

**Identification Guide to Flora and Fauna of Hides Ridge
and the Agogo Range (Moro), Papua New Guinea**



Edited by Stephen Richards

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Front Cover image: *Hipposideros cervinus* (Fawn-coloured Leaf-nosed Bat).

Back Cover image: *Clytoceyx rex* (Shovel-billed Kookaburra) caught on camera trap.



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Introduction

This guide was developed as a resource to aid the identification of frogs, mammals, birds and plants encountered during ExxonMobil PNG Limited's PMA3 biodiversity monitoring program on Hides Ridge and the Agogo Range (near Moro) in Hela and Southern Highlands Provinces. It is based on the results of two PMA3 surveys conducted during June–July 2015 and May 2017, and will be modified over time to incorporate additional species documented during subsequent surveys. The document should be treated as a 'live' resource that will become more comprehensive after each survey as knowledge about the biodiversity of this spectacular region improves.

This document emphasises the importance of images and, where relevant, of sounds as aids to identify species. Characters most important for identification are highlighted, and information is provided on how best to distinguish between morphologically similar species. It is hoped that this book will be a useful resource for future participants in the PMA3 biodiversity monitoring program, and also for residents and visitors alike who have an interest in the local flora and fauna.

The PNG LNG Upstream Project Area is located in an extremely biodiverse and poorly documented tropical forest ecosystem so there is a high chance that additional species not illustrated in this document will be encountered during future PMA3 surveys. Selected references to publications or website resources that may aid identification of these additional species are presented for each group of species. However it is also probable that species new to science will continue to be discovered during PMA3 surveys, particularly in groups such as frogs and rodents.

The information presented here was collected predominantly in two Biodiversity Assessment Areas (BAAs): BAA 1 on Hides Ridge at altitudes of 2,200–2,400 m asl (Hides Low) and 2,600–2,800 m asl (Hides High); and BAA 2 on the Agogo Range near Moro (~1,400 m asl at KP107 and ~1000 m asl at Arakubi; Figure 1), but some additional species encountered outside of the BAAs, particularly around Lake Kutubu (~800 m asl) are also illustrated.

Comprehensive results of the Phase 1 (2015) PMA3 survey are presented in the document:

Richards, S.J. (editor). (2017). Biodiversity assessment of the PNG LNG Upstream Project Area, Southern Highlands and Hela Provinces, Papua New Guinea. ExxonMobil PNG Limited. Port Moresby.

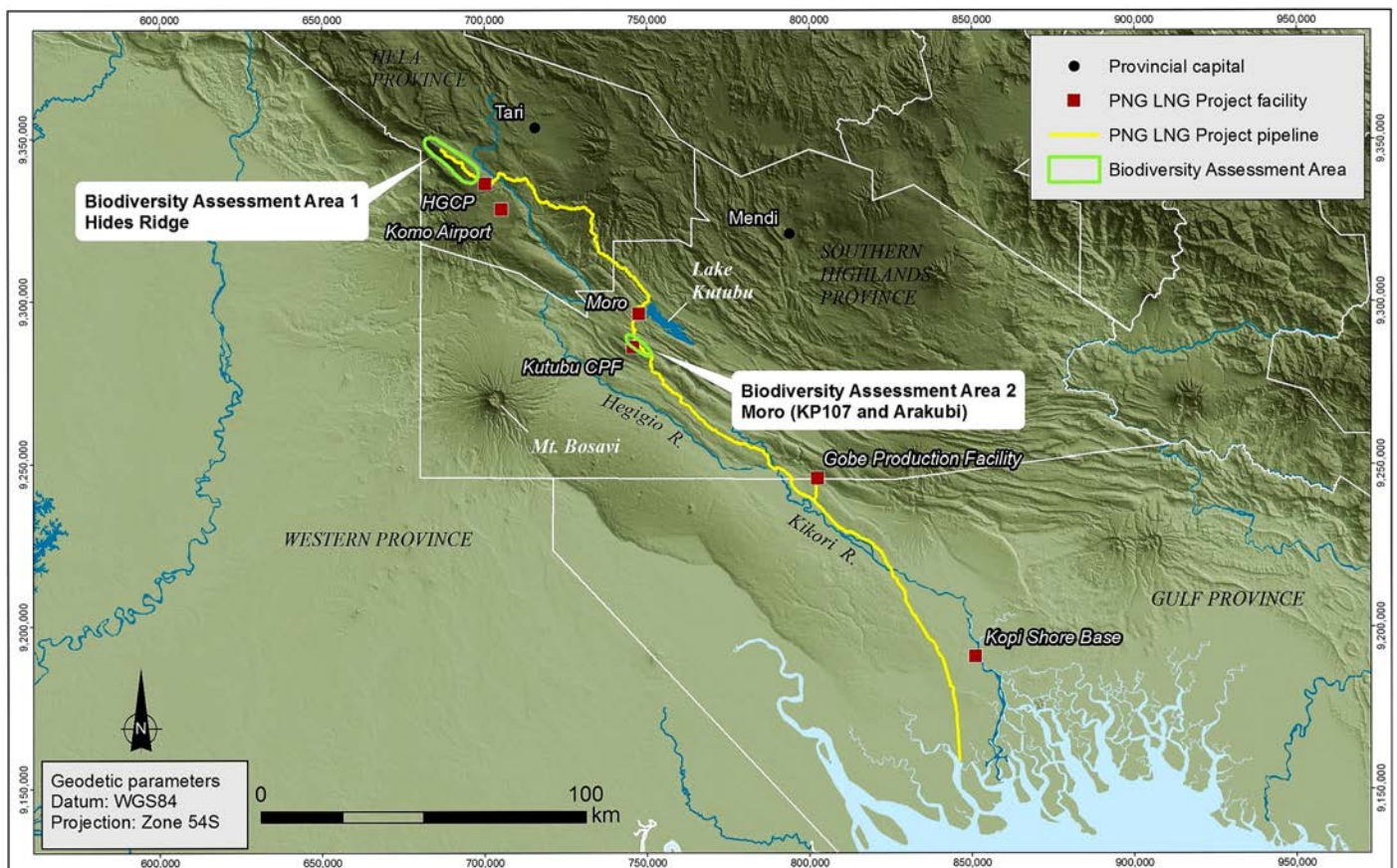


Figure 1. Regional map showing location of the two BAAs surveyed during the PMA3 surveys.

Acknowledgements

The information presented in this document was obtained during the 2015 and 2017 PMA3 biodiversity monitoring surveys which relied on the considerable efforts of an excellent support team from ExxonMobil PNG Limited. We are extremely grateful to Jane Mogina, Anita Mosby and Rebekah Ilave for their organisational skills and ongoing support during the surveys and to our drivers including Dopo Uriye, Richard Tiki and Henry Helo who transported the team to and from field sites at all hours of the day and night. We are also grateful to the PGA support crew Simon Gawa, Simon Maka, Luem Narawec, John Handale and Simon Kelip at HGCP and Henny Hekari, Thomas Samo, Douglas Simala and Samu (Village Liaison Officer) at Moro. Hides Security Services at HGCP and James March and Toby Gleeson at Moro provided security arrangements that ensured the team's safety at all times. Many other people behind the scenes contributed to the success of the project including Rebekah Lovi and Sharon Lauatu from Environment at HGCP; Ken Rhyason and Ken Musante, PICs at HGCP; Mark Monica, George Shaw and Patrick Blackmon, PICs at Moro; Tom Tomala, Simon Mawa and Pipi Mea from logistics and Kenny Stevens the Hides Security Contact. We also thank Mathilda Haguai and Luana Koniel, and Simah Epi and Margaret Pehara who provided wonderful admin support at HGCP and Moro respectively.

The authors thank the Binatang Research Centre for their invaluable support and Chris Dahl, Amos Ona, Muse Opiang, Enock Kale, Leo Legra and Pagi Toko for their collaboration and camaraderie in the field.

Finally, we thank the PNG Conservation and Environment Protection Authority for approval to undertake this project.

PLANTS

Fanie Venter



Dendrobium cuthbertsonii

Introduction

Many plant taxa in PNG are difficult to identify because different species within certain genera look very similar to the untrained eye, especially if material is sterile (without flowers or fruit). Particularly difficult genera include *Saurauia* (Actinidiaceae), *Begonia* (Begoniaceae), *Calophyllum* (Calophyllaceae), *Garcinia* (Clusiaceae), *Dimorphanthera* (Ericaceae), *Cyrtandra* (Gesneriaceae), *Cryptocarya* (Lauraceae), *Levieria* (Monimiaceae), *Medinilla* (Melastomataceae), *Myristica* (Myristicaceae), *Piper* (Piperaceae), *Hydnophytum*, *Psychotria* (Rubiaceae), *Acronychia* (Rutaceae), *Casearia* (Salicaceae) and *Zygogynum* (Winteraceae). Compounding this problem is the lack of sufficient comparative material in herbaria to directly compare and identify many poorly-known species.

Main techniques used in plant identification

The most important piece of equipment for plant identification is a 10X magnification hand lens. Many important features of the flowers and leaves, in particular hairiness, can only be seen clearly and described accurately by using a hand lens. Start by comparing plant specimens with images in this booklet. If the plant is not in the booklet, then binary identification keys in publications should be used. The most important publications are listed below but many more are available from libraries and Herbaria. Specimens can also be identified using flora databases on the World Wide Web. Many species in PNG occur more widely in Asia and Australia and there are useful websites covering these areas that might help to identify PNG species. Some of these are also listed below.

Important characters for identification

Plants that flower and fruit intermittently throughout the year (*Ficus*, *Medinilla*, *Rhododendron*, *Schefflera* and various Urticaceae genera) are relatively easy to identify when specimens are compared with Herbarium material or when identification keys in the literature are used. For plants encountered in the sterile state one has to rely on the structure of leaves, bark and other characters such as spines for identification. The most important characters used for identification are:

Important characters for identification		
Leaves	Bark	Other
leaf arrangement - simple or compound leaf	smooth	presence of spines
presence of stipules	fissured	presence of watery sap or milky latex
shape of the leaf margin	tessellated	
presence of an intramarginal vein	flaky	
leaf venation	nondescript	
characters of the midrib		
texture of the leaf surface		
hairiness of the leaf surface		
petiole length		
presence of a pulvinus		
shape of the leaf apex and leaf base		
compound leaf ending in a leaflet or not		

Examples of morphologically similar taxa in the study area and how to distinguish between them when they are not in flower:

Actinidiaceae	
<i>Saurauia calyptata</i>	leaf margin with small teeth that ends in a long thin point, petiole covered in scales.
<i>Saurauia conferta</i>	leaf margin with larger teeth that do not end in a thin point, petiole smooth
Ericaceae	
<i>Dimorphanthera brevipes</i>	leaf margin serrate, leaf blade without dots
<i>Dimorphanthera ingens</i>	leaf margin smooth, leaf blade with prominent dots
<i>Dimorphanthera inopinata</i> -	leaf margin smooth with a pair of glands at base, leaf blade without dots
Lauraceae	
<i>Cryptocarya apimifolia</i>	leaf blade with 5-7 prominent veins.
<i>Cryptocarya densiflora</i>	leaf blade with 3-5 prominent veins.
Monimiaceae	
<i>Levieria acuminata</i>	petiole long and thin.
<i>Levieria squarrosa</i>	petiole short and much thicker.
Myristicaceae	
<i>Myristica globosa</i>	petiole curved and thick.
<i>Myristica schleinitzii</i>	petiole straight and much thinner.
Piperaceae	
<i>Piper caninum</i>	venation on underside of leaf slightly raised, petiole smooth.
<i>Piper macropiper</i>	venation on underside of leaf prominently raised, petiole hairy.
Rubiaceae	
<i>Hydnophytum microphyllum</i>	secondary venation prominent on lower leaf surface.
<i>Hydnophytum parvifolium</i>	secondary venation absent on lower leaf surface.
Rubiaceae	
<i>Psychotria leiophloea</i>	leaves glabrous/smooth, petiole long.
<i>Psychotria leucococca</i>	leaves slightly hairy, petiole short.

Rutaceae	
<i>Acronychia foveata</i>	leaf apex obtuse to slightly acute.
<i>Acronychia pedunculata</i>	leaf apex strongly acute.
Salicaceae	
<i>Casearia clutiifolia</i>	lamina elliptic, venation prominent, apex acute.
<i>Casearia papuana</i>	lamina lanceolate, venation much less prominent, apex acuminate.
Winteraceae	
<i>Zygogynum argenteum</i>	lamina light green underneath, apex obtuse to acute.
<i>Zygogynum sylvestre</i>	lamina whitish underneath, apex apiculate.

References and further reading

Websites

Flora of the Philippines (www.philippineplants.org),

Flora of Singapore (www.uforest.org),

Tree Flora of Sabah and Sarawak (www.chm.frim.gov.my/Resources/Publications/Books/Floras/Tree-Flora-of-Sabah-and-Sarawak),

Trees of Tropical Asia (www.plantsofasia.com),

Ferns and Lycophytes of the World (www.fernsoftheworld.com),

Legumes of the World (www.kew.org/science-conservation/research-data/resources/legumes-of-the-world/scientific-names),

Palms of the World Online (www.palmweb.org)

Aroideana (<http://www.aroid.org/aroidiana/>) for members of the Araceae.

Published literature

Argent, G. 2016. *Rhododendrons of subgenus Vireya*. Royal Botanic Gardens, Edinburgh.

Baker, W. J. & Dransfield, J. 2006. *Field Guide to the Palms of New Guinea*. Royal Botanic Gardens, Kew.

Berg, C. C., Corner, E. J. H. & Nooteboom, H. P. 2005. Moraceae - *Ficus*. *Flora Malesiana* 17: 1–154.

Davis, A. P. & Bridson, D. M. 2004. A Taxonomic Revision of the genus *Amaracarpus* (Rubiaceae, Psychotriaceae). *Blumea* 49: 25–68.

De Wilde, W. J. J. 2000. Myristicaceae. *Flora Malesiana* Volume 14: 1–634.

Gardner, R. O. 2013. *Piper* (Piperaceae) in New Guinea: the climbing species. *Blumea* 57(3): 275–294.

Handbooks of the Flora of Papua New Guinea Vol. 1–3. Melbourne University Press.

Hartley, T. G. 1974. A Revision of the Genus *Acronychia* (Rutaceae). *Journal of the Arnold Arboretum* 55(3): 469–523.

- Hay, A. 1990. *Aroids of Papua New Guinea*. Christensen Research Institute.
- Heenan, P. B. & Smitsen, R. D. 2013. Revised circumscription of *Nothofagus* and recognition of the segregate genera *Fuscospora*, *Lophozonia* and *Trisyngyne* (Nothofagaceae). *Phytotaxa* 146: 1–31.
- Hoffman, P. 2005. *Antidesma* in Malesia and Thailand. Kew Publishing.
- Maxwell, J. F. & Veldkamp, J. F. 1990. Notes on the Astronieae (Melastomataceae) I. *Astrocalyx*, *Astronia*. *Blumea* 35: 71–114.
- Pannell, C. M. 1992. A taxonomic monograph of the genus *Aglaia* Lour. (Meliaceae). *Kew Bulletin* additional series. 1–379.
- Philipson, W. R. 1984. A synopsis of the Malesian species of *Steganthra* (Monimiaceae). *Blumea* 29: 481–497.
- Royen, P. van 1982. Saurauiceae. *The alpine flora of New Guinea* 3: 1367–1396.
- Schuiteman, A. 1998. Revision of *Agrostophyllum*. *Orchid Monographs* 8: 1–272.
- Schuiteman, A. 2013. *A Guide to Dendrobium of New Guinea*. Natural History Publications (Borneo).
- Sleumer, H. 1955. Proteaceae. *Flora Malesiana* 5: 147–206.
- Sleumer, H. 1967. Ericaceae. *Flora Malesiana* 6: 469–914.
- Sohmer, S. H. 1988. The Nonclimbing Species of the Genus *Psychotria* (Rubiaceae) in New Guinea and the Bismarck Archipelago. *Bishop Museum Bulletin in Botany* 1. Bishop Museum Press, Honolulu.
- Stevens, P. F. 2003. New taxa in *Paphia* and *Dimorphantha* (Ericaceae) in Papuasias and the problem of generic limits in *Vacciniieae*. *Edinburgh Journal of Botany* 60: 267–298.
- Verdcourt, B. 1979. A Manual of New Guinea Legumes. Botany Bulletin No. 11. Office of Forests, Lae.
- Wilde, de W. J. J. O. 2000. Myristicaceae. *Flora Malesiana* 14: 1–634.

Image credits

Images in this section are mostly of plants encountered in plant plots in the two BAAs during 2015, with some additional species from outside the plots also illustrated. They were provided by the author, except those photos listed below that were supplied by copyright owners with permission for use.

Plant Name	Copyright owner
<i>Aglaia sapindina</i> (Meliaceae)	CSIRO
<i>Asplenium marattioides</i> (Aspleniaceae)	Shelly James, Bishop Museum
<i>Bulbophyllum leucothyrsus</i> (Orchidaceae)	Eric Hunt
<i>Camposperma brevipetiolatum</i> (Anacardiaceae)	Arison Arihafa
<i>Ceratostylis subulata</i> (Orchidaceae)	Ron Hanko
<i>Diploblechnum fraseri</i> (Blechnaceae)	Phil Bendle
<i>Dryopteris wallichiana</i> (Dryopteridaceae)	Shelly James, Bishop Museum
<i>Elatostema mongiensis</i> (Urticaceae)	Shelly James, Bishop Museum
<i>Elatostema morobense</i> (Urticaceae)	Shelly James, Bishop Museum
<i>Fagraea ceilanica</i> (Gentianaceae)	Top Tropics
<i>Macaranga strigosa</i> (Euphorbiaceae)	Shelly James, Bishop Museum
<i>Papuacedrus papuana</i> (Cupressaceae)	Stephane Alix
<i>Polystichum daymanense</i> (Dryopteridaceae)	Shelly James, Bishop Museum
<i>Santalum macgregorii</i> (Santalaceae)	D.L. Nickrent

Ferns and Lycophytes

ASPLENIACEAE



Asplenium bipinnatifidum



Asplenium marattioides

BLECHNACEAE



Blechnum revolutum



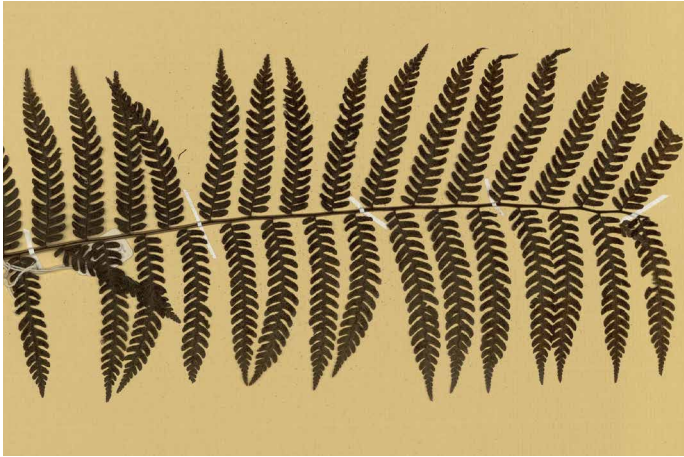
Blechnum revolutum



Diploblechnum fraseri

Ferns and Lycophytes (cont)

CYATHEACEAE



Cyathea brackenridgei



Cyathea contaminans



Gymnasphaera hornei

DRYOPTERIDACEAE



Dryopteris wallichiana



Polystichum daymanense

Ferns and Lycophytes (cont)

GLEICHENIACEAE



Dicranopteris linearis

GRAMMITIDACEAE



Grammitis dolichosora

HYMENOPHYLLACEAE



Crepidomanes aphlebioides



Hymenophyllum ooides

MARATTLACEAE



Marattia tafaensis

Ferns and Lycophytes (cont)

OLEANDRACEAE



Oleandra pilosa

OSMUNDACEAE



Leptopteris alpina



Oleandra pilosa

POLYPODIACEAE



Calymmodon cucullatus



Ctenopterella blechnoides

Ferns and Lycophytes (cont)

POLYPODIACEAE (cont)



Lepisorus novoguineensis



Selligaea albidosquamata



Selligaea plantaginea



Selligaea plantaginea



Themelium yoderi

Ferns and Lycophytes (cont)

PTERIDACEAE



Atrophyum alatum



Vittaria elongata

THELYPTERIDACEAE



Syngamma schlechteri



Sphaerostephanos adenostegius

Gymnosperms
CUPRESSACEAE



Papuacedrus papuana

PODOCARPACEAE



Podocarpus neriifolius



Papuacedrus papuana

Monocots
ARACEAE



Alocasia hollrungii



Alocasia lancifolia



Epipremnum papuanum



Alocasia nicholsonii



Holochlamys beccarii



Schismatoglottis calyptrata

Monocots (cont)

ARECACEAE



Areca multifida



Calamus fertilis



Calamus heteracanthus



Caryota rumphiana



Heterospathe elegans



Linospadix albertisianus

ASPARAGACEAE



Cordyline fruticosa

MARANTACEAE



Phrynium pedunculatum

Monocots (cont)

Orchidaceae



Aglossorhyncha biflora



Agrostophyllum brachiatum



Agrostophyllum superpositum



Anoectochilus papuanus



Appendicula polystachya



Bulbophyllum fractiflexum



Bulbophyllum leucothysus



Calanthe rhodochila



Calanthe wernerii

Monocots (cont)
ORCHIDACEAE (cont)



Ceratostylis acutifolia



Ceratostylis subulata



Dendrobium cuthbertsoniae



Dendrobium subclausum



Dendrochilum longifolium



Epiblastus basilis



Glomera aurea



Glomera hamadryas

Monocots (cont)
ORCHIDACEAE (cont)



Glossorhyncha tubisepala



Medicalcar bifolium

PANDANACEAE



Freycinetia angutissima



Pandanus brosimos



Pandanus kaernbachii

POACEAE



Nastus longispicula

SMILACACEAE



Smilax calophylla

Monocots (cont)
ZINGIBERACEAE



Alpinia stenobracteolata



Hornstaedtia scottiana



Pleuranthodium tephrochlamys



Riedelia corallina



Riedelia montana

Dicots
ACTINIDIACEAE



Actinidia sp. A



Actinidia stichophylla



Saurauia calyptрата



Saurauia conferta



Saurauia holotricha



Saurauia naumannii

Dicots (cont)
APIACEAE



Mackinlaya schlechteri

APOCYNACEAE



Cerbera floribunda



Cerbera floribunda



Marsdenia sp



Melodinus forbesii

Dicots (cont)
ARALIACEAE



Polyscias ledermannii



Schefflera dentata



Schefflera setulosa

BEGONIACEAE



Begonia randiana



Calophyllum soulattri

Dicots (cont)

CLUSIACEAE



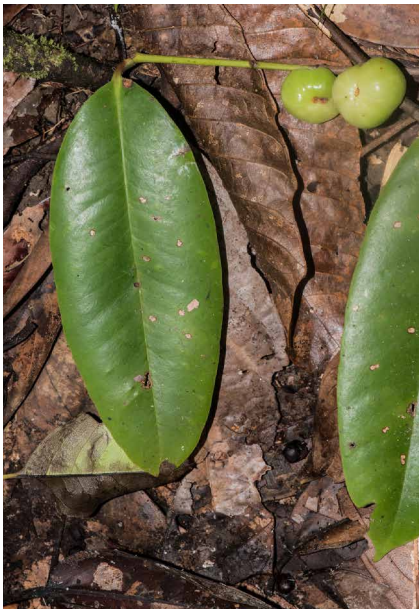
Garcinia hollrungii



Garcinia hunsteinii



Garcinia latissima



Garcinia ledermannii



Garcinia schraderi

CUNONIACEAE



Caldcluvia celebica



Caldcluvia nymanii

Dicots (cont)
CUNONIACEAE (cont)



Pullea glabra



Schizomeria serrata

ELAEocarpaceae



Elaeocarpus sarcanthus



Sericolea arfakensis



Sloanea sogerensis

Dicots (cont)
ERICACEAE



Dimorphanthera brevipes



Dimorphanthera brevipes



Dimorphanthera ingens



Dimorphanthera ingens



Dimorphanthera inopinata



Diplycosia rupicola

Dicots (cont)
ERICACEAE



Paphia sp.



Rhododendron beyerinckianum



Rhododendron christii



Rhododendron macgregoriae

ESCALLONIAACEAE



Polyosma subfoliosa

Dicots (cont)
EUPHORBIACEAE



Codiaeum variegatum



Codiaeum variegatum 1



Euphorbia plumerioides



Homalanthus novoguineensis



Macaranga strigosa

GENTIANACEAE



Fagraea ceilanica

Dicots (cont)
GESNERIACEAE



Aeschynanthus kermesinus



Cyrtandra decurrens



Cyrtandra fuscovellea



Cyrtandra hispida



Cyrtandra sp. A



Cyrtandra wareana

GUNNERACEAE



Gunnera macrophylla

LAMIACEAE



Oxera splendida

Dicots (cont)
LAURACEAE



Cryptocarya apimifolia



Cryptocarya densiflora



Cryptocarya multipaniculata



Cryptocarya schoddei



Cryptocarya xylophylla



Endiandra glauca



Litsea guppyi



Neolitsea sp.

Dicots (cont)
LOGANIACEAE



Neuburgia corynocarpa

LYTHRACEAE



Duabanga moluccana

MELASTOMATACEAE



Astronia feruginea



Astronia ledermannii



Astronia papuana



Medinilla rubiginosa



Medinilla versteegii

Dicots (cont)

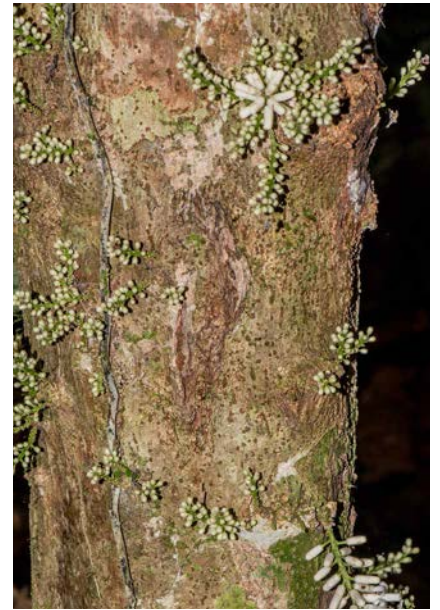
MELIACEAE



Aglaia sapindina



Chisocheton lasiocarpus



Dysoxylum papuanum



Dysoxylum pettigrewianum

MENISPERMACEAE



Stephania japonica

Dicots (cont)
MONIMIACEAE



Kibara laurifolia



Levieria acuminata



Levieria acuminata



Levieria squarrosa



Steganthera ilicifolia

Dicots (cont)
MORACEAE



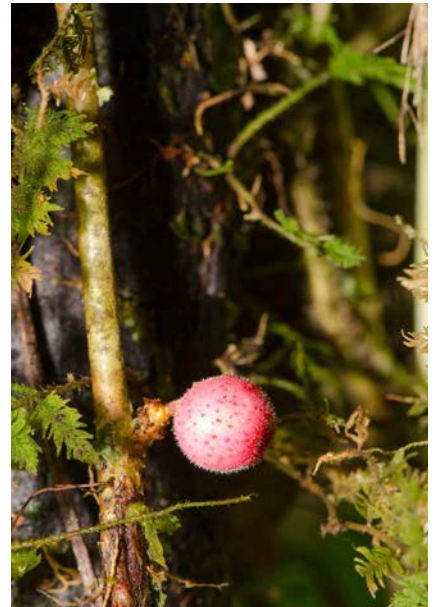
Ficus armitii



Ficus armitii



Ficus cereicarpa



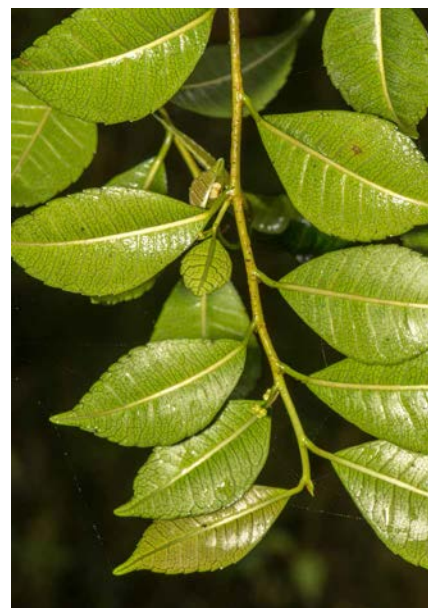
Ficus subulata



Ficus subulata



Ficus wassa



Streblus glaber

Dicots (cont)
MYRISTICACEAE



Horsfieldia hellwigii



Myristica globosa



Myristica globosa



Myristica schleinitzii



Myristica subulalata

Dicots (cont)

MYRTACEAE



Syzygium buettnerianum



Syzygium nemorale



Syzygium nutans



Syzygium stipulare



Xanthomyrtus scolopacina

NOTHOFAGACEAE



Nothofagus grandis



Nothofagus pullei



Nothofagus pullei

Dicots (cont)
PENTAPHYLLACEAE



Ternstroemia britteniana

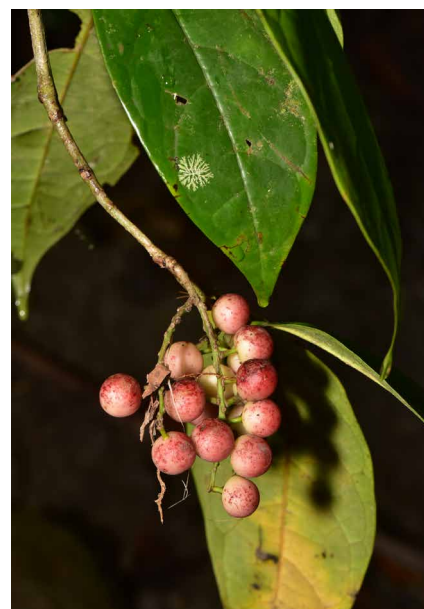


Ternstroemia britteniana

PHYLLANTHACEAE



Ternstroemia cherrei



Antidesma excavatum var. *indutum*



Antidesma excavatum var. *indutum*



Breynia cernua

Dicots (cont)

PIPERACEAE



Piper caninum



Piper macropiper

PRIMULACEAE



Fittingia tubiflora

PITTOSPORACEAE



Pittosporum ramiflorum



Helicia hypoglauca

PROTEACEAE



Helicia latifolia



Macadamia ternifolia

Dicots (cont)
PUTRANJIVACEAE



Drypetes longifolia



Drypetes longifolia

ROSACEAE



Prunus oligantha



Rubus archboldianus



Rubus ferdinandi-muelleri



Rubus moluccanus

Dicots (cont)
RUBIACEAE



Amaracarpus grandiflorus var. *humilis*



Argostemma bryophilum



Gardenia pallens



Hydnophytum microphyllum



Ixora minor



Lasianthus strigosus

Dicots (cont)
RUBIACEAE (cont)



Mussaenda scratchleyi



Psychotria leiophloea



Psychotria leiophloea



Timonius belensis



Uncaria lanosa

RUTACEAE



Acronychia foveata



Acronychia pedunculata

Dicots (cont)
RUTACEAE (cont)



Melicope rubra



Melicope rubra

SALICACEAE



Casearia clutiiifolia

SAPOTACEAE



Planchonella firma



Pouteria densinervia

STEMONURACEAE



Gomphandra papuana



Medusanthera laxiflora

TRIMENIACEAE



Trimenia papuana

Dicots (cont)
URTICACEAE



Cypholophus kerewensis



Elatostema filicinum



Elatostema mongiensis



Elatostema morobense



Pilea cuneata



Pilea melastomoides



Pilea melastomoides



Pilea papuana



Procris grueningii

Dicots (cont)

VITACEAE



Cayratia geniculata



Leea indica



Tetrastigma petrophilum

WINTERACEAE



Tasmannia piperita



Zygogynum argenteum



Zygogynum argenteum



Zygogynum sylvestre

Additional plants found outside plots. Ferns and Lycophytes

ASPLENIACEAE



Asplenium cromwellianum

CYATHEACEAE



Cyathea hornei

MARATTIACEAE



Marattia tafaensis

Conifers. CYCADACEAE



Cycas scratchlyana

Monocots. MARANTACEAE



Phrynium macrocephalum

ORCHIDACEAE



Agrostophyllum spicatum

Additional plants found outside plots. Monocots (cont)

ORCHIDACEAE (cont)



Appendicula biloba



Appendicula dendrobioides



Bulbophyllum clandestinum



Bulbophyllum patella



Dendrobium chrysopeterum



Oberonia drepanophylla

ZINGIBERACEAE



Phreatia micrantha



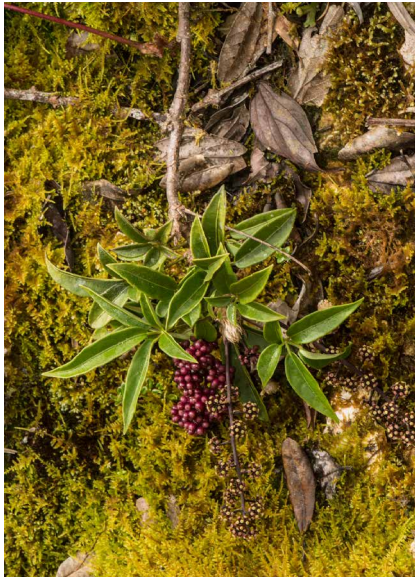
Pristiglottis coerulescens



Alpinia calycodes

Additional plants found outside plots. Dicots

ARALIACEAE

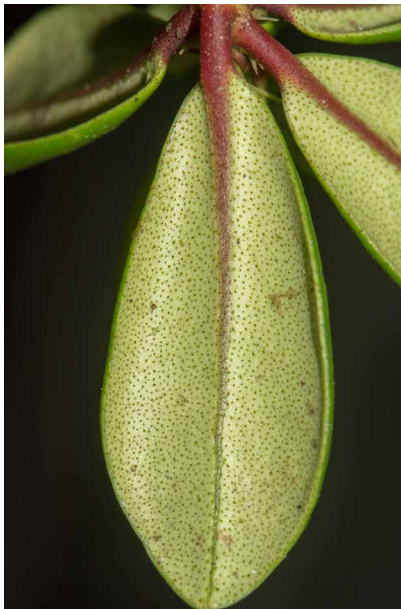


Schefflera pachystyla

ERICACEAE



Rhododendron rubeiniflorum



Rhododendron sp. 1



Vaccinium schoddei

GESNERIACEAE



Cyrtandra schumanniana

LAMIACEAE



Plectranthus scutellarioides

MONIMIACEAE



Levieria beccariana

Additional plants found outside plots. Dicots (cont)

MORACEAE



Ficus irritans



Ficus pungens

MYRTACEAE



Syzygium decipiens

NEPENTHACEAE



Nepenthes maxima

RUBIACEAE



Amaracarpus montisgiluwensis



Schradera ledermannii

URTICACEAE



Cypholophus pachycarpus

FROGS

Stephen Richards and Kyle N. Armstrong



Litoria sp.1 'yellow legs'

Introduction

Papua New Guinea has an exceptionally diverse frog fauna, with nearly 400 species described from the country to date. Many more species await formal description, and expeditions to poorly-documented parts of PNG regularly encounter frog species entirely new to science.

A comprehensively illustrated guide to frogs of PNG is not currently available, and many morphologically similar species are difficult to distinguish in the field. However with careful observation and measurements of features such as body shape, colouration, limb length, presence and extent of webbing between the fingers and toes, and presence and size of discs on the fingers and toes many species can be successfully identified in the hand.

The most diverse group of frogs encountered in the Upstream Project Area is the family Microhylidae. Many members of this group are particularly difficult to identify, with some genera containing multiple extremely similar species. Fortunately, as with almost all frog species, microhylid frogs have unique advertisement calls that distinguish them from all other species.

In PNG frogs of the family Microhylidae do not use streams to breed, instead depositing their eggs on the leaves or in the axils of plants, or under litter on the forest floor. There they hatch directly into froglets without going through a tadpole stage. Because they do not require aquatic habitats to breed this group dominates the frog faunas of karst habitats typical of the Moro and Hides Ridge areas.

A simple key to identifying the major groups of frogs in the Upstream Project Area is presented below. Short illustrated species accounts, including information to help distinguish between similar species and to recognise frogs by their calls, follow. In call figures amplitude = volume and frequency = pitch. These data should permit the identification of frog species encountered to date at PMA3 monitoring sites on Hides Ridge and in the Moro area.

1. a) Extensive webbing between the toes2
b) Toes without webbing or with narrow fringe of webbing4
2. a) Size large (to >100 mm); limbs short; snout blunt; skin granular with large poison glands behind eyes..... Bufonidae (Cane toad, *Rhinella marina*)
b) Not as above3
3. a) Size large (generally >45 mm, but up to ~150 mm); limbs long; snout usually moderately to acutely pointed; fingers without webbing; fingers & toes with relatively small discs.
..... Ranidae (bullfrogs)
- b) Size small to large (<30 mm to >100 mm); limbs short to long; snout usually rounded; fingers with at least basal, and generally with extensive, webbing; fingers & toes with well-developed discs Pelodryadidae [previously named Hylidae] (treefrogs)
4. a) Size tiny (<15 mm) to large (~80 mm); limbs short; toes with at most basal webbing, normally without webbing; finger & toe discs usually well-developed but occasionally poorly-developed or absentMicrohylidae
- b) Size large (to ~75 mm); limbs short; finger and toe discs absent; head extremely broad Limnodynastidae (ground frogs)

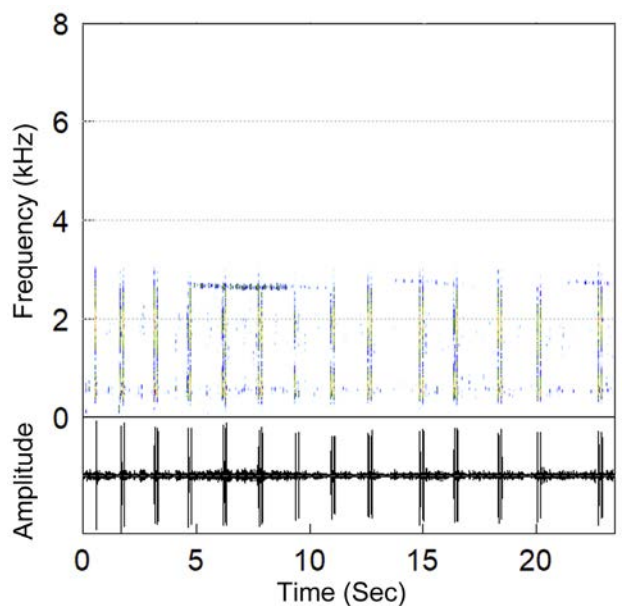
LIMNODYNASTIDAE

Lechriodus aganoposis



This is a large (to ~80 mm) and distinctive ground-dwelling frog with an extremely broad head, raised longitudinal ridges on the dorsum and a well-defined ridge extending posteriorly behind the eye. There is no webbing between the fingers or toes and there are narrow dark bands on the front and hind limbs. A dark lateral stripe extending from the nostril through the eye and tympanum (ear drum) has a distinctive 'wavy' ventral edge. *Lechriodus aganoposis* has a wide distribution in the mountains of New Guinea at elevations above about 1,000 m asl, and it occurs on Hides Ridge in BAA 1 and at KP107 in BAA 2.

Lechriodus melanopyga

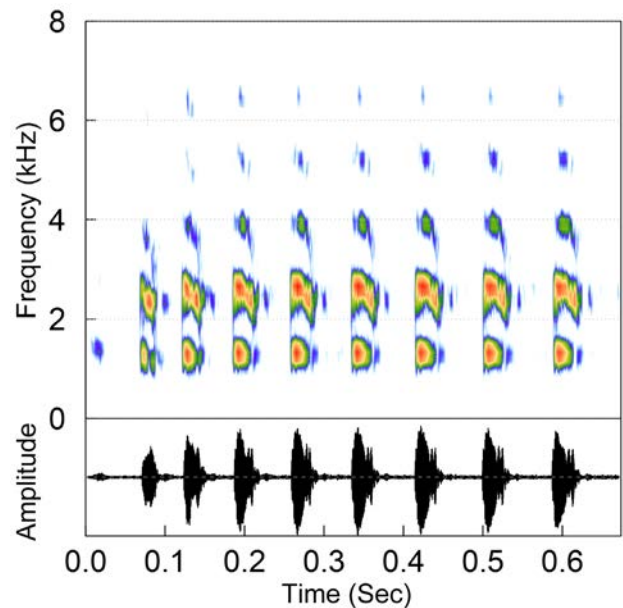


This species is similar to *L. aganoposis*, from which it is distinguished by its smaller size (to ~60 mm), and relatively smooth (vs distinctly ridged) dorsum. Although *L. melanopyga* has a broad altitudinal range that overlaps with *L. aganoposis*, it is generally found at lower altitudes, and the two species have not been found in sympatry in the Kikori basin. The call of this species is a deep but rather melodious 'popping' note uttered singly, in couplets, or in groups of up to five notes for extended periods. Breeding is 'explosive' – males congregate in small pools on the forest floor after heavy rain where they call while floating on the water surface. This species occurs in lowland and hill forests across mainland New Guinea.



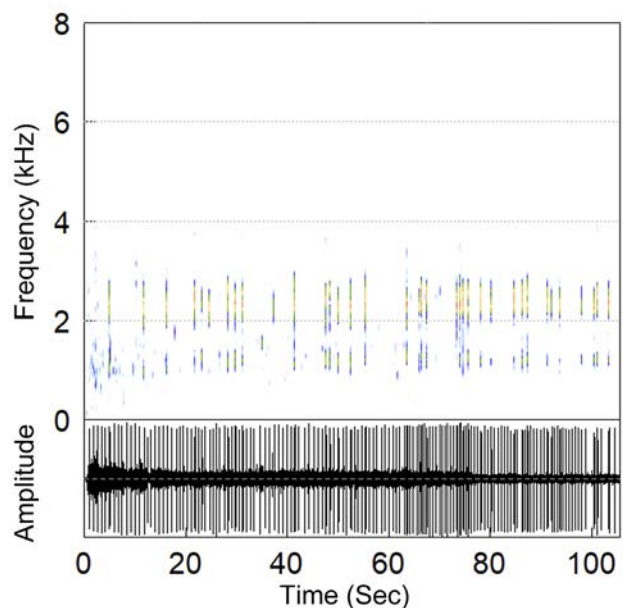
MICROHYLIDAE

Asterophrys slateri



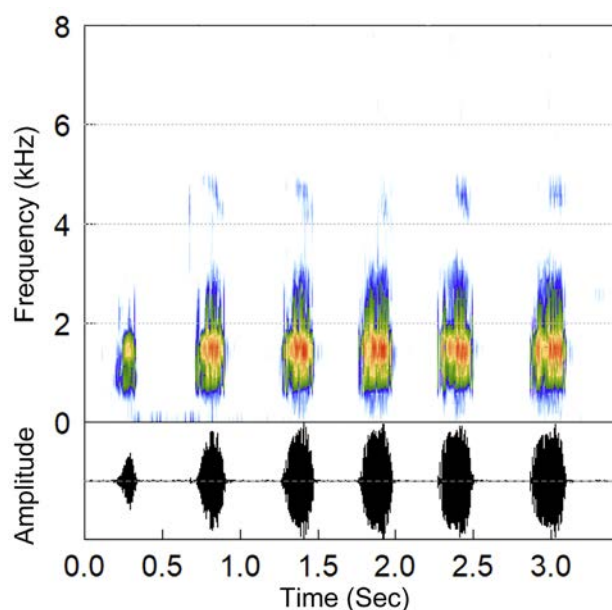
A moderately large (to ~60 mm) and robust arboreal frog with a broad head, short legs and very large, truncate discs on the fingers and toes. This species is rarely seen because it calls from perches high in the forest. Pandanus trees appear to be favourite calling sites. The call is a series of <10 loud, melodious notes produced intermittently at long intervals. *Asterophrys slateri* is known from scattered localities at altitudes between sea level and ~1,500 m asl in southern PNG, and this species was common at Arakubi and around Lake Kutubu.

Austrochaperina derongo



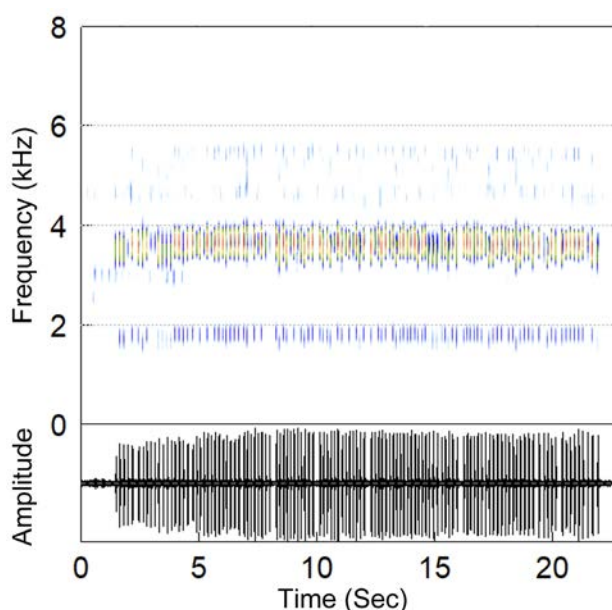
A rather plump grey or brown frog with a narrow snout, that reaches about 50 mm. There are small discs on the fingers and toes. This species is found along small streams where males call from hidden positions among accumulated litter or between rocks, with a very long series of harsh yapping notes. *Austrochaperina derongo* has a wide distribution in the lowlands and mountains of New Guinea, up to about 1,500 m asl. It was found on the lagifu Ridge near Moro.

Austrochaperina laurae



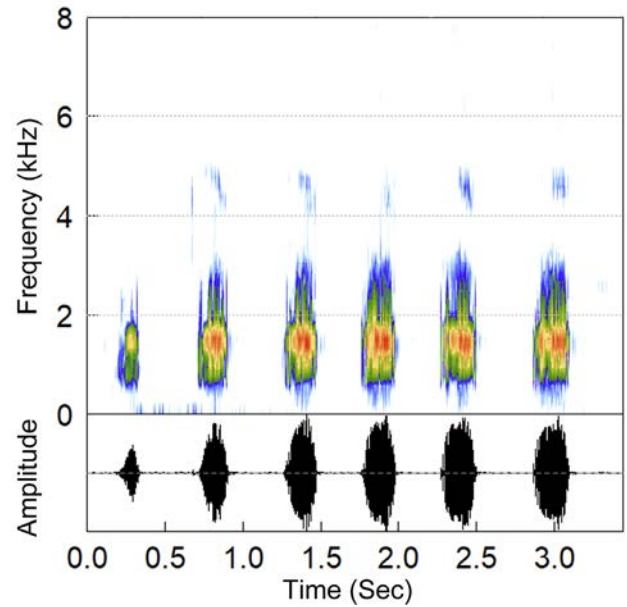
A medium-sized (females to 35 mm), moderately robust frog with a relatively narrow snout, short legs, and small but distinct discs on the fingers and toes. It is a predominantly brown or orange-brown frog and there may be paler flecking on the dorsum and sides. This is a ground-dwelling species and males call from the forest floor with a series of rapid, distinctly pulsed yapping notes produced at a rate of about 7–8 notes/s and lasting ~1.2–3 seconds. *Austrochaperina laurae* is known from a handful of sites in the central mountains of Papua New Guinea, from the Muller Range in the west to the upper Kikori basin in the east where it occurs at KP107 in BAA 2.

***Austrochaperina* sp. 1**



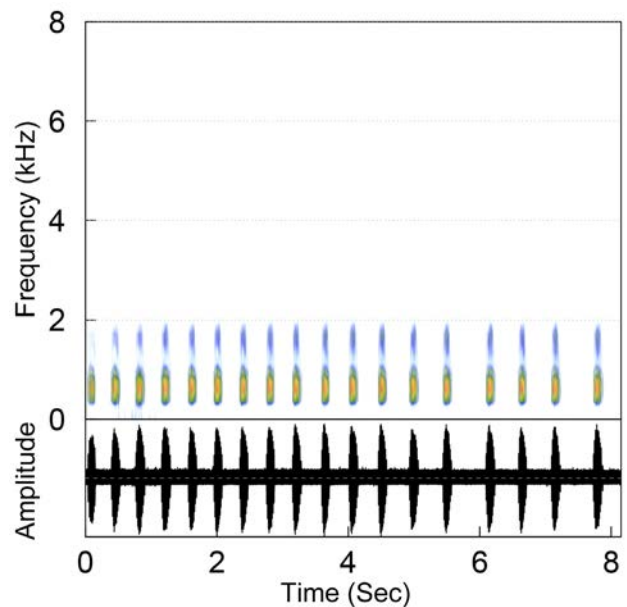
A medium-sized (to ~35 mm) predominantly pale orange-brown frog with a pale, translucent tip of the snout, short legs, and small but distinct discs on the fingers and toes. It is a ground-dwelling species and males call from the forest floor with a series of more than 85 extremely rapid, 'chattering' notes lasting more than 15 seconds. This frog is known from a handful of sites in the central lowlands and mountains of Papua New Guinea, and was encountered near Moro in BAA 2.

Callulops omnistriatus



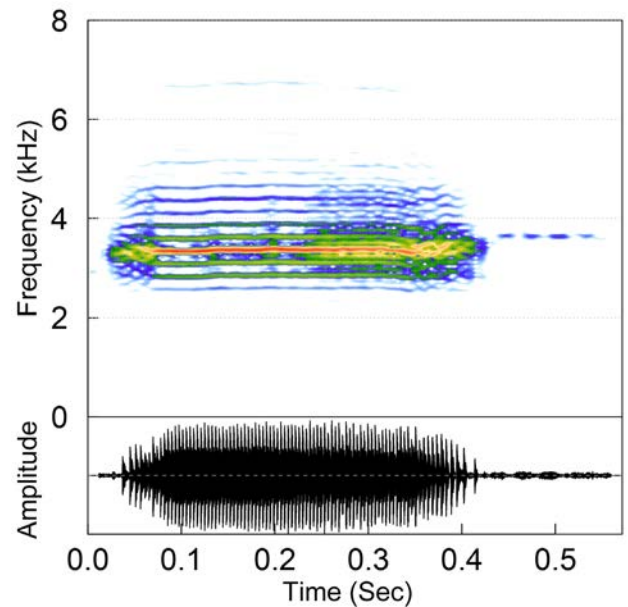
A large (to 67 mm) robust frog with extremely short legs and moderately expanded discs on the fingers and toes. The dorsum is grey-brown and there may be a distinct darker spot in the groin. This species probably lives in holes in the ground, from which it emerges on rainy nights to call from the forest floor with a series of ~5–6 loud, barking notes. It occurs in the hills around Moro and more broadly in the Kikori basin, but has not been encountered at Hides where the altitude is probably too high for this species.

Callulops wilhelmanus



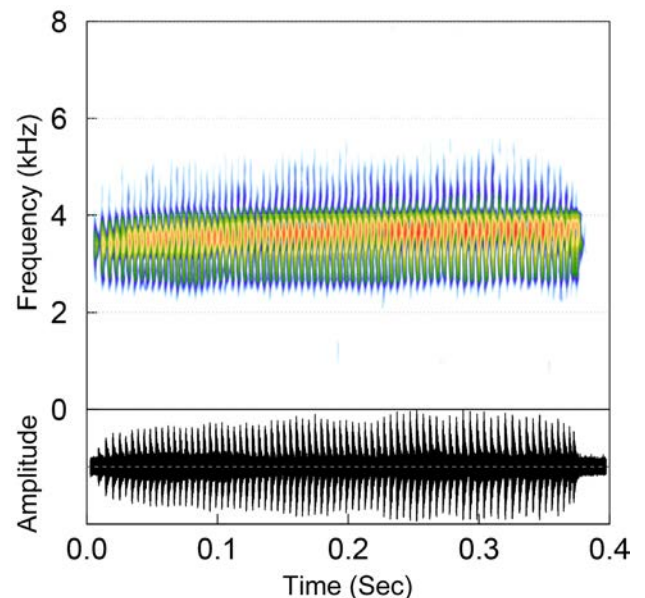
A large (to 60 mm) robust frog with extremely short limbs that resembles *C. omnistriatus*. It can be distinguished from that species by lacking expanded discs on the fingers and toes. The dorsum may be plain brown or mottled. The call is a series of >15 deep, harsh barking notes uttered from holes in the ground, and this species is abundant at higher elevations on Hides Ridge where males called from holes and deep crevices among rock piles and in the steep banks of road cuttings. *Callulops wilhelmanus* has a moderately broad distribution in the mountains of central PNG.

Choerophryne alaindubois



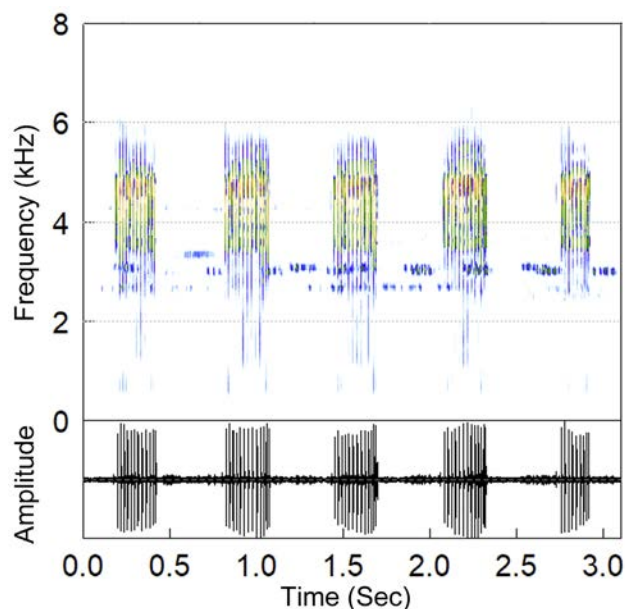
A moderately large (for the genus), shrub-dwelling species (to ~19 mm) with a smooth or at most finely granular dorsum, large finger discs and a call consisting of a single finely pulsed note lasting ~0.4 seconds and sounding like a short 'buzz'. The call is repeated for long periods at a relatively low rate. Morphologically, this species is most similar to *C. murrita* and *C. sp. 1 'arboreal'* (see below). It differs from *murrita* in lacking prominent tubercles across the dorsum and in having a pulsed 'buzz' call (vs a 'peep' call in *murrita*). It is smaller than *C. sp. 1 'arboreal'*, and has a much longer call (~0.4 s vs 0.1 s) that is produced at a slower rate than that species. It also calls from lower perches, normally <2 m above the ground (vs normally >5 m high in *C. sp. 1 'arboreal'*). *Choerophryne alaindubois* is currently known only from the Moro area, so its distribution does not overlap with *C. sp. 1 'arboreal'* which is known only from Hides Ridge.

Choerophryne brevicrus



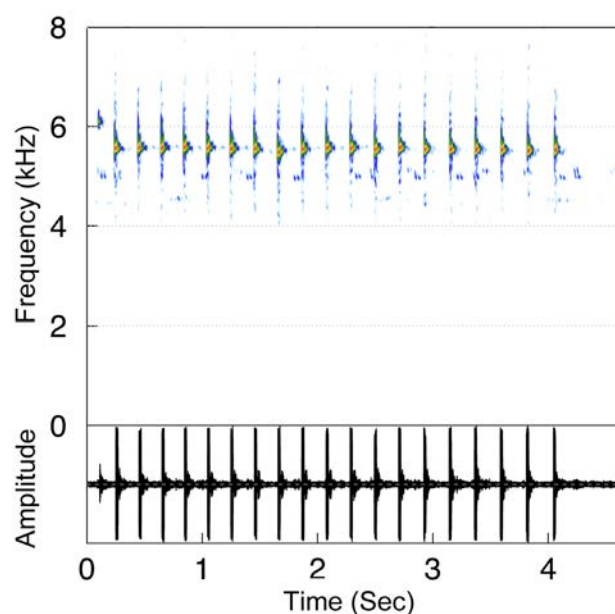
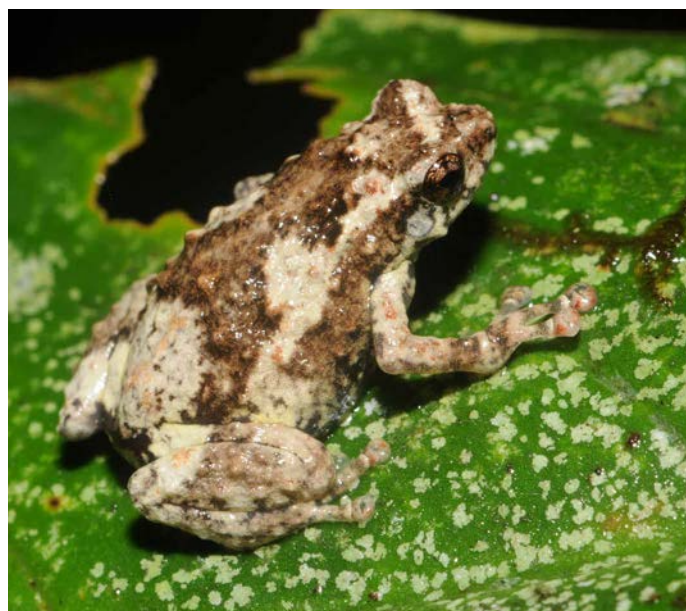
A medium-sized (~14–18 mm) shrub-dwelling member of the genus that can be distinguished from other *Choerophryne* in the area by a combination of its extremely short legs and very rugose dorsum. Calling males can be immediately identified by their unique call which is a single, multi-pulsed note sounding like a short 'buzz' that lasts around 0.5 seconds and is uttered singly or repeated at a relatively low rate. This is a species of montane forests that is known from several sites in the mountains of central PNG. It was present at Hides ridge in BAA 1 but was not detected in BAA 2 and it is unlikely to occur there.

Choerophryne burtoni



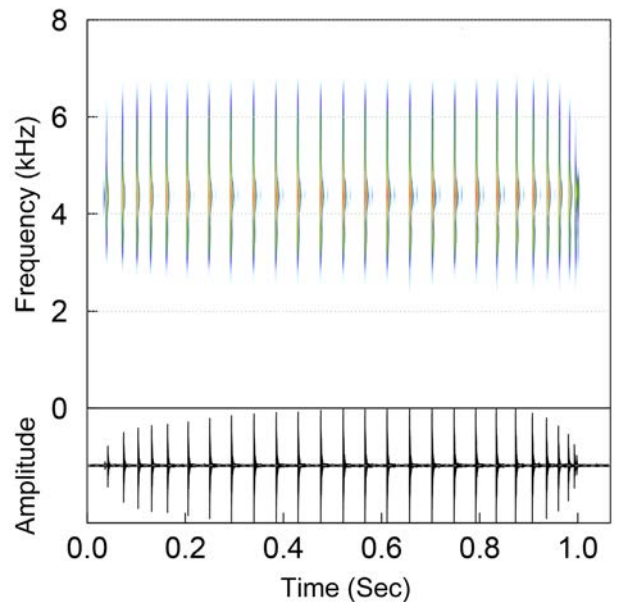
This is a very small (males <13 mm), slender and predominantly brown frog that can be distinguished from other members of the genus in the area by its elongated snout, which distinctly 'overhangs' the lower jaw. It can also be recognized by its call, a series of ~5–6 soft, multi-pulsed notes, uttered singly or in long series separated by at least several seconds: 'creak-creak-creak-creak-creak-creak'. Males call from hidden positions in the litter or among debris from fallen branches and logs on the forest floor, and are extremely difficult to locate. *Choerophryne burtoni* was originally described from Moran near Moro, and is now known from a number of additional sites in the mountains of south-central PNG. It is common at KP107 in BAA 2 where its calls can be heard regularly after rain.

Choerophryne crucifer



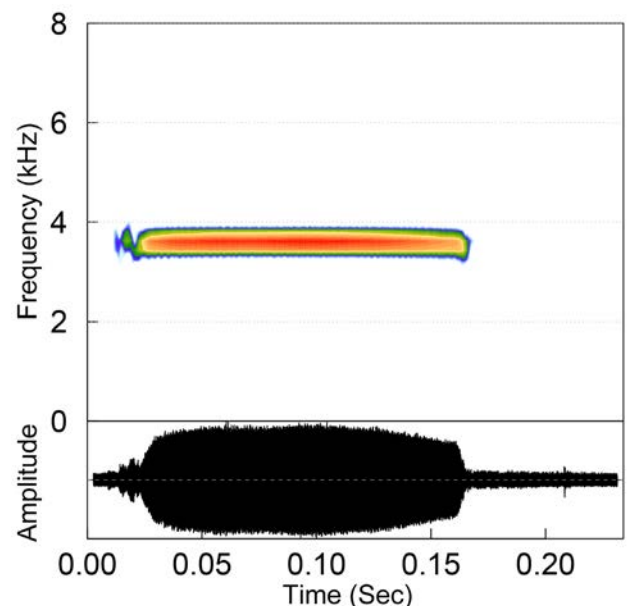
A moderately large (to ~17 mm) arboreal member of the genus that has a dorsum covered with small tubercles and a conspicuous brown hour-glass shaped mark behind the head. The call is a series of ~5–20 musical clicks, produced more slowly than those of *C. multisyllaba* and sounding like 'tink..tink..tink'. This species is known from several sites in the Kikori basin between Iagifu Ridge on the Agogo Range and Wau Creek in the Kikori Delta.

Choerophryne multisyllaba



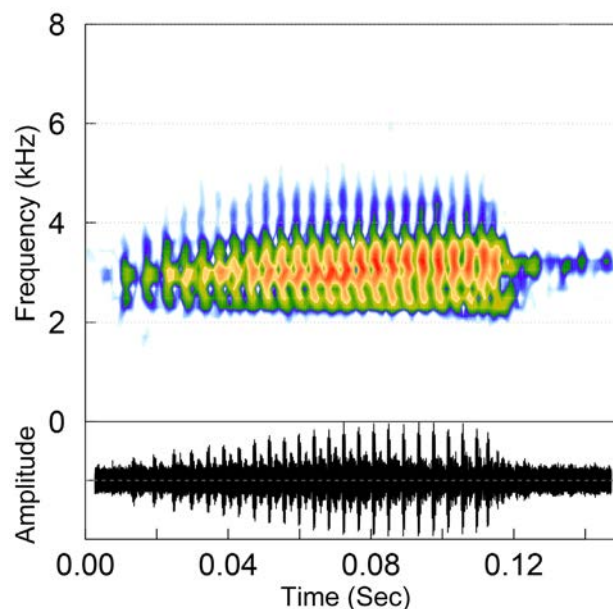
A small (to ~14 mm), shrub-dwelling member of the genus with short legs, large finger discs and scattered small to large tubercles on the dorsum. It has a distinctive call consisting of a series of more than 20 loud and rapid 'clicks' reminiscent of hitting two marbles together. The call lasts for about one second, and the clicks are so close together that it sounds like a short 'rattle'. There is a tendency for the clicks to be produced more rapidly towards the end of the call. No other member of the genus has a call that can be confused with this species which is known from several localities in the mountains of south-central PNG including at KP107 in BAA 2.

Choerophryne murrita



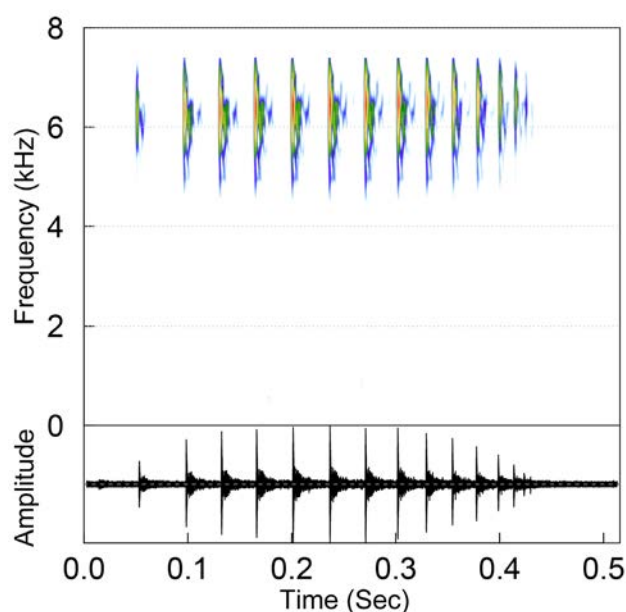
A medium-sized (~14–18 mm), shrub-dwelling member of the genus that can be distinguished from other *Choerophryne* in the area by having scattered but distinct tubercles on the dorsum. It has longer legs and larger finger discs than *C. brevicrus*, and that species also has a more generally rugose dorsum compared to the distinct tubercles on a relatively smooth dorsum exhibited by *C. murrita*. Calling males can be immediately identified by their unique call which is a single musical 'peep' repeated for long periods at a relatively slow rate. This is a species of lower-montane forests that is known from several sites at elevations between about 1,400–2,200 m asl in the mountains of central PNG. It is present at KP107 in BAA 2 but was not detected at Hides Ridge and probably does not occur there.

***Choerophryne* sp. 1 ‘arboreal’**



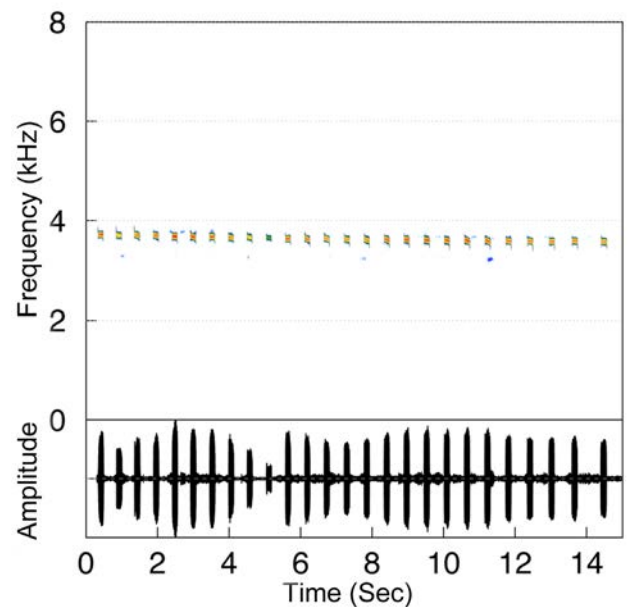
A large (to ~21 mm) arboreal member of the genus that can be distinguished from other *Choerophryne* in the area by its large size, large finger discs, and relatively smooth skin. It has longer legs and larger finger discs than *C. brevircus*, with which it co-occurs on Hides Ridge. Calling males can be immediately identified by their unique call which is a single, finely-pulsed note lasting just ~0.1 second and sounding like a short ‘buzz’ or ‘ank’ that is repeated for long periods. This species’ habitat use may also assist with identification because males were heard calling only from elevated perches > ~5 m above the ground. Only *Choerophryne crucifer* from around Moro calls from similarly elevated positions but it is smaller and has a call comprising a series of musical notes sounding like ‘tink-tink-tink’ (see species account, above). *Choerophryne* sp. 1 ‘arboreal’ was not detected around Moro in BAA 2 and probably does not occur there.

***Choerophryne* sp. 2 ‘tiny’**



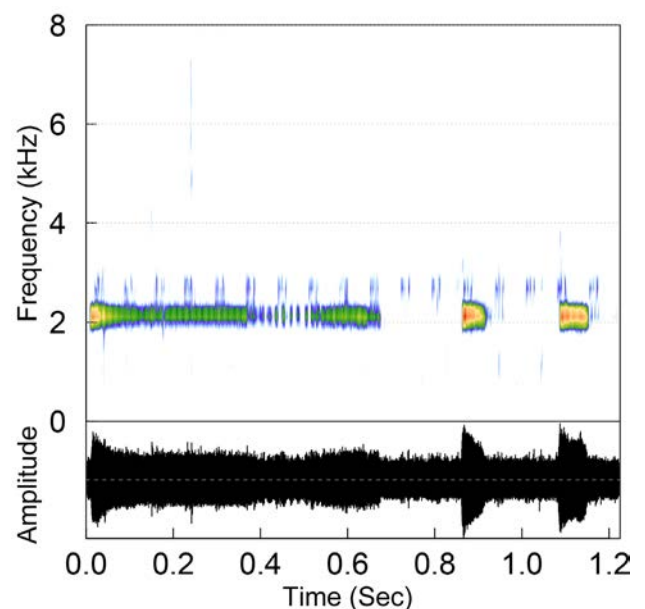
One of the smallest frogs in New Guinea, this tiny (males ~11 mm) undescribed species has extremely short legs, slightly pustulous skin on the dorsum, and a snout that slightly overhangs the lower jaw (but less so than in *C. burtoni*). This species calls from hidden positions in litter on the forest floor and is extremely difficult to locate, having the appearance of a tiny speck of dirt or debris among the litter. The call is a single multi-pulsed note that sounds like a short series of rapid, high-pitched clicks and is often repeated for long periods. Unlike most other frogs encountered in the Kikori basin, *Choerophryne* sp. 2 ‘tiny’ appears to call mostly during the day, although it was also heard calling at night on rare occasions. This species is currently known only from Hides Ridge and from one additional site in the mountains of south-western Enga Province.

Cophixalus wempi



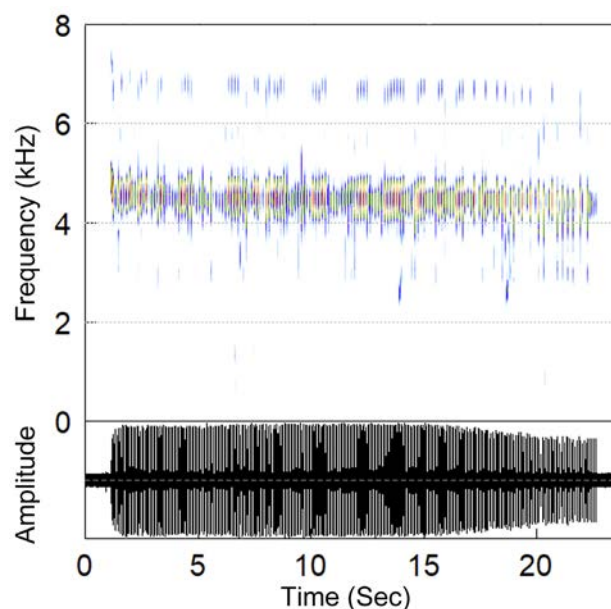
A small (to ~19 mm), shrub- or moss-dwelling frog with tubercular skin, that can be distinguished from all other frog species in the area by its small size and the presence of elongated conical tubercles on the limbs and above the eyes. The call is a series of 25–35 musical peeping notes lasting about 10–20 seconds. *Cophixalus wempi* was described in 2010 from specimens collected in the Moran area and the Agogo Range near KP107. It remains known only from these two locations at elevations between 1,300 and 1,800 m asl. Specimens similar to this species from Arakubi and Lake Kutubu are less tubercular than those from KP107 but have similar calls and are currently being compared using DNA studies.

***Cophixalus* sp. I ‘musical call’**



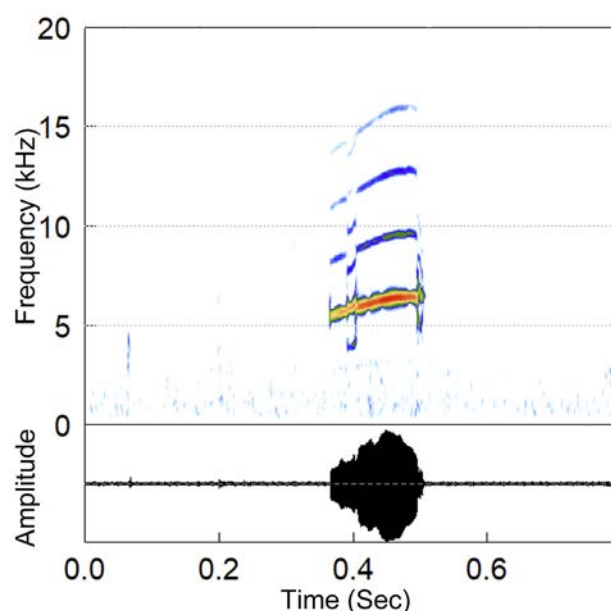
A medium-sized (to ~35 mm), mottled green and brown shrub-dwelling species with low ridges along the dorsum and long, slender fingers and toes with broadly expanded terminal discs. The advertisement call is a series of ~3–5 musical peeping notes in which the first note is drawn out so that it is 3–4 times longer than subsequent notes. This frog is similar to *C. caverniphilus*, a species currently known only from the Muller Range, so DNA comparisons with that species are being undertaken to confirm its status. This species was previously known from several sites in the upper Kikori basin above about 1,000 m asl and appears to be common at KP107 in BAA 2.

***Cophixalus* sp. 2 ‘Tiny A’**



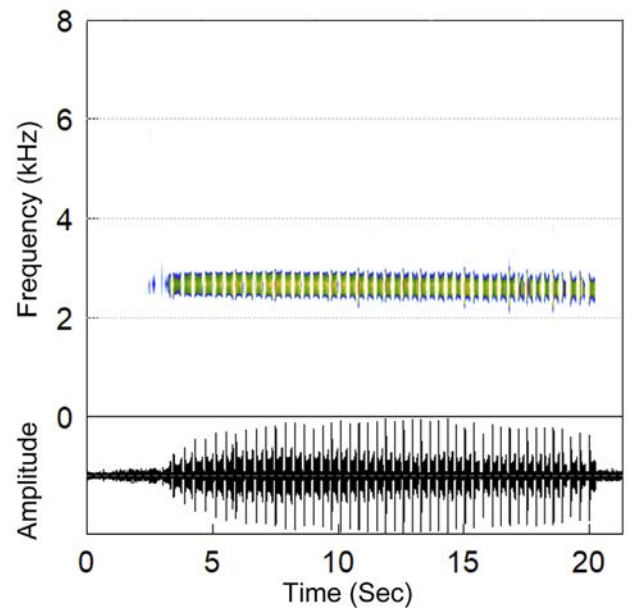
A very small (14 mm) , shrub-dwelling frog with a dark face ‘mask’, distinct ridges on the dorsum and short limbs with slightly expanded discs on the fingers and toes. This is one of two genetically distinct but morphologically similar species of tiny *Cophixalus* found at KP107 in BAA 2. Three call types attributable to these two species were recorded. Two of these were heard only where *Cophixalus* sp. 2 ‘Tiny A’ was found, and so are tentatively associated with this species. One of these calls (illustrated) is an extremely long series of rapidly repeated, high-pitched clicking notes produced at a rate of ~14/second for more than 20 seconds and the first note in each call is distinctly longer than the remainder. The other call type has a similar structure but is shorter.

***Cophixalus* sp. 3 ‘Tiny B’**



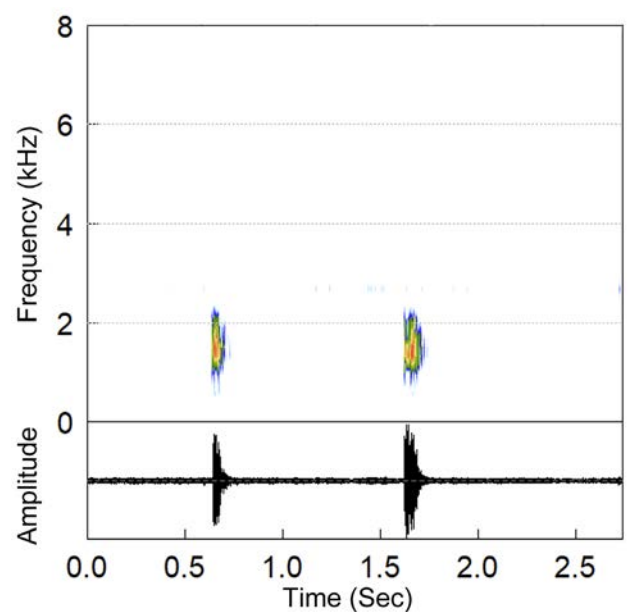
A very small (15 mm) shrub-dwelling frog with a dark face ‘mask’, distinct ridges on the dorsum and short limbs with slightly expanded discs on the fingers and toes. The colour pattern on the back is highly variable, and there may be a mid-dorsal stripe or this may be lacking. This species is difficult to distinguish morphologically from *Cophixalus* sp. 2 ‘Tiny A’, but the two species are genetically distinct. Several individuals of *Cophixalus* sp. 3 ‘Tiny B’ were observed producing single-note calls, and frogs producing single-note calls were never observed producing multi-note calls such as those attributed here to *Cophixalus* sp. 2 ‘Tiny A’.

***Cophixalus* sp. 4 ‘peeping call’**



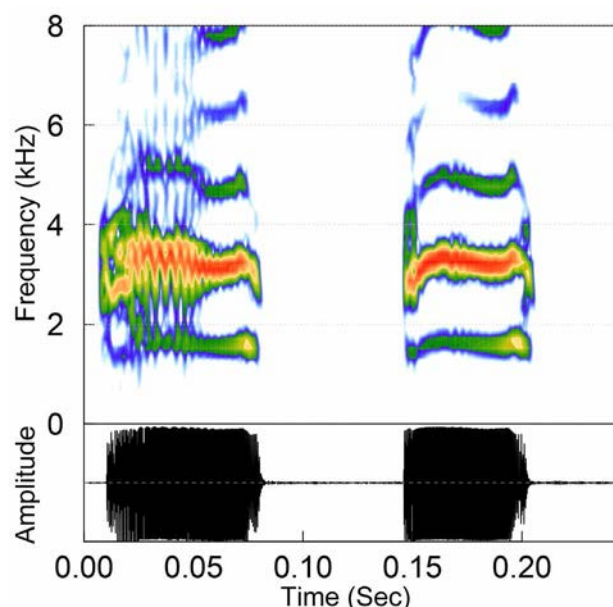
A medium-sized (to ~35 mm), shrub-dwelling frog with long, slender fingers and toes and broadly expanded terminal discs. This species is very similar to *Cophixalus* sp. 1 ‘musical call’, and the two species are difficult to distinguish morphologically. However the two species are genetically distinct, and their advertisement calls are different. The call of *Cophixalus* sp. 4 ‘peeping call’ consists of a very long series of musical ‘peeps’ in which the first note is not substantially longer than subsequent notes. It is known only from the upper Kikori basin and it occurs at KP107 in BAA 2.

***Cophixalus* sp. 5 ‘loud grunter’**



A large (> 40 mm) member of the genus with a rounded snout, long fingers and toes, and broadly expanded terminal discs. This undescribed species is known only from Hides Ridge, and possibly from nearby Mt Sisa, where males call from tree holes high in the forest canopy. The call is one or more (most commonly 1–2) harsh, barking notes.

***Copiula* sp. I '2-note call'**

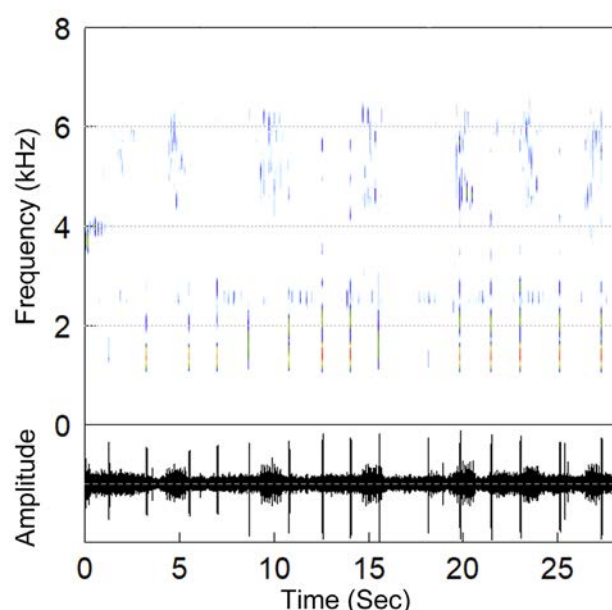


A moderate-sized (~35 mm), rather plump ground-dwelling species with a narrow snout and a dark spot above the groin. The advertisement call is a series of harsh 'barking' notes produced in couplets, or occasionally triplets. This species is undescribed but is known to occur at several other sites to the west of the Kikori basin. It was common in forest at Arakubi.

***Hylophorbus* spp.**

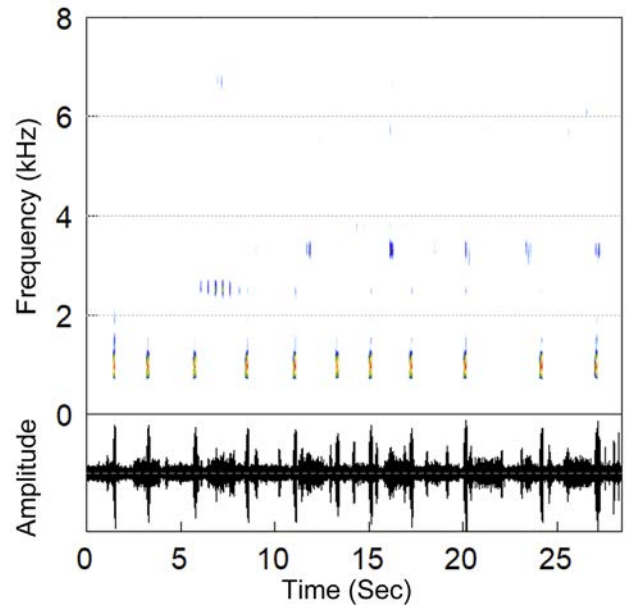
DNA barcoding confirms the presence of three species of this taxonomically difficult genus, two in BAA 2 (two at KP107 and one of these at Arakubi) and one in BAA 1. The species in BAA 1 at Hides Ridge is *H. richardsi*. Both species in BAA 2 are probably undescribed, and comparisons of their DNA and calls with other *Hylophorbus* populations in the Kikori basin and further afield are under way to confirm their status.

Hylophorbus richardsi



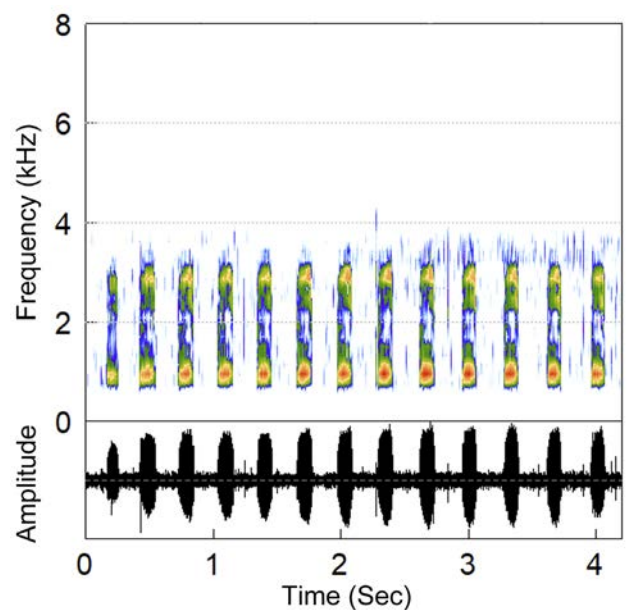
This is one of the smallest species in the genus, not exceeding 25 mm. It is a nondescript brown or reddish-brown frog, sometimes with darker blotches on the dorsum. *Hylophorbus richardsi* is a terrestrial species, and males call from hidden positions in litter on the forest floor with a long series of soft, slowly-repeated and high pitched notes: 'ank....ank'. It is a species of wet montane forests in central and western PNG, and was found at lower elevations (~2,200 m asl) on Hides Ridge.

***Hylophorbus* sp. 1. ‘slow call’**



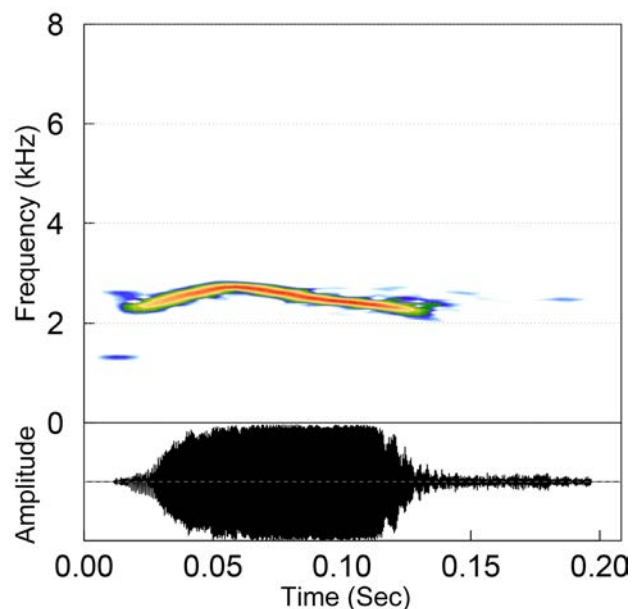
A moderately large (to at least ~35 mm), ground-dwelling member of the genus. This is a slender frog with smooth skin, long fingers with small but distinct terminal discs, and a dark spot above the groin. The call is a slowly repeated series of honking notes sounding like ‘ank...ank...ank...’, uttered at ~1.5–4 second intervals for more than 30 seconds. Morphologically, this species is difficult to distinguish from *Hylophorbus* sp. 2 ‘fast call’ but the two species are genetically distinct and have different calls. This species was found at KP107.

***Hylophorbus* sp. 2 ‘fast call’**



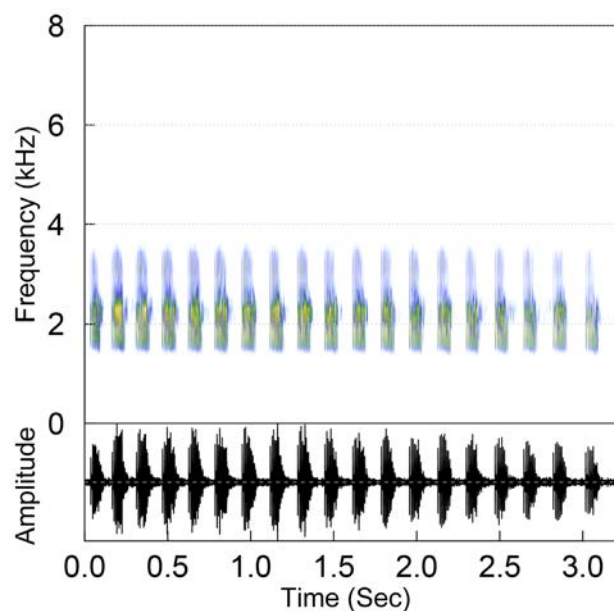
A large (to ~36 mm), ground-dwelling member of the genus that is difficult to distinguish morphologically from *Hylophorbus* sp. 1. ‘slow call’. Like that species it is a slender frog with smooth skin, long fingers with distinct terminal discs, and a dark spot above the groin. The call is a rapidly produced series of ~8–13 ‘ank..ank..ank’ notes lasting less than five seconds. Calls of this species were heard at both KP107 and Arakubi.

Liophryne schluginhaufeni



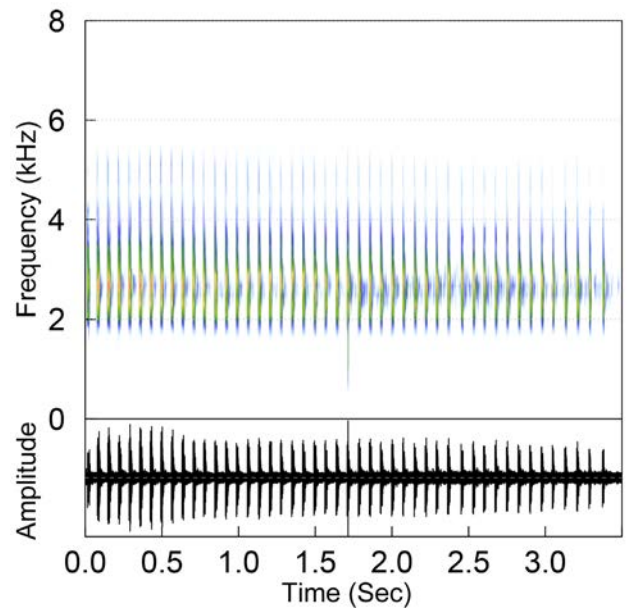
A moderately large (45 mm) ground-dwelling frog with a broad head, rather angular snout and a pair of narrow raised folds on the dorsum shaped like ><. The call is a series of 1–10 loud, musical chirps, with long intervals of silence between calls. This species has a wide distribution in the lowlands and foothills of PNG. It occurs at Arakubi and around Lake Kutubu.

Oreophryne anamiatoi



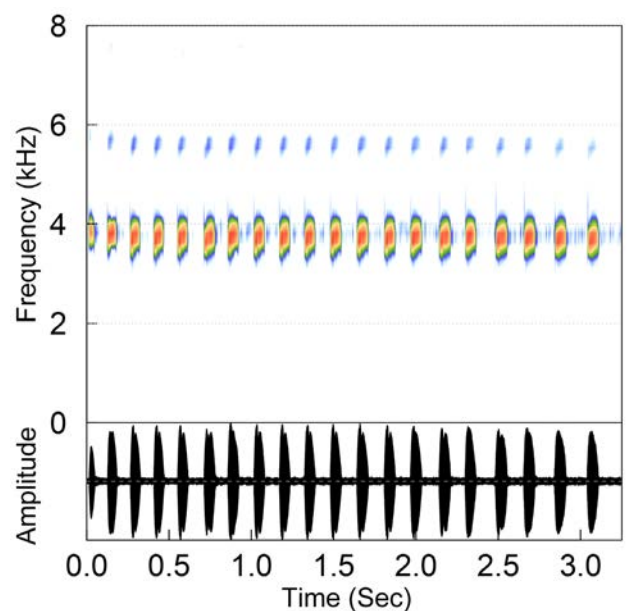
A moderately large (to ~30 mm), shrub-dwelling member of the genus with an extremely variable back pattern, a dark face mask and large discs on the fingers and toes. The call is a loud 'rattle' or 'cackle' lasting about 2–3 seconds and consisting of ~15–20 distinctly pulsed notes. This species is known from several localities in Southern Highlands and Hela Provinces, and it is frequently encountered at lower elevations on Hides Ridge.

Oreophryne flavomaculata



This recently described (Gunther & Richards 2016) arboreal and shrub-dwelling species is a medium-sized member of the genus (to ~ 27 mm) with a variable colour pattern, large eyes, and large yellow spots in the groin. Males produce a loud rattling call lasting more than two seconds. It is known only from Gobe Ridge and the Agogo Range, and occurs at both KP107 and Arakubi.

Oreophryne notata

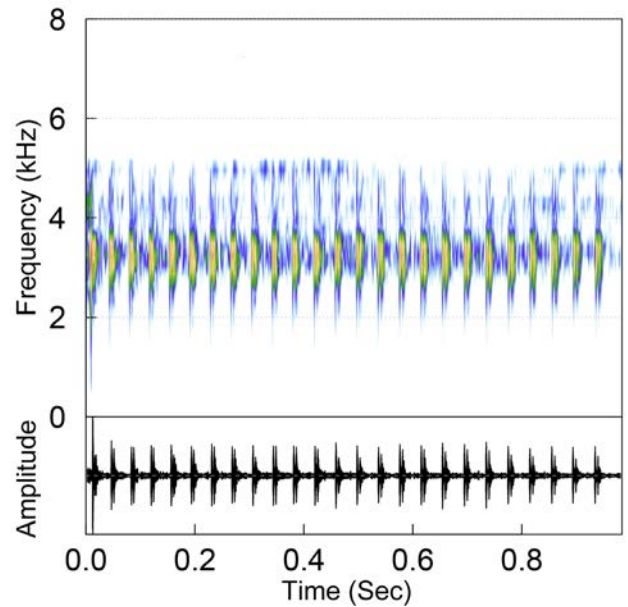


This is a small (<18 mm) arboreal and shrub-dwelling frog with a distinct pale, upturned 'U'-shaped mark on the upper lip. The male produces a rapid series of up to 20 loud 'peeping' notes lasting around three seconds. *Oreophryne notata* is found in mossy high-elevation forest in south-central PNG and this species is abundant on Hides Ridge. Calls reminiscent of this species were also heard at both KP107 and Arakubi but the status of this lower elevation population requires confirmation.

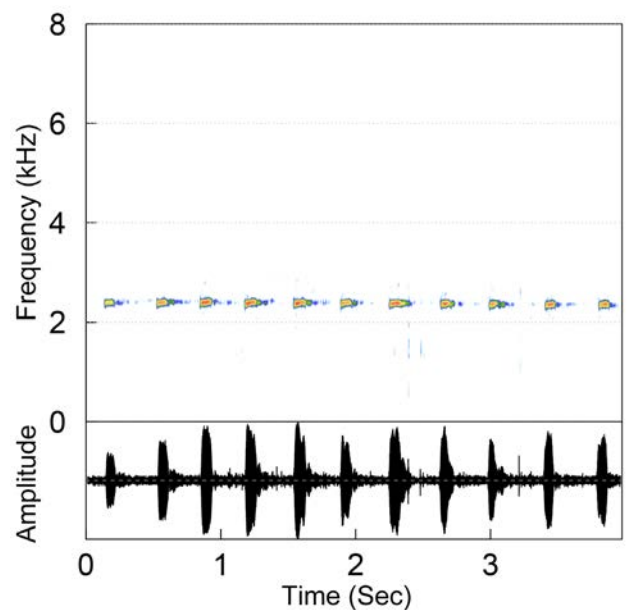
Oreophryne oviprotector



A medium-sized (to ~ 27 mm) shrub-dwelling member of the genus, *O. oviprotector* has large eyes, a conspicuous lime-green bar between the eyes and, usually, a longitudinal lime green stripe on the sides. The call is a short rattle lasting ~1 second and containing 23–26 notes. This species has a broad distribution in the lowlands and foothills of southern New Guinea and is common at Arakubi.

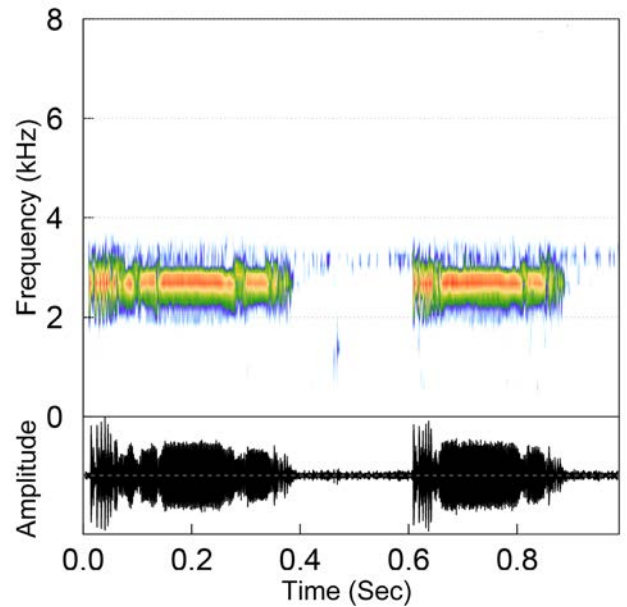


Oreophryne pseudunicolor



This recently described (Gunther & Richards 2016) arboreal species is a moderately large (to ~35 mm) arboreal member of the genus with short limbs, short fingers and toes, and exhibiting dense pale stippling (and occasionally patches of tan) on the dorsum. The call is a series of ~8–12 loud peeping notes, produced more slowly than those of *O. notata*, and lasting for around four seconds. It is known from several sites in the lowlands and foothills of the Kikori basin, and it was found at KP107 and Arakubi.

***Oreophryne* sp. 1 ‘rasping call’**



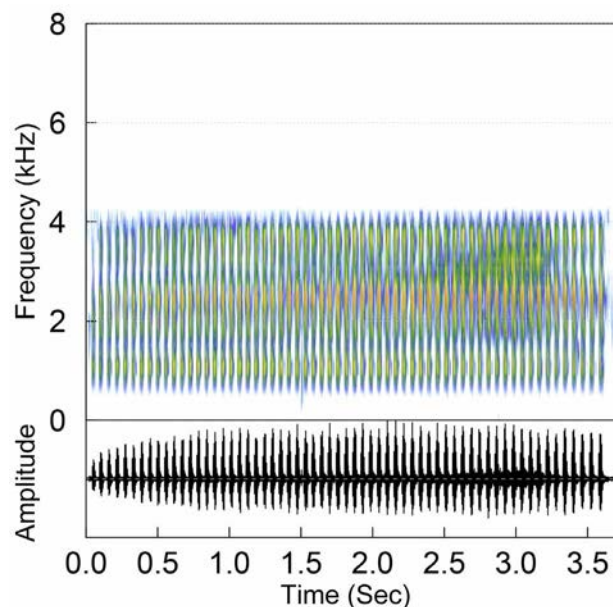
A medium-sized (to ~30 mm) shrub-dwelling *Oreophryne* species with long, slender fingers, toes with broadly expanded discs, and often with darkly-pigmented tubercles on the dorsum that produce a ‘spotted’ appearance. The advertisement call is a series of harsh rasping or buzzing notes, often produced in couplets and lasting up to several minutes. This species is known from several sites in the Kikori basin below about 1,000 m asl, and on the Agogo Range it occurs at Arakubi.

***Oreophryne* sp. 2 ‘ratchet call’**



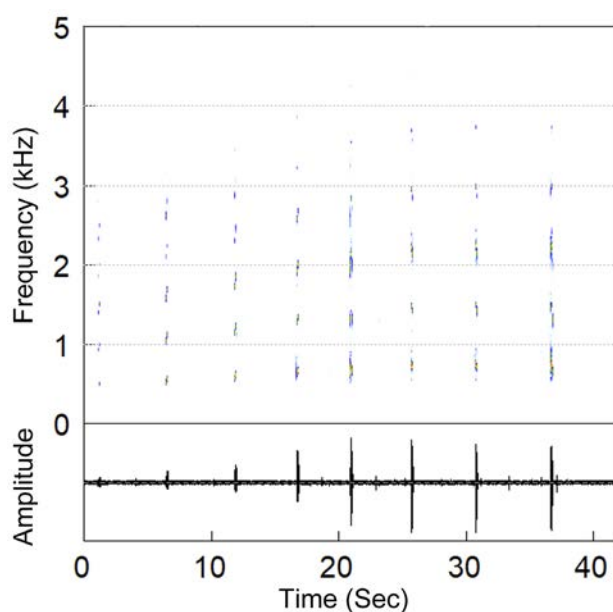
A medium-sized (a single specimen 23 mm) arboreal member of the genus with a distinctly rugose dorsum, a dark face mask, and long fingers and toes with enlarged discs. A call resembling the rapid winding of a ratchet that was heard frequently from high in the trees at KP107 and less commonly at Arakubi, is tentatively assigned to this species. However *Oreophryne* sp. 2 was not observed calling and it is possible that the species producing the ‘ratchet call’ has not yet been captured.

Sphenophryne cornuta



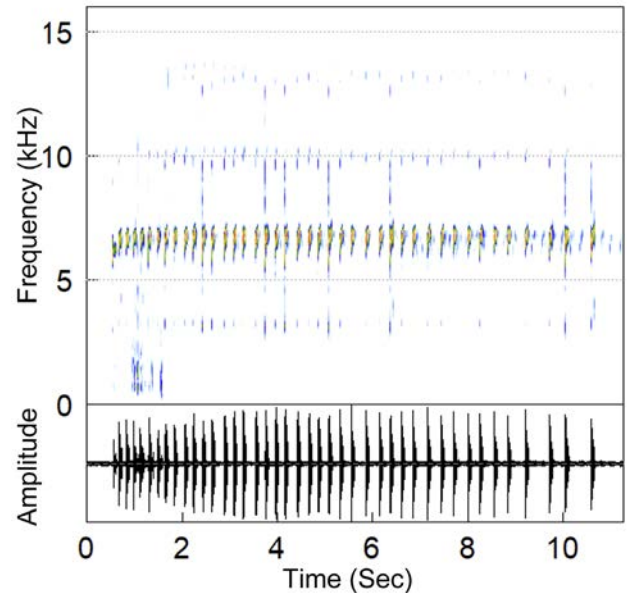
A moderately large (to ~40 mm) and slender shrub-dwelling frog that is easily distinguished from other frogs in the region by its angular, pointed snout, long legs with large discs on the fingers and toes, and the presence of a conspicuous, elongated spike above each eye. Call sequences start with a series of intermittent 'pop' sounds followed by 1–3 long 'rattling' calls each containing >60 rapidly-produced multi-pulsed notes lasting several seconds. Males carry their babies around on their backs for a short period after they hatch. This species is widespread in the lowlands and foothills of mainland New Guinea.

Xenorhina sp. I 'slow call'



A moderately large (~45 mm) frog with a broad body, extremely narrow snout and small eyes. This terrestrial species calls from within the litter on the forest floor, or from a small hole in the humus, with a series of melodious 'hoots'. The call is unusual because the volume and pitch of each note normally increases during the call sequence. This species has a broad distribution in the lowlands and foothills of the Kikori basin, and was heard calling at Arakubi after rain.

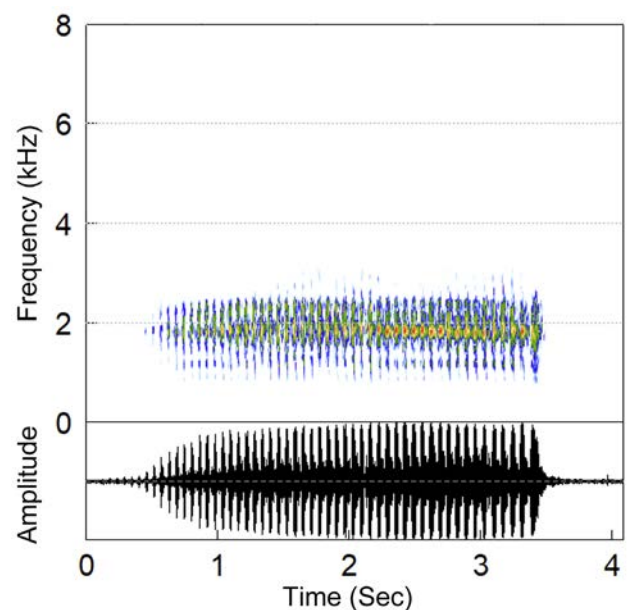
Microhylid new genus and species



This tiny species (SVL<13 mm) is new to science and is known only from forest at Arakubi in BAA 2 and around Lake Kutubu, where it lives in litter on the forest floor. It can be distinguished from all other frogs in the region by a combination of its extremely small size, narrow tips on the fingers (without expanded discs), narrow snout and distinct black face and black stripe extending from behind the eye to above the groin. The call is a series of rapid, high-pitched 'chirping' notes lasting around 10 seconds. DNA barcoding revealed that this species probably warrants placement in a new genus of microhylid frogs distinct from all others known in New Guinea.

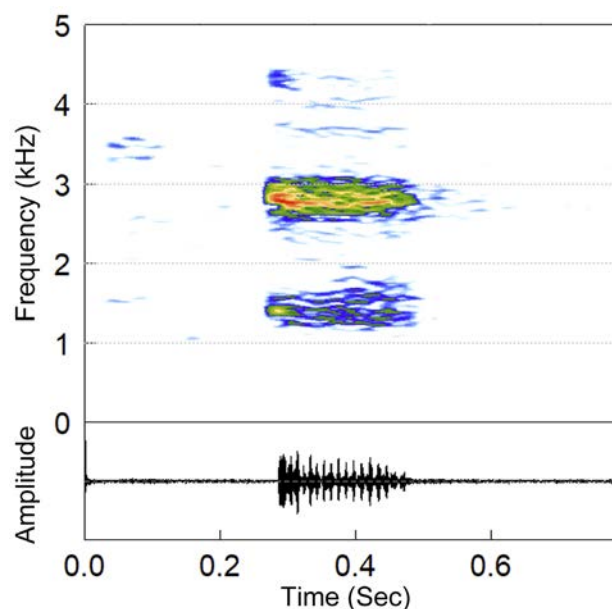
PELODRYADIDAE (PREVIOUSLY HYLIDAE)

Litoria amboinensis



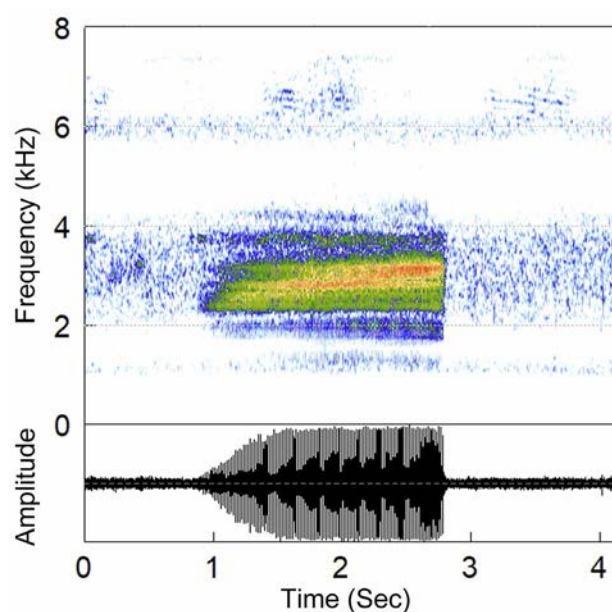
A moderately large treefrog (to ~65 mm) with extensive webbing between the fingers and toes, a diamond-shaped pupil, and pale creamy yellow and dark markings on the hidden parts of the thighs. The colour is variable, and the same individual can change from very pale to dark brown, sometimes with small green flecks. *Litoria amboinensis* is a widespread species that is most commonly found near forest pools after rain, and it also occurs in heavily disturbed habitats; it has been found around Moro. The call is a loud chuckle lasting around 3–4 seconds that is similar to the call produced by *L. darlingtoni*.

Litoria arfakiana



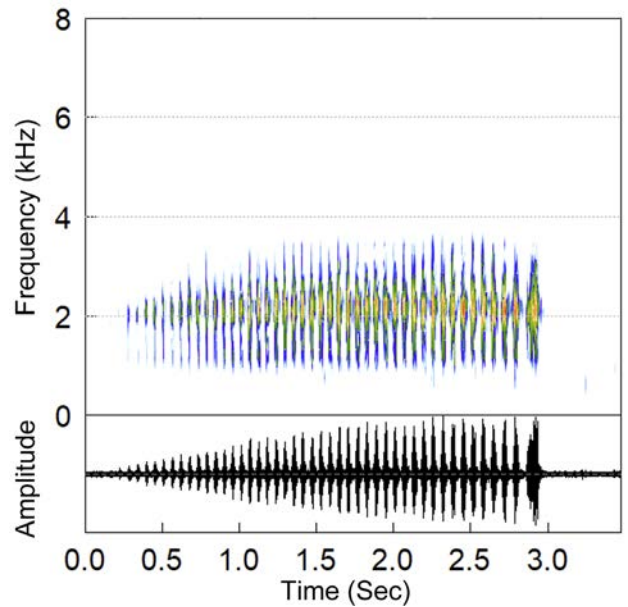
A moderately large treefrog (to ~65 mm) with little or no webbing between the fingers, a sharply pointed snout and a small spike on each heel. The colour is extremely variable, ranging from green to brown, and may be uniform or have contrasting patches of colour. This species is found along rocky mountain streams where males call from elevated perches in trees with a loud, distinctly pulsed call that has a 'ringing' quality and lasts about 0.2 seconds. It occurs on several streams near Moro, and elsewhere has a broad distribution in the mountains of southern New Guinea.

Litoria auae



This attractive little frog (to ~40 mm) is normally bright green dorsally, sometimes with scattered pale yellow spots. The fingers and toes are extensively webbed, and there is a narrow pale line extending along the edge of the snout from the eye to the tympanum. It breeds in swamps, ponds and even roadside ditches where males call from the ground or low vegetation with a single, distinctly pulsed and drawn out 'moaning' note: 'waaaaaa'. *Litoria auae* is widespread in the lowlands and foothills of southern New Guinea and occurs in the vicinity of Moro.

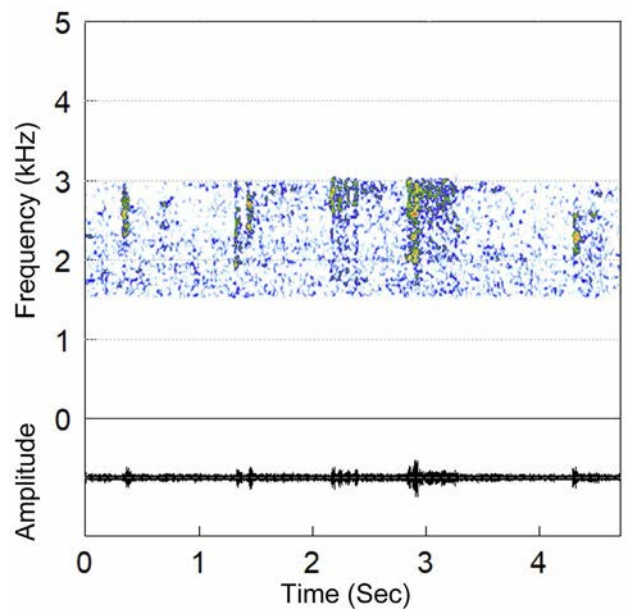
Litoria darlingtoni



This species is similar to *L. amboinensis* (see above) from which it can be distinguished predominantly by its smaller size (to ~55 mm) and in having more strongly contrasting yellow and black markings in the hidden parts of the legs. This species replaces *L. amboinensis* at higher altitudes in New Guinea, and it is abundant around HGCP at the base of Hides Ridge where males call from ponds with a loud chuckle lasting ~3 seconds.

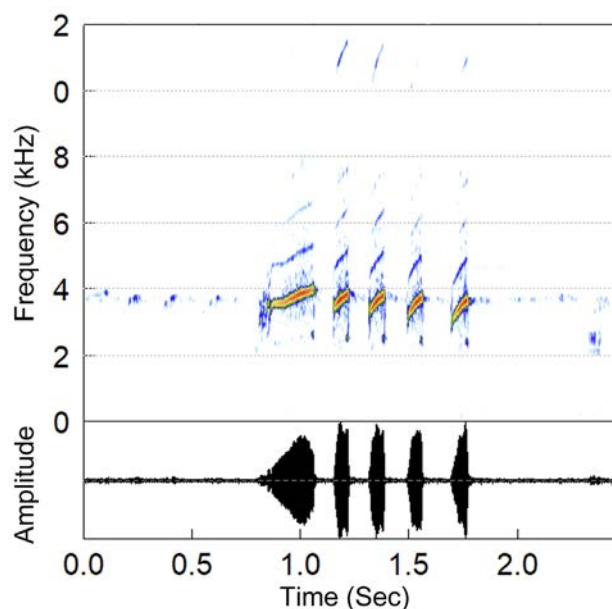


Litoria eucnemis



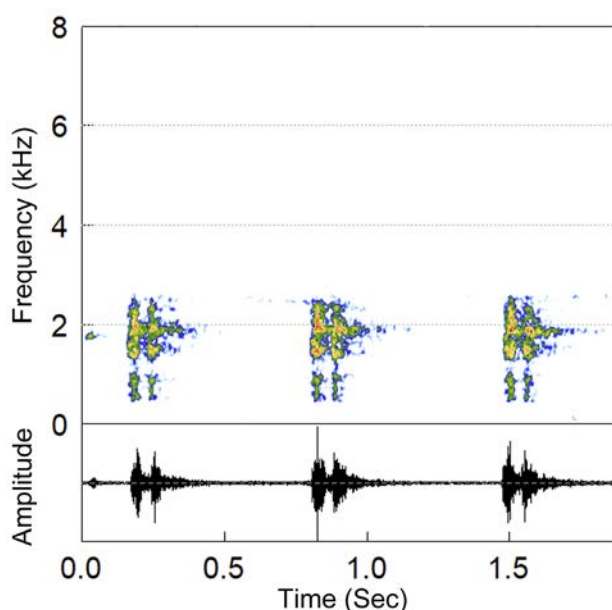
A large treefrog (females to ~70 mm) with extensively webbed fingers, well developed crenulated (wavy) ridges along the outside edges of the limbs, and a large pointed spine on each heel. The colouration is extremely variable, ranging from predominantly brown to predominantly green, often with irregular mottling of both colours across the dorsum. *Litoria eucnemis* breeds in slow-flowing streams and seepages, where males call from low shrubs with a soft rather guttural 'wa-a-a-a, wa-a-a-a, wa-a-a-a'. This is a very widespread species in the lowlands and foothills of New Guinea, and it occurs around Moro but not at Hides Ridge.

Litoria havina



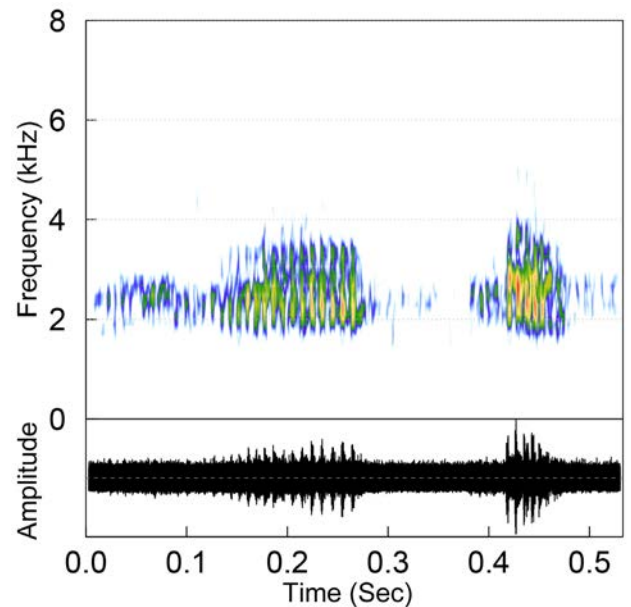
A moderately small (to ~35 mm) treefrog with a uniformly green dorsum and a short but distinct 'rostral spike' on the tip of the snout in the male (absent in the female). This species breeds in ponds and ditches, where males call from low vegetation with a series of ~1–6 melodious whistling notes. Eggs are glued to leaves above the pond and tadpoles drop into the water when they can swim. The tadpole is strikingly coloured in black and gold. *Litoria havina* has a broad distribution in southern PNG and is common in the foothills of the Kikori basin.

Litoria infrafrenata



This is one of New Guinea's largest native frogs, and females can exceed 120 mm. *Litoria infrafrenata* is a slender species that is normally bright green dorsally but may change to dark greenish brown. It occupies both forest and urban environments and breeds in ponds and swamps, where males call from elevated perches such as banana plants with a very loud series of slowly repeated two-part barking notes. They may also produce a short series of more rapidly repeated notes. This species has a very wide distribution in the lowlands and foothills of New Guinea, and is common around Lake Kutubu.

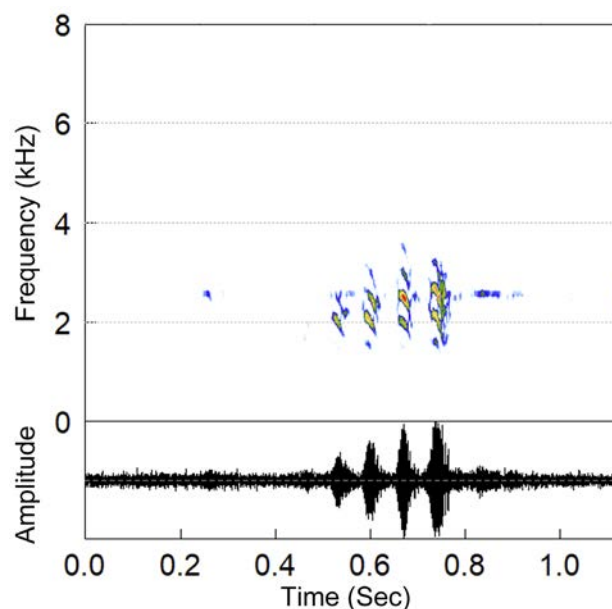
Litoria iris



A moderately small (males to ~35 mm) and slender treefrog with a variable back pattern that is normally green or green with brown markings, and the dorsum is often speckled with darker flecks and larger spots. Rare individuals may be brown or brown with green markings. There are always striking violet-coloured patches in the axilla (armpits) and groin, and the concealed surfaces of the thighs are marked boldly with blue, white and/or red. The combination of violet patches in the groin and blue or red patches on the limbs distinguishes this species from all other frogs in the area. The call, a series of short buzzes and clicks often produced in rapid succession, is also a useful character to identify this species.

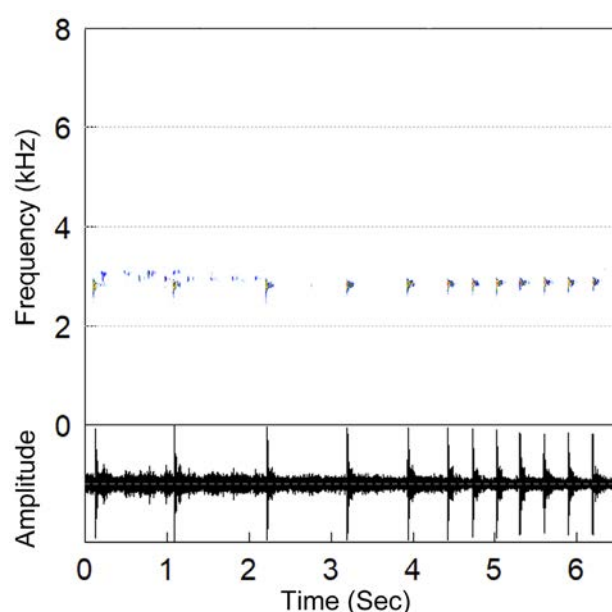
Litoria iris lays its eggs attached to leaves hanging over ponds where they develop into tadpoles before dropping into forest pools below, and the species' characteristic gelatinous egg masses are an excellent indicator of its presence on Hides Ridge. This is a montane species that is widespread in the mountains of PNG and it was common at small roadside ditches, and at a pond at Wellpad D, on Hides Ridge in BAA 1.

Litoria prora



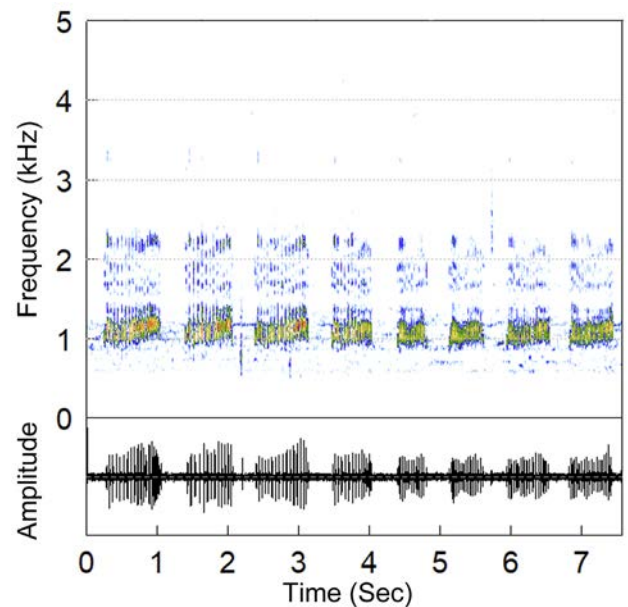
A very distinctive, medium-sized (to ~55 mm) frog with fully webbed fingers, prominent lappets along the outside edge of the limbs, and a large rostral spike on the tip of the snout in both males and females. Colour is normally mottled green/brown. *Litoria prora* breeds in small forest pools where eggs are glued to leaves above the water, and tadpoles hatch and drop into the pools below when they can swim. The call is a short series of soft, rapidly-repeated notes producing a rather melodious 'bleating' sound. This species is widespread in the southern foothills of mainland New Guinea.

Litoria spartacus



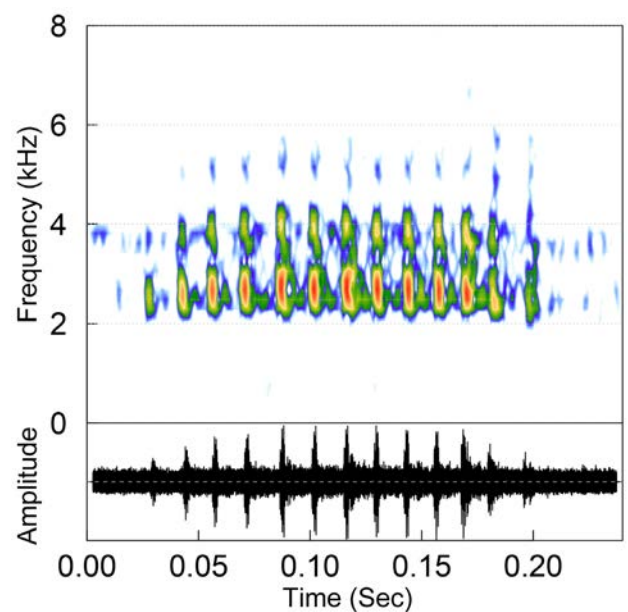
A medium-sized (to ~50 mm) green and brown-mottled frog with bright yellow on the hidden surfaces of the thighs and reduced webbing between the fingers. This is a torrent-dwelling species that lives along large rocky streams, and males produce a series of 10–14 loud, bell-like notes lasting up to 20 seconds from elevated perches in trees on the stream banks. It is known only from a small number of localities in the mountains of south-central PNG including Iagifu Ridge near Moro.

Litoria thesaurensis



A medium-sized (to ~60 mm), slender frog that is highly variable in colour but is commonly pale to dark brown or olive yellow. Young frogs have distinct longitudinal stripes, which fade with age. The bones are green. This 'species' is a complex, and the Kikori population may be undescribed. *Litoria thesaurensis* breeds in swamps and temporary pools and ditches, where males call from the ground or low foliage with a series of soft, distinctly pulsed 'buzzing' or 'growling' notes. Frogs referred to *L. thesaurensis* occur throughout the lowlands of New Guinea and the Solomon Islands.

***Litoria* sp. 1 'yellow-legs'**



A moderately small (males to ~32 mm) and slender green treefrog that in general body size and shape looks superficially like *Litoria iris*. However the two species can be immediately distinguished by examining the colouration of their ventral surfaces and thighs. *Litoria* sp. 1 lacks the violet patches that are so conspicuous in *L. iris*, instead having pale yellow colouration in the thighs and across the lower portions of the belly. It also has a different call, which consists of a single, multi-pulsed note sounding like a scratchy 'chirp' repeated relatively slowly. The species' breeding biology remains unknown.

Litoria sp. 1 'yellow-legs' appears to occupy a lower elevational range than *Litoria iris* so the two species may not occur anywhere in sympatry. It was previously known from the Agogo Range and Gobe Ridge in the Kikori basin and it occurs adjacent to Arakubi and at KP107. This species was illustrated as '*Litoria* sp. nov. 8' in Richards (2002).

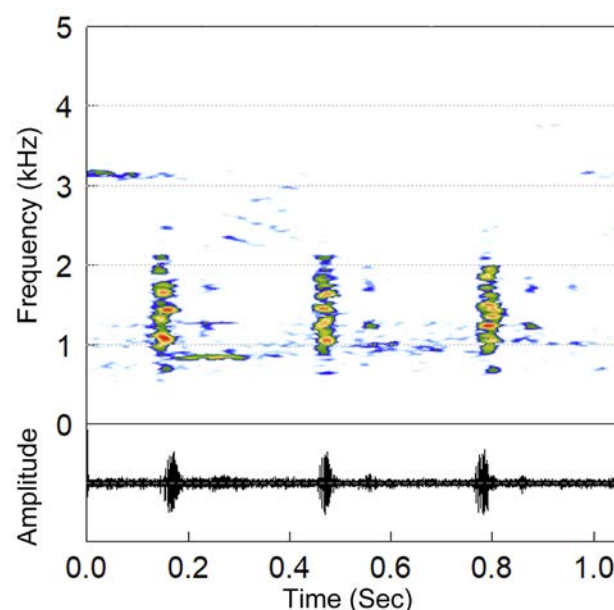


Litoria* sp. 2 cf. *pronimia



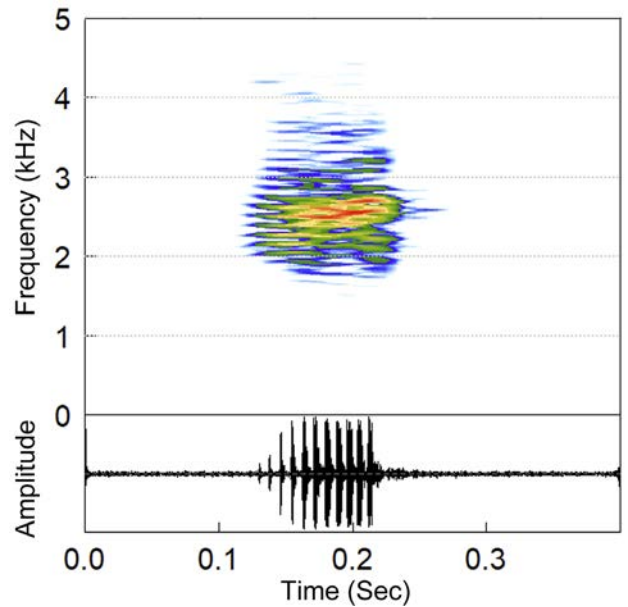
A single specimen of a small (30 mm), slender treefrog with a prominent spike on the nose was found at a pond on Hides Ridge. This predominantly pale yellowish brown frog closely resembles *L. pronimia* but is genetically distinct from that species. Its call has yet to be confirmed. This species is currently known only from Hides Ridge.

Litoria* sp. 3 cf. *genimaculata



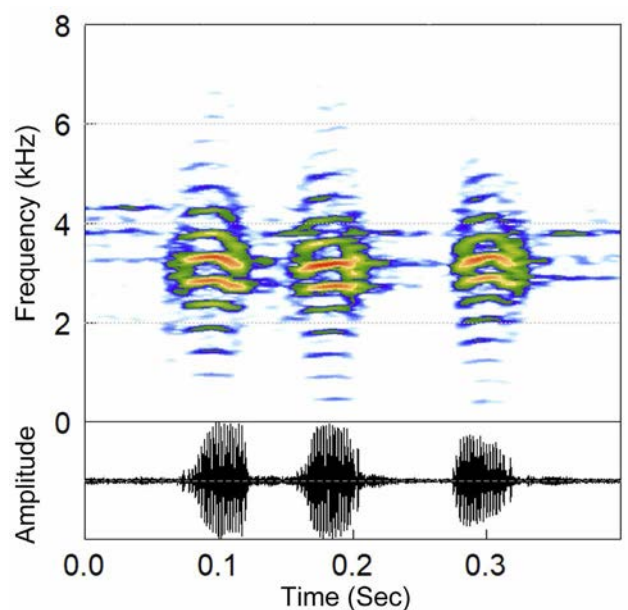
A medium sized (males to ~40 mm) slender treefrog with large eyes, limited webbing between the fingers and a small spine on each heel. This species occurs on the lower slopes of lagifu Ridge and around Lake Kutubu, where it breeds in slow-flowing but clear streams. Males call from low riparian vegetation with a series of quiet ticking notes occasionally followed by a short trill. *Litoria* sp. 1 'cf. *genimaculata*' belongs to a taxonomically difficult group of frogs related to *Litoria genimaculata* and is listed as *Litoria* sp. nov. 4 in Richards (2002).

***Litoria* sp. 4 'red legs'**



A moderately small (< 40 mm), slender, predominantly green frog with a white bar behind the eye and bright red colouration on the lower belly and underside of the legs. *Litoria* sp. 4 'red legs' is known from lagifu Ridge, Gobe Ridge and near Arakubi. It is also common along small seepage streams at Lake Kutubu. The call is a short, harsh 'raak'. This species was listed as *Litoria* sp. nov. 7 in Richards (2002).

Litoria* sp. 5 cf. *nigropunctata



A small (< 35 mm) very slender, predominantly brown frog with scattered green flecks on the back and pale yellow on the undersides of the legs. It is common along small seepage streams at Lake Kutubu and on the lower slopes of lagifu Ridge, where males call from leaves up to 2 m high with a series of 2–6 rapidly repeated notes. This species is illustrated as *Litoria nigropunctata* in Richards (2002) but it is an undescribed species with a broad distribution along the southern flanks of New Guinea's central cordillera.

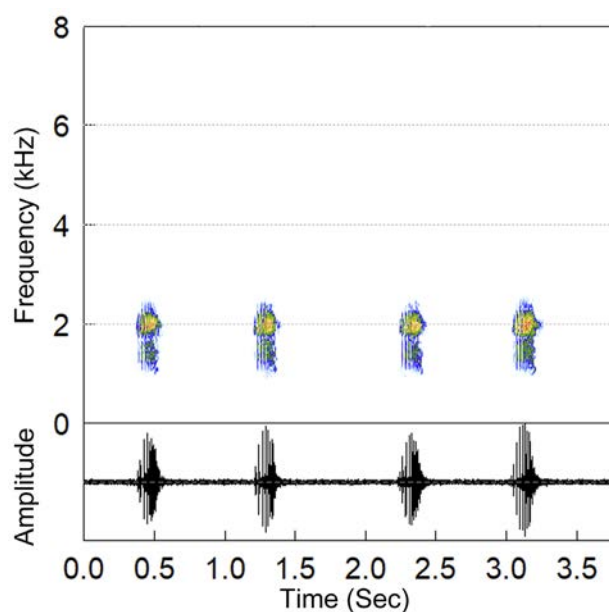
Litoria* sp. 6 cf. *becki



A single specimen of a frog resembling *L. becki* was found adjacent to the ROW on Hides Ridge. Webbing between the toes is greatly reduced. This group of frogs normally occupies torrential streams, which are absent from the summit of Hides Ridge. The animal in question may have been dispersing between distant breeding sites.



Nyctimystes kuduki

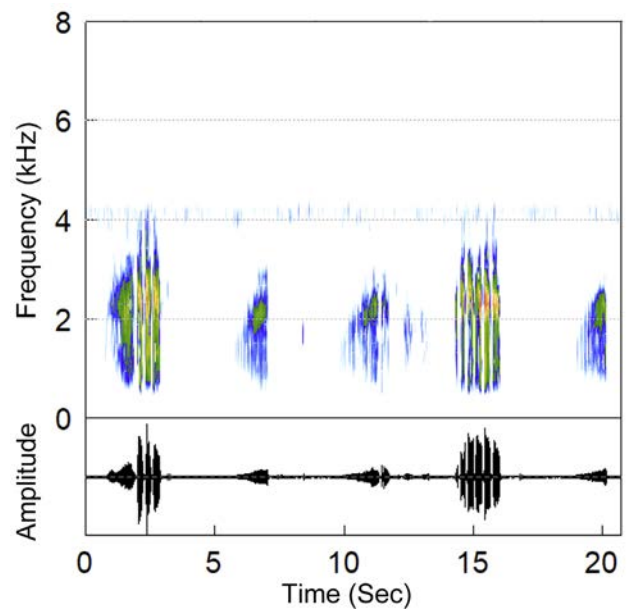


A moderately large (to ~60 mm) pale to dark brown treefrog with long legs, a vertical pupil, and a reticulum of golden-yellow veins oriented predominantly vertically across the lower eyelid. *Nyctimystes kuduki* is known from several clear-flowing streams on the slopes of lagifu Ridge where males call from elevated positions with a very long (often >5 mins) series of distinctly pulsed, monotonously repeated rasping notes. Its broader distribution is poorly known.



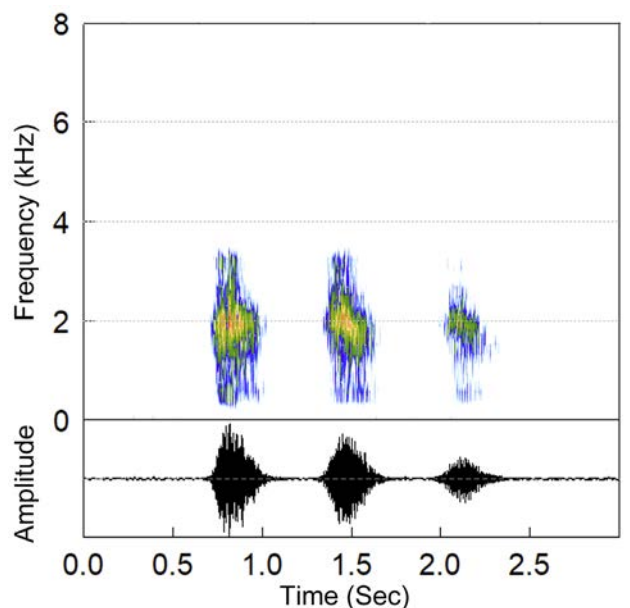
RANIDAE

Papurana daemeli



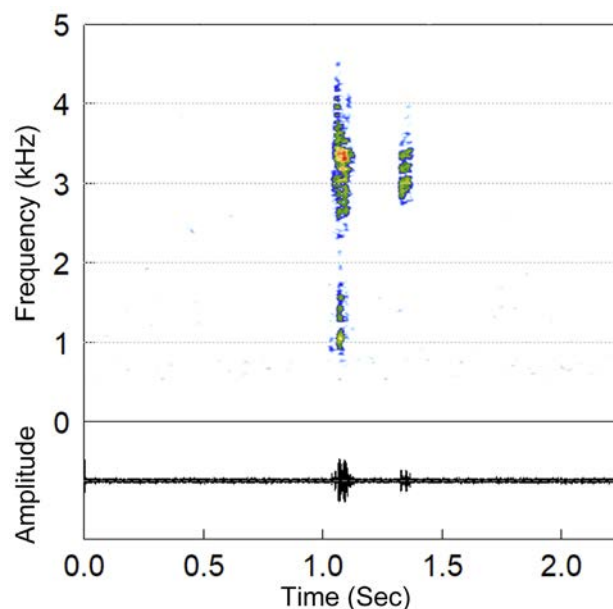
A large frog (to ~80 mm) with a moderately angular snout, very long legs with extensively webbed toes, and a pair of narrow raised dorsolateral folds along the body. It is commonly encountered around Moro. The call is a series of wavering 'quacking' notes that has been compared to the sound made by a duck. This is a very widespread and abundant species that breeds in swamps, ponds and flooded ditches throughout the lowlands and foothills of southern New Guinea.

Papurana sp. 1 cf. *arfaki*



This is a very large (to >100 mm) robust frog that was previously considered to be *Papurana arfaki*, a species widespread across the lowlands and foothills of New Guinea. However recent genetic studies have shown local populations to be genetically distinct from that species (L. Oliver et al. in prep). Males are more tubercular dorsally than females. *Papurana* sp. 1 cf. *arfaki* appears to be widespread along streams and small rivers in the Kikori basin and it has been found along streams draining into Lake Kutubu, and on Iagifu Ridge. The call is a short series of deep, rather resonant rasping notes.

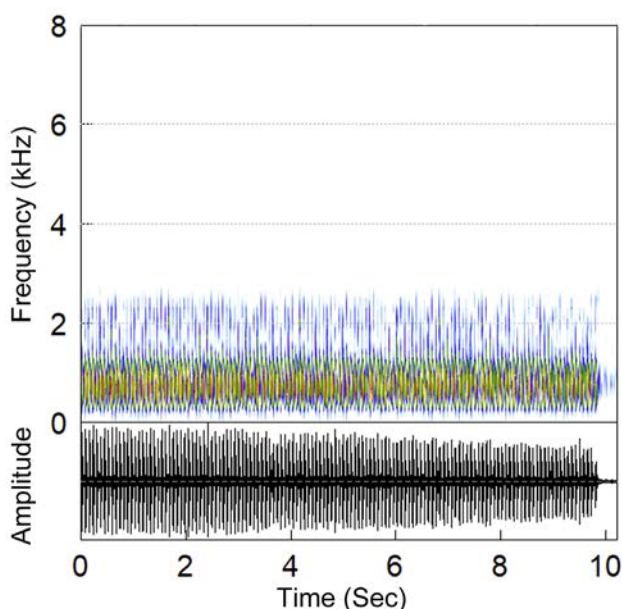
Papurana* sp. 2 cf. *grisea



A large (to ~90 mm) brown frog with an angular snout, long legs with extensively webbed toes, and a prominent dark 'mask' on the side of the head. Males become yellowish during breeding, when the dark face mask may be less visible. This species is part of a taxonomically difficult 'complex' of frogs and more than one species may occur around Moro and Hides. Calls of this species are one or more brief but loud chirping or squawking notes. It is common along small streams, and at HGCP occurs in small ditches around the camp. Its broader distribution is poorly understood.

BUFONIDAE

***Rhinella marina* (Cane Toad or Marine Toad)**



A very large frog (to >200 mm but usually <150 mm) that has been introduced to PNG. It is normally mottled with different shades of brown, and there is a large poison gland behind each eye. The call is a long, melodious trill lasting up to ~10 seconds (illustrated recording courtesy of Ben Muller). This species is common around Moro where males call from ponds and flooded ditches. The small black eggs are laid in long strings, which distinguishes them from the eggs of all other native species in the area.

References and further reading

- Günther, R. & Richards, S. J. 2016. Description of two new species of the microhylid genus *Oreophryne* (Amphibia: Anura: Microhylidae) from southern Papua New Guinea. *Vertebrate Zoology* 66: 157–168.
- Menzies, J. I. 2006. *The frogs of New Guinea and the Solomon Islands*. Pensoft. Sofia-Moscow.
- Papuan Herpetofauna website 2013. Available at <http://pbs.bishopmuseum.org/papuanherps/project.html>.
- Richards, S. J. 2002. *Rokrok: An illustrated guide to the frogs of the Kikori River Basin*. WWF-South Pacific.
- Richards, S. J. & Armstrong, K. 2017. Frogs. In: Richards, S. J. (editor). *Biodiversity assessment of the PNG LNG Upstream Project Area, Southern Highlands and Hela Provinces, Papua New Guinea*. ExxonMobil PNG Limited. Port Moresby.

CAMERA TRAP BIRD IDENTIFICATION MATERIALS

Iain Woxvold



Pheasant Pigeon (*Otidiphaps nobilis*)

Introduction

Accounts are presented below for all bird species camera trapped within the Biodiversity Assessment Areas (BAAs) in 2015 and 2017, and for a small number of additional species that may occasionally be photographed in future sampling years. The 49 species shown here represent approximately one quarter of the nearly 200 bird species recorded to date within the study area. Accounts are presented in taxonomic order (IOC: Gill and Donsker 2018) and include a description of diagnostic features, geographic range within the study area and the potential for confusion with other camera trapped species. References to specific sites include Hides Low and Hides High within BAA 1 (respectively in the Wellpad D and Wellpad E–G areas), and Arakubi and KP107 within BAA 2. Where a BAA is mentioned without specific sites, the species is known to occur at both sites within that BAA. Unless otherwise stated, species are predominantly terrestrial and there is no notable sexual dimorphism (adults appear similar). Summary information on the distribution and status of various species is taken from Coates (1985, 1990), recent works by Pratt and Beehler (2015; Beehler and Pratt 2016) and Woxvold and Legra (2017), and from the Handbook of the Birds of the World (HBW Alive 2018). Scientific names accompany English names in account headings, and where a species is mentioned for comparison but does not have its own account.

CASUARIIDAE

Dwarf Cassowary (*Casuarius bennetti*)



A very large (to 1.5 m high), flightless bird of upland forests to 3,300 m asl. Adult (top left & right)—all black plumage, skin of upper neck blue with some red, pink or yellow areas, and with a black face and a short, bony 'casque' on top of the head; juvenile (bottom left)—brown plumage, grading to black with age, and with bare skin of head and neck either brown or developing colour with age; chick (bottom right)—striped dark and light brown. This cassowary is present in both BAAs and is easily distinguished from all other co-occurring species—other cassowary species do not occur in the BAAs (lowlands only), and megapodes are much smaller and easily distinguished from the similarly sized cassowary chicks by shape and plumage.

MEGAPODIIDAE

Wattled Brushturkey (*Aepypodius arfakianus*)



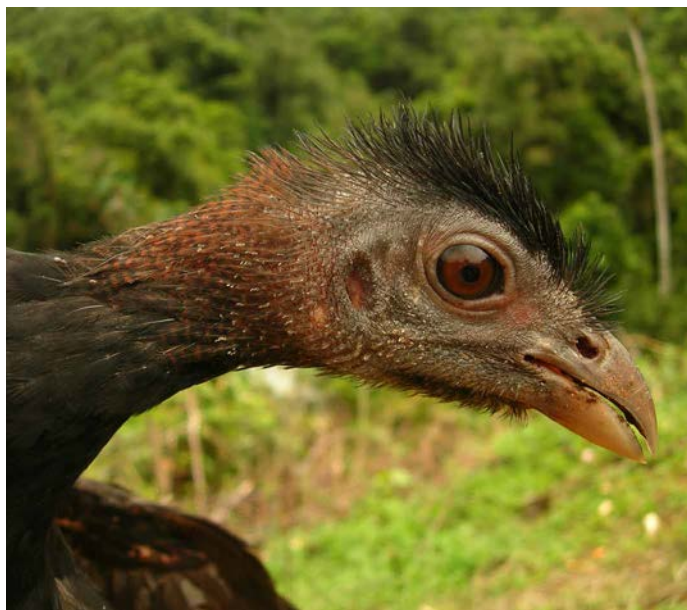
A large (to 46 cm) chicken-like bird of upper hill and montane forests at 750–2,700 m asl. Adult (left top & middle)—black plumage with rust-brown upper tail coverts and large laterally compressed tail, legs dark, sometimes olive-yellow posterior, bare neck and face white or grey, sometimes with yellow, and with red wattles on the lower neck and on top of the head; chick (bottom left)—brown plumage, blue facial skin sometimes apparent around the eyes.

Present in both BAAs, it is one of three megapode species occurring locally—it can be distinguished from the Collared Brushturkey by leg colour, tail coverts and head and neck appearance; and from the New Guinea Scrubfowl by overall plumage, tail shape and head and neck appearance. The broadly similar Pheasant Pigeon is easily distinguished by shape and colouration (see account for that species).



MEGAPODIIDAE (cont)

Collared Brushturkey (*Talegalla jobiensis*)



A large (to 61 cm) chicken-like bird of northern New Guinea and uplands of the southern watershed. Adult (left top & middle)—black plumage with large tail, rusty brown neck feathers and a short, shaggy crest of stiff feathers, legs salmon red, bill dark; chick (bottom left)—mottled black and tan plumage and diagnostic reddish legs. The Collared Brushturkey is present only in BAA 2 where it is one of three locally occurring megapode species—it can be distinguished from both the Wattled Brushturkey and the New Guinea Scrubfowl by leg colour and head patterning, and further from New Guinea Scrubfowl by tail shape and from Wattled Brushturkey by tail colour. In areas of gentle terrain, the Black-billed Brushturkey (*Talegalla fuscirostris*) may occur locally up to c. 800 m asl—it is distinguished by its yellow legs and all black plumage (no brown collar). The broadly similar Pheasant Pigeon is easily distinguished by shape and colouration (see account for that species).



MEGAPODIIDAE (cont)

New Guinea Scrubfowl (*Megapodius decollatus*)



A medium-sized (to 35 cm) chicken-like bird of northern New Guinea and uplands of the southern watershed. Olive-brown plumage with slate grey neck and breast, short tail and with prominent pointed crest at rear of head, legs dark, sometimes olive-yellow posterior, red facial skin variably visible through sparse feathering of face and neck. It is present at BAA 2 and at Hides Low and is one of three locally occurring megapode species—it can be distinguished from both the Wattled and Collared Brushturkeys by overall plumage, tail shape and head and neck appearance, and further from the Collared Brushturkey by leg colour. The broadly similar Pheasant Pigeon is easily distinguished by shape and colouration (see account for that species).

ACCIPITRIDAE

Papuan Eagle (*Harpyopsis novaeguineae*)



A very large eagle (to 90 cm) of forests up to 3,000 m asl. Medium brown upperparts with darker barring on wings and tail, pale underparts, strong yellow legs and heavy grey bill. The Papuan Eagle hunts below the forest canopy, taking prey from trees or on the ground where it is occasionally camera trapped. It occurs in both BAAs.

ACCIPITRIDAE (cont)

Grey-headed Goshawk (*Accipiter poliocephalus*)



A medium-sized raptor (to 38 cm) of forest interior and edge up to 1,500 m asl. It has grey upperparts with darker wings and tail, white underparts and coral-orange legs, cere (base of bill) and skin around the eye. This goshawk is present at BAA 2. Though not terrestrial it takes lizards and large invertebrates from the ground where it may occasionally be camera trapped. It may be confused only with the grey or white morphs of the Variable Goshawk (*Accipiter hiogaster*), which show uniform plumage colour (all white or dark grey) and yellow bare parts.

RALLIDAE

Chestnut Forest Rail (*Rallicula rubra*)



A medium-sized (to 23 cm) rail of montane forest to 3,050 m asl. Adult male (top left & bottom left)—rufous-brown plumage with black flight feathers narrowly appearing in folded wing, dark bill, legs and eye; adult female (top right, bottom left)—mostly rufous-brown, wings black with white spots, flanks and undertail black with pale spots; juvenile—all sooty brown. It is present only in BAA 1 where it may be confused with Forbes's Forest Rail. Where both species are present the Chestnut Forest Rail typically occurs at higher elevations. However, at BAA 1 it is present both at Hides High, where it is the only forest rail present, and locally at Hides Low (confirmed by voice, to date only on higher ridgelines) where Forbes's Forest Rail is also present. Males can be distinguished from Forbes's Forest Rail by their all chestnut upperparts, females by their spotted (not barred) flanks, and both sexes by a lack of barring on the all-chestnut tail. The two *Rallicula* species may be difficult to distinguish in some images.

RALLIDAE (cont)

Forbes's Forest Rail (*Rallicula forbesi*)



A medium-sized (to 25 cm) rail of montane forest at 1,150–3,000 m asl. Adult male (left)—chestnut with almost black wings, dark barring on flanks and undertail and some dark barring on tail (variable and often indistinct), dark bill, legs and eye; adult female (right)—similar to male but with buff spots on the wings; juvenile—all sooty brown. This species is confirmed present at Hides Low in BAA 1 and at KP107 in BAA 2. It co-occurs locally with Chestnut Forest Rail at lower elevations in BAA 1—male Forbes's Forest Rail is distinguished by its black, unspotted wings; female less reliably so—look for diagnostic dark barring on flanks (cf. pale spots) or tail (diagnostic only when clearly present—not certainly Chestnut Forest Rail if barring not visible). The two *Rallicula* species may be difficult to distinguish in some images.

Bare-eyed Rail (*Gymnocrex plumbeiventris*)



A medium-sized (to 25 cm) rail of lowland, hill and lower montane forest. Adult (left) unique plumage and bare parts colour combination: chestnut head, neck and breast, olive-brown back and wings, black tail, rump and vent, grey belly, red legs, long dark bill with pale yellow base and bare pink skin around the eye; chick (right)—black downy plumage gradually developing adult colouration with age, typically accompanied by one or more adults. The Bare-eyed Rail is inconspicuous but regularly camera trapped at KP107 in BAA 2. It is easily distinguished from all other locally occurring species.

SCOLOPACIDAE

New Guinea Woodcock (*Scolopax rosenbergii*)



A medium-sized (to 30 cm) forest 'snipe' endemic to the New Guinea mountains at 2,400–3,800 m asl. Brown with black markings above and below, a variable white mark across the breast, and a very long bill used to probe for invertebrates on the forest floor. It is present in BAA 1, where the Papuan Logrunner is also mottled brown but easily distinguished by shape, bill, legs and plumage. Generally considered to be uncommon, in 2017 this secretive species was the most frequently camera trapped bird at Hides High.



COLUMBIDAE

Stephan's Emerald Dove (*Chalcophaps stephani*)



A small (to 26 cm) terrestrial pigeon of lowland and hill forests, normally below 700 m asl but occasionally up to 1,400 m asl. Adult male (left)—reddish brown with emerald green wings, white forehead, broad buff and dark bars on the rump, red bill and reddish legs; adult female (right)—lacks the white forehead. It is present only in BAA 2 where it has been recorded on few occasions at Arakubi. This species is similar in size to the more common Cinnamon Ground Dove, but easily distinguished by shape and general plumage characters.

New Guinea Bronzewing (*Henicophaps albifrons*)



A medium-sized (to 36 cm) terrestrial pigeon present up to 2,000 m asl. Adult (left)—all dark plumage with white forehead (duller in female) and iridescent sheen on wings showing green, yellow and red-purple hues that vary with lighting, long tail, unusually long bill and reddish legs; juvenile (right)—lacks sheen on wings. This species is present but uncommon in BAA 2. In poor quality images this species could be confused with Stephan's Emerald Dove which has been recorded at Arakubi, the adult male of which also has a white forehead. However, the New Guinea Bronzewing is much larger and darker, lacks the overall green wing plumage of Stephan's Emerald Dove and has proportionally much longer bill and tail.

COLUMBIDAE (cont)

Cinnamon Ground Dove (*Gallicolumba rufigula*)



A small (to 24 cm) terrestrial pigeon of forests up to 1,600 m asl. Adult (pictured)—brown above and pale yellow below with pale forehead and four pale wing bars evident in most images; juvenile—underparts brown. This species is present at BAA 2 where it is most frequently camera trapped at Arakubi. The Bronze Ground Dove, which co-occurs with the Cinnamon Ground Dove at KP107, is similar in shape, size and habits but lacks the pale wing bars and is generally darker below (female) or has two-toned underparts (male).

White-breasted Ground Dove (*Alopecoenas jobiensis*)



A small (to 25 cm) terrestrial pigeon, patchily distributed in forests up to 1,600 m asl, occasionally to 2,400 m asl. Adult male—boldly patterned black with white eyebrow, throat and upper breast and purple sheen on back showing in some light; female—variable, like male or with duller plumage; juvenile—dark grey-brown with whitish chin. This species may occur at all sites except Hides High, but is generally rare; to date there is only one camera trap image from Hides Low. It is unlikely to be confused with any other species.

COLUMBIDAE (cont)

Bronze Ground Dove (*Alopecoenas beccarii*)



A small (to 24 cm) terrestrial pigeon of montane forests at 1,400–2,900 m asl. Adult male (top left, bottom left & right)—dark above with glossy maroon shoulder patch (visible in good light), grey head and white breast sharply demarcated from dark belly; female (top right, bottom right)—duller, all brown with grey face and no shoulder patch; juvenile—brown edges to feathers. This species is most common in BAA 1 and present in small numbers at KP107 in BAA 2. It may be confused with the Cinnamon Ground Dove at KP107; see account of that species for distinguishing features.

COLUMBIDAE (cont)

Pheasant Pigeon (*Otidiphaps nobilis*)



A large (to 48 cm) pheasant-like pigeon of hill and montane forest. Overall dark plumage, with red-brown wings and upper back, green-toned lower back and upper tail coverts, black head, neck, underparts and tail and a prominent pale grey nape (appearing white in some images), bright yellow legs with red 'knees' and red bill. The unusual tail is laterally compressed in a vertical fan-like array. It is common in BAA 2, where in 2017 it was the most frequently camera trapped species at Arakubi, and occurs in lower numbers at Hides Low in BAA 1. This unique pigeon can be confused only with the megapodes, but is easily distinguished from Wattled Brushturkey, Collared Brushturkey and New Guinea Scrubfowl by its unique combination of plumage and bare parts (bill and legs) colouration and by its overall shape, including its much larger tail, relatively long thin legs and smaller head and bill.

Papuan Mountain Pigeon (*Gymnophaps albertsii*)



A medium-sized (to 36 cm), wide-ranging pigeon recorded from the lowlands up to 3,700 m asl. Adult (pictured)—dark with a pale breast and pale band at the end of the tail, and red legs and facial skin; juvenile—lacks red facial skin. Though not a terrestrial species it may occasionally come to ground in search of fruit. Camera trapped only rarely, one was photographed at Hides High in 2017. It is unlikely to be confused with any other species.

ALCEDINIDAE

Shovel-billed Kookaburra (*Clytoceyx rex*)



A large (to 32 cm) kingfisher, rare in forest interior from the lowlands to 2,400 m asl. Adult male (left)—dark brown above with rufous nape, post-orbital stripe and underparts, pale throat, pale blue rump, darker blue tail and unusually thick, short bill; adult female (right)—like male but tail brown; juvenile—like female but rusty tips to feathers of upperparts and dark scalloping to feathers of underparts. It is not strictly terrestrial, but forages on the ground where it digs for invertebrates with its large, stubby bill. It is confirmed present at Hides Low in BAA 1 and may occur in BAA 2. It is only occasionally camera trapped and is unlikely to be confused with any other species.

PITTIDAE

Papuan Pitta (*Erythropitta macklotii*)



A medium-sized (to 17 cm), colourful ground-bird of forest up to c. 1,600 m asl. Adult (top & bottom left)—brown head, rusty red nape, dull green back, blue wings and breast, bright red belly, black throat and breast band, short tail not apparent in camera trap images, black bill and long dark legs; juvenile (top right)—mottled brown, developing gradually into adult plumage. This species is present only in BAA 2, where in 2017 it was the most frequently camera trapped bird at KP107. Adults are not likely to be confused with any other species, even when poorly imaged. In poor quality images the overall colouring of juveniles may appear similar to Russet-tailed Thrush and Piping Bellbird, but Papuan Pitta has distinctive shape (no apparent tail, upright stance), lacks the pale wing bars, pale facial markings, white belly and dark feather scalloping of Russet-tailed Thrush, and its mottled appearance differs from the even tones of the Piping Bellbird.

PTILONORHYNCHIDAE

Ochre-breasted Catbird (*Ailuroedus stonii*)



A medium-sized (to 25 cm) bowerbird of lowland forests in southern New Guinea to c. 1,300 m asl. Emerald green wings, back and tail, neck with heavy black streaks, dark olive-brown crown, white cheek and throat, buff underparts with black spots, red eye and heavy pale grey bill. It is not strictly terrestrial but forages in lower strata and regularly visits the ground where it is occasionally camera trapped. Within the study area it is present only at Arakubi and is replaced at higher elevations by the Black-eared Catbird. It may be confused only with the Black-eared Catbird but is readily distinguished by patterning of the head, neck and underparts.

Black-eared Catbird (*Ailuroedus melanotis*)



A medium-sized (to 25 cm) bowerbird of upland forests between 600 and 2,250 m asl. Green wings and back, green tail with white tip, complex head patterning with black ears and crown, pale brown underparts with black feather edges giving 'scalloped' appearance, scalloping heavier on the upper breast (throat mostly black), heavy pale-grey bill and grey legs. It is not strictly terrestrial but occasionally forages on the ground. It is confirmed present at BAA 2 where it was camera trapped in low numbers at KP107. It may be confused only with the Ochre-breasted Catbird but is readily distinguished by patterning of the head, neck and underparts.

PTILONORHYNCHIDAE (cont)

Archbold's Bowerbird (*Archboldia papuensis*)



A large (to 37 cm) bowerbird of montane forests usually above 2,300 m asl. Adult male—black plumage with long forked tail and yellow crest; adult female (pictured)—all black plumage but for ochre-yellow mark on 'wrist' of folded wing; juvenile male—lacks the yellow crest. Rare and normally occupies canopy, but male displays at a terrestrial bower decorated with snail shells, ferns and King of Saxony Bird-of-paradise (*Pteridophora alberti*) head plumes. Birds may occasionally visit the ground to forage, display or to collect bower materials and may be camera trapped. It was recorded at BAA 1 during preconstruction surveys by the location of a bower, and in 2017 a female (pictured) was camera trapped at Hides High. It may be confused only with the male Black Pitohui (*Melanorectes nigrescens*), a non-terrestrial species which has a shorter tail and lacks yellow markings.

MacGregor's Bowerbird (*Amblyornis macgregoriae*)



A medium-sized (to 26 cm) bowerbird of montane forests at 1,600–3,300 m asl. Adult male (top right, bottom left)—a robust, brown bird with large head and orange crest extending down the neck, crest often folded and not visible, thick dark bill; female (top left) and juvenile—all brown. This species normally occupies upper forest strata, but males display at terrestrial bowers decorated with moss and twigs (top right, bottom left), and birds may occasionally visit the ground to forage, display or to collect bower materials. It is present at BAA 1 where it may be confused only with female or immature satinbirds. Loria's Satinbird (*Cnemophilus loriae*) is present at Hides Low but has not been camera trapped; it can be distinguished by its olive-green colouring contrasting with brown wings and tail and its smaller bill. The Crested Satinbird is occasionally camera trapped at Hides High, and can be distinguished with care by the features outlined for that species below.

MELIPHAGIDAE

Long-billed Honeyeater (*Melilestes megarhynchus*)



A medium-sized (to 23 cm) passerine (perching bird) of forest up to 1,500 m asl, occasionally higher. Adult (right)—olive-brown plumage with orange eye and a very long and robust decurved bill; juvenile (left)—with pale eye ring. Not a terrestrial species, it forages in lower and mid-stage forest strata where it sometimes perches near the ground and may occasionally be camera trapped. It is present at BAA 2 where it is unlikely to be confused with any other species.

ACANTHIZIDAE

Rusty Mouse-warbler (*Crateroscelis murina*)



A small (12 cm) passerine of upland forests to 1,700 m asl. Brown above, paler yellow-brown below with white throat, short tail, long pale legs, red-brown eye and short dark bill with pale lower mandible. This species forages on the ground and up to 1–2 m in the understorey. It is fairly common at BAA 2 (based on call frequency) but is infrequently camera trapped, due perhaps to its small size. The Mountain Mouse-warbler is most similar but occurs at higher elevations (BAA 1). The rare Bicolored Mouse-warbler (*Crateroscelis nigrorufa*; not pictured) may occur locally but is distinguished by its lack of white throat, all dark bill and richer colouring. The Rusty Mouse-warbler is readily distinguished from other birds by its shape, small size and even-toned colour pattern.

ACANTHIZIDAE (cont)

Mountain Mouse-warbler (*Crateroscelis robusta*)



A small (12 cm) passerine of montane forests at 1,750–3,600 m asl. Dark brown plumage with white throat and pale belly, short tail, dark bill and legs, pale eye variably coloured red, yellow, orange or red-brown. It forages on the ground and up to 1–2 m in the understorey. This species is fairly common at BAA 1 (based on call frequency) but is infrequently camera trapped, due perhaps to its small size. The Rusty Mouse-warbler is most similar but occurs at lower elevations (BAA 2). The rare Bicolored Mouse-warbler (*Crateroscelis nigrorufa*; not pictured) may occur locally but is distinguished by its lack of white throat and richer colouring. The Mountain Mouse-warbler can be distinguished from other similarly-sized birds, predominantly non-terrestrial scrubwrens (such as the Large Scrubwren) of the montane forest understorey, by its shape, even-toned colour pattern with a distinctly pale throat and its pale eye.

Large Scrubwren (*Sericornis nouhuysi*)



A small (to 14 cm) passerine endemic to New Guinean montane forests, mostly at 1,400–3,500 m asl. Sombre but distinct colouration—brown above with rufous face, olive-yellow wash to underparts and red eye. It is not terrestrial but forages in the forest understorey, often near the ground, where it may occasionally be camera trapped (right). It is fairly common at BAA 1 where it can be distinguished from the terrestrial Mountain Mouse-warbler by its varied plumage tones (distinct upper- and underparts) and lack of a white throat. It is most similar to two other co-occurring non-terrestrial scrubwrens – the Papuan Scrubwren (*Sericornis papuensis*) and Buff-faced Scrubwren (*S. perspicillatus*) – each of which can be distinguished in good quality images by a combination of plumage, especially on the head and face, and eye colour.

ORTHONYCHIDAE

Papuan Logrunner (*Orthonyx novaeguineae*)



A medium-sized (18 cm), quail-shaped passerine of montane forests at 1,200–3,500 m asl. Adult male (left)—mottled brown and black above with prominent wing bars, rich brown rump and flanks, grey face, nape and shoulder, black stripe down side of neck, white throat and belly, dark tail with ‘spiny’ feather tips, dark bill and eye and long dark legs; adult female (right)—like male but throat orange and with grey flanks; juvenile—mottled black and rufous with white marked olive belly. Rare, patchy and secretive. Generally considered to be uncommon, in 2017 this secretive species was regularly camera trapped at BAA 1. It may also occur at KP107 in BAA 2. If present at BAA 2 it may be confused with Russet-tailed Thrush, though the Papuan Logrunner has a distinctive shape and is readily distinguished by its richer colouration and different plumage pattern at all angles. It is not easily confused with any other species.

CNEMOPHILIDAE

Crested Satinbird (*Cnemophilus macgregorii*)



A robust, medium-sized (25 cm) passerine of montane forest normally above 2,600 m asl. Adult male (top left & right)—unique and distinctive, bright orange above and dark chocolate brown below; adult female (bottom left & right)—rusty brown, paler below with grey eye and, when viewed well, diagnostic groove in forehead plumage; juvenile—like female but with brown eye. This species is predominantly arboreal but occasionally visits the ground where it is sometimes camera trapped (top right). Within the study area it is present only at Hides High in BAA 1. While the male is unique, female/juvenile birds may be confused with female Loria's Satinbird (*Cnemophilus loriae*; not pictured), but the latter is not terrestrial, has olive-green plumage, lacks the forehead groove, has brown eyes and generally occurs at lower elevations (mostly below 2,500 m asl, present at Hides Low).

MELANOCHARITIDAE

Fan-tailed Berrypecker (*Melanocharis versteri*)



A small (to 15 cm) understorey passerine of montane forest normally above 1,700 m asl. Adult male (bottom left)—Iridescent blue-black above, clear grey underparts, long tail with white basal flanks (may not be visible), dark legs, bill and eye; female and juvenile (top left & right)—olive brown with paler underparts, white spot in mid tail (often not visible) and pale yellow bill gape (corner of mouth). This species is fairly common at BAA 1. Mostly arboreal, it forages in all strata from understorey to canopy and is rarely camera trapped—one female/juvenile was camera trapped at Hides Low in 2015 (top right). While the male is unique, female/juvenile birds may be distinguished by shape and colour pattern from other small, even-toned terrestrial passerines.

PSOPHODIDAE

Spotted Jewel-babbler (*Ptilorrhoa leucosticta*)



A medium-sized (20 cm) terrestrial passerine of montane forests at 1,750–2,400 m asl. Adult (pictured)—chestnut crown, black face, white cheek, olive back, black wings with white spotted wing coverts, long black tail with white tips, olive and blue toned underparts, long black legs, black bill and eye; juvenile—heavily washed olive, wing spots whitish or rufous. The Spotted Jewel-babbler is present at BAA 1 and in 2017 was the second most frequently camera trapped species at Hides Low. It is easily distinguished from other species.

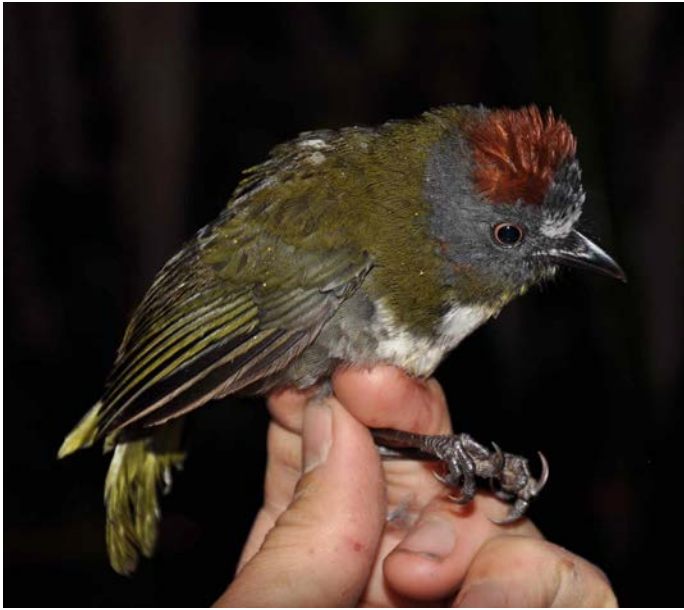
Chestnut-backed Jewel-babbler (*Ptilorrhoa castanonota*)



A medium-sized (23 cm) passerine of hill and lower montane forest up to c. 1,600 m asl. Adult male (right, background)—rich chestnut back and crown, blue wings, underparts, eyebrow, rump and tail, white throat, black stripe through eye and around white throat patch, black flight feathers narrowly appearing in folded wing, long black legs, black bill and eye; adult female (left & right foreground)—like male but with chestnut rump and flanks and darker tail; juvenile—dark brownish grey with white throat. The Chestnut-backed Jewel-babbler is fairly common at BAA 2 and is easily distinguished from other species.

OREOICIDAE

Rufous-naped Bellbird (*Aleadryas rufinucha*)



A small (to 18 cm) understorey passerine of montane forest normally above 1,750 m asl. Adult (pictured)—olive-green above, grey head and face with copper-chestnut cap, white forehead and breast and yellow throat, dark legs and bill, coral pink iris; juvenile—olive above and chestnut below with some white and yellow in underparts in some individuals. This species is fairly common at BAA 1 where it forages in the understorey and on the ground. Its plumage colour combination is unique. The green upper parts and chestnut cap are broadly similar to Spotted Jewel-babbler, but the latter species easily distinguished by its overall shape, black wings and tail with white spots and white cheek patch.

Piping Bellbird (*Ornorectes cristatus*)



A medium-sized (to 25 cm) understorey passerine of hill and lower montane forest up to c. 1,400 m asl. Adult (pictured)—even brown above, paler rusty brown below, short crest may be raised (left) or held flat (right), dark bill, eye and legs; juvenile—rufous edges to wing coverts. This secretive species forages in the understorey and on the ground. It is fairly commonly camera trapped at BAA 2. A number of other species present at BAA 2 have even-toned brown upperparts: the female/juvenile Magnificent Bird-of-paradise is distinguished by its pale bill, legs and eye-stripe and its rich brown cap; the Northern Scrub Robin is distinguished by its facial pattern and dark wings with white wing bars; the Rusty Mouse-Warbler is distinguished by its smaller size, short tail, white throat and pale legs and lower mandible.

PACHYCEPHALIDAE

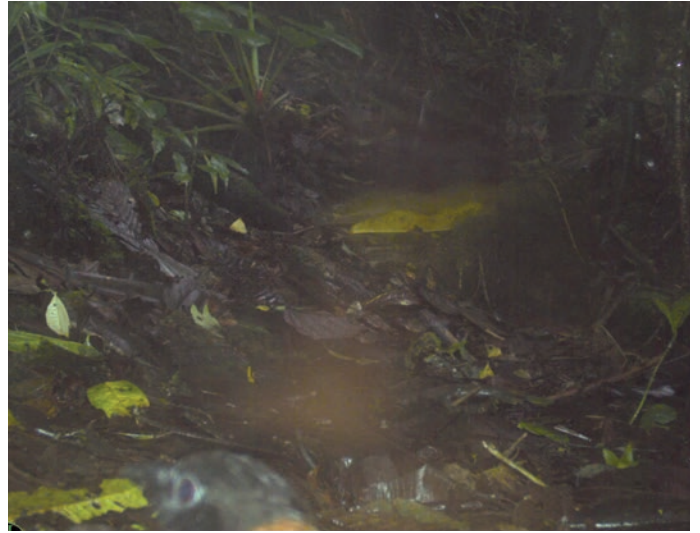
Sclater's Whistler (*Pachycephala soror*)



A small (15 cm) passerine of montane forest up to c. 2,450 m asl. Adult male (top left)—boldly patterned with black head, face and chest band, white throat, rich yellow underparts, dull greenish upperparts, black bill, dark legs and eye; adult female (top right, bottom left)—black plumage replaced with dull grey-brown head and face and diffuse dull olive upper breast and flanks. This is an arboreal species that forages mostly in the middle forest strata. It is fairly common at Hides Low in BAA 1, where in 2017 a female was camera trapped on the ground. It is unlikely to be confused with any terrestrial species.

ORIOLIDAE

Hooded Pitohui (*Pitohui dichrous*)



A medium-sized (to 23 cm) passerine of hill and lower montane forest up to 2,000 m asl. Adult (pictured)—boldly patterned, rich orange-chestnut with black head, upper breast, wings and tail, black bill and dark legs and eye. This is an arboreal species that forages in all strata from the understorey to the canopy. It is present at BAA 1, with a single bird camera trapped at KP107 in 2017 (right). Even in poor quality images this distinctive species is unlikely to be confused with any other bird.

RHIPIDURIDAE

Black Fantail (*Rhipidura atra*)



A small (to 17 cm) passerine of montane forest normally at 1,000–2,150 m asl. Adult male (top left)—all black plumage but for a small white eyebrow, tail fanned, black legs and upper bill, orange-rufous lower bill; female and juvenile (top right, bottom left)—all rufous plumage with black central tail feathers and rufous edges to black flight feathers. This species of the forest understorey is fairly common at BAA 1 where a female was photographed at Hides Low in 2017 (bottom left). Male Black Fantails may be easily confused with the co-occurring Black Monarch (*Symposiachrus axillaris*), which is best distinguished by its pale blue-grey bill, white tuft of feathers at the bend of the wing and the lack of a white eyebrow. Female and juvenile Black Fantails are most easily confused with the Dimorphic Fantail (*Rhipidura brachyrhyncha*), though they are readily distinguished where the tail pattern is visible.

MELAMPITTIDAE

Lesser Melampitta (*Melampitta lugubris*)



A medium-sized (18 cm) passerine of montane forests normally above 2,100 m asl. Adult male (left)—all black with short tail, long black legs, black bill and red eye; adult female—like male but with dark eye; juvenile (right)—like female but with brownish underparts. This species is present at BAA 1 where it is the only all-black bird likely to be regularly camera trapped. Similar in colour only to the male Black Pitohui (*Melanorectes nigrescens*) and Archbold's Bowerbird, but the Lesser Melampitta is easily distinguished by its smaller size and distinctive shape.

Greater Melampitta (*Megalampitta gigantea*)



A large (29 cm) passerine of hill and lower montane forest on limestone up to 1,400 m asl. Adult (left)—all black with long tail, sometimes with frayed ends (from its habit of roosting in limestone caves and sinkholes), long black legs, strong black bill and dark eye, often with pale mark behind the eye (variable); juvenile (right)—like adult but with brown underparts. This species is present at BAA 2 where it is the only all-black bird likely to be camera trapped.

PARADISAEIDAE

Queen Carola's Parotia (*Parotia carolae*)



A medium-sized (to 26 cm) bird-of-paradise of hill and lower montane forest to c. 1,800 m asl. Adult male (pictured)—strikingly patterned, black with white flanks, buffy face and throat, white edge to forehead crest, six elongated black plumes emerging from behind the head, iridescent pinkish-golden breast plumes and bright yellow eye; female and juvenile, brown with breast finely barred brown and buff, rufous wings, and broad buff stripes above and below the pale eye. Predominantly a canopy dweller, the male displays to females at a 'lek' located on the ground, and birds may occasionally visit the ground at other sites or be camera trapped low in the forest understorey. This species is present at KP107 in BAA 2 where an adult male was camera trapped at two adjacent camera stations in 2017. Males are unique and cannot be confused with any other locally occurring species. Female/juvenile parotias are broadly similar

in appearance to female/juvenile Magnificent Bird-of-paradise, though the latter is readily distinguished by its even-toned face and upperparts, finer barring on the underparts, pale blue bill, blue legs and blue skin behind the dark eye.

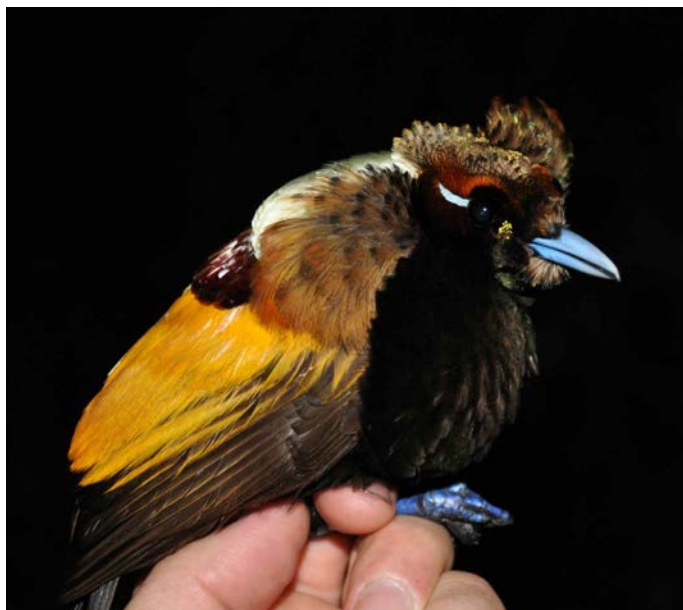
Brown Sicklebill (*Epimachus meyeri*)



A large, long-tailed bird-of-paradise (male 96 cm, female 52 cm) of montane forest mostly at 1,900–2,900 m asl. Adult male (left)—black plumage with iridescent sheen on the head, upperparts and very long tail, even brown underparts with long flank plumes, long black decurved bill and obvious pale eye; adult female/juvenile (right)—brown wings, back and shorter tail, darker face, rufous crown and nape, finely barred underparts and pale eye. Brown Sicklebills forage at all layers of the forest, from canopy to understorey, and occasionally visit the ground. They are present at BAA 1 where both sexes were regularly camera trapped in 2017. At Hides Low the Brown Sicklebill co-occurs with the similar-looking Black Sicklebill (*Epimachus fastosus*), though the latter species is less likely to visit the ground and is readily distinguished by the male's black underparts and by the dark eye in both sexes.

PARADISAEIDAE (cont)

Magnificent Bird-of-paradise (*Diphyllodes magnificus*)



A medium-sized (19 cm) passerine of hill and lower montane forest up to 1,400+ m asl. Adult male (top right, bottom left & right)—strikingly plumed, with yellow, chestnut and shades of brown above, deep velvet green underparts, short tail with two elongated curled tail plumes, pale blue legs, bill and bare skin patch behind the eye; female and juvenile (top left)—brown above with chestnut head and face, underparts narrowly striped dark and light brown. Males display to females at a ground 'lek'. While not otherwise terrestrial, this species may occasionally visit the ground at other sites or be camera trapped low in the forest understorey. It is fairly common at BAA 2. The male is unique. Female somewhat similar to all brown Piping Bellbird but is distinguished by its pale bill, legs and eye-stripe and its rich brown cap.

PETROICIDAE

Ashy Robin (*Heteromyias albispecularis*)



A small (15–18 cm) passerine of montane forest normally between 1,700 and 2,400 m asl, sometimes lower and higher. Adult male (left)—black head with bold white markings, black wings with white wing bar, brown back and tail, white throat and pale brown underparts, black bill with a pale tip, long pale legs; adult female—like male but without pale bill tip; juvenile—rufous with some adult patterning. This species forages in the understorey and on the ground. It is fairly common at BAA 1, including above usual elevations at Hides High, and is easily distinguished from all other locally occurring species.

Slaty Robin (*Peneothello cyanus*)



A small (to 15 cm) passerine of montane forest normally between 1,500 and 2,500 m asl. Adult (pictured)—body plumage deep blue-grey, black wings and tail, black bill, legs and eye; juvenile—grey with brown streaking and spotting. This species forages in the understorey and on the ground where it is occasionally camera trapped. It is present at Hides Low in BAA 1. Among co-occurring species, it is most similar to the Lesser Melampitta but is easily distinguished by its shape and plumage colour.

PETROICIDAE (cont)

White-eyed Robin (*Pachycephalopsis poliosoma*)



A small (to 16 cm) passerine of hill and lower montane forest normally between 700 and 1,700 m asl. Adult (pictured)—an all grey robin but for white throat and pale eye; juvenile—similar but tinged brown. This species forages in the understorey and on the ground. It is present at BAA 2. No other all grey terrestrial passerines are expected to occur at BAA 2. The Slaty Robin has occasionally been reported from these elevations but is easily distinguished by its black wings, the blue tone of its remaining plumage, lack of white throat and dark legs and eye.

Papuan Scrub Robin (*Drymodes beccarii*)



A medium-sized (20 cm) passerine of hill and lower montane forest to 1,450 m asl. Adult (pictured)—mid-brown above, pale brown underparts, black wings with two white wing bars, bold vertical line through eye, pale eye ring, lores (spot between bill and eye) and throat, black bill and eye, long pale legs. Present at BAA 2. It is most similar in size and shape to Russet-tailed Thrush and Piping Bellbird, but is easily distinguished by its unique plumage pattern.

PETROICIDAE (cont)

Greater Ground Robin (*Amalocichla sclateriana*)



A large (20 cm), pitta-like terrestrial robin endemic to New Guinea's high mountain forests normally above 2,700 m asl. Adult (pictured)—brown above with pale throat, buff face and eye ring, grey breast and flanks, short tail, a long, heavy, dark bill with a hooked tip and long grey legs; juvenile—rufous with dark mottling. In 2017 this rare and cryptic species was among the most frequently camera trapped birds at Hides High (80 independent events at 70% of camera positions). This represents a significant range extension—the species was heretofore known from three isolated populations located at the extreme east and west of the central cordillera and on the Huon Range, with Hides Ridge situated in the centre of a distributional gap spanning nearly 900 km. While the Greater Ground Robin and Lesser Ground Robin are similar in appearance, these two closely related species can be readily distinguished by a combination of facial patterning, bill shape and underparts colouration. Moreover, they occupy different elevational zones within BAA 1—while the Lesser Ground Robin is reported from as high as 2,750 m asl, it normally occurs below 2,500 m and to date within BAA 1 has been recorded only at Hides Low.

PETROICIDAE (cont)

Lesser Ground Robin (*Amalocichla incerta*)



A medium-sized (to 16 cm) terrestrial robin of montane forest up to 2,750 m asl. Adult (top left, right & bottom left)—rich brown above, pale brown below, whitish throat and loreal spot (between bill and eye), buff eye ring, black bill, dark eye, long pale legs and upright stance; juvenile (bottom right)—darker underparts and pale brown tips to body feathers. The Lesser Ground Robin is present at Hides Low where it is commonly camera trapped. It is most similar to the Greater Ground Robin which replaces this species at Hides High; see account of that species for distinguishing features. Among co-occurring species, it is most similar to the Mountain Mouse-warbler but is readily distinguished by a combination of shape, often upright stance, its longer legs, darker eye and the arrangement of pale markings on the face and throat.

TURDIDAE

Russet-tailed Thrush (*Zoothera heinei*)



A medium-sized (to 23 cm) passerine of hill and lower montane forest between 500 and 1,700 m asl. Adult (pictured)—mid-brown above, with dark 'scalloping' to feather edges, two buff wing bars, pale eye ring, moustachial stripe and other facial markings, white belly with bold dark scalloping, buff throat, breast mottled buff and dark, black bill, dark eye and pale legs. This species is present at BAA 2 where it is most commonly camera trapped at KP107. Among co-occurring species its overall appearance is most similar to Northern Scrub Robin, though the Russet-tailed Thrush is easily distinguished by its shape, heavily mottled appearance and facial patterning.

References and further reading

- Beehler, B. M. & Pratt, T. K. 2016. *Birds of New Guinea: distribution, taxonomy, and systematics*. Princeton University Press, Princeton, New Jersey.
- 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.
- Gill, F. & Donsker, D. (eds) 2018. IOC World Bird List (v 8.2). <http://www.worldbirdnames.org/>
- HBW Alive. 2018. Multiple species accounts. *Handbook of the Birds of the World Alive*. Lynx Edicions, Barcelona. (retrieved from <https://www.hbw.com/> October 2018)
- Pratt, T. K. & Beehler, B. M. 2015. *Birds of New Guinea*. Second edition. Princeton University Press, Princeton, New Jersey.
- Woxvold, I. & Legra, L. 2017. Birds. Pp. 121–139 in Richards, S. (ed.) *Biodiversity assessment of the PNG LNG Upstream Project Area, Southern Highlands and Hela Provinces, Papua New Guinea*. ExxonMobil PNG Limited, Port Moresby.

NON-VOLANT MAMMALS

Ken Aplin, Kyle N. Armstrong and Iain Woxvold



Neophascogale lorenzii (Speckled Dasyure)

Introduction

Identifications of non-volant mammals are required for animals captured in live trapping along permanent transects and for images recorded by camera traps. Different approaches are used in each case.

Identification of captured animals

Identification of captured non-volant mammals in the field is best approached in a stepwise fashion. The first step is to determine whether it is a marsupial or a rodent. This can be done by examining the ear and/or the incisor teeth. The next step is to assess the maturity of the individual—this is important because young animals often look quite different from adults. Maturity is assessed by checking features of the reproductive organs (methods are described briefly below). The final step is to determine the genus and species, based on a combination of general body size and shape, fur colour and texture, and various features of the ears, feet and tail, and occasionally of the incisor teeth and mammary teats.

Using this stepwise approach it should be possible to reliably identify most species of non-volant mammals. However, for some groups, especially among the rodents, the differences between species can be very subtle and reliable identification in the hand may not be possible. For this reason a second method of identification based on genetic methods needs to be used for the identification of some species, and for the detection of cryptic undescribed species.

Identification of camera trap images

Camera trap images rarely show all of the features that might be examined on a captured individual. Generally an animal is either partially concealed or standing at an angle so that only the front or back is clearly visible. Quite often they are also moving, sometimes rapidly in response to the sound or flash emitted by the camera trap.

A good approach to camera trap identifications is to first look through most or all of the images obtained at a site, making a list of the clearly different species based on the clearest and most complete images. Indistinct or incomplete images can often be referred to one or other of these species during a second pass through the remaining images. Not every image will be identifiable.

Identification of camera trap images makes use of a subset of the features used for identification in the hand. This includes general body form and size (although the latter can only be approximated), fur colour and body patterning, and tail length (in some views) and patterning. In addition, some aspects of behavior can be informative, such as the way that the tail is carried when moving or standing still.

The camera trap images shown in this guide are usually cropped out of a broader image.

Scope of this identification guide

This guide is limited to those species that were encountered during the first (2015) and second (2017) phases of PMA3 biodiversity monitoring. In a few cases, comparative notes are provided to distinguish these species from others that may occur in the PMA3 study area.

Distinguishing the major groups of mammals

Three major groups of non-volant mammals are found in Papua New Guinea and all three occur within the PMA3 study area. The three groups are the primitive egg-laying monotremes, the pouched marsupials, and the non-pouched rodents that belong to the same large group as humans, cats and dogs—the placental mammals. The key diagnostic features of each group are listed below and illustrated in Figures 4.1–4.4.

Monotremes (Subclass Prototheria, Order Monotremata)

Represented in Papua New Guinea by several different kinds of echidnas, members of the Family Tachyglossidae. Adult echidnas are easily recognised by the long, sharp spines that cover most of the body, by their long tapering snout that terminate in a small mouth that lacks any teeth, and by their short tail that is also covered in long spines. While some bandicoots also have long-snouts and some have quite spiny fur, all bandicoots have a snout that is furred to near the tip, a more typical tail that is almost naked, and a long mouth with a full set of teeth. Male echidnas have a spur just above the ankle on each hindleg but the penis and testes are held inside the body. Females have a patch of mammary glands on the abdomen but no distinct teats; this patch is not very obvious outside of the breeding season.

Marsupials (Subclass Metatheria, several Orders)

Represented in Papua New Guinea by members of three orders—Order Dasyuromorphia (insectivorous and carnivorous marsupials), Order Peramelemorphia (bandicoots) and Order Diprotodontia (possums and wallabies/kangaroos). Papua New Guinean marsupials can be distinguished from rodents in the region using a number of

anatomical features: the arrangement of their reproductive organs, the number and shape of their anterior teeth, and the form of their external ear.

In all Papua New Guinean marsupials the females have a distinct abdominal pouch in which they rear the young during the first few months of life. All of the teats are contained within the pouch. Males lack a pouch but they have a distinctive rounded scrotum that is suspended on a short stalk (Figure 4.2). The penis is contained within the body and emerges through the anterior part of the urogenital opening, behind the scrotum. The lack of an obvious penis has confused many fieldworkers but this is normal for male marsupials.

Although it is not always easy to examine the teeth of a captive mammal, it is often possible to observe the incisor teeth at the front of the mouth. In all Papua New Guinean marsupials the upper jaw has at least six small teeth arranged in a u-shaped arcade across the front of the mouth (three or more on each side; see Figure 4.3). This is very different to the pair of chisel-like teeth at the front of the mouth in the upper jaw of a rodent. The number of teeth in the lower jaw of marsupials is variable; some have six small teeth (three on each side) while others have a single large tooth that superficially resembles that of rodents (Figure 4.3). Unlike the condition in many rodents, the enamel is never orange but instead is cream or white.

In all Papua New Guinean marsupials the external ear has a number of ridges and raised bumps on its inner surface, often with associated tufts of fur. Two examples are shown in Figure 4.4.

Rodents (Subclass Eutheria, Order Rodentia)

Represented in Papua New Guinea by members of one family only—Family Muridae (the typical rats and mice).

Female rodents lack a pouch and the mammary teats are arranged on either side of the body. In most Papua New Guinean rodents there are only two teats on each side and these are located low on the sides of the abdomen. In some species there are additional teats positioned either just forward or just behind the forelimbs. Female rodents have a prominent clitoris contained within a sheath of furred skin; this is often mistaken for a penis. Just behind the clitoris is a urogenital opening (vagina and ureter), and behind that again, a separate anus (the opening of the rectum; Figure 4.1). Male rodents have an external penis contained within a furred sheath, a non-pendulous scrotum situated behind the penis, and an anus positioned behind the scrotum.

All rodents have only two teeth in each of the upper and lower jaws (i.e. one on each side; Figure 4.3). These are chisel-like teeth that grow throughout life. The enamel is usually orange.

In all Papua New Guinean rodents the external ear is a simple flap of skin that lacks any ridges and raised bumps on its inner surface (Figure 4.4).

Distinguishing juveniles from adults in each groups of mammals

Echidnas

Juvenile echidnas display all of the same features as an adult except that the fur and spines may be shorter and less dense. The spur of a juvenile male is poorly developed.

Marsupials

Juvenile female marsupials have a small pocket in the position of the future pouch. In juvenile males the scrotum is distinct but small and more closely pressed against the abdomen.

In most marsupials the fur of juveniles is shorter and less shaggy than in adults but there are no marked changes through life either in fur colour or body patterning.

Rodents

In juvenile female rats the teats are low to the skin and sometimes difficult to see. The urogenital opening behind the clitoris is sealed by a thin layer of shiny skin (a hymen). In juvenile males the scrotum is not developed because the testes are held within the abdomen. With growth and maturation of the rat, the testes enlarge and descend into the scrotum.

In many species, young rats are shades of grey above and below, irrespective of the final adult colours. However, a rat that has pure white or cream belly fur as an adult will most likely have the same colour as a juvenile. The texture of the fur is also likely to change through life. Juveniles always have short, soft fur but this will change during two or more 'moult' into the adult coat that may be quite different in both colour and texture. The head, hands and feet of juvenile rats are proportionally oversized while the tail is always proportionally shorter than in the adult.

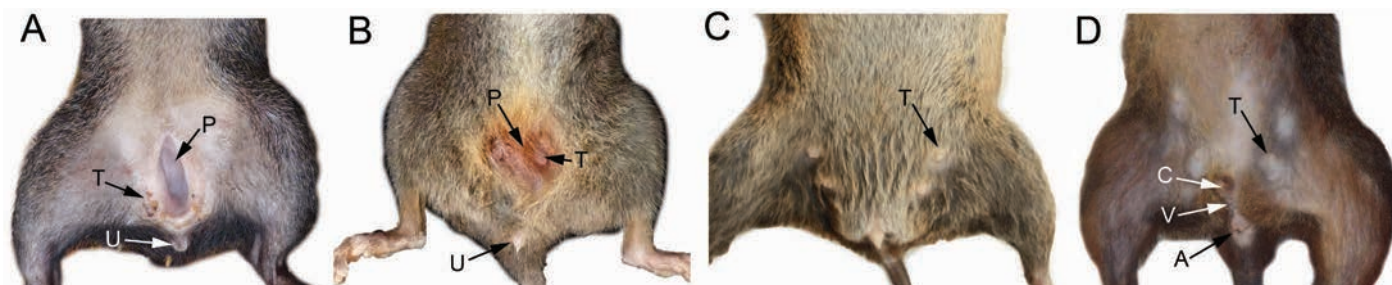


Figure 4.1. Reproductive anatomy of female marsupials (A–B) and rodents (C–D).

A: a young bandicoot (*Echymipera rufescens*) with a narrow pouch (P) with inconspicuous teats (T) and a single urogenital opening (U) behind the pouch; **B:** an adult dasyure (*Murexia naso*) with enlarged pouch (P) and prominent teats (T); **C:** an adult *Paramelomys* (*P. cf. rubex*) with enlarged teats (T) but other structures obscured by the thick fur; **D:** an adult Black-tailed Tree Rat (*Uromys anak*) with enlarged teats (T) and the clitoris (C), vagina (V) and anus (A) all clearly visible.



Figure 4.3. Skulls of two marsupials (A–B) and a rodent (C) illustrating the different number and arrangement of the incisor teeth (to the right in each image).

A: a bandicoot with four small upper incisors (one hidden) and three small lower incisors; **B:** a possum with three small upper incisors and one elongated lower incisor; **C:** a rodent with one upper incisor and one lower incisor, both curved, with orange enamel and with chisel-shaped ends.

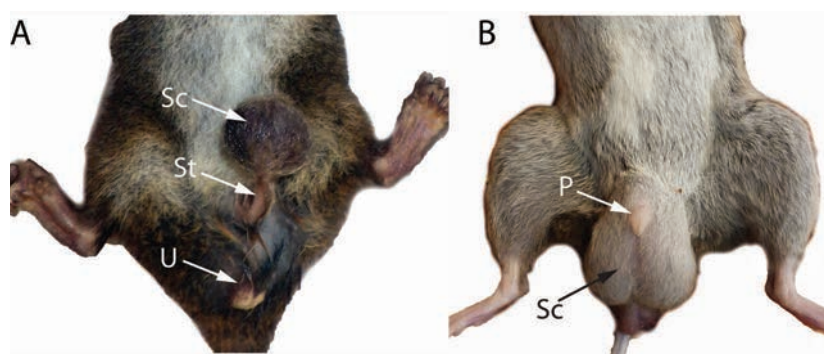


Figure 4.2. Reproductive anatomy of male marsupial (A) and rodent (B).

A: an adult dasyure (*Murexia naso*) with a pendulous scrotum (Sc) suspended on a stalk (St) and positioned forward of the single urogenital opening (U) that houses the penis and the anus; **B:** an adult *Paramelomys* (*P. cf. rubex*) with the penis (P) positioned forward of the bulging but non-pendulous scrotum. The anus in the rodent is at the base of the tail and is hidden by the scrotum in this view.

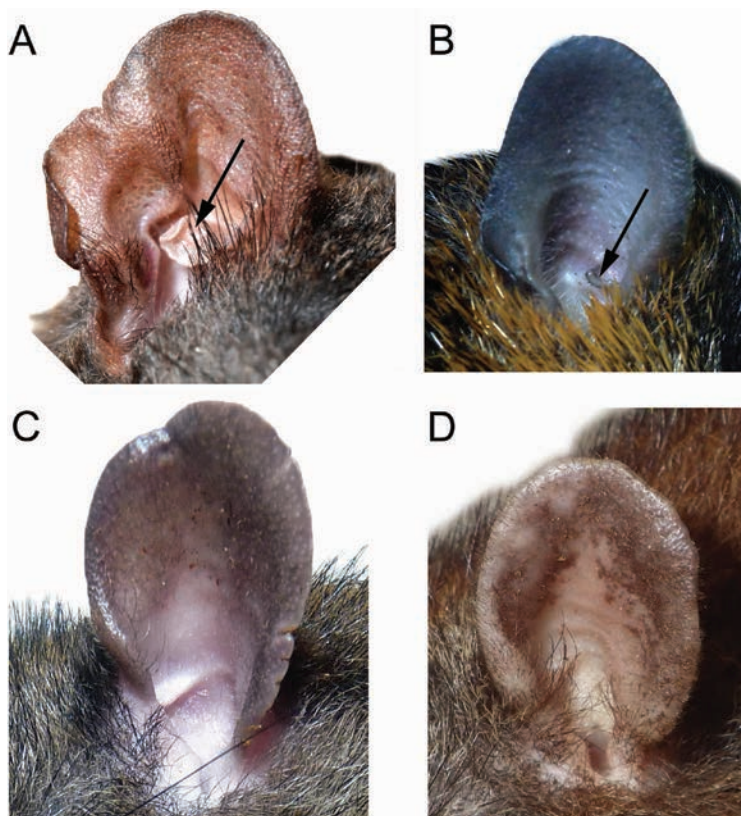


Figure 4.4. External ears of marsupials (A–B) and rodents (C–D).

A: a dasyure (*Murexia naso*) with a large folded interior process (arrow); **B:** a bandicoot (*Echymipera rufescens*) with a small but distinct interior process (arrow); **C:** an adult *Mammelomys* (*M. lanosus*) with a large but simple ear; **D:** an adult Black-tailed Tree Rat (*Uromys anak*) with a short but simple ear.

ORDER MONOTREMATA (Monotremes)

TACHYGLOSSIDAE (Echidnas)

Echidnas are robust ground-dwelling mammals with compact bodies, short powerful limbs, strong claws for digging, and a tubular snout with a protrusible tongue. The fur includes numerous strong, sharply pointed spines.

Tachyglossus aculeatus (Short-beaked Echidna)



General features: A small echidna with a short straight snout, and relatively short fur so that the spines project through the fur over the entire body. Adults measure 30–45 cm in body length and weigh 2–6 kg., with males and females approximately the same size. They are mainly active at night.

Identification from camera trap images: A short snout and the presence of numerous pale spines projecting through the fur on the back and sides are both diagnostic. The related Eastern Long-beaked Echidna (*Zaglossus bartoni*) has a much longer snout and thicker fur that usually obscures all but the longest of the spines.

Zaglossus bartoni (Eastern Long-beaked Echidna)



General features: A remarkable mammal with a long, thin snout that feeds on earthworms, and a variety of soil and log-dwelling arthropods. Head-body size is 48–55 cm in males and 51–64 cm in females, but 100 cm in total length has been recorded. They are mostly nocturnal, and have been recorded at elevations between 2,000 and 3,200 m asl (Wilson et al. 2015).

Identification from camera trap images: A roundish body with a very long, thin snout. The snout is around double the length of that in *Tachyglossus aculeatus*. The fur is jet black, and thicker spines can be seen projecting through it. The number of spines visible will vary, but generally there will be much fewer visible than in *Tachyglossus aculeatus*. The legs and feet are stumpy, and they have long, swept-back claws. The eye is small.

SUBCLASS METATHERIA (Marsupials)

DASYURIDAE (Carnivorous marsupials or dasyures)

Dasyures are quadrupedal predatory marsupials that are mostly scansorial (dividing their time between low bushes and trees and the ground). They show considerable variation in size and body form, from tiny shrew-like animals to the fearsome, cat-sized quolls and dog-sized Tasmanian Devil.

Dasyurus albopunctatus (New Guinea Quoll)



General features: A moderately large marsupial with a stocky build and a broad head with a short snout. The body fur is reddish brown to rich chocolate brown with white spotting. The tail lacks spots. Adults measure 23–35 cm in body length and weigh up to 500 g in females and 700 g in males. Primarily nocturnal but possibly active also during daylight.

Identification from camera trap images: The white spotting is diagnostic and allows reliable identification of even very partial images.

Murexia longicaudata (Short-furred Murexia)



General features: A medium-sized, powerfully built dasyure with an elongate snout, and a long, tapering tail. The body fur is short but dense and is grey above and pale grey below. There are no distinctive marks on the face or body. Adults measure 20–27 cm in body length and weigh up to 90 g in females and 140 g in males. They are probably active only at night.

Identification from camera trap images: The two species of *Murexia* share distinctive diagnostic features including their short, plain grey body fur and sharply pointed snout. *Murexia longicaudata* is larger and more powerfully built than *M. naso* and it has a distinctly longer snout. These differences may not be obvious in every case.

***Murexia naso* (Long-nosed Murexia)**



General features: A small dasyure with grey-brown fur on the back and flanks and pale grey to cream fur on the belly. The tail is thinly furred and sometimes ends in a short white tip. Adults measure 11–18 cm in body length and weigh up to 50 g in females and 75 g in males. They are probably active only at night.

Identification from camera trap images: This species is smaller and less powerfully built than *Murexia longicaudata* and it has a distinctly shorter snout but these differences may not be obvious in every image.

***Myoictis leucura* (Woolley's Three-striped Dasyure)**



General features: A medium-sized dasyure with a unique pattern of gold and black longitudinal stripes that run from just behind the ears to the rump. The snout is pointed as in the species of *Murexia*. The tail fur is thick around the base but narrows toward the tip, and the tail tip is white. Adults measure 19–23 cm in body length and weigh up to 230 g. Males and females are of approximately the same size.

Identification from camera trap images: The colourful striping of the fur on the back is unique to this species. If this is not visible, the form and colouration of the tail would be diagnostic. Unlike most other Papua New Guinean marsupials, this species tends to be active during the day. It is likely to be an excellent climber.

***Neophascogale lorentzii* (Speckled Dasyure)**



General features: A medium-sized dasyure with a pointed snout, thick bronze-tipped fur, a brushy tail and long curved claws on the hands and feet. Adults measure 16–23 cm in body length and weigh up to 220 g. Males and females are of approximately the same size. They appear to be equally at home on the ground and climbing in trees and are sometimes active during daylight.

Identification from camera trap images: The thickly furred tail combined with lack of any striping or spotting on the body is diagnostic. The fur has a metallic glow in sunlight due to the bronze tipping.

***Phascolosorex dorsalis* (Narrow-striped Dasyure)**



General features: Small carnivorous marsupial with a body size of 16–17 cm in males and 11–14 cm in females. They eat insects, spiders, frogs, lizards and small mammals. They breed throughout the year, are active during the day and are ground-dwelling. They occur in forest between 1,500–3,600 m asl in elevation (Wilson et al. 2015).

Identification from camera trap images: A small marsupial with a pointed face, dark-brown dorsal fur and a prominent single black stripe along the full length of the backbone. The presence of the dorsal stripe distinguishes them from *Neophascogale lorentzii* in the study area, but both species may have a bronze-coloured glow in sunlight. The belly fur is typically rich red.

PHALANGERIDAE

***Phalanger gymnotis* (Ground Cuscus)**



General features: A large, powerful cuscus with a body size between 30–54 cm in length and a tail between 29–40 cm. It lives in forested habitats mostly at elevations between 500–1,500 m asl, but can be found up to 2,700 m asl. There does not seem to be a distinct breeding season, so young individuals may be present at any time of the year. They rest during the day in dens under tree roots, along steep banks next to rivers, amongst rockpiles, and in caves. They may sun themselves in the morning, and scent mark in their home range (Wilson et al. 2015).

Identification from camera trap images: A large cuscus with grey or grey-brown dorsal fur and a dark vertebral stripe. The ears are small and have pale flashes behind them. Over half of the tail is without fur (distal portion), and it generally has a white tip.

PSEUDOCHEIRIDAE

Pseudochirops sp. (An unidentified ring-tailed possum)

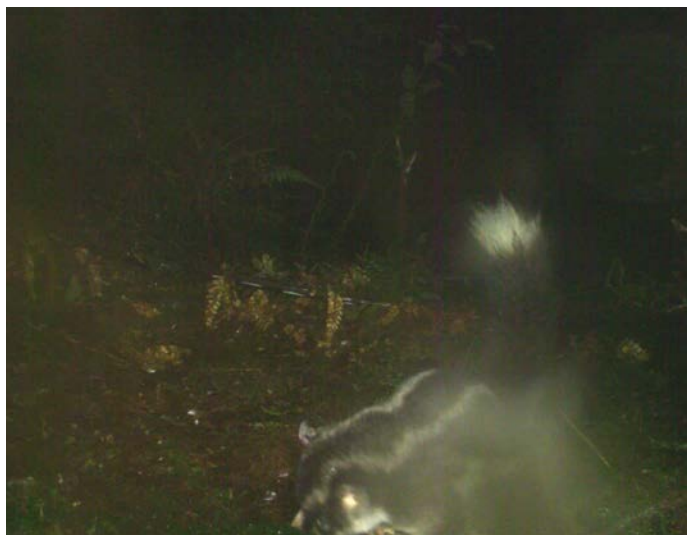


General features: Most likely *Pseudochirops cupreus* or *P. corinnae* in the study area. Both these species live in the highlands of Papua New Guinea. Body size is around 36–41 cm in *P. cupreus* and 30–38 cm in *P. corinnae*, the ears are small, and the partly-naked tail tip is prehensile. The first two digits of the hand (thumb and forefinger) are somewhat opposable, and the hallux (big toe) is opposable. They sleep on tree branches or in tree hollows during the day (Wilson et al. 2015).

Identification from camera trap images: *Pseudochirops* species differ from the much larger Ground Cuscus (which has grey fur with a dark dorsal stripe) in colour and by having a tail that is covered by fur apart from the underside of the last third (and the tip of the tail in *P. cupreus*). *Pseudochirops corinnae* has three dark stripes of varying development on the back and silvery-green fur. By contrast, *P. cupreus* has copperish fur and no dark stripes.

PETAURIDAE

Dactylopsila palpator (Long-fingered Striped Possum)



General features: This is one of the more distinctive possums, not only because of the black and white striped fur patterning, but for the remarkably long fourth digit (finger) that is used to hook out insect larvae from beneath rotting timber. A heel-like structure on their wrists is used to tap on wood to help locate their prey. They are arboreal and den inside tree hollows, but also may spend a significant proportion of their time on the ground. They have a pungent odour to match their skunk-like patterning. Body size is 20–26 cm. They occur between 850–3,050 m asl in elevation (Wilson et al. 2015).

Identification from camera trap images: Fur with a series of black and white longitudinal stripes. Two white stripes extend from the nose to the rump. The fourth digit on the hand is remarkably long. The ears are relatively small, and there is no gliding membrane between the legs and arms.

PERAMELIDAE (Bandicoots)

Bandicoots all share a distinctive body form —powerful haunches combined with more slender forelimbs and a thin, weakly furred tail. They are active only on the ground and appear to be exclusively nocturnal.

Echymipera sp. cf. *kalubu* (An undescribed *Echymipera*)



General features: A medium-sized, heavily built bandicoot with a relatively short snout, a particularly short tail, and a boldly patterned face combined with an unpatterned body. The hand and lower part of the forelimb are white. Adults measure 20–30 cm in body length and probably weigh up to 1 kg. Males grow slightly larger than females.

Identification from camera trap images: The echymiperas have shorter snouts and tails than other bandicoots. Their fur is spiny and brindled (a mix of yellow, brown and black hairs) and has a distinctive, gold-speckled appearance on camera trap images. The strong facial patterning and white forelimbs are also diagnostic for this species.

***Microperoryctes ornata* (Eastern Striped Bandicoot)**



General features: A relatively small bandicoot with an elongate snout, a relatively long, thinly furred tail, and a complex pattern of stripes on the face and body. This includes a black dorsal stripe on the head and back, a black facial stripe passing through the eye, and short lateral stripes on the forelimbs and rump. The belly fur is cream, contrasting with the grey-brown fur of the back and flanks. The tail is dark but usually has a long white tip. Adults measure 20–25 cm in body length and probably weigh up to 500 g. Males and females are of approximately the same size.

Identification from camera trap images: The strong facial patterning that includes a midline stripe is diagnostic from a frontal view. From the side the facial pattern combined with striping on the forelimb and rump is diagnostic. From the rear, the dorsal stripe and striped rump are distinctive. Some individuals, including the live captured young animal illustrated above (bottom right), are less strongly patterned but it remains unclear whether this is individual variation, age-related, or evidence of a second species of *Microperoryctes* in the sites.

***Peroryctes raffrayana* (Raffray's Bandicoot)**



General features: A medium-sized, powerfully built bandicoot with an exceptionally elongate snout, a moderately long tail, and dark brown fur on the back and flanks. Ventral fur is pure white. The fur of juveniles is reddish tan that darkens with age. The tail is dark all the way to the tip. Adults measure 25–40 cm in body length and probably attain weights up to 1 kg. Males grow to a slightly larger size than females (Wilson et al. 2015).

Identification from camera trap images: The lack of any facial or other body patterning is diagnostic, and other features such as the relatively long tail and very elongate snout will also aid with identification.

MACROPODIDAE (Wallabies and kangaroos)

Wallabies and kangaroos have a common body plan that combines powerful and elongate back legs and tail, with less powerful forelimbs. Most species are exclusively ground dwelling and move either by hopping on the hindlimbs or by swinging the hindlimbs forward while taking the body weight on the forelimbs and tail. Tree kangaroos have taken to the trees as a secondary evolutionary adaptation and they have more powerful forelimbs to aid in climbing. When on the ground, they move around like other wallabies. All tree kangaroos probably sleep on the ground but do most of their foraging and social activity after dark in the trees. Daytime activity has been observed in the low canopy of upper montane mossy forest.

***Dendrolagus goodfellowi* (Goodfellow's Tree Kangaroo)**



General features: A large tree-dwelling macropod with a long, thick tail. Body size is 50–85 cm in males and 53–64 cm in females. Tail is 65–85 cm in males and 54–64 cm in females. Fur is generally brown and yellow, being chestnut to dark brown dorsally, and paler beneath. There is a dark-brown mid-dorsal stripe of varying length and thickness. They live in the mid-montane rainforest, and feed both in the forest canopy and on the ground. They can be crepuscular in their activity in remote areas, but nocturnal where they are more heavily hunted (Wilson et al. 2015).

Identification from camera trap images: Broad head, brown and yellow fur with a dark vertebral stripe, and a thick tail that is as long as the body that terminates with squared end.

***Dendrolagus notatus* (Western Montane Tree Kangaroo)**



General features: A large, powerfully built tree kangaroo with exceptionally powerful forelimbs, a broad head and short, thickly furred ears. The fur is dense and woolly, usually a chocolate brown on the back and flanks but tending to a more silvery grey on the forelimbs, head and tail. The only bold patterning on the body is a cream or yellow spot at the base of the tail. The tail is long and heavily furred and almost cylindrical all the way to the tip. Adults measure 60–70 cm in body length and weigh up to 7 kg (females) and 9.5 kg (males).

Identification from camera trap images: The powerful limbs, massive head with short rounded ears and general lack of body patterning is diagnostic. More restricted views showing the cylindrical tail or the yellow spot at the base of the tail might also be sufficient for identification.

***Dorcopsulus* sp. cf. *vanheurni* (A small forest wallaby)**



General features: A small wallaby with a short face, rounded ears, slender forelimbs, and a short tail that is held in a distinctive way at rest, with only the tip of the tail in contact with the ground. The fur on the back and sides is grey-brown and the belly fur is a paler grey, lightening further on the chest. Adults measure 30–45 cm in body length and weigh up to 2.3 kg. Males and females are approximately the same size.

Identification from camera trap images: General body form and posture are usually diagnostic, and the unusual down-curved tail is often visible. Juveniles are very similar to adults in body shape and colouration but they have a shorter snout with proportionally larger ears and eyes. Juveniles are usually accompanied by an adult female.

***Thylogale* sp. (An unidentified pademelon)**



General features: Most likely the more common New Guinea Pademelon *Thylogale browni*, but Calaby's Pademelon *Thylogale calabyi* is also a possibility. Combined head and body size is 53–67 cm in males and 49–56 cm in females. They have dark brown fur on the dorsal surface, and paler underparts. The fur is generally short, but can be longer at higher elevations. *Thylogale browni* can be found between sea level and 3,800 m in elevation, in a variety of habitats including primary and secondary rainforest, grasslands and abandoned gardens. Females breed continuously so young can be seen at any time of the year (Wilson et al. 2015).

Identification from camera trap images: Typical form of a small kangaroo, with a shortish pointed snout, and darkish brown fur on the dorsal surface. The ears are larger than in *Dorcopsulus vanheurni* and more pointed, and the snout is slightly more elongated. It is also around one and a half times the size.

MURIDAE (Typical rats and mice)

Papua New Guinea has a diverse rodent fauna—from small shrew-like species to water rats and giant rats. Despite this diversity, they all have a similar body form, with fore- and hind-limbs of approximately equal length and bulk, and a narrow tapering tail that is only rarely shorter than the combined length of the head and body.

Another feature common to all rodents is the presence of a single pair of chisel-like incisor teeth in each of the upper and lower jaws. These are rarely visible on a camera trap image but are easily observed on a captive animal.

Anisomys imitator (Uneven-toothed Rat)



General features: This species has very distinctive incisor teeth—the upper pair is of normal size and shape but the lowers are extremely deep (vertically) and narrow (from side to side). This feature is readily observed on a captive animal. Otherwise they are characterised by relatively short brindled fur on the back and flanks, a paler grey belly, a deep head, and a long tail that exceeds the head and body in length. The tail is divided into a short black section at the base and a much longer white section to the tip. The tail scales are quite small and the hairs are clearly visible to the naked eye. Adults of both sexes measure 20–29 cm in body length and weigh up to 600 g. They are probably active only at night when they move around on the ground and in low trees and shrubs.

Identification from camera trap images: Distinguished from most other Papua New Guinean rodents by its short, brindled fur combined with a very elongate tail that is white for most of its length. *Anisomys imitator* is similar to the White-tailed Giant Rat (*Uromys* sp. cf. *caudimaculatus*) in general body proportions and size, and in fur colour and texture. They differ in the colouration of the tail—in *Uromys* sp. cf. *caudimaculatus* the basal black portion is usually proportionally longer and the boundary between the black and white sections is mottled rather than sharp as in *Anisomys imitator*.

***Uromys anak* (Black-tailed Giant Rat)**



General features: A large rat with a head-body 270–330 mm and tail 228–400 mm. The ear is relatively small (16–27 mm), and the hind foot is 61–76 mm. The fur is long and consists mostly of dark-coloured guard hairs. They are found in primary tropical moist forests, and degraded and secondary forest (Wilson et al. 2017).

Identification from camera trap images: Dorsal fur appears dark and spiny, with shiny long hairs, intermixed with greyish-brown or rufous fur. The midline fur colour transition is poorly defined and the underparts are paler. The feet are black and furred, and ears long, rounded and naked. The tail is at least as long as the body and dark in colour, though with small irregular pale blotches in the distal half. In *Uromys* sp. cf. *caudimaculatus* the fur is lighter, and the whole distal portion of the tail is pale.

***Uromys* sp. cf. *caudimaculatus* (White-tailed Giant Rat)**



General features: This species closely resembles the Uneven-toothed Rat (*Anisomys imitator*) in body form and fur texture but it lacks the peculiar dental features of that species. The tail has more flattened scales and shorter hairs than the Uneven-toothed Rat and, while the basic tail colouration is much the same in both species, in the White-tailed Giant Rat the boundary between the black and white sections is almost always mottled. They are large rats with head and body lengths up to 28 cm and body weights to 700 g. They are probably active only at night and are equally at home on the ground and in the trees.

Identification from camera trap images: Distinguished from most other Papua New Guinean rodents by its short, brindled fur combined with a very elongate tail that is white for most of its length. It is difficult to distinguish from the Uneven-toothed Rat unless the tail is clearly visible—in *Uromys* sp. cf. *caudimaculatus* the basal black portion is usually longer and the boundary between the black and white sections is mottled rather than sharp as in *Anisomys imitator*.

***Hyomys* sp. (A white-eared giant rat)**



General features: Several species of White-eared Giant Rats are found in Papua New Guinea and it is not yet clear which one occurs in the monitoring sites. All are essentially similar in external features—they are very large rats with head and body lengths of 30 cm or more and body weights up to 1 kg, they have a stocky build that is accentuated further by their dense shaggy fur, and they have tails that are usually about the same length as the combined head and body. The tails are more coarsely scaled than most other rodents and appear almost naked. The basal half or so of the tail is dark grey or black and there is a sharp boundary to a long white distal portion. The ears are thinly furred and have pale skin so they stand out from the dark fur of the head. They are probably active only at night and spend most of their time on or close to the ground.

Identification from camera trap images: Distinguished from most other Papua New Guinean rodents by their large size, thick shaggy fur and their striking pale ears. The only potential confusion is with a Woolly Giant Rat (*Mallomys* sp.) but that species has dark skin on the ears.

***Mallomys* sp. (A woolly giant rat)**



General features: Several species of Woolly Giant Rats are found in Papua New Guinea and it is not yet clear which one occurs in the monitoring sites. They closely resemble the White-eared Giant Rats (*Hyomys* spp.) in body form and fur texture but have more finely-scaled tails and dark skin on their ears. They are very large rats with head and body lengths of 40 cm or more and body weights up to 1.5 kg. They are probably active only at night and may spend less time on the ground than the White-eared Giant Rats.

Identification from camera trap images: Distinguished from most other Papua New Guinean rodents by their large size and thick shaggy fur. The only potential confusion is with a White-eared Giant Rat (*Hyomys* sp.) but the colour of the ears allows them to be distinguished.

***Leptomys elegans* (Large Leptomys)**



General features: A brightly coloured small rodent with a characteristic, slender build. It has brown fur on the back, chestnut/brick-red fur on the flanks and pure white fur on the belly. Patterning of the head is also striking, with a dark 'mask' across the eyes and white fur on the cheeks. The ears have dark skin and are proportionally larger than most other Papua New Guinean rodents. The hindfeet are long, narrow and pure white above. The tail is slightly longer than the combined head and body and usually has grey skin along the upper surface and white skin below. The tip is usually white above and below. Sometimes the entire tail has a mottled appearance. Body length can reach 18 cm and body weight can exceed 100 g. This species is probably active only at night and probably spends all of its time on the ground. All *Leptomys* species are probably carnivorous, eating small vertebrates as well as invertebrates.

Identification from camera trap images: Distinguished from most other Papua New Guinean rodents by its bright chestnut-coloured dorsal fur, bright-white belly fur and black face, large ears, and mottled tail that ends in a white tip. It most closely resembles some species of *Paramelomys* in fur colour but is readily distinguished by its more slender build, larger ears, more brightly patterned (dark) face, and white-tipped tail.

***Parahydromys asper* (Waterside Rat)**



General features: A medium-sized rodent with a stocky build, partially webbed feet, and a distinctive swollen snout with a dense array of whiskers. They have grey-brown fur on the back, paler yellow-brown fur below and often a brick-red patch of fur on the chest. The tail is more thickly furred than most other rodents and is usually black to the tip. The ears are dark-skinned, short and round. Body length reaches 23 cm and body weight is up to 600 g. They are probably active only at night and spend all of their time on the ground. They are carnivorous and are known to consume worms as well as crabs.

Identification from camera trap images: Distinguished from most other Papua New Guinean rodents by their black, densely furred tail and distinctive swollen snout. The only potential confusion is with the Common Water Rat (*Hydromys chrysogaster*) which always has a long white section on the tail and denser, woolly fur.

***Paramelomys* (Mosaic-tailed Rats)**



General features: Small to medium-sized rats with a 'plump' body form, short dense fur that lacks obvious spines, and a tail that is usually equal in length or shorter than the combined head and body. The tail has very short hairs and thus appears naked, and the tail scales are flattened and non-overlapping, producing a mosaic-like effect. In most species the tail is distinctly 'bicoloured'—dark on the upper surface but cream or white below—but this feature is not unique and also occurs in some other genera such as *Leptomys*. Most species have reddish-brown fur on their back with strongly contrasting white or cream fur on the belly and some have a ring of darker fur around the eye, as also seen in *Leptomys* spp. The ears are typically short and rounded and have at least an outer rim of dark skin. Adults range in length from 10–20 cm and weigh from 40–120 g, depending on the species. All *Paramelomys* species appear to be active only at night and to spend most or all of their time on the ground.

Identification from camera trap images: A combination of features should allow referral to *Paramelomys*—the 'plump' body shape, the typically sharp contrast in fur colour between the flanks and belly, and the bicoloured nature of the tail. Identification to an individual species within *Paramelomys* is probably only possible for captured animals.

Identification of captured animals: Captured *Paramelomys* are most likely to be confused with species of the genus *Rattus*, with which they share a similar body form. Three features provide the best means of distinguishing between *Paramelomys* and *Rattus*—the mammary teats (females only), the tail, and the hindfeet. While some morphological features may give a clue to species-level identification (see below), distinguishing among the species of *Paramelomys* requires genetic analysis for complete confidence. In BAA 1 on the Agogo Range near Moro (below 1,500 m asl), three species have been confirmed using genetics-based identification: *Paramelomys lorentzii*, *P. platyops* and *Paramelomys* sp. cf. *rubex* B. In BAA 2 on Hides Ridge (above 2,000 m asl), three different species were confirmed using genetics-based identification: *Paramelomys intermedius*, *Paramelomys* sp. cf. *rubex* A and *Paramelomys* sp. cf. *mollis* AD. Most of these forms are part of unresolved species complexes.

Mammary teats: All *Paramelomys* have only two teats on each side and these are at the rear of the body. The locally occurring *Rattus* have an extra teat on each side; this is positioned just forward of the forelimb.

Tail: The tail in all species of *Paramelomys* feels smooth and looks hairless to the naked eye (Figure 4.5); if examined under magnification, 1–3 very fine hairs can be found emerging from the back of each scale. In all species of *Rattus* the tail feels hairy and the hairs are clearly visible to the naked eye (Figure 4.6).

Hindfeet: The upper surface of the hindfeet in all *Paramelomys* is clothed in fine white hairs (Figure 4.5). In locally occurring species of *Rattus* the upper surface is at least partially clothed in short black hairs. The undersurface also shows various differences if examined closely—there are more scale rings on each toe in *Paramelomys* than in *Rattus* and the pad closest to the heel is long and narrow in *Paramelomys* but more ‘comma’-shaped in *Rattus*.



Figure 4.5 Left: *Paramelomys mollis* upper and lower surface of hindfeet, Centre: *Paramelomys mollis* tail, Right: *Paramelomys rubex* tail



Figure 4.6 Left: *Rattus* upper and lower surface hindfeet, Right: *Rattus* tail

Six species of *Paramelomys* have been confirmed at the monitoring sites on the basis of morphological and genetic evidence. These fall into two clear groups—two smaller species with adult weights of 40–55 g and a ‘spotted’ pattern on the tail; and four larger species, each with adult weights in excess of 80 g and without the spotting pattern on the tail (Figure 4.5). Within each of these groups, the morphological contrasts are very small and reliable determinations may always require genetic analysis.

Illustrations of some captured animals are shown below to illustrate the close overall similarity among the species of *Paramelomys*. Some distinguishing features are listed below:

***Paramelomys* sp. cf. *rubex* A**



***Paramelomys* sp. cf. *rubex* B**



***Paramelomys* sp. cf. *mollis* A**



Paramelomys platyops



Smaller-bodied *Paramelomys*

Paramelomys sp. cf. *rubex* A – tail slightly shorter than in the other ‘small’ species and eye and ear possibly both smaller. No obvious differences in fur colouration or patterning.

Paramelomys sp. cf. *rubex* B – tail slightly longer and the eye and ear possibly larger.

Larger-bodied *Paramelomys*

Paramelomys sp. cf. *lorentzii* – tail relatively shorter than other species in this group and each tail scale has three short hairs. Fur on back and flanks plainer brown, less pronounced red or orange hues than *P. platyops* with which it co-occurs.

Paramelomys platyops – each tail scale has one short hair; fur on back and flanks shorter than in either form of ‘*mollis*’ and hindfeet and tail are also slightly shorter than in the other ‘large’ species.

Paramelomys sp. cf. *mollis* A – each tail scale has one short hair; fur on back and flanks thicker and denser than in *P. platyops*; hindfeet and tails are also slightly longer.

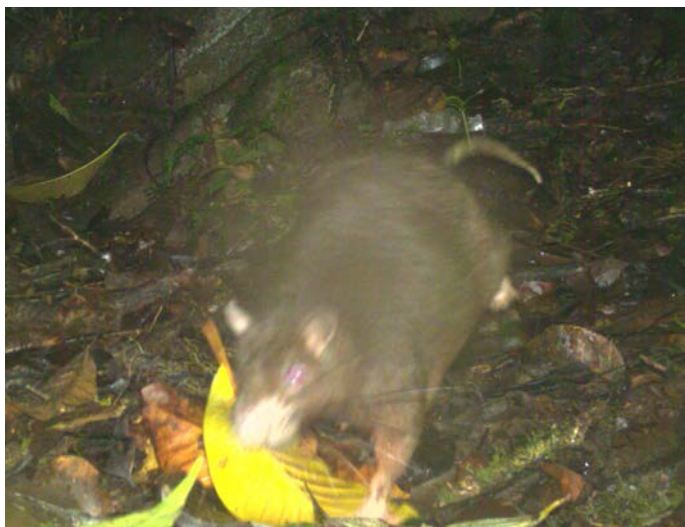
Paramelomys sp. cf. *mollis* B – this species was identified in the field as *Paramelomys* cf. *mollis* A but proved distinct on genetic testing. Further captures are required to establish its morphological features.

***Rattus* (Typical rats)**

Rattus* sp. cf. *niobe



Rattus* *verecundus



General features: Small to medium-sized rats with dense shaggy fur that includes obvious pale spines, and a tail that is usually equal in length or shorter than the combined head and body. The tail feels and looks hairy and is usually the same colour above and below, either black or a grey with paler mottles. It is usually the same colour to the end but occasionally has a short white tip. The tail is usually held out straight from the body. Most species either have shaggy bridled fur on the back and flanks or they have darker, thicker fur. The belly fur is also variable in colour among the species. The ears are moderately long and rounded, and are typically grey. All *Rattus* species appear to be active primarily after dark. The native species probably spend most or all of their time on the ground but the two introduced species are often seen climbing in low shrubs and trees.

Identification from camera trap images: A combination of features should allow referral to *Rattus* — a typical ‘rat-like’ body shape, a lack of sharp contrast in fur colour between the flanks and belly, and a dark tail that is held straight back from the body (the tip is sometimes elevated but with the tail straight). Identification to an individual species within *Rattus* is only possible for some images and for captured animals. In good images it is possible to differentiate between the larger and coarse-furred *Rattus verecundus* and the smaller, softer-furred forms of *Rattus* cf. *niobe*.

Identification from captures: While some morphological features may give a clue to species-level identification (see below), distinguishing among the species of *Rattus* requires genetic analysis for complete confidence. In BAA 1 on the Agogo Range near Moro (below 1,500 m asl), four species have been confirmed using genetics-based identification: *Rattus exulans*, *R. steini*, *R. verecundus* and *Rattus* sp. cf. *niobe* D. In BAA 2 on Hides Ridge (above 2,000 m asl), two different species were confirmed using genetics-based identification: *Rattus rattus* and *Rattus* sp. cf. *niobe* B. Most of these forms are part of unresolved species complexes.

Six species of *Rattus* have been confirmed at the monitoring sites on the basis of morphological and genetic evidence. These fall into two clear groups—four smaller species with adult weights of 30–85 g; and two larger species, each with adult weights in excess of 100 g. Four of the species are native to Papua New Guinea; the other two are exotic invasive species.

Smaller-bodied *Rattus*

Rattus sp. cf. *niobe* B – fur very long and shaggy, soft to the touch, with no coarse spines. Fur of back and flanks is grey-brown with no patterning on the head or limbs. Belly fur is tipped with paler grey or cream. Tail very dark all the way to the tip; tail length approximates that of the combined head and body. Upper surface of hindfeet clothed with black hairs. Body weight reaches 60 g in males but usually less than 55 g in non-pregnant females.

***Rattus* sp. cf. *niobe* B**



Rattus sp. cf. *niobe* D – very similar in appearance to *R. sp. cf. niobe* B but adults often with prominent reddish brown patch on the chest. Tail is dark but occasionally has a very short white tip. Body weight reaches 87 g in males but usually less than 70 g in non-pregnant females.

Rattus exulans – fur is shaggy but shorter than previous species, harsh to the touch due to presence of numerous coarse spines. Fur of back and flanks is brindled, with no patterning on the head or limbs. Belly fur is tipped with paler grey or cream. Tail is paler than in the other species and often blotchy. Upper surface of hindfeet is mainly white but with a narrow strip of darker hairs along the outer margin. Body weight reaches 40 g in males, probably slightly less in non-pregnant females.

Rattus steini – fur is moderately long and very shaggy, harsh to the touch due to presence of numerous coarse spines—similar to *R. verecundus*. Requires genetics-based identification.

Larger-bodied *Rattus*

Rattus verecundus – fur is moderately long and very shaggy, harsh to the touch due to presence of numerous coarse spines. Fur of back and flanks is brindled and there is no patterning on the head or limbs. Belly fur is grey tipped with paler grey or cream. Tail is slightly shorter or equal to the combined length of the head and body, and is pale and blotchy with short dark hairs visible along its entire length. The upper surface of the hindfeet is clothed in white hairs with scattered black hairs. Body weight reaches 157 g in males but only 110 g in non-pregnant females.

Rattus rattus



Rattus verecundus



Rattus rattus (Black Rat) – fur is shaggy but relatively shorter, harsh to the touch due to presence of numerous coarse spines. Fur colour of this species is often highly variable. Typical form is brindled on back and flanks. Belly fur can be cream or grey tipped with paler grey or cream. A common variant is black to dark grey above and below. The tail is slightly longer to much longer than the combined length of the head and body, grey to black in colour, and often blotchy. The upper surface of the hindfeet is typically white with a narrow strip of darker hairs along the outer margin but is black in the darker variant. Body weight of one adult male was 98 g. Individual weights to 150 g or more are expected for both sexes.

CANIDAE (Dogs)

Canis familiaris (Wild/Domestic Dog)



General features: Papua New Guinean wild and domestic dogs are highly variable in size and colouration but their general features are all those of a typical dog.

Identification from camera trap images: An image of almost any part of the animal is diagnostic.

FELIDAE (Cats)

Felis catus (Domestic Cat)

General features: Cats in Papua New Guinea are of the same size or a little larger than domesticated cats. They are excellent hunters that prey on native wildlife.

Identification from camera trap images: Clearly recognisable from their face, fur patterning and paws. Fur colour is generally tabby, but ginger tabby is also a possibility.

SUIDAE (Pigs)

Sus scrofa (Feral Pig)



General features: Pigs vary in size according to age, but adult wild pigs are around the size of Papua New Guinean wild and domestic dogs. Their fur is dark.

Identification from camera trap images: An image of almost any part of the animal is diagnostic. Their fur is dark, with the pale-coloured flesh visible beneath the sparser areas. A snout is the most diagnostic feature, and the face is long and broad. The cloven hooves may be visible in photos.

References and further reading

Flannery, T. F. 1995. *The Mammals of New Guinea*. (Revised Edition). Reed Books: Chatswood, NSW.

Menzies, J. I. 2011. *A Handbook of New Guinea's Marsupials and Monotremes*. (Second Edition). UPNG Press: Port Moresby, P.N.G.

Wilson, D. E., Mittermeier, R. A. & François, T. L. (editors) (2015). *Handbook of the mammals of the world. Vol. 5. Monotremes and Marsupials*. Lynx Edicions, Barcelona, 799 pp.

Wilson, D. E., Lacher, T. E., Mittermeier, R. A. & François, T. L. (editors) (2017). *Handbook of the mammals of the world. Vol. 7. Rodents II*. Lynx Edicions, Barcelona, 1008 pp.

BATS

Kyle N. Armstrong



Rhinolophus megaphyllus (Eastern Horseshoe Bat)

Introduction

The bat component of the PMA3 monitoring study is focused on echolocating species, which are detected from recordings of their echolocation calls. This guide presents information relevant to identifying the species present in the study area on the basis of these calls. It also includes a brief description of morphological features that can be used to identify captured live bats of both echolocating and non-echolocating species.

A brief overview of identifying bat species from echolocation calls

Most bat species use echolocation to fly through their surroundings in darkness, and to detect and locate their insect prey. Each species emits their own unique signal for these tasks, which can be recorded using electronic ‘bat detectors’ capable of detecting ultrasound, and then identified by an experienced analyst. Bats usually call continuously when in flight, and bat detectors typically record multiple pulses when the bat comes within range of the microphone. Many bats emit their echolocation calls through the mouth. Others keep their mouths closed while in flight and emit the calls through the nose—these species usually have a complex dish-shaped structure surrounding the nostrils that focuses each pulse into a beam in front of the animal.

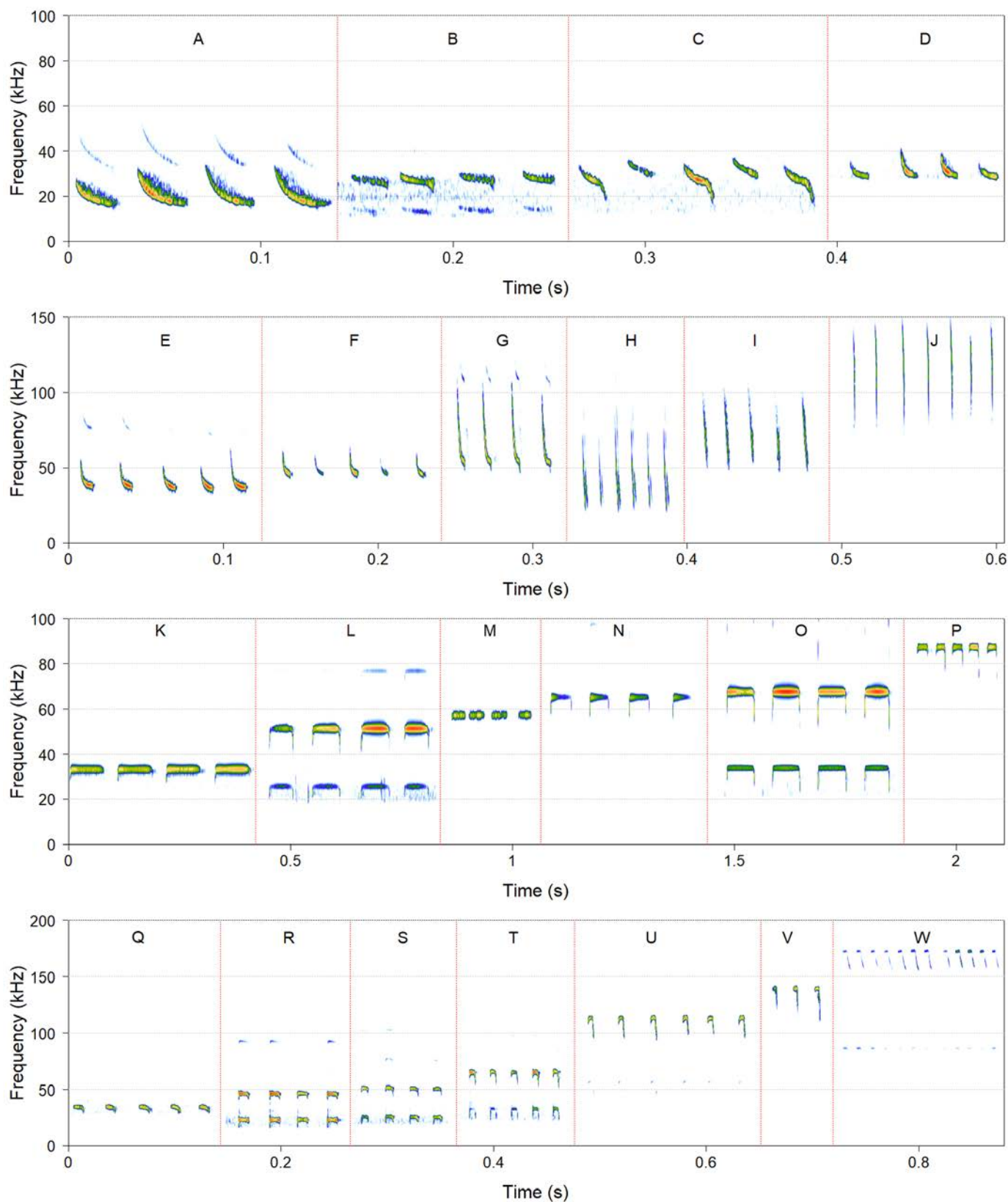
Most bat species can be identified from their calls relatively easily, but there are several factors that make identification from calls challenging. Firstly, in any given habitat, there are usually one or more groups of species that produce similar calls. While there may be subtle features of signals that are species-specific, the variation in pulse features and measurements can overlap considerably, and so distinguishing them reliably and unambiguously might not be possible. Secondly, each individual bat varies its calls slightly depending on what it is doing. For example, bats that forage in the open next to vegetation generally reduce the duration and increase the frequency range of their pulses when they approach a background of vegetation or water. This aspect greatly increases the variation in pulse measurements within species. Lastly, pulse features can vary slightly according to geographic location, as well as the sex, age and body size of individuals. But despite these three considerations, it is possible to identify most species, with varying levels of confidence.

After numerous surveys in Papua New Guinea in the last decade, there is now a reasonable resource for attributing anonymously-recorded echolocation calls to bat species (Armstrong and Aplin 2011, 2014a,b; Leary and Pennay 2011; Robson et al. 2012; Armstrong et al. 2015a,b; K.N. Armstrong and K.P. Aplin unpublished data). Given the diversity of species, it is helpful to firstly classify any bat calls into categories based on the scheme in Table 1. Once a call is classified this way, it might be attributed to a species as a second step. The semi-automated data analysis system used in this study is based on this classification approach (Armstrong and Aplin 2014c; Armstrong et al. 2016). In the 2015 PMA3 survey, 19 call types were recognised, with each of these being identified to species (taxonomic issues notwithstanding; Figure 1 provides a quick reference guide to the species present). In the 2017 survey, six species were added.

As further surveys are undertaken, it is very likely that additional species will be recorded at the various survey sites, and it will be important to distinguish their calls from the types already identified. Diagnostic details of each call type are therefore included in the species profiles to allow the identification of those already encountered, as well as providing a reference when trying to allocate a call type not yet represented in the collection. In addition, while most calls and captures will be of species already taxonomically described or known to scientists, there is always the possibility that a completely new species will be discovered—as occurred on the 2015 survey with the call type named as *Hipposideros* sp. cf. *ater*, and in the 2017 survey with the capture of high elevation forms resembling *Kerivoula muscina* and *Nyctophilus microtis*.

Table 1. Echolocation call categories based on the morphology of the dominant type of single search-phase pulses in high quality sequences (adapted from: de Oliveira 1998a,b; Corben and O’Farrell 1999; Gannon et al. 2004; Armstrong and Aplin 2011; examples are not scaled equally). Pulses generally consist of three main sections: an initial frequency sweep (IFS), followed by the main body (BST: Body Sub Type), and ending in a terminating frequency sweep (TFS). The shape of the pulse is represented by the codes in the form ‘IFS.BST.TFS’, prefixed by a value representing the mode characteristic frequency in kHz.

Code	Description	Examples
CF	Constant Frequency Body Sub Type (BST)^{1,2}	
	¹ Reserved for Hipposideridae and Rhinolophidae	
	² No use of IFS or TFS	
<i>ICF</i>	Long duration constant frequency pulse (>30 ms)	
<i>mCF</i>	Medium duration constant frequency pulse (15–30 ms)	
<i>sCF</i>	Short duration constant frequency pulse (<15 ms)	
FM	Frequency Modulated Body Sub Type (BST)	
<i>bFM</i>	Broadband, slight curvature only, no significant development of serpentine component (<i>sFM</i>)	
<i>cFM</i>	Curved, simple or curvilinear trace	
<i>fFM</i>	Flat, no decrease, or a very slight decrease in frequency over the pulse body, not classed as <i>CF</i>	
<i>sFM</i>	Serpentine, generally S-shaped	
Ends	Initial Frequency Sweep (IFS)	
<i>i.</i>	Inclined, a narrowband increasing frequency sweep	
<i>sh.</i>	Short, shallow or narrowband frequency sweep	
<i>st.</i>	Steeply decreasing, broadband frequency sweep	
	Terminating Frequency Sweep (TFS)	
<i>.d</i>	Drooped, decreasing frequency sweep following the characteristic frequency in the main body of the call	
<i>.h</i>	Hooked, increasing in frequency	



Key to species in Figure 1.

A: 20 cFM *Chaerephon jobensis*; **B:** 25 sFM *Saccolaimus saccolaimus*; **C:** 30 sFM *Otomops* sp.; **D:** 30 cFM *Philetor brachypterus*;

E: 38 st.cFM *Miniopterus* sp. 1 'large'; **F:** 45 st.cFM *Miniopterus* sp. 2 'medium'; **G:** 53 st.cFM *Miniopterus* sp. 3 'small'; **H:** 30 bFM *Nyctophilus microdon*; **I:** 50 bFM *Nyctophilus microtis*; **J:** 80 bFM *Kerivoula* sp. cf. *muscina* / *Murina* sp. cf. *florium*;

K: 33 ICF *Rhinolophus* sp. cf. *robertsi*; **L:** 52 ICF *Rhinolophus euryotis*; **M:** 58 mCF *Hipposideros diadema*; **N:** 65 ICF *Rhinolophus megaphyllus*; **O:** 70 ICF *Rhinolophus mcintyreii*; **P:** 88 mCF *Hipposideros wollastoni*;

Q: 35 i.fFM.d *Emballonura diana*; **R:** 45 i.fFM.d *Emballonura raffrayana*; **S:** 52 i.fFM.d *Emballonura furax*; **T:** 65 i.fFM.d *Mosia nigrescens*; **U:** 120 sCF *Aselliscus tricuspidatus*; **V:** 140 sCF *Hipposideros cervinus*; **W:** 172 sCF *Hipposideros* sp. cf. *ater*.

Figure 1. Representative echolocation pulses of each bat species (time between pulses has been compressed)

Glossary of terms related to bat echolocation and morphology

Antitragus—a small flap of skin on the lower edge of the ear that is continuous with the rest of the pinna; only in the Rhinolophidae.

Anonymous calls—echolocation calls that were recorded by placing a bat detector overnight at a sampling point, and recording bats that pass near the microphone. These bats were recorded 'anonymously', i.e. the identity of the bat is not known at the time it was recorded.

Bat detector—an electronic device with a microphone capable of detecting the ultrasonic signals of bats, and converting and storing them in computer sound files within its flash memory.

Call—a general term to describe a vocalisation, in this case an echolocation signal from a bat.

Call sequence—the section of the continuous stream of pulses emitted by bats that is recorded when they fly past a bat detector microphone.

Characteristic frequency—the frequency where the call is loudest, typically at the end of the main body of the pulse.

Constant Frequency (CF) call—an echolocation call with most of its duration (length in milliseconds) being stable in frequency.

Cryptic (species)—closely related species that are very similar in external appearance and not distinguished in the current taxonomic arrangement. Cryptic species are often discovered by genetic analysis.

Duration—how long a pulse is in milliseconds (ms).

Echolocation—the system of ultrasonic vocalisations and echo detection that enable an echolocating bat to avoid obstacles and locate prey while flying in darkness.

Frequency—how high or low the pitch of the call is, measured in kilohertz (kHz). Bat calls in Papua New Guinea range from around 12 to 172 kHz. The upper limit of human hearing is around 15 to 20 kHz, hence most bat calls are 'ultrasonic'.

Frequency Modulated (FM) call—an echolocation call where most of the pulse duration is spent decreasing through a range of frequencies.

Frequency range—the range in kHz between the maximum and minimum frequencies of a pulse, also called the 'bandwidth'. 'Broadband' pulses have a higher frequency range than 'narrowband' pulses.

Harmonic—one of the higher or lower frequency 'copies' of the pulse shape than form part of the overall pulse.

Noseleaf—the dish-like flaps and ridges of skin around the nostrils of some bats. Each species has a different shape, and there are characteristic differences between the general form of the noseleaf between the Hipposideridae and Rhinolophidae. The noseleaf can be divided into anterior, central and posterior sections.

Pulse—a discrete signal separated from other such signals by silence.

Pulse body—the main section of the pulse that contains most of the signal energy, between any initial and terminating sweeps of frequencies.

Tragus—a small flap of skin on the lower edge of the ear that appears discontinuous with the rest of the pinna, as seen in the Miniopteridae and Vespertilionidae; absent in the Hipposideridae and Pteropodidae.

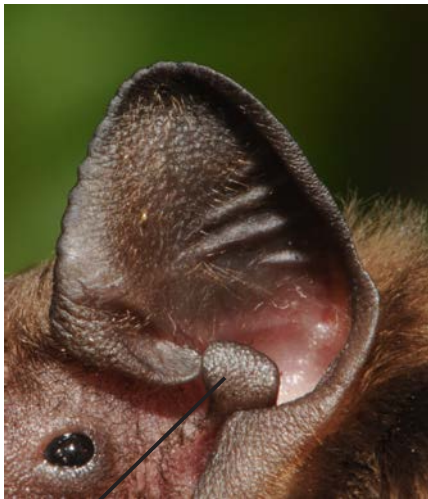
Introduction to the bat species accounts

The following accounts contain information on how each species can be identified from both echolocation calls and external morphology, plus a brief note on their major ecological characteristics. Information on morphology comes from Bonaccorso (1998).

When a bat is captured, note should be taken of several features that will help with identification: forearm length and overall body size (best measured by its weight), whether a noseleaf is present, size and shape of the ears, size of the eye, and colour of fur on the back and belly (Figure 2). In some groups, other details may need to be examined, or genetic analysis undertaken if the identification of the animal cannot be established from morphological features alone. The identification of bats in this study area can usually be made from a good photograph, a note of the above features and ideally by later genetic analysis of a skin plug taken from the wing membrane with a biopsy punch and placed into a clean tube with silica beads.

As mentioned above, identification of echolocation calls is generally undertaken by a specialist or someone that has received training. The approach followed in this study begins with a semi-automated data analysis process that separates bat calls from other sounds, and then groups the calls into echolocation call types. Examination of a selection of the sound files in a spectrogram display then allows each type to be classified according to the scheme in Table 1, and identified to species by comparison with the various exemplars that are presented in Figure 1.

Ear



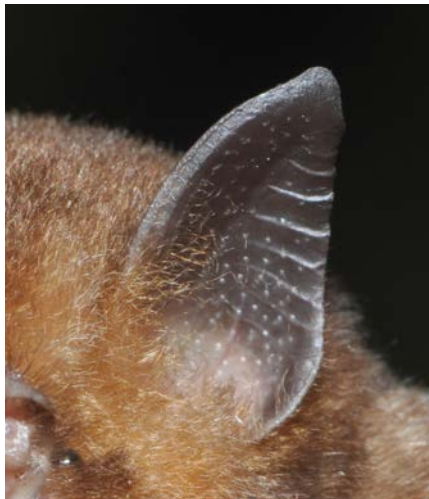
Tragus
Vespertilionidae, Miniopteridae



Antitragus
Rhinolophidae



Tragus absent
Hipposideridae (example of short ears)

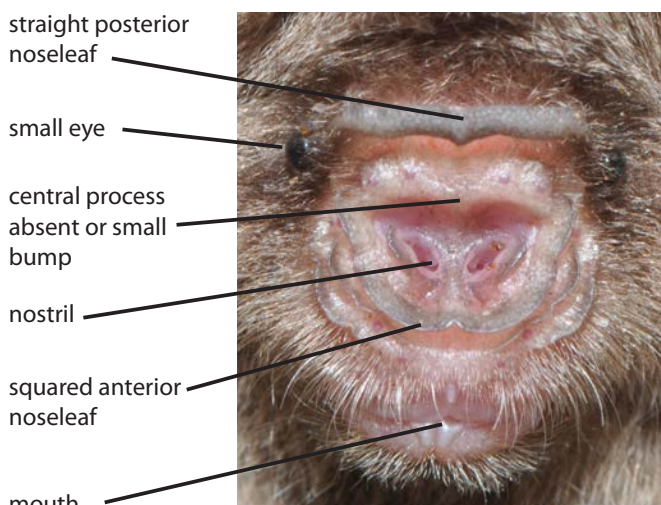


Hipposideridae (example of pointed ears)

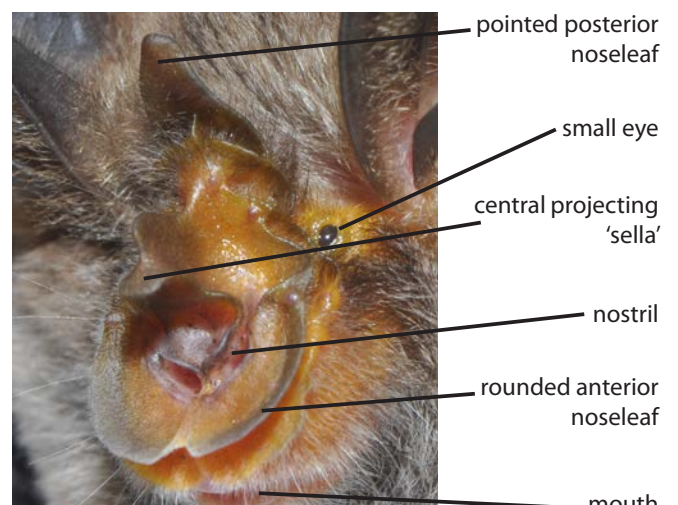


Miniopteridae (example of rounded ears)

Noseleaf



Hipposideridae



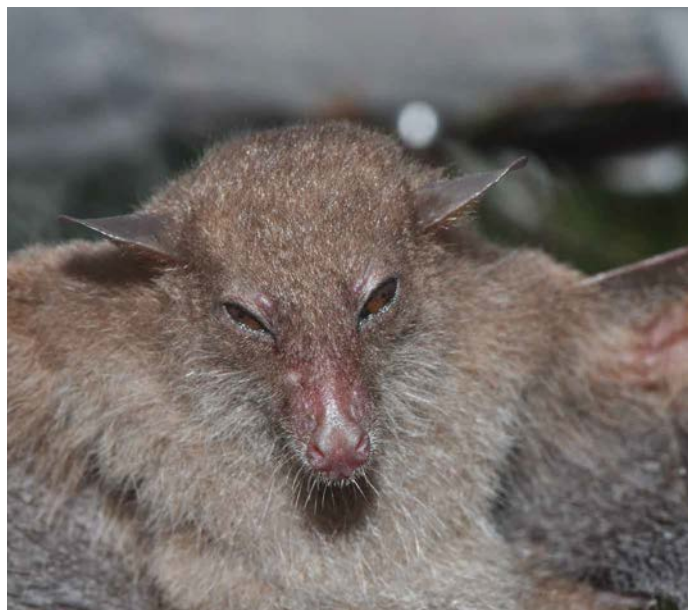
Rhinolophidae

Figure 2. Annotated parts of the bat ear and noseleaf, with some examples of ear shape.

PTEROPODIDAE (Blossom Bats, Fruit Bats and Flying-foxes)

Syconycteris sp. 'montane'

Syconycteris sp. cf. *australis*



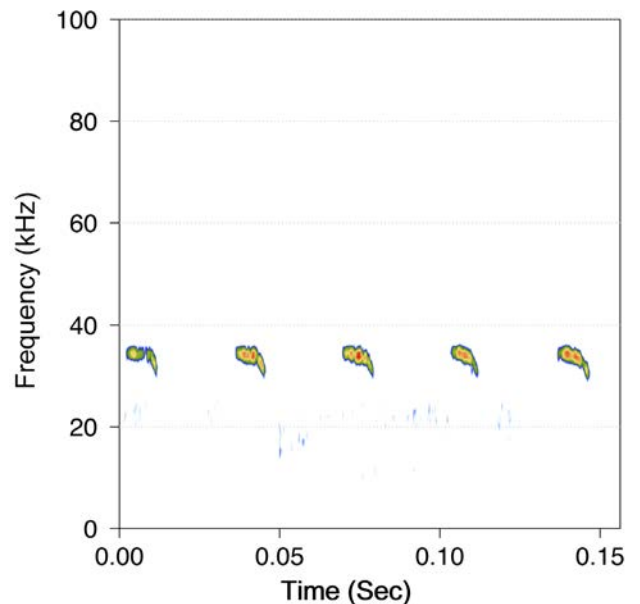
The PMA3 bat monitoring study does not include members of this family, which fly by sight rather than by echolocating. However, mist nets and harp traps set for echolocating bats are likely to capture some of the smaller blossom bats (species of *Macroglossus* and *Syconycteris*) and tube-nosed fruit bats (species of *Nyctimene* and *Paranyctimene*). All of these genera are known to contain undescribed cryptic species. The blossom bats are around the same size as some of the larger insectivorous species (forearm lengths 40–50 mm), but the tube-nosed fruit bats are a little larger (forearm lengths 50–70 mm). Both groups are immediately recognisable by their large eyes. The blossom bats have relatively long snouts and light brown fur (tending to reddish in the lowland *Syconycteris*, grey in the mid-montane *Syconycteris*, and with some parts quite dark in the montane *S. hobbit*). Species of *Syconycteris* are distinguishable from *Macroglossus minimus* by the absence of a thin tail membrane on the inside of the legs. Species of *Nyctimene* and *Paranyctimene* are more robust, with stockier snouts, and tube-shaped nostrils. The tube-nosed fruit bats all have yellow and green blotches on the skin that give them a camouflaged look, some individuals of *Paranyctimene* have green-coloured fur, and species of *Nyctimene* have a black stripe down the middle of the back. Two different forms of *Syconycteris* 'australis' (currently undescribed cryptic species) are illustrated above.

EMBALLONURIDAE (Sheath-tailed Bats)

The most commonly encountered sheath-tailed bat species in New Guinea are the small species of *Emballonura* and *Mosia*. They have a relatively large eye, and the tail appears to be separate from the tail membrane, but is actually partly rolled within it. Their calls can be quite common in recordings, especially calls of *Mosia nigrescens*. Echolocation call shape is typically an almost constant-frequency pulse that decreases very slightly in frequency towards the end, and terminates in a short frequency sweep (a 'droop'). The calls are multi-harmonic, with much energy in both the fundamental frequency and the second harmonic. The highest second harmonic frequency in any species of Emballonuridae is around 70 kHz, which is well below that of most Hipposideridae that produce similar-shaped calls. They tend to forage within and around the canopy, whereas larger emballonurids like *Saccolaimus saccolaimus* tend to fly over the canopy, and are seldom recorded.

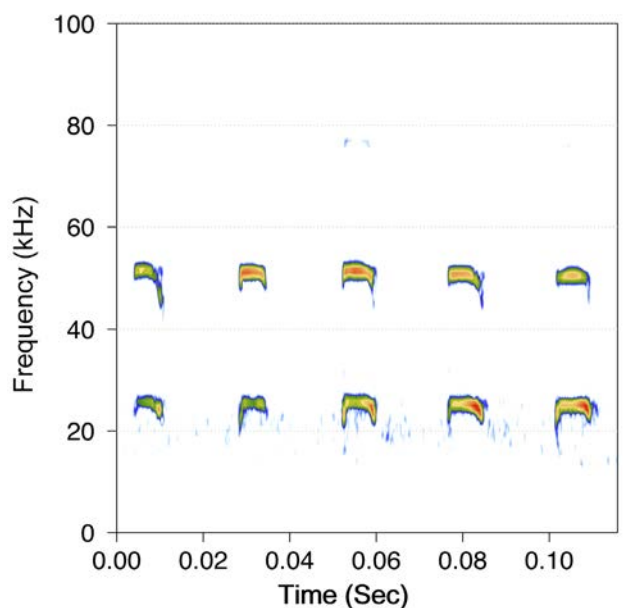
Emballonura diana (Large-eared Sheath-tailed Bat; call type 35 i.fFM.d)

A small bat around 10 g, with a forearm range of 45–48 mm, dark brown fur, broad funnel-like ears lacking a sharp apex, and with white claws. The characteristic frequency of each pulse is around 35 kHz at the second harmonic. The main body of the call is relatively flat, and the terminal section is drooped. The fundamental frequency at around 18 kHz is often not visible, but provides greater confidence in the identification because the second harmonic of *E. diana* can be confused with the fundamental frequency of *Mosia nigrescens*. This species roosts in the twilight zones of caves and forages around the tree canopy with agile flight, emitting echolocation calls from the mouth and capturing insect prey by hawking. Rarely captured outside of caves, but occasionally in mist nets. Further information at <https://www.iucnredlist.org/species/7673/12842653>

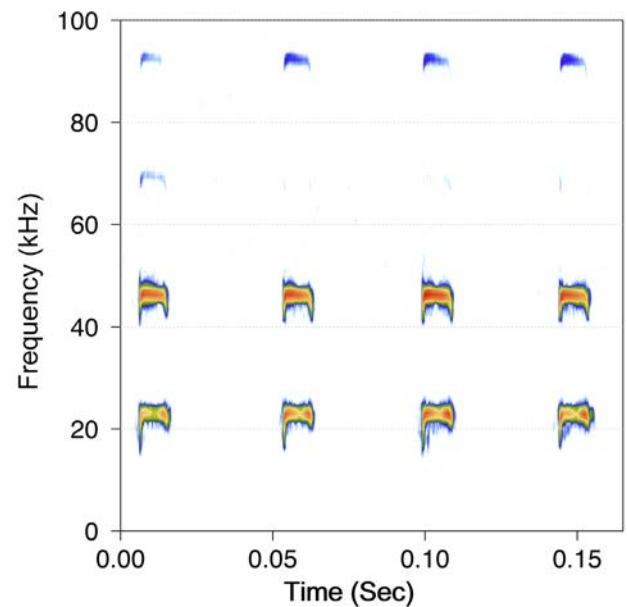


Emballonura furax (New Guinea Sheath-tailed Bat; call type 52 i.fFM.d)

A small bat up to 14 g, with a forearm range of 48–53 mm, dark brown fur that is white at the bases, and white claws. The ear is longer, narrower and more acutely tapered than that of *E. diana*. The characteristic frequency of each pulse is around 52 kHz at the second harmonic. The main body of the call is relatively flat, and the terminal section is drooped. The fundamental frequency at around 26 kHz is usually visible. This species roosts in the twilight zones of caves and possibly also tree hollows. It forages around the tree canopy with agile flight, emitting echolocation calls from the mouth and capturing insect prey by hawking. Rarely captured outside of caves, but occasionally in mist nets. Further information at <https://www.iucnredlist.org/species/7667/22135664>

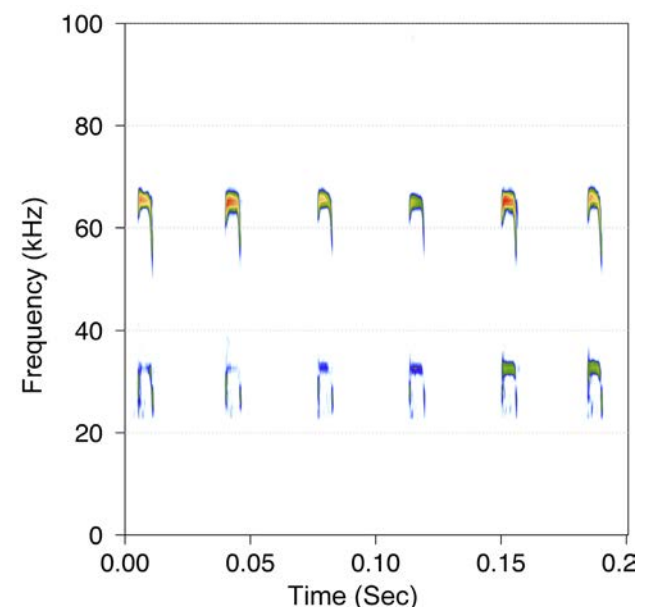


***Emballonura raffrayana* (Raffray's Sheath-tailed Bat; call type 45 i.fFM.d)**



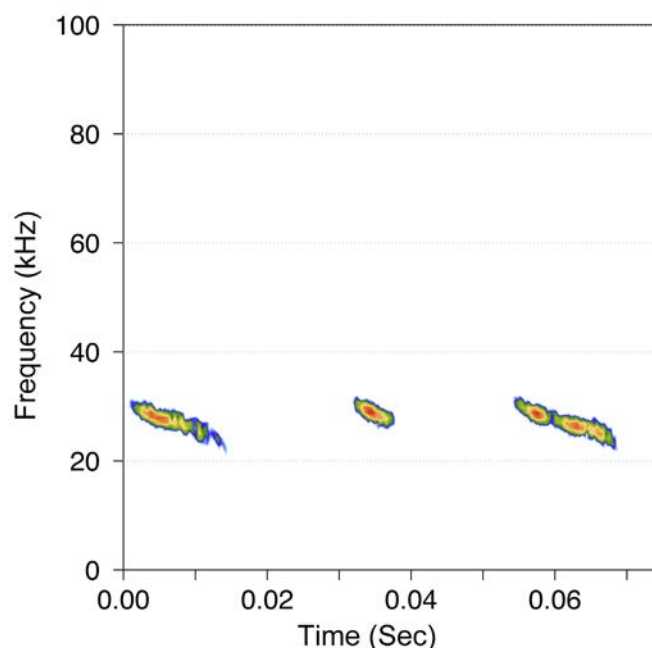
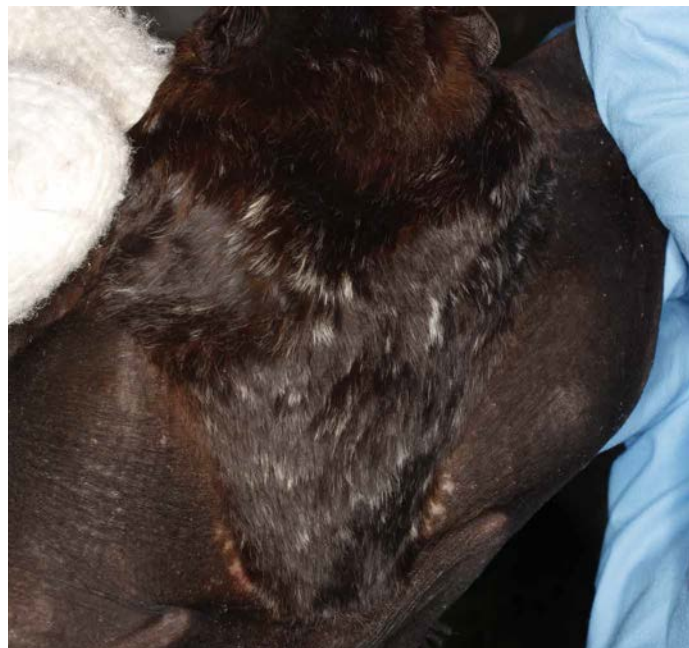
A small bat up to 6 g, with a forearm range of 38–42 mm, dark brown fur that is white at the bases, a narrow ear with a broadly rounded apex, and claws with white tips and dark bases. The characteristic frequency of each pulse is around 45 kHz at the second harmonic. The main body of the call is relatively flat, and the terminal section is drooped. The fundamental frequency at around 23 kHz is usually visible. Variation in the characteristic frequency of pulses of *E. raffrayana* overlaps with that of *E. furax*, sometimes making it difficult to distinguish their calls. This species roosts in the twilight zones of caves and forages around the tree canopy with agile flight, emitting echolocation calls from the mouth and capturing insect prey by hawking them. Rarely captured outside of caves, but occasionally in mist nets. Further information at <https://www.iucnredlist.org/species/7668/12841588>

***Mosia nigrescens* (Lesser Sheath-tailed Bat; call type 65 i.fFM.d)**



A very small bat up to 6 g, with a forearm range of 30–35 mm, dark brown fur, and the ear is narrow with a bluntly rounded tip. The characteristic frequency of each pulse is around 65 kHz at the second harmonic. The main body of the call is relatively flat, and the terminal section is drooped. The fundamental frequency at around 33 kHz is usually visible. This species roosts in caves and under large-leaved plants, and forages around and below the tree canopy with agile flight, emitting echolocation calls from the mouth and capturing insect prey by hawking. Occasionally captured in mist nets and harp traps. Further information at <https://www.iucnredlist.org/species/13904/4364016>

***Saccolaimus saccolaimus* (Bare-rumped Sheath-tailed Bat; call type 25 sFM)**

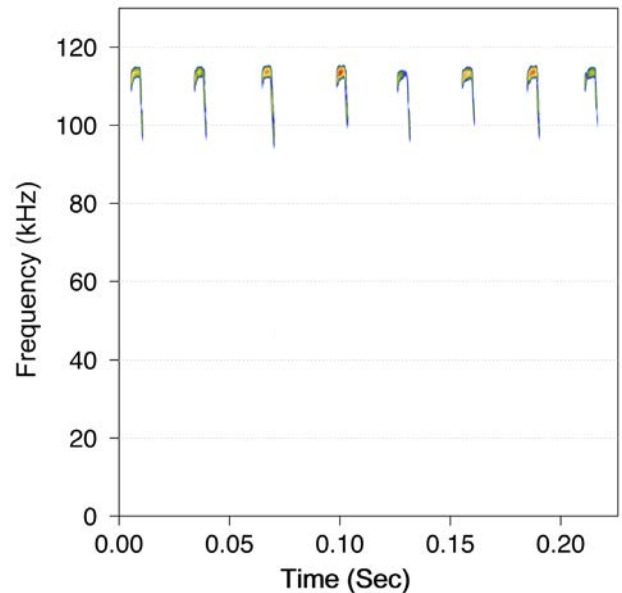


A large bat around 49 g, with a forearm range of 72–80 mm, dark fur on the back with numerous small patches of fur with lightened tips making it appear speckled (pictured), belly fur either slightly paler or quite cream-coloured, large eyes, and a ball-like bump that is easily felt on the back of the head. The characteristic frequency of each echolocation pulse is around 25 kHz, but it may be a few kilohertz higher. The main body of the call is relatively flat, which would distinguish it from species of free-tailed bats (*Otomops* spp.). The end of the pulse often has a droop, making the pulse serpentine in overall shape. The harmonic profile is also distinctive, with the loudest or dominant harmonic at the second frequency (c. 25 kHz), with the fundamental frequency at around 12.5 kHz (often not visible), and higher harmonics with characteristics frequencies continuing at 12.5 kHz intervals. Usually only the dominant second harmonic is visible in recordings. Calls can be confused with those of free-tailed bats (*Mormopterus* spp.) at the lower end of its characteristic frequency range, and with *Philetor brachypterus* at the upper end. This species roosts in large tree hollows at the tops of trees, and forages in the open and above the tree canopy with relatively fast, low agility flight, emitting echolocation calls from the mouth and capturing insect prey by intercepting them. Mostly captured by setting mist nets in vertical arrays (the ‘canopy net’ setup) in the open spaces between large trees. Capture success can be increased if one individual is captured and makes alarm calls, which then draw in other individuals. Further information at <https://www.iucnredlist.org/species/19802/22004019>

HIPPOSIDERIDAE (Leaf-nosed Bats)

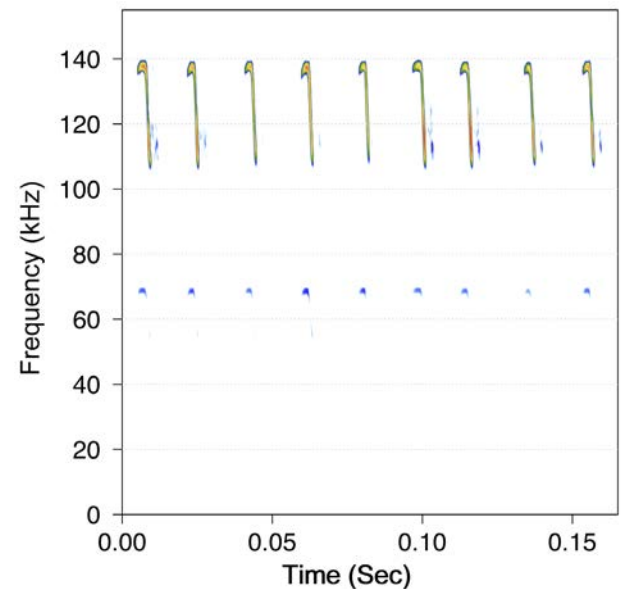
The leaf-nosed bats are one of two families of insectivorous bats in Papua New Guinea that emit their echolocation calls through the nose and have a conspicuous dish-like arrangement of skin around the nostrils called a noseleaf. They differ from the Horseshoe Bats (Rhinolophidae) by lacking a prominent central and forward-pointing projection on their noseleaf, though some species often have a small bump or ridge. The overall shape of the noseleaf also tends to be square, rather than pointed at the top, and round (or horseshoe-shaped) at the bottom as in the other family. They also lack a tragus or antitragus on the lower edge of the ear. The ears are very mobile and tend to be rounded with pointed tips, but vary in size among species. The tail is enclosed in the tail membrane and usually terminates at the edge. The range of body sizes in this family is large (3–80 g), but most leaf-nosed bats are less than 20 g. Most species also emit calls with the second harmonic above 80 kHz, but the large-bodied Diadem Leaf-nosed Bat (*Hipposideros diadema*) has a lower frequency call. They usually rest during the day in caves and shallow rocky shelters, but some species will also roost in tree hollows or other parts of trees that provide suitable refuge for species that hang vertically when at rest. Fur colour in some species can be very dark, but in others it is much lighter fawn or even tending to orange. They hunt in closed habitats below the forest canopy, but also at the edge of clearings, and generally have short, broad wings that favour slow but manoeuvrable flight.

***Aselliscus tricuspidatus* (Temminck's Leaf-nosed Bat; call type 120 sCF)**



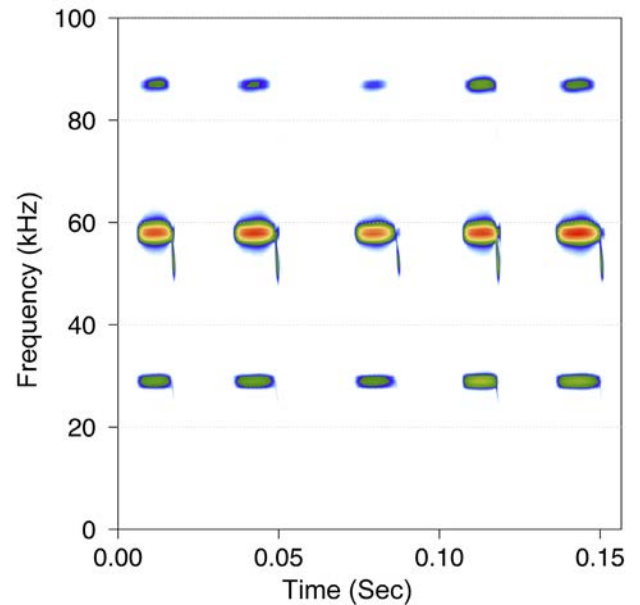
This is a small bat (forearm 39–45 mm) with fawn or orange fur, a square noseleaf with three prominent rounded projections on the top posterior part, and small, narrow, pointed ears. In combination the fur colour, ear shape and three noseleaf projections allow it to be distinguished reliably from other similar-sized leaf-nosed bats such as *Hipposideros ater* and *H. cervinus*. The tail also extends a small distance beyond the tail membrane, in contrast to species of *Hipposideros* where it terminates at the membrane edge. Their calls are typical short constant frequency-type signals (sCF), with the characteristic frequency varying between 108 to 120 kHz in recordings. They roost in small or large caves and forage for small insects below the forest canopy. They are captured commonly in both mist nets and harp traps. Further information at <https://www.iucnredlist.org/species/2156/9301230>

***Hipposideros cervinus* (Fawn-coloured Leaf-nosed Bat; call type 140 sCF)**



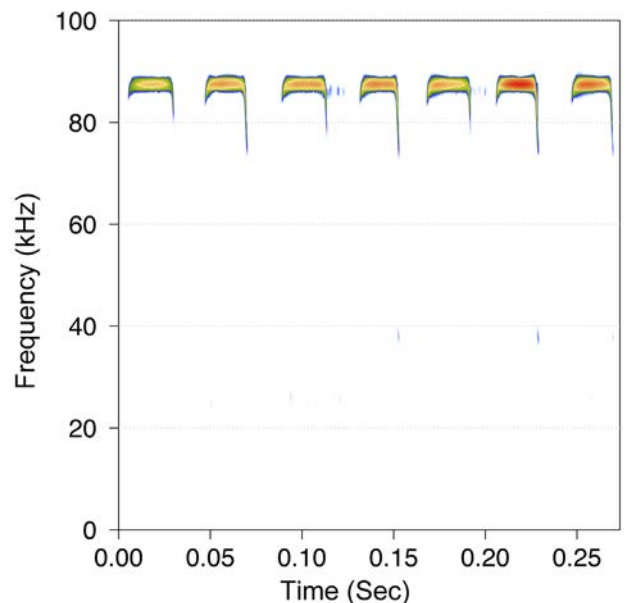
This is a small bat (forearm 44–50 mm) with fawn-coloured fur, a square noseleaf with a straight edge to the top posterior part, and very small, rounded ears with a pointed tip. The noseleaf is smaller than that of *Aselliscus tricuspidatus*. Their calls are typical short constant frequency-type signals (sCF), with the characteristic frequency around 140 kHz. The high frequency of their calls means that they are only recorded if they pass very close to the microphone, but nevertheless their calls can sometimes be quite common in recordings. They roost mainly in caves, though sometimes also in tree hollows, and forage for small insects below the forest canopy. Further information at <https://www.iucnredlist.org/species/10118/3167457>

***Hipposideros diadema* (Diadem Leaf-nosed Bat; call type 58 mCF)**



This is the largest insectivorous bat in Papua New Guinea (forearm 72–83 mm). It has a stout, muscular body and face, and a large, square-shaped noseleaf. The fur colour can be variable. Some individuals have fawn-coloured fur that is slightly darker on the back. Others have a pale underside and dark brown dorsal fur with conspicuous large pale spots. Their echolocation call can be up to 30 ms in length, and the characteristic call frequency is usually very close to 58 kHz. The initial frequency sweep seen in the calls of other hipposiderid calls is usually lacking. This species roosts in shallow rocky shelters and caves, and hunts from a perch such as a hanging branch above the forest understorey—hanging and emitting calls until it detects insects prey (usually larger moths and beetles) that it then flies off to intercept. It often seems to be active in twilight at dusk and near dawn. Further information at <https://www.iucnredlist.org/species/10128/3169874>

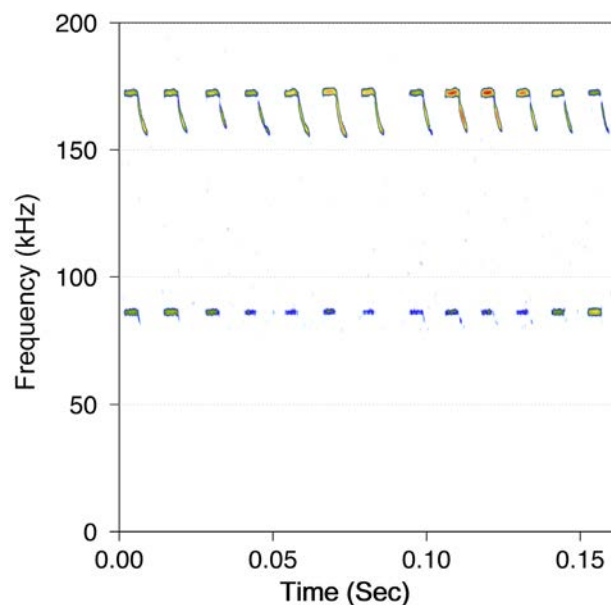
***Hipposideros wollastoni* (Wollaston's Leaf-nosed Bat; call type 88 mCF)**



This species is around the same size (forearm 40–45 mm) as *Aselliscus tricuspidatus* and *Hipposideros cervinus*. In some parts of Papua New Guinea their fur is light brown and their skin a similar tan colour. In other parts of the country, the fur can be dark brown, and the skin black. The noseleaf appears slightly more complex and large compared to *A. tricuspidatus* and *H. cervinus*, and there is a conspicuous central ridge. They can be relatively common on recordings, and their calls are relatively long compared to other species in this family (around 30 ms; mCF type calls). They are very similar in appearance to their closest relatives, *H. muscinus* and *H. semoni*, being distinguished by a different call frequency and slight differences in the shape of the ears and noseleaf features (the latter two species having a more or less prominent central wart-like projection rather than a ridge as in *H. wollastoni*). They roost in rocky shelters and caves, and forage below the forest canopy. Further information at <https://www.iucnredlist.org/species/10166/22099864>

***Hipposideros* sp. cf. *ater* (An unnamed leaf-nosed bat; call type 172 sCF)**

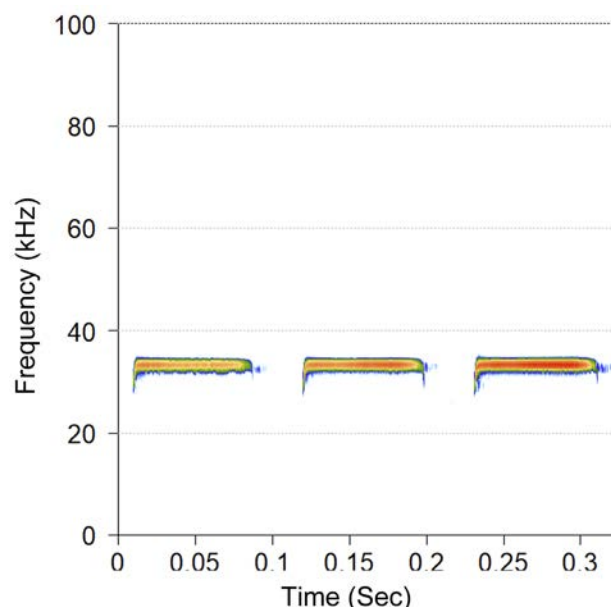
This bat is almost certainly new to science, and may never have been captured. Evidence of its existence comes in the form of a single good quality echolocation call sequence, which is typical in shape of leaf-nosed bats, but higher in frequency than any known New Guinean *Hipposideros*. The characteristic frequency of the main part of each pulse is around 172 kHz at the second harmonic, exceeding that of the Dusky Leaf-nosed Bat (*Hipposideros ater*), which has been recorded elsewhere in the surrounding region. It is likely to be a small-bodied bat around the same size as *H. ater* (forearm around 39 mm), with a small noseleaf around the nostrils and presumably large ears given the very high frequency of the calls. It may roost in caves or tree hollows, or both, like *H. ater*. As a potentially undescribed species, it is not listed by the IUCN. Further information on *H. ater* at <https://www.iucnredlist.org/species/10111/3164225>



RHINOLOPHIDAE (Horseshoe Bats)

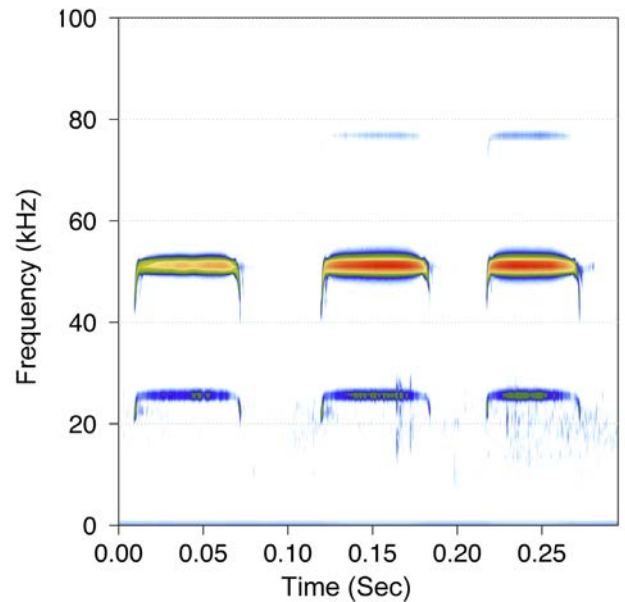
The horseshoe bats are one of two bat families in Papua New Guinea that have a dish-shaped structure of skin dominating their facial region, and that emit echolocation calls through the nostrils. In this family, the anterior part of the noseleaf is distinctly rounded (except in *Rhinolophus robertsi* and *R. philippinensis* where it is more square), with a large central projection (the 'sella') emanating from between the nostrils, and a sharply-pointed and pocketed rear projection. The outer margin of the ear extends around the bottom of the ear aperture into a broad flap of skin called the antitragus. The calls are very distinctive, comprising long (50–100 ms) pulses with short initial and terminating frequency sweeps, each separated by very short inter-pulse periods. The frequency of horseshoe bat calls in Papua New Guinea varies from around 33 kHz in *R. robertsi* to around 70 kHz in *R. mcintyre*. Rhinolophid bats generally roost in caves. They hunt in closed habitats below the forest canopy, but also at the edge of clearings, and generally have short, broad wings that facilitate slow but manoeuvrable flight.

***Rhinolophus robertsi* (Large-eared Horseshoe Bat; call type 33 ICF)**



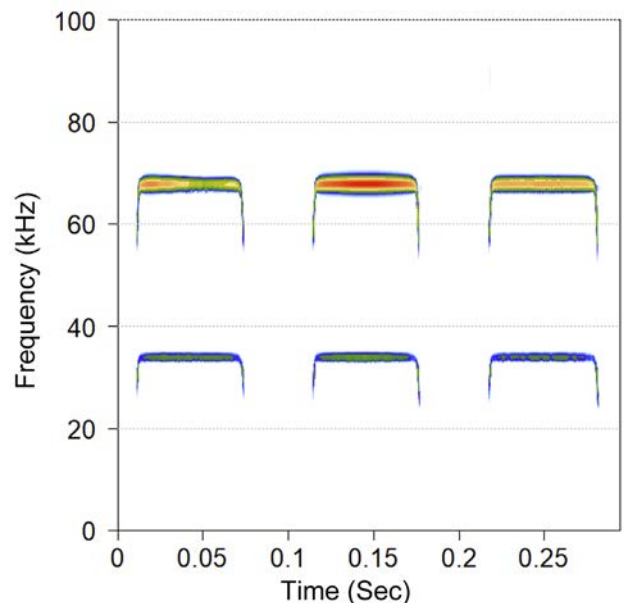
This species is a member of the *Rhinolophus philippinensis* species complex that is readily recognisable from other horseshoe bats by their enormous and obviously oversize noseleaf and ears. The noseleaf may be light brown, dark brown or yellow, and is more square-shaped than in other species of horseshoe bat. From call recordings (Armstrong et al. 2014b) it appears that two species of this group occur in Papua New Guinea, but it is possible that the larger form (*R. robertsi*, illustrated here by an Australian example captured on Cape York) with the lower frequency call of around 33 kHz has never been captured in PNG. The forearm of this species in Australia is 50–55 mm. They probably roost in caves, and hunt in closed habitats below the forest canopy and at the edge of clearings. Further information at <https://www.iucnredlist.org/species/19560/8977427>

***Rhinolophus euryotis* (New Guinea Horseshoe Bat; call type 52 ICF)**



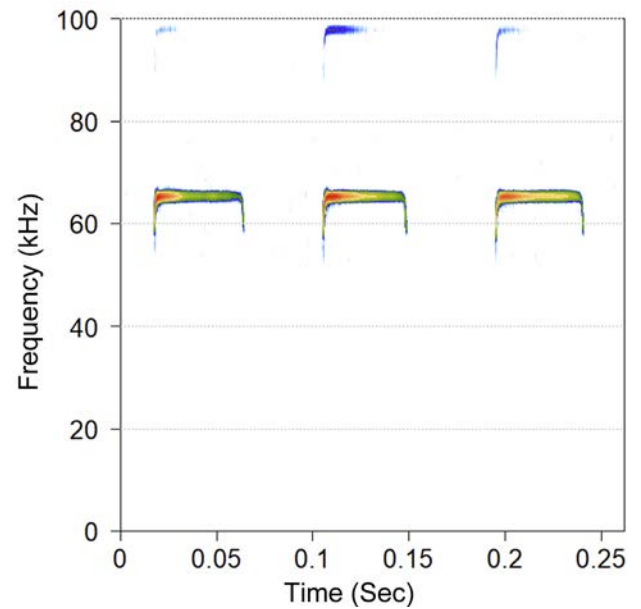
A large species of horseshoe bat a little bigger than *Rhinolophus robertsi* (forearm 53–58 mm), with a broad, round anterior noseleaf that covers the muzzle. This species roosts in caves and hunts in closed habitats below the forest canopy, and also at the edge of clearings. Further information at <https://www.iucnredlist.org/species/84372418/21979220>

***Rhinolophus mcintyre* (A horseshoe bat; call type 70 ICF)**



A large species of horseshoe bat around the same size as *Rhinolophus robertsi* (forearm length 50–58 mm), with a broad, round anterior noseleaf that has a small bunch of bristles above the central process. It produces an echolocation call a few kilohertz higher than *Rhinolophus megaphyllus*. This species roosts in caves and hunts in closed habitats below the forest canopy, and also at the edge of clearings. Prior to recent taxonomic work, it was called *Rhinolophus arcuatus*. Further information at <https://www.iucnredlist.org/species/84372245/84372277>

***Rhinolophus megaphyllus* (Eastern Horseshoe Bat; call type 65 ICF)**

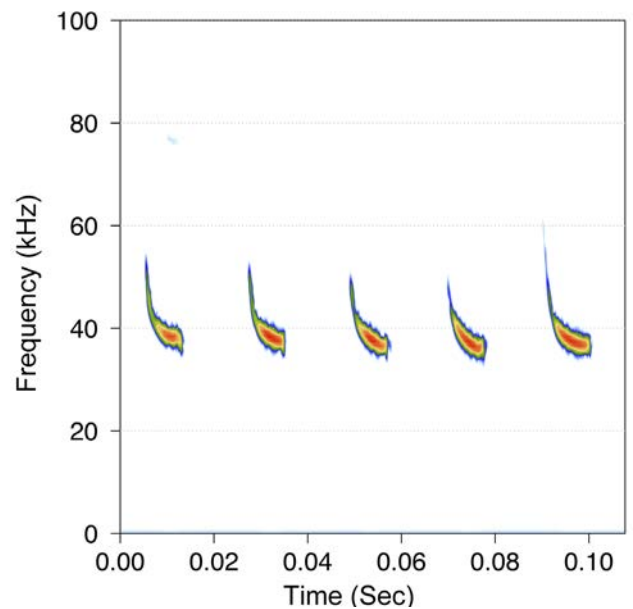


This is the smallest species of horseshoe bat in Papua New Guinea (forearm 43–49 mm), with a rounded anterior noseleaf. The noseleaf can be pale pink, brown or sometimes yellow, as has been recorded in the PMA3 study area. This species roosts in caves and hunts in closed habitats below the forest canopy, and also at the edge of clearings. Further information at <https://www.iucnredlist.org/species/19553/21993377>

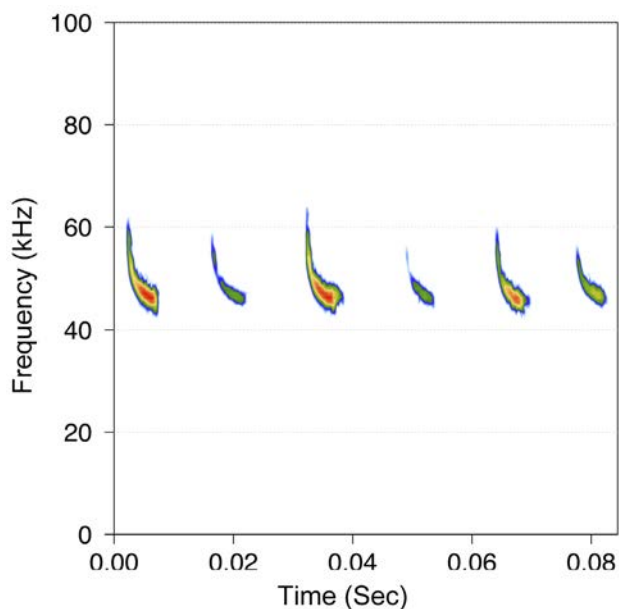
MINIOPTERIDAE (Bent-winged Bats)



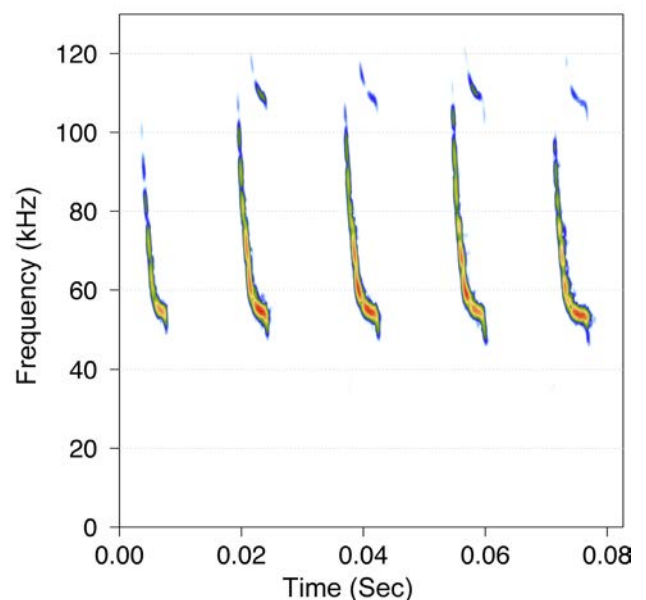
Captured example of *Miniopterus* sp. 1 'large'



Call of *Miniopterus* sp. 1 'large'



Call of *Miniopterus* sp. 2 'medium'



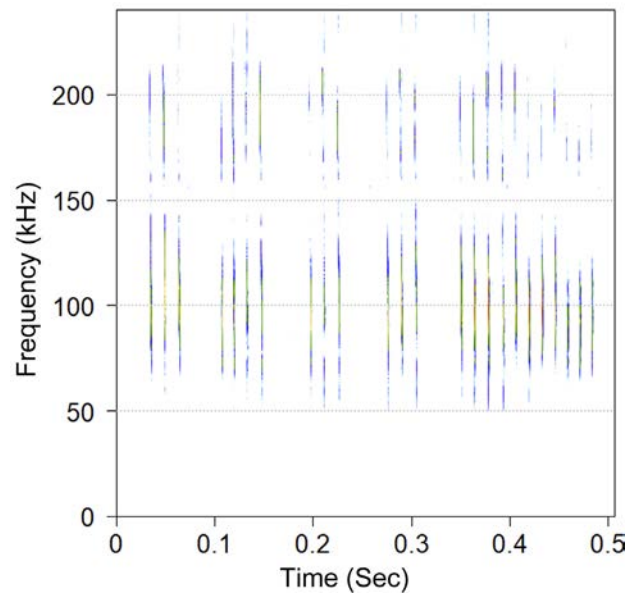
Call of *Miniopterus* sp. 3 'small'

Bent-winged bats are found throughout almost the entire elevational range of landforms in Papua New Guinea (from sea level up to around 3,000 m; Armstrong and Aplin 2011). In any given habitat in Papua New Guinea, there can be up to three call types that are attributable to at least three species of bent-winged bat. However, all members of this family are very similar in appearance—with short, blackish or dark-brown fur (sometimes tending to orangey-brown, or bicoloured with a darker chest and lighter belly), very rounded or triangular-shaped ears with a bent-looking tragus, and relatively narrow wings with a pointed tip. Variation in body size probably overlaps among species. For these reasons, bent-winged bats are notoriously difficult to identify from external morphological characters, and the taxonomy of this entire group in New Guinea is unreliable. Calls of bent-winged bats tend to be curvilinear frequency-modulated chirps that sweep through a range of frequencies and contain most of their energy in the second half of the call around the characteristic frequency. The terminating part of the call typically ends abruptly rather than in an upswept 'hook' or downswept 'droop'. Bent-winged bats roost in caves and rock shelters, often in large aggregating colonies. Their relatively long and narrow wing-shape is typical of species that fly straight and relatively fast. They fly both above and amongst the canopy, as well as through open linear features beneath the canopy. Since none of the three bent-winged bat call types are referable to named species, their call types are presented for comparison. Further information can be found in the profile for *Miniopterus magnater*, as an example, at <https://www.iucnredlist.org/species/13566/4173040>

VESPERTILIONIDAE (Evening Bats)

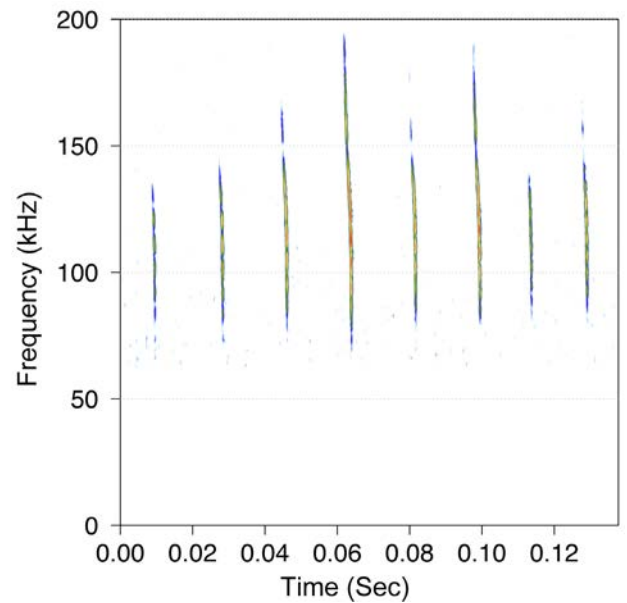
Members of this family of bats lack a noseleaf, and they are generally small with brown fur. Their ears can range from short and round or triangular as in *Pipistrellus*, to long and funnel-shaped as in *Kerivoula*, to long and broad in species of *Nyctophilus*. A distinct tragus projects from the base of the ear aperture, which can be either short and rounded or elongate and pointed. Some species have short, straight fur, but in others it is woolly and extends onto the wing and tail membrane as in *Murina*. They resemble the Miniopteridae in general appearance, but have a shorter and broader wing shape. The tail is fully enclosed in the membrane, with just the tip protruding from the end. Their calls are typically frequency modulated chirps (*cFM*-type pulses), which steepen, flatten and shorten the closer they are emitted to vegetation background (broadband *bFM*- and *sFM*-type pulses). Some species prefer the interior of forests and forage beneath and around the canopy, while others show a clear preference for foraging in open areas and in the open against the edges of stands of vegetation. They tend to roost in tree hollows or other parts of vegetation, and may change their roost site regularly.

***Kerivoula* sp. cf. *muscina* (An unnamed woolly bat; call type 80 *bFM*)**



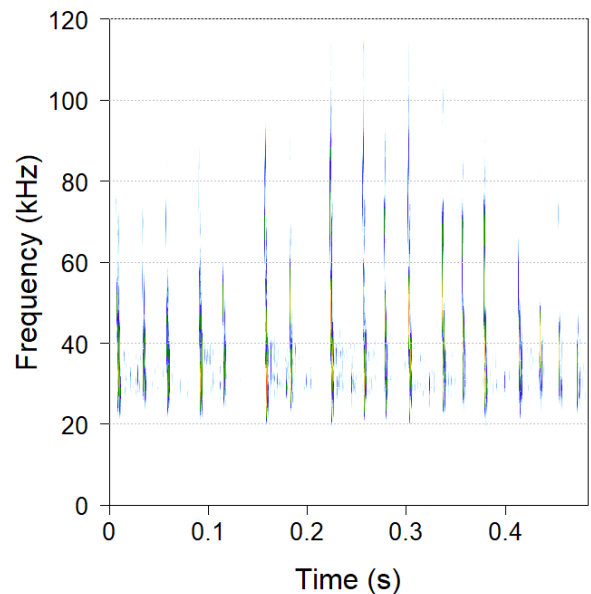
A small bat resembling *Kerivoula muscina* that was captured at 2,700 m asl during the 2017 survey might be new to science. *Kerivoula muscina* has been recorded from sea level to around 1,600 m asl (Bonaccorso 1998). The potentially new species has a relatively small forearm length compared to *K. muscina* (32 mm; range is 32–36 mm in *K. muscina*), and darker-coloured fur (rather than pale brown). It is distinguished from *Murina florum* by having a very thin, blade-like tragus in the ear (compared to the wider bilobed tragus in *M. florum*), funnel-shaped ears, and a short snout without the tubular nostrils. Species of *Kerivoula* produce very short broadband high frequency calls that are typical of bats that forage within closed forest. The calls are difficult to distinguish from those made by *Murina florum*, and are usually only recorded if the bat comes within a metre or two of bat detectors. They roost in hollow tree limbs and large curled leaves. Further information at <https://www.iucnredlist.org/species/10979/22022252>

***Murina sp. cf. florum* (Flute-nosed Bat; call type 80 bFM)**



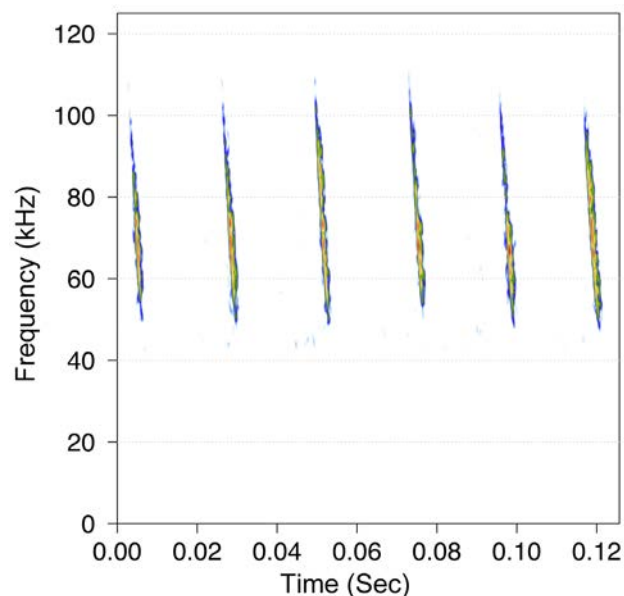
This is a small bat (forearm 33–36 mm) with fur that can be light brown, but also a little darker on the dorsal surface with light-coloured tips. The ears are funnel-shaped and the most distinctive feature is the tubular nostrils. The tragus is long and pointed, and the fur is woolly and extends onto the wing and tail membranes. Their calls are very distinctive, being high frequency and very short-duration broadband linear pulses (call type *bFM*) that begin around 150 kHz and drop to around 80 kHz. The higher second harmonic is sometimes observable and gives the impression that the call extends way above 200 kHz. The calls can be confused with those of *Kerivoula* and *Phoniscus*, which have a similar ecological niche. They tend to forage very close to vegetation below the forest canopy and roost under bark or clumps of leaves. Males maintain territories and the species is known to emit loud ultrasonic social calls. Further information at <https://www.iucnredlist.org/species/13939/4367794>

***Nyctophilus microdon* (Small-toothed Long-eared Bat; call type 30 bFM)**



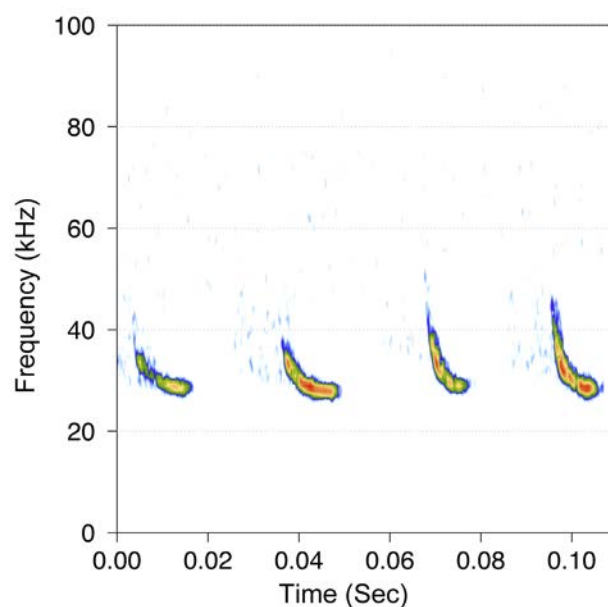
This is a medium-sized long-eared bat with dark brown fur and a forearm length between 38–41 mm. The ears are indeed long, compared to *N. microtis*. The face of long-eared bats is distinctive in having a short, pig-like snout, with a small ridge above the nostrils that resembles a rudimentary noseleaf. There is a prominent tragus. The canines of *N. microdon* are small (max length 2 mm), distinguishing it from other long-eared bat species. It is also found at elevations much higher than the other species (1,900–2,200 m asl). Echolocation calls were recorded for the first time from captures on Hides Ridge, and they are of relatively low frequency compared to other *Nyctophilus* and also *Myotis moluccarum*. It forages within mid-montane forests, gleaning soft-bodied insects from vegetation, and roosts in tree hollows. Further information at <https://www.iucnredlist.org/species/15007/4487792>

***Nyctophilus microtis* (Papuan Long-eared Bat; call type 50 bFM)**



Most long-eared bats have conspicuously long ears (as their name suggests), but in this species the ears are not too much longer than those of other vespertilionids. The forearm length is between 37–41 mm, which is very similar to *N. microdon*. It is thought that *N. microtis* comprises more than one species in the lowland areas of Papua New Guinea, and the known range extends from sea level to 1,450 m asl. The higher elevation form captured at 2,700 m on Hides Ridge could therefore be a distinct species. The wings tend to be broad, allowing for manoeuvrable flight below the forest canopy. Like *N. microdon*, their calls are broadband, but very short in duration (less than 5 ms), and linear or slightly serpentine in shape. They tend to forage very close to vegetation, and roost in tree hollows, under bark and clumps of leaves. Further information at <https://www.iucnredlist.org/species/15008/22009622>

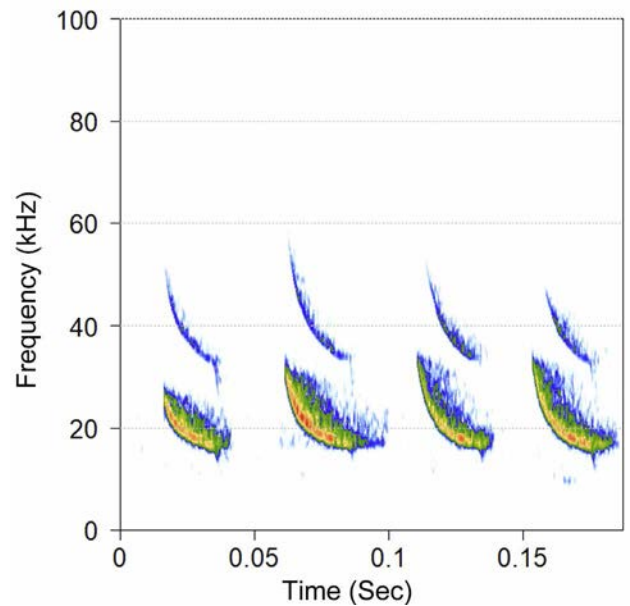
***Philetor brachypterus* (Short-winged Pipistrelle; call type 30 cFM)**



This is a small bat (forearm 33–38 mm) with short brown fur. It has a triangular-shaped ear with a rounded apex, a prominent tragus, and a face that is mostly bare of fur and often appears swollen due to the presence of enlarged glands. It is quite similar in appearance to species of *Pipistrellus*, but can be distinguished by its larger body size (forearms of *Pipistrellus* species reach just 33 mm in most species, except up to 38 mm in *P. collinus* at higher altitudes), and also by a prominent ridge or flap of skin that extends from the outside edge of the ears to the corner of the mouth. The wings are narrow and stubby, and it forages below forest canopy, and also in the open. Further information at <https://www.iucnredlist.org/species/16981/6676740>

MOLOSSIDAE (Free-tailed Bats)

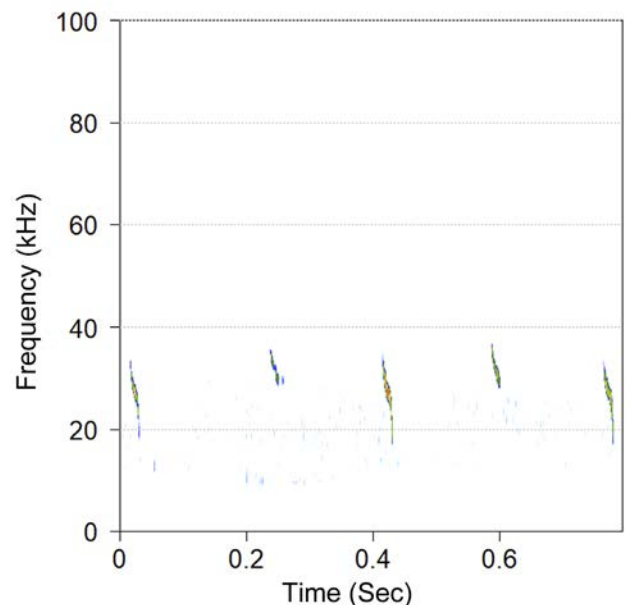
Chaerephon jobensis (Greater Northern Free-tailed Bat; call type 20 cFM)



This species is common in northern Australia across a range of monsoonal woodland and forest habitats. In New Guinea there are a few records up to 1,400 m asl. It produces low frequency calls with the first harmonic at about 20 kHz. They are a medium-sized insectivorous bat with a forearm length of 43–50 cm, and their fur is pale brown, lighter on the underside. Their lips fold into a series of obvious wrinkles when the mouth is closed. Roosts are found in tree hollows, and sometimes in buildings and holes in cliffs, with colonies up to c. 350 individuals in the larger spaces. They often produce social calls when flying in groups, and a bat trapped in a mist net often attracts other individuals. Capture is most likely to be successful in open spaces under breaks in the canopy, and over open waterways or similar open linear features. Further information at <https://www.iucnredlist.org/species/4312/10778313>

Otomops sp. (An unidentified free-tailed bat; call type 30 sFM)

There are two species of *Otomops* in New Guinea: *Otomops papuensis* (forearm length 48–50 cm) and *O. secundus* (forearm length 57–58 cm). Both are known from captures at only a handful of localities across Papua New Guinea, and more recent identification of their calls at additional sites. *Otomops papuensis* has been collected only at low elevations, and *O. secundus* between sea level and 2,000 m asl. Compared to *Chaerephon*, species of *Otomops* have much longer ears and a slightly longer snout, and their calls tend to be of higher frequency. Like *Chaerephon*, they roost in trees in small colonies, and fly in open spaces above the tree canopy and waterways. Further information at <https://www.iucnredlist.org/species/15650/4954833> and <https://www.iucnredlist.org/species/15649/4953304>



References and further reading

- Armstrong, K. N. & Aplin, K. P. 2011. Bats of the Muller Range, Papua New Guinea. Chapter 19, pp. 222–234 in *Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments* (S. J. Richards and B. G. Gamui, eds.). RAP Bulletin of Biological Assessment 60. Conservation International, Arlington, USA.
- Armstrong, K. N. & Aplin, K. P. 2014a. Chapter 7. A survey of bats (Chiroptera) in the Baiyer River Wildlife Sanctuary, Western Highlands Province, Papua New Guinea. pp. 111–133 in *A rapid biodiversity assessment of the Baiyer River region, Western Highlands Province, Papua New Guinea* (S. J. Richards, ed.). A report to the Mul Baiyer Lumusa District Administration, Papua New Guinea.
- Armstrong, K. N., Novera, J. & Aplin, K. P. 2014b. Survey for bats in the P'nyang Range, Western Province, Papua New Guinea. Field survey and acoustic analysis. PNG LNG Expansion Project. Unpublished report by Specialised Zoological, Ken Aplin Fauna Studies Pty Ltd and the Papua New Guinea Institute for Biological Research for Coffey Environments Pty Ltd and ExxonMobil, 21 April 2014.
- Armstrong, K. N. & Aplin, K. P. 2014c. Identifying bats in an unknown acoustic realm using a semi-automated approach to the analysis of large full spectrum datasets. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland. *The Australasian Bat Society Newsletter* 42: 35–36.
- Armstrong, K. N., Novera, J. & Aplin, K. P. 2015a. Acoustic survey of the echolocating bats of Manus Island and Mussau Island, Papua New Guinea. pp. 69–85 in *A Rapid Biodiversity Survey of Papua New Guinea's Manus and Mussau Islands* (N. Whitmore, ed.) Wildlife Conservation Society Papua New Guinea Program. Goroka, Papua New Guinea.
- Armstrong, K. N., Aplin, K. P. & Lamarin, J. S. 2015b. Chapter 10. Bats. pp. 166–180 in *A rapid biodiversity assessment of Papua New Guinea's Hindenburg Wall region* (S. J. Richards and N. Whitmore, eds.). Wildlife Conservation Society Papua New Guinea Program. Goroka, Papua New Guinea.
- Armstrong, K. N., Aplin, K. P., & Crotty, S. 2016. A pipeline and app for massive filtering and assisted inspection of enormous acoustic datasets. Poster presentation at the 17th Australasian Bat Society Conference, Hobart, Tasmania, Australia 29 March–1 April 2016. *The Australasian Bat Society Newsletter* 46: 51.
- Bonaccorso, F. J. 1998. *Bats of Papua New Guinea*. Conservation International Tropical Field Guide Series. Conservation International, Washington, D.C.
- Corben, C. & O'Farrell, M. J. 1999. *AnaBat system user's guide. AnaBat system manual*, 2nd ed. Published by the authors, 1999.
- de Oliveira, M. C. 1998a. Towards standardized descriptions of the echolocation calls of microchiropteran bats: pulse design terminology for seventeen species from Queensland. *Australian Zoologist* 30: 405–411.
- de Oliveira, M. C. 1998b. *Anabat system practical guide*. Queensland Department of Natural Resources.
- Gannon, W. L., O'Farrell, M. J., Corben, C. & Bedrick, E. J. 2004. Call character lexicon and analysis of field recorded bat echolocation calls. pp. 478–484 in *Echolocation in Bats and Dolphins* (J. A. Thomas, C. F. Moss and M. Vater, eds.). University of Chicago Press, Chicago.
- Leary, T. & Pennay, M. 2011. Echolocation calls of eight microchiroptera from Papua New Guinea. pp. 106–127 in *The biology and conservation of Australasian bats*, (B. Law, P. Eby, D. Lunney and L. Lumsden, eds.). Royal Zoological Society of New South Wales.
- Robson, S. K. A., Inkster, T. E. & Krockenberger, A. K. 2012. *Bats of the YUS Conservation Area, Papua New Guinea*. Result 5. Task 3.1. Centre for Tropical Biodiversity and Climate Change, and Centre for Tropical Environmental and Sustainability Science, School of Marine and Tropical Biology, James Cook University, Australia.

