Columbidae	Wompoo Fruit-Dove	<i>Ptilinopus magnificus</i>		x	x	x	x	x	x		x			x			
Columbidae	Pink-spotted Fruit-Dove	<i>Ptilinopus perlatus</i>			x		x	x			x			x			
Columbidae	Ornate Fruit-Dove	<i>Ptilinopus ornatus</i>					x	x			x	x	x	x	x	x	x
Columbidae	Orange-fronted Fruit-Dove	<i>Ptilinopus aurantiifrons</i>															

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Columbidae	Superb Fruit-Dove	<i>Ptilinopus superbus</i>		x	x		x	x			x	x	x				
Columbidae	Coroneted Fruit-Dove	<i>Ptilinopus coronulatus</i>	x			x	x										
Columbidae	Beautiful Fruit-Dove	<i>Ptilinopus pulchellus</i>	x	x	x	x	x	x	x		x						
Columbidae	White-bibbed Fruit-Dove	<i>Ptilinopus rivoli</i>					x				x		x	x			x
Columbidae	Orange-bellied Fruit-Dove	<i>Ptilinopus iozonus</i>		x	x		x				x						
Columbidae	Dwarf Fruit-Dove	<i>Ptilinopus naina</i>			x		x				x						
Columbidae	Purple-tailed Imperial-Pigeon	<i>Ducula rufigaster</i>			x	x	x	x			x						
Columbidae	Shining Imperial-Pigeon	<i>Ducula chalconota</i>						x	x		x			x		x	x
Columbidae	Pinon Imperial-Pigeon	<i>Ducula pinon</i>	x	x	x	x	x	x			x						
Columbidae	Collared Imperial-Pigeon	<i>Ducula mullerii</i>															
Columbidae	Banded Imperial-Pigeon	<i>Ducula zoeae</i>	x	x	x	x	x	x	x		x	x	x				
Columbidae	Torresian Imperial-Pigeon	<i>Ducula spilorrhoa</i>															
Columbidae	Papuan Mountain-Pigeon	<i>Gymnophaps albertisii</i>			x		x	x	x		x	x	x	x	x	x	x
Columbidae	Southern Crowned-Pigeon	<i>Goura scheepmakeri</i>	x				x										
Rallidae	Forbes's Forest-Rail	<i>Rallina forbesi</i>														x	
Rallidae	Red-necked Crake	<i>Rallina tricolor</i>					x	x			x						
Rallidae	Buff-banded Rail	<i>Gallirallus philippensis</i>															
Rallidae	Rufous-tailed Waterhen	<i>Amauornis moluccana</i>	x		x		x				x						
Rallidae	White-browed Crake	<i>Porzana cinerea</i>									x						
Rallidae	New Guinea Flightless Rail	<i>Megacrex inepta</i>					x										
Rallidae	Dusky Moorhen	<i>Gallinula tenebrosa</i>						x									

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Scolopacidae	Black-tailed Godwit	<i>Limosa limosa</i>															
Scolopacidae	Bar-tailed Godwit	<i>Limosa lapponica</i>															
Scolopacidae	Whimbrel	<i>Numenius phaeopus</i>															
Scolopacidae	Far Eastern Curlew	<i>Numenius madagascariensis</i>															
Scolopacidae	Marsh Sandpiper	<i>Tringa stagnatilis</i>															
Scolopacidae	Common Greenshank	<i>Tringa nebularia</i>															
Scolopacidae	Terek Sandpiper	<i>Xenus cinereus</i>															
Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>		x			x										
Scolopacidae	Grey-tailed Tattler	<i>Heteroscelus brevipes</i>															
Scolopacidae	Ruddy Turnstone	<i>Arenaria interpres</i>															
Scolopacidae	Asian Dowitcher	<i>Limnodromus semipalmatus</i>															
Scolopacidae	Great Knot	<i>Calidris tenuirostris</i>															
Scolopacidae	Red Knot	<i>Calidris canutus</i>															
Scolopacidae	Sanderling	<i>Calidris alba</i>															
Scolopacidae	Red-necked Stint	<i>Calidris ruficollis</i>															
Scolopacidae	Sharp-tailed Sandpiper	<i>Calidris acuminata</i>															
Scolopacidae	Curlew Sandpiper	<i>Calidris ferruginea</i>															
Burhinidae	Beach Thick-knee	<i>Esacus giganteus</i>															
Charadriidae	Pacific Golden-Plover	<i>Pluvialis fulva</i>															
Charadriidae	Grey Plover	<i>Pluvialis squatarola</i>															
Charadriidae	Little Ringed Plover	<i>Charadrius dubius</i>	x				x				x						
Charadriidae	Mongolian Plover	<i>Charadrius mongolus</i>															
Charadriidae	Greater Sand Plover	<i>Charadrius leschenaultii</i>															
Charadriidae	Masked Lapwing	<i>Vanellus miles</i>					x										

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Glareolidae	Australian Pratincole	<i>Stiltia isabella</i>															
Laridae	Silver Gull	<i>Larus novaehollandiae</i>															
Laridae	Gull-billed Tern	<i>Gelochelidon nilotica</i>															
Laridae	Caspian Tern	<i>Sterna caspia</i>															
Laridae	Lesser Crested-Tern	<i>Sterna bengalensis</i>															
Laridae	Great Crested-Tern	<i>Sterna bergii</i>															
Laridae	Black-naped Tern	<i>Sterna sumatrana</i>															
Laridae	Common Tern	<i>Sterna hirundo</i>															
Laridae	Little Tern	<i>Sterna albifrons</i>															
Laridae	Whiskered Tern	<i>Chlidonias hybridus</i>															
Laridae	White-winged Tern	<i>Chlidonias leucopterus</i>															
Laridae	Black Noddy	<i>Anous minutus</i>															
Accipitridae	Pacific Baza	<i>Aviceda subcristata</i>			x		x	x	x		x						
Accipitridae	Long-tailed Honey-buzzard	<i>Henicopernis longicauda</i>			x		x	x			x					x	
Accipitridae	Whistling Kite	<i>Haliastur sphenurus</i>															
Accipitridae	Brahminy Kite	<i>Haliastur indus</i>	x	x			x	x			x	x				x	x
Accipitridae	White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>									x						
Accipitridae	Eastern Marsh-Harrier	<i>Circus spilonotus</i>									x						
Accipitridae	Grey Goshawk	<i>Accipiter novaehollandiae</i>		x	x		x	x			x	x					
Accipitridae	Brown Goshawk	<i>Accipiter fasciatus</i>											x				
Accipitridae	Black-mantled Goshawk	<i>Accipiter melanochlamys</i>											x			x	
Accipitridae	Grey-headed Goshawk	<i>Accipiter poliocephalus</i>					x				x						
Accipitridae	Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>					x				x		x				
Accipitridae	Meyer's Goshawk	<i>Accipiter meyerianus</i>									x					x	

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Accipitridae	New Guinea Eagle	<i>Harpyopsis novaeguineae</i>	x				x				x			x			x
Accipitridae	Gurney's Eagle	<i>Aquila gurneyi</i>									x			x			
Accipitridae	Little Eagle	<i>Hieraaetus morphnoides</i>		x	x		x				x						
Falconidae	Brown Falcon	<i>Falco berigora</i>					x				x				x		
Falconidae	Australian Kestrel	<i>Falco cenchroides</i>															
Falconidae	Oriental Hobby	<i>Falco severus</i>									x						
Falconidae	Australian Hobby	<i>Falco longipennis</i>															
Falconidae	Peregrine Falcon	<i>Falco peregrinus</i>					x	x		x	x						
Anhingidae	Australian Darter	<i>Anhinga novaehollandiae</i>									x						
Phalacrocoracidae	Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>						x					x				
Phalacrocoracidae	Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>											x				
Ardeidae	Little Egret	<i>Egretta garzetta</i>					x	x									
Ardeidae	Pacific Reef-Egret	<i>Egretta sacra</i>															
Ardeidae	Great-billed Heron	<i>Ardea sumatrana</i>															
Ardeidae	Pied Heron	<i>Ardea picata</i>						x	x								
Ardeidae	Great Egret	<i>Ardea alba</i>	x				x	x									
Ardeidae	Intermediate Egret	<i>Mesophoyx intermedia</i>						x	x								
Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>							x								
Ardeidae	Striated Heron	<i>Butorides striatus</i>															
Ardeidae	Rufous Night-Heron	<i>Nycticorax caledonicus</i>	x														
Ardeidae	Black Bittern	<i>Dupetor flavicollis</i>															
Threskiornithidae	Straw-necked Ibis	<i>Threskiornis spinicollis</i>					x										
Pelecanidae	Australian Pelican	<i>Pelecanus conspicillatus</i>															
Fregatidae	Lesser Frigatebird	<i>Fregata ariel</i>					x										

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Pittidae	Hooded Pitta	<i>Pitta sordida</i>		x			x				x			x			
Pittidae	Red-bellied Pitta	<i>Pitta erythrogaster</i>		x	x	x	x				x						
Climacteridae	Papuan Treecreeper	<i>Cormobates placens</i>															x
Ptilonorhynchidae	White-eared Catbird	<i>Ailuroedus buccoides</i>	x	x	x	x	x				x						
Ptilonorhynchidae	Spotted Catbird	<i>Ailuroedus melanotis</i>					x				x		x	x			
Ptilonorhynchidae	Macgregor's Bowerbird	<i>Amblyornis macgregoriae</i>												x			x
Maluridae	Orange-crowned Fairywren	<i>Clytomyias insignis</i>														x	x
Maluridae	Wallace's Fairywren	<i>Sipodotus wallacii</i>						x									
Maluridae	White-shouldered Fairywren	<i>Malurus alboscapulatus</i>	x		x		x	x	x	x	x	x	x				
Maluridae	Emperor Fairywren	<i>Malurus cyanocephalus</i>			x		x	x			x						
Meliphagidae	Red-throated Myzomela	<i>Myzomela eques</i>			x		x				x						
Meliphagidae	Dusky Myzomela	<i>Myzomela obscura</i>															
Meliphagidae	Red Myzomela	<i>Myzomela cruentata</i>					x				x			x			
Meliphagidae	Black Myzomela	<i>Myzomela nigrita</i>					x				x						
Meliphagidae	Mountain Myzomela	<i>Myzomela adolphinae</i>									x						
Meliphagidae	Red-collared Myzomela	<i>Myzomela rosenbergii</i>												x			x
Meliphagidae	Olive Straightbill	<i>Timeliopsis fulvigula</i>														x	x
Meliphagidae	Long-billed Honeyeater	<i>Melilestes mearnsianus</i>	x		x	x	x	x	x		x	x	x	x			
Meliphagidae	Green-backed Honeyeater	<i>Glycichaera fallax</i>					x				x						
Meliphagidae	Mottle-breasted Honeyeater	<i>Meliphaga mimikae</i>			x		x				x			x			
Meliphagidae	Hill-forest Honeyeater	<i>Meliphaga orientalis</i>					x				x		x	x			
Meliphagidae	Scrub Honeyeater	<i>Meliphaga albonotata</i>		x	x		x	x	x		x	x	x	x			

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Meliphagidae	Puff-backed Honeyeater	<i>Meliphaga aruensis</i>	x		x	x	x				x						
Meliphagidae	Mimic Honeyeater	<i>Meliphaga analoga</i>	x	x		x	x				x		x				
Meliphagidae	Graceful Honeyeater	<i>Meliphaga gracilis</i>															
Meliphagidae	Yellow-gaped Honeyeater	<i>Meliphaga flavirictus</i>															
Meliphagidae	Honeyeater	<i>Meliphaga sp.</i>			x		x				x		x				
Meliphagidae	Black-throated Honeyeater	<i>Lichenostomus subfrenatus</i>												x			x
Meliphagidae	Obscure Honeyeater	<i>Lichenostomus obscurus</i>			x	x	x				x						
Meliphagidae	Varied Honeyeater	<i>Lichenostomus versicolor</i>															
Meliphagidae	Tawny-breasted Honeyeater	<i>Xanthotis flaviventer</i>	x	x	x	x	x	x	x		x	x	x	x			
Meliphagidae	Spotted Honeyeater	<i>Xanthotis polygramma</i>					x				x		x	x			
Meliphagidae	Plain Honeyeater	<i>Pycnopygius ixoides</i>									x			x			
Meliphagidae	Streak-headed Honeyeater	<i>Pycnopygius stictocephalus</i>			x		x	x			x						
Meliphagidae	Meyer's Friarbird	<i>Philemon meyeri</i>			x		x	x			x						
Meliphagidae	New Guinea Friarbird	<i>Philemon novaeguineae</i>	x	x	x	x	x	x	x		x		x				
Meliphagidae	Rufous-backed Honeyeater	<i>Ptiloprora guisei</i>												x		x	x
Meliphagidae	Black-backed Honeyeater	<i>Ptiloprora perstriata</i>														x	x
Meliphagidae	Belford's Melidectes	<i>Melidectes belfordi</i>														x	
Meliphagidae	Yellow-browed Melidectes	<i>Melidectes rufocrissalis</i>												x	x		x
Meliphagidae	Ornate Melidectes	<i>Melidectes torquatus</i>											x	x			
Meliphagidae	Smoky Honeyeater	<i>Melipotes fumigatus</i>												x	x	x	x

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Meliphagidae	Brown-backed Honeyeater	<i>Ramsayornis modestus</i>															
Pardalotidae	Rusty Mouse-warbler	<i>Crateroscelis murina</i>	x	x	x	x	x	x	x		x		x				
Pardalotidae	Mountain Mouse-warbler	<i>Crateroscelis robusta</i>												x	x	x	x
Pardalotidae	Tropical / Beccari's Scrubwren	<i>Sericornis beccarii</i>					x				x			x			
Pardalotidae	Large Scrubwren	<i>Sericornis nouhuysi</i>												x		x	x
Pardalotidae	Buff-faced Scrubwren	<i>Sericornis perspicillatus</i>												x	x	x	x
Pardalotidae	Grey-green Scrubwren	<i>Sericornis arfakianus</i>												x			
Pardalotidae	Papuan Scrubwren	<i>Sericornis papuensis</i>														x	x
Pardalotidae	Pale-billed Scrubwren	<i>Sericornis spilodera</i>	x	x		x	x				x			x			
Pardalotidae	Papuan Thornbill	<i>Acanthiza murina</i>														x	
Pardalotidae	Mountain Gerygone	<i>Gerygone cinerea</i>														x	x
Pardalotidae	Green-backed Gerygone	<i>Gerygone chloronotus</i>			x		x	x			x		x		x		
Pardalotidae	Fairy Gerygone	<i>Gerygone palpebrosa</i>		x	x		x	x			x			x			
Pardalotidae	Yellow-bellied Gerygone	<i>Gerygone chrysogaster</i>	x	x	x	x	x	x			x						
Pardalotidae	Large-billed Gerygone	<i>Gerygone magnirostris</i>					x				x						
Pardalotidae	Brown-breasted Gerygone	<i>Gerygone ruficollis</i>												x	x	x	x
Pardalotidae	Mangrove Gerygone	<i>Gerygone levigaster</i>															
Petroicidae	Lesser Ground-robin	<i>Amalocichla incerta</i>													x		x
Petroicidae	Torrent Robin	<i>Monachella muelleriana</i>	x	x			x				x	x	x				
Petroicidae	Yellow-legged Flyrobin	<i>Microeca griseiceps</i>					x				x			x			
Petroicidae	Olive Flyrobin	<i>Microeca flavovirescens</i>			x	x	x				x	x	x				
Petroicidae	Canary Flyrobin	<i>Microeca papuana</i>														x	x
Petroicidae	Garnet Robin	<i>Eugerygone rubra</i>														x	x

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Petroicidae	White-faced Robin	<i>Tregellasia leucops</i>					x				x		x	x			
Petroicidae	Mangrove Robin	<i>Eopsaltria pulverulenta</i>															
Petroicidae	Black-sided Robin	<i>Poecilodryas hypoleuca</i>		x	x	x	x	x			x						
Petroicidae	Olive-yellow Robin	<i>Poecilodryas placens</i>			x	x					x						
Petroicidae	Black-throated Robin	<i>Poecilodryas albonotata</i>												x	x		x
Petroicidae	White-winged Robin	<i>Peneothello sigillatus</i>														x	x
Petroicidae	Blue-grey Robin	<i>Peneothello cyanus</i>												x	x	x	x
Petroicidae	White-rumped Robin	<i>Peneothello bimaculatus</i>			x	x	x				x						
Petroicidae	Ashy Robin	<i>Heteromyias albispecularis</i>													x		x
Petroicidae	White-eyed Robin	<i>Pachycephalopsis poliosoma</i>					x				x		x	x			
Petroicidae	Northern Scrub-Robin	<i>Drymodes superciliaris</i>					x				x			x			
Pomatostomidae	New Guinea Babbler	<i>Pomatostomus isidorei</i>					x										
Laniidae	Long-tailed Shrike	<i>Lanius schach</i>											x				
Corvidae (Cinclosomatinae)	Spotted Jewel-babbler	<i>Ptilorrhoa leucosticta</i>												x	x		x
Corvidae (Cinclosomatinae)	Blue Jewel-babbler	<i>Ptilorrhoa caerulescens</i>	x	x	x	x	x										
Corvidae (Cinclosomatinae)	Chestnut-backed Jewel-babbler	<i>Ptilorrhoa castanonota</i>				x	x	x			x						
Corvidae (Cinclosomatinae)	Ifrit	<i>Ifrita kowaldi</i>												x	x	x	x
Corvidae (Pachycephalinae, Neosittini)	Varied Sittella	<i>Daphoenositta chrysoptera</i>														x	x

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Corvidae (<i>Pachycephalinae</i> / <i>Falculculini</i>)	Mottled Whistler	<i>Rhagologus leucostigma</i>												x			x
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Goldenface	<i>Pachycare flavogrisea</i>					x				x	x	x	x			
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Rufous-naped Whistler	<i>Aleadryas rufinucha</i>												x	x	x	x
Corvidae (<i>Pachycephalinae</i> <i>Pachycephalini</i>)	Rusty Whistler	<i>Pachycephala hyperythra</i>		x	x	x	x				x						
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Brown-backed Whistler	<i>Pachycephala modesta</i>													x	x	x
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Grey-headed Whistler	<i>Pachycephala griseiceps</i>			x		x				x	x	x	x			
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Sclater's Whistler	<i>Pachycephala soror</i>			x								x	x	x	x	x
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Regent Whistler	<i>Pachycephala schlegelii</i>												x	x		x
Corvidae (<i>Pachycephalinae</i> , <i>Pachycephalini</i>)	Black-headed Whistler	<i>Pachycephala monacha</i>										x				x	

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Corvidae (Pachycephalinae, Pachycephalini)	Little Shrike-thrush	<i>Colluricincla megarhyncha</i>	x	x	x	x	x	x			x	x	x	x	x		
Corvidae (Pachycephalinae, Pachycephalini)	Variable Pitohui	<i>Pitohui kirhocephalus</i>			x		x	x			x			x			
Corvidae (Pachycephalinae, Pachycephalini)	Hooded Pitohui	<i>Pitohui dichrous</i>				x	x	x			x	x	x				
Corvidae (Pachycephalinae, Pachycephalini)	Rusty Pitohui	<i>Pitohui ferrugineus</i>	x	x	x	x	x	x			x						
Corvidae (Pachycephalinae, Pachycephalini)	Crested Pitohui	<i>Pitohui cristatus</i>			x	x	x				x			x			
Corvidae (Pachycephalinae, Pachycephalini)	Black Pitohui	<i>Pitohui nigrescens</i>															x
Corvidae (Pachycephalinae, Pachycephalini)	Wattled Ploughbill	<i>Eulacestoma nigropectus</i>														x	
Corvidae (Corvinae, Corvini)	Grey Crow	<i>Corvus tristis</i>	x	x	x	x	x	x	x		x	x					
Corvidae (Corvinae, Paradisaeini)	Greater Melampitta	<i>Melampitta gigantea</i>					x				x					x	
Corvidae (Corvinae, Paradisaeini)	Yellow-breasted Bird-of-paradise	<i>Loboparadisea sericea</i>														x	x

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Corvidae (Corvinae,Paradisaeini)	Loria's Bird-of-paradise	<i>Cnemophilus loriae</i>															x
Corvidae (Corvinae,Paradisaeini)	Glossy-mantled Manucode	<i>Manucodia atra</i>			x		x										
Corvidae (Corvinae,Paradisaeini)	Crinkle-collared Manucode	<i>Manucodia chalybata</i>		x	x	x	x	x			x						
Corvidae (Corvinae,Paradisaeini)	Trumpet Manucode	<i>Manucodia keraudrenii</i>			x		x										
Corvidae (Corvinae,Paradisaeini)	Short-tailed Paradigalla	<i>Paradigalla brevicauda</i>													x	x	x
Corvidae (Corvinae,Paradisaeini)	Black Sickiebill	<i>Epimachus fastuosus</i>												x	x	x	x
Corvidae (Corvinae,Paradisaeini)	Brown Sickiebill	<i>Epimachus meyeri</i>														x	x
Corvidae (Corvinae,Paradisaeini)	Black-billed Sickiebill	<i>Epimachus albertsi</i>									x						
Corvidae (Corvinae,Paradisaeini)	Superb Bird-of-paradise	<i>Lophorina superba</i>									x		x	x	x	x	x
Corvidae (Corvinae,Paradisaeini)	Carola's Parotia	<i>Parotia carolae</i>					x				x			x			
Corvidae (Corvinae,Paradisaeini)	Lawes's Parotia	<i>Parotia lawesii</i>										x	x			x	x
Corvidae (Corvinae,Paradisaeini)	Magnificent Riflebird	<i>Ptiloris magnificus</i>		x	x		x	x			x	x	x				
Corvidae (Corvinae,Paradisaeini)	Magnificent Bird-of-paradise	<i>Cicinnurus magnificus</i>			x	x	x	x			x		x	x			

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Corvidae (Corvinae,Paradisaeini)	King Bird-of-paradise	<i>Cicinnurus regius</i>	x	x	x	x	x	x	x		x						
Corvidae (Corvinae,Paradisaeini)	Ribbon-tailed Astrapia	<i>Astrapia mayeri</i>														x	x
Corvidae (Corvinae,Paradisaeini)	King-of-Saxony Bird-of-paradise	<i>Pteridophora alberti</i>														x	x
Corvidae (Corvinae,Paradisaeini)	Twelve-wired Bird-of-paradise	<i>Seleucidis melanoleuca</i>			x						x						
Corvidae (Corvinae,Paradisaeini)	Raggiana Bird-of-paradise	<i>Paradisaea raggiana</i>	x	x	x	x	x	x	x		x	x	x	x			
Corvidae (Corvinae,Paradisaeini)	Blue Bird-of-paradise	<i>Paradisaea rudolphi</i>											x				
Corvidae (Corvinae,Artimini)	Hooded Butcherbird	<i>Cracticus cassicus</i>	x	x	x	x	x	x	x		x						
Corvidae (Corvinae,Artimini)	Black Butcherbird	<i>Cracticus quoyi</i>	x	x	x	x	x				x			x			
Corvidae (Corvinae,Artimini)	White-breasted Woodswallow	<i>Artamus leucorhynchus</i>															
Corvidae (Corvinae,Artimini)	Great Woodswallow	<i>Artamus maximus</i>						x	x		x	x	x				x
Corvidae (Corvinae,Artimini)	Lowland Peltops	<i>Peltops blainvillii</i>		x	x		x	x			x						
Corvidae (Corvinae,Artimini)	Mountain Peltops	<i>Peltops montanus</i>					x		x		x		x	x	x		x
Corvidae (Corvinae,Oriolini)	Brown Oriole	<i>Oriolus szalayi</i>		x	x	x	x				x	x	x				

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Corvidae (Corvinae, Oriolini)	Black-faced Cuckooshrike	<i>Coracina novaehollandiae</i>															
Corvidae (Corvinae, Oriolini)	Stout-billed Cuckooshrike	<i>Coracina caeruleogrisea</i>					x	x	x		x		x	x			
Corvidae (Corvinae, Oriolini)	Yellow-eyed Cuckooshrike	<i>Coracina lineata</i>			x						x						
Corvidae (Corvinae, Oriolini)	Boyer's Cuckooshrike	<i>Coracina boyeri</i>			x		x	x			x						
Corvidae (Corvinae, Oriolini)	White-bellied Cuckooshrike	<i>Coracina papuensis</i>															
Corvidae (Corvinae, Oriolini)	Hooded Cuckooshrike	<i>Coracina longicauda</i>														x	x
Corvidae (Corvinae, Oriolini)	Slender-billed Cicadabird	<i>Coracina tenuirostris</i>									x						
Corvidae (Corvinae, Oriolini)	Black-shouldered Cicadabird	<i>Coracina incerta</i>			x		x				x	x	x				x
Corvidae (Corvinae, Oriolini)	Grey-headed Cuckooshrike	<i>Coracina schisticeps</i>		x	x		x	x	x		x						
Corvidae (Corvinae, Oriolini)	New Guinea Cuckooshrike	<i>Coracina melas</i>			x		x	x	x		x						
Corvidae (Corvinae, Oriolini)	Black-bellied Cuckooshrike	<i>Coracina montana</i>					x				x		x	x	x	x	x
Corvidae (Corvinae, Oriolini)	Golden Cuckooshrike	<i>Campochaera sloetii</i>		x	x		x	x	x		x						
Corvidae (Corvinae, Oriolini)	Varied Triller	<i>Lalage leucomela</i>			x		x	x			x	x	x	x			

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Willie-wagtail	<i>Rhipidura leucophrys</i>	x				x	x	x	x	x	x	x				
Corvidae(<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Northern Fantail	<i>Rhipidura rufiventris</i>		x	x	x	x	x			x		x				
Corvidae(<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Sooty Thicket-Fantail	<i>Rhipidura threnothorax</i>	x	x	x	x	x				x						
Corvidae(<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Black Thicket-Fantail	<i>Rhipidura maculipectus</i>															
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	White-bellied Thicket-Fantail	<i>Rhipidura leucothorax</i>	x				x	x			x						
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Black Fantail	<i>Rhipidura atra</i>									x		x	x	x	x	x
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Chestnut-bellied Fantail	<i>Rhipidura hyperythra</i>		x	x		x				x	x	x				
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Friendly Fantail	<i>Rhipidura albolimbata</i>												x	x	x	x
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Mangrove Fantail	<i>Rhipidura phasiana</i>															
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Dimorphic Fantail	<i>Rhipidura brachyrhyncha</i>														x	x
Corvidae (<i>Dicrurinae</i> , <i>Rhipidurini</i>)	Rufous-backed Fantail	<i>Rhipidura rufidorsa</i>	x		x	x	x				x						
Corvidae (<i>Dicrurinae</i> , <i>Dicrurini</i>)	Pygmy Drongo	<i>Chaetorhynchus papuensis</i>					x				x			x			x
Corvidae (<i>Dicrurinae</i> , <i>Dicrurini</i>)	Spangled Drongo	<i>Dicrurus bracteatus</i>	x	x	x	x	x	x	x		x						
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Black Monarch	<i>Monarcha axillaris</i>					x				x		x	x	x	x	
Corvidae (<i>Dicrurinae</i> , <i>Monarchini</i>)	Rufous Monarch	<i>Monarcha rubiensis</i>									x						

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Corvidae (Dicrurinae, Monarchini)	Black-winged Monarch	<i>Monarcha frater</i>					x				x	x	x	x			
Corvidae (Dicrurinae, Monarchini)	Spot-winged Monarch	<i>Monarcha guttulus</i>	x	x	x	x	x	x	x		x		x				
Corvidae (Dicrurinae, Monarchini)	Hooded Monarch	<i>Monarcha manadensis</i>		x	x		x										
Corvidae (Dicrurinae, Monarchini)	Golden Monarch	<i>Monarcha chrysomela</i>			x		x	x			x						
Corvidae (Dicrurinae, Monarchini)	Frilled Monarch	<i>Arses telescopthalmus</i>	x	x	x		x	x			x		x				
Corvidae (Malaconotinae, Malaconotini)	Satin Flycatcher	<i>Myiagra cyanoleuca</i>															
Corvidae (Malaconotinae, Malaconotini)	Shining Flycatcher	<i>Myiagra alecto</i>	x			x	x										
Corvidae (Malaconotinae, Malaconotini)	Yellow-breasted Boatbill	<i>Machaerirhynchus flaviventer</i>			x		x				x			x			
Corvidae (Malaconotinae, Malaconotini)	Black-breasted Boatbill	<i>Machaerirhynchus nigripectus</i>											x	x	x	x	x
Muscicapidae	Russet-tailed Thrush	<i>Zoothera heinei</i>											x				
Muscicapidae	Island Thrush	<i>Turdus poliocephalus</i>														x	
Muscicapidae	Pied Bushchat	<i>Saxicola caprata</i>							x		x	x	x				
Sturnidae	Metallic Starling	<i>Aplonis metallica</i>			x		x				x						
Sturnidae	Yellow-eyed Starling	<i>Aplonis mystacea</i>	x				x										

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Sturnidae	Golden Myna	<i>Mino anais</i>		x	x	x	x										
Sturnidae	Yellow-faced Myna	<i>Mino dumontii</i>	x	x	x	x	x	x	x		x						
Hirundinidae	Pacific Swallow	<i>Hirundo tahitica</i>	x	x			x		x	x	x	x					
Hirundinidae	Tree Martin	<i>Hirundo nigricans</i>					x				x						
Zosteropidae	Black-fronted White-eye	<i>Zosterops minor</i>					x	x			x	x	x	x			
Zosteropidae	New Guinea White-eye	<i>Zosterops novaeguineae</i>														x	
Sylviidae	Gray's Grasshopper-Warbler	<i>Locustella fasciolata</i>									x						
Sylviidae	Clamorous Reed-Warbler	<i>Acrocephalus stentoreus</i>						x			x						
Sylviidae	Mountain Leaf-Warbler	<i>Phylloscopus trivirgatus</i>					x				x		x	x	x		x
Nectariniidae	Red-capped Flowerpecker	<i>Dicaeum geelvinkianum</i>		x	x	x	x	x	x		x		x	x			x
Nectariniidae	Black Sunbird	<i>Nectarinia aspasia</i>			x		x	x			x						
Nectariniidae	Olive-backed Sunbird	<i>Nectarinia jugularis</i>															
Melanocharitidae	Black Berrypecker	<i>Melanocharis nigra</i>	x	x	x	x	x				x		x	x			
Melanocharitidae	Lemon-breasted Berrypecker	<i>Melanocharis longicauda</i>									x						
Melanocharitidae	Fan-tailed Berrypecker	<i>Melanocharis versteri</i>												x		x	x
Melanocharitidae	Streaked Berrypecker	<i>Melanocharis striativentris</i>														x	
Melanocharitidae	Grey-winged Longbill	<i>Toxorhamphus poliopterus</i>				x	x		x		x		x	x			
Melanocharitidae	Green-crowned Longbill	<i>Toxorhamphus novaeguineae</i>		x	x		x										
Melanocharitidae	Plumed Longbill	<i>Toxorhamphus iliolophus</i>		x	x	x	x				x	x		x			
Melanocharitidae	Pygmy Longbill	<i>Oedistoma pygmaeum</i>			x		x				x						

Appendix 3 Birds recorded in the PNG LNG Project Upstream Project Area in 1995 – 2005. Upland sites (>300 m). Data compiled from all sources in Table 1.

Site			Libano Sok	Wassi Falls	Kantobo	Darai Plateau	Gobe	Lake Kutubu	Moro	Agogo	Moro/Kutubu/ Agogo	Nogoli	Benaria	Mt Bosavi	Mt Moran	H3	Mt Sisa
Altitude (m)			400	400	410	500	520	808	870	1000	1050	1200	1239	1500	1650	2163	2200
Family	Common Name	Scientific Name															
Paramythiidae	Tit Berrypecker	<i>Oreocharis arfaki</i>												X			X
Paramythiidae	Crested Berrypecker	<i>Paramythia montium</i>															X
Passeridae	Grey Wagtail	<i>Motacilla cinerea</i>			X												
Passeridae	Blue-faced Parrotfinch	<i>Erythrura trichroa</i>					X				X			X	X		X
Passeridae	White-spotted Munia	<i>Lonchura leucosticta</i>									X						
Passeridae	Hooded Munia	<i>Lonchura spectabilis</i>										X	X				
Total Species			63	78	136	70	210	103	48	6	208	44	89	102	46	65	85

**Appendix 4 Species that may occur but have not been recorded in the PNG LNG Project
Upstream Project Area.**

Scientific Name	Common Name	Status ¹			Res ²	Hab ³	Elevation (m asl)			
		IUCN	PNG	RR			Min. Lower	Av. Lower	Av. Upper	Max. Upper
<i>Coturnix ypsilophora</i>	Brown Quail				BR	G		0	2600	3600
<i>Turnix maculosa</i>	Red-backed Buttonquail				BR	G		0	2500	
<i>Tanysiptera galatea</i>	Common Paradise-Kingfisher				BR	F		0	600	820
<i>Chrysococcyx lucidus</i>	Shining Bronze-Cuckoo				M	F		0	1920	
<i>Psittacella brehmii</i>	Brehm's Tiger-Parrot				BR	F	1100	1600	2800	3200
<i>Psittacella picta</i>	Painted Tiger-Parrot			CPM	BR	F	1370	2450	3680	4000
<i>Psittacella modesta</i>	Modest Tiger-Parrot			CPM	BR	F		1700	2800	
<i>Tyto capensis</i>	African Grass-Owl				BR	G		1000	2500	
<i>Ninox connivens</i>	Barking Owl				BR	F/O		0	1040	
<i>Uroglaux dimorpha</i>	Papuan Hawk-Owl	DD			BR	F		0	1500	
<i>Aegotheles wallacii</i>	Wallace's Owlet-Nightjar	DD			BR	F		100	1100	
<i>Aegotheles archboldi</i>	Archbold's Owlet-Nightjar			CPM	BR	F	1350	1350	3600	3600
<i>Aegotheles tatei</i>	Starry Owlet-Nightjar	DD			BR	F		?		
<i>Eurostopodus mystacalis</i>	White-throated Eared-Nightjar				M	F/Sv/O		0	1650	
<i>Ptilinopus aurantiifrons</i>	Orange-fronted Fruit-Dove				BR	F		0	300	
<i>Rallina rubra</i>	Chestnut Forest-Rail			CPM	BR	F		1500	3050	
<i>Lewinia pectoralis</i>	Lewin's Rail				BR	W/G	1040	1040	2600	2600
<i>Gymnocrex plumbeiventris</i>	Bare-eyed Rail				BR	F/W/G		0	2100	2100
<i>Porzana pusilla</i>	Baillon's Crake				BR	W/G		0	2450	2450
<i>Porzana tabuensis</i>	Spotless Crake				BR	W/G		0	3300	3300
<i>Porphyrio porphyrio</i>	Purple Swamphen				BR	W/G		0	1800	
<i>Fulica atra</i>	Common Coot				BR	W		0	2320	2320
<i>Scolopax rosenbergii</i>	New Guinea Woodcock				BR	F		1700	3800	
<i>Gallinago hardwickii</i>	Latham's Snipe				M	W/G		0	3350	3350
<i>Gallinago megala</i>	Swinhoe's Snipe				M	W/G		0	3720	3720
<i>Numenius minutus</i>	Little Curlew				M	G/O		0	1100	4500
<i>Tringa glareola</i>	Wood Sandpiper				M	W/G		0	1735	1735
<i>Irediparra gallinacea</i>	Comb-crested Jacana				BR	W		0	600	600
<i>Himantopus leucocephalus</i>	White-headed Stilt				BR	W		0	1670	1670
<i>Glareola maldivarum</i>	Oriental Pratincole				M	O/W		0	1500	1500
<i>Elanus caeruleus</i>	Black-winged Kite				BR	O/G		0	1830	
<i>Erythrotriorchis buergersi</i>	Chestnut-shouldered Goshawk	DD			BR	F		450	1580	
<i>Megatriorchis doriae</i>	Doria's Goshawk	NT			BR	F		0	1070	1650
<i>Egretta novaehollandiae</i>	White-faced Heron				BR+M	W/G		0	1500	1700
<i>Threskiornis molucca</i>	Australian Ibis				BR?+M	W/G		0		
<i>Archboldia papuensis</i>	Archbold's Bowerbird	NT		CPM	BR	F	1750	2600	2900	3660
<i>Sericulus aureus</i>	Flame Bowerbird				BR	F		0	1400	
<i>Malurus grayi</i>	Broad-billed Fairywren				BR	F		0	1600	
<i>Pycnopygius cinereus</i>	Marbled Honeyeater				BR	F	500	1000	2000	
<i>Ptiloprora plumbea</i>	Leaden Honeyeater			CPM	BR	F		1100	1900	
<i>Ptiloprora meekiana</i>	Olive-streaked Honeyeater			CPM	BR	F		1300	2440	
<i>Melidectes fuscus</i>	Sooty Melidectes			CPM	BR	F	1700	2200	3700	
<i>Conopophila albogularis</i>	Rufous-banded Honeyeater				BR	Sv/Fm/O		0	600	
<i>Microeca flavigaster</i>	Lemon-bellied Flyrobin				BR	Sv/O		0	670	1460
<i>Pachycephalopsis hattamensis</i>	Green-backed Robin			CPM	BR	F		0	1650	2000
<i>Androphobus viridis</i>	Papuan Whipbird	DD		CPM	BR	F		1400	2700	
<i>Orthonyx temminckii</i>	Logrunner				BR	F	1200	1980	2840	3450

Appendix 4 Species that may occur but have not been recorded in the PNG LNG Project Upstream Project Area.

Scientific Name	Common Name	Status ¹			Res ²	Hab ³	Elevation (m asl)			
		IUCN	PNG	RR			Min. Lower	Av. Lower	Av. Upper	Max. Upper
<i>Cinclosoma ajax</i>	Painted Quail-thrush			SPL	BR	F		0	800	
<i>Daphoenositta miranda</i>	Black Sittella			CPM	BR	F	2450	2000	3700	
<i>Pachycephala lorentzi</i>	Lorentz's Whistler			CPM	BR	F		1600	3800	
<i>Pachycephala aurea</i>	Golden-backed Whistler				BR	F		0	700	1460
<i>Colluricincla umbrina</i>	Sooty Shrike-thrush			CPM	BR	F		1450	2150	
<i>Pitohui incertus</i>	White-bellied Pitohui	NT		SPL	BR	F		low		
<i>Melampitta lugubris</i>	Lesser Melampitta				BR	F	1150	2000	2800	3500
<i>Cnemophilus macgregorii</i>	Crested Bird-of-paradise		P	CPM	BR	F	2100	2600	3500	3650
<i>Paradisaea apoda</i>	Greater Bird-of-paradise		P	SPL	BR	F		0	950	
<i>Monarcha melanopsis</i>	Black-faced Monarch				M	F		0	800	
<i>Myiagra rubecula</i>	Leaden Flycatcher				BR+M	Sv/F/O		0	650	
<i>Hirundo rustica</i>	Barn Swallow				M	F		0	1740	
<i>Cisticola exilis</i>	Golden-headed Cisticola				BR	G		0	1250	2225
<i>Zosterops fuscicapillus</i>	Capped White-eye				BR	F	750	1200	1850	2200
<i>Nectarinia jugularis</i>	Olive-backed Sunbird				BR	O	0	500	1580	1580
<i>Melanocharis arfakiana</i>	Obscure Berrypecker	DD		CPM	BR	F		950	950	
<i>Oreostruthus fuliginosus</i>	Mountain Firetail			CPM	BR	F	2200	2700	3700	
<i>Erythrura papuana</i>	Papuan Parrotfinch				BR	F	500	1200	2600	

¹ Conservation status indicates species listed by the IUCN as Vulnerable (VU), Near-threatened (NT) or Data Deficient (DD), those birds protected (P) under PNG law (PNG) and Restricted Range species (RR) endemic to the Central Papuan Mountains (CPM) and South Papuan Lowlands (SPL) Endemic Bird Areas.

² Residency status (Res) defines birds as breeding residents (BR), migrants (M) or breeding residents with populations seasonally augmented by non-breeding visitors (BR+M).

³ Habitat preferences (Hab) include forest (F), open and disturbed areas (O), grassland (G), rivers and wetlands (W), savannah (Sv), mangroves (Fm) and aerial foraging habitat (A).

Plates



Plate 1. Juvenile Dwarf Cassowary (NT) at South Karius. This bird was captured locally and being raised as a pet.



Plate 2. Local residents at South Karius.



Plate 3. This Salvadori's Teal (VU; P) was captured in the small creek next to the camp at South Karius.



Plate 4. Skins of three Fairy and one Papuan Lorikeet captured by locals at South Karius.



Plate 5. Cuscus and juvenile Wattled Brush-turkey captured by a local hunter at South Karius.



Plate 6. The blue facial skin identifies this bird as a juvenile Wattled Brush-turkey.



Plate 7. Brown-collared Brush-turkey snared by locals at Juha North.



Plate 8. Brown-collared Brush-turkey photographed with a camera trap at Juha North.



Plate 9. Mimic (top) and Mottled-breasted Meliphaga mist-netted at Juha North. This picture illustrates the difficulty in separating these species in the field.



Plate 10. Superb Fruit-Dove mist-netted at Juha North.



Plate 11. New Guinea Scrubfowl photographed with a camera trap at Juha South.

Annex 09

Biodiversity survey results:

Herpetofauna at Hides, Nogoli and Benaria in 2005

This report originally appeared in the PNG Gas Project EIS as:
Supporting Study 6 “Biodiversity and conservation status of herpetofauna of the Papua
New Guinea Gas Project Area”

BIODIVERSITY AND CONSERVATION STATUS OF HERPETOFAUNA OF THE PAPUA NEW GUINEA GAS PROJECT AREA

Prepared by

Stephen Richards
Honorary Curator
South Australian Museum

The microhylid frog *Albericus* sp.



A report prepared for ENESAR and Exxon-Mobil

July 10th 2005

CONTENTS

1	Preface	4
2	Executive Summary	4
3	Introduction	6
3.1	Objectives	6
4	Methods	6
4.1	Sites.....	6
4.2	Herpetofauna sampling	7
5	Results & Discussion	8
5.1	Species diversity.....	8
5.2	Significant species.....	15
5.3	Significant Habitats.....	17
5.3.1	Montane forests – Hides 3-Mt Sisa	17
5.3.2	Rocky mountain streams – Benaria and Iagifu Ridge	17
5.3.3	Riparian habitats in lowland forests	18
5.3.4	Extremely wet forests of the Darai Plateau	18
5.4	Potential impacts and impact mitigation	18
5.4.1	River crossings.....	18
5.5	Forest gaps: ROW, flow lines, and permanent roads.....	19
5.5.1	Narrow corridors.....	19
5.5.2	Permanent and temporary infrastructure	20
5.6	Chemical leaks	20
6	Final conclusions and recommendations	21
7	References.....	22

TABLES

Table 1	Sites and Schedule for Herpetofauna assessment
Table 2	Frog and reptile species documented at Nogoli, Benaria and Hides 3
Table 3	Total Frog Species documented from PNG Gas Project area 1999-2005
Table 4	Total Reptile Species documented from PNG Gas Project area 1999-2005
Table 5	Conservation status of described frog species documented in PNG Gas Project area 1999-2005

FIGURES

Figure 1 Montane moss forest at Hides3.

Figure 2 Nogoli sample site.

Figure 3 Benaria Camp.

Figure 4 Benaria River.

Figure 5 Litoria iris in amplexus near Hides 3.

Figure 6 The skink Sphenomorphus at Hides 3.

Figure 7 Rana sp. Aff. grisea near the Benaria River.

Figure 8 The microhylid Choerophryne allisoni at Hides3.

Figure 9 Hylophorbus richardsi.

Figure 10 Oreophryne notata (?).

Figure 11 Montane forest near Hides 2.

Figure 12 Open water in the Hides uplands is limited to small pools in sinkholes.

Figure 13 The fast flowing Benaria River - home to torrent frogs.

Figure 14 Riparian forest along Benaria River.

Figure 15 Forest clearing for gardens.

1 Preface

This study is part of a suite of terrestrial biodiversity investigations that have been conducted for the EIS for the proposed PNG Gas Project. This study report forms Supporting Study 6 of the EIS and the findings herein support the assessment of potential impacts on terrestrial biodiversity that are discussed in Supporting Study 1 of the EIS. An outline of the project components is given in Supporting Study 1 and detailed description of proposed development in Chapter 2 of the Main EIS report.

2 Executive Summary

- A total of 19 frog and 17 reptile species were documented at three sites, Nogoli, Hides 3 and Benaria in the PNG Gas Project area, Southern Highlands Province.
- The herpetofauna at Hides 3 is substantially a sub-set of the fauna previously documented at nearby Mt Sisa, and the survey at Hides 3 documented valuable range extensions for at least two poorly known species previously known only from Mt Sisa - the microhylid frogs *Choerophryne allisoni* and *Hylophorbus richardsi*. These species were classified as 'Data Deficient' in the recent Global Amphibian Assessment.
- The drill pad and helipad clearing at Hides 3 appear to have had negligible impact on the local herpetofauna, with high densities of most species persisting within a few metres of the forest edge. Infrastructure/clearings isolated from human populations can co-exist with significant herpetofaunal diversity, and the forests around Hides 3 are of high significance for conservation of poorly known frogs.
- The herpetofauna at Nogoli is dominated by widespread species with broad habitat tolerances. This certainly reflects the moderately to severely disturbed nature of the forest in the area. One exception may be a small, unidentified skink (*Lygisaurus* sp.) collected at Nogoli and Benaria. Taxonomic studies are required to determine whether this represents a new species.
- The herpetofauna at Benaria was moderately depauperate, reflecting a long history of habitat disturbance in the area. However the Benaria River is a significant habitat for torrent-dwelling frogs, including one species (*Litoria wollastoni*) not previously reported from the project area and two undescribed species previously known only from the Moro area. Limiting damage to riparian vegetation will be a high priority to maintain the integrity of these species' populations.
- This survey increased the known herpetofauna of the project area to 90 frog species and 52 reptile species. The frog fauna is the most diverse assemblage documented for any catchment in New Guinea, and includes an extremely high proportion of undescribed species (> 50%).
- Significant species in the project area include the Saltwater Crocodile, *Crocodylus porosus*, the goanna *Varanus salvadori*, the Pig-nosed turtle *Carrettochelys insculpta* and Boelen's Python *Morelia boeleni*.

- Potential impacts on significant species include localised damage to nesting sites of *Carrettochelys insculpta* at lowland river crossings, and increased hunting pressure on this species and on *Crocodylus porosus*, *Varanus salvadori* and *Morelia boeleni*. Methods to control hunting by the workforce should be investigated, with due and effective account of the cultural and social constraints, especially customary land ownership and of any other mitigation possibilities to prevent over-harvesting of these species.
- Significant habitats include the montane moss forests around Hides 3 and Hides 2 that harbour a number of microhylid frog species with limited known distributions, the torrential streams on Jagifu Ridge and Benaria that have an assemblage of torrent-dwelling frogs not documented elsewhere in the project area, the wet karst forests of the Darai Plateau and the riparian zones of lowland forests.
- Given the restricted width of the ROW and Flow Lines, direct impacts of the project will be minimal. However, the establishment of permanent roads to provide improved access for local people could lead to serious secondary impacts through forest clearing, both in the short- and long-term.

3 Introduction

The herpetofauna of Papua New Guinea is exceptionally diverse, with the total species count expected to approach 700 (Allison 1993). Taxonomic revisions of the fauna, and exploration of remote regions, continue to reveal new species, particularly in the frog families Hylidae and Microhylidae. Since 1999 a series of surveys have documented the herpetofauna of the Kikori Integrated Conservation and Development Project (ICDP) Area in Southern Highlands and Gulf Provinces (Richards 2000; 2002a; 2002b; Richards & Allison 2003). These surveys focused most intensively on frogs and data accumulated up until 2002 were summarised by Richards (2002c). Prior to the Kikori ICDP surveys the most intensive and comprehensive survey of herpetofauna at a single site in New Guinea was undertaken in the Lakekamu Basin by Allison et al (1998). Seventy-four species of amphibians and reptiles were reported, including 18 undescribed taxa. In contrast, Richards (2002c) reported 55 species of frogs from lowland and foothill forests of the Kikori ICDP including 29 undescribed taxa. Subsequently Richards & Allison (2003) added a number of undescribed frog species from the Darai Plateau and Libano.

The previous Kikori ICDP herpetofauna surveys have been undertaken in forests within the oil and gas fields currently being operated by Oilsearch Ltd. Careful management of forest use in the project area to date has resulted in minimal impacts on the herpetofauna. This is reflected in the fact that many of the new species discovered since 1999 persist in close proximity to existing infrastructure and roads. The decision by ExxonMobil to advance the PNG Gas project by preparing an EIS has necessitated a biodiversity assessment for the project, and in particular for the additional 125 km pipeline route upstream of Kutubu Central Processing Facility. This report presents an assessment of the overall herpetofaunal diversity of the project area, and more specifically addresses the potential impacts on herpetofauna of additional pipeline construction and development of major infrastructure associated with the proposed PNG Gas Pipeline.

3.1 Objectives

The objectives of this survey were to: 1) quantify the diversity of frogs and reptiles at three new sites in the PNG Gas Project area, Southern Highlands Province; 2) summarise existing knowledge of herpetofauna in the broader project area; 3) identify any species of conservation significance; and 4) identify threats to significant species and recommend mitigation options for these threats.

4 Methods

4.1 Sites

Surveys were undertaken at three sites in the PNG Gas Project area of Southern Highlands Province:

The Hides 3 site was in mid-montane mossy forest at an altitude of 2163 m ASL (Fig. 1) A series of trails connected the camp to Hides 2 at 2400 m and provided access to a range of habitats, including extremely wet gullies, ridge tops, dense stands of bamboo, and a small permanent forest pool. A conspicuous feature of this

camp and the surrounding forests is the lack of any running water, a critical habitat for many frog species.

The Nogoli site was in moderately to heavily disturbed forest, and included gardens, a permanent road, a fast-flowing stream (Wara Korae), small seepages and the Tamali River (Fig. 2).

Table 1. Sampling localities and schedule for 2005 PNG Gas Project herpetofauna survey.

Locality	Coordinates*	Dates (2005)	Sites Surveyed
Hides 3	05°56.910'S 142°44.730'E	21 – 23 April	Mid-montane mossy forest within ~ 500 m radius of camp between 2100-2400 m asl. Small forest pool below camp.
Nogoli	05°56.057'S 142°47.287'E	24 – 30 April	Degraded forest near road 'junction'. River bank, torrential stream & flooded ditches in Nogoli compound @ ~ 1250 m asl.
Benaria	06°03.287'S 142°58.707'E	01-05 May	Disturbed lower-montane forest and grassland, slow-flowing stream and large torrent adjacent camp @ 1345 m asl.

*Coordinates refer to main camps only.

'Benaria Camp' was located on a broad, grassy, gentle slope adjacent to the Benaria River (Fig. 3). Cattle and pigs were present in the grassy areas and adjacent forest. Major habitats include: a small, slow-flowing tributary of the Benaria River exiting a large forested swamp; the Benaria River itself (a large rocky torrential stream: Fig. 4); and heavily disturbed lower montane forest on the slopes adjacent to the camp.

4.2 Herpetofauna sampling

At each site, all accessible habitats were first identified and then intensive searches were conducted for frogs and reptiles in each habitat. During the day I searched for heliothermic (basking) reptiles along forest trails, clearings, and stream banks. Small lizards were collected after being stunned with a large rubber band. Large lizards and snakes were collected by hand. Non-heliothermic reptiles were sampled by searching in deeply shaded forest, during rain, or at dusk. I searched for nocturnal reptiles, including geckos, by walking along forest trails and stream banks at night with a headlamp.

I searched for frogs at night by conducting visual-encounter and aural surveys along streams, and in and around small ponds. Because a large proportion of New Guinean frogs have life cycles that are independent of free-standing water, I also conducted extensive visual and aural searches along forest trails away from water. During the day I searched for diurnal frogs along streams, and sampled tadpoles with a dip-net in all available water bodies. No attempt was made to sample aquatic reptiles (turtles, crocodiles) because all three sites were above the altitudinal ranges of these taxa.

Frog calls are an important diagnostic character that assist greatly with species identification. Whenever possible I recorded the advertisement calls of frogs with a Sony TCM-5000 Tape Recorder and Sennheiser ME66 microphone. Most species were photographed alive before preparation as voucher specimens. Specimens were euthanized by submersion in chlorotone (for amphibians and small reptiles), or

with lethal injection of nembutal for larger reptiles. Specimens were fixed in 10% formalin solution, and then stored in 70% ethanol. Samples of liver tissue for DNA analyses were extracted from many specimens and stored in 95% ethanol.

Voucher specimens will be deposited in the University of Papua New Guinea and the South Australian Museum, Australia.

5 Results & Discussion

5.1 Species diversity

A total of 19 frog and 17 reptile species were recorded from Hides 3, Nogoli and Benaria (Table 2). The high proportion of microhylid frogs and small number of hylid frogs (tree-frogs) at the highest altitude sampled (Hides 3) reflects the limited free-standing water at this site. The only habitat at Hides 3 that is suitable for hylid frogs was a small pool below the camp that contained a very large population of the Rainbow Treefrog (*Litoria iris*) (Fig. 5). This is an abundant and widespread species in montane New Guinea. A surprising discovery at this pool was a single specimen of *Litoria pronimia*, a 'spike-nosed frog' previously known from much lower altitudes (~ 1000 m ASL) in the project area and elsewhere in New Guinea.

The bulk of the diversity documented at Hides 3 were frogs in the family Microhylidae (Table 2). This group of frogs has a reproductive strategy that is independent of free-standing water, and they have radiated extensively in the constantly moist montane habitats typical of Hides 3 where their terrestrial embryos do not face desiccation. The frog fauna at Hides 3 is largely a sub-set of the fauna previously documented at nearby Mt Sisa (Table 3 & Richards 2000). It is unclear whether these species will prove to be widespread in montane forests of the region, and the Hides uplands must be considered a significant habitat.

Similarly, the reptile fauna at Hides 3 shows great similarities to that documented at Mt Sisa including the widespread montane lizards *Papuascincus* sp. and *Lobulia elegans* and the snake *Tropidonophis statisticus* (Table 4). The identities of one skink of the genus *Emoia* and one skink of the genus *Sphenomorphus* (*solomonis* group) (Fig. 6) from Hides 3 remain to be determined. One significant reptile record from Hides 3 is an Amethistine Python (*Morelia amethistina*), observed basking on the scree slope at the edge of the Hides 3 helipad clearing. This record is nearly 500 m higher than previously recorded for this species (O'Shea 1996). The extremely low reptile diversity at this site is not surprising given that few reptiles are known in New Guinea from such predominantly cold and wet habitats.

The herpetofauna at the Nogoli site was dominated by species with broad distributions and habitat tolerances in New Guinea. Although two species of microhylid frogs (an *Oreophryne* and a *Hylophorbus*) are undescribed, they are known from widely scattered sites in the broader project area and clearly have wide distributions. The large *Carlia* skink observed in gardens and large forest gaps at Nogoli and Benaria remains unidentified, but it likely has a broad distribution in the southern mountains of Papua New Guinea. One species of potential interest is a small *Lygisaurus* that may represent an undescribed species. It was found in the disturbed forests at Nogoli and in the surrounds of Benaria Camp. Additional taxonomic studies are required to determine its status.

Snake diversity at Nogoli was high, with at least 4 widespread species confirmed for the site during limited survey time (Table 2). Of particular significance were the

Green Tree Python (*Morelia viridis*) and the Amethystine Python (*Morelia amethystina*) which appear to persist in relatively high densities in gardens and forests despite hunting pressure. We observed one *M. viridis* collected for food near the Junction" and shortly before the survey an Amethystine Python was also collected for food (photographed by Chris Ballard in April 2005).

Table 2. Frog and reptile species documented at Nogoli, Beneria & Hides 3

Species	Nogoli	Beneria	H3
Reptiles			
Lizards			
<i>Carlia</i> sp.	+	+	
<i>Emoia</i> sp. 1			+
<i>Emoia</i> sp. 2		+	
<i>Hemidactylus frenatus</i>	+		
<i>Hypsilurus modestus</i>		+	
<i>Lipinia</i> sp.		+	
<i>Lobulia elegans</i>			+
<i>Lygisaurus</i> sp.	+	+	
<i>Papuascincus</i> sp.			+
<i>Sphenomorphus jobiensis</i>		+	
<i>Sphenomorphus muelleri</i>		+	
<i>Sphenomorphus</i> sp. 1			+
Snakes			
<i>Morelia amethistina</i>	+		+
<i>Morelia viridis</i>	+		
<i>Dendrelaphis gastroticta</i>	+	+	
<i>Stegonotus modestus</i>	+	+	
<i>Tropidonophis statisticus</i>			+
TOTAL SPECIES	7	9	6
Frogs			
Microhylidae			
<i>Albericus</i> sp 1 (large)			+
<i>Albericus</i> sp 2 (medium)			+
<i>Callulops prob wilhelmanus</i>			+
<i>Choerophryne allisoni</i>			+
<i>Hylophorbus richardsi</i>			+
<i>Hylophorbus</i> sp.	+	+	
<i>Oreophryne</i> sp. (peeper)	+	+	
<i>Oreophryne</i> sp. (notata?)			+
<i>Oreophryne</i> sp. (arboreal)			+
Hylidae			
1.1.1.1 <i>Litoria darlingtoni</i>	+		
<i>Litoria iris</i>			+
<i>Litoria infrafronata</i>	+		
<i>Litoria pronimia</i>			+
<i>Litoria wollastoni</i>		+	
<i>Litoria</i> sp. cf <i>arfakiana</i>		+	
<i>Litoria</i> sp. (bell call)		+	
<i>Litoria</i> sp. (red-legs)		+	
Ranidae			
<i>Rana daemeli</i>	+	+	
<i>Rana cf grisea</i>	+	+	
TOTAL SPECIES	6	8	8

Table 3. List of frog species documented in PNG Gas Project area 1999-2005

	Mt Sisa	Hides 3	Moran	Moro	Gobe	Nogoli	Beneria	Darai Plateau	Libano-Sok	Kopi	Dark end Lumber
Microhylidae											
<i>Albericus tuberculatus</i>				+	+						
<i>Albericus</i> sp. nov. 1 (rattler)	+		+	+	+						
<i>Albericus</i> sp. nov. 2 (short peeper)			+	+							
<i>Albericus</i> sp. nov. 3 (rasper)				+	+			+			
<i>Albericus</i> sp. nov. 4 (large)	+	+									
<i>Albericus</i> sp. nov. 5 (medium)	?	+									
<i>Albericus</i> sp. nov. 6 (clicker)				+				+	+		
<i>Albericus</i> sp. nov. 7 (peeper 2)								+			
<i>Asterophrys turpicola</i>					+				+	+	
<i>Asterophrys</i> sp. nov.			+								
<i>Austrochaperina derongo</i>				+				+	+		
<i>Austrochaperina guttata</i>											+
<i>Austrochaperina palmipes</i>											+
<i>Austrochaperina</i> sp. nov. 1			+	+	+			?	?		+
<i>Austrochaperina</i> sp. nov. 2 (cf <i>derongo</i>)								+			
<i>Callulops doriae</i>					+					+	+
<i>Callulops slateri</i>				+	+			+	+	+	+
<i>Callulops wilhelmanus</i>	+	?									
<i>Callulops</i> sp. nov. 1 (<i>C. robusta</i> group)					+			+		?	
<i>Callulops</i> sp. nov. 2 (small)			+								
<i>Choerophryne allisoni</i>	+	+									
<i>Choerophryne</i> sp. nov.			+								
<i>Cophixalus cryptotympanum</i>			+								
<i>Cophixalus shellyi</i> ?			+								
<i>Cophixalus</i> sp. nov. 1 (eye-spikes)			+	+							
<i>Cophixalus</i> sp. nov. 2 (buzz call)					+			+		+	
<i>Cophixalus</i> sp. nov. 3 (cf <i>balbus</i>)					+			+	+		
<i>Cophixalus</i> sp. nov. 4 (musical call)	+			+	+						
<i>Cophixalus</i> sp. nov. 5. (triple-calls)			+								
<i>Cophixalus</i> sp. nov. 6. (tiny)								+			
<i>Cophixalus</i> sp. nov. (cf <i>shellyi</i>)			+								
<i>Copiula</i> sp. nov. 1 (small, fast call)										+	?
<i>Copiula</i> sp. nov. 2 (2-note call)				+				+	+		

Table 3. List of frog species documented in PNG Gas Project area 1999-2005

	Mt Sisa	Hides 3	Moran	Moro	Gobe	Nogoli	Beneria	Darai Plateau	Libano-Sok	Kopi	Dark end Lumber
<i>Copiula sp. nov. 3. (tiny)</i>					+						
<i>Hylophorbus richardsi</i>	+	+									
<i>Hylophorbus rufescens</i>											+
<i>Hylophorbus sp. nov. 1 (Moro broad head)</i>				+		+	+	?	?		
<i>Hylophorbus sp. nov. 2 (zig-zag)</i>					+					+	
<i>Hylophorbus sp. nov. 3 (slow call)</i>			+	+	+			+	+	+	
<i>Hylophorbus sp. nov. 4 (tiny)</i>								+			
<i>Liophryne schlaginhaufeni</i>				+	+			+	+		
<i>Mantophryne lateralis</i>									+	+	+
<i>Oreophryne notata?</i>	+	+	+								
<i>Oreophryne sp. nov. 1 (small rattler)</i>				+	+			+	+	+	+
<i>Oreophryne sp. nov. 2 (large rattler)</i>			+	+	+						
<i>Oreophryne sp. nov. 3 (peeper)</i>				+	+	+	+	+	+	+	+
<i>Oreophryne sp. nov. 4. (large, montane)</i>	+	+									
<i>Sphenophryne cornuta</i>				+	+			+	+	+	+
<i>Xenorhina parkerorum</i>	+		+								
<i>Xenobatrachus sp. 1 (small)</i>								+	+		
<i>Xenobatrachus sp. (slow call)</i>								+		?	?
Hylidae											
<i>Litoria amboinensis</i>				+	+						
<i>Litoria angiana</i>	+										
<i>Litoria auae</i>			+	+				+		+	
<i>Litoria darlingtoni</i>	+					+					
<i>Litoria eucnemis</i>			+	+							
<i>Litoria graminea</i>					+			+			+
<i>Litoria havina</i>			+	+							
<i>Litoria infrafronata</i>				+		+		+	+	+	+
<i>Litoria iris</i>	+	+									
<i>Litoria majikthise?</i>								+			
<i>Litoria micromembrana</i>	+										
<i>Litoria modica</i>	+		+								
<i>Litoria cf nigropunctata 1 (bleating call)</i>				+							
<i>Litoria cf nigropunctata 2</i>								+			
<i>Litoria pronimia</i>		+	+	+	+						
<i>Litoria prora</i>				+	+						+
<i>Litoria thesaurensis</i>				+					+		

Table 3. List of frog species documented in PNG Gas Project area 1999-2005

	Mt Sisa	Hides 3	Moran	Moro	Gobe	Nogoli	Beneria	Darai Plateau	Libano-Sok	Kopi	Dark end Lumber
<i>Litoria wollastoni</i>							+				
<i>Litoria sp. nov. 1 (nr arfakiana)</i>				+			+				
<i>Litoria sp. nov. 2 (bell-call)</i>				+			+				
<i>Litoria sp. nov. 3 (nr bicolor)</i>										+	
<i>Litoria sp. nov. 4 (nr genimaculata 1)</i>				+							
<i>Litoria sp. nov. 5 (nr genimaculata 2)</i>								+		+	+
<i>Litoria sp. nov. 6. (small, arboreal)</i>								+			
<i>Litoria sp. nov. 7 (small, green torrent)</i>									+		
<i>Litoria sp. nov. 8 (scarlet venter)</i>			+	+	+		+				
<i>Litoria sp. nov. 9 (yellow venter)</i>				+	+						
<i>Litoria sp. nov. 10 (torrent)</i>									+		
<i>Litoria sp. nov. 11 (cf pygmaea)</i>			+								
<i>Nyctimystes pulcher</i>				+							
<i>Nyctimystes sp. nov.</i>			?	+							
Myobatrachidae											
<i>Lechriodus aganoposis</i>	+		+								
<i>Lechriodus melanopyga</i>				+				+	+		+
Ranidae											
<i>Rana arfaki</i>				+				+	+		+
<i>Rana daemeli</i>				+	+	+	+	+	+	+	+
<i>Rana cf grisea 1</i>			+	+		+	+	+			
<i>Rana cf grisea 2</i>								+			
<i>Rana novaeguineae</i>										+	
<i>Rana sp. nov.</i>										+	
TOTAL ALL SITES = 90	16	9	25	38	26	6	8	33	22	20	19

Table 4. Reptile species documented at 8 sites in the PNG Gas Project area

Species	Hides 3	Mt Sisa	Nogoli	Beneria	Darai Plateau	Libano-Sok	Kopi area	Dark End Lumber
CROCODILES								
<i>Crocodylus porosus</i>							+	+
<i>Crocodylus novaeguineae</i>						+		
LIZARDS								
Agamidae								

Table 4. Reptile species documented at 8 sites in the PNG Gas Project area

Species	Hides 3	Mt Sisa	Nogoli	Beneria	Darai Plateau	Libano-Sok	Kopi area	Dark End Lumber
<i>Hypsilurus dilophus</i>					+	+		+
<i>Hypsilurus modestus</i>				+	+	+		+
<i>Hypsilurus</i> sp.						+		
Gekkonidae								
<i>Cyrtodactylus loriae</i>						+		
<i>Cyrtodactylus lousiadensis?</i>								+
<i>Cyrtodactylus papuensis</i>						+		
<i>Cyrtodactylus</i> sp. nov.					+			
<i>Hemidactylus frenatus</i>			+					
<i>Nactus pelagicus</i>					+	+		
Scincidae								
<i>Carlia aramia</i>					+	+	+	+
<i>Carlia</i> sp (no available name)			+	+				
<i>Emoia caeruleocauda</i>						+		
<i>Emoia kordoana</i>					+	+		
<i>Emoia longicauda</i>						+		
<i>Emoia pallidiceps?</i>					+			
<i>Emoia physicina</i>								+
<i>Emoia</i> sp. 1	+							
<i>Emoia</i> sp 2				+				
<i>Eugongylus rufescens</i>						+		
<i>Lipinia</i> sp. 1					+			
<i>Lipinia</i> sp. 2				+				
<i>Lobulia elegans</i>	+	+						
<i>Lygisaurus novaeguineae</i>								+
<i>Lygisaurus</i> sp			+	+				
<i>Papuascincus</i> sp.	+	+						
<i>Sphenomorphus melanopogon</i>								+
<i>Sphenomorphus muelleri</i>				+				
<i>Sphenomorphus meyeri</i>						+		
<i>Sphenomorphus pratti</i>					+			
<i>Sphenomorphus simus</i>					+	+		+
<i>Sphenomorphus cf jobiensis</i>				+	+	+		
<i>Sphenomorphus</i> sp. 2 cf cinereus	+							
Varanidae								
<i>Varanus indicus</i>							+	
<i>Varanus dorianus</i>						+		
<i>Varanus salvadori</i>								+
Snakes								
Elapidae								
<i>Acanthophis antarcticus</i>								+
<i>Aspidomorphus muelleri</i>							+	
<i>Toxicocalamus preussi angustitinctus</i>							+	
Pythonidae								
<i>Candoia aspera</i>						+		
<i>Candoia carinata</i>							+	
<i>Morelia amethystina</i>	+		+		+			+
<i>Morelia viridis</i>			+			+		
Colubridae								

Table 4. Reptile species documented at 8 sites in the PNG Gas Project area

Species	Hides 3	Mt Sisa	Nogoli	Beneria	Darai Plateau	Libano-Sok	Kopi area	Dark End Lumber
<i>Boiga irregularis</i>							+	+
<i>Dendrelaphis calligaster</i>								+
<i>Dendrelaphis gastrosticta</i>			+	+				
<i>Stegonotus modestus</i>			+	+		+		
<i>Stegonotus parvus</i>								+
<i>Stegonotus cucullatus</i>								+
<i>Tropidonophis statisticus</i>	+	+						
<i>Tropidonophis novaeguinea</i>						+		
NUMBER OF SPECIES AT EACH SITE	6	3	7	9	12	20	8	16
TOTAL NUMBER OF SPECIES							52	

The herpetofauna at Benaria was surprisingly depauperate. In particular a number of taxa occurring at similar altitudes elsewhere in the project area appear to be absent (i.e. *Albericus* spp., *Cophixalus* spp., and a diversity of *Oreophryne* spp. – all microhylid frogs - and *Emoia* spp.). Although it is possible that seasonal effects played some role in herpetofaunal activity, the weather during this survey included heavy rain, hot dry days and cool overcast days indicating climate alone cannot explain this observation. The most obvious explanation is the long history of human disturbance at this site. Cows grazed the grassy fields around the camp, and the forest showed signs of heavy utilisation. The increased exposure and hence drier conditions of the forest and substrate through this disturbance may well have had a major impact on microhylid frogs that rely on perpetually moist conditions to reproduce successfully.

A diverse assemblage of at least four torrent-dwelling frogs, *Litoria cf arfakiana*, *Litoria wollastoni* and *Litoria* sp. nov. 'yellow-legs', and the torrent ranid *Rana cf grisea* (Fig. 7) occurred only along the Benaria River (see 'significant habitats' below).

The results of this survey have increased the total known herpetofaunal diversity of the project area to 90 species of frogs and 52 species of reptiles. The reptile diversity is certainly a significant under-estimate, because previous surveys have focused predominantly on the frog fauna. However, it is also extremely likely that many more frog species occur in the project area, especially in the lower and mid-montane habitats.

The total frog and reptile faunas documented to date from the project area are presented in Tables 3 and 4 respectively. It is clear from these tables that altitude plays a significant role in determining the distributions of most species. In particular, there is a distinctive component of the fauna occurring predominantly at mid- or high altitudes, and many species occurring only at lower altitudes. The general issues affecting these groups are similar at the different altitudes, but montane species may typically have smaller distributions.

5.2 Significant species

Although at least seven frogs and possibly one lizard documented during this survey are new species, with one possible exception all have been previously reported from the project area (e.g. Richards 2002c). Perhaps the most significant records for this survey are the documentation of two microhylid frogs, *Choerophryne allisoni* (Richards 2003) (Fig. 8) and *Hylophorbus richardsi* (Fig. 9) from Hides 3. Both of these species were previously known only from a single locality on nearby Mt Sisa, and their collection at Hides 3 indicates a broader distribution for these species in the montane moss forests of the region. Both of these species were classified as 'Data Deficient' in the recent IUCN-sponsored Global Amphibian Assessment. Other frogs from the project area classified as Data Deficient are *Cophixalus cryptotympanum*, and two species tentatively identified as *Oreophryne notata* from Mt. Sisa and Hides 3 and *Litoria majikthise* from the Darai Plateau. *Oreophryne notata*(?) (Fig. 10) was abundant at Hides 3 during this survey. No frog species documented from the area are classified as threatened or endangered.

Four reptile species known from the project area, the Estuarine Crocodile *Crocodylus porosus*, the large Goanna *Varanus salvadorii*, the Pig-nosed Turtle *Carettochelys insculpta* and the Boelen's Python *Morelia boeleni* are considered of conservation significance, due to their large size and use as food by the local communities. Several other species known or expected to occur within the Kikori River basin are probably significant food items for local communities; the goanna *Varanus indicus*, the large freshwater turtle *Pelochelys bibroni*, and the crocodile *C. novaeguineae*. Several other freshwater turtles, including *Chelodina novaeguineae*, *C. siebenrocki*, *Elseya cf novaeguineae* and *Emydura subglobosa* may occur in this region of the basin, and are probably also a food source for local communities. The only species likely to be of conservation significance in the montane areas around Hides 3 is Boelen's Python (*Morelia boeleni*) which has a distribution restricted to montane New Guinea. This species is protected under Papua New Guinea legislation. Although we did not encounter this species, locals reported that it does occur in the Hides 3 area and if so it is likely to be a food item for local communities.

Table 5. Conservation status of described frog species documented in PNG Gas Project area 1999-2005 according to IUCN/CI Global Amphibian Assessment 2004. Designations adopted by IUCN. DD = Data Deficient, LC = Least Concern

Species	Status	Species	Status
Microhylidae			
<i>Albericus tuberculatus</i>	LC	<i>Litoria darlingtoni</i>	LC
<i>Asterophrys turpicola</i>	LC	<i>Litoria eucnemis</i>	LC
<i>Austrochaperina derongo</i>	LC	<i>Litoria graminea</i>	LC
<i>Austrochaperina guttata</i>	LC	<i>Litoria havina</i>	LC
<i>Austrochaperina palmipes</i>	LC	<i>Litoria infrafronata</i>	LC
<i>Callulops doriae</i>	LC	<i>Litoria iris</i>	LC
<i>Callulops slateri</i>	LC	<i>Litoria majikthise?</i>	DD
<i>Callulops wilhelmanus</i>	LC	<i>Litoria micromembrana</i>	LC
<i>Choerophryne allisoni</i>	DD	<i>Litoria modica</i>	LC
<i>Cophixalus cryptotympanum</i>	DD	<i>Litoria pronimia</i>	LC
<i>Cophixalus shellyi?</i>	LC	<i>Litoria prora</i>	LC
<i>Hylophorbus richardsi</i>	DD	<i>Litoria thesaurensis</i>	LC
<i>Hylophorbus rufescens</i>	LC	<i>Litoria wollastoni</i>	LC

Table 5. Conservation status of described frog species documented in PNG Gas Project area 1999-2005 according to IUCN/CI Global Amphibian Assessment 2004. Designations adopted by IUCN. DD = Data Deficient, LC = Least Concern

Species	Status	Species	Status
<i>Liophryne schlaginhaufeni</i>	LC	<i>Nyctimystes pulcher</i>	LC
<i>Mantophryne lateralis</i>	LC	Myobatrachidae	
<i>Oreophryne notata?</i>	DD	<i>Lechriodus aganoposis</i>	LC
<i>Sphenophryne cornuta</i>	LC	<i>Lechriodus melanopyga</i>	LC
<i>Xenorhina parkerorum</i>	LC	Ranidae	
Hylidae		<i>Rana arfaki</i>	LC
<i>Litoria amboinensis</i>	LC	<i>Rana daemeli</i>	LC
<i>Litoria angiana</i>	LC	<i>Rana novaeguineae</i>	LC
<i>Litoria auae</i>	-		

5.3 Significant Habitats

The results of this survey and previous studies at lower altitudes in the project area have identified a number of habitats that are significant for the maintenance of herpetofaunal diversity in the project area.

5.3.1 Montane forests – Hides 3-Mt Sisa

The montane forests of the Hides-3 and -2 and Mt Sisa uplands (Figs 11 and 12) are an important habitat for a number of microhylid species with restricted known distributions. This habitat contains three of the five species known from the project area that are listed by IUCN (Global Amphibian Assessment) as 'Data Deficient'. At least two species (and as many as five species – taxonomic studies are continuing) are known only from Mt Sisa and Hides 3. It is likely that these species occur throughout the montane moss forests between these sites, and so individually are unlikely to be of conservation concern. However, the concentration of a large number of species with limited known distributions in this habitat identifies the montane moss forests around Hides-3 as of great significance for ensuring maintenance of a distinct herpetofaunal assemblage.

5.3.2 Rocky mountain streams – Benaria and lagifu Ridge

Despite the degradation of forest habitats around Benaria, the Benaria River and its riparian zone were identified as a significant habitat during this survey (Figs 13 and 14). The river provides habitat for an assemblage of frogs that has been documented only at this site and at several rocky streams on lagifu Ridge. These include at least two undescribed *Litoria* known from Benaria and lagifu, and the frog *Litoria wollastoni* previously not recorded from the project area. The rocky streams at lagifu ridge also contain an undescribed *Nyctimystes* (tree-frog) not known from elsewhere in the project area or PNG.

Many of these species are likely to occur in other streams of similar morphology in the project area. Inasmuch as the mountain streams at mid-montane elevations in the project area are a significant habitat for a unique assemblage of frogs they are identified as a significant habitat requiring careful management during construction activities.

5.3.3 Riparian habitats in lowland forests

The riparian forests along lowland rivers in the project area, particularly the river banks, provide nesting sites for a variety of aquatic reptiles (see 'Significant species' above). Many of these species, particularly the Estuarine Crocodile and Pig-nosed turtle, are utilized intensively by local communities who harvest adult reptiles and eggs from nests.

5.3.4 Extremely wet forests of the Darai Plateau

The extremely wet forests of the Darai Plateau to the west of the proposed pipeline revealed an extremely diverse frog fauna (Richards & Allison 2003), several species of which have not been found at other sites in the general area. This area is in karst with limited flowing water. It is outside the proposed pipeline corridor and unlikely to be impacted.

5.4 Potential impacts and impact mitigation

An assessment of options, by which to mitigate potential impacts on herpetofauna is warranted, with a view to incorporating those that are prudent and feasible in environmental management plans and requirements of contractors and workforces where appropriate.

The following impacts and priorities for planning, design and management have been identified for consideration.

5.4.1 River crossings

The method used for spanning streams and rivers has yet to be determined. Unless the pipeline is placed beneath rivers then both roads and the pipeline construction across water-bodies will involve localised damage to riparian vegetation at river crossings in both lowland and montane habitats. This assessment identified rocky mountain streams and lowland riparian forests as significant habitats for herpetofauna species. Localised impacts at these crossings will involve removal of and damage to existing vegetation, and disturbance and movement of soil adjacent to and within waterways during construction. More widespread impacts will occur due to siltation of the stream-beds downstream of the crossings. This impact is likely to be a minor issue in the high-silt rivers of the Kikori delta, but may significantly impact populations of torrent-dwelling frogs in clear mountain streams such as the Benaria River.

The direct effects on herpetofauna of this soil loss will be siltation of interstitial spaces among rocks in mountain streams, potentially reducing habitat available for torrent-dwelling hylid (*Litoria*, *Nyctimystes*) tadpoles that occupy these benthic habitats; and removal of perch sites for adult frogs, at the same time increasing insolation and drying the riparian vegetation.

To mitigate these impacts, crossings should be designed and constructed to limit the width of disturbed area as far as feasible and with corresponding priority to retaining established vegetation. Bank stabilisation, preferably through replacement of riparian seedlings, will contribute to limiting impacts at crossings. Mountain streams in New Guinea are characterised by rapid and violent fluctuations in volume. Once banks are stabilised, siltation impacts will be limited and temporary because excess silt is removed rapidly during spates.

At lowland sites the major impacts will be localised damage to river-banks where turtles and crocodiles nest. Given the restricted width of the river crossings, this impact will be minor. Of substantially greater concern is the increased access for employees and locals to populations of aquatic reptiles.

If undertaken with due care for retaining maximum riparian vegetation, and encouraging river/stream bank stabilisation, river crossings should be a relatively minor impact on the herpetofauna irrespective of the method employed. **However methods to control hunting of local herpetofauna should be investigated, with due and effective account of the cultural and social constraints, especially customary land ownership and of any other mitigation possibilities.**

5.5 Forest gaps: ROW, flow lines, and permanent roads

The major direct impact of this project will be forest removal, whether for flow lines, roads, or for temporary or permanent infrastructure. Vegetation removal exposes the forest floor and nearby vegetation to increased exposure to sunlight and evaporation. This is particularly significant for the diverse assemblage of microhylid frogs in the project area that rely on moist conditions for survival and reproduction, because they lay terrestrial or arboreal eggs requiring constantly moist conditions.

5.5.1 *Narrow corridors*

Examination of existing ROWs, flow lines at Hides 2, and extensive work along permanent roads and the pipeline between the coastal lowlands and montane moss forests in the project area since 1999 have indicated a remarkable ability for diverse frog and reptile assemblages to persist immediately adjacent to narrow open 'corridors'. This persistence is certainly related to minimal vegetation removal that in turn promotes maximum vegetation heterogeneity and humidity only metres inside the forest edge. During this survey the flow line at Hides 2 was observed to provide an artificial 'gap' for basking skinks, while harbouring many microhylid frogs within 5 m of the corridor's edge.

Limiting width of flow-lines and other forest corridors (preferably < 25 m) will limit direct impacts on even the most sensitive of microhylid frogs by reducing moisture loss and will result in no threat to populations of any known herpetofauna species (see 'river crossings' above for discussion of impacts at riparian habitats). However, this minimal impact will rely on:

- Methods to control hunting by the workforce should be investigated, with due and effective account of the cultural and social constraints, especially customary land ownership and of any other mitigation possibilities to prevent over-harvesting of these species.
- a) Allowing forest regeneration to occur to as large an extent as practical towards the pipeline.
- b) Methods to control subsequent vegetation removal along new and existing roads in the project area and as much as possible stabilising edges of corridors should be investigated with due and effective account of the cultural and social constraints, especially customary land ownership and of any other mitigation possibilities.

Methods to control hunting of herpetofauna (pythons, turtles, crocodiles) along roads by the workforce should be investigated, with due and effective account of the cultural and social constraints, especially customary land ownership and of any other mitigation possibilities.

5.5.2 Permanent and temporary infrastructure

Temporary infrastructure will be rapidly recolonised by at least some herpetofauna species if infrastructure is removed and natural recolonisation is allowed to proceed from the surrounding forest. However, permanent infrastructure and associated permanent clearings in the project area generally provide an unsuitable habitat for most forest-dwelling herpetofauna. Exceptions are several species of *Emoia* and *Carlia* and at higher altitudes *Papuascincus* sp. that naturally occur in gaps and proliferate in the sunny drier conditions provided by permanent clearings.

Impacts of these permanent 'clearings' are severe but localised, and with careful controls on forest disturbance maximum diversity of herpetofauna species can be retained immediately adjacent to the infrastructure. The excellent forest retained at close proximity to Moro Camp is an example of how limiting forest disturbance adjacent to a major camp can retain a very large proportion of the fauna occurring in the area. Furthermore, the large bare clearing at Hides 3 contained no frog species, but the forest within 5 m of the camp contained a high diversity of frogs including rare and restricted-range species.

5.6 Chemical leaks

A potential threat to the herpetofauna along the pipeline, and at any site with storage of toxic chemicals, is a chemical spill. Chemical spillages may have particularly severe impacts on aquatic frogs, and these impacts may extend substantially downstream if they enter streams or rivers. Amphibians are particularly susceptible to chemical pollution due to their moist and porous skin and their aquatic larvae (except microhylids). Impacts on aquatic reptiles are less well understood but likely to be severe.

The operators of the PNG Gas project have stringent chemical handling protocols to avoid the possibility of chemical spills, but additional **precautions should be evaluated (if not already standard practice) to minimise the possible impacts of spillage, including:**

- **generally storing all chemicals securely a sufficient distance AWAY from rivers and streams so that in the event of spillage chemicals cannot enter waterways;**
- **where chemicals must be transported over water or near water-courses, all receptacles should be securely sealed to prevent spillage in the event of an accident.**

6 Final conclusions and recommendations

The herpetofauna of the PNG Gas project area is exceptionally diverse. This diversity has persisted alongside the major oilfields and infrastructure of the existing oil and gas project. Careful management of the project area, particularly through strict controls on forest degradation along roads and the existing ROW, have contributed to this. It is clear that impacts will occur as a result of additional pipeline construction, both in the Hides-Kutubu section and in the lower reaches of the Kikori catchment. Many of these impacts will be localised and temporary if controls on access to the area by locals and outsiders are enforced.

The major impacts of this project on herpetofaunal diversity and biodiversity overall will be the secondary impacts resulting from improved access along permanent public roads to currently remote areas (Figure 15). Although short-term direct impacts will be minor (see above) permanent public roads will lead to increased habitat destruction along and adjacent to roads as local populations move into previously inaccessible areas. This may not occur until the project ceases, if controls on population movements are enforced, but in the long term the improved access will be a particularly significant issue for habitats including lowland swamps and riparian forests, and particularly the significant moss forests in the vicinity of the current and proposed Hides Gas wells. In these high-altitude and biologically significant montane moss-forest habitats, the feasibility of options to construct facilities other than by roads should be investigated, for example by helicopter. In addition, options for restricting access during operations should also be evaluated, for example by controls on public access.

7 References

- Allison, A. 1993. Biodiversity and conservation of the fishes, amphibians and reptiles of Papua New Guinea. In: B. Beehler ed. Papua New Guinea Conservation Needs Assessment. Government of Papua New Guinea.
- Allison, A., Bickford, D., Richards, S.J. and Torr, G. 1998. Herpetofauna in A Biological assessment of the Lakekamu Basin, Papua New Guinea. Rapid Assessment Program Working Paper Number 9. Washington, Conservation International.
- O'Shea, M. 1996. A guide to the snakes of Papua New Guinea. Independent Publishing, Port Moresby
- Richards, S.J. 2000. Herpetofauna and Odonata of Dark End Lumber (Gulf Province) and Mt Sisa (Southern Highlands Province), Papua New Guinea. Unpublished report to World Wide Fund for Nature (USA).
- Richards, S.J. 2002a. Frogs and reptiles of Moro, Gobe and Kopi (Southern Highlands and Gulf Provinces), Papua New Guinea: Results of a dry-season survey 19 October – 1 November 2001. Unpublished report to WWF-PNG.
- Richards, S.J. 2002b. updated list of Frogs from Moro, Gobe and Kopi (Southern Highlands and Gulf Provinces), Papua New Guinea: Preliminary results of a wet-season survey 14 – 30 May 2002. Unpublished report to WWF-PNG
- Richards, S.J. 2002c. Rokrok: A field guide to frogs of the Kikori ICDP. Report to WWF-PNG.
- Richards, S.J. and Allison, A. 2003. Frogs and reptiles of Darai Plateau and Libano (Southern Highlands and Gulf Provinces), Papua New Guinea: Results of a biodiversity survey 22 July 12 August 2003. Unpublished report to WWF-PNG
- Richards, S.J. and Burton, T.C. (2003) A new species of *Choerophryne* (Anura: Microhylidae) from Southern Highlands Province, Papua New Guinea. *Trans. R. Soc. S. Aust.* 127: 47-51.



Figure 1 Montane moss forest at Hides3.



Figure 2 Nogoli sample site.



Figure 3 Benaria Camp.



Figure 4 Benaria River.



Figure 5 *Litoria iris* in amplexus near Hides 3.



Figure 6 The skink *Sphenomorphus* at Hides 3.



Figure 7 *Rana sp. Aff. grisea* near the Benaria River.



Figure 8 The microhylid *Choerophryne allisoni* at Hides3.



Figure 9 *Hylophorbus richardsi*.



Figure 10 *Oreophryne notata* (?).



Figure 11 Montane forest near Hides 2.



Figure 12 Open water in the Hides uplands is limited to small pools in sinkholes.

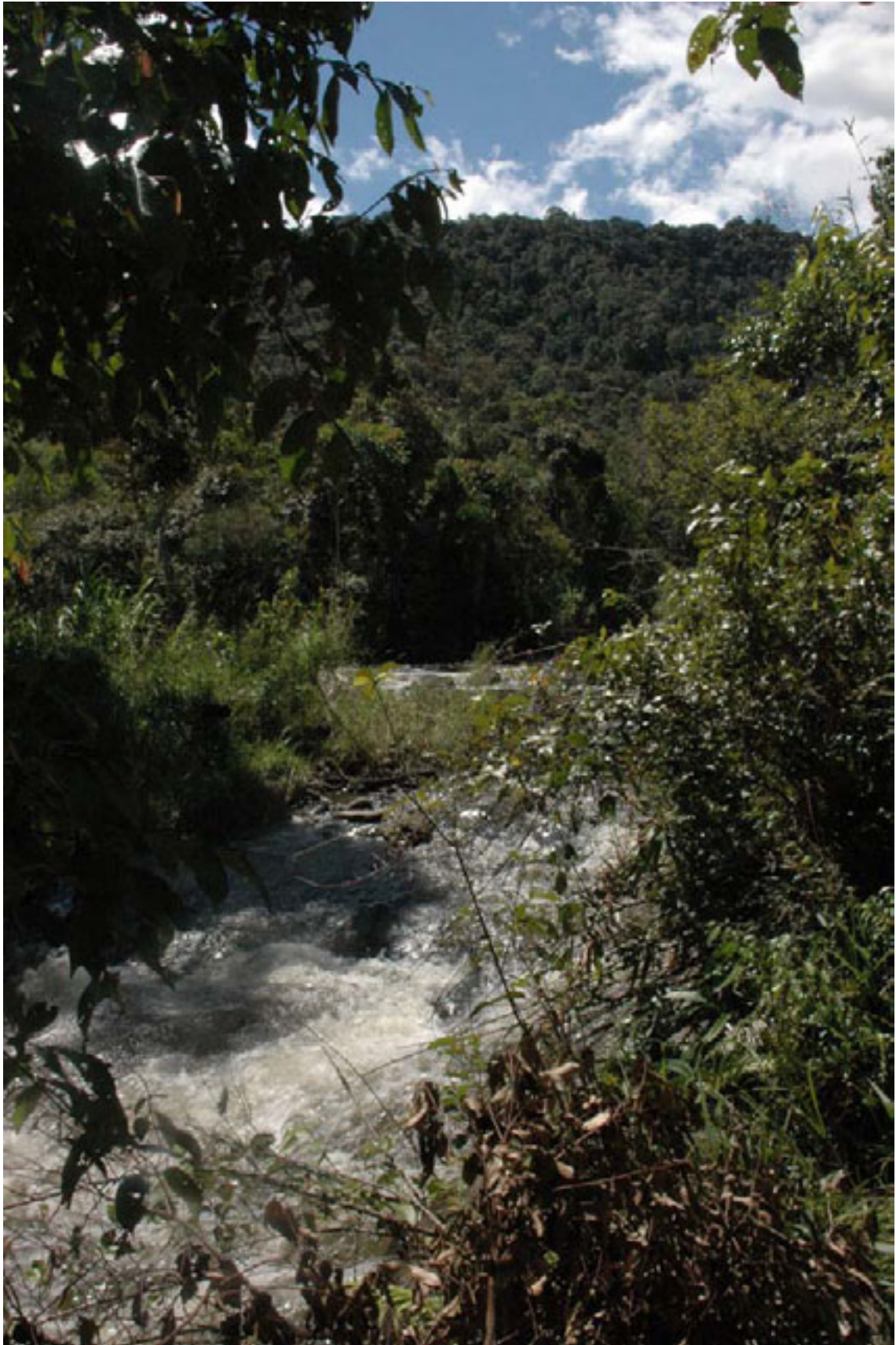


Figure 13 The fast flowing Benaria River - home to torrent frogs.



Figure 14 Riparian forest along Benaria River.



Figure 15 Forest clearing for gardens.

Annex 10

Biodiversity survey results:

**Herpetofauna at Juha North, Juha South, Baia River, South Karius and
Deviation Camp in 2008**

**BIODIVERSITY AND CONSERVATION STATUS OF HERPETOFAUNA OF
THE NORTHERN UPSTREAM PORTION OF THE PAPUA NEW GUINEA
LIQUEFIED NATURAL GAS PROJECT**

prepared by

Stephen Richards

Honorary Curator

South Australian Museum

A report prepared for Coffey Natural Systems and Exxon-Mobil

May 30th 2008

A new species of microhylid frog *Xenobatrachus* sp. discovered during this assessment



CONTENTS

1	EXECUTIVE SUMMARY	3
2	INTRODUCTION & OBJECTIVES	6
3	METHODS	8
3.1	Sites	8
3.2	Herpetofauna sampling	12
4	RESULTS & DISCUSSION	14
4.1	Species diversity	14
4.1.1	Frogs	14
4.1.2	Reptiles	14
4.2	Species of conservation significance	20
4.3	Important Habitats	21
4.3.1	Off-river waterbodies – Baia River	21
4.3.2	Rocky mountain streams – South Karius, Deviation Camp and Juha North	24
4.3.3	Wet forests of the Juha South area	24
5	POTENTIAL IMPACTS AND RECOMMENDED IMPACT MITIGATION MEASURES	26
5.1	River crossings	26
5.2	Forest gaps: ROW, flow lines, and permanent roads	26
5.3	Contamination	28
5.4	Hunting	28
6	FINAL CONCLUSIONS AND RECOMMENDATIONS	30
7	REFERENCES	31

Tables

Table 1	Survey areas and schedule for the 2008 PNG LNG Project herpetofauna survey.
Table 2	Frogs documented at survey areas during February-April 2008
Table 3	Reptiles documented at survey areas during February-April 2008
Table 4	Conservation status of described frog species documented in PNG LNG Upstream Project area 1999–2008 (IUCN/CI Global Amphibian Assessment 2007).

Figures

Figure 1.1. Juha North research building at night

Figure 4.1. Green Tree Python, *Morelia viridis*, a common snake throughout the project area

Figure 4.2. An undescribed species of *Choerophryne* from Juha South

Figure 4.3. A juvenile New Guinea Crocodile, *Crocodylus novaeguineae*, in an off-river water body at Baia River survey area.

Figure 4.4. Maruba River at Deviation Camp. Clear mountain streams provide habitat for a specialised assemblage of treefrogs

Figure 4.5. *Litoria arfakiana* at South Karius. This species breeds only in clear mountain streams

Appendix 1 Combined herpetofauna of the PNG Gas Project area 1999–2008

1 Executive Summary

- A total of 70 frog and 32 reptile species were documented at five sites along the proposed the Juha-Hides Pipeline ROW and the LNG Project Gas Pipeline in Southern Highlands and Western Provinces, Papua New Guinea (PNG). These results bring the total number of frog and reptile species documented from the broader PNG LNG Project area to 167 (107 frogs, 61 reptiles).
- Frog diversity along the proposed pipeline alignment between Hides and Juha is exceptionally high, representing the equivalent of nearly 20% of the frog fauna described from the island of New Guinea. This reflects the extremely wet climate, broad elevational range and topographic variability of the project area. In contrast the wet conditions, particularly at higher elevations, are not optimal for reptiles and diversity of this group was moderately low.
- Juha South had the largest number of frog species reported to date for any single site on the island of New Guinea (at least 36 species within a radius of 500 m of camp). The drill pad and clearings at Juha South appear to have had negligible impact on the local herpetofauna, with high densities of many species persisting within the clearing and at least three new frog species discovered near the camp.
- The herpetofauna at South Karius was typical of similar elevations in the southern highlands of PNG. Local informants reported that the Boelen's Python (*Morelia boeleni*) occurs in the area. This rare snake is widespread at high elevations across New Guinea's central cordillera and is protected in PNG. A moderately diverse assemblage of stream-dwelling frogs occurs in the headwaters of the Baia River. One of these is an undescribed species previously known only from the foothills of the Star Mountains near the Papua (Indonesia) border. This species was found only along heavily vegetated clear, rocky sections of the Baia River along Trail A.
- The herpetofauna at Baia River was surprisingly depauperate, but the species encountered were typical of lowland forests in southern New Guinea. A small permanent water-body adjacent to the Baia River contained at least three juvenile Freshwater Crocodiles (*Crocodylus novaeguineae*), and a crocodile nest on the banks of this pool was excavated by locals during camp construction. Given the rapid flow and unstable banks of the Baia River, off-river water-bodies probably represent important nursery habitats for crocodiles in this area.
- Juha North had a more diverse fauna than Baia River. The lizard assemblage in particular was more speciose and abundant. The reason for this disparity remains unclear, but the herpetofauna at Juha North was typical of the diversity and abundance encountered at most sites in southern PNG. A single specimen of the poorly-known skink *Lipinia nototaenia* collected at Juha North represents only the fifth record of this poorly known species and only the second record for PNG.
- Deviation Camp had few reptiles, a reflection of the very cold and wet conditions at this site. The herpetofauna was similar to that at Hides 3 (Richards 2005 = Annex 09 to Biodiversity Appendix), except that a flowing

stream provided habitat for an assemblage of at least four torrent-dwelling frogs. One of these is a new species known only from this site.

- The Freshwater Crocodile, *Crocodylus novaeguineae*, is harvested in the project area by local communities, and juveniles of this species occurred in nursery pools adjacent to the Baia River. A large monitor lizard, *Varanus indicus*, was observed at Baia River and locals keenly hunted this species. Other large reptiles that are very likely to occur along the RoW but were not documented during these surveys include the giant goanna *Varanus salvadori*, and the Boelen's Python *Morelia boeleni*.
- Potential impacts on species of conservation significance include localised damage to and over- harvesting of nesting sites of *Crocodylus novaeguineae* at off-river waterbodies along the Baia River and increased hunting pressure on this species and on *Varanus indicus*, *V. salvadori* and *Morelia boeleni*. Strict control of hunting by the workforce will need to be enforced to prevent over-harvesting of these species.
- Important habitats include 1) off-river water bodies adjacent to the Baia River that are nesting and nursery sites for Freshwater Crocodiles; 2) clear mountain streams including the headwaters of the Baia River, and the Maruba River at Deviation Camp, each of which harbours a diverse assemblage of torrent-dwelling frogs; and 3) the forests on the ridge at Juha South which harbour the most diverse assemblage of frogs known from any site in PNG.
- Given the restricted width of the proposed pipeline ROWs, direct impacts of the project will be minimal. However if permanent roads are established this may lead to serious secondary impacts through forest clearing resulting from improved access for local people, both in the short- and long-term.
- Infrastructure/clearings can co-exist with high herpetofaunal diversity if broader impacts of human populations are controlled. For example forests around the disturbed Juha South site are of high significance for the conservation of a diverse and poorly known frog assemblage. Minimising damage to riparian vegetation will be a high priority to maintain the integrity of stream-dwelling frog populations during project construction, and control of human access to currently remote areas will prevent longer-term impacts on frogs and reptiles in the project area.

Figure 1.1. Juha North research building at night



2 Introduction & Objectives

The Papua New Guinea (PNG) Liquefied Natural Gas () Project aims to commercialise reserves from multiple gas fields present in the Southern Highlands and Western Provinces of PNG. Project infrastructure will largely follow the same route between the Kutubu Central Production/Processing Facility (CPF) and the Omati River that has been the subject of numerous biodiversity surveys conducted since 1995. However, the PNG LNG Project is planning to expand these operations to extract gas from the Juha gas fields west of Hides and from the Angore area east of Hides. The decision by Esso Highlands Limited, a subsidiary of Exxon Mobil Corporation to advance the PNG LNG Project has necessitated a biodiversity assessment of the proposed pipeline from the Juha Gas fields in Western Province to Hides and a section of the LNG Project Gas Pipeline near Homa (Figure 2.1).

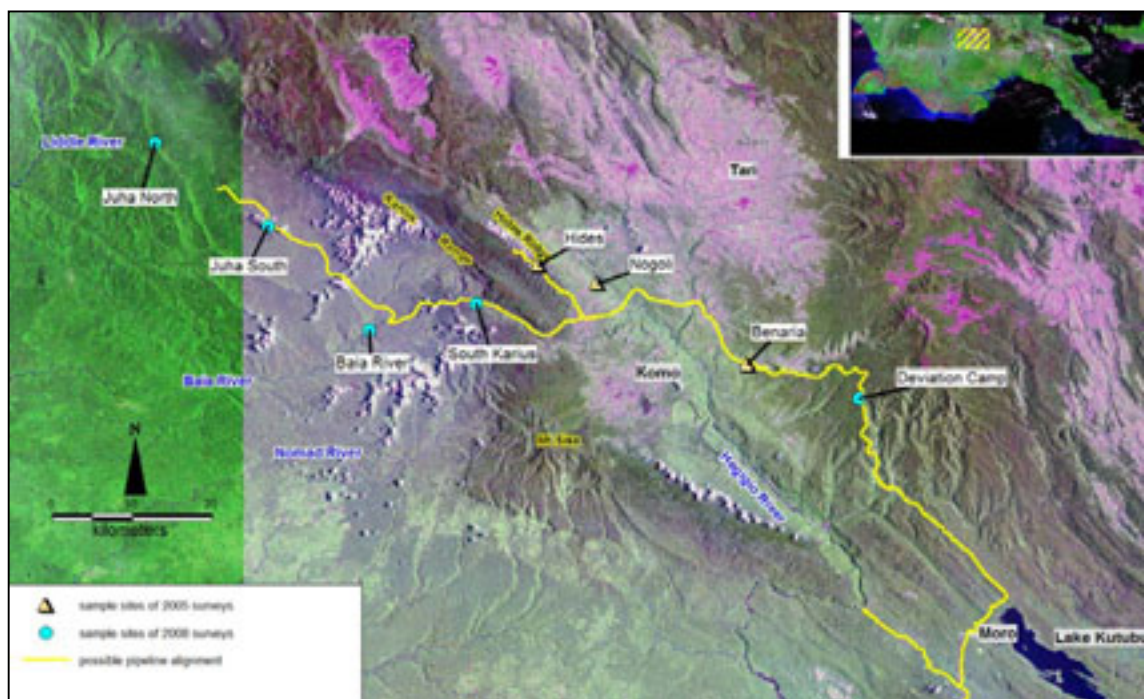


Figure 2.1 Map of all sites.

The herpetofauna of Papua New Guinea is exceptionally diverse, with the total species count expected to approach 700 (Allison 1993). Taxonomic revisions of the fauna and exploration of remote regions continues to reveal new species, particularly in the frog families Hylidae and Microhylidae. Since 1999 a series of surveys have documented the herpetofauna of the Kikori Integrated Conservation and Development Project Area in Southern Highlands and Gulf Provinces (Richards 2000; 2002a; 2002b; Richards & Allison 2003). These surveys focused most intensively on frogs and data accumulated up until 2002 were summarised by Richards (2002c). Prior to the Kikori ICDP surveys the most intensive and comprehensive survey of herpetofauna at a single site in New Guinea was undertaken in the Lakekamu Basin by Allison et al (1998). Seventy-four species, including 30 amphibians and 44 reptiles were reported, including 18 undescribed taxa. In contrast, Richards (2002c) reported 55 species of frogs from lowland and foothill forests of the Kikori ICDP including 29 undescribed taxa. Subsequently Richards & Allison (2003) added a number of undescribed frog species from the Darai Plateau and Libano and Richards (2005 = Annex 09 to Biodiversity

Appendix) provided significant new data on herpetofauna from Hides 3 and Benaria River.

This report presents an assessment of the overall herpetofaunal diversity of the PNG LNG Project, and more specifically addresses the potential impacts on herpetofauna of pipeline construction and development of major infrastructure associated with the proposed project.

The objectives of this survey were to 1) quantify the diversity of frogs & reptiles at five new sites – four along the proposed the Juha-Hides Pipeline ROW and one at the LNG Project Gas Pipeline east of Benaria, 2) summarise existing knowledge of herpetofauna in the broader project area, 3) identify any species of conservation significance, and 4) identify threats to significant species and recommend mitigation options for these threats.

3 Methods

3.1 Sites

Surveys were undertaken at four survey areas along the proposed Juha to Hides Pipeline in Southern Highlands Province and Western Province and a site along the proposed Homa deviation (Table 1).

Table 1 Survey areas and schedule for the 2008 PNG LNG Project herpetofauna survey.

Site	Latitude	Longitude	Elevation (m)	Dates
Juha North	5.8078	142.3083	213	26 th March – 2 nd April 2008
Juha South	5.90189	142.436	953	17 th – 22 nd Feb 2008
Baia River	6.0205	142.54735	328	11 th – 16 th Feb 2008
South Karius	5.99112	142.67063	1368	4 th – 10 th Feb 2008
Deviation Camp	6.096767	143.1045167	2060	3 rd – 8 th April 2008

Juha North Site (Figure 3.1) was on the Liddel River, a tributary of the Strickland River, in low hills on the edge of limestone terrain. There were waterfalls emanating from holes in the limestone close to the camp. The forest was “small crowned low altitude forest on uplands (Hm)” with evidence of disturbance and hunting. An anomalous feature of the vegetation was the presence of many plant groups normally found only in montane environments above 1,000 m elevation. Among the unusual elevational occurrences were many species in Ericaceae, Myrsinaceae, and Myrtaceae.

Juha South Site (Figure 3.2) is technically in the transition ecotone between traditionally defined lowland and montane zones but due to local conditions of very high rainfall this area is clearly a well-developed mossy montane forest. It would classify as transitional between “small crowned lower montane forest (L) and “very small crowned lower montane forest (Ls)”. As is generally the case for montane formations, the canopy is low (less than 20 m average height) with considerable epiphytic loads on trunks and upper branches. The forest understorey is generally rich in cryptogamic growth and in remarkably pristine condition due to the absence of wild pigs. The lack of pigs is probably attributable to low human population densities. The camp itself was located on an old well pad sunk by Gulf Oil in 1983/84 and was contaminated with waste left by the drillers. Forest regeneration at the site was well advanced, composed for the most part of *Eurya*, *Ficus*, *Macaranga*, *Timonius*, and urticates. Numerous sinkholes were present on the surrounding karst terrain.

Baia River Site (Figure 3.3) was located on the banks of the Baia River in an area dominated by landslides. The landscape was extremely unstable and this site was 2 to 3 km downstream from the originally designated site. This was because of the difficulty in locating a sufficiently stable stretch of stream bank that was considered safe enough to build a camp on. This section of the Baia River and the helicopter approaches to the river from Camp 4 (South Karius) appears to be highly unstable sedimentary formations with numerous and large landslides. The camp area is an exclusively lowland vegetation formation with a floristically distinct alluvial and flood zone along the streams (collectively including various communities in Po, Ps, Wsw), and “small crowned low altitude forest on uplands (Hm)” on higher slopes.

There were numerous talus slopes and active landslides with early pioneer and secondary vegetation. The principal genera represented at the site were *Ficus*, *Gymnostoma*, *Macaranga*, *Pimelodendron*, and *Pometia*.

South Karius Site (Figure 3.4) was located at the base of the Karius range in a complex of streams and swamps that form the headwaters of the Baia River. The camp was located on the edge of a flat area that had been converted to gardens within the last few years. It was surrounded by swamplands with pandanus emergents (Wsw) that merged into “very small crowned lower montane forest” (Ls) on the surrounding hills. The surrounding hills appeared to be karst while the camp was on the alluvial soils of the surrounding streams and swamps. The community structure of the natural-growth vegetation was similar to that at Camp 2 (Juha South), however due to the presence of human habitation near the camp there was a distinct component of weedy species, including some cosmopolitan plants not found at other locations. Anthropogenic influences are also reflected in the higher incidence of successional stands along the margins of the primary forest.

Deviation Camp (Figure 3.5) was located approx. 5.5 km southwest of Benaria village and close to a potential pipeline deviation. It was in mossy montane *Nothofagus* forest” next to a fast flowing tributary of the Maruba River. The overstory was composed almost exclusively of *Nothofagus pullei* emergents that are up to 40 m tall. Sub-canopy genera included primarily *Acronychia*, *Elaeocarpus*, *Sphenostemon*, and *Syzygium*. Understories were characterized by dense bryophyte and lycophyte growth, with particular dominance by *Cyathea microphylloides* and *C. perpelvigera*. Most of the floristic diversity was concentrated in the near-ground interval up to ca. 5 m height.

The camp bordered an area of forest burnt in the 1996-7 fires. These regenerating areas were dominated by dead stags and coppicing surviving trees, with saplings up to 15m high. There was extensive regeneration by light-demanding *Nothofagus* and other heliophytes such as *Macaranga*, *Omalanthus*, and *Cyathea* spp. (e.g., *C. contaminans*). The understorey included many shade tolerant species, suggesting that in this area the fires had been crown fires that had not burnt the mossy ground layer.

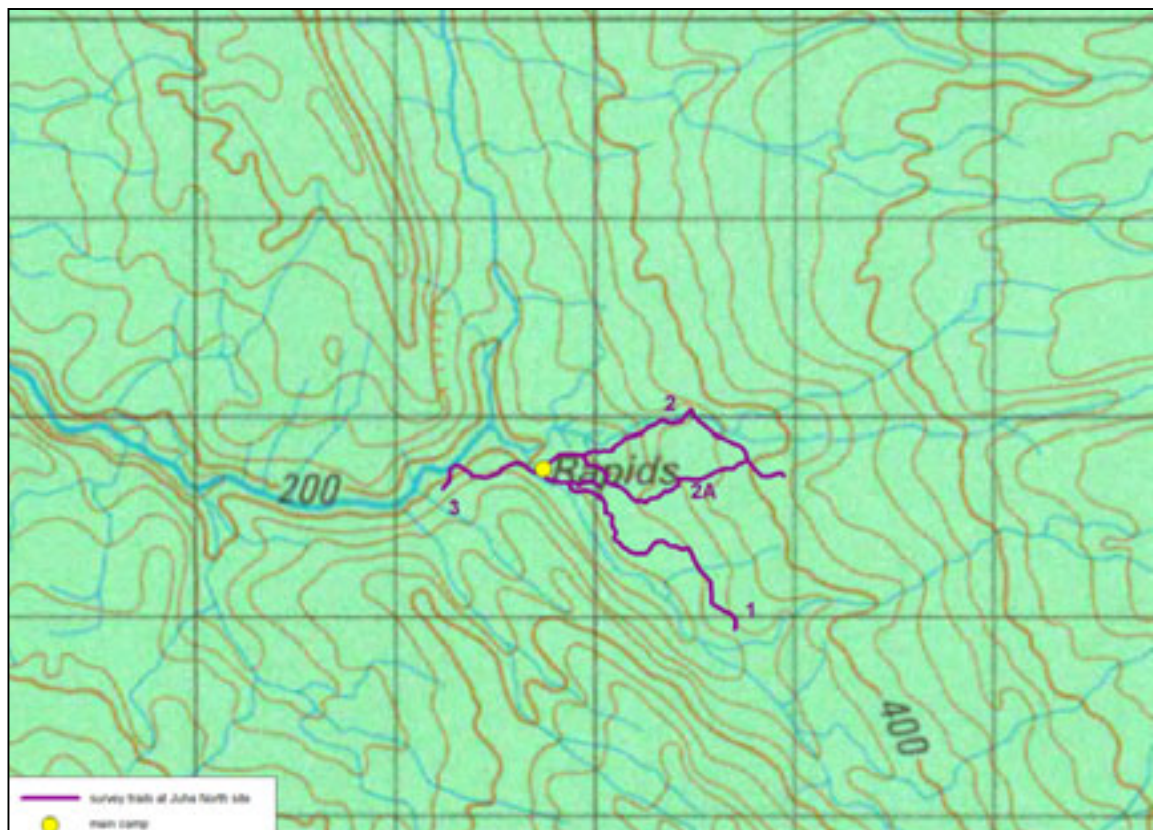


Figure 3.1 Sampling trails at Juha North survey area.

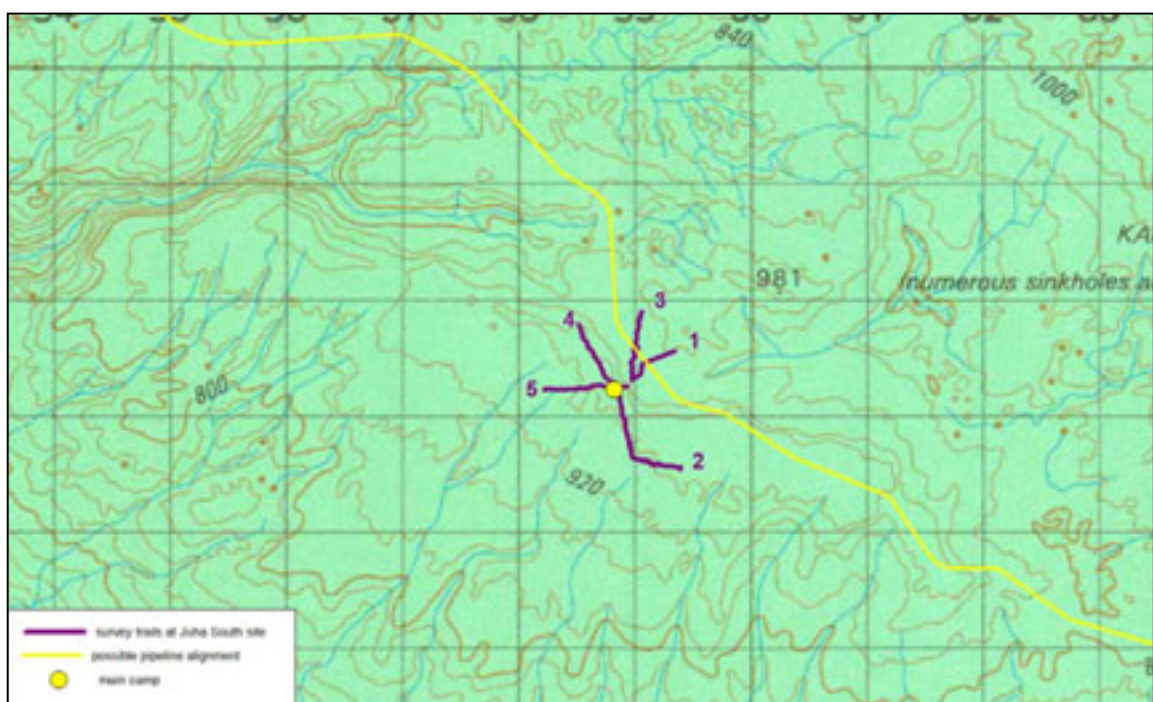


Figure 3.2 Sampling trails at Juha South survey area.

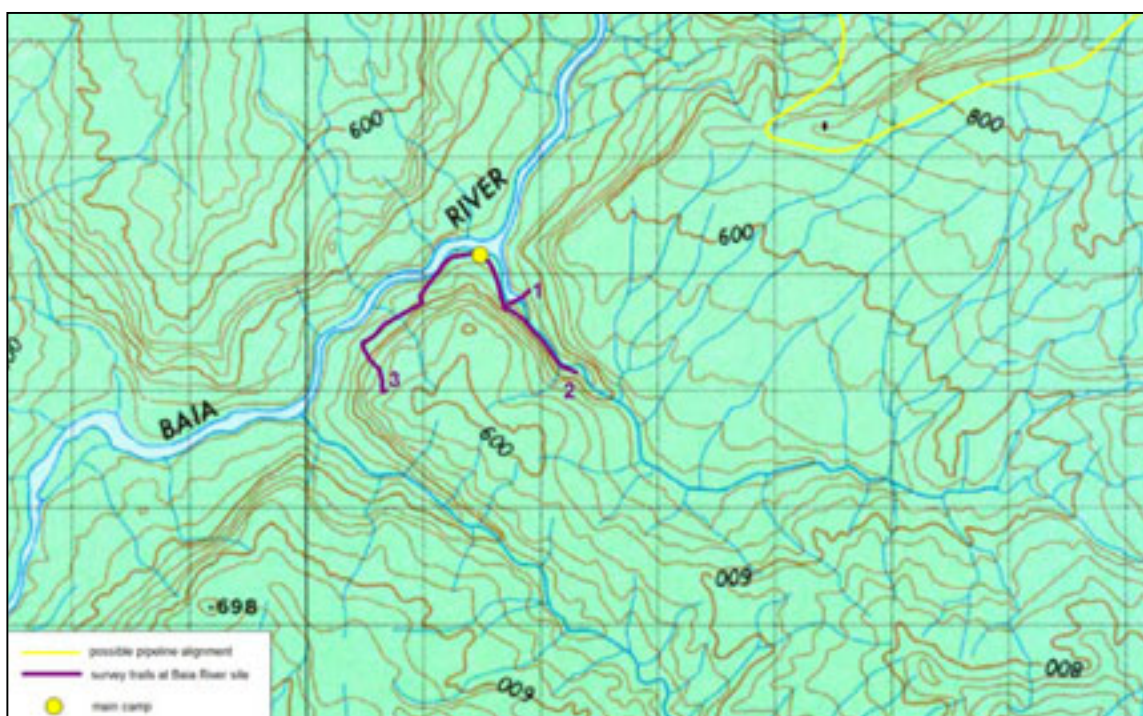


Figure 3.3 Sampling trails at Baia River survey area.

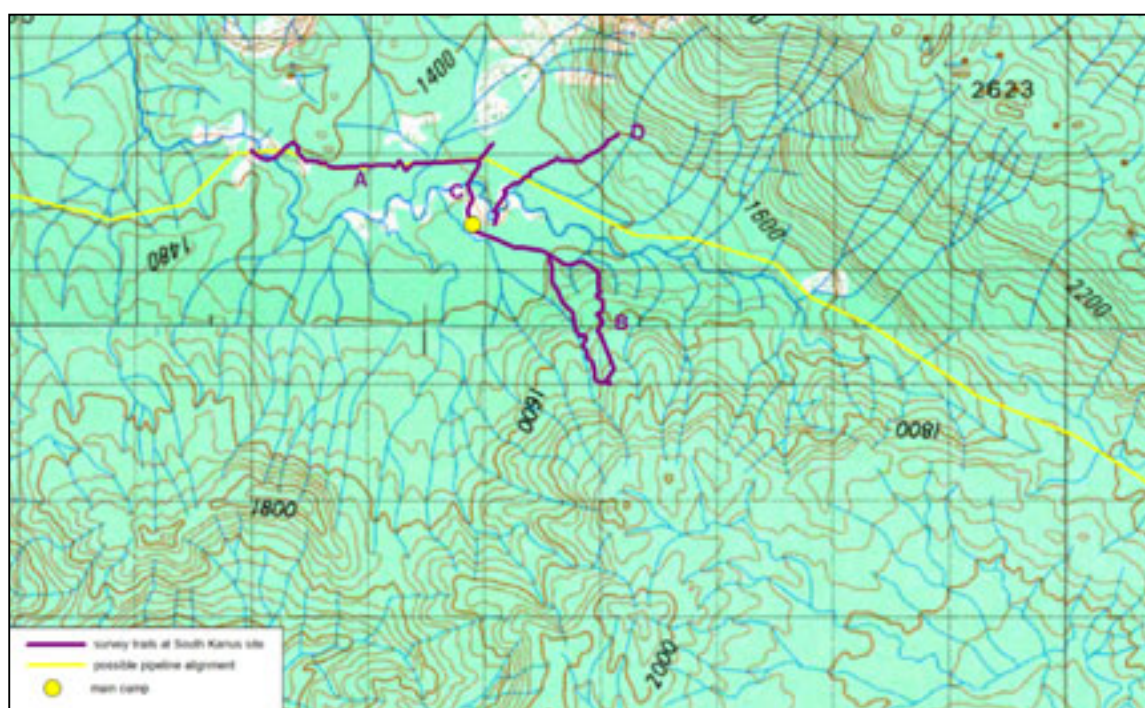


Figure 3.4 Sampling trails at South Karius survey area.

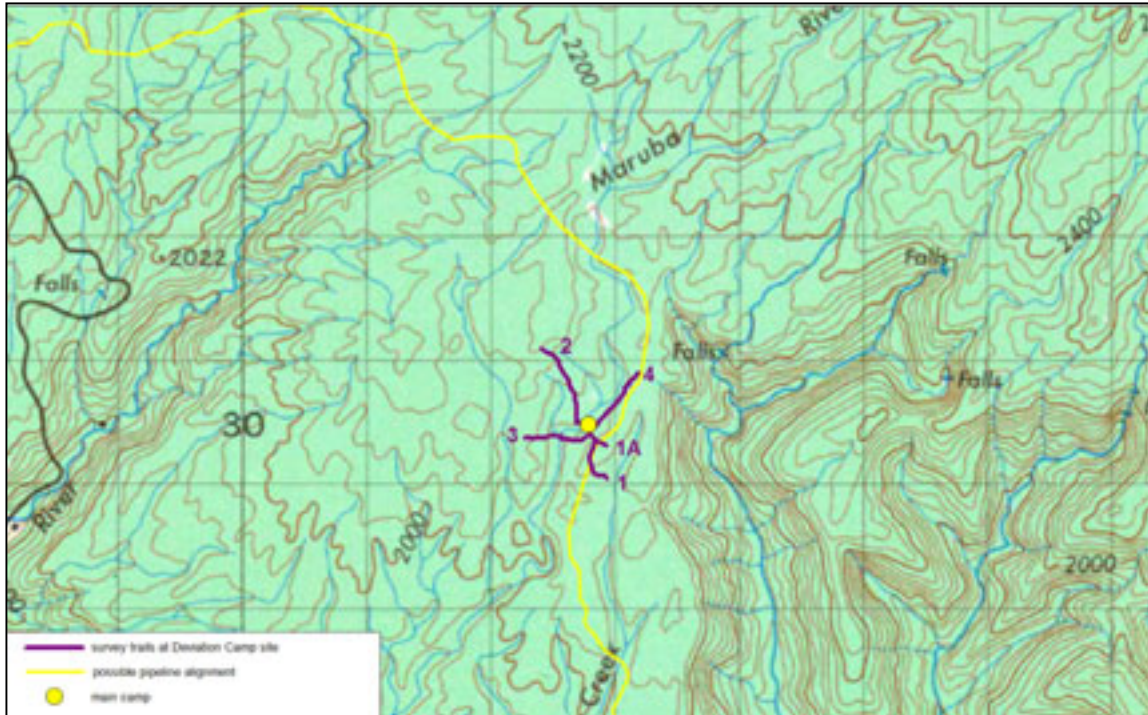


Figure 3.5 Sampling trails at Deviation Camp survey area.

3.2 Herpetofauna sampling

At each site intensive searches for frogs and reptiles were conducted along trails established for this purpose. Trail networks at each site are illustrated in Figures 3.1–3.5. Each day 2-3 hours were spent searching for heliothermic (basking) reptiles along trails through forest, clearings, and on stream banks. Small lizards were collected after being stunned with a large rubber band. Large lizards and snakes were collected by hand. Non-heliothermic reptiles were sampled by searching in deeply shaded forest, during rain, or at dusk. Diurnal frogs were sampled along streams, and tadpoles were sampled with a dip-net in all available water bodies.

Each night 4 hours were spent searching for frogs and nocturnal reptiles, including geckos, by walking along forest trails at night with a headlamp. Frogs were also detected at night using visual-encounter and aural surveys along streams, and in and around small ponds. Because a large proportion of New Guinean frogs have life cycles that are independent of free-standing water, extensive visual and aural searches were also conducted along trails in forest away from water.

Frog calls are an important diagnostic character that assists greatly with species identification. Whenever possible the advertisement calls of frogs were recorded with a Sony TCM-5000 Tape Recorder and Sennheiser ME66 microphone. Most species were photographed alive before preparation as voucher specimens. Specimens were euthanized by submersion in chlorotone (for amphibians and small reptiles), or with lethal injection of chlorotone for larger reptiles. Specimens were fixed in 10% formalin solution, and then stored in 70% ethanol. Samples of liver tissue for DNA analyses were extracted from representative specimens of each species and stored in 95% ethanol.

Voucher specimens will be deposited in the University of Papua New Guinea's Natural Sciences Resource Centre, Port Moresby, and the South Australian Museum, Australia.

4 Results & Discussion

4.1 Species diversity

A total of 70 frog and 32 reptile species were recorded from the five survey areas (Tables 2 & 3). This brings the total number of herpetofauna species known from the broader PNG LNG Upstream Project Area to 167 (107 frogs, 61 reptiles; Appendix 1).

4.1.1 FROGS

The highest frog diversity was encountered at Juha South where 36 species of frogs were identified and the calls of at least two other unidentified species were heard.

Although total species diversity at each site varied (maximum of 36 species at Juha South, minimum of 15 species at Deviation Camp) this variation was expected because in New Guinea herpetofaunal species richness declines at altitudes above around 1500 m and peaks (particularly for frogs) between around 500 and 1000 m. Interestingly, the relative contribution of the four native frog families to the fauna was remarkably consistent at each site. The family Microhylidae represented between 50% and 66% of the documented diversity at each site, while the treefrogs (Family Hylidae) accounted for between 25 and 33% of the frogs at each site. In comparison at Hides 3 (Richards 2005 = Annex 09 to Biodiversity Appendix) frogs in the family Microhylidae, which have a reproductive strategy that is independent of free-standing water, dominated the fauna and hylids were poorly represented (Table 2, Appendix 1). Microhylids have radiated extensively in the constantly moist montane habitats typical of Hides 3 where their terrestrial embryos do not face desiccation. The stronger representation of hylids at Deviation Camp, which is at a similar altitude to Hides 3 reflects the presence of a permanent stream at that site; this provided excellent habitat for an assemblage of stream-breeding frogs. Fast flowing streams were absent from Hides 3 (Richards 2005 = Annex 09 to Biodiversity Appendix) demonstrating how availability of specific habitats determines frog assemblage structure at any site in PNG. The remaining two families, Myobatrachidae and Ranidae, were poorly represented at all sites, with less than four species at each. These two families are poorly represented in New Guinea and this low number is typical of sites across the island.

4.1.2 REPTILES

The reptile fauna at Deviation Camp is depauperate and similar to that documented at Hides 3 and Mt Sisa (Richards 2005 = Annex 09 to Biodiversity Appendix), with all sites dominated by the widespread montane lizards *Papuascincus* sp. and *Lobulia elegans*. South Karius also had a depauperate but typical montane reptile fauna including the widespread snake *Tropidonophis* *statisticus*. One skink of the genus *Emoia* and one skink of the genus *Sphenomorphus* appear to be shared between South Karius and Hides 3 (Richards 2005 = Annex 09 to Biodiversity Appendix). Local informants at Deviation Camp reported that large pythons do not occur in that area, but at South Karius they described accurately the Boelen's Python (*Morelia boeleni*) and reported that they hunt and eat this species in the area. This montane snake (O'Shea 1996) clearly occurs in the South Karius area and may also occur around Deviation Camp

despite lack of confirmation by local informants. The extremely low reptile diversity at the two montane sites surveyed is not surprising given that few reptiles are known in New Guinea from such predominantly cold and wet habitats.

The herpetofauna at the two lowland sites, Juha North and Baia River, was dominated by species with broad distributions and was typical of frog and reptile assemblages across lowland southern New Guinea. Although several microhylid frogs encountered at these sites are undescribed, they are already known from widely scattered sites in the broader project area and clearly have wide distributions. The most unusual aspect of the herpetofauna at these two sites was the relatively low diversity and abundance of reptiles at Baia River. The herpetofauna at this site was largely a sub-set of the fauna at Juha North and of sites elsewhere in the Gulf Region (Appendix 1; Richards 2005 = Annex 09 to Biodiversity Appendix). A number of common, widespread species in the genus *Emoia* were absent or rare at this site, and the abundance of small lizards was remarkably low compared to equivalent sites studied elsewhere in the Kikori Basin. This low abundance and diversity may be related to the extremely dynamic landscape at Baia River. Disturbance of river banks or nearby riparian and alluvial habitats along the Baia River in this area is therefore unlikely to have a major impact on any component of the local herpetofauna.

Snake diversity was generally rather low, and most species encountered are common, widespread species. Notable species were the Green Tree Python (*Morelia viridis*; Figure 4.1) at Juha North and the record of a Brown Water Python (*Liasis fuscus*) collected by local labourers at Baia River. No dangerously venomous snakes were documented during these surveys, although Death Adders (*Acanthophis* sp) and Small-eyed Snakes (*Micropechis ikaheka*) certainly occur throughout the lower elevations of the Project area.



Figure 4.1. Green Tree Python, *Morelia viridis*, a common snake throughout the project area

Table 2 Frogs documented at survey areas during February-April 2008^{1,2}

Site		Juha North	Juha South	Baia River	South Karius	Deviation Camp
ALTITUDE		213	953	328	1368	2060
Family						
Microhylidae	<i>Albericus</i> sp. nov. 1 (rattler)				+	+
Microhylidae	<i>Albericus</i> sp. nov. 2 (short peeper)				+	
Microhylidae	<i>Albericus</i> sp. nov. 3 (rasper)	+	+			
Microhylidae	<i>Albericus</i> sp. nov. 4 (large)					+
Microhylidae	<i>Albericus</i> sp. nov. 5 (medium)					+
Microhylidae	<i>Albericus</i> sp. nov. 6 (clicker)			+		
Microhylidae	<i>Asterophrys turpicola</i>	+		+		
Microhylidae	<i>Asterophrys</i> sp. nov.				+	
Microhylidae	<i>Austrochaperina derongo</i>	+	+	+	+	
Microhylidae	<i>Austrochaperina rivularis</i>		+			
Microhylidae	<i>Austrochaperina</i> sp. nov. 1 (small)		+	+?	+	
Microhylidae	<i>Austrochaperina</i> sp. nov. 3 (medium)		+			
Microhylidae	<i>Callulops doriae</i>	+				
Microhylidae	<i>Callulops slateri</i>	+	+	+		
Microhylidae	<i>Callulops</i> sp. nov. 1 (<i>C. robusta</i> group)	+	+			
Microhylidae	<i>Choerophryne burtoni</i>	+?	+?		+?	
Microhylidae	<i>Cophixalus shellyi</i> ?				+	+
Microhylidae	<i>Cophixalus</i> sp. nov. 1 (eye-spikes)		+		+	
Microhylidae	<i>Cophixalus</i> sp. nov. 2 (buzz call)	+	+	+		
Microhylidae	<i>Cophixalus</i> sp. nov. 3 (cf <i>balbus</i>)			+		
Microhylidae	<i>Cophixalus</i> sp. nov. 5. (triple-calls)					+
Microhylidae	<i>Copiula</i> sp. nov. 3. (tiny)		+			
Microhylidae	<i>Copiula</i> sp. nov. 4. (large)	+	+?			
Microhylidae	<i>Hylophorbus richardsi</i>					+
Microhylidae	<i>Hylophorbus rufescens</i>	+?		+		
Microhylidae	<i>Hylophorbus</i> sp. nov. 1 (Moro broad head)		+?		+?	
Microhylidae	<i>Hylophorbus</i> sp. nov. 3 (slow call))		+?			
Microhylidae	<i>Mantophryne lateralis</i>	+	+	+		

Table 2 Frogs documented at survey areas during February-April 2008^{1,2}

Site		Juha North	Juha South	Baia River	South Karius	Deviation Camp
ALTITUDE		213	953	328	1368	2060
Microhylidae	<i>Oreophryne</i> sp. nov. 1 (small rattler)	+		+	+	
Microhylidae	<i>Oreophryne</i> sp. nov. 2 (loud rattler)	+	+		+	
Microhylidae	<i>Oreophryne</i> sp. nov. 3 (large peeper)		+?			
Microhylidae	<i>Oreophryne</i> sp. nov. 5. (small peeper)	+		+		
Microhylidae	<i>Oreophryne</i> sp. nov. 6. (tiny peeper)*					+
Microhylidae	<i>Oreophryne</i> sp. nov. 7. (medium)*?					+
Microhylidae	<i>Oreophryne</i> sp. nov. 8. (long rattle)				+	
Microhylidae	<i>Oreophryne</i> sp. nov. 9. (cf notata)*	+?	+			
Microhylidae	<i>Sphenophryne cornuta</i>	+	+	+		
Microhylidae	<i>Xenobatrachus</i> sp. nov. 2 (slow call)	+	+	+		
Microhylidae	<i>Xenobatrachus</i> sp. nov. 3 (fast call)*?		+	+	+	
Microhylidae	<i>Xenobatrachus</i> sp. nov. 4 (tiny)*		+			
Microhylidae	<i>Xenobatrachus</i> sp. nov. 5 (colourful)*		+			
Microhylidae	<i>Xenobatrachus</i> sp. nov. 6 (bi-coloured legs)*?		+			
Hylidae	<i>Litoria angiana</i>				+	+
Hylidae	<i>Litoria arfakiana</i>	+	+	+	+	
Hylidae	<i>Litoria auae</i>	+	+	+		
Hylidae	<i>Litoria darlingtoni</i>				+	
Hylidae	<i>Litoria eucnemis</i>		+			
Hylidae	<i>Litoria havina</i>		+	+		
Hylidae	<i>Litoria infrafronata</i>	+		+		
Hylidae	<i>Litoria iris</i>				+	+
Hylidae	<i>Litoria majikthise</i>	+	+			
Hylidae	<i>Litoria micromembrana</i>				+	
Hylidae	<i>Litoria modica</i>		+		+	+
Hylidae	<i>Litoria multiplica?</i>		+			
Hylidae	<i>Litoria spartacus</i>	+				
Hylidae	<i>Litoria thesaurensis</i>			+		
Hylidae	<i>Litoria</i> sp. nov. 1 cf <i>nigropunctata</i> 1 (bleating call)		+			
Hylidae	<i>Litoria</i> sp. nov. 5 (nr <i>genimaculata</i> 2)	+	+			

Table 2 Frogs documented at survey areas during February-April 2008^{1,2}

Site		Juha North	Juha South	Baia River	South Karius	Deviation Camp
ALTITUDE		213	953	328	1368	2060
Hylidae	<i>Litoria</i> sp. nov. 6 (Torrent chirper)				+	
Hylidae	<i>Litoria</i> sp. nov. 7 (small, green torrent)	+				
Hylidae	<i>Litoria</i> sp. nov. 8 (scarlet venter)			+		
Hylidae	<i>Litoria</i> sp. nov. 12 (Trilling torrent)*					+
Hylidae	<i>Litoria</i> sp. nov. 14 (cf Ok Menga)	+				
Hylidae	<i>Nyctimystes pulcher</i>	+		+		
Hylidae	<i>Nyctimystes</i> sp. nov. 1*				+	+
Myobatrachidae	<i>Lechriodus aganoposis</i>				+	+
Myobatrachidae	<i>Lechriodus melanopyga</i>		+			
Ranidae	<i>Rana arfaki</i>	+		+		
Ranidae	<i>Rana daemeli</i>	+	+	+	+	
Ranidae	<i>Rana cf grisea</i> 1	+	+	+	+	+
TOTAL		29	36	24	24	15

1 sp. nov. designates undescribed species currently without scientific names. For consistency numbers associated with these species correspond to those used in the 2005 Hides Herpetofauna Report (Richards 2005 = Annex 09 to Biodiversity Appendix) so numbers in this Table may not be consecutive.

2 Species marked with an * are new species discovered for the first time during this biodiversity survey. A ? indicates that further studies are required to determine the taxonomic status of the population in question.

Table 3 Reptiles documented at survey areas during February-April 2008

Site		Juha North	Juha South	Baia River	South Karius	Deviation
ALTITUDE		213	953	328	1368	2060
Family						
Crocodylidae	<i>Crocodylus novaeguineae</i>			+		
Agamidae	<i>Hypsilurus modestus</i>	+	+	+		
Agamidae	<i>Hypsilurus</i> sp. (semi-aquatic)	+		+		
Gekkonidae	<i>Cyrtodactylus capreoloides?</i>	+				
Gekkonidae	<i>Cyrtodactylus serratus</i>	+		+		
Gekkonidae	<i>Cyrtodactylus</i> sp. nov. 1 (cf <i>lousiadensis</i>)	+		+		
Gekkonidae	<i>Hemidactylus frenatus</i>	+				
Scincidae	<i>Emoia caeruleocauda</i>	+		+		
Scincidae	<i>Emoia kordoana</i>	+				
Scincidae	<i>Emoia longicauda</i>	+		+		
Scincidae	<i>Emoia pallidiceps?</i>	+?				
Scincidae	<i>Emoia</i> sp. 1				+	
Scincidae	<i>Emoia</i> sp 2 (<i>obscura?</i>)	+	+	+		
	<i>Lipinia nototaenia</i>	+				
Scincidae	<i>Lipinia</i> sp. 1		+			
Scincidae	<i>Lobulia elegans</i>					+
Scincidae	<i>Papuascincus</i> sp.					+
Scincidae	<i>Sphenomorphus meyeri</i>			+		
Scincidae	<i>Sphenomorphus schultzei</i>		+			
Scincidae	<i>Sphenomorphus simus</i>	+	+	+		
Scincidae	<i>Sphenomorphus</i> sp (<i>annectens</i> complex)					+
Scincidae	<i>Sphenomorphus</i> sp. nov. cf <i>jobiensis</i>	+	+			
Scincidae	<i>S.</i> sp. nov. cf. <i>papuae</i> (pale stripes)				+	
Scincidae	<i>S.</i> sp. nov. cf. <i>leptofasciatus</i> (dark stripes)				+	
Varanidae	<i>Varanus indicus</i>			+		
Elapidae	<i>Toxicocalamus loriae</i>	+				
Pythonidae	<i>Morelia viridis</i>	+				
Pythonidae	<i>Morelia boeleni</i>			h		
Pythonidae	<i>Liasis fuscus</i>			+		
Colubridae	<i>Boiga irregularis</i>	+				
Colubridae	<i>Dendrelaphis calligastra</i>		+	+		
Colubridae	<i>Tropidonophis statisticus</i>				+	
TOTALS		17	7	13	4	3

+ - record

h – local record from villagers or hunters

4.2 Species of conservation significance

One large turtle from lower elevations in the project area, *Carettochelys insculpta*, is listed as Vulnerable by the IUCN (2007). However it is unlikely to occur, at least in large numbers, in the shallow, fast-flowing water-bodies typical of the sites sampled during this survey. Another large turtle, *Pelochelys bibroni*, was not recognised as a valid species by the IUCN's 2007 Red List but was included in *P. cantorii*, a widespread species considered to be Endangered across its range. Four other large reptiles known from lower altitudes in the project area, the Freshwater Crocodile *Crocodylus novaeguineae*, the Goannas *Varanus indicus* and *V. salvadorii*, and the Brown Water Python *Liasis fuscus* are harvested for food by local communities. A Brown Water Python was captured and eaten by local labourers during construction of the Baia River camp. Several other pythons including the Amethystine Python *Morelia amethystina*, the Green Python *Morelia viridis* and the D'Albertis Python *Leiopython albertisii* are common in the area and eaten by local people. Additional species known or expected to occur in the Gulf Region of the broader project area that are harvested by local communities include the Estuarine Crocodile *Crocodylus porosus* and several small freshwater turtles (*Chelodina novaeguineae*, *C. rugosa*, *Elseya cf novaeguinea* and *Emydura subglobosa*).

The Boelen's Python (*Morelia boeleni*) which has a distribution restricted predominantly to montane New Guinea, occurs in the montane areas around South Karius and possibly at Deviation Camp. This species is protected under Papua New Guinea's Fauna (Protection & Control) Act of 1976. Conservation status of described frog species is listed in Table 4.

These surveys documented at least 40 frogs and 3–6 reptiles that are undescribed. However all of these undescribed species, except 8–10 of the frogs, had been documented previously from the Kikori Integrated Conservation and Development area or the foothills of the Star Mountains to the west. The discovery of new species at any site in Papua New Guinea is not unexpected (e.g. Richards 2002c). New species discovered for the first time during this project include two torrent-dwelling treefrogs: one species of *Litoria* known only from Deviation Camp, and one species of *Nyctimystes* known from South Karius and Deviation Camps.

One species of the microhylid genus *Xenobatrachus* from South Karius may also represent a new species. Most of the remaining new species were discovered at Juha South. These include 2–3 species of *Xenobatrachus* and a species of *Choerophryne* (Figure 4.2). These species are currently not known from any other localities. However it is important to recognise that ongoing studies of voucher material and associated recordings of vocalisations obtained during these surveys is likely to reveal a greater number of new species.



Figure 4.2. An undescribed species of *Choerophryne* from Juha South

4.3 Important Habitats

These surveys identified a number of habitats that are important for the maintenance of herpetofaunal diversity or species of conservation significance in the project area.

4.3.1 OFF-RIVER WATERBODIES – BAIA RIVER

A permanent pool adjacent to Baia River Camp was a nursery habitat for juvenile Freshwater Crocodiles (*Crocodylus novaeguineae*) (Figure 4.3) during our surveys. This species is one of only two crocodilians occurring in New Guinea. It is a widespread species, occurring both north and south of the central cordillera, and it is hunted widely by local communities. The highly unstable banks of the main channel of the Baia River provide a poor nesting environment for Freshwater Crocodiles. In contrast, permanent pools isolated from the river channel provide a nesting habitat that is less likely to be destroyed during the nesting season. During construction of the camp at Baia River local labourers excavated a crocodile nest on the banks of the permanent pool. They consumed the eggs but made no attempt to capture or kill the juveniles. Interviews with local informants indicated that they are aware that *C. novaeguineae* use off-river waterbodies for nesting in the Baia River area. Informants reported that they harvest the nests, and will kill adult crocodiles when they are encountered, but that they do not harm the juvenile crocodiles within these nursery habitats. These off-river breeding and nursery habitats therefore provide important habitats and refugia for breeding crocodiles, and their protection from disturbance should be a priority during any construction activities in the Baia River area.

Table 4 Conservation status of described frog species documented in PNG LNG Project area 1999–2008 (IUCN/CI/Nature-serve, Global Amphibian Assessment 2006). Designations adopted by IUCN. DD = Data Deficient, LC = Least Concern, N/A = Not yet assessed

Species	Status	Species	Status
Microhylidae			
<i>Albericus tuberculatus</i>	LC	<i>Litoria auae</i>	LC
<i>Asterophrys turpicola</i>	LC	<i>Litoria darlingtoni</i>	LC
<i>Austrochaperina derongo</i>	LC	<i>Litoria eucnemis</i>	LC
<i>Austrochaperina guttata</i>	LC	<i>Litoria havina</i>	LC
<i>Austrochaperina palmipes</i>	LC	<i>Litoria infrafronata</i>	LC
<i>Austrochaperina rivularis</i>	LC	<i>Litoria iris</i>	LC
<i>Callulops doriae</i>	LC	<i>Litoria majikthise</i>	DD
<i>Callulops slateri</i>	LC	<i>Litoria micromembrana</i>	LC
<i>Callulops wilhelmanus</i>	LC	<i>Litoria modica</i>	LC
<i>Choerophryne allisoni</i>	DD	<i>Litoria multiplica</i>	LC
<i>Choerophryne burtoni</i>	N/A	<i>Litoria pronimia</i>	LC
<i>Cophixalus cryptotympanum</i>	DD	<i>Litoria prora</i>	LC
<i>Cophixalus shellyi</i>	LC	<i>Litoria sauroni</i>	N/A
<i>Hylophorbus richardsi</i>	DD	<i>Litoria spartacus</i>	N/A
<i>Hylophorbus rufescens</i>	LC	<i>Litoria thesaurensis</i>	LC
<i>Liophryne schlaginhaufeni</i>	LC	<i>Litoria wollastoni</i>	LC
<i>Mantophryne lateralis</i>	LC	<i>Nyctimystes pulcher</i>	LC
<i>Oreophryne notata</i>	DD	Myobatrachidae	
<i>Sphenophryne cornuta</i>	LC	<i>Lechriodus aganoposis</i>	LC
<i>Xenorhina parkerorum</i>	LC	<i>Lechriodus melanopyga</i>	LC
Hylidae	LC	Ranidae	
<i>Litoria amboinensis</i>	LC	<i>Rana arfaki</i>	LC
<i>Litoria angiana</i>	LC	<i>Rana daemeli</i>	LC
<i>Litoria arfakiana</i>	LC	<i>Rana novaeguineae</i>	LC



Figure 4.3. A juvenile New Guinea Crocodile, *Crocodylus novaeguineae*, in an off-river water body at Baia River survey area.



Figure 4.4. Maruba River at Deviation Camp. Clear mountain streams provide habitat for a specialised assemblage of treefrogs

4.3.2 ROCKY MOUNTAIN STREAMS – SOUTH KARIUS, DEVIATION CAMP AND JUHA NORTH

Clear, fast-flowing mountain streams, including the headwaters of the Baia River at South Karius Camp and the Maruba River at Deviation Camp were identified as important habitats during this survey (e.g., Figure 4.4). These streams and the dense riparian vegetation along their banks provide habitat for distinct assemblages of frogs that rely on cool, clear streams for successful reproduction. Within these assemblages are two new species of frogs (genera *Litoria* and *Nyctimystes*) discovered during these surveys, and at least one other undescribed species that was previously known only from the Star Mountains. The lowland but clear, rocky streams of the Juha North site also supported populations of two undescribed frogs in the genus *Litoria*; both of these are known only from one other site; one from Libano and the other from Ok Menga, Star Mountains.

It is clear that the structure and density of riparian vegetation associated with these streams is a crucial factor determining the species of frogs that are able to persist along these streams. For example, at both South Karius and Deviation Camp frog assemblages were different in stretches of stream retaining dense overhanging riparian vegetation from those in more open, heavily disturbed sections of the same stream. Common, widespread species (*Litoria angiana*, *L. arfakiana*, *L. micromembrana*; Figure 4.5) dominated in more open, disturbed stretches of Baia River at South Karius, and were replaced by two undescribed species along nearby upstream stretches retaining dense riparian vegetation.

Although many of these species are likely to occur in other streams of similar morphology in the project area, these fast-flowing streams are an important habitat for a unique assemblage of frogs and they are identified as a noteworthy habitat requiring careful management during construction activities.

4.3.3 WET FORESTS OF THE JUHA SOUTH AREA

The wet forests of the Juha South Camp had an extremely diverse frog fauna (36 species), several species of which are considered new to science. These species are not known from any other sites in New Guinea. This area borders karst and has relatively limited flowing water compared to the other sites. Despite this, the forests retain the most diverse frog assemblage reported for any single site in PNG. Juha South is on an old drill pad and the site was first cleared 25 years ago. It is in the area where the Juha Processing Facility may be located and it is important that damage to surrounding forests and aquatic habitats is minimised to protect this remarkable frog assemblage.



Figure 4.5. *Litoria arfakiana* at South Karius. This species breeds only in clear mountain streams

5 Potential impacts and recommended impact mitigation measures

5.1 River crossings

Road and pipeline construction across water-bodies will involve localised damage to riparian vegetation at river crossings in both lowland and montane habitats. This study identified clear rocky streams and their associated riparian vegetation as important habitats for herpetofauna species. Localised impacts at these crossings involve removal of and damage to existing vegetation, and disturbance and movement of soil adjacent to and within waterways during construction. More widespread impacts may occur due to siltation of the stream-beds downstream of the crossings. This may impact populations of torrent-dwelling frogs in clear mountain streams such as the headwaters of the Baia River at South Karius and the Maruba River at Deviation Camp.

The direct affects on herpetofauna of this impact will be siltation of interstitial spaces among rocks in streams, potentially reducing habitat available for torrent-dwelling hylid (*Litoria*, *Nyctimystes*) tadpoles that occupy these benthic habitats, filling in of deep holes in the river, and removal of perch sites for adult frogs, at the same time increasing insolation and drying the riparian vegetation.

Key recommendations

It is suggested that these impacts may be mitigated by reducing the width of crossings and retaining streamside vegetation as far as possible at stream crossings, particularly small ones that may otherwise go unnoticed. It is difficult to specify a minimum stream width because different species occur on different sized streams, but generally the torrent assemblages that occupy clear flowing streams are on streams more than about 3 m wide. Bank stabilisation will also contribute to minimising impacts at crossings. Mountain streams in New Guinea are characterised by rapid and violent fluctuations in volume. Once banks are stabilised siltation impacts will be minimised and temporary because excess silt is removed rapidly during spates. An exception is the main channel of the Baia River. The banks of the Baia River at Baia River Camp are a very dynamic and naturally disturbed habitat. There are unlikely to be any significant impacts of crossings over the Baia River on the few herpetofauna species that are able to occupy this highly mobile environment.

If undertaken with due care for retaining maximum riparian vegetation, and encouraging river/stream bank stabilisation, river crossings should be a relatively minor impact on the herpetofauna irrespective of the method employed.

5.2 Forest gaps: ROW, flow lines, and permanent roads

The major direct impact of this project will be forest removal, whether for pipelines, roads, or for temporary or permanent infrastructure. Vegetation removal exposes the forest floor and nearby vegetation to increased insolation and evaporation. Although recent studies have demonstrated that direct-developing frog embryos may be more resistant to habitat modification than aquatic larvae, it was apparent at Juha South that microhylid frogs, which require moist habitats on the forest floor

for reproduction, were most abundant in the moist gullies and dense forest adjacent to the cleared camp area. It was also clear that the most diverse assemblage of frogs yet reported from a single site in PNG was able to persist in the immediate vicinity of an area disturbed for oil and gas exploration infrastructure at Juha South.

The minimal impact of narrow gaps on herpetofauna was evident during examinations of flow lines at Hides 2 (Richards 2005 = Annex 09 to Biodiversity Appendix), and extensive work along permanent roads, the existing flowlines around the Ridge and Moro and the existing oil export pipeline between the coastal lowlands and montane moss forests in the project area since 1999. They indicated a remarkable ability for diverse frog and reptile assemblages to persist immediately adjacent to narrow open 'corridors'. This persistence is certainly related to minimal vegetation removal that in turn promotes maximum vegetation heterogeneity and humidity within meters inside the forest edge. During the 2005 survey a flow line at Hides 2 was observed to provide an artificial 'gap' for basking skinks while harbouring many microhylid frogs within 5 m of the corridor's edge (Richards 2005 = Annex 09 to Biodiversity Appendix).

Larger gaps with temporary infrastructure will have more impact than narrow corridors, and will generally provide an unsuitable habitat for most forest-dwelling herpetofauna in the short term. Exceptions are several species of *Emoia* and *Carlia* and, at higher altitudes, *Papuascincus* sp. that naturally occur in gaps and proliferate in the sunny drier conditions provided by large clearings. However large gaps will be rapidly re-colonised by at least some herpetofauna species if infrastructure is removed and natural recolonisation is allowed to proceed from the surrounding forest (see Juha South, above).

Impacts of permanent 'clearings' are severe but localised and with careful controls on disturbance to forest surrounding the facility a maximum diversity of herpetofauna species can be retained immediately adjacent to the infrastructure. For example the excellent forest remaining in close proximity to Juha South Camp harbours the most diverse assemblage of frogs reported from a single site in New Guinea. This camp was the site of a large construction and drilling camp in the early 1980s and is an example of how minimising forest disturbance adjacent to a large camp can help retain a very large proportion of the fauna occurring in the area.

Key recommendations

Minimising width of forest corridors whether they be for roads or pipelines to preferably less than 25 m will reduce direct impacts on even the most sensitive of frogs by alleviating moisture loss and will result in reduced or no threat to populations of any known herpetofauna species (see 'river crossings' above for discussion of impacts at riparian habitats). However, achieving this low level of impact will rely on:

- a) Allowing forest regeneration to occur to as large an extent as possible towards the pipeline.
- b) Enforcing strict controls on subsequent vegetation removal along new and existing roads in the project area and as much as possible stabilising edges of corridors.

When temporary facilities are no longer required all infrastructure should be removed from the site and natural regeneration processes should be allowed to operate. Conversion of cleared land to gardens will hinder natural regeneration and recovery of herpetofauna populations.

Strict controls on vegetation clearance and disturbance adjacent to permanent and temporary facilities will greatly facilitate recolonisation of the site when infrastructure is removed, and maintain a diverse herpetofaunal assemblage within close proximity to existing infrastructure.

5.3 Contamination

A potential impact on herpetofauna by the project is the potential for contamination of streams by accidental fuel, oil and toxic chemical spills. Depending on the volume, spills may have particularly severe impacts on aquatic frogs and these impacts may extend substantially downstream if they enter streams or rivers. Amphibians are particularly susceptible to chemical pollution due to their moist and porous skin and the aquatic larvae of the species that have them. Impacts on aquatic reptiles are less well understood but likely to be severe.

Key recommendations

The project should have stringent materials handling practices for handling and management of chemical spills, including storing all hazardous chemicals a sufficient distance away from rivers and streams so that in the event of spillage they cannot enter waterways. Where chemicals must be transported over water or near water courses, all receptacles should be securely sealed to prevent spillage in the event of an accident.

5.4 Hunting

Hunting of wild animals is a traditional activity for local communities throughout New Guinea. Hunting may be for food or to obtain feathers or skins for important ceremonies. Several large species of frogs including the Giant River Frog *Rana arfaki* are widely consumed. Consumption of frogs is unlikely to have a major impact on any populations in the project area due to their high abundance, and decreasing interest among locals in frogs as a food source. However several species of large reptiles are regularly hunted. Monitor lizards are hunted for their skins, which are used to make Kundu Drums, and to eat, and crocodiles, freshwater turtles and pythons are keenly sought after as food items. One species of python, the Boelen's Python, is protected in PNG and several freshwater turtles that occur in the project area are considered to be of conservation significance by the IUCN. Improved access along roads and the proliferation of high-powered rifles and boats has increased hunting pressure on these large reptiles.

Key recommendations

There must be strict controls on hunting of local herpetofauna, particularly crocodiles, pythons, goannas and turtles, by project employees. These controls should be actively enforced, and should aim to prevent hunting for consumption as well as hunting for trade or sale. Movement of reptiles out of the project area should be monitored and employees should be educated about the need to protect

this component of the local fauna. Actively promoting the protection of all large reptiles could become an integral part of the project such as for example the existing Management Plan, established by Oil Search Ltd, for the Boelen's Python.

6 Final conclusions and recommendations

The herpetofauna of the PNG LNG Project area is exceptionally diverse. This diversity has persisted along-side the major oilfields and infrastructure of the existing oil project. Careful management of the project area, particularly through strict controls on forest degradation along roads and the existing ROW have contributed to this. It is evident that impacts are expected to occur as a result of additional pipeline construction in the Juha area. However these impacts will be localised and temporary if controls on access to the area by locals and outsiders are enforced.

The major potential impacts of this project on herpetofaunal diversity and biodiversity overall will be likely secondary impacts from improved access along permanent roads to currently remote areas. Although short-term direct impacts will be minor (see above), permanent roads may lead to increased habitat destruction along and adjacent to roads as local populations move into previously inaccessible areas. This may not occur until the project ceases if controls on population movements are enforced, but in the long-term may be a significant conservation management issue if controls on human access and movement decline.

7 References

- Allison, A. 1993. Biodiversity and conservation of the fishes, amphibians and reptiles of Papua New Guinea. In: B. Beehler ed. Papua New Guinea Conservation Needs Assessment. Government of Papua New Guinea.
- Allison, A., Bickford, D., Richards, S. J. and Torr, G. 1998. Herpetofauna *in* A Biological assessment of the Lakekamu Basin, Papua New Guinea. Rapid Assessment Program Working Paper Number 9. Washington, Conservation International.
- IUCN, Conservation International, and NatureServe. 2006. Global Amphibian Assessment. <www.globalamphibians.org>.
- IUCN-SSC. 2007. Red List of Threatened Species. <<http://www.iucnredlist.org/>>
- O'Shea, M. 1996. A guide to the snakes of Papua New Guinea. Independent Publishing, Port Moresby
- Richards, S. J. 2000. Herpetofauna and Odonata of Dark End Lumber (Gulf Province) and Mt Sisa (Southern Highlands Province), Papua New Guinea. Unpublished report to World Wide Fund for Nature (USA).
- Richards, S. J. 2002a. Frogs and reptiles of Moro, Gobe and Kopi (Southern Highlands and Gulf Provinces), Papua New Guinea: Results of a dry-season survey 19 October – 1 November 2001. Unpublished report to WWF-PNG.
- Richards, S. J. 2002b. Updated list of Frogs from Moro, Gobe and Kopi (Southern Highlands and Gulf Provinces), Papua New Guinea: Preliminary results of a wet-season survey 14 – 30 May 2002. Unpublished report to WWF-PNG
- Richards, S. J. 2002c. Rokrok: A field guide to frogs of the Kikori ICDP. Report to WWF-PNG.
- Richards, S. J. 2005. Biodiversity and Conservation Status of Herpetofauna of the Papua New Guinea Gas Project Area. Unpublished report to ENESAR and Exxon Mobil. (Annex 09 to Biodiversity Appendix)
- Richards, S. J. and Allison, A. 2003. Frogs and reptiles of Darai Plateau and Libano (Southern Highlands and Gulf Provinces), Papua New Guinea: Results of a biodiversity survey 22 July – 12 August 2003. Unpublished report to WWF-PNG.

Appendix 1 Combined herpetofauna of the PNG LNG Upstream Project area 1999–2008

	Benaria	Darai Plateau	Dark End Lumber	G2 to G6	Hides 3	Kopi	Libano Sok	Mt Moran	LK1 to LK3	MS1 and MS2	Nogoli	Juha North	Juha South	Baia River	South Karius	Deviation Camp
Crocodylia																
<i>Crocodylus porosus</i>			+			+										
<i>Crocodylus novaeguineae</i>							+							+		
Geckonidae																
<i>Hypsilurus dilophus</i>		+	+				+									
<i>Hypsilurus modestus</i>	+	+	+				+					+	+	+		
<i>Hypsilurus</i> sp. (semi-aquatic)							+					+		+		
<i>Cyrtodactylus capreoloides</i>									+			+				
<i>Cyrtodactylus loriae</i>		+					+		+							
<i>Cyrtodactylus novaeguineae</i>			+				+									
<i>Cyrtodactylus papuensis</i>							+									
<i>Cyrtodactylus serratus</i>												+		+		
<i>Cyrtodactylus</i> sp. nov. 1 (cf <i>lousiadensis</i>)			+									+		+		
<i>Cyrtodactylus</i> sp. nov. 2 (nr <i>marmoratus</i>)				+												
<i>Hemidactylus frenatus</i>											+	+				
<i>Nactus pelagicus</i>		+					+									
Scincidae																
<i>Carlia aramia</i>		+	+			+	+									
<i>Carlia</i> sp (no available name)	+										+					
<i>Emoia caeruleocauda</i>							+					+		+		
<i>Emoia kordoana</i>		+					+					+				
<i>Emoia longicauda</i>							+					+		+		
<i>Emoia pallidiceps?</i>		+										+				
<i>Emoia physicina</i>			+													
<i>Emoia</i> sp. 1					+										+	
<i>Emoia</i> sp 2 (<i>obscura?</i>)	+											+	+	+		
<i>Eugongylus rufescens</i>							+									
<i>Lipinia nototaenia</i>												+				
<i>Lipinia</i> sp. 1		+											+			
<i>Lipinia</i> sp. 2	+															
<i>Lobulia elegans</i>					+					+						+

Appendix 1 Combined herpetofauna of the PNG LNG Upstream Project area 1999–2008

	Benaria	Darai Plateau	Dark End Lumber	G2 to G6	Hides 3	Kopi	Libano Sok	Mt Moran	LK1 to LK3	MS1 and MS2	Nogoli	Juha North	Juha South	Baia River	South Karius	Deviation Camp
<i>Lygisaurus novaeguineae</i>			+													
<i>Lygisaurus</i> sp	+										+					
<i>Papuascincus</i> sp.					+					+						+
<i>Sphenomorphus muelleri</i>	+															
<i>Sphenomorphus meyeri</i>							+							+		
<i>Sphenomorphus pratti</i>		+														
<i>Sphenomorphus schultzei</i>													+			
<i>Sphenomorphus simus</i>		+	+				+					+	+	+		
<i>Sphenomorphus</i> sp (annectens complex)																+
<i>Sphenomorphus</i> sp. nov. cf <i>jobiensis</i>	+	+	+				+					+	+			
<i>S.</i> sp. nov. cf. <i>papuae</i> (pale stripes)					+										+	
<i>S.</i> sp. nov. cf. <i>leptofasciatus</i> (dark stripes)															+	
Varanidae																
<i>Varanus indicus</i>						+								+		
<i>Varanus dorianus</i>							+									
<i>Varanus salvadori</i>			+													
Elapidae																
<i>Acanthophis antarcticus</i>			+													
<i>Aspidomorphus muelleri</i>						+										
<i>Toxicocalamus loriae</i>												+				
<i>Toxicocalamus preussi angustitinctus</i>						+										
Pythonidae																
<i>Candoia aspera</i>							+									
<i>Candoia carinata</i>						+										
<i>Morelia amethystina</i>		+	+		+						+					
<i>Morelia boeleni</i> *								p							h	
<i>Morelia viridis</i>							+				+	+				
<i>Liasis fuscus</i>														p		
Colubridae																

Appendix 1 Combined herpetofauna of the PNG LNG Upstream Project area 1999–2008

	Benaria	Darai Plateau	Dark End Lumber	G2 to G6	Hides 3	Kopi	Libano Sok	Mt Moran	LK1 to LK3	MS1 and MS2	Nogoli	Juha North	Juha South	Baia River	South Karius	Deviation Camp
<i>Boiga irregularis</i>			+			+						+				
<i>Dendrelaphis calligastrea</i>			+										+	+		
<i>Dendrelaphis gastrosticta</i>	+										+					
<i>Stegonotus modestus</i>	+						+				+					
<i>Stegonotus parvus</i>			+													
<i>Stegonotus cucullatus</i>			+													
<i>Tropidonophis statisticus</i>					+					+					+	
<i>Tropidonophis novaeguinea</i>							+									
TOTALS		12	17	1	6	7	21	1	2	3	7	17	7	13	5	3
Microhylidae																
<i>Albericus tuberculatus</i>				+					+							
<i>Albericus</i> sp. nov. 1 (rattler)				+				+	+	+					+	+
<i>Albericus</i> sp. nov. 2 (short peeper)								+	+						+	
<i>Albericus</i> sp. nov. 3 (rasper)		+		+					+			+	+			
<i>Albericus</i> sp. nov. 4 (large)					+					+						+
<i>Albericus</i> sp. nov. 5 (medium)					+					?						+
<i>Albericus</i> sp. nov. 6 (clicker)		+					+		+					+		
<i>Albericus</i> sp. nov. 7 (peeper 2)		+														
<i>Asterophrys turpicola</i>				+		+	+					+		+		
<i>Asterophrys</i> sp. nov.								+							+	
<i>Austrochaperina derongo</i>		+					+		+			+	+	+	+	
<i>Austrochaperina guttata</i>			+													
<i>Austrochaperina palmipes</i>			+													
<i>Austrochaperina rivularis</i>													+			
<i>Austrochaperina</i> sp. nov. 1 (small)		?	+	+			?	+	+				+	+	+	
<i>Austrochaperina</i> sp. nov. 2 (cf <i>derongo</i>)		+														
<i>Austrochaperina</i> sp. nov. 3 (medium)													+			
<i>Callulops doriae</i>			+	+		+						+				

Appendix 1 Combined herpetofauna of the PNG LNG Upstream Project area 1999–2008

	Benaria	Darai Plateau	Dark End Lumber	G2 to G6	Hides 3	Kopi	Libano Sok	Mt Moran	LK1 to LK3	MS1 and MS2	Nogoli	Juha North	Juha South	Baia River	South Karius	Deviation Camp
<i>Callulops slateri</i>		+	+	+		+	+		+			+	+	+		
<i>Callulops wilhelmanus</i>					?					+						
<i>Callulops</i> sp. nov. 1 (<i>C. robusta</i> group)		+		+		?						+	+			
<i>Callulops</i> sp. nov. 2 (small)								+								
<i>Choerophryne allisoni</i>					+					+						
<i>Choerophryne burtoni</i>								+				+?	+?		+?	
<i>Cophixalus cryptotympanum</i>								+								
<i>Cophixalus shellyi</i> ?								+							+	+
<i>Cophixalus</i> sp. nov. 1 (eye-spikes)								+	+				+		+	
<i>Cophixalus</i> sp. nov. 2 (buzz call)		+		+		+						+	+	+		
<i>Cophixalus</i> sp. nov. 3 (cf <i>balbus</i>)		+		+			+							+		
<i>Cophixalus</i> sp. nov. 4 (musical call)				+					+	+						
<i>Cophixalus</i> sp. nov. 5. (triple-calls)								+								+
<i>Cophixalus</i> sp. nov. 6. (tiny)		+														
<i>Cophixalus</i> sp. nov. (cf <i>shellyi</i>)								+								
<i>Copiula</i> sp. nov. 1 (small, fast call))			?			+										
<i>Copiula</i> sp. nov. 2 (2-note call)		+					+		+							
<i>Copiula</i> sp. nov. 3. (tiny)				+									+			
<i>Copiula</i> sp. nov. 4. (large)												+	+?			
<i>Hylophorbus richardsi</i>					+					+						+
<i>Hylophorbus rufescens</i>			+									+?		+		
<i>Hylophorbus</i> sp. nov. 1 (Moro broad head)	+	?					?		+		+		+?		+?	
<i>Hylophorbus</i> sp. nov. 2 (zig-zag)				+		+										
<i>Hylophorbus</i> sp. nov. 3 (slow call))		+		+		+	+	+	+				+?			
<i>Hylophorbus</i> sp. nov. 4 (tiny)		+														

Appendix 1 Combined herpetofauna of the PNG LNG Upstream Project area 1999–2008

	Benaria	Darai Plateau	Dark End Lumber	G2 to G6	Hides 3	Kopi	Libano Sok	Mt Moran	LK1 to LK3	MS1 and MS2	Nogoli	Juha North	Juha South	Baia River	South Karius	Deviation Camp
<i>Liophryne schlaginhaufeni</i>		+		+			+		+							
<i>Mantophryne lateralis</i>			+			+	+					+	+	+		
<i>Oreophryne notata</i>					+			+		+						
<i>Oreophryne</i> sp. nov. 1 (small rattler)		+	+	+		+	+		+			+		+	+	
<i>Oreophryne</i> sp. nov. 2 (loud rattler)				+				+	+			+	+		+	
<i>Oreophryne</i> sp. nov. 3 (large peeper)	+	+	+	+		+	+		+		+		+			
<i>Oreophryne</i> sp. nov. 4. (large, montane)					+					+						
<i>Oreophryne</i> sp. nov. 5. (small peeper)												+		+		
<i>Oreophryne</i> sp. nov. 6. (tiny peeper) - NEW SPECIES																+
<i>Oreophryne</i> sp. nov. 7. (medium) - NEW SPECIES																+
<i>Oreophryne</i> sp. nov. 8. (long rattle)															+	
<i>Oreophryne</i> sp. nov. 9. (cf notata) - NEW SPECIES												+	+			
<i>Sphenophryne cornuta</i>		+	+	+		+	+		+			+	+	+		
<i>Xenorhina parkerorum</i>								+		+						
<i>Xenobatrachus</i> sp. nov. 1 (small)		+					+									
<i>Xenobatrachus</i> sp. nov. 2 (slow call)		+	?			?						+	+	+		
<i>Xenobatrachus</i> sp. nov. (fast call) - NEW SPECIES													+	+	+	
<i>Xenobatrachus</i> sp. nov. 4 (tiny) - NEW SPECIES													+			
<i>Xenobatrachus</i> sp. nov. 5 (colourful) - NEW SPECIES													+			
<i>Xenobatrachus</i> sp. nov. 6 (bi-coloured legs) - NEW SPECIES?													+			
Hylidae																
<i>Litoria amboinensis</i>				+					+							

Appendix 1 Combined herpetofauna of the PNG LNG Upstream Project area 1999–2008

	Benaria	Darai Plateau	Dark End Lumber	G2 to G6	Hides 3	Kopi	Libano Sok	Mt Moran	LK1 to LK3	MS1 and MS2	Nogoli	Juha North	Juha South	Baia River	South Karius	Deviation Camp
<i>Litoria angiana</i>										+					+	+
<i>Litoria arfakiana</i>	+								+			+	+	+	+	
<i>Litoria auae</i>		+				+		+	+			+	+	+		
<i>Litoria darlingtoni</i>										+	+				+	
<i>Litoria eucnemis</i>								+	+				+			
<i>Litoria havina</i>								+	+				+	+		
<i>Litoria infrafronata</i>		+	+			+	+		+		+	+		+		
<i>Litoria iris</i>					+					+					+	+
<i>Litoria majikthise</i>		+										+	+			
<i>Litoria micromembrana</i>										+					+	
<i>Litoria modica</i>								+		+			+		+	+
<i>Litoria pronimia</i>				+	+			+	+							
<i>Litoria prora</i>			+	+					+							
<i>Litoria richardsi</i>		+														
<i>Litoria sauroni</i>		+	+	+												
<i>Litoria spartacus</i>	+								+			+				
<i>Litoria thesaurensis</i>							+		+					+		
<i>Litoria wollastoni</i>	+															
<i>Litoria</i> sp. nov. 1 cf <i>nigropunctata</i> 1 (bleating call)									+				+			
<i>Litoria</i> sp. nov. 2 cf <i>nigropunctata</i> 2 (Darai)		+														
<i>Litoria</i> sp. nov. 3 (nr <i>bicolor</i>)						+										
<i>Litoria</i> sp. nov. 4 (nr <i>genimaculata</i> 1 - yellow eye)									+							
<i>Litoria</i> sp. nov. 5 (nr <i>genimaculata</i> 2)		+	+			+						+	+			
<i>Litoria</i> sp. nov. 6 (Torrent chirper)															+	
<i>Litoria</i> sp. nov. 7 (small, green torrent)							+					+				
<i>Litoria</i> sp. nov. 8 (scarlet venter)	+			+				+	+					+		
<i>Litoria</i> sp. nov. 9 (yellow venter)				+					+							

Appendix 1 Combined herpetofauna of the PNG LNG Upstream Project area 1999–2008

	Benaria	Darai Plateau	Dark End Lumber	G2 to G6	Hides 3	Kopi	Libano Sok	Mt Moran	LK1 to LK3	MS1 and MS2	Nogoli	Juha North	Juha South	Baia River	South Karius	Deviation Camp
<i>Litoria</i> sp. nov. 10 (Libano torrent)						+										
<i>Litoria</i> sp. nov. 11 (cf <i>pygmaea</i>)							+									
<i>Litoria</i> sp. nov. 12 (Trilling torrent) - NEW SPECIES															+	
<i>Litoria</i> sp. nov. 13 (multiplica?)												+				
<i>Litoria</i> sp. nov. 14 (cf Ok Menga)											+					
<i>Nyctimystes pulcher</i>								+			+		+			
<i>Nyctimystes kudukui</i>							?	+								
<i>Nyctimystes</i> sp. nov. - NEW SPECIES														+	+	
Myobatrachidae																
<i>Lechriodus aganoposis</i>							+		+					+	+	
<i>Lechriodus melanopyga</i>		+	+			+		+				+				
Ranidae																
<i>Rana arfaki</i>		+	+			+		+			+		+			
<i>Rana daemeli</i>	+	+	+	+		+	+		+		+	+	+	+	+	
<i>Rana cf grisea</i> 1	+	+						+	+		+	+	+	+	+	+
<i>Rana cf grisea</i> 2		+														
<i>Rana novaeguineae</i>						+										
<i>Rana</i> sp. nov.						+										
TOTALS	8	33	19	26	9	20	22	25	38	16	6	29	36	24	24	15

+ specimen record

+? Specimen may be of this species

h Acceptable hunter record

p Identifiable photograph

