Frieda River Limited

Sepik Development Project

Environmental Impact Statement

Appendix 8a – Terrestrial Biodiversity Field Assessment for the Frieda River Copper-Gold Project and the Frieda River Hydroelectric Project

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Terrestrial Biodiversity Field Assessment for the Frieda River Copper-Gold Project and the Frieda River Hydroelectric Project

Report to Coffey Environments and
Frieda River Limited

03 March 2015

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Ken was a research scientist at the Australian National Wildlife Collection, CSIRO Sustainable Ecosystems, Canberra and a research associate with the American Museum of Natural History and the West Australian Museum. He is one of the leading authorities on New Guinea mammals having conducted field research and expeditions there since 1981. His PNG experience is very broad and he has worked in most provinces including Sandaun. He has carried out extensive taxonomic work on marsupials and rodents and has over 100 publications, most in referred journals, and chapters in learned books. He set up his own consultancy in 2011. Ken is on the board of the Australasian Monotreme and Marsupial Specialist Group, and a member of the IUCN Small Non-Volant Mammal Task Force.

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Kyle is a bat specialist with a particular focus on the remote detection and design of targeted surveys for bat species of conservation significance. He has surveyed bats in Southern Highlands Province of PNG. His bibliography includes over 60 publications in referred journals and books and conference papers.

Iain Woxvold, Melbourne University - Birds

Iain is a specialist ornithologist, with significant recent experience in New Guinea. Since completing his Ph.D. he has focused on diversity analyses and conservation of vertebrate fauna in Asia and the Pacific. He has published numerous peer-reviewed scientific papers and provides specialist advice on the significance and management of vertebrate communities to industry, government and NGOs. Iain has worked in Australia, Indonesia, PNG and Lao PDR on projects for the oil and gas industry, mineral resource companies, infrastructure development, commercial agriculture and conservation NGOs.

Stephen Richards, Honorary Research Associate at the South Australian Museum - Herpetofauna and Odonates

Stephen is one of New Guinea’s leading frog and odonate experts and has extensive knowledge of Melanesian reptiles. A research scientist affiliated with the South Australian Museum, Stephen has been working for 18 years on the herpetofauna of the Melanesian region and tropical Australia. During this time, he has conducted more than 30 biodiversity surveys across the region, from western Papua Province in Indonesian New Guinea to Papua New Guinea, the Solomon Islands and New Caledonia. Stephen has published more than 80 scientific papers in peer-reviewed publications, including descriptions of many new species of frogs and reptiles from Melanesia. He is the Working Group Chair for Melanesia of the of IUCN-Species Survival Commission’s Amphibian Specialist Group.

Chris Müller - Butterflies

Chris is an entomologist/geologist currently working in Morobe Province. He has been working full time in PNG for the past five years as a geologist, but during this time, he has also conducted several lepidoptera surveys for mining companies and for the IUCN, plus various academic institutions. He first visited PNG at the age of six, and has conducted numerous surveys in various provinces in search of new butterfly species. He has observed nearly 80% of the 900+ known species in PNG plus discovered and described nearly 20 new butterfly species in the region, working closely with associates at the Natural History Museum (London), Museum Naturalis (Leiden, Netherlands) and Australian Museum (Sydney). His long, keen interest in both butterflies and geology has culminated in a PhD thesis, titled ‘Wallacea – tying geology with genetics’, a combination of molecular phylogenetics, biogeography and plate tectonics, which is near completion and comprises several papers, some of which are in press. He is currently working, jointly with John Tennent (Natural History Museum), on a book, “The Butterflies of Indonesia”.

Francis Crome, Francis Crome Pty. Ltd. - Coordinator

Francis had a long research career with the CSIRO Division of Wildlife and Ecology as a Principal Research Scientist where he worked on wetland ecology, waterbird dynamics, wetland survey methods, rainforest management, rainforest faunal dynamics and logging impacts. He has been involved in a range of very high profile projects in tropical regions as a senior environmental adviser, planner, field scientist and auditor, including the development of a biodiversity strategy for BHP in Borneo and work on large pipelines in PNG, Australia, Myanmar and Peru. He has worked extensively in Asia and the Pacific for the private and conservation sectors and is fully familiar with Melanesian forests and forest wildlife and the environmental, biodiversity and social issues of PNG. He has carried out over 15 consultancies in New Guinea. He is exceptionally broad based and has over 160 reports and publications.

Contents

PREFACE

This document is an independent report for the Environmental Impact Statement (EIS) for the Frieda River CopperGold Project (the Project), a component of the Sepik Development Project. The Project aims to develop the Horse-Ivaal-Trukai, Ekwai and Koki (HITEK) copper-gold deposits in Sandaun (West Sepik) Province approximately 200 km south of the northern coast PNG and 75 km east of the border with the Indonesian province of West Papua. Supporting infrastructure and facilities will be located in the Sandaun and East Sepik provinces and will include a subaqueous Integrated Storage Facility (ISF) to store produced tailings and waste rock and a hydroelectric power facility (termed the FRHEP), and linear infrastructure including roads, a concentrate pipeline, electricity transmission lines.

The Project is located in one of the least biologically explored parts of New Guinea and there was insufficient available information on terrestrial biodiversity to characterise the area. In view of this, the Project commissioned a series of terrestrial biodiversity surveys from 2009 to 2011, with the objective of gathering sufficient information for an impact assessment. The targets for survey, confirmed after consulting with the PNG Department of Environment and Conservation, were vascular flora, mammals, birds, amphibians, reptiles, dragonflies and damselflies (Odonata) and butterflies. Each group was surveyed by an individual specialist (see contributors above).

This part of PNG is road-less and the surveys were carried out entirely from 16 helicopter-supported bush camps. A further 8 sites were surveyed more briefly from overnight fly camps, flyovers or day trips; additional data was also obtained from hunters at seven villages. All this activity took place within a Study Area that was more-or-less defined on a catchment basis and encompassed the Mine and FRHEP disturbance areas and surrounds.

Each specialist prepared a standalone report of their survey findings. Each specialist also contributed to a joint impact assessment and contributed suggestions for mitigations which were assembled into a final set that were recommended to Coffey Environments. The reports and the impact assessment have been assembled into this document and appear as individual chapters in what is intended to be an integrated assessment. Although there is some repetition and duplication of information between chapters, none are stand-alone reports.

Chapter 1 provides the geographic context for the Project, an overview of legislation, regulations and standards relevant to the assessment, and the rationale for defining the Study Area. It also takes the vegetation analysis provided in Chapter 2 and defines a modified set of vegetation types used throughout the zoological chapters. It finally provides an introduction to data collection approaches and the adequacy of the data for the assessment.

Chapter 2 presents the results of the botanical surveys which found at least 1,354 species (technically “morphotaxa”) with 22 being undescribed, most of those new to science, and many range extensions of known species. The surveys also discovered Peat Forest, a previously unknown vegetation type in PNG.

Chapter 3 presents results from the mammal survey team. A desktop analysis suggested up to 140 species could be candidates to occur in the Study Area. Eighty-one species were recorded, including two species new to science. Twelve of these were species of bats recorded from calls but not identified. All “candidate” mammals were considered in the impact assessment.

Chapter 4 presents the bird survey results in which 220 species were recorded. A further 195 species could occur based on their known distributions in New Guinea. All 415 species were considered in the impact assessment. Small groups of migratory waders were recorded but the area of habitat available is large and suggestive of an area that could accommodate large numbers.

Chapter 5 presents results of frogs and reptiles, of which 58 and 41 species respectively were recorded. This includes at least 20 frogs and a reptile likely new to science. Frogs were most diverse at higher elevations.

Chapter 6 presents results for dragonflies and damselflies which, like frogs, require both forest and stream condition to be optimal for survival. 107 species were recorded, of which 12 are new to science. The odonate fauna split quite clearly into Hill Zone species that generally inhabited forest streams and Lowland Zone species that preferred open ponds.

Chapter 7 presents results on butterflies of which 359 species were recorded. Nine appear to be new to science and there are numerous range extensions for PNG.

Geographic Conventions

The Project uses the datum PNG MG94 Zone 54. Biodiversity field operations were active prior to being informed of the use of this datum and collected location data in WGS84 Zone 54S. To avoid complicating continuing field operations the authors continued to collect GPS data in WGS84 Zone 54S. The two datums are very similar, certainly enough for the purposes of this assessment. Further, the biogeographic analyses in this assessment reference locations in the literature which have been reported as latitude and longitude and/or are in areas using datums other than PNG MG94 Zone 54.

In this document all site data collected by the biodiversity team are reported here in both PNG MG94 Zone 54 and latitude and longitude while all location data taken from the literature or maps is expressed in latitude and longitude, which again is accurate enough for the assessment presented here.

The Project uses RL (relative level) to express elevation. However, literature records of elevation information for species distributions used in this assessment are published as “above sea level”. For the level of accuracy used in the assessment the terms are interchangeable and the word “elevation” is used e.g. 2000 to 2500 m elevation means 2000 to 2500 metres above mean sea level.

GAZETTEER

PLACE	ILLUSTRATED ON FIGURE	NOTES
Adelbert Range	1	North Coastal Ranges element
Aitape	2	
Aki River	2	
Alotau	1	
Amanab	2	
Amaromin	3	
Ambua Lodge		Lodge near Tari in the Eastern Highlands
Ambunti	2	
Angoram	2	
Anguganak	2	
Aoum 3	3	
April River	2	
Aroa River		Central Province
Arfak Mountains	1	
Araucaria Camp		Idenburg River 03.5°'S 139.183° E 850m elevation
Aru Islands	1	
Aseki		Village 60 km W of Wau
Astrolabe Bay	1	
Baiyer River Sanctuary		55 km N of Mt Hagen
Batanta	1	
Bernhard Camp		Idenburg River. 03.483° S 139.2166° E 75 m elevation.
Bewani Mountains	2	North Coastal Ranges element
Biak Island	1	
Bismarck Archipelago	1	
Bismarck Range	1	
Bomberai Peninsula	1	
Bulolo	1	
Busilmin	2	
Central Range or Central Cordillera		Central spine of mountains extending the length of New Guinea
Chauve Government Station		Site in Chimbu Province near Kundiawa
Collingwood Bay	1	
Crater Mountain Wildlife Management Area		Protected area of 275,000 ha SE of Karimui
Cyclops Mountains	1	
D'Entrecasteaux Archipelago	1	
Deria	1	
Drei Zinnen Mountains	2	
East Asian-Australasian Flyway		A migratory bird route extending from Alaska and Siberia to Australasia and covering most of eastern Asia and the western Pacific
Elevala River	1	
Eliptaman		Village 40 km south-southwest of the Study Area
Etappenberg		Augusta Fluss expedition survey site approx. 58 km E of Frieda Strip (4.63° S, 142.48° E), between April and Wario rivers.
Fak Fak	1	
Fiak	3	
Finisterre Mountains	1	North Coastal Ranges element

PLACE	ILLUSTRATED ON FIGURE	NOTES
Fly River	1	
Foya Mountains	1	North Coastal Ranges element
Geelvink Bay	1	
Gogol River		Small river flowing to the coast close to Madang
Goodenough Is.	1	
Grasberg	1	
Gratzack Range	2	
Green River	2	
Hauna	3	
Heroana		Village 70 km E of Karimui, Chimbu Province
Hertzog Range		Range 20 km W of Lae, Morobe Province
Hindenburg Range	1	
Hotmin	3	
Humboldt Bay		The bay in which Jayapura is located; Yos Sudarso Bay in Indonesian
Hunstein Range	2	
Hunsteinspitze		Mt Hunstein in the Hunstein Range
Huon Gulf	1	
Hydrographer Mountains	1	
Idenberg River	1	
Imonda	2	
Inagre	2	
Iniok	3	
Iniok Wi		Small wetland just north of Iniok
Jayapura	1	
Kaijende Highlands	1	
Kairiru Island	2	
Karawari River	2	East Sepik
Karimui	1	
Kau Wildlife Management Area		A WMA 12 km N of Madang
Kiunga	1	
Kokoda Trail		Trail running NS across the Owen Stanley Range
Kratke Range	1	
Krisa	2	
Kundiawa	1	
Lae	1	
Lake Chambri	2	
Lake Habbema		Small lake north of Mt Wilhelmina
Lake Kutubu	1	
Lake Murray	1	
Lake Narisin	4	
Lake Tawa		Small lake in the Kaijende Highlands
Lake Warangai	3	
Lake Warwi		Small lake near Lake Warangai
Lake Wati	4	
Lakekamu River	1	
Left May River	2	
Loloipa River	1	Central Province
Lordberg (Durchblick)		Augusta Fluss expedition survey site. 70 km ESE of Frieda Strip

PLACE	ILLUSTRATED ON FIGURE	NOTES
Lorentz River	1	
Louisiade Archipelago	1	
Lumi	2	
Luplupwintem		Cave in Western Province near Tabubil
Madang	1	
Mailu Island	1	
Malesia		Malaysia, Indonesia New Guinea and the Philippines
Malolo Plantation Lodge		Site approximately 30 km N of Madang on Astrolabe Bay
Mamose region		Madang, Morobe and East Sepik Provinces
Maprik	2	
Markham River	1	
May River	2	
Meander Mountain	2	
Melanesia		Region encompassing New Guinea and the Pacific islands east to Fiji
Memberamo River Mamberamo	1	
Mianmin Divide	2	
Miliom		A village about 3 km E of Lumi
Milne Bay	1	
Misool	1	
Mowi	3	
Mt Asowa	2	
Mt Borme		A village and mountain in the Star Mountains at 4.466667 S 140.7 E
Mt Bosavi	1	
Mt Donner	2	
Mt Hagen	1	
Mt Kaindi		Mountain adjacent to Wau
Mt Menawa	2	
Mt Nakru		A mine and peak in West New Britain
Mt Nibo		Aprox. 5 km E of Mt. Somoro (may be Mt. Sulen)
Mt Somoro	2	
Mt Stolle	2	
Mt Turu	2	Prince Alexander Mountains
Mt Wilhelmina	1	Puncak Trikora in Indonesian
Müller Range	1	
Murik Lakes (Karau Lagoon)	2	
Musgrave River		Stream north of Port Moresby near Sogeri
Nabire	1	
Nena River	3	
Nengian	2	
New Guinea		The large island of New Guinea without satellite islands
New Guinea and its satellite islands		New Guinea and its satellite islands including the Raja Ampats and the Papuan Islands
Niar River	5	Tributary of the Frieda River
Nimbokrang		Village near Jayapura
Ninigo Islands	1	
Nogoli		Site southeast of and close to Tari
North Coastal Ranges	1	
Oenake Range	2	North Coastal Ranges element

PLACE	ILLUSTRATED ON FIGURE	NOTES
Ok Isai	3	
Ok Tedi		A gold mine at Tabubil
Owen Stanley Range	1	
Pagwi	2	
Papua Province	1	
Papuan Islands		The islands off the south-eastern tip of PNG (D'Entrecasteaux and Louisiade groups)
Papuasia		New Guinea and its satellite islands
Paupe	3	
Peripatus Mountain		Peak in the Gratzack Range
Pionierlager (on/near Sepik R.)		Augusta Fluss expedition survey site approx. 6 km NNW by N of Iniok
PNG		Country of PNG
PNG mainland		Refers to the mainland portion of the country of PNG
Porgera	1	
Port Moresby	1	
Prince Alexander Mountains	2	North Coastal Ranges element
Puwani River	2	
Rai coast		One of the six administrative districts of Madang province west of Astrolabe Bay
Ramu River	1	
Right May River	2	
Roon Island	1	Papua Province, Indonesia
Ruboni Range		Western end of Adelbert Range at 4.25° S 144.83° E
Salawati	1	
Samou	2	
Sariba Island	1	
Saruwaged Mountains	1	North Coastal Ranges element
Schatteburg Mountains	2	
Schrader Range	1	
Seleo Island	2	
Sepik River	1	
Simberi Island		A small island east of New Ireland
Sissano Lagoon	2	
Sokamin	3	
Sorong	1	
Southern limestone		Large limestone area east and south of Tari
Standlager (on April R.)		Augusta Fluss expedition survey site approx. 61 km ESE of Iniok
Star Mountains	1	
Stephansort		Site 40 km S of Madang
Strickland River	1	
Tabubil	1	
Tagula Island	1	Now Vanatinai Is. - the largest island of the Louisiade Archipelago
Tari	1	
Tauri	2	
Telefomin	2	
Thurnwald Range	2	
Tifalmin	2	
Timika	1	Papua Province, near Freeport Mine
Torricelli Mountains	2	North Coastal Ranges element
Upper Sepik		The drainage interval above Ambunti

PLACE	ILLUSTRATED ON FIGURE	NOTES
Urapmin	2	
Usake River	3	
Utai	2	
Van Rees Range	1	North Coastal Ranges element
Vanimo	2	
Victor Emanuel Range	2	
Wabia	3	
Wafi		Gold project 50 km SW of Lae (Figure1)
Waigeo Island	1	
Wameimin 1	3	
Wameimin 2	3	
Waria River	1	
Wario (Leonhard Schultze) River	3	
Waskuk or Waskut	2	
Wau	1	
West Papua Province	1	
West Papuan Islands		The islands of Waigeo, Misool and Batanta west of the Vogelkop
Wewak	2	
Weyland Mountains	1	
Wiap River or Waiyap		Connects Lake Warangai with the Sepik River
Yapen		
Yapsiei	2	
Yapsiei River	2	

Chapter 1 Introduction

Francis Crome

A report prepared for Coffey Environments and

Frieda River Limited

3 March 2015

Contents

Tables

Figures

EXECUTIVE SUMMARY

1. This introduction provides an overview of legislation regulations and standards relevant to impact assessment of the terrestrial biodiversity for the Frieda River Copper-Gold Project, an overview of the Study Area, and data collection approaches.

2. A Study Area is defined based on taking a landscape view of the Project. It is bounded to the north by the Sepik River, to the west by the Saniap, Usake and Upper May rivers, to the east by the Wogamush, Hewe, Miwe and Tau rivers, and to the south by the 1,500-m contour. It is zoned into three elevational regions: Study Area Lowland Zone, Hill Zone and Montane Zone.

3. A common set of vegetation and stream descriptors, based on botanical analyses presented in Chapter 2 Area is presented which is then used throughout Chapters 3 to 7 of this impact assessment.

4. Survey sites and total sampling effort are presented.

ACRONYMS AND GLOSSARY

BBOP	Business and Biodiversity Offsets Program
CITES	Convention on International Trade in Endangered Species
EAAF	East Asian-Australasian Flyway
EIS	Environmental Impact Statement
EP	Equator Principles
EPFI	Equator Principles Financial Institutions
FIMS	Forest Inventory Mapping System
ICMM	International Council on Mining and Metals
IFC	International Finance Corporation
ITTA	International Tropical Timber Agreement
IUCN	International Union for the Conservation of Nature
JORC	Joint Ore Reserves Committee
NBSAP	National Biodiversity Strategy and Action Plan
NSF	National Science Foundation
PNG	Papua New Guinea
PNGNH	PNG National Herbartium
PS	Performance Standard
REDD	Reducing Emissions from Deforestation and Forest Degradation
UN	United Nations
UNEP	United Nations Environment Program
WBSCD	World Business Council for Sustainable Development
WMA	Wildlife Management Area

1 LOCATION AND PREVIOUS TERRESTRIAL BIODIVERSITY WORK

The Frieda River Copper-Gold Project (the Project) is located in the Frieda River area of the upper Sepik River Basin, one of the least biologically explored parts of New Guinea (Figures 1 to 3). There has been only one significant biological expedition to the Frieda River - the Kaiserin-Augustafluss (Sepik River) Expedition of 1912–13 (hereinafter called Augusta Fluss Expedition). Much of the data from this expedition was lost with the destruction of specimens during WWII. Apart from this expedition the only biological exploration within the Frieda catchment appears to have been a collection of mosses reported on in Norris and Koponen (1985), Norris *et al*. (1988) and Piipo (1986 and 1998).

Up until 2010 nearby biological exploration had been more-or-less confined to five areas.

- Extensive work on vertebrates in the North Coastal ranges and coastal areas (Figure 1).
- Work on plants and some vertebrates in the Hunstein Range.
- Work on vertebrates, particularly mammals in the higher ranges to the south around Telefomin (Figure 2).
- Studies of arboreal mammals at Mt Stolle (Figure 2).
- Minor botanical collecting along the May River (Figure 3) reaching *c.* 10 km south of the furthest point reached by the Augusta Fluss Expedition (W. Takeuchi *pers. obs.*)

In addition PNG is signatory to the following international agreements relevant to biodiversity:Achieving

- Convention on Biological Diversity (1992), which was ratified by PNG in 1993.
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971) (The Ramsar Convention).
- Convention on the Protection of Natural Resources and Environment of the South Pacific Region and related Protocols (Noumea, 1986).
- Plant Protection Agreement for the Asia and Pacific Region (Rome, 1956) as amended.
- Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean.
- Convention Concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972).
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979) and incorporating the African-Eurasian Migratory Water Bird Agreement (1995) and the Agreement on the Conservation of Bats in Europe (1991) (The “Bonn Convention”).
- Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Washington, 1973).
- International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Fund Convention), 1992.

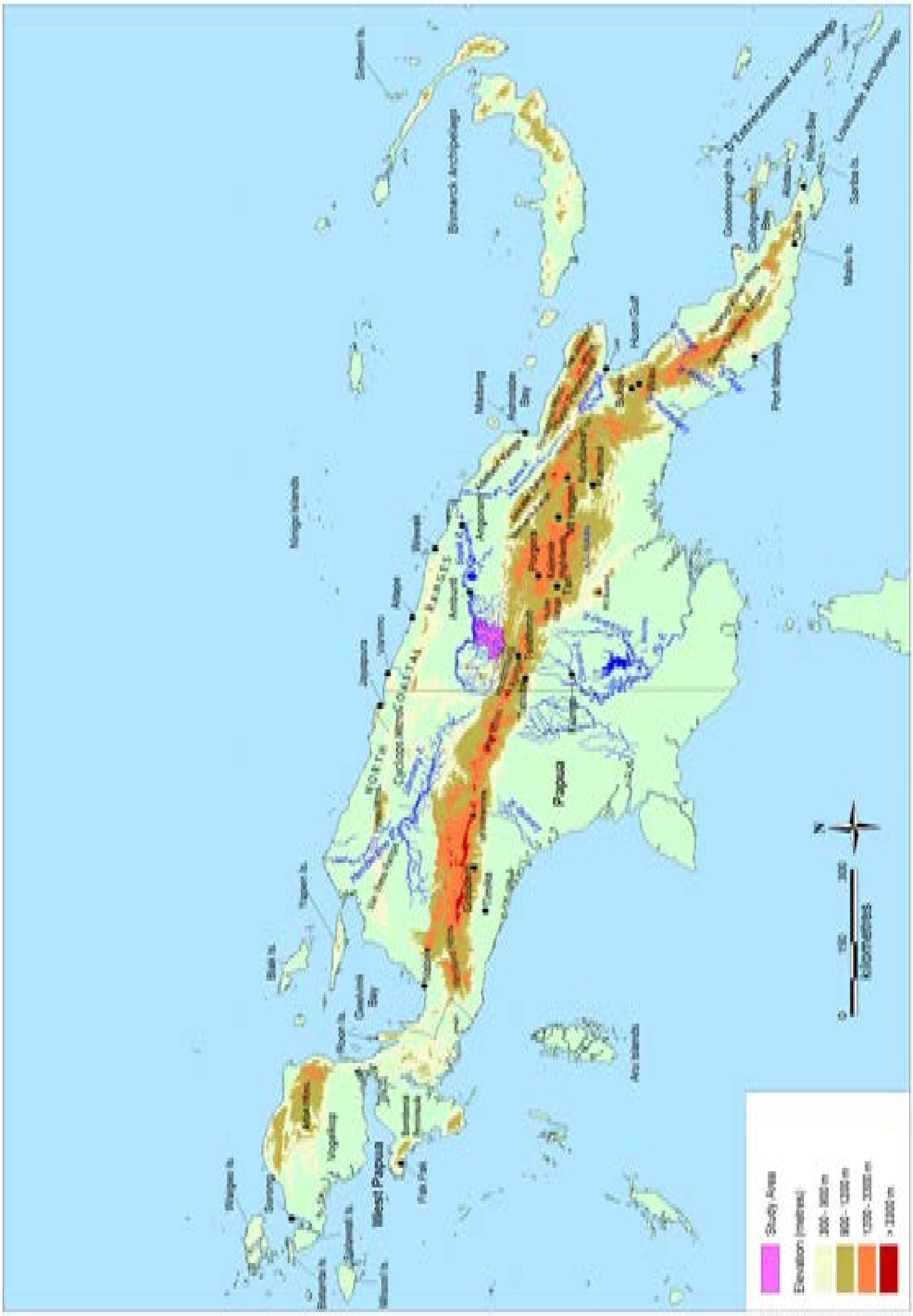

Figure 1. Location of Study Area and places mentioned in the text.

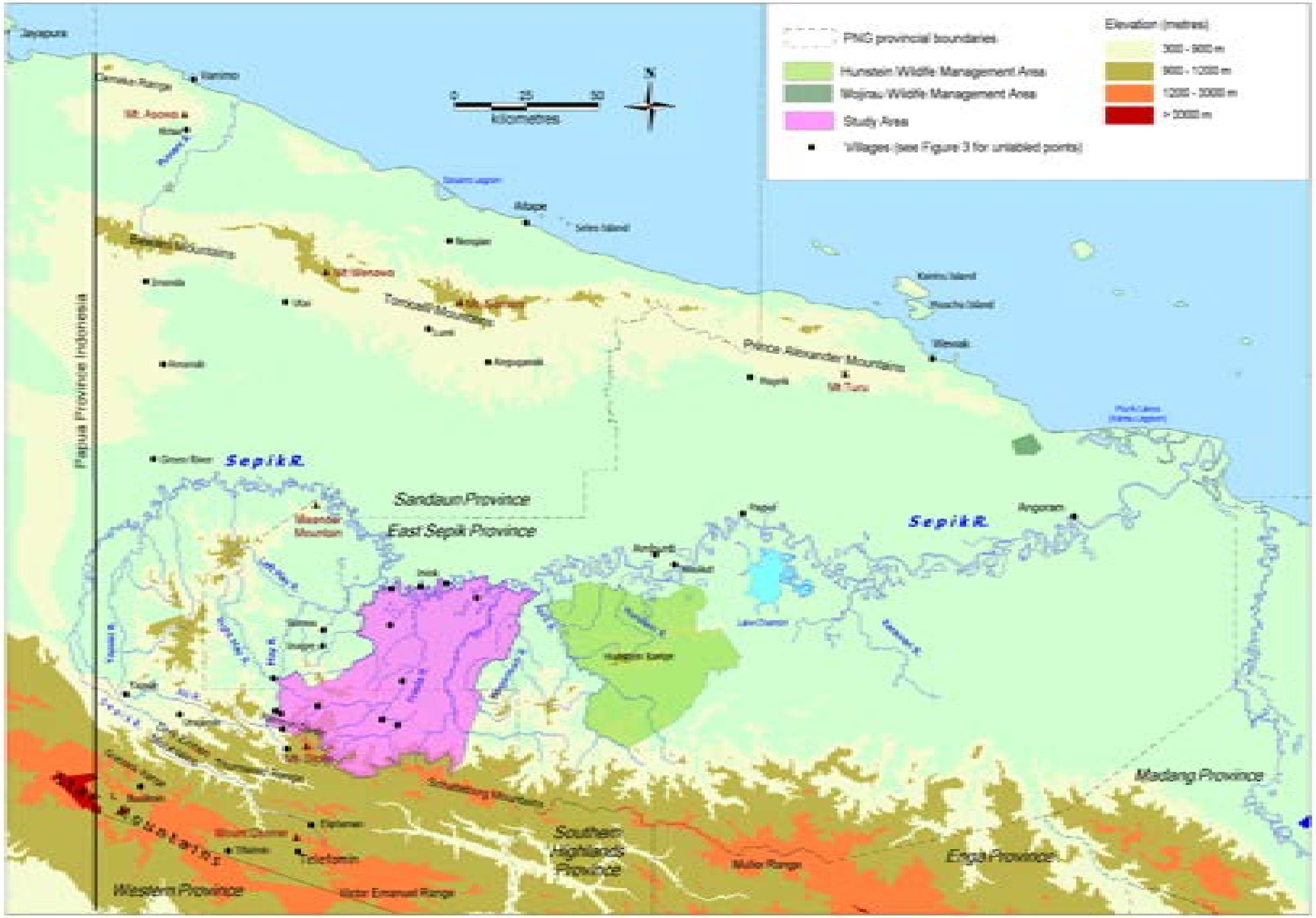

Figure 2. Location of Study Area (detail).

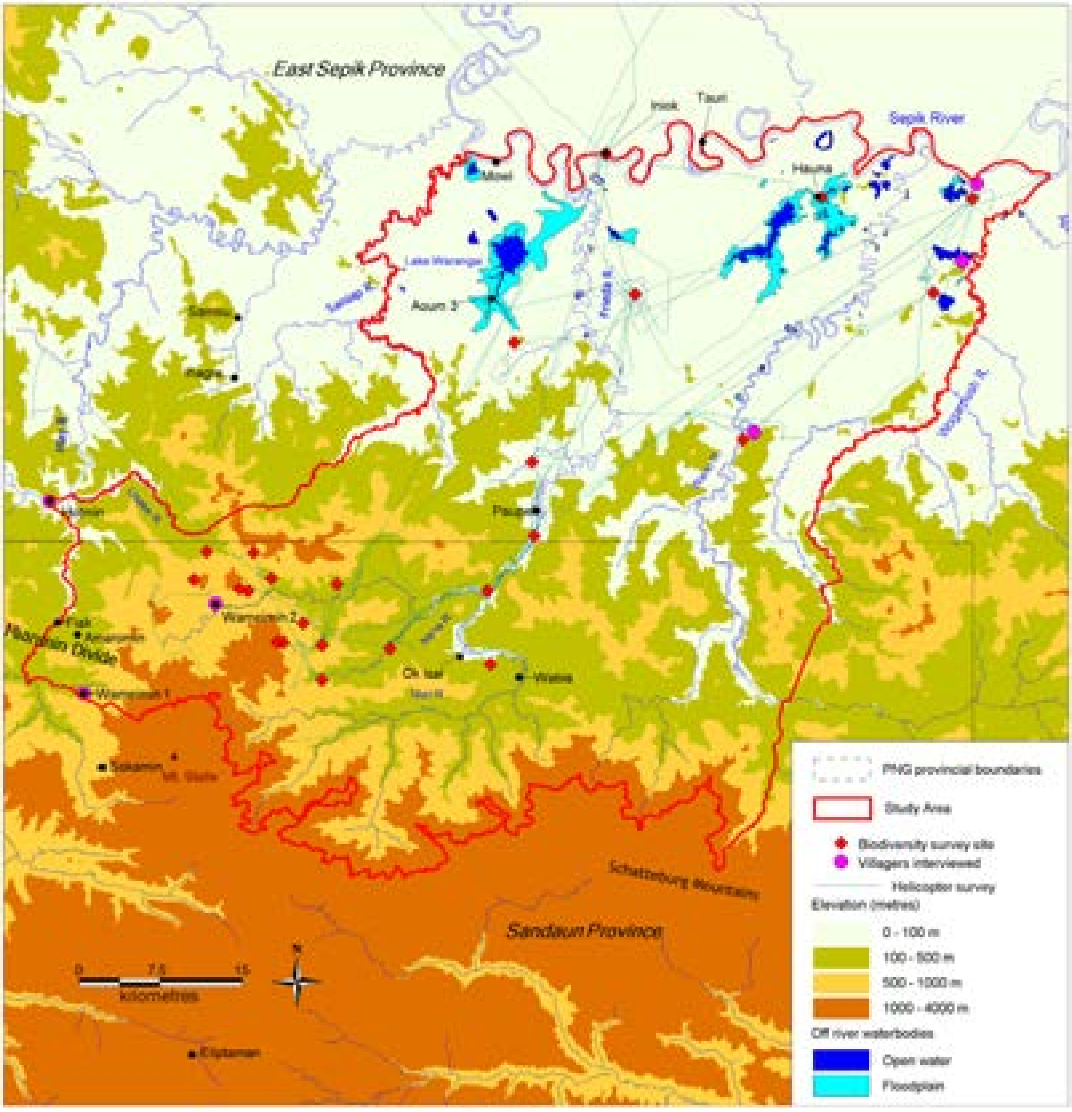

Figure 3. Study Area.

2 STUDY AREA

2.1 Design

There is no generally accepted way to define a Study Area for impact assessment. Impacts of a single project can vary spatially from the micro scale, such as the loss of a single tree, to the international scale, such as the accidental introduction of an exotic disease that may spread throughout PNG and into Indonesia. A fundamental guiding principle, however, is available from PanAust's Sustainability Management System, the watershed emphasis of Program 6 of the NBSAP, and IFC performance standard 6, which is that a broad landscape view of project impacts is required.

For this assessment an appropriate Study Area has been selected which

1. Covers all locations where proposed Project infrastructure is, has been or may be located[1].

2. Be an area within which the majority of impacts are expected to occur.

3. Has some ecological rationale and has relatively well defined natural boundaries.

4. Is an area within which the concept of "local" populations of species has some meaning.

The Study Area defined for this impact assessment is bounded to the north by the Sepik River, to the west by the Saniap River, Usake and Upper May rivers, to the east by the Wogamush, Hewe, Miwe and Tau rivers, and to the south by the 1,500-metre contour (Figure 3). It encompasses approximately 350,000 ha and covers all past, present and potential future infrastructure, but excludes the transport route along the Sepik River where potential impacts would be relevant to aquatic biodiversity and are covered elsewhere in the EIS.

Rivers were chosen as boundaries because they present barriers to movement of a range of terrestrial fauna. The 1,500-m contour was chosen because high mountains present barriers to lowland and hill fauna. While the Frieda catchment extends higher to elevations over 2,200 m, these extreme heights were excluded because the Project will not be developed into these elevations.

2.2 Zonation

The Study Area is divided into three zones.

Study Area Lowland Zone consists of depositional landforms resulting from past or present overbank flooding of the Sepik River and its major tributaries. Its upper elevational limit is 100 m and is here defined as all lands below 100 m. This zone is one of flat lands forming river floodplains and excludes isolated hills, such as Frieda Mountain, that jut out of the plains even where these hills do not reach 100 m. These hills are rightly part of the Study Area Hill Zone as their vegetation is not subject to the effects of overbank river flooding due to the abrupt gradient change at their bases.

Study Area Hill Zone consists of primary erosional and colluvial (i.e. slope deposit) landforms comprising the northern foothills of the Central Cordillera between 100 and 1,000 m elevation. It includes both continuous hills and ranges, and isolated hills surrounded by areas of active alluviation of the Study Area Lowland Zone

1 Project design evolves as information improves. In its early phases there are often many design options of which the most feasible is developed through a detailed design phase into the 'final" design. However, even this requires flexibility because, until a construction team gets on the ground, the feasibility of building any project element exactly to the design brief remains a hypothesis. Perfect information can never be available in the design phase and design has to adapt to the conditions encountered. Even design ideas abandoned in the early design phases may be resurrected at a late stage in the design process.

Study Area Montane Zone consists of primary erosional and colluvial (i.e. slope deposit) landforms comprising the northern foothills of the Central Cordillera above 1,000 m elevation.

2.3 Vegetation Nomenclature

Each discipline in biodiversity surveys tends to use it own classification system and nomenclature for vegetation. For uniformity in this impact assessment, a common set of vegetation descriptors has been derived from the vegetation analysis in Chapter 2 and the individual requirements of zoological disciplines (Chapters 3 to 7), and is presented in Table 1. Chapter 2 describes vegetation in terms of the commonly used PNG Forest Inventory Mapping System (FIMS), which is based on post-1975 aerial photography updated in 1996 from Landsat imagery (Saunders, 1993a, b; Hammermaster & Saunders, 1995a, b).

The FIMS system is effective for large-scale use, but detailed ground-truthing frequently uncovers anomalies in the FIMS categories. Chapter 2 discusses these anomalies in detail and notes, in particular, that montane forest characteristics extend to lower elevations in the Study Area than would be expected based on FIMS mapping and that the FIMS mapping does not capture the complexity of Swampy Forest in the Study Area Lowland Zone.

These FIMs type are usually defined too finely for zoological use and so have been combined where appropriate to reflect this. Table 1 thus includes

- FIMS-derived types mappable at 1:100K scale,
- a vegetation type (Peat Forest) not in FIMS but also mappable at 1:100K scale,
- vegetation types that occur at too small a scale to be included in FIMS and that are not mappable at 1:100K scale, and
- general categories.

Chapters 3 to 7 all use this common system.

The FIMS system also includes an assessment of forest condition based on scoring forest areas between 10 (completely intact forest), and 0 (forest all cleared and/or degraded). However, for some parts of the Study Area 25 cm resolution aerial photography captured in 2008, 2010 and 2011 was available. This allowed a more accurate and simpler condition assessment system to be developed based on a three point scale for these areas (Table 2).

An important result of this photography was the demonstration that Riverine Mixed Successions (Fri/Wri) blend imperceptibly into Lowland Open Forest (Po). By definition Riverine Mixed Successions (Fri/Wri) are precisely that, successions to other forest types, and only really identifiable as such in the early stages of succession; they cannot be mapped except as part of a condition class for Lowland Open Forest (Po).

2.4 Stream Nomenclature

There are a wide range of streams that support fauna in the Study Area from the wide deep turbid waters of the Frieda River to rapid clear waters in mountain streams. A set of standard stream descriptions has been developed by S. Richards in Chapter 5 and Chapter 6 and is presented in Table 3. See Chapters 2 to 7 for a full presentation of the streamside and stream habitat values for flora, terrestrial vertebrates, odonates and butterflies in the Study Area.

3 DATA COLLECTION

3.1 The Project Surveys

Biodiversity surveys were carried out within the Study Area during four periods:

- Trip 1 – Nena Surveys: 29 November to 15 December 2009. The 2009 Nena Surveys were conducted from five locations centred on the Nena copper and gold deposit and situated in the headwaters of the Nena (Frieda River catchment) and Usake (May River catchment) rivers.

- Trip 2 – From 1 February to 3 March 2010 surveys were conducted from seven sites centred on the Project's major area of operations in the Study Area Hill Zone. Surveys focused on the mineral deposits at Horse-Ivaal-Trukai and Koki, and other sites earmarked for development of associated logistics and infrastructure centres during the early stages of Project design. All of the Trip 2 survey sites were located within the Frieda River catchment.

- Trip 3 – Study Area Lowland Zone and Hill Zone: 26 May to 20 June 2010. The 2010 Trip 3 surveys were conducted from one site in the Study Area Hill Zone and five sites in the Study Area Lowland Zone. Most sites were situated in the Frieda River catchment. Surveys of the Hauna area were conducted in the April River catchment.

- Trip 4 – Study Area Lowland Zone: 23 February to 15 March 2011. The 2011 Trip 4 surveys were conducted from four sites in the Study Area Lowland Zone in the Wario, Ok Binai and Wogamush River catchments. Limited observations were also made from Frieda Airstrip (Frieda Strip Site).

Additional data for some species were collected opportunistically during two reconnaissance visits undertaken in preparation for subsequent detailed biodiversity surveys.

- Trip 1 Reconnaissance: 7–20 October 2009. Birds were recorded at various locations in the Study Area Hill and Lowland zones while on reconnaissance for the Trip 1–3 biodiversity surveys.

- Trip 4 Reconnaissance: 1 November 2010. Birds were recorded in the Study Area Lowland Zone during a brief stop-over at Kubkain Site in preparation for the Trip 4 biodiversity surveys.

Data was obtained from a total of 24 sites (Table 4 and Figures 4 and 5). Sixteen were major camps where sampling extended over a period of several days, the rest being sites that were visited more briefly. The surveys involved use of numerous techniques to maximise chances of recording as full an inventory of diversity of the target groups as possible. The bulk of sampling was done by groundwork but canoe transects and aerial surveys of waterbirds and other fauna were also carried out. Full details of sample locations, methods and results of these surveys are presented in Chapters 2 to 7. A significant source of information was obtained from interviewing residents of seven villages either at their villages or in the survey camps (Table 4).

This 91 days of field sampling is arguably the single most intensive biodiversity survey done in New Guinea to date and is a significant addition to the scientific effort expended in PNG on biodiversity.

Figures 4 and 5 show the locations of survey sites, survey tracks and interview villages and Table 5 presents the sampling effort for the surveys. Sample effort at individual sites can be found in Chapters 2 to 7.

3.2 Adequacy of Data

Chapters 2 to 7 discuss taxon-specific sampling issues and biases but generally tropical biotas present a range of peculiar sampling problems. First, weather has a profound influence on sampling though its effect depends on the group being surveyed; e.g. extreme rainfall hampers bird sampling but benefits frog sampling. Second, many tropical species are to some degree nomadic, may be less detectable at certain times of the year or may undergo regular local elevational and horizontal movements (McClure 1974, Crome 1993, Nix 1993) confounding sampling at particular times and places. Most significantly, tropical biotas are very diverse, most species are naturally rare, there appears to be natural small-scale patchiness in the distribution of many species that has no obvious explanation, and diversity at single locations, for resident birds at least, varies from year to year (e.g. Beehler *et al.* 1995; Diamond and Bishop 2003).

Beehler *et al.* (1995) have investigated the issue of inventory adequacy for birds in New Guinea. They concluded that sampling needed to last for several weeks to get an exhaustive inventory of species present. Census periods of several weeks at a site are usually impractical and rarely, if ever, achievable. Moreover, the issue of a complete inventory at a site may itself be an illusion. Considering the spatial and temporal dynamics of populations, the number of species present only has meaning in relation to a specified area over a specified time period. “Complete inventories” refers to the number of species that could be recorded within the site boundaries over an extended period (e.g. many years). At any one time the numbers actually present will be a subset of that and there is likely to be stochasticity in which particular species are present at any instant. Over longer periods range expansions and contractions on a geographic or global scale will inevitably add to or subtract from the inventory. Even with sedentary species like plants, dynamics still produce a turnover in species on a particular site as individuals die and are recruited. This turnover is simply likely to be slower than for animals, giving plant communities the appearance of greater stability. Stochasticity is a major issue for botanical surveys because positive identification of New Guinea plants requires fertile specimens and there is great spatial and temporal variation in phenology.

Overall, therefore, it is unreasonable to aspire to produce “complete inventories” for each small survey site in the Study Area and it is unnecessary. What counts is the extent to which the total data set approaches a “complete inventory” for the Study Area. At this larger scale variability produced by movement, stochastic variation and population dynamics is dampened and more stability in species inventory can be expected than at the site scale. Within the Study Area inventory, the full range of species adapted to a particular habitat at a particular elevation provides the sampling universe for survey sites at said habitat and elevation. For the purposes of impact assessment, any such species should be considered a candidate for occurrence at a specific site with suitable habitat and elevation at some time or another.

In order to bring the Study Area inventory as close as possible to “complete”, Chapter 4 has included extra bird species whose known ranges overlap with the Study Area but were not recorded during the Project surveys; many of these are waterbirds or nomadic frugivores and nectarivores. Similarly, Chapter 3 includes extra mammals that could occur in the Study Area. For all other groups too little is known about species distributions in New Guinea to compile a reliable list of possible additional species.

Taken alone, the data collected during the surveys are sufficient to determine the biodiversity values present in the Study Area. With the inclusion of possible additional species of birds and mammals the data set is also sufficient to carry out the impact assessment. Where data are insufficient or where ecological understanding is lacking the matter is specifically addressed.

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Table 1. Vegetation types defined for the Study Area

VEGETATION TYPE	FIMS TYPE	FIMS CODE	DESCRIPTION	ELEVATION (M)*
FIMS derived types mappable at 1:100K scale				
Lowland Open Forest (Po)	Open low-altitude forest on plains and fans	Po	The canopy is approximately 30 m high and consists of small and medium crowned trees with large crowned emergents up to 40 m high. The canopy profile is very uneven with many large gaps. A variety of palms occur, and climbing rattans are common. In low-lying areas, sago palm stands develop, and where they have the opportunity, broad-leaved trees can reach great sizes (greater than 100 cm dbh).	<250 (<1000)
Small Crowned forest (Ps)	Small crowned forest	Ps	Forest 25 to 30 m high with a dense even canopy of small crowned trees usually on floodplains with poorly drained or gravelly soils.	<250m (<1000)
Swamp Woodland (Wsw)	Swamp woodland	WsW	This consists of a dense tall layer of sago or pandanus with scattered trees over a ground layer of sedges, ferns, grass or bare ground. It is permanently inundated.	<100 (<1,000)
Mixed Swamp Forest (Fsw)	mixed swamp forest	Fsw	This forest has an even canopy with varying degrees of openness. It is generally low, 20 – 30m high, and usually has a dense understorey of sago. The water table where this type develops fluctuates greatly, sometimes daily.	<100 (<1,000)
Alluvial Wooded Swamp Complexes (Wsw/FsW)	Swamp woodland and Mixed swamp forest	WsW & Wsw/ FsW	These are complexes of Swamp Woodland and Mixed Swamp Forest	<100 (<1,000)
Herbaceous Swamp (Hsw)	Herbaceous swamp	Hsw	These are open water swamps dominated by water plants and sedges. Waterlilies are very common.	<100m (N/A)
Riverine Mixed Successions	Riverine mixed successions and Riverine successions dominated by woodland	Fri and Wri	This “type” is actually a sere on sites deforested by e.g. river movements and varies from grass through an arborescent-stage community which is nearly always accompanied by the proliferation of vines through to secondary forest. Advanced stages grade into Lowland Open Forest (Po).	<250m (<1,000)
Hill Forest (Hm)	Medium-crowned upland (hill) forest	Hm	This forest has a canopy 25 to 30 m high with emergents up to 40 m. Canopy closure is 60% to 80% Species composition varies with elevation.	0-1,000m (<1,000)

VEGETATION TYPE	FIMS TYPE	FIMS CODE	DESCRIPTION	ELEVATION (M)*
Lower Montane Forest (L ± c)	Small crowned lower montane forest and complexes and transitions with Small crowned lower montane forest with conifers	L	This forest has an even to undulating canopy 20 to 30 m high and is very dense to almost closed. Ferns and epiphytes are common. Trees tend to be thin, and oaks (*Castanopis* and *Lithocarpus*) are common, dominating in some areas. This includes Small crowned lower montane forest with conifers (Lc) including the genera *Dacrydium, Libocedrus* and *Phyllocladus* and Small crowned lower montane forest with *Nothofagus* (LN).	1,000-1500m (1,000 - 3000)
Montane Forest	Very small crowned Forest	Mo and Mo/ Ga	This is very small crowned forest ("elfin" forest) and alpine grassland complexes. It is low, 5 to 15 m high with thin crooked stems and no emergents.	Discussed in text but does not occur in Study Area (>3000 m)
Cleared Areas	"Land use intensity class 0-4"	O	Areas of anthropogenic clearance, large landslides etc.	All (All)
Vegetation type not in FIMS but mappable at 1:100K scale				
Peat Forest			This is a newly discovered forest type for PNG but well known in Malesia. It is developed on a peat dome with a stilted water table higher than the ground surface of surrounding, non-peat communities. It is stunted forest with extremely low floristic diversity and endemism with a preponderance of pole-stem trees with poor crown development and small leaves. It has many plant families missing from situations where they would normally be expected to occur.	<100 (N/A)
Vegetation type not in FIMS and not mappable at 1:100K scale				
Gallery Forest			Strips of forest edging streams through otherwise open habitat such as grasslands, shrublands or savanna.	<250m (N/A)
Riparian Forest	N/A		Lowland Open Forest (Po), Hill Forest (Hm) or Lower Montane Forest (L ± c) immediately adjacent to waterways (> ca. 4m wide at least flow) within continuously forested areas. Variously developed from mature forest with understorey of often specialised stream side trees and shrubs to sites dominated by tall grass or vines and scrubby regrowth.	All elevations (N/A)

VEGETATION TYPE	FIMS TYPE	FIMS CODE	DESCRIPTION	ELEVATION (M)*
Mossy Forest	N/A		Small crowned lower montane forest and Small crowned lower montane forest with conifers with strong development of mosses on the trees and the ground	>600m on ridge crests but generally above 1,000 m. (1,000 - 3000)
Heath			Areas of Hill Forest (Hm), Lower Montane Forest (L ± c), Coniferous Lower Montane Forest (Lc) and/or Mossy Forest where the vegetation is stunted, usually less than 8 metres tall. Few species of trees with fleshy fruits but nearly all with hardened trunks and branches. Essentially restricted to exposed sites at higher elevations.	Various (N/A)
General categories				
Grasslands	Various	Various		All (All)
Swampy Forest	Any combination of Swamp Woodland, Mixed Swamp Forest, Swamp Woodland and mixed swamp forest	WSw/FsW &/ or WsW &/or FsW	A general category to refer to Swamp Woodland, Mixed Swamp Forest, Swamp Woodland and mixed swamp forest and refers to swampy areas with a tree or palm canopy as opposed to open water swamps, shrublands and grasslands.	<100 (<1,000)
Closed Forest	N/A		All forested areas where the canopy closure >60%	All (N/A)

* Elevation range in Study Area and, in brackets, the range in PNG given by Hammermaster and Saunders (1995a).

Table 2. Vegetation condition defined for Lowland Open Forest and Hill Forest where aerial photography available.

CODE	CONDITION	LOWLAND OPEN FOREST (PO)	HILL FOREST (HM)
A	Mature forest	Advanced stages of succession with continuous cover of medium to large crowned trees and a very uneven canopy but can have numerous gaps but few > 0.2 ha. Little evidence of human activity.	Old growth or primary habitat with natural levels of small gap disturbance (approx. 1%) and, if present, infrequent scattered larger gaps up to 0.2 ha each caused by large wind throws, small landslips or possibly human activity far from settlements.
C	Lightly disturbed forest	Lightly disturbed and/or advanced successional open forests. They may be (1) advanced stages of succession but with a more even canopy produced by dominance of early secondary species and/or (2) well developed but not mature open forest with numerous large gaps likely to have resulted from gardening activity. Gaps generally greater than 0.2 ha, and areas of canopy damage or thinning. Generally occurs adjoining settlements, garden areas, or successional areas (Type D)	Forest with small areas of clearance or disturbance caused by isolated garden plots, or larger landslips. Gaps generally greater than 0.2 ha, and areas of canopy damage or thinning. Generally occurs adjoining settlements, garden areas, or areas of heavily disturbed forest (Type D)
D	Heavily disturbed, cleared or early successional forest	Complexes of areas of pioneer, early secondary and other regenerating forest with areas of degraded but intact mature or lightly disturbed forest. These are either early to mid stage successions after flooding (Riverine Mixed Successions (Fri/Wri) under FIMS) or have been heavily disturbed by man.	Forest that has been heavily disturbed by man or large-scale natural disturbance such as extensive landslides or flooding. Consisting of complexes of areas of pioneer, early secondary and other regenerating forests with areas of degraded but intact natural or lightly disturbed forest.

* These are the only two vegetation types within the proposed Project disturbance area.

Table 3. Definition of stream types in the Study Area.

STREAM TYPE	CODE	MAJOR CHARACTERISTICS
STREAM TYPES		
Upland Torrential Stream	UTS	Small to medium (1-10 m wide), clear water creeks. Generally above 300 m elevation. Moderate-high velocity. Rocky substrate with riffle-pool morphology and sometimes with waterfalls. Transport capacity greater than supply for sand, so sand and litter are minor components of substrate except in deeper pools. Water temperatures cool and high levels of dissolved oxygen. Severely influenced by spates.
Upland Low-gradient Stream	ULGS	Small to medium (1-10 m wide), clear water creeks. Generally above 300 m elevation. Low velocity, so sand is dominant substrate and litter accumulation evident. Riffle/pool morphology substantially lacking. Water cool and oxygen levels lower than in UTS. Moderately influenced by spates.
Lowland Torrential Stream	LTS	As for Upland Torrential Stream but generally below 300 m elevation. Moderate velocity so sand and litter more evident than in UTS although rocky substrate still dominates. Riffle/pool morphology less well defined than in LTS.
Lowland Low-gradient Stream	LLGS	As for ULGS except water may be muddy or clear. Generally below 300 m elevation. Very low velocity so sand and litter dominate the substrate – exposed rocky substrate generally negligible. Riffle/pool morphology absent. Oxygen levels low.
Seepage	SP	Shallow (< 10 cm), slow-flowing water bodies seeping from the ground. Generally < 5 m wide. Velocity negligible, surface movement barely detectable. Substrate usually mud and/or litter. Riffle/pool morphology absent. Oxygen levels low.
Within stream habitats		
Riffle	none	Shallow (normally <30 cm deep) turbulent water flow with broken water surface over rocky substrate.
Riffle/Pool morphology	none	Streams characterized by stretches of higher-velocity, turbulent water flowing over rocks (riffles), that separate slower, deeper stretches (pools) generally containing some sand.
Spate	none	A rapid and very large change in stream volume/velocity in response to intense rainfall events.

Table 4. Survey sites and sampling data.

SITE	NORTHING	EASTING	LAT (S)	LONG (E)	ELEVATION (M)	TRIP #	SURVEY DATES
BIODIVERSITY SURVEY SITES							
Hauna (& lakes) Site	633102	9521859	4°19.492	142°11.968	30 (35 - 50)	3	12 - 13 Jun '10
Warangai South Site	604838	9508484	4°26.772	141°56.696	40 (40 - 55)	R	16 Oct '09; 18 Oct '09;
East Sepik Site	615978	9512957	4°24.337	142°02.716	45 (35 - 55)	3,4	07 – 12 Jun '10; 14 Mar '11
Iniok Site	613257	9525933	4°17.296	142°01.236	45 (35 - 50)	3	13 -18 Jun '10
Kubkain Site	647022	9521801	4°19.510	142°19.493	50 (30 - 135)	R,4	01 Nov '10; 05 – 10 Mar '11
Wogamush Site	643437	9513096	S 04° 24.238'	142° 17.563'	55 (45 - 120)	4	28 Feb – 05 Mar '11
Frieda Strip Site	606679	9490687	4°36.430	141°57.704	60 (60 - 60)	R, 1, 2, 3, 4	brief transits
Wario Site	625869	9499578	04° 31.589'	142° 08.076'	65 (40 - 335)	4	24 – 28 Feb '11
Frieda Bend Site	602364	9485624	4°39.181	141°55.374	80 (65 - 150)	R, 2	10 Oct '09; 23 - 28 Feb '10
Kaugumi Site	606472	9497488	4°32.739	141°57.588	90 (60 - 90)	3	01 – 07 Jun '10
Ok Binai 1 Site	593391	9480315	4°42.068	141°50.524	125 (115 - 330)	R, 4	20 Oct '09; 10 - 15 Mar '11
Ok Isai Site	602620	9478846	4°42.859	141°55.517	135 (100 - 145)	3	26 May – 01 Jun '10
Malia Site	588503	9486267	4°38.841	141°47.876	290 (225 - 400)	R, 2	14 Oct '09; 17 Oct '09; 2 – 8 Feb '10 28 Feb - 02 Mar '10
Nena D1 Site	582451	9486788	4°38.562	141°44.602	400 (365 - 500)	1	5 – 8 Dec '09
Frieda Base	587095	9480591	4°41.923	141°47.118	400 (390 - 515)	R, 2	8 - 19 Oct '09; 12 – 14 Feb '10
Upper Ok Binai Site	587128	9477389	4°43.660	141°47.138	425 (325 - 575)	2	18 – 23 Feb '10
Nena-Usage Site	576498	9489217	4°37.247	141°41.380	440 (305 - 460)	1	12 – 14 Dec '09
Koki Site	585378	9482657	4°40.802	141°46.188	560 (510 - 660)	2	8 – 12 Feb '10
Nena D2 Site	580804	9489145	4°37.283	141°43.710	655 (640 - 685)	1	3 – 4 Dec '09
HI Site	583557	9480843	4°41.788	141°45.204	825 (610 - 1305)	2	14 – 18 Feb '10
Nena Base Site	580316	9485643	4°39.185	141°43.448	835 (750 - 1030)	R, 1	15 Oct '09; 29 Nov – 14 Dec '09
Nena Limestone Site	575324	9486656	4°38.637	141°40.747	950 (880 - 1055)	1	8 – 11 Dec '09
Nena Top Site	579516	9485824	4°39.087	141°43.015	1065 (950 - 1100)	3	06 – 08 Jun
Ubiame Site	582960	9480935	4°41.738	141°44.881	1380 (1360 - 1385)	2	16 – 17 Feb '10
VILLAGE INTERVIEW SITES							

SITE	NORTHING	EASTING	LAT (S)	LONG (E)	ELEVATION (M)	TRIP #	SURVEY DATES
Hotmin Village Site	561993	9493904	4°34.710	141°33.533	83 (83 - 155)	2	26 Feb '10
Wameimin 1 Village Site	565138	9476150	4°44.429	141°35.177	500 (500 - 500)	2	21 Feb '10
Wameimin 2 Village Site	577335	9484453	4°39.832	141°41.836	637	1	03 Dec '09
Nekiei Village	626130	9500220	4°31.24	141°8.648	45	4	27 Feb '11
Kubkain village	647416	9523164	4°18.77	141°19.705	50	4	09 Mar '11
Paru Village (interviews at Wogamush site)	646118	9515964	4°22.678	141°19.1	45	4	03 Mar '11

Note: eastings and northings in PNG MG94 Zone 54. Trips are R: recconniasance 7-20 Oct '09 and 1 Nov '10. Trip 1: 29 Nov - 15 Dec '09. Trip 2: 01 Feb '10 - 03 Mar '10. Trip 3: 26 May - 20 Jun '10. Trip 4: 23 Feb - 16 Mar '11

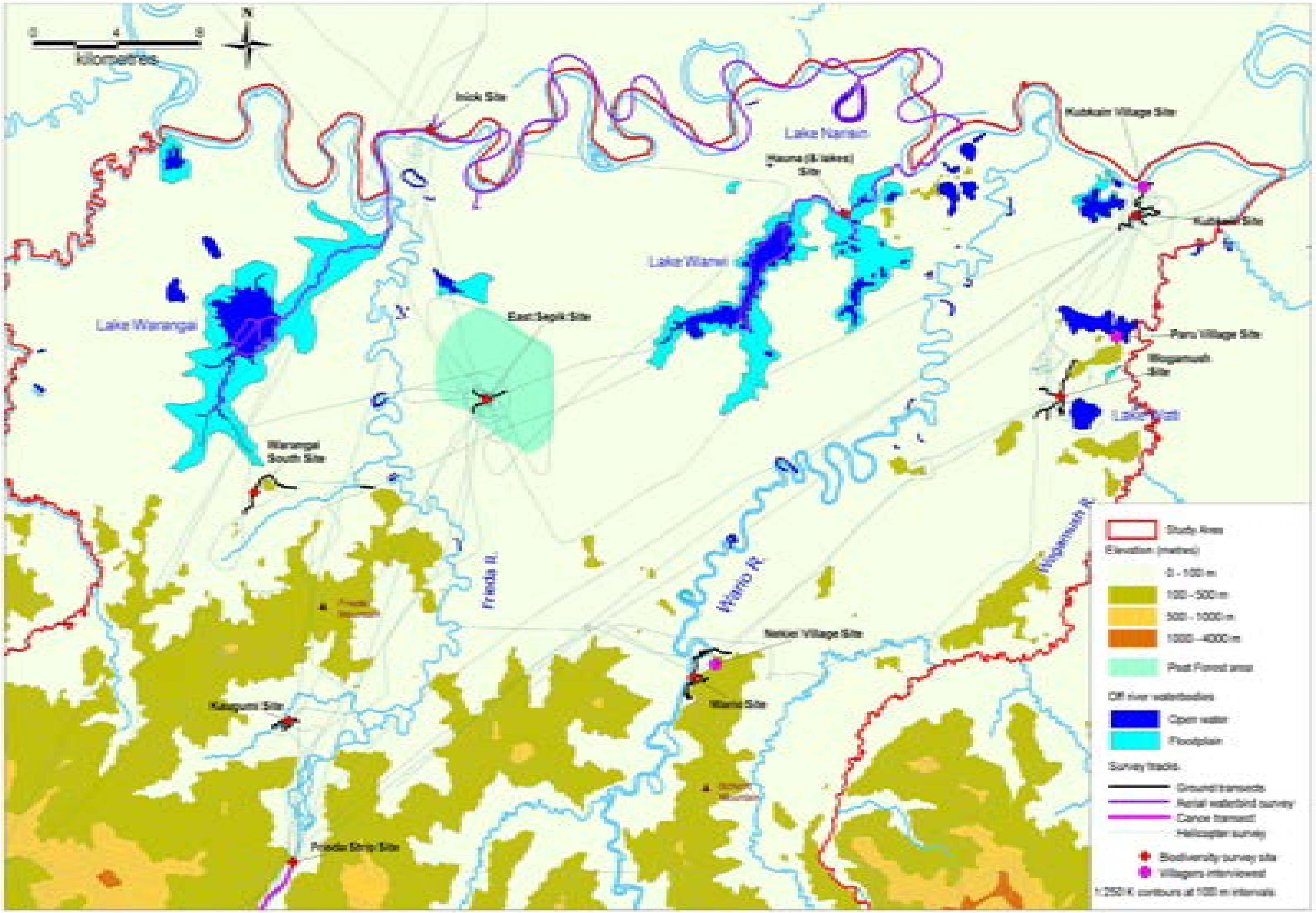

Figure 4. Survey sites 1. Contours are 1:250,000 at 10 m intervals. See also Figure 3.

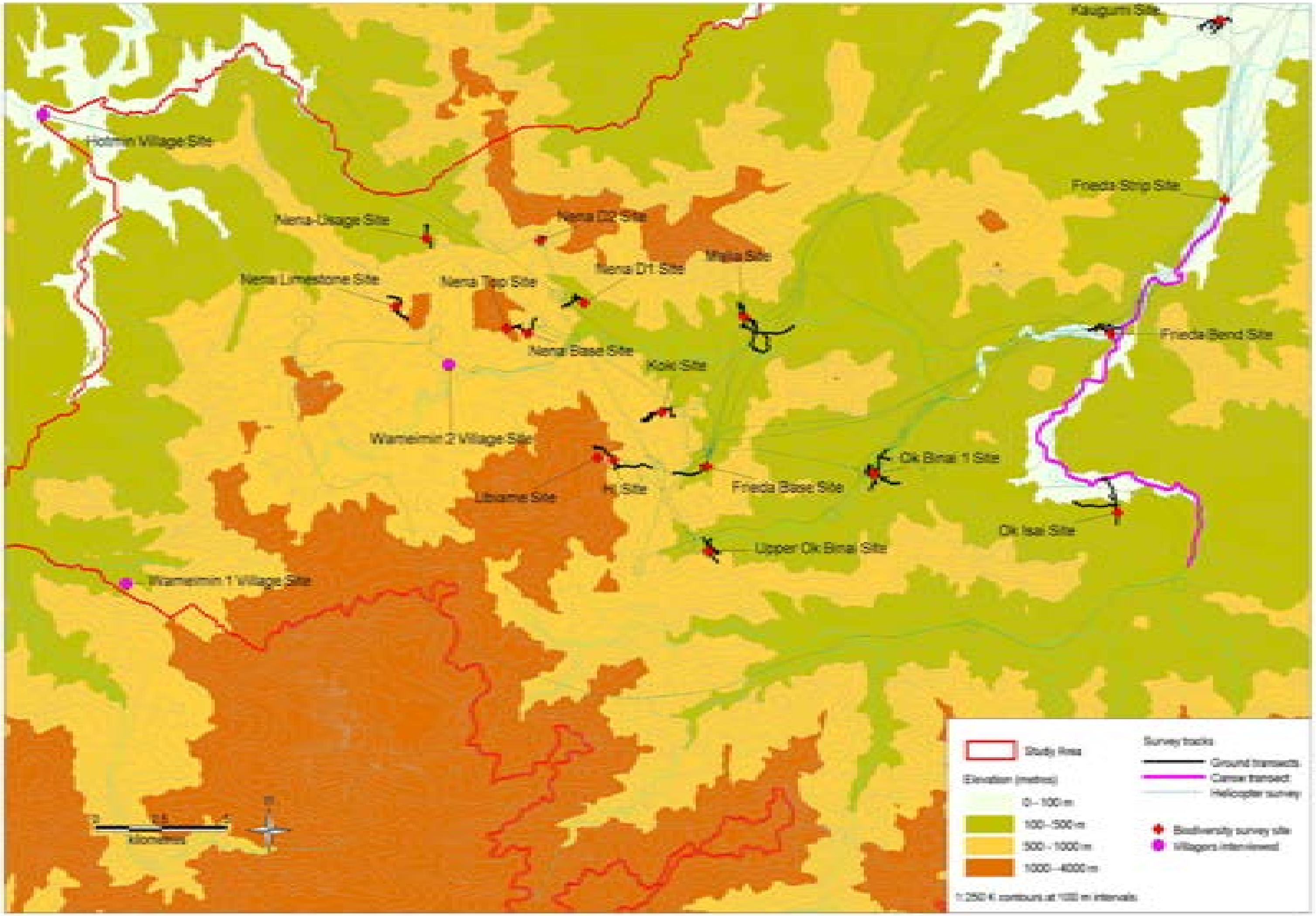

Figure 5. Survey sites 2. Contours are 1:250,000 at 10 m intervals. See also Figure 3.

Table 5. Total sample effort.

GROUP	SAMPLE METHOD	TOTALS
Flora	Man hours of searches	1,820
Mammals	Ground trap nights	7,493
	Cage trap nights	177
	Harp trap nights	83
	Bat detector sessions	143
	Mist-net metre-hrs (night only)	69,193.75
Birds	Day transect man hours of searches	516.5
	Mist-net metre-hrs (day and night)	138,565.25
	# of sound recordings	325
	Minutes of sound recordings	537.19
Mammals and birds	Camera trap days(24 hour period)	491
	Camera-trap hours	>11,616
	Mist-net nights	546
	Night transects man hours of searches	224.5
Herpetofauna	Man hours of searches	1,391.5
Odonates	Man hours of searches	875
Butterflies	Man hours of searches	1203
	# of butterfly bait traps	1,742

Chapter 2 Vegetation and Flora

Dr. Wayne Takeuchi

A report prepared for Coffey Environments and

Frieda River Limited

03 March 2015

CONTENTS

TABLE

FIGURES

APPENDICIES

GLOSSARY

3-merous	having 3 parts.
adventive	a species introduced by man and subsequently becoming naturalized.
amphiphyte	growing in seasonally or permanently wet mud; helophyte.
aril	an appendage or outer covering of a seed, produced from the hilum or funiculus.
bryology	the study of mosses and liverworts.
catena	a connected series of related parts (e.g., a community sequence in a floristic succession).
colline	pertaining to environments with low, hilly terrain.
congener	a member of the same genus.
conspectus	content, synopsis; an enumeration of taxa comprising a particular group of plants.
cosmopolitan	worldwide, or of geographically extensive distribution.
deciduous	of parts falling at the end of a growing season or other period of development.
edaphic	pertaining or relating to the substrate.
epiphytic	growing on another plant or other supporting object.
facies	a particular appearance or expression.
facultative	occurring contingently (e.g., occurring under some conditions but not others).
glabrescent	nearly glabrous, or becoming glabrous with age.
glabrous	lacking hairs or scales.
heliophyte	a light-demanding plant, consisting primarily of pioneer or seral species establishing in forest gaps and newly cleared environments.
indument(um)	a hair- or scale-covering on any plant part.
lacustrine	pertaining to lakes.
lycophyte	lycopsid, a member of the Lycopodium group (Lycopsida).
macrophyllous	large-leaved.
microphyllous	small-leaved.
monography	a taxonomic treatise or revision dealing with a specific group of plants.
neotype	the specimen exemplar for a particular taxon, formally designated after the original types have been lost.
ombrotrophic	receiving hydrological and nutrient inputs only from precipitation.
ophiolite	uplifted sections of oceanic lithosphere, characterized by ultrabasic mineralogy and often loosely equated with “serpentine” or “ultramafic”.
panicle	an indeterminate branching raceme; an inflorescence in which the branches of the primary axis are racemose and the flowers pedicellate.
Papuasia	the biogeographic region consisting of New Guinea, the Bismarck Archipelago, and the Solomon Islands. Due to pronounced floristic similarities between these three areas, they are usually treated as a single unit in botanical studies.
peltate	attached to a point within the margin.
perfect	of flowers with functional male (staminate) and female (carpellate) parts.

pneumatophores	negatively geotropic (upward growing) roots with aerating tissues, characteristic of plants in swampy habitats.
rheophyte	a flood resistant plant adapted to the habitat along rivers.
sensu	in the sense of: sensu lato (in a broad sense), sensu stricto (in a narrow sense).
sere	a successional series of ecological communities.
stoloniferous	spreading by horizontal stems.
synusia	a vegetation stratum composed of species of similar stature and life form.
trifoliolate	with three leaflets.

EXECUTIVE SUMMARY

Botanical results are presented for the Study Area. Nine principal vegetation formations have been identified and characterized from a total of 18 sites at which flora was surveyed. A taxonomic assessment of the flora (based on 1,478 collection numbers and 500+ sight enumerations) has documented the presence of species-rich habitats of exceptional floristic value. Although herbarium studies are still ongoing, the findings thus far include two genera and 22 species new to science, two new generic and three species distributional records for New Guinea, three species distributional records for PNG, four rediscoveries of plants known only from lost types, three range extensions for species previously known only from type localities, 15 range extensions of taxonomically significant plants, and 14 taxa listed by IUCN as other than Least Concern (2 critically endangered, 1 endangered, 6 vulnerable and 5 near threatened). The collective significance of these results is distilled into a series of discursive observations.

1 INTRODUCTION

1.1 The Study Area and Project Context

The Sepik River Basin is one of Malesia's most biologically diverse environments (Marshall and Beehler, 2007). Its 77,700-sq-km catchment is the largest in PNG, providing vital watershed and subsistence services for nearly 350,000 human inhabitants (Gomez, 2006). Many Sepik habitats, particularly those of the interior foothills, have long been regarded as an exploration priority for nearly every biological discipline (Beehler, 1993).

In addition to its biotic values, the Sepik River catchment has a number of significant mineral assets, including asbestos, chromite, cobalt, copper, gold, magnesite, and nickel (Shearman, 1999). Near the border of East Sepik and Sandaun Provinces, a world-class copper-gold resource within the Frieda River catchment. Several foundation studies were commissioned in 2009 by the proponent. Among these studies was a terrestrial biodiversity assessment for a comprehensive EIS covering the proposed mine and its associated infrastructure. The following report presents the findings from the botanical component of that assessment.

The circumscription of the Study Area has undergone several modifications following the initial surveys of November-December 2009. Due to changes in the positioning of infrastructure corridors and facilities, several of the survey sites covered by botanical evaluation are no longer within the Project disturbance area. These sites have nonetheless been integrated into the present report because of obvious floristic similarities between the sampled habitats, irrespective of whether they are actually within the Project disturbance area or not and their utility in characterizing the Study Area. As presently configured, the Study Area is bounded to the north by the Sepik River, to the south by the Central Cordillera, to the east by the Wogamush River, and to the west by the Saniap River and includes the Horse-Ivaal-Trukai, Ekwai and Koki copper-gold deposits and all planned infrastructure (both current and historic) associated with planned extraction. This final configuration provides the geographic context for the impact assessment of the Project EIS.

1.2 Study Objectives

The botanical survey of the Study Area was designed to meet the following goals and objectives:

- To identify and describe the principal plant communities and their distributions, using the Forest Inventory Mapping System (FIMS) as a reference baseline.

- To provide a floristic inventory of vascular plant species relative to their sites of occurrence, including an assessment of potential threats from alien species.

- To identify sensitive habitats and taxonomic assets of conservation significance.

- To identify species of conservation significance listed by IUCN and PNG *Fauna (Protection and Control)Act 1966*.

- In consideration of the preceding, to provide management advice for the mitigation of potential Project impacts.

1.3 Historical Exploration and its Relevance to the Present Survey

The upper Sepik River catchment (here regarded as the drainage interval above Ambunti) is an historically critical locality for botanical documentation in PNG. Starting with the German Augustafluss Expedition of 1912–13, this region has long been recognized as one of the most fruitful venues for taxonomic discovery in Papuasia.

The Augustafluss Expedition is best remembered for the scientific contributions from a legendary contingent, which included among its members the botanist Carl Ledermann (Townsend, 1968). During a survey itinerary lasting 18–19 months, Ledermann obtained a total of 6,639 specimens, from which several hundred were designated as type specimens (Steenis-Kruseman, 1950; Frodin, 1990). Most of his collection localities have never been revisited. The unfortunate circumstances of Ledermann's labours are an enormous obstacle to modern scientific inquiry, for the botanical sets were destroyed in the 1943 fire at the Berlin Herbarium, effectively erasing the primary basis for the identification of numerous plant species (Veldkamp *et al.*, 1988; Frodin, 1990; Bakker, 1994).

The Hunstein area (encompassing Ambunti and the April River), was a focal venue for the Augustafluss Expedition, receiving considerably more exploration attention than the Frieda River. An attempt to reenact the classical schedule was first made in 1966, when Hoogland and Craven surveyed the area between Ambunti and Hunsteinspitz. Among their ca. 1,000 gatherings were several new species published in a variety of specialist monographies, mainly in the families Apocynaceae, Melastomataceae, and Rubiaceae. At least ten Augustafluss localities, including Aprilfluss, Bani-Schlucht, Hunsteinfluss, Hunsteinspitze, Kamelsrucken-Etappenberg (lower slopes), Lagerberg, Malu, Peilungsberg, Pyramide, and Seerosensee were later inventoried by Takeuchi *et al.*, during a series of linked operations in 1989, 199, 1994, 1995, 2001, 2004, 2005, and 2007 (partial account in Takeuchi and Golman, 2002)[1]. An attempt to reach the enigmatic Lordberg (Ledermann's furthest inland penetration of the Hill Zone) was unsuccessful due to the physical difficulties of access, most of the Augustafluss localities remain unknown to modern science. However with the advent of helicopter-supported logistics, the constraints are being dramatically reduced (Takeuchi, 2008a).

Although the Hunstein area (and many venues visited by the Augustafluss Expedition) are outside the Study Area, the exploration results from historical localities have been incorporated into the present report whenever such studies are relevant to an understanding of floristic distributions through the upper Sepik. The presumed relevance will become apparent in the following sections, particularly with regards to the probable occurrences of Sepik plants beyond their presently documented limits.

1 including Aprilfluss, Bani-Schlucht, Hunsteinfluss, Hunsteinspitze, Kamelsrucken-Etappenberg (lower slopes), Lagerberg, Malu, Peilungsberg, Pyramide, and Seerosensee. An attempt to reach the enigmatic Lordberg (Ledermann's furthest inland penetration of the Hill Zone) was unsuccessful.

2 METHODS

2.1 Botanical Inventory

The surveys were based on the same sampling procedures used in other rapid assessments (e.g., Mack, 1998; Mack and Alonso, 2000; Beehler and Alonso, 2001; Richards, 2007). In conformity with modern botanical surveys, vascular plants (ferns, gymnosperms, angiosperms) were checklisted and vouchered by herbarium specimens, with particular attention directed to taxa of probable conservation interest. Species seen only in sterile condition were enumerated as sight records in lieu of collection, if an identification could be made with certainty by the writer. This procedure (sight enumeration) was also applied to geographically widespread plants such as *Gymnacranthera farquehariana, Gynotroches axillaris, Morinda umbellata*, *Pimelodendron amboinicum*, etc., since their collection would add nothing to the existing corpus of botanical knowledge.

Exploratory surveys of poorly known areas are generally accompanied by high-volume collecting, in order to maximize specimen outputs from one-off operations. However because of the expedited reporting schedule for the Project surveys, field procedures were necessarily adjusted to reduce the processing time associated with large collection sets. In addition to the greater reliance on sight checklisting, specimen volumes were consciously minimized through judicious selection. Plants of minor taxonomic significance were secured only in small sets. Alien weeds for example, are represented in the gatherings primarily as double sets. Only specimens pre-identified as floristic records were obtained in increments exceeding five replicates.

Collections were field-packed in 75% ethanol for subsequent processing at the PNG National Herbarium (PNGNH). Identifications were confirmed by the author at PNGNH, using keys from the formal literature and/or by comparison with published descriptions. Family assignments generally conform to the following sources: ferns and lycophytes (Brummitt, 1992; Smith *et al.*, 2006), gymnosperms (Laubenfels, 1988), and angiosperms (Angiosperm Phylogeny Group, 1998, 2003, 2009). First sets and holotypes will be deposited at PNGNH. Duplicates will be distributed after appropriate protocols are established for the survey's biological products.

2.2 Forest Typing

All forest communities in PNG have been comprehensively mapped at 1:100,00 using aerial photography and GIS typing (Saunders, 1993a, b; Hammermaster and Saunders, 1995a, b). From a total of 63 typing codes employed by the current FIMS, at least eight (Fri, Fsw, Hm, Hsw, L, Lc, Po, Wsw) are applicable to the Study Area. As an adjunct activity to the taxonomic assessment, forest communities at each of the study localities have been ground-truthed against the FIMS overlays. Adoption of the PNG mapping protocols serves as a basis for standardization of forest descriptions across New Guinea, facilitating direct comparisons between diverse undertakings such as the Conservation International Rapid Assessment Program and the Harvard-National Science Foundation plant surveys. The alternative procedure of customized or ad hoc descriptions would inhibit comparison of vegetation units between different programs, and has been avoided.

2.3 Survey Sites

The floristic team (i.e., the writer and one or two tree climbers) examined a total of 18 of the 24 field survey sites in the Study Area during the period 30 November to 14 December 2009 (Trip 1), 2-27 February 2010 (Trip 2), 30 May 30 to 18 June 2010 (Trip 3), and 24 February to 14 March 2011 (Trip 4). Each of the study localities consisted of a basecamp with an improvised network of access tracks into surrounding habitats. Botanical collections and forest observations were made around these camps in accordance with the procedures described above. The individual sites are shown on Figures 4 and 5 of Chapter 1 and their location, altitudes and dates of surveying are shown on Table 4 in Chapter 1. Table 1 here shows the sample effort and the sequence of sampling of those sites at which the flora and vegetation was surveyed.

Table 1. Survey effort

PHASE	SURVEY SITE	SEQUENCE	EFFORT (MAN HOURS)
Trip 1 yr 2009	Nena Base	1	120
Trip 1 yr 2009	Nena D2	2	48
Trip 1 yr 2009	Nena D1	3	72
Trip 1 yr 2009	Nena Limestone	4	72
Trip 1 yr 2009	Nena-Usage	5	48
Trip 2 yr 2010	Malia	6	216
Trip 2 yr 2010	Koki	7	96
Trip 2 yr 2010	HI	8	120
Trip 2 yr 2010	Upper Ok Binai	9	120
Trip 2 yr 2010	Frieda Bend	10	120
Trip 3 yr 2010	Ok Isai	11	56
Trip 3 yr 2010	Kaugumi	12	56
Trip 3 yr 2010	Nena Base	13	108
Trip 3 yr 2010	East Sepik	14	192
Trip 3 yr 2010	Iniok	15	100
Trip 4 yr 2011	Wario	16	61.5
Trip 4 yr 2011	Wogamush	17	72
Trip 4 yr 2011	Kubkain	18	60
Trip 4 yr 2011	Ok Binai 1	19	69
Trip 4 yr 2011	Nena Base	20	13.5

3 RESULTS - VEGETATION

Disregarding the anthropogenic vegetation caused by human activities, FIMS maps ten principal forest types within the Study Area - Fri, Fsw, Hm, Hsw, L, Lc, Po, Ps, Wri and Wsw, No survey sites and no part of the Project disturbance area are located in Ps (Small crowned forest) or Wri (Riverine mixed successions dominated by woodland) and so these formations could not be characterised and are not discussed here. An additional forest type, Peat Forest, is not recorded by FIMS and is a new formation previously undocumented in PNG. In the following discussion, the nine vegetation classes surveyed are characterized and described in relation to the sites surveyed. Descriptive terminology generally follows Paijmans (1976) or Hammermaster and Saunders (1995a, b).The vegetation types at the botanical survey sites are summarized in Table 2.

Table 2. FIMS types at survey sites

SITE	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Riverine Mixed Successions (Fri)	X					X												
Lowland Open Forest (Po)					X	X			X									
Swamp Woodland & Mixed Swamp Forest (Wsw, Fsw)			X	X	X		X											
Hill Forest (Hm)			X	X	X	X		X	X	X	X	X	X	X	X	X	X	
Lower Montane Forest (L±c, L)																X		X
Coniferous Lower Montane Forest (L±c, Lc)																X		X
Herbaceous Swamp (Hsw)	X		X															
Peat Forest (uncoded)		X																

3.1 Riverine Mixed Successions (Fri)

Frieda Bend Site and Iniok Site. (Figures 1 and 2)

Floristic description. Along the braided channel downriver of Frieda Bend Site, the Fri vegetation succession typically begins with tussock grasses colonizing the outwash gravel, involving primarily the sugar cane *Saccharum spontaneum* and (at lesser frequencies) *Pennisetum macrostachyum* and *Phragmites karka*. The bunchgrass sere is soon augmented by woody invaders, including for the most part: *Archidendron clypearia*, *Cassia alata*, *Glochidion perakense*, *Macaranga aleuritoides*, *M. fallacina*, *Omalanthus novoguineensis*, *Paraserianthes falcataria*, *Planchonia papuana*, *Premna serratifolia*, *Timonius timon*, *Trema cannabina*, *Trichospermum pleiostigma* and various species of invasive *Ficus*. The woody pioneers characteristically form even-aged stands of similar height, indicative of establishment from a single destabilizing event connected to the river. Such communities are always one-storied or nearly so. Eventually the short-statured colonizers are replaced by true arborescents such as *Alstonia scholaris*, *Artocarpus altilis*, *Canarium* spp., *Elaeocarpus angustifolius*, *Intsia bijuga*, *Maniltoa* spp., *Melicope elleryana*, *Octomeles sumatrana*, *Pometia pinnata*, and *Pterocarpus indicus*. The taller-stage sere will usually have an understorey with gingers (e.g., *Hornstedtia scottiana*) and large terrestrial ferns (chiefly *Pneumatopteris* and *Pteris*) but the multistoried structures of the hill communities are decidedly absent. Progression to the arborescent-stage community is nearly always accompanied by the proliferation of festooning vines along forest margins (e.g., riverfronts), mostly by *Entada pursaetha*, *Flagellaria indica*, *Hugonia jenkinsii*, *Merremia peltata*, *Mucuna novoguineensis*, *Tetrastigma lauterbachiana*, *Uncaria lanosa*, and rattans (*Calamus* spp., *Korthalsia zippelii*). In light-demanding successional environments, the vining plants presumably have a competitive advantage over taxa which produce supporting tissues (Clausing and Renner, 2001). Floristic dominance of the vine synusia is very obvious in riparian vegetation, far exceeding the representation in other communities within the Study Area.

At any point in the Fri succession, a change in the river can reverse or accelerate the vegetation sequence. Because these streamcourse changes are spatially discontinuous, Fri communities are similarly fragmented. When proceeding downstream from Frieda Bend Site, all stages in the presumed sequence described above are displayed side by side, and an observer can mentally reconstruct the temporal schedule from this spatial variation.

Community variation. Among the sites evaluated during Trips 1 and 2, the Fri facies was seen only near Frieda Bend Site, where the Nena River flows into the Lowland Zone. The streambed gradient here is sharply reduced from the upland section, and riparian habitats become more susceptible to seasonal flooding and changes in rivercourse. These environmental influences are reflected in the successional status of the affected communities, especially by the floristic dominance of fast-growing heliophytes with oftentimes cosmopolitan distributions.

During the botanical surveys of Trips 3 and 4, the Fri vegetation was also encountered at Iniok Site, but the successional patterns there are spatially different from those present in the tributary valleys. The distinction is mainly attributable to contrasts in the physical structure of the streamcourse. River channels are usually braided in their upland zone of confluence with the Sepik Plains, but form extensive meander complexes on the floodplain proper. At Iniok Site this contrast is reflected in the vegetation scrolling typical of meanders, in which the seral communities are arrayed in continuous arcs reflecting stepwise shifts in the riverbed. Topographic constraints preclude occurrence of such patterns in the upper Frieda River, where the succession is thus more fragmented and localized. Except for the spatial distinctions, floristic environments are essentially the same at both locations, particularly with respect to taxonomic profiles.

3.2 Lowland Open Forest (Po)

Frieda Bend Site, Ok Isai Site, Wario Site. (Figures 3 and 4)

Floristic description. Po forests are generally characterized by uneven canopies with numerous gaps, and the presence of at least two arborescent layers. Overstorey emergents (especially of *Octomeles sumatrana*) are found as scattered trees to 40 m in height. The most frequently seen genera are *Artocarpus*, *Cananga*, *Ficus*, *Intsia*, *Nauclea*, *Octomeles*, *Planchonia*, *Teijsmanniodendron*, and *Vitex*.

Community variation. Forest class Po is found at Frieda Bend, Ok Isai and Wario Sites. The downstream communities below Frieda Bend Site are much smaller in area than the others, and cannot be acquired by the 1: 250,000 scale resolution of the FIMS overlay (Hammermaster and Saunders, 1995b: sheet SB 54-3). However these smaller communities clearly satisfy the diagnostic profile for Po-class vegetation, as evidenced by the open overstorey of *Cananga odorata, Intsia bijuga*, *Nauclea orientalis*, and *Octomeles sumatrana*—with a layer underneath composed of many species from the Fri woodland sere. The Frieda Bend Site formations are probably an advanced stage in the riverine succession. Due to its topographic position at the base of the Study Area Hill Zone, Frieda Bend Site is unusual in having three different forest types (Hm, Fri, Po) in close juxtaposition. Only the topographically similar Wario Site had a more varied vegetation around the survey site (consisting of Hm, Po, Fsw, and Wsw).

Figure 1. Riverine mixed succession in relation to stream-cutting and riverbank displacement.

A, active erosion on the degradational side of a river, indicated by steep-sided banks. Mature forest will be found only behind this kind of front. B, active siltation on the opposing, aggradational side, characterized by gradually sloping ground being built up by sedimentation. The vegetation here is always early-successional because of regrowth encroachment onto the new substrate. In meander complexes the community sere is determined by the aggradational-degradational context, and will switch from one side of the river to the other in relation to the point bar. Experienced speedboat operators always drive on the side marked by “A,” knowing that the riverbed is deeper there. Sepik River bathymetries are undoubtedly wedge-shaped, being progressively shallower towards the depositional side represented by “B.”

Figure 2. Aerial view of the vegetation scrolling characteristic of Riverine Mixed Successions.

The alternating bands of forest and herbaceous swamp are induced by lateral displacements in the river meanders.

Figure 3. Lowland Open Forest at Ok Isai Site.

Unlike most forest types, the ground is usually visible through a Po-class canopy. A, rattans such as *Korthalsia zippelii* are prevalent; B, *Campnosperma brevipetiolata* is locally common in the upper story, often accompanied by *Buchanania, Elaeocarpus, Endospermum, Octomeles, Pangium* etc. *Rhaphidophora* (left centre) and other adhesive climbers are occasionally present on larger trees.

Ok Isai Site is a particularly wet version of the Po typing code. A considerable volume of standing water (on riparian flats) was present during the survey of this location, no doubt exacerbated by heavy rainfalls experienced at that time. Judging from the open canopy and profuse undergrowth, the observed swamping severity probably represents prevailing conditions and is not merely seasonal.

Riparian canopies at Ok Isai Site were species-poor. Approximately 20 arborescent taxa were recorded, represented primarily by *Artocarpus altilis*, *Buchanania* spp., *Campnosperma brevipetiolata*, *Elaeocarpus angustifolius*, *Endospermum labios*, *Intsia bijuga*, *Pangium edule*, and *Trichospermum pleiostigma*. Understorey growth was prolific owing to increased penetration of light through the sparse overstorey. The high frequencies of pioneer taxa suggest that the Po forest here is dynamically connected to the Fri class communities and is not an edaphic climax.

3.3 Swamp Woodland And Mixed Swamp Forest (Wsw and Fsw)

Kaugumi Site, Wario Site, Wogamush Site, Kubkain Site. (Figures 5, 6 and 7)

Floristic description. The Kaugumi Site vegetation is an alluvial wooded swamp complex comprised of forest types Wsw (Swamp Woodland) and Fsw (Mixed Swamp Forest). *Metroxylon*-dominant stands at Kaugumi Site are clearly referable to the Wsw code, the best examples being found along the stream north of the bivouac. Such communities are usually sago-monodominant, but some stands also have significant populations of *Horsfieldia* cf. *sylvestris*, *Intsia bijuga*, *Kleinhovia hospita*, *Nauclea orientalis*, *Pangium edule*, *Pometia pinnata*, and *Sterculia ampla/macrophylla*, either intermixed with sago in the same height interval or occurring as a diffuse, emergent story. Pioneering *Endospermum labios* and *Macaranga* (mainly *M. fallacina*, *M. strigosa*) are particularly common in sunlit clearings, as are the vining plants characteristic of edge situations (cf. list of lianes in Appendix 2.1, all of which are present at Kaugumi Site with the addition of *Quisqalis indica*, a possible escape from cultivation).

A spatially discrete community at the Kaugumi Site, is an obvious example of the Fsw facies. The forest there has an even canopy composed of Clusiaceae (*Calophyllum* and *Garcinia*, seen only as sterile trees), with *Gynotroches axillaris*, *Myristica* cf. *lancifolia*, *Podocarpus neriifolius*, *Terminalia* sp. ("*canaliculata-complanata* morphotype"), and *Vatica rassak* at lesser frequencies. *Metroxylon sagu* forms a distinct, second tier beneath the depauperated overstorey. Most of the ground surface is covered by pools of standing water with hydrophytic *Hanguana malayana* and *Hydrostemma motleyi*. The numerous masses of ascending pneumatophores at this site are indicative of a fluctuating water table, the latter probably keyed to periodic overflows from adjacent rivers.

Community variation. The spatial components of the Kaugumi Site vegetation can be collectively assembled into a continuum of variation, with no two units being exactly alike in terms of taxonomic compositions, frequencies of indicator taxa, and physical structure. This is generally true of riparian communities because of their status as labile, succession-determined environments. Certain forest stands at Kaugumi Site are exemplars of typing code Fsw and Wsw, but much of the area between them are mixed entities with the constituents of either facies expressed in differing proportions. The forest section immediately to the east of Kaugumi Site is charted by the FIMS as a Po formation, but ground and air reconnaissance suggest it is actually transitional to the FswC swamp (*Campnosperma*-dominant). The FIMS has referred the vegetation at Kaugumi Site to a composite code "Fsw/Wsw," implying that the forest is either of intermediate character between the given classes, or else the individual Fsw and Wsw units are too small to be presented at the operational resolution. Despite some ambiguity in its manner of code specification, the FIMS interpretation of Kaugumi Site is essentially correct and does not require substantive alteration.

Because of their position on the Sepik flood plain, Wario, Wogamush and Kubkain Sites are predominantly covered by Fsw. Although taxonomic compositions are comparable to the flooded floors in higher valleys, Fsw canopies at Wogamush and Kubkain Sites are distinguished by the unusual presence and

Figure 4. Lowland Open Forest at Ok Isai Site.

Forest understorey at photo station for Figure 3. Light penetrating through the open canopy enables development of a dense herb layer. Foreground: *Curculigo orchoides*, a plicate-leaved monocot rooted in standing water.

Figure 5. Swamp Woodland at Kaugumi Site.

Understorey view of the Wsw facies, generally *Metroxylon* monodominant (as shown) or with shared codominance by a species-poor dicot association. Replacement of the sago palm by other swamp-adapted trees is a principal indicator of transition to the various F-class forests.

Figure 6. Mixed Swamp Forest at Kaugumi Site.
An example of the Fsw formation. Sago is the subordinate tier beneath a microphyllous upper story.

Figure 7. Kubkain Site, alluvial wooded swamp complex.
A, Fsw forest, floristically transitional to the Peat Forest at East Sepik Site; B, Wsw swamp woodland. Moving from “A” to “B” (west to east) community structures grade progressively from Fsw to Wsw, in response to the increasing frequency and severity of flooding.

dominance of *Tetramerista glabra* (Figure 16). The genus and its family (Tetrameristaceae) had been newly recorded for Papuasia during the survey of East Sepik Site (see discussion in Chaper 8, Section 2.2.1), and was initially regarded as an indicator of peat substrates. Two rarely collected taxa (vines of *Schradera novoguineensis* and *Timonius caudatus*) were consistently observed in these *Tetramerista* stands. Arborescent *Calophyllum* and *Garcinia* spp. from the East Sepik Site Peat Forest were also registered at high frequencies with the *Tetramerista*.

In the swampland southwest of Kubkain Site, the characteristic Fsw understorey (*Hanguana malayana* dominant) is replaced by a congested groundcover composed almost exclusively of vining *Freycinetia* and *Nepenthes*. The overstorey and understorey physiognomies are identical to the Peat Forest as presently understood, except for the occurrence of palms (*Calamus* spp., *Metroxylon sagu*) and the presence of a standing water table. The Kubkain Site swamps are thus transitional to East Sepik Site, the former communities having the appearance of a successional facies—either a former peat formation that is losing its ombrotrophic status, or an Fsw swamp *sens. str.* that is moving towards peat development.

3.4 Hill Forest (Hm)

All sites except Nena Limestone, Kaugumi, Lower Frieda, East Sepik, Iniok and Wario. (Figures 8 and 9).

Floristic description. The Hm Hill Forest is the most extensive vegetation in the Study Area, comprising most of the environments examined by botanical survey. This is unambiguously indicated by the FIMS mapping, and was easily verified by ground reconnaissance.

Hm communities in the Study Area are contiguous with Fri and Po forests at the lower elevations (starting at ca. 50 m elevation), and with the L and Lc forests at the higher elevations near 1,000 m. Taxonomic compositions in the Hm vegetation change progressively between these antipodes. All 27 of the FIMS indicator genera were collected or sight-recorded during the combined surveys (viz. the 10 genera characteristic of the Hm interval below 500 m elevation, and 17 in the interval above that level; cf. Hammermaster and Saunders, 1995a: 11). Two genera with patchy distributions (*Koompasia* and *Eucalyptopsis*) were not checklisted, but the others listed by the FIMS as locally significant (*Dillenia*, *Hopea*, and *Vatica*) are very common both within and outside the Study Area.

At the upper part of its elevation range, the Hill Forest mixes with the L/Lc formation and taxonomic compositions are overlapping. Hm canopies near this transition typically include *Alstonia macrophylla*, *Castanopsis acuminatissima*, *Elaeocarpus* spp., *Gordonia papuana*, *Helicia* sp. nov. aff. *macrothyrsa*, *Kania eugenioides*, *Lithocarpus* (*L. celebicus*, *L. rufovillosus*), *Planchonella* spp., *Prunus* (*P. arborea*, *P. schlechteri*), *Sloanea* (*S. pulchra*, *S. sogerensis*), *Sphenostemon papuanum*, *Syzygium* spp., *Trimenia papuana*, and *Weinmannia fraxinea*. Lauraceous trees (*Cinnamomum*, *Cryptocarya*, *Litsea*) are locally dominant. Together with *Sloanea*, sapling crops are often primarily composed of regeneration from the Lauraceae. In contrast to lowland communities, Hm understoreys are enriched by Begoniaceae, Cyatheaceae, Gesneriaceae, Monimiaceae, Myrsinaceae, Rubiaceae (Psychotrinae), Thelypteridaceae, Urticaceae, and Zingiberaceae. Epiphytic plants become increasingly numerous with elevation, particularly involving *Asplenium*, *Bulbophyllum*, *Davallia*, *Dendrobium*, *Lindsaea*, *Medinilla*, *Phreatia*, *Riedelia*, *Selliguea*, and the grammitioid ferns.

Unlike the premontane transition to L/Lc forests, the contact between Hm and lowland habitats is usually abrupt and marked by easily perceived contrasts in community structure. The distinctions are obviously attributable to sharp delineation of physical controls (drainage, seasonal flooding) at the intersection of hill terrain and riparian flats. Distinguishing features of the Hm forest at this boundary include (corresponding qualities of the lowland vegetation in parentheses):

1. complex stratification with niche-specific plants in the various layers (simplified vertical structures with little evidence of niche specialization);

2. uneven canopy outline (canopy layer, when present, of even height);

3. individual tree crowns often narrowly-longitudinal in form (crowns mostly horizontally spreading and frequently flat-topped);

4. tree dynamics apparently determined by gap-phase regeneration over small areas (population dynamics determined by wave regeneration over relatively large areas and conditioned by flooding); and

5. vining plants infrequent (vines abundant, typically dominating forest edges).

Agathis labillardieri is the dominant Hm emergent and of special biogeographic significance as a Gondwanic relict. The towering trees are the giants of the Study Area hill environments, capable of attaining heights exceeding 50 m and usually clustering in visually unmistakable colonies. Large populations of *A. labillardieri* are present as far north as the April River, at Gipa (9505861, 691,420; 4°28.11' S, 142°43.51' E) and Natawe (9494736, 672192; 4°33.13' S, 142°34.17' E; *pers. obs.*). The species is endemic to New Guinea, occurring primarily on the Indonesian side of the island and reaching its easternmost limits in the April and Frieda River tributaries (Laubenfels, 1988).

Community variation. Of all the forest types seen in the Study Area, the Hill Forest is the most variable. The elevation dependency of this variation is so pronounced that individual formations are virtually impossible to characterize except in relation to specific elevations of occurrence (refer discussion in preceding section).

Despite the physiognomic distinctions between hill and lowland communities, a number of arborescent taxa are distributed through both habitats. The facultative elements include *Alstonia scholaris*, *Canarium acutifolium*, *C. vitiense*, *Caryota rumphiana*, *Cerbera floribunda*, *Chisocheton ceramicus*, *Dracontomelon dao*, *Dysoxylum excelsum*, *D. gaudichaudianum*, *Neuburgia corynocarpa*, *Pangium edule*, *Sloanea sogerensis*, *Spondias cytherea*, *Sterculia ampla*, *S. macrophylla*, and *Syzygium pachycladum*. Other trees are restricted to well-drained slopes, rarely intruding onto the lowland flats. *Aglaia* (excepting *A. sapindina*), *Anisoptera thurifera*, *Calophyllum soulattri*, *Canarium maluense*, *Celtis* spp., *Ceratopetalum succirubrum*, *Chionanthus* spp., *Crypteronia cumingii*, *Diospyros papuana*, *Dysoxylum alliaceum*, *D. latifolium*, *Elaeocarpus* (excepting *E. angustifolius*), *Ixonanthes reticulata*, *Mastixia kaniensis*, *Parinari papuana*, *Polyosma* spp., *Syzygium effusum*, *Teijsmanniodendron ahernianum*, *Weinmannia fraxinea*, and *Xanthophyllum papuanum*, are part of this latter assemblage. Most of the Lauraceae (spp. in *Alseodaphne*, *Cinnamomum*, *Cryptocarya*, *Endiandra*, *Litsea*, *Phoebe*) are strictly hill taxa, and can collectively dominate the lower elevation colline communities. However *Agathis labillardieri* and *Gymnostoma papuana* are unquestionably the most conspicuous and reliable indicators of the Hill Forest transition. These tall trees can be immediately recognized by their unusual form, and while often descending to within a few metres of the alluvial plain, will rarely overstep the boundary.

Although the Hm forest is the most species-rich formation in New Guinea (Louman and Nicholls, 1995), Wogamush and Kubkain Sites are unusually depauperate examples of the Hm mapping code. As small hills surrounded by an alluvial swamp complex, these sites are the ecological equivalent of geographic islands. The characteristic Hm genera are present, but usually represented only by single species—the apparent result of dispersal failure from the Central Ranges and/or of increased niche competition from spatial reductions in habitat (cf. the area-species relationship of MacArthur and Wilson, 1967). Moving sequentially from Wario Site to Wogamush Site, and then ending at Kubkain Site, the hill-islands become progressively smaller and more separated from the main body of the Study Area Hill Zone. Not surprisingly, the most isolated locality (Kubkain Site) had the lowest species counts of any surveyed habitat.

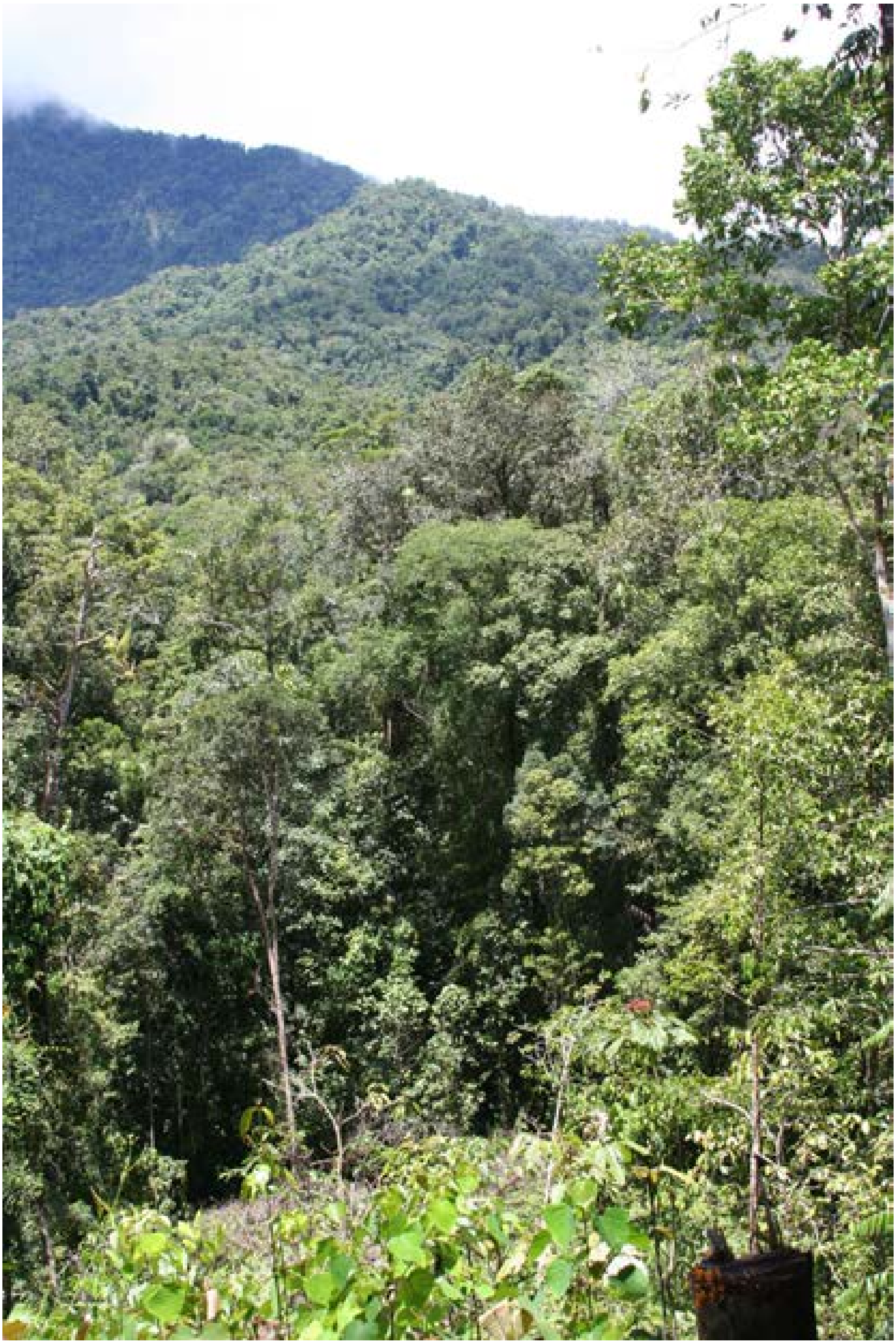

Figure 8. Hill Forest at Malia Site.
Hm landscapes are visually heterogeneous, reflecting their presumed status as PNG’s most species-rich forest environment. Canopies are uneven in outline, polychromatic, and multi-storied.

Figure 9. Hill Forest at Malia Site.

Forest edge view of an Hm stand, showing its characteristically complex stratification and dense occupation of all height intervals.

Figure 10. Small Crowned Lower Montane Forest at Hl Site.

L forest. The principal arborescent families are Cunoniaceae, Lauraceae, Myrsinaceae, Myrtaceae, Sphenostemonaceae and Theaceae.

3.5 Lower Montane Forest (L±c)

Includes Lower montane forest (L) *sens. str.* and transitions to Coniferous Lower montane forest Lc

Nena Limestone Site and HI Site. (Figure 10)

Floristic description. With the sole exception of *Zanthoxylum* (Rutaceae), all of the 38 floristic indicators for L-class forest (in Hammermaster and Saunders, 1995a: 14) were recorded by the botanical survey. At Nena Limestone and HI Site, canopies are composed primarily of *Cryptocarya*, *Daphniphyllum*, *Gordonia*, *Helicia*, *Litsea*, *Myrsine*, *Polyosma*, *Pullea*, *Quintinia*, *Sphenostemon*, *Syzygium*, *Weinmannia*, and *Xanthomyrtus*. Some of the FIMS indicator genera (e.g., *Dryadodaphne*, *Galbulimima*, *Mischocarpus*) were rarely seen, but local variation of this sort is expected within widely distributed ecological units, and does not detract from the given assignment. The inclusion of *Zanthoxylum* as a characteristic genus by FIMS list is peculiar and inappropriate; the genus is very rare and thus hardly to be regarded as a characteristic component of the lower montane forest (*pers. obs*.). Most foresters have never seen these plants.

Most of the botanical diversity at Nena Limestone and HI Sites is attributable to development of the epiphytic flora on moss-enveloped trees. Ericoid plants (*Dimorphanthera*, *Diplycosia*, *Rhododendron*, *Vaccinium*), ferns (*Asplenium*, *Ctenopteris*, *Goniophlebium*, *Grammitis*, *Pyrrosia*, *Selliguea*), gesnerids (*Aeschynanthus*, *Agalmyla*, *Cyrtandra*), gingers (*Riedelia*), melastomes (*Catanthera*, *Creochiton*, *Medinilla*), and orchids (*Bulbophyllum*, *Dendrobium*) are especially speciose elements. Forest understoreys were rather depauperate and often congested by impenetrable thickets of climbing bamboo (*Nastus productus*).

Community variation. HI Site is mapped by the FIMS under category O, non-vegetated areas with land use intensities from 0–4 (low to very high; Hammermaster and Saunders, 1995a: 10) within a land section spatially corresponding to the proposed pit and implicitly described as an anthropogenic unit. Notwithstanding this characterization, it is quite clear that the vegetation at HI Site is actually part of the Study Area Montane Zone extending northeast from Mount Stolle (cf. Mianmin overlay sheet SB 54-3). At Nena Limestone Site, forest structures have been similarly misinterpreted by the FIMS. Although the limestone flora there is assigned to mapping code Hm, the community physiognomy and composition are obviously montane, and more consistent with the L-type formation. Examples of the L forest are mapped by the FIMS on several ridgetops within a 5-km radius of Nena Limestone Site, mainly to the southwest (Iku), south, southeast, and northeast, but the elevational limits for montane forest have been set too high for this particular sector and Nena Limestone Site (950 m elevation) is thus excluded. Because local topography and meteorology can cause significant displacements in vegetation zones, the FIMS mapping algorithms do not always reflect what is actually on the ground.

3.6 Coniferous Lower Montane Forest (Lc)

Nena Limestone Site and HI Site. (Figures 11 and 12)

Floristic description. Lc-class forests were seen only in mossy crestline habitats near 1,000 m elevation. These communities are dominated by Gondwanic gymnosperms, mainly *Dacrycarpus imbricatus* var. *robustus*, *Decussocarpus wallichianus*, *Libocedrus papuana*, *Phyllocladus hypophyllus*, *Podocarpus* sp. ("*pilgeri-rubens* group"), and *Prumnopitys amara*. In addition to the coniferous component, Lc angiosperms in the Study Area are represented primarily by the families Cunoniaceae (*Opocunonia*, *Pullea*, *Schizomeria*, *Weinmannia*), Elaeocarpaceae (*Elaeocarpus*, *Sloanea*), Ericaceae (*Dimorphanthera*, *Diplycosia*, *Vaccinium*), Fagaceae (*Castanopsis*, *Lithocarpus*), Lauraceae (*Cryptocarya*), Melastomataceae (*Astronia*, *Beccarianthus*, *Catanthera*, *Medinilla*, *Pternandra*), Myrsinaceae (*Ardisia*, *Maesa*, *Myrsine*), Myrtaceae (*Syzygium*, *Xanthomyrtus*), Sphenostemonaceae (*Quintinia*, *Sphenostemon*), Theaceae (*Eurya*, *Gordonia*), and Winteraceae (*Drimys*, *Zygogynum*). These same plants are often present in adjacent L

Figure 11. Small Crowned Lower Montane Forest with Conifers at HI Site.
Lc forest on crestline. Conifers dominate the emergent canopy.

forests but usually at different frequencies.

Community variation. Frieda Lc forests grade into the L-type forest (viz. L±c), especially with respect to angiosperm compositions. At Nena Limestone and HI Sites, flowering plants of the Lc are not much different from the L-profile. Ferns and epiphytes are well-represented in both facies. Except for the abundance and stature dominance of gymnosperms in the Lc communities, it is difficult to draw clear separations with the L formation. In recognition of the structural overlap, transitional communities have been designated as L±c.

Figure 12. HI Site. Lc understorey.
Coniferous forests are cloud-zone environments. The presence of Lc communities at unusually low elevations is suggestive of a depressed cloud belt in the Study Area.

3.7 Hsw - Herbaceous Swamp

Iniok Site and Kubkain Site.

Floristic description. Herbaceous swamps can be found near Iniok and Kubkain Sites, either as discrete lacustrine habitats (e.g., Lake Warangai) or as stranded ox-bows and backswamps from former meanders. The Hsw vegetation was not specifically targeted by the survey. Because of its well-documented (and onerous) features, the botanical team made no attempt to visit these environments. However from flyover observations and photos taken by members of the fauna team, it is quite clear that the areas charted by FIMS under the Hsw code have been correctly classified.

The Hsw swamp is a monocot-dominant association composed primarily of amphiphytes. Such communities typically include clump-forming or stoloniferous taxa such as *Hanguana malayana*, *Scleria ciliaris*, *S. polycarpa*, *Thoracostachyum sumatranum* and representatives from the characteristic wetland genera (*Carex*, *Eleocharis*, *Lipocarpha*, *Schoenus*, and *Scirpus*). Grasses are prominently represented by *Hymenachne amplexicaulis* and *Leersia hexandra*.

Community variation. The Herbaceous Swamp is one of several herbland formations in PNG and is often associated with sago swamp woodland. Prior to the recent disappearance of floating grass islands from stillwater bodies, Hsw species in the water would have included *Leersia hexandra* (the principal component of the grass islands) with *Cyperus cephalotes*, *C. platystylis* and the native rice *Oryza rufipogon*. These species were very common in the early 1990s when the writer made collections from back swamps near Ambunti, but have since experienced marked population declines.

3.8 Peat Forest

East Sepik Site. (Figures 13, 14 and 15)

Floristic description. Canopies at East Sepik Site are dominated by *Tetramerista glabra* (Figure 16), *Calophyllum papuanum*, *Garcinia* sp. (sect. *Cambogia*), *Gmelina ledermanni*, *Syzygium* aff. *hemilamprum*, *S. effusum*, *Palaquium* sp., and *Podocarpus neriifolius* (in descending order of importance). A dense undergrowth of sprawling *Freycinetia* blankets the understorey. The shrub/subarborescent layers are mostly empty, their vertical position in the forest collectively replaced by prolific populations of vining *Nepenthes ampullaria*, *Schradera novoguineensis*, and *Timonius caudatus*. Epiphytic growth is exceptionally poor for such a seemingly wet habitat: *Asplenium nidus*, *A. phyllitidus*, *Davallia solida*, *Goniophlebium percussum*, and "*Schefflera*" sp. comprising the only taxa present at meaningful frequencies. In spite of the pronounced simplification in structure and composition, the vegetation at East Sepik Site cannot be categorized by the FIMS and is undocumented in PNG. The formation involved (Peat Forest) has been extensively studied in West Malesia, and has also been reported from Irian Jaya, but its existence in East Malesia has otherwise been discounted. Although contemporary mapping systems do not acknowledge the presence of Peat Forests in PNG (e.g., Paijmans, 1976; Hammermaster and Saunders, 1995a), there is no doubt that such a forest class is represented at East Sepik Site. Based on FIMS acronym conventions, the mapping code for the new forest should be FswTg (swamp forest with *Tetramerista glabra*).

Peat Forests may be more widespread in PNG than is presently suspected. Judging from East Sepik Site, other occurrences in the Sepik River Basin should be ascertainable by remote sensing (aerial photography and high-resolution satellite imagery), using the following markers:

- Peat Forests will be found on flatlands without large, in-flowing rivers (rivers always flow out of peatlands, not into them).

- The canopy will be homogeneous, flat, small- or medium-crowned, and microphyllous (unlike riparian swamps, macrophyllous *Buchanania*, *Campnosperma*, *Octomeles*, *Pangium*, *Schuurmansia*, *Sterculia*, etc. will be excluded or nearly so).

- There are no emergent trees in Peat Forest (in contrast, riparian communities are often characterized by a sporadic overstorey of *Intsia bijuga*).

- Palms will be conspicuous by their absence—no rattans will be in the canopy, and emergents like *Actinorhytis*, *Cyrtostachys*, *Hydriastele* (sens. lat.), and *Metroxylon* will be missing. The exclusion of the sago palm (*Metroxylon*) is virtually diagnostic.

Certain expressions of the Fsw/Wsw swampland can mimic the aerial signature of the peat swamp, but such communities will usually have *Metroxylon* as a principal canopy component, or as a visible substage underneath a microphyllous-dicotyledonous overstorey (e.g., at Kaugumi Site). Although a transitional forest facies has been recorded at Kubkain Site, the differentiating features noted above are still preserved. Based on observations from overflights, the structural markers can be used to identify other potential occurrences within the Sepik flood plain. In the event a mapping solution proves difficult to achieve, the forest classification methodologies used in Borneo and Sumatra (Laumonier, 1990, 1997a, b; Laumonier *et al.* 1983, 1986, 1987; RePPProT, 1990) should be considered for possible application to PNG.

Tree canopies around East Sepik Site are structurally similar to the low-pole phasic forest of Anderson (1963; types 4 and 5), characterized by low nutrient budgets and active peat accumulation. No evidence has been found thus far of the taller phasic forests reported from Kalimantan (refer to discussion in following section). These latter communities are always associated with situations where decomposition of the peat column is occurring at the top, thereby removing the younger layers. The apparent absence of tall, diversified forest is a circumstantial indication that Sepik stratigraphies are currently aggradational, and not in climatic decline. Photographic plate B61.1 in Douglas Partners (2010) shows uneven-canopied forest in the foreground, which may be this community. However because the peat survey was confined to a single site, the possibility of multiple, physiognomically distinct seres cannot be discounted. The low-pole forest documented by recent reconnaissance is possibly just one of several, still-unseen facies. If a multi-phasic forest is actually present on the peatland, this will defeat attempts at aerial mapping, since the criteria enumerated earlier will capture only a part of the communal variation. In such an eventuality, ground-truthing will be the only effective procedure for defining the spatial extension of this formation.

The remarkable thickness of the peat stratigraphy at East Sepik Site (28 metres as determined by Photographic plate B61.1 in Douglas Partners (2010) shows uneven-canopied forest in the foreground, which may be this community). It is suggestive of an early origin for the deposit (although exceptionally high sedimentation rates can also produce the same result, hence thickness in itself is not a sufficient indicator of antiquity). The acrotelm, or aerated portion, of this column is very narrow—water tables at East Sepik Site were only 18–25 cm below the surface during a two-day period without rainfall (11-12 July 2010), as measured from two dipwells of 40 cm and 85 cm depth. The narrow acrotelm is a necessary condition for peat accumulation, since aeration would otherwise result in degradation of the deposit.

Community patterns in Peat Forests outside PNG. Lowland Peat Forests are widespread in the Malay Peninsula, Borneo, and Sumatra, where their essential features have been characterized in detail. While superficially similar in some respects to the kerangas (heath forest), peat swamps are easily distinguished by their taxonomic and edaphic attributes (Ashton, 1995). Based on correlations between Malesian exemplars, the defining features of this formation in its relation to the Sepik River Basin are: 1. the presence of a dome-shaped (lenticular) peat stratigraphy, sometimes of considerable thickness (20+ metres have been reported toward the centre of some deposits; Whitmore, 1975, 1984); 2. a stilted water table (not necessarily surface-perched, but higher than the ground surface of surrounding, non-peat communities); 3. extremely low floristic diversity and endemism; 4. stunted forest growth, including a preponderance of pole trees with poor crown development and small leaves; 5. severely disharmonic floristic compositions (i.e., with many plant families missing from situations where they would normally be expected to occur). A pattern reported from Borneo peat swamps but not applicable everywhere, is the occurrence of a community successional catena when moving from the outer edge of the dome towards its centre, suggestive of the oldest forest being the innermost one (Anderson, 1963). All of the above features are present at East Sepik Site or at least not at variance with observations made there.

Peat substrates are consistently oligotrophic (infertile) and highly acidic (pH <4), characteristics which induce nutrient deficiencies in their associated floras (Anderson, 1963). The conspicuous abundance of *Nepenthes ampullaria* at East Sepik Site implies that such conditions are actually present, even if unverified by actual measurement. Since the survey did not extend to the outer parts of the Peat Forest, the character contrasts with surrounding communities are also unverified. However in light of compelling floristic evidence, the unobserved qualities of this vegetation can be plausibly inferred from occurrences documented elsewhere in Malesia. The community patterns in themselves, provide overwhelming support for the given characterization. With the discovery of a genus/family previously regarded as an endemic of West Malesian peat swamps (*Tetramerista*), the botanical evidence is rather conclusive.

In West Malesian peatland successions, the pole-stand facies is found on youthful surfaces with high rates of peat deposition. Whenever tall forest is part of the succession, the near-surface peat has much older radiocarbon ages, indicating that the column is oxidizing (degrading) and releasing nutrients back into the normally ombrotrophic environment (Page *et al.*, 1999). The increased nutrient capital provided by this conversion allows for seemingly anomalous development of tall and luxuriant forest over an oftentimes deep catotelm (i.e., the anoxic substratum, see Anderson, 1963; Page *et al.*, 1999).

If Peat Forest are drained and allowed to dry out the dried peat is also exceedingly prone to combustion. Fires in Peat Forest can penetrate deep into the organic column, emerging elsewhere at unexpected places (Page *et al.*, 2002, 2004; Whitmore, 1984). Because of their inherent fragility when disturbed, peatlands should always be retained as part of an undeveloped forest estate (Whitmore, 1984)

Forest-classification significance of the Peat Forest. The detection of forest types unrecognized by contemporary classification is not unprecedented. During the Conservation International Kaijende Expedition, a similar discovery (of montane *Pandanus* savanna) was reported from around Lake Tawa (in Richards, 2007). The pandan savanna had clearly been misinterpreted by FIMS as a subalpine grassland (Gi) and scrub (Sc), an assignment which violated the elevation criteria for those codes in addition to ignoring obvious structural discrepancies. Modern systems of PNG forest mapping have not been comprehensively ground-tested, so these sort of errors can be expected. The FIMS type Wsw mapped at East Sepik Site is clearly incorrect. The forest observed on the ground has little in common with that kind of vegetation, even within the wide circumscription adopted by the FIMS.

The genesis and ecology of peat swamps are determined by factors other than alluvial influence—consequently such formations will not be traversed by large rivers. Because forestry exploration in PNG historically followed navigable waterways, interior communities like the peat swamp were invisible to previous itineraries. The fact that such forests were first reported from Irian Jaya by Polak (1933) and by van Steenis (1957) can be understood in terms of their professional backgrounds. Both Polak and Steenis had firsthand knowledge of the West Malesian vegetation and were thus prepared to recognize the Peat Forest formation and the conditions associated with its occurrence and distribution. In contrast, the collective experiences of forestry authors in PNG were decidedly with the Australasian flora, where such communities are absent. The FIMS classification failures are largely attributable to this combination of cognitive bias and habitat inaccessibility.

Biogeographic significance of the Peat Forest. West Malesian peat swamps are a recently established vegetation of Holocene or Late Quaternary origins. The extensive swamps of East Borneo for example, began as embayed mangroves at 5500 BP and later expanded in response to changes in sea levels (Ashton, 1995). Geomorphological events in the Sepik River Basin suggest that its Peat Forests have developed along similar chronologies linked to climatic change.

Löffler (1977) attributed the postglacial drowning of the Sepik River Basin to changes in flood plain gradients caused by the higher sea levels. According to his interpretation, swamping occurred as earlier periods of downcutting were curtailed and drainage became less effective. Newer evidence shows however, that the basin was a shallow sea during the Holocene, and became progressively filled in during the 3000–3500 yr interval leading to the present (Chappell, 1993; Swadling, 1997). Based on the latest reconstruction, existing peat stratigraphies were probably initiated as organic deposits in brackish estuarine communities—as with East Borneo, and grew in response to comparable late-postglacial events. If formation of the inland sea has occurred during other Pleistocene interglacials (as inferred by Chappell; *ibid*.) the paleohistory of the Sepik Peat Forest must be cyclical, involving periods of formation and decline at individual sites, and possibly accompanied by spatial dislocations to other parts of the basin.

If the Sepik Peat Forest had developed in this way, it is hard to understand why *Tetramerista* is so common here. The genus is a geographic specialist restricted to Sundaland and it is implausible that it could have got to PNG within the narrow Holocene-postglacial time window available, especially as there is no other botanical genus with that particular kind of disjunction. However, if the Peat Forest has a longer history extending through previous Pleistocene cycles, the probabilities for such dispersal events are commensurately higher. Coastal and lowland swamps are more extensive during periods of interglacial sea advance (Terrell, 2002)—providing paleohistorical stepping stones that are no longer apparent.

Figure 13. East Sepik Site, Peat Forest.

Interior visibility is good in comparison to other closed forest types. The substage is either clear or (as shown here) sparsely occupied.

Figure 14. Peat forest understorey with its characteristic groundcover of sprawling *Freycinetia* (foreground).

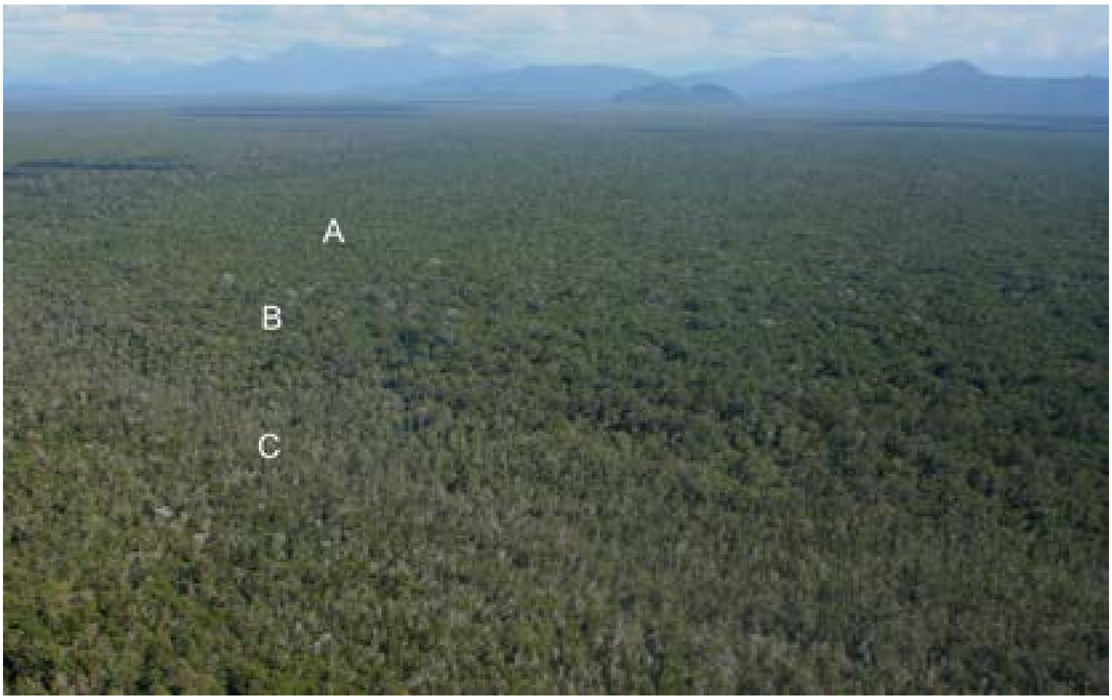

Figure 15. Aerial perspective of East Sepik Site.

A, peat dome; B, transitional forest, probably a successional community to the peat formation; C, dieback zone in alluvial wooded swamp, visible as a light-colored circumferential arc. The presence of dead/dying trees on its periphery implies ongoing (outward) accretion of the peat formation.

Figure 16. ***Tetramerista glabra*** **is an indicator specialist of Peat Forests in Peninsular Malaysia, Borneo, and Sumatra.**

The genus and its family (viz., Tetrameristaceae) were previously unknown in the Papuasian region. Initially discovered on peat substrates at East Sepik Site, the tree was also recently documented from Fsw and Wsw communities at Wogamush and Kubkain Sites. ***Tetramerista glabra*** **is a dominant species in swamp forests of the Study Area.**

Figure 17. HI Site.

The proposed open pit as seen from the crestline depicted in Figures 9 and10. Arrow: area of extensive drilling and associated vegetation regrowth. Notwithstanding the increased presence of weedy plants around the drill pads, local forest structures are presently determined only by natural processes of floristic succession.

4 RESULTS - FLORA

4.1 Diversity

The botanical survey of the Study Area has yielded a total of 1,478 specimen numbers in replicate sets. There are 184 vascular plant families, 735 genera, and at least 1,354 morphospecies represented in the cumulative checklist. The vouchers are accompanied by 59 accessory samples bottled in spirit (mainly flowers with delicate parts), 107 leaf samples for DNA sequencing, and 55.9 gigabytes of high-resolution digital imagery (usually 3456 x 2304 pixels). In addition to the physical collections, the survey checklist includes 500+ taxa enumerated by sight recognition. More than 1,354 morphospecies have been documented thus far, but an exact tally is not possible due to the absence of diagnostic structures on many specimens and the provisional nature of identifications in unrevised groups. Taxonomic counts from the survey are enumerated in Table 3 according to the principal categories of vascular plants and a full species list in Appendix 2.1.

It is impossible for rapid assessment surveys to find every species within a territory as large as the Study Area. Unlike plants of the high montane zones, the lowland flora is characterized by unpredictable and ephemeral phenologies which impede attempts at floristic stock take. The sampling coverage achieved by recent investigation is an imponderable, but may be one of the highest in modern Papuasian inventories (cf. Takeuchi, 2003b). More species have been recorded and collected during the Project survey than for any comparable operation in PNG's post-Independence period, exceeding even the combined results from previously unexplored areas on the Papuan karst (cf. Crome, 2009). Conservation International's Rapid Assessment Program of biological exploration, widely recognized as the most successful itinerary of its kind, generally produces botanical checklists about half the size of the Project Survey tallies (see Mack, 1998; Mack and Alonso, 2000; Beehler and Alonso, 2001; Richards, 2007). The results from the Study Area are suggestive of exemplary diversity and underscore the difficulties of developing a comprehensive understanding of this flora. Definitive improvements to the knowledge base will require considerable effort and are many years, probably decades, into the future.

Table 3. Taxonomic counts by vascular plant category

	FERNS	GYMNOSPERMS	MONOCOTYLEDONS	DICOTYLEDONS	TOTALS
Families	28	5	30	121	184
Genera	90	10	140	495	735
Species	209	14	207	924	1354

4.2 Species New to Science or Undescribed

Although the herbarium study is ongoing, a substantial number of floristic records have already been obtained and the results to date are that the surveys discovered 2 genera and 22 species new to science or undescribed (Table 4).

4.3 Range Extensions

Range extensions included two generic distributional records for New Guinea, three species distributional records for PNG, four rediscoveries of plants known only from lost types, three range extensions for species previously known only from type localities and 15 range extensions of taxonomically significant plants.

Table 4. Occurrence of species new to science or undescribed at survey sites.

TAXON	FAMILY	FIMS TYPE	FRIEDA BEND	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE	# SITES AT WHICH RECORDED
Species new to Science													
Phyllanthera sp. nov.	Apocynaceae	Hm & L	X					X		X			3
Diospyros sp. nov.	Ebenaceae	L & Lc								X		X	2
Glochidion sp. nov.	Euphorbiaceae	Hm & L								X	X		2
Archidendron sp. nov.	Fabaceae	Hm			X						X		2
Catanthera sp. nov.	Melastomataceae	Hm & L						X	X	X	X		4
Creochiton sp. nov.	Melastomataceae	Hm, L, & Lc									X	X	2
Medinilla sp. nov. A	Melastomataceae	Hm, L, & Lc	X					X		X	X	X	5
Medinilla sp. nov. B	Melastomataceae	Hm & L						X		X			2
Medinilla sp. nov. C	Melastomataceae	Hm & L						X		X	X		3
Chisocheton sp. nov.	Meliaceae	Hm	X		X	X	X						4
Kibara sp. nov.	Monimiaceae	Hm & L					X	X		X			3
Ardisia sp. nov. A	Myrsinaceae	Hm									X		1
Ardisia sp. nov. B	Myrsinaceae	Hm					X					X	2
Discocalyx sp. nov.	Myrsinaceae	Hm	X	X		X	X						4
Helicia sp. nov.	Proteaceae	Hm & L								X	X		2
Psychotria sp. nov. A	Rubiaceae	Hm		X		X			X				3
Psychotria sp. nov. B	Rubiaceae	Hm & L		X						X	X		3
Timonius sp. nov.	Rubiaceae	Hm	X	X									2
Zygogynum sp. nov.	Winteraceae	Hm			X		X		X				3
Undescribed species previously discovered outside the Study Area													
genus (undescribed)	Annonaceae	Hm	X	X		X							3
genus (undescribed)	Melastomataceae	Hm & L	X			X				X			3
Cyrtandra sp. (undescribed)	Gesneriaceae	Hm		X	X								2
Psychotria sp. (undescribed)	Rubiaceae	Hm	X			X							2
Beccariella sp. (undescribed)	Sapotaceae	Hm		X									1
Totals			**8**	**7**	**4**	**6**	**5**	**6**	**3**	**11**	**9**	**4**	

4.4 Conservation Listed Species

Fourteen taxa were found that listed by IUCN as other than Least Concern - one Critically Endangered, one Endangered, six Vulnerable and six Near Threatened (Table 5). In addition one of the mosses described in Piipo (1986) is Critically Endangered (see Table 5).

Table 5. IUCN listed species recorded

FAMILY	*SPECIES*	IUCN STATUS	INIOK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA LIMESTONE
Rutaceae	*Halfordia papuana* Lauterb.	CE					X											
Rutaceae	*Flindersia pimenteliana* F. Muell.	EN				S			S				X				X	
Cunoniaceae	*Ceratopetalum succirubrum* C.T. White	VU							S						X		X	
Fabaceae	*Intsia bijuga (Colebr.) Kuntze*	VU	S	S	S	S	S	S	S	S	S			S		S		
Fabaceae	*Pterocarpus indicus* Willd.	VU	S	S	S	S	S				S			S	S			
Myristicaceae	*Horsfieldia ampliformis* de Wilde	VU															X	
Myristicaceae	*Horsfieldia sepikensis* Markgr.	VU					X											
Myristicaceae	*Myristica buchneriana* Warb.	VU			X		X						X					
Cycadaceae	*Cycas rumphii* Miq.	NT	S		S	S			S									
Meliaceae	*Aglaia agglomerata* Merr. & Perry	NT									X							
Meliaceae	*Aglaia sapindina (F. Muell.)* Harms	NT							S					X				
Meliaceae	*Aglaia subcuprea* Merr. & Perry	NT												X				S
Myristicaceae	*Myristica globosa* Warb.	NT									X	X		X				
Meliaceae	*Aglaia rimosa* (Blanco) Merr.	NT	S			S			S	S	X							
Taxa not included in this botanical survey																		
Bryophyte	*Moss Schistochila undulatifolia* Piipo	CE																

note: entries S = specimen collected, X = sighted, CE - Critically Endangered, E - Endangered, VU - Vulnerable, NT - Near Threatened.

5 RESULTS - ALIEN PLANTS IN THE STUDY AREA.

Occurrences of alien plants are directly correlated to human presence and infrastructure. At Iniok Site the environment has been so thoroughly impacted by introduced species that nothing of botanical interest was found within walking distance of the settlement. The entire area is essentially an altered anthropogenic landscape. Alien floras were similarly recorded at at Wario,Wogamush, Kubkain and Ok Binai sites, as a result of proximity to villages and major pedestrian tracks.

Nena Base Site predictably had significant levels of floristic disturbance (at least 26 introduced and/or adventive species) but these are confined to the historic exploration facilities and immediately adjacent areas. Because of the presence of a gauging station and helipad, Nena D1 Site had four herbaceous aliens and Malia Site had three. In places where drilling has occurred (e.g., HI Site), weeds were always found around the drill holes including *Ageratum conyzoides*, *Crassocephalum crepidioides*, *Cyperus brevifolius*, *Eragrostis chariis*, *Erechtites valerianifolia*, *Lophatherum gracile*, and *Paspalum conjugatum*. Along open streambeds the weedy *Cassia alata*, *Celosia argentea*, *Chrysopogon aciculatus*, *Paspalum conjugatum*, and *Passiflora foetida*, were often recorded. All observed adventives are benign plants of low invasive capacities and are not regarded as conservation threats. With the foregoing exceptions, environments within the Study Area are entirely weed free. One site in particular (East Sepik Site), was botanically pristine, with no evidence of alien species even on the helipad. The acidic substrate at that locality is probably inhibiting establishment of non-native plants.

6 DISCUSSION

6.1 Community Patterns in Hill and Montane Environments

The presence of L/Lc forest at Nena Limestone and HI Sites is clearly conveyed by the heavy epiphyte loads on trees, the reduction in tree statures and crown size, and (most decisively) by the species composition. Despite unambiguous evidence of L/Lc occurrences, the elevations involved (≤1,000 m elevation) are very unusual and far below the usual elevation range for such formations.

The surprising records of high montane plants, especially at Nena Limestone Site, is reminiscent of reports from PNG's southern region (Takeuchi, 2010). Massenerhebung (i.e., the elevational compression and lowering of vegetation zones in isolated ranges) cannot be invoked in explanation of observed anomalies since the Study Area Hill Zone is contiguous with the Central Cordillera. Elevation-related irregularities from PNG's southern flora have been attributed to exceptionally high rainfalls on specialized substrates (Takeuchi, 2008b, c, d) and this is arguably also true for Nena Limestone and HI Sites . The unusual development of montane forest at low elevations was similarly attributed to perhumid conditions by Brass (1938) and by Jermy (1965). Ultramafic geology in the Study Area, acting in possible synergy with rainfall, may be contributing to the observed elevation patterns. Vertical displacement of vegetation zones is well-documented in forests of the Papuan Ultrabasic Belt and is spatially correlated with the presence of ophiolite in that district (Takeuchi, 2003a).

In Frieda Hm environments, the streambeds have steeper gradients and narrower channels than those from lowland localities. Forest canopies are able to close over the numerous creeks comprising these upland watersheds. Heliophytic species characteristic of the flatlands are thus excluded. To a limited extent, the indicator trees of lowland plains (*Intsia*, *Nauclea*, *Octomeles*, *Pterocarpus*, etc.) can be found in certain parts of the descending channels (e.g., at Nena-Usage Site), but the riparian communities are too limited in spatial extension to have any kind of mapping significance. Despite being accompanied by higher frequencies of seral taxa, Hill Forest extends more or less continuously along such riverbeds.

Flood surges are common in the upland channels, as evidenced by the presence of rheophytic specialists (*Dipteris lobbiana*, *Ficus arbuscula*, *F. trinervia* (*pachystemon* facies), *Heterospathe macgregorii*, *Phyllanthus rheophilus*, *Sphaerostephanos warburgii*, *Syzygium xylopiaceum*). The adjacent forest supports a diverse conspectus of endemic taxa, particularly in the ground and substage intervals. This can be contrasted with the lowland plains, where vegetation is chiefly composed of a repeating assemblage of cosmopolitan plants. From the perspective of descriptive taxonomy, the high-value environments in the survey tract are the hill or montane forests. As a general rule, little of botanical significance will be found on flood plains traversed by turbid waterways. Such distinctions are also reflected in the historical results from the Augustafluss Expedition—the German botanical discoveries occurred in the hill habitats, not the lowland ones.

6.2 Community Patterns in Lowland Environments

Sepik lowland forests are a catena of successionally related environments, whose major facies (Fri, Fsw, Po, Wsw) are interlinked by gradations in community physiognomy and structure. These swampland habitats also merge into the lacustrine vegetation represented by code Hsw (e.g., at Lake Warangai; Hammermaster and Saunders, 1995a, b). The wetland biome is thus a continuum of principal components individually capable of gross characterization, but for which specific forest units are not always going to show precise conformity. As evidenced by the FIMS, it is often impossible to draw discrete lines between communities, owing to structural overlap, but this is a corollary of any system involving continuous variation. Rather than focusing excessively on the mapping identity of certain land sections, it is more useful to examine the environmental trends reflected in their interrelation.

In general, increasing levels of swamping severity (as measured by temporal persistence of standing water), will result in progressively reduced beta diversity, lower tree statures, crown-form depauperation, elimination of macrophyllous taxa, and simplified stratification usually involving disappearance of the middle layers. These tendencies are embodied in the structural sequence: Po/Fri (late stage) Fsw Wsw/ Fri (early stage) Hsw, moving in the direction of impoverishment and simplification. Although the given sequence is not necessarily a successional series, it summarizes the physical contrasts between forest types studied by the survey.

6.3 Comparative Community Values

The Hm and lowland communities (Fri, Fsw, Po, Wsw) are the forest types most susceptible to direct impacts from mineral extraction. Of these five, the Hm formation will be of most concern judging from documented taxonomic values. Lowland-successional communities are species-poor and weedy. No botanical novelties have been confirmed from these latter places, but at least 12 new plants were found exclusively in Hm forests. Among the vegetation types examined, Fri, Fsw, Po, and Wsw communities are the least prospective for scientific discovery and have the lowest intrinsic botanical significance. This is not the same as saying that the environments are collectively expendable, since there are anthropogenic services to be considered when assessing such vegetation. Lowland habitats are usually the most accessible to local villagers and many of its plants are ethnobotanically useful. The resilient bark of *Trichospermum pleiostigma* for example, is employed for cordage and house flooring throughout New Guinea (Takeuchi, 2008e). Among the extensive listings of Sepik medicinal plants in Powell (1976), *Cassia alata* can be randomly mentioned as a widely-used palliative for skin diseases. Trees of the Fri-Po zone (e.g., *Intsia*, *Pometia*, *Pterocarpus*) are also high-grade timbers whose desirability is enhanced by the logistical ease of commercial extraction, compared to hill species like *Agathis labillardieri*. Although the present assessment explicitly adopts a botanical bias, there are admittedly other considerations, including social-economic ones, that are beyond the purview of floristic evaluation.

6.4 Threats From Alien Species

In addition to their speciose contents, the Study Area forests are remarkably free of terrestrial weeds (Figure 17) except in well-defined and localized situations close to village settlements (e.g., Iniok, Wogamush and Kubkain Sites)—where anthropogenic changes have already occurred). This pattern is particularly applicable to the upland sections where human foot traffic is minimal or absent. The good condition of the Hill Forest can be contrasted to Sepik still-water habitats where invasive species (*Eichhornia crassipes*, *Pistia stratioides*, *Salvinia molesta*) once had devastating impacts (Mitchell *et al.*, 1980; Gewertz, 1983) that were only recently alleviated by biocontrol intervention (see Mitchell, 1981; Thomas and Room, 1985). Thus far only floating aquatic weeds have created problems in Sepik stillwater habitats, but substrate-rooted weeds (*Egeria*, *Elodea*, *Hydrilla*, *Lagarosiphon*, etc.) could create future difficulties.

There are new reports of environment-altering aliens in the Jayapura-Vanimo border area, involving *Chromolaena odorata*, *Cleome rutidosperma*, *Limnocharis flava*, and *Mikania micrantha* (Waterhouse, 2003). These recently established weeds could become intractable pests if they move upriver into the Study Area. The neotropical *Piper aduncum* has already inflicted serious damage on native ecosystems of north-central New Guinea (Rogers and Hartemink, 2000; Leps *et al.*, 2002), but has thus far not invaded the Frieda River catchment. Among the wetland adventives extant in New Guinea, *Mimosa pigra* is probably the most significant potential threat (Orapa and Julien, 1996; Shearman, 1999). Preventive measures should be considered for the Study Area, in proactive response to the emerging situation in nearby territories.

In some upland environments (e.g., Nena Base and HI Sites) the vegetation is a mosaic of successional communities and mature forest. Although human activities have increased the frequencies of pioneer taxa, the floristic changes in such areas are merely quantitative in nature, not qualitative. The collective composition of the flora remains the same despite the proportional increases in successional plants. As long as preexisting patterns of floristic succession are preserved, the forest will eventually reconstitute itself through natural process. Even though the canopy at Nena Base and HI Sites has been disrupted by drillpad operations, the vegetation is still an Hm or L±c formation, because the floristic composition has not been qualitatively altered (Figure 17). The gap-phase regrowth at those sites is a transient condition, and is actually necessary for long term maintenance of forest structure. Whether or not the dynamic sequence of demographic renewal is initiated by human or natural agency is immaterial, if the end result is the same.

Floristic successions in Study Area Hill and Montane Zone habitats are presently determined by native species, with only inconsequential participation by alien plants. However the weeds listed previously (e.g., *Chromolaena odorata*, *Limnocharis flava*, *Piper aduncum*) are aggressive invaders in newly opened areas, capable of establishing suppressive groundcover which can smother native regeneration. *Piper aduncum* is particularly effective at coppicing from horizontal stems and excluding other species by forming impenetrable stands (Leps *et al.*, 2002). Among vining aliens, *Mikania micrantha* and the ecologically similar *Passiflora mollissima*, are probably the most significant future threats (see de Wilde, 1972; Henty and Pritchard, 1988). Dense infestations of these neotropical lianes typically occur in forest gap regrowth, displacing native plants and subverting the normal sequence of vegetation succession. Undetected incursions by such weeds can eventually lead to habitat degradation, biodiversity losses, and reduced watershed values.

Alien flora is probably of least concern for the Peat Forest at East Sepik Site. Peat substrates have deleterious qualities which discourage invasion by plants unadapted to that kind of edaphic environment. Aliens only invade if the water balance in Peat Forests is altered (e.g., by construction of roads or deliberate drainage, neither of which are planned by the Project) which can change dramatically soil chemistry (Page *et al.*, 1999). Aeration and oxidation of the peat column will release nutrients into an expanded acrotelm, facilitating invasion by species presently excluded from those habitats.

6.5 Relationships of the Frieda Flora

Contemporary studies in the Hunstein area are of considerable relevance to the Study Area, as such inquiries are providing increasing indications of substantial overlap between the respective floras, particularly in regards to their most outstanding constituents. With no obvious habitat discontinuities to separate them, Hunstein-Frieda colline environments collectively comprise a natural geofloristic unit (the Sepik Hill Zone, or the “East Sepik Foothill Zone” sensu Hammermaster and Saunders, 1995b). Plant records documented by recent Hunstein surveys are very likely to be duplicated in the Frieda River basin. In anticipation of future developments, modern discoveries from the April-Ambunti Hill Forest are collated in Appendix 2.2. Judging from historical and contemporary precedent, many of the listed plants will be eventually enumerated from the Study Area.

6.6 Patterns in Floristic Documentation

Based on the results from past exploration, modern authorities have consistently rated the upper Sepik as an area deserving of priority conservation action (Stevens, 1989; Beehler, 1993; Sekhran and Miller, 1994). These earlier estimates have been corroborated by the Project surveys. Despite unfavourable phenologies, floristic counts were very high and consistent with elevated richness.

Vascular plants are always present in considerably greater numbers than the vertebrate fauna sharing their habitat. There are at least 30,000 plant species in New Guinea (Supriatna, 1999), but only 329 aquatic fishes (Allen, 1991), 831 birds (Mack and Dumbacher, 2007), 603 herpetofaunal species (Allison, 2007), and 92 bats (PNG only; Bonaccorso, 1998). The task of documenting a specific plant against the background diversity is thus of a commensurately higher level of difficulty compared to the faunal groups. Because of the limitations imposed by a large sample universe, a small number of documenting collections seldom translates to biological rarity when relevant habitats are subjected to intense scrutiny.

The disconnection between documentation rarity on one hand, and floristic rarity on the other, is mirrored in post-classical expeditions to the upper Sepik. Beginning with the Hoogland and Craven expedition in 1966, and continuing to the present, each successive entry into the Augustafluss localities has produced more recoveries of lost taxa and discoveries of new ones. The expanding ledger of Augustafluss plants has not been confined to the type localities, showing conclusively that the species concerned are not single-site endemics. And contrary to expectations derived from the historical record, the recovered taxa are often present in large populations (e.g., *Airosperma grandifolia*, *Ardisia laciniata*, *Chlamydogramme hollrungii*, *Sepikea cylindrocarpa*, *Tetracera lanuginosa*).

A recurring theme from modern biosurveys in Papuasia is the occurrence of unexpected records involving plants otherwise documented only from type localities. Many lost Augustafluss species have been found far outside the Sepik River Basin. *Aporosa brevicaudata*, previously known only from Ledermann's destroyed collections, was recently neotypified from Western Highlands Province, and additional populations reported from Irian Jaya (Schot, 2004). *Agalmyla chrysostyla*, *Aporosa flexuosa*, *A. reticulata*, *Elaeocarpus peistocarpus*, *E. sarcanthus*, *Rhododendron gardenia*, and *Timonius subcoriaceus*, whose types were all lost at Berlin, were rediscovered at sites far removed from the original locations. The converse has also occurred. At least three species once known only from type localities outside the Sepik (*Diospyros fusicarpa*, *Prunus osiana*, *Syzygium kipidamasii*) have now been registered in the Study Area. Many more taxa could also be cited—only five genera (in Coode, 1978, 1981; Darwin, 1994, 1997; Hilliard and Burtt, 2002; Schot, 2004; Argent, 2006) have been sifted as demonstrative models. Judging from general pattern and historical precedent, plants are nearly always more widely distributed than collections-based knowledge will tend to indicate.

Geocladistic analyses of species distributions show very poor correlations between plants and individual terrains (Welzen, 1997; Heads, 2003). The distributional linkages to geology are expressed on larger spatial scales, involving paleohistorical phases of tectonic accretion rather than particular crustal sections (ibid.). Based on the evidence from geological process, future records of April River plants should be skewed to the west (Takeuchi and Golman, 2002), in the direction of the accretion unit subsuming the Sepik (cf. Pigram and Davies, 1987; Davies *et al.*, 1997). All distributional records obtained from the Study Area (excepting *Barringtonia josephstaalensis* of Madang) are extensions from localities in the west; none include taxa strongly centred to the east.

6.7 Floristic Knowledge Gaps

The most cogent demonstration of contingent knowledge gaps is provided by *Gyrinops ledermannii* (eaglewood), a subarborescent species highly sought in international commerce. Prior to 1998, the species was known from Ledermann's single collection (now lost) at Pfingstberg (9511752, 566569; 4°25' S, 141°36' E), and only a taxonomic specialist would have been able to identify the plant. Immediately following media reports of high prices being paid by Asian traders, knowledge of eaglewood improved in astonishing fashion as village prospectors scoured their lands for the valuable product. Within the last 10 years, *G. ledermannii* has dramatically emerged from scientific obscurity, and has now been reported from at least 45 localities in 7 provinces (Gunn *et al.*, 2004). The circumstances responsible for this remarkable transformation are also applicable to many of PNG's supposedly rare plants. To a significant but unappreciated extent, rarity resides in the population of human observers more than the botanical targets. Species are more or less constant over periods of historical time. It is the human traffic of motivated observers and their itineraries which change.

Overhanging all of these considerations is a historical fact often ignored in conservation assessments of the Papuasian flora. There is no well-supported example of an endemic plant becoming extinct in New Guinea because of anthropogenic action or commercial development. The most likely candidates for such distinction would be *Illigera novoguineensis* and *Lauterbachia novoguineensis* of the Ramu-Gogol basin, both of which are known only from historical collections made over 100 years ago (Philipson, 1986; Duyfjes, 1996). Because of extensive fires (possibly El Nino related) in the 1940s, and subsequent clearcut operations within former logging concessions, extinctions may have occurred in that particular basin (Johns, 1986). But aside from the empirical impossibility of proving physical absence in nature, floristic claims for man-made extinctions are particularly speculative when natural-growth habitats remain intact adjacent to impacted localities. The distinctive *Psychotria dipteropoda*, a sympatric associate of the preceding species, was recently rediscovered in the Ramu district after a similar documentation hiatus of ca. 100 years (Takeuchi, 2000). As evidenced by *Gyrinops ledermannii* and *Psychotria dipteropoda*, the historical absence of information is an especially weak foundation for scientific inference.

The upper Sepik is a critical type locality for several plant families, the most obvious of which are the Elaeocarpaceae, Euphorbiaceae, Melastomataceae, Myrsinaceae, Myrtaceae, Proteaceae, and Rubiaceae. The botanical survey provides unmistakable indications of the importance of these families in the Sepik vegetation. At least five recoveries have been obtained of German taxa lost at Berlin. New plants have been added. The most unusual novelties are significantly in genera and families where the upper Sepik has already yielded distinctive species, suggesting that its floristic diversity is far from adequately sampled. This circumstance in itself, argues for caution when interpreting survey results, particularly those implying rarity.

Notwithstanding the discovery of a new overstorey *Helicia*, the lost congeners *H. ledermannii*, *H. schlechteri*, and *H. torricellensis*, seen only by early German botanists, have yet to be recovered. Arborescent *Elaeocarpus* are especially in need of further exploration attention. The identities of *Elaeocarpus cheirophorus*, *E. clethroides*, *E. compactus*, *E. flavescens*, *E. fuscus*, *E. mallotoides*, *E. pachydactylus*, *E. pentadactylus*, and *E. terminalioides*, cannot be ascertained because of a continuing lack of specimens referable to those names (Weibel, 1971; Coode, 1978, 1981). In other recently revised plant groups, 3 species of *Rhododendron* (Argent, 2006), 10 of *Psychotria* (Sohmer, 1988), and 13 of *Aglaia* (Pannell, 1992) can be cited as taxa awaiting recollection. There are certainly many more.

7 CONCLUSION

The most salient points from the preceding discussion are recanted in summation.

1. The floristic-tectonic affinities of the Sepik flora are primarily to the west (Irian Jaya), a region with less than 30% of the botanical documentation coverage of PNG (Takeuchi, 2007). The poor knowledge base in West New Guinea will exaggerate the level of apparent endemism in the Sepik flora, by masking the actual range of its plants.

2. As a consequence of item “1” above, single-locality records are unlikely to represent veridical examples of localized distribution.

3. Of the botanical novelties discovered thus far, two are known from a single site, 10 from two sites, and 12 from three or more sites. Five of the taxa, including 2 gen. nov., have been recorded outside the Study Area by earlier surveys of the Hunstein district.

4. Eight of the species new to science were seen only in Hill Forest (Hm , ten were found in both Hill Forest and Montane Forest L±c and one was found only in L±c forest. There were no species new to science in the lowland (Fri/Fsw/Po/Wsw) vegetation. Similarly, of the five undescribed but already known species, four were only found in Hm and the fifth in both Hill Forest and Montane Forest L±c . The highest-value assets are thus all in the Study Area Hill and Montane zones, where taxonomic compositions are overlapping.

5. The botanical novelties are concentrated in three speciose families (Melastomataceae, Myrsinaceae, and Rubiaceae). These families were also of special significance as sources of new plant descriptions for the Augustafluss Expedition.

6. There are 15 species listed as other than Least Concern by IUCN.

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APPENDICES

Appendix 2.1. Plants Recorded In The Study Area

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Pteridophytes																				
Adiantaceae	Adiantum hollandiae Alderw.															X			S	
Adiantaceae	Pityrogramma calomelanos (L.) Link				S	S	S			S		X							X	
Adiantaceae	Rheopteris cheesmaniae Alston							S		S		X	S	X	S	X				
Adiantaceae	Syngramma borneensis (Hook.) J. Sm.							S				S			X					
Adiantaceae	Syngramma schlechteri Brause				S	S	S			S	X	X		X		X		X		
Adiantaceae	Taenitis blechnoides (Willd.) Sw.					S	S					X			S	X		S	S	
Adiantaceae	Taenitis sp.									X	X									
Aspleniaceae	Asplenium acrobryum H. Christ				S	S	S		S	S	S	X	S	S	S		S		S	S
Aspleniaceae	Asplenium affine Sw.														S	X			S	S
Aspleniaceae	Asplenium bipinnatifidum Baker						S		S	X	S	X			X					
Aspleniaceae	Asplenium contiguum Kaulf.																	X		
Aspleniaceae	Asplenium cromwellianum Rosenst.																	S		S
Aspleniaceae	Asplenium cuneatum Lam.					S	S				S			S					S	
Aspleniaceae	Asplenium decorum Kunze														S					
Aspleniaceae	Asplenium foersteri Rosenst.										S	X			X					
Aspleniaceae	Asplenium macrophyllum Sw.														X					
Aspleniaceae	Asplenium musifolium Mett.										S									
Aspleniaceae	Asplenium nidus L.			S	S	S	S	S	S	S	S			S						
Aspleniaceae	Asplenium pellucidum Lam																X			
Aspleniaceae	Asplenium phyllitidus D. Don			S	S	S	S		S	S	S	X	S		S	S	S	S	S	
Aspleniaceae	Asplenium scandens J. Sm.											S	X		S	S	X			
Aspleniaceae	Asplenium subemarginatum Rosenst.											X				X				
Aspleniaceae	Asplenium tenerum Forst. f.			S	S		S	S	S	S	S	S		S	S	S				
Aspleniaceae	Didymochlaena truncatula (Sw.) J. Sm.											S								
Athyriaceae	Diplazium accedens Blume														X					

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Athyriaceae	Diplazium bantamense Blume															X				
Athyriaceae	Diplazium cordifolium Blume				S	S	S			S	S	S			S	S		S	S	
Athyriaceae	Diplazium esculentum (Retz.) Sw.								S						X					
Athyriaceae	Diplazium stipitipinnula Holttum				S	S								S		X				
Athyriaceae	Diplazium weinlandii H. Christ																	X		
Blechnaceae	Blechnum keysseri Rosenst.				S	S	S			S					X					
Blechnaceae	Blechnum orientale L.					S	S			S	S					S		S		
Blechnaceae	Stenochlaena areolaris (Harr.) Copel.				S	S	S													
Blechnaceae	Stenochlaena milnei Underwood		S		S			S	S					S						
Blechnaceae	Stenochlaena palustris (Burm. f.) Bedd.		S		S	S	S	S	S		S	S		S						
Cyatheaceae	Cyathea archboldii C. Chr.																	X		
Cyatheaceae	Cyathea contaminans (Wall.) Copel.															X				
Cyatheaceae	Cyathea hornei (Baker) Copel.															X			S	
Cyatheaceae	Cyathea hunsteinii Brause																	X		X
Cyatheaceae	Cyathea lepidoclada (C. Chr.) Domin																	X	S	
Cyatheaceae	Cyathea perpelvigera Alderw.																			X
Cyatheaceae	Cyathea pulcherrima Copel.															X				
Cyatheaceae	Cyathea spp.		S	S	X	X	S	S		S	S	S	S	S	S	S	S	S	X	S
Cyatheaceae	Cystodium sorbifolium (Sm.) J. Sm.				S	S	S	S	S	S				S						
Davalliaceae	Davallia heterophylla Sm.													X						
Davalliaceae	Davallia pectinata Sm.									S				S		X		S		
Davalliaceae	Davallia pentaphylla Blume											S			S					
Davalliaceae	Davallia repens (L. f.) Kuhn									S		X								
Davalliaceae	Davallia solida (G. Forst.) Sw.		S	S				S		S										
Davalliaceae	Davallodes novoguineense (Rosenst.) Copel.																X			
Davalliaceae	Leucostegia pallida (Mett.) Copel.											X			X	S		S	X	
Dennstaedtiaceae	Dennstaedtia scandens (Blume) T. Moore															S			S	
Dennstaedtiaceae	Histiopteris integrifolia Copel.											X								

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Dennstaedtiaceae	Microlepia speluncae (L.) T. Moore																		X	
Dennstaedtiaceae	Orthiopteris campylura (Kunze) Copel.						S					X								
Dennstaedtiaceae	Pteridium aquilinum (L.) Kuhn																	S	S	
Dipteridaceae	Dipteris conjugata Reinw.							S								S		X	S	
Dipteridaceae	Dipteris lobbiana (Hook.) T. Moore											S	S	S	S	X	S	X	X	
Dipteridaceae	Dipteris novo-guineensis Posthumus																	X		
Dryopteridaceae	Dryopolystichum phaeostigma (Ces.) Copel.						S				X									
Dryopteridaceae	Dryopteris sp															S		S		S
Dryopteridaceae	Lastreopsis novoguineensis Holttum																S	X		
Dryopteridaceae	Polystichum bamlerianum Rosenst.																	S		
Gleicheniaceae	Dicranopteris linearis (Burm. f.) Underwood		S		S			S	S	S	S	S	S			S		S	S	S
Gleicheniaceae	Gleichenia hirta Blume																	X		
Gleicheniaceae	Gleichenia milnei Baker														S	X				
Gleicheniaceae	Gleichenia sp., subg. Diplopterygium																	S		S
Grammitidaceae	Calymmodon clavifer (Hook.) T. Moore																	X		
Grammitidaceae	Ctenopteris eximia Copel.																	X		
Grammitidaceae	Ctenopteris subsecundodissecta (Zoll.) Copel.																	S		S
Grammitidaceae	Ctenopteris taxodioides (Baker) Copel.															S		X		S
Grammitidaceae	Grammitis adspersa (Blume) Blume																	X		X
Grammitidaceae	Grammitis pleurogrammoides (Rosenst.) Copel.															S			S	
Grammitidaceae	Loxogramme sp.															S				
Grammitidaceae	Oreogrammitis fasciata (Blume) Parris												S				X			
Grammitidaceae	Prosaptia contigua (Forst. f.) Presl									X			X				X			
Grammitidaceae	Scleroglossum minus (Fee) C. Chr.																	X		S
Hymenophyllaceae	Abrodictyum meifolium (Bory ex Willd.) Ebihara & K. Iwats.								S		S		X						X	
Hymenophyllaceae	Abrodictyum obscurum (Blume) Ebihara & K. Iwats.																	X		

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Hymenophyllaceae	Abrodictyum schlechteri (Brause) Ebihara & K. Iwats.																	X		X
Hymenophyllaceae	Callistopteris apiifolia (Presl) Copel.												X							X
Hymenophyllaceae	Cephalomanes atrovirens Presl					S				X			S		S		S		X	
Hymenophyllaceae	Cephalomanes oblongifolium Presl												X							
Hymenophyllaceae	Cephalomanes singaporeanum Bosch											S	X							
Hymenophyllaceae	Crepidomanes aphlebioides (H. Christ) I.M. Turner						S			S		S								
Hymenophyllaceae	Crepidomanes intermedium (Bosch) Ebihara & K. Iwats.									S	S	X			S					
Hymenophyllaceae	Hymenophyllum brassii C. Chr.																	S		X
Hymenophyllaceae	Hymenophyllum denticulatum Sw.																	S		X
Hymenophyllaceae	Hymenophyllum ellipticosorum Alderw.																	S		X
Hymenophyllaceae	Hymenophyllum gorgoneum Copel.																	S		X
Hymenophyllaceae	Hymenophyllum pallidum (Blume) Ebihara & K. Iwats.															S		X		S
Hymenophyllaceae	Hymenophyllum pilosissimum (C. Chr.) Copel.																	X		
Hymenophyllaceae	Hymenophyllum sp.									X										
Hymenophyllaceae	Trichomanes humile G. Forst.											S				S				
Lindsaea Group	Lindsaea bakeri (C. Chr.) C. Chr.												S						X	
Lindsaea Group	Lindsaea kingii Copel.												X							
Lindsaea Group	Lindsaea lucida Blume								S	X	S	X	S						S	
Lindsaea Group	Lindsaea microstegia Copel.					X		S				X	S	S	S		S			
Lindsaea Group	Lindsaea obtusa J. Sm.		S			S	S	S	S	S	S	S	S	S	S				S	
Lindsaea Group	Lindsaea repens (Bory) Thwaites											S	S		S	S		X		
Lindsaea Group	Lindsaea rosenstockii Brause										X							S		X
Lindsaea Group	Lindsaea tenuifolia Blume							X		S	X	S	S	S	S					
Lindsaea Group	Sphenomeris chinensis (L.) Maxon					S							S				S		S	
Lindsaea Group	Sphenomeris retusa (Cav.) Maxon							S		S		X	S							S

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Lindsaea Group	Tapeinidium longipinnulum (Ces.) C. Chr.					S			S	S	S	X								
Lindsaea Group	Tapeinidium novoguineense Kramer															S				X
Lomariopsidaceae	Bolbitis heteroclita (Presl) Ching				S			S		S			S	S	S	X				
Lomariopsidaceae	Bolbitis quoyana (Gaudich.) Ching				S	S	S	S	S	S	S	S	S	S	S					
Lomariopsidaceae	Bolbitis rivularis (Brack.) Ching					S	S		S	S	X		X	S	S					
Lomariopsidaceae	Elaphoglossum novoguineense Rosenst.											S		S					X	S
Lomariopsidaceae	Lomagramma sinuata C. Chr.				S		S			S	S	S			S					
Lomariopsidaceae	Lomariopsis kingii (Copel.) Holttum								X	S	S									
Lomariopsidaceae	Teratophyllum articulatum (J. Sm.) Mett.			X						S	S					S		S	S	S
Lycopodiaceae	Huperzia nummularifolia (Blume) Jermy													X						
Lycopodiaceae	Huperzia phlegmaria (L.) Rothm.							S	S	S	S	S	S	S	S	S			S	
Lycopodiaceae	Huperzia squarrosa (Forst. f.) Trevis.															X				
Lycopodiaceae	Lycopodiella cernua (L). Pic. Serm.		S						S	S	S				S	S		S		S
Lycopodiaceae	Lycopodium volubile Forst. f.																	X		
Marattiaceae	Angiopteris evecta (Forst.) Hoffm.				S		S				S								S	
Marattiaceae	Christensenia aesculifolia (Blume) Maxon							S		X			X	S	X			X		
Marattiaceae	Marattia sp. A, pinnae glaucous												S							
Marattiaceae	Marattia sp. B, not glaucous				S		S			S	S	S		S				S		
Oleandraceae	Arthropteris articulata (Brack.) C. Chr.						S			S	S	X	X	S	X				X	
Oleandraceae	Nephrolepis cordifolia (L.) Presl														S	S	X	S		
Oleandraceae	Nephrolepis davallioides (Sw.) Kunze															X				
Oleandraceae	Nephrolepis obliterata (R. Br.) J. Sm.							X												
Oleandraceae	Nephrolepis sp.				S	S	S			S										
Oleandraceae	Oleandra neriiformis Cav.											X								
Oleandraceae	Oleandra werneri Rosenst.											X				X			X	
Ophioglossaceae	Helminthostachys zeylanica (L.) Hook.		S											S						
Ophioglossaceae	Ophioglossum pendulum L.				S							S			S					
Parkeriaceae	Ceratopteris thalictroides (L.) Brongn.		S					S												

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Polypodiaceae	Aglaomorpha drynarioides (Hook.) Roos											X	S		S	S			S	
Polypodiaceae	Aglaomorpha heraclea (Kunze) Copel.				S		S			S		X								
Polypodiaceae	Aglaomorpha novoguineensis (Brause) C. Chr.																	X		
Polypodiaceae	Belvisia mucronata (Fee) Copel.									S		X	S		S					
Polypodiaceae	Belvisia spicata (L. f.) Mirbel ex Copel.									S								X	S	S
Polypodiaceae	Drynaria rigidula Bedd.						S												S	
Polypodiaceae	Drynaria sparsisora (Desv.) T. Moore		S			S	S			S		S	S		S					
Polypodiaceae	Goniophlebium demersum (Brause) Rodl-Linder															S		S	S	S
Polypodiaceae	Goniophlebium percussum (Cav.) Wagner & Grether														X					
Polypodiaceae	Goniophlebium persicifolium (Desv.) Bedd.			X								X								
Polypodiaceae	Goniophlebium pseudoconnatum (Copel.) Copel.																	X		S
Polypodiaceae	Lecanopteris deparioides (Ces.) Baker											X				X				
Polypodiaceae	Lecanopteris sinuosa Copel.											X	S		S					
Polypodiaceae	Lemmaphyllum accedens (Blume) Donk						S	S	S	S		S	S	S	S	S		S	X	
Polypodiaceae	Leptochilus sp.								X											
Polypodiaceae	Microsorum linguiforme (Mett.) Copel.				S		S	S		S		S	S	S	S	S	S			
Polypodiaceae	Microsorum membranifolium (R. Br.) Ching				S		S		S		S	S				S		S	X	X
Polypodiaceae	Microsorum papuanum (Baker) Parris				S					S		X					X			
Polypodiaceae	Microsorum powellii (Hook. & Baker) Copel.																		X	
Polypodiaceae	Microsorum pteropus (Blume) Copel.							S			S									
Polypodiaceae	Microsorum punctatum (L.) Copel.									S	S	X			X					
Polypodiaceae	Microsorum rampans (Baker) Parris						S					S	S	S	S					
Polypodiaceae	Pyrrosia foveolata (Alston) Morton																	S		S
Polypodiaceae	Pyrrosia lanceolata (L.) Farwell						S	X		S		S			S	S				S
Polypodiaceae	Pyrrosia longifolia (Burm.) Morton							S												
Polypodiaceae	Pyrrosia novoguineae (H. Christ) Price												S							
Polypodiaceae	Pyrrosia piloselloides (L.) Price				S			S				X								

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Polypodiaceae	Pyrrosia princeps (Mett.) Morton							X								S				
Polypodiaceae	Selliguea albidosquamata (Blume) Parris															S		S		X
Polypodiaceae	Selliguea enervis (Cav.) Ching									S			X					X	X	S
Polypodiaceae	Selliguea hellwigii (Diels) Hovenkamp										S	S						S	X	X
Polypodiaceae	Selliguea plantaginea Brack.																	X		S
Psilotaceae	Psilotum complanatum Sw.						S												S	
Psilotaceae	Psilotum nudum (L.) P. Beauv.																S			
Pteridaceae	Pteris ligulata Gaudich.				S			X		S					X					
Pteridaceae	Pteris moluccana Bl.				S															
Pteridaceae	Pteris papuana Ces.					S						X								
Pteridaceae	Pteris tripartita Sw.				X			S		S								X	S	
Pteridaceae	Pteris wallichiana Agardh				X															
Pteridaceae	Pteris warburgii H. Christ									S					X				S	
Salviniaceae	Azolla pinnata R. Br.		S					S												
Salviniaceae	Salvinia molesta Mitchell		S																	
Salviniaceae	Lygodium circinnatum (Burm. f.) Swartz					S														
Schizaeaceae	Lygodium dimorphum Copel.										S	X						X		
Schizaeaceae	Lygodium salicifolium Presl					S				S										
Schizaeaceae	Lygodium scandens (L.) Sw.		S							S						X				
Schizaeaceae	Lygodium versteegii H. Christ													S	S					
Schizaeaceae	Schizaea dichotoma (L.) J. Sm.					S	S			S		S	S	S	S	S		S	X	
Schizaeaceae	Schizaea digitata (L.) Sw.														S					
Schizaeaceae	Schizaea malaccana Baker																	S		
Schizaeaceae	Schizaea wagneri Sell.																	S		
Selaginellaceae	Selaginella angustiramea Muell.											X					S			
Selaginellaceae	Selaginella cf. durvillei (Bory) Brown														X					
Selaginellaceae	Selaginella velutina Ces.				S	S	S					S	S	S		S	S	S		
Selaginellaceae	Selaginella spp.		S		S		S	S	S	S	S	S	S	S	S	S	S	S	S	S

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Tectaria Group	Pleocnemia irregularis (Presl) Holttum											X				S				
Tectaria Group	Pteridrys sp.				S					S									S	
Tectaria Group	Tectaria bamleriana (Rosenst.) C. Chr.									S										
Tectaria Group	Tectaria decurrens (Presl) Copel.								S	S	S	X								
Tectaria Group	Tectaria menyanthides (Presl) Copel.				S		S		S	S	S	X	S		S					
Tectaria Group	Tectaria pleiosora (Alderw.) C. Chr.											S			S					
Thelypteridaceae	Ampelopteris prolifera (Retz.) Copel.		S		S															
Thelypteridaceae	Amphineuron immersum (Blume) Holttum							S				X		S						
Thelypteridaceae	Coryphopteris sp.													X					X	S
Thelypteridaceae	Plesioneuron sp.												S		X			S		
Thelypteridaceae	Pneumatopteris sp.				S	S	S	S	S		S			S						
Thelypteridaceae	Pronephrium cf. micropinnatum Holttum											X								
Thelypteridaceae	Sphaerostephanos invisus (Forst. f.) Holttum				S		S	X		S										
Thelypteridaceae	Sphaerostephanos multiauriculatus (Copel.) Holttum						S			S							S	S	X	
Thelypteridaceae	Sphaerostephanos unitus (L.) Holttum		S		S		S	S		S										
Thelypteridaceae	Sphaerostephanos warburgii (Kuhn & H. Christ) Holttum									S		X	S		S	X			X	
Thelypteridaceae	Sphaerostephanos spp.		X		X		S	S		S	X	X	S	S	S	S	S	X	X	
Vittariaceae	Antrophyum plantagineum (Cav.) Kaulfuss											X								
Vittariaceae	Anthrophyum sp., "reticulatum-callifolium group"							S							S			S		
Vittariaceae	Haplopteris elongata (Sw.) Crane		S					S	S	S	S			X	S					
Vittariaceae	Haplopteris scolopendrina (Bory) Presl		S				S					X				X				
Vittariaceae	Monogramma dareicarpa Hook.									X						S				
Gymnosperms																				
Araucariaceae	Agathis labillardieri Warb.					S	S	X		S				S		S			S	S
Cupressaceae	Libocedrus papuana F. Muell.																	S		X

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Cycadaceae	Cycas rumphii Miq.	NT	S			S	S			S										
Gnetaceae	Gnetum gnemon (L.) Lauterb. & K. Schum.		S		S	S	S	S	S	S	S		S	S	X	S				
Gnetaceae	Gnetum gnemonoides Brongn.		S					S												
Gnetaceae	Gnetum latifolium Blume		S		S									S						
Podocarpaceae	Dacrycarpus sp.																			S
Podocarpaceae	Dacrydium imbricatus (Blume) de Laub.																			X
Podocarpaceae	Decussocarpus wallichianus (Presl) de Laub.																	S		S
Podocarpaceae	Phyllocladus hypophyllus Hook. f.																	S		S
Podocarpaceae	Podocarpus neriifolius D. Don			S	S	S	S		S											
Podocarpaceae	Podocarpus pilgeri Foxw.																			X
Podocarpaceae	Podocarpus rubens de Laub.																	S		X
Podocarpaceae	Prumnopitys amara (Blume) de Laub.																			S
Monocotyledons																				
Amaryllidaceae	Crinum asiaticum L.		S									S								
Araceae	Aglaonema marantifolium Blume		S																S	
Araceae	Alocasia brancifolia (Schott) A. Hay		S		S		S	S	S											
Araceae	Alocasia hollrungii Engl.		S		S		S			S				S					S	
Araceae	Alocasia lauterbachiana (Engl.) A. Hay				S		S	X												
Araceae	Alocasia macrorrhizos (L.) G. Don				S		S			S		S								
Araceae	Alocasia nicolsonii A. Hay																	S		
Araceae	Amydrium zippelianum (Schott) Nicolson		S				S		S											
Araceae	Caladium bicolor Vent.		S																	
Araceae	Colocasia esculenta (L.) Schott		S		S		S		S	S									S	
Araceae	Cyrtosperma macrotum Becc. ex Engl.		S		S		S			S	S	S		S					S	
Araceae	Cyrtosperma sp.																	X		
Araceae	Epipremnum amplissimum (Schott) Engl.		S		S						S		S							
Araceae	Epipremnum pinnatum (L.) Engl.		S		S		S		S	S					S		S			

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Araceae	Holochlamys beccarii (Engl.) Engl.		S							S		X								
Araceae	Homalomena lauterbachii Engl.							X			X?			S					X	
Araceae	Homalomena stollei Engl. & K. Krause																	X	X	
Araceae	Homalomena sp.						S			X										
Araceae	Pothos falcifolius Engl. & K. Krause											X								
Araceae	Pothos tener Wall.						S	X		X		S								
Araceae	Pothos versteegii Engl.							S				S		S						
Araceae	Rhaphidophora spp.		S				S		S	S	S	S	S	S	S	S				
Araceae	Schismatoglottis cf. acutangula Engl.									S	S							X		
Araceae	Scindapsus schlechteri K. Krause																	S		
Araceae	Spathiphyllum schlechteri (Engl. & K. Krause) Nicolson							S				X			X					
Arecaceae	Actinorhytis calapparia H. Wendl & Drude		S																	
Arecaceae	Areca catechu L.		S		S	S	S	S	S	S										
Arecaceae	Areca macrocalyx Zipp. ex Blume		S																S	
Arecaceae	Arenga microcarpa Becc.												S				S			
Arecaceae	Calamus hollrungii Becc.							S			S			S	S					
Arecaceae	Calamus spp.		S		X	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Arecaceae	Calyptrocalyx spp.		S			X	S								S					
Arecaceae	Caryota rumphiana Martelli		S		X	S	S	S		S		S		S	S				S	
Arecaceae	Cocos nucifera L.		S		X		S	S		S										
Arecaceae	Cyrtostachys sp.		S			S														
Arecaceae	Heterospathe humilis Becc.														X					
Arecaceae	Heterospathe macgregorii (Becc.) H.E. Moore							X				X								
Arecaceae	Hydriastele costata F.M. Bailey		S		S	S	S			S	S							S		
Arecaceae	Hydriastele ledermanniana (Becc.) W.J. Baker & Loo																	X		
Arecaceae	Hydriastele microspadix (Becc.) Burret		S		S	S		S				S	S	S	S		S			

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Arecaceae	Korthalsia zippelii Blume		S		S	S	S	S	S	S	S	S	S		S		S			
Arecaceae	Licuala sp.				S			S	S	X	X									
Arecaceae	Linospadix albertisiana (Becc.) Burrett																	X	X	
Arecaceae	Livistona sp.																		X	
Arecaceae	Metroxylon sagu Rottb.		S		S	S	S		S		S	S								
Arecaceae	Orania glauca Essig		S							S	S	S								
Bromeliaceae	Ananas comosus (L.) Merr.		S		S	S	S			S									S	
Burmanniaceae	Burmannia longifolia Becc.															S				
Cannaceae	Canna indica L.		S				S								S				S	
Commelinaceae	Amischotolype mollissima Hassk.																	X		
Commelinaceae	Aneilema acuminatum R. Br.							S							X			S		
Commelinaceae	Commelina diffusa Burm. f.		S		S	S	S		S	S									S	
Commelinaceae	Floscopa scandens Lour.		S		S			S	S	S										
Commelinaceae	Pollia thyrsiflora (Blume) Steud.									S					X					
Corsiaceae	Corsia sp.																	S		
Costaceae	Costus speciosus (Koen.) J. Sm.		S			S	S		S	S									S	
Costaceae	Tapeinochilos hollrungii Warb.		S			S		S	S		S			S	S					
Cyperaceae	Capitularina involucrata (J.V. Suringar) Kern				X							X								
Cyperaceae	Cyperus brevifolius (Rottb.) Hassk.		S															X		
Cyperaceae	Cyperus cephalotes Vahl		S																	
Cyperaceae	Cyperus cyperinus (Retz.) J.V. Suringar														X			X		
Cyperaceae	Cyperus diffusus Vahl					S				S					X					
Cyperaceae	Cyperus platystylis R. Br.		X																	
Cyperaceae	Cyperus sp.																		X	
Cyperaceae	Eleocharis sp.				S		X													
Cyperaceae	Fimbristylis dichotoma (L.) Vahl		S	X														X		
Cyperaceae	Fimbristylis littoralis Gaudich.		S					X												
Cyperaceae	Hypolytrum compactum Nees & Mey		S													S		S		

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Cyperaceae	Hypoletrum nemorum (Vahl) Spreng.		S									S							S	
Cyperaceae	Machaerina glomerata (Gaudich.) Koyama											S							S	
Cyperaceae	Mapania macrocephala (Gaudich.) K. Schum.		S		S		S		S		S	X	S					S		
Cyperaceae	Paramapania parvibractea (Clarke) Uittien				S	S					X				X	X			S	
Cyperaceae	Paramapania sp.																		S	
Cyperaceae	Scirpodendron ghaeri (Gaertn.) Merr.							S												
Cyperaceae	Scirpus sp.														S				S	
Cyperaceae	Scleria ciliaris Nees											X								
Cyperaceae	Scleria polycarpa Boeck.		X		S			X		S	S								X	
Cyperaceae	Scleria scrobiculata Nees & Mey		S				X													
Cyperaceae	Thoracostachyum sumatranum (Miq.) Kurz				X									X						
Dioscoreaceae	Dioscorea bulbifera L.				S			S												
Dioscoreaceae	Dioscorea esculenta (Lour.) Burk.		S		S		S	S	S		S									
Dioscoreaceae	Dioscorea nummularia Lam.		S				S		X			X			X					
Flagellariaceae	Flagellaria indica L.		S		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
Hanguanaceae	Hanguana malayana (Jack) Merr.				S	X	S		S							S	S		X	
Heliconiaceae	Heliconia papuana W.J. Kress														X				S	
Hypoxidaceae	Curculigo capitulata (Lour.) Kuntze		S																	
Hypoxidaceae	Curculigo orchoides Gaertn., or aff.			X			S				S	X		X						
Juncaceae	Juncus effusus L.																	X		
Laxmanniaceae	Cordyline fruticosa (L.) A. Chev.		S		S	S	S	S	S	S					S			S	S	
Liliaceae	Dianella ensifolia (L.) DC.		S		S	S	S	S	S		S	S	S	S	S	S	S	S	S	S
Marantaceae	Cominsia gigantea (Scheff.) K. Schum.							S												
Marantaceae	Donax cannaeformis (Forst. f.) K. Schum.		S		S	S	S	S				S	S		S					
Marantaceae	Phrynium sp.		S		S	S	S		S		S					S		X		
Musaceae	Musa paradisiaca L.		S		S		S			S										
Musaceae	Musa sp.		S					S							S					
Nymphaeaceae	Hydrostemma motleyi (Hook. f.) Mabberley				S	S			S	S	S	X								

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Orchidaceae	Acriopsis javanica Reinw.		S							S		S								
Orchidaceae	Agrostophyllum sp.								S	S	S									
Orchidaceae	Apostasia wallichii R. Br.						X			S				S						
Orchidaceae	Appendicula dendrobioides (Schltr.) Schltr.																		X	
Orchidaceae	Appendicula reflexa Blume																		X	
Orchidaceae	Bromheadia pulchra Schltr.						S	S		S		S								
Orchidaceae	Bulbophyllum chloranthum Schltr.														X					
Orchidaceae	Bulbophyllum digoelense J.J. Sm.												X							
Orchidaceae	Bulbophyllum longipedicellatum J.J. Sm.														X					
Orchidaceae	Bulbophyllum montense Ridl.												X						X	
Orchidaceae	Bulbophyllum werneri Schltr.															X			X	S
Orchidaceae	Bulbophyllum spp.							X				X	X	X	X	X	X	X	X	X
Orchidaceae	Calanthe cf. ventilabium Rchb. f.																		X	
Orchidaceae	Ceratostylis sp.																	S		
Orchidaceae	Chilopogon cf. bracteatum Schltr.													X						
Orchidaceae	Cleisostoma sp.														S					
Orchidaceae	Coelogyne asperata Lindl.		S		S	S				S		S	S		S					
Orchidaceae	Corymborkis veratrifolia (Reinw.) Blume		X					S	X	S		S		S	S					
Orchidaceae	Dendrobium cyperifolium Schltr.																	X		
Orchidaceae	Dendrobium globiflorum Schltr.																	X		
Orchidaceae	Dendrobium insigne (Blume) Rchb. f.							X												
Orchidaceae	Dendrobium lineale Lindl.													X						
Orchidaceae	Dendrobium pachystele Schltr.							X												
Orchidaceae	Dendrobium spectabile (Blume) Miq.														S					
Orchidaceae	Dendrobium spp.																	S		S
Orchidaceae	Diplocaulobium sp.									X								S		
Orchidaceae	Dipodium pandanum F.M. Bailey									S		S								
Orchidaceae	Eria sp.																			S

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Orchidaceae	Galeola cf. gracilis Schltr.							S												
Orchidaceae	Glomera sp.															S		S		S
Orchidaceae	Goodyera sp.							S												
Orchidaceae	Grammatophyllum papuanum J.J. Sm.		S					S						S						
Orchidaceae	Habenaria dracaenifolia Schltr.							S												
Orchidaceae	Hippeophyllum sp.														X					
Orchidaceae	Hylophila sp.														X					
Orchidaceae	Liparis condylobulbon Rchb. f.													X						
Orchidaceae	Liparis pedicellaris Schltr.																		X	
Orchidaceae	Malaxis sp.									S					S				S	
Orchidaceae	Mediocalcar sp.																	S		S
Orchidaceae	Nervillea sp.										X		S							
Orchidaceae	Oberonia sp.															S				
Orchidaceae	Phreatia spp.															S		S	S	S
Orchidaceae	Plocoglottis papuana Schltr.										X			X						
Orchidaceae	Plocoglottis cf. tarana J.J. Sm.						S				X			X						
Orchidaceae	Podochilus imitans Schltr.											X								
Orchidaceae	Podochilus scapelliformis Blume																	X		
Orchidaceae	Pseuderia cf. diversifolia J.J. Sm.															X				
Orchidaceae	Spathoglottis plicata Blume		S		S							S			S	S		S	S	
Orchidaceae	Tropidia similis Schltr.					X						X								
Orchidaceae	Vanilla planifolia Andrew		S		S		S													
Pandanaceae	Freycinetia angustissima Ridl.			S		S				S	S	X								
Pandanaceae	Freycinetia elegantula B.C. Stone																	X		
Pandanaceae	Freycinetia elliptica Merr. & Perry																	X		
Pandanaceae	Freycineta klossii Ridl.															X				
Pandanaceae	Freycinetia marantifolia Hemsl.														S		S			
Pandanaceae	Freycinetia percostata Merr. & Perry											X								

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Pandanaceae	Freycinetia spp.		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Pandanaceae	Pandanus adinobotrys Merr. & Perry							S												
Pandanaceae	Pandanus danckelmannianus K. Schum.						S	S							S					
Pandanaceae	Pandanus sp., sect. Maysops				S									S					S	
Pandanaceae	Pandanus spp.		S			S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Philydraceae	Helmholtzia novoguineensis (K. Krause) Skottsb.																	X		
Poaceae	Axonopus compressus (Sw.) P. Beauv.		S		S	S	S		S	S		X	X							
Poaceae	Bambusa forbesii (Ridl.) Holttum				S	S			S	S			S		S	S				
Poaceae	Bambusa vulgaris Schrad.		S		S	S	S		S											
Poaceae	Centotheca latifolia (Osb.) Trin.		S		S	S	S		S	S	S							X	X	
Poaceae	Chrysopogon aciculatus (Retz.) Trin.		S		S			X		S										
Poaceae	Coix lacryma-jobi L.		S																S	
Poaceae	Cyrtococcum accrescens (Trin.) Stapf.							S												
Poaceae	Echinochloa stagnina (Retz.) Beauv.		X																	
Poaceae	Eragrostis chariis (Schult.) Hitchc.											X						X		
Poaceae	Ichnanthus vicinus (F.M. Bailey) Merr.						S													
Poaceae	Imperata cylindrica (L.) P. Beauv.		S					X		X										
Poaceae	Isachne albens Trin.											X								
Poaceae	Isachne sp.				X				X	X										
Poaceae	Leersia hexandra Sw.							X												
Poaceae	Leptaspis urceolata (Roxb.) R. Br.				S	S	S						S		S					
Poaceae	Lophatherum gracile Brongn.				S	S	S		S	S	S	X						X	S	S
Poaceae	Nastus productus (Pilg.) Holttum															S		S		S
Poaceae	Oplismenus sp.													S						
Poaceae	Paspalum conjugatum Berg.		S		S			S				X			X			S	X	
Poaceae	Paspalum longifolium Roxb.		S							X										
Poaceae	Paspalum scrobiculatum L.																		X	
Poaceae	Pennisetum macrostachyum (Brongn.) Trin.		S					S												

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Poaceae	Phragmites karka (Retz.) Trin. ex Steud.		S				S	S												
Poaceae	Saccharum officinarum L.		S		S		S			S									S	
Poaceae	Saccharum robustum Brandes & Jeswiet ex Grassl		S		S		S	X	S	S										
Poaceae	Sorghum sp.				X		X			X		X								
Poaceae	Thysanolaena maxima (Roxb.) Kuntze		S													X				
Poaceae	Urochloa mutica (Forssk.) T.-Q.Nguyen		S		S		S			S										
Poaceae	Zea mays L.		S		S		S			S										
Pontederiaceae	Eichhornia crassipes (Mart.) Solms		S																	
Ruscaceae	Pleomele angustifolia (Roxb.) N.E. Br.		S		S		S		S						S					
Smilacaceae	Smilax cf. zeylanica L.					S						S								
Smilacaceae	Smilax sp.		S				S	S					S							
Triuridaceae	Sciaphila sp.						X								X				X	
Zingiberaceae	Alpinia calycodes K. Schum.				S		S			S		X				S			S	
Zingiberaceae	Alpinia cf. pulchra (Warb.) K. Schum.															X				
Zingiberaceae	Alpinia sp. A									S										
Zingiberaceae	Alpinia sp. B			X	S					S										
Zingiberaceae	Curcuma australasica Hook. f.		S												X					
Zingiberaceae	Etlingera sp.							S												
Zingiberaceae	Hornstedtia cyathifera Valeton											X								
Zingiberaceae	Hornstedtia scottiana (F. Muell.) K. Schum.		S				S	S	S		S	X								
Zingiberaceae	Pleuranthodium sp.											S						X	S	
Zingiberaceae	Riedelia corallina Valeton		S				S	S	S		S			S	S					
Zingiberaceae	Riedelia longifolia Valeton														S				S	
Zingiberaceae	Riedelia macrantha K. Schum.												X				S			
Zingiberaceae	Riedelia spp.								S		S							S		S
Zingiberaceae	Zingiber officinale Roxb.		S																	
Zingiberaceae	Zingiber zerumbet (L.) J.E. Sm.		S																	

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Dicotyledons																				
Acanthaceae	Coleus sp.								S										S	
Acanthaceae	Gendarussa vulgaris Nees					S													S	
Acanthaceae	Hemigraphis reptans (Forst.) T. And. ex Hemsl.				S							X		X	X	S				
Acanthaceae	Hulemacanthus densiflorus Bremek.													X						
Acanthaceae	Hypoestes floribunda R. Br.						X													
Acanthaceae	Lepidagathis sp.		S		S															
Acanthaceae	Ptyssiglottis pubisepala (Lindau) B. Hansen												X	X						
Acanthaceae	Ruellia sp.									S	S									
Acanthaceae	Sanchezia sp.																		S	
Acanthaceae	Staurogyne novoguineensis (Kaneh. & Hatus.) B.L. Burtt													X						
Achariaceae	Erythrospermum candidum (Becc.) Gibbs		S					S					S							
Achariaceae	Pangium edule Reinw.		S		S	S	S	S	S	S	S		S	S	S					
Achariaceae	Ryparosa calotricha Mildbr.							X												
Achariaceae	Trichadenia philippinensis Merr.							S							S					
Actinidiaceae	Saurauia conferta Warb.											X								
Actinidiaceae	Saurauia schumanniana Diels		S								S	S			S			X		
Actinidiaceae	Saurauia stichophlebia Diels, or aff.													S		S				
Actinidiaceae	Saurauia sp.				S		S		S	S		X								
Amaranthaceae	Achyranthes aspera L.								S											
Amaranthaceae	Alternanthera sessilis (L.) DC.						X													
Amaranthaceae	Amaranthus spinosus L.		S		S		S													
Amaranthaceae	Celosia argentea L.							X												
Amaranthaceae	Cyathula prostrata (L.) Blume							S								S				
Anacardiaceae	Buchanania amboinensis Miq.		S	S	S	S	S	S		S	S									
Anacardiaceae	Buchanania arborescens (Blume) Blume		S		S	S	S	S				S	S							

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Anacardiaceae	Campnosperma brevipetiolata Volkens		S		S	S	S	X	S	S	S	S	S		S		S			
Anacardiaceae	Campnosperma montanum Lauterb.							S							S	S				
Anacardiaceae	Dracontomelon dao (Blanco) Merr. & Rolfe				S			S		S				S						
Anacardiaceae	Euroschinus papuanus Merr. & Perry				S		S	S		S			S		S					
Anacardiaceae	Mangifera minor Blume		S				S			S									S	
Anacardiaceae	Rhus caudata Lauterb.							X								X				
Anacardiaceae	Rhus taitensis Guill.				S			S		S					S					
Anacardiaceae	Semecarpus albicans Lauterb.											X								
Anacardiaceae	Semecarpus aruensis Engl.														S					
Anacardiaceae	Semecarpus bracteatus Lauterb.							X												
Anacardiaceae	Semecarpus magnificus K. Schum.		S		S	S	S		S	S				S						
Anacardiaceae	Semecarpus nidificans (Lauterb.) Ding Hou											X			X					
Anacardiaceae	Spondias cyatherea Sonnerat						S	S		S				X						
Annonaceae	Annona muricata L.		S		S															
Annonaceae	Artabotrys sp., “suaveolens-inodorus group”												S							
Annonaceae	Cananga odorata Hook. f. & Thoms.		S		S		S	S		S				S						
Annonaceae	Cyathocalyx sp.							S					X							
Annonaceae	Goniothalamus aruensis Scheff.				X								X				S			
Annonaceae	Goniothalamus imbricatus Scheff.															X				
Annonaceae	Haplostichanthus longirostris (Scheff.) van Heusden						S		X	S			X			X				
Annonaceae	Mitrella kentii (Blume) Miq.																	X		
Annonaceae	Papualthia longirostris (Scheff.) Diels							X						X						
Annonaceae	Polyalthia sp.									S				S						
Annonaceae	Popowia cf. pisocarpa Endl.						S					X			X	X			X	
Annonaceae	Pseuduvaria sp.								X											
Annonaceae	Schefferomitra subaequalis (Scheff.) Diels						S											X		
Annonaceae	Xylopia sp.							X												

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Annonaceae	genus nov. ined.							S				X		S						
Apiaceae	Centella asiatica (L.) Urb.													S			X			
Apocynaceae	Alstonia macrophylla Wall. ex G. Don									S						S		X	S	
Apocynaceae	Alstonia scholaris (L.) R. Br.		S		S		S	S						S						
Apocynaceae	Alyxia acuminata K. Schum.							S		S					X			X		X
Apocynaceae	Anodendron oblongifolium Hemsl.		S					S												
Apocynaceae	Cerbera floribunda K. Schum.		S		S	S		X	S		S		S	S	S	S			X	
Apocynaceae	Dischidia hirsuta Decne.															X				
Apocynaceae	Dischidia torricellensis (Schltr.) P.I. Forst.							S		S			X	S	X				X	
Apocynaceae	Dischidia sp.				S		S			S										
Apocynaceae	Gymnema sp.																	X		
Apocynaceae	Hoya lauterbachii K. Schum.														X					
Apocynaceae	Hoya piestolepis Schltr.															X				
Apocynaceae	Hoya sussuela (Roxb.) Merr.														X					
Apocynaceae	Hoya torricellensis Schltr.																		X	
Apocynaceae	Hoya sp.		S		S				X	X										
Apocynaceae	Ichnocarpus frutescens (L.) R. Br.						X									X		X		
Apocynaceae	Lepiniopsis ternatensis Valeton															S		S		
Apocynaceae	Marsdenia sp.														S					
Apocynaceae	Melodinus forbesii Fawc.		S					S		S										
Apocynaceae	Micrechites rhombifolius Markgr.														S		S			
Apocynaceae	Ochrosia citrodora Lauterb. & K. Schum.		S						S		S		X				S			
Apocynaceae	Papuechites aambe (Warb.) Markgr.		S					S		S	S			S						
Apocynaceae	Parsonsia curvisepala K. Schum.														S	S				
Apocynaceae	Parsonsia lata Merr. & Perry							S								S				
Apocynaceae	Phyllanthera lancifolia (P.I. Forst.) Venter													X		S			X	
Apocynaceae	Phyllanthera sp. nov.							S								X		X		
Apocynaceae	Tabernaemontana aurantiaca Gaudich.		S				S	S	S	S										

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Apocynaceae	Tabernaemontana pandacaqui Poir.				S										X					
Apocynaceae	Tylophora cissoides Blume		S				X	S	S					S						
Apocynaceae	Voacanga grandifolia (Miq.) Rolfe		S					S												
Aquifoliaceae	Ilex scabridula Merr. & Perry																			X
Araliaceae	Arthrophyllum sp.																	X		
Araliaceae	Gastonia spectabilis (Harms) Philipson							S		S					S			S	S	
Araliaceae	Mackinlaya celebica (Harms) Philipson		S									S	S		S	X	S		S	
Araliaceae	Mackinlaya radiata Philipson																	X		
Araliaceae	Osmoxylon boerlagei (Warb.) Philipson		S									S							X	
Araliaceae	Osmoxylon geelvinkianum Becc.						S			S		S			S	S	S	S	X	
Araliaceae	Osmoxylon novoguineense (Scheff.) Becc.		S		S	S	S	S	S	S	S									
Araliaceae	Polyscias zippeliana (Miq.) Valeton															S		S		
Araliaceae	Schefflera spp.		S	S		S		S	S		S	S	S	S	S	S	S	S	S	S
Aristolochiaceae	Aristolochia "jackii" Steud.								X											
Aristolochiaceae	Aristolochia lauterbachiana Schmidt or A. novoguineensis Schmidt															X		X		
Aristolochiaceae	Aristolochia tagala Cham.		S												S					
Asteraceae	Adenostemma lavenia (L.) Kuntze		S				S			S									X	
Asteraceae	Ageratum conyzoides L.		S				S			S		X						X		
Asteraceae	Bidens pilosa L.		S				S					S							S	
Asteraceae	Blumea arfakiana Martelli		S									S			S				X	
Asteraceae	Blumea riparia (Blume) DC.		S					S				S	S		S			S	S	
Asteraceae	Cosmos caudatus H.B.K.						S													
Asteraceae	Crassocephalum crepidioides (Benth.) S. Moore						S	S		S		X			S	S		X	X	
Asteraceae	Erechtites valerianifolia (Wolf) DC.		S															X	X	
Asteraceae	Erigeron sumatrensis Retz.		S																X	
Asteraceae	Olearia sp.												X							X
Asteraceae	Tagetes cf. patula L.						S													

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Asteraceae	Vernonia cuneata Less.									S						S		X	X	
Balanophoraceae	Balanophora papuana Schltr.															S				
Balsaminaceae	Impatiens hawkeri Bull															S		X		S
Begoniaceae	Begonia brachybotrys Merr. & Perry		S									X							X	
Begoniaceae	Begonia kaniensis Irmscher																		X	
Begoniaceae	Begonia papuana Warb.											X								
Begoniaceae	Begonia spp.		S					S		S		S	S	S	S	S	S	S	S	S
Bignoniaceae	Neosepicaea viticoides Diels																	X		
Bignoniaceae	Pandorea pandorana (Andr.) Steenis																		X	
Bignoniaceae	Tecomanthe dendrophila (Blume) K. Schum.		S					S						S	S		S		X	
Bixaceae	Bixa orellana L.		S						S											
Boraginaceae	Tournefortia sarmentosa Lamk							S			S				S					
Brassicaceae	Rorippa nasturtium-aquaticum (L.) Hayek																		S	
Burseraceae	Canarium acutifolium (DC.) Merr.					S		X		S			S				S			
Burseraceae	Canarium indicum L.		S					S												
Burseraceae	Canarium maluense Lauterb.		S			S				S		X	S		S			S	S	
Burseraceae	Canarium oleosum Engl.															X				
Burseraceae	Canarium vitiense A. Gray						S	X	S	S				X						
Burseraceae	Haplolobus floribundus (K. Schum.) H.J. Lam																X			X
Burseraceae	Santiria rubiginosa Blume						X					X								
Campanulaceae	Peracarpa carnosa (Wall.) Hook. & Thompson																	X		
Capparaceae	Crataeva religiosa Forst. f.		X													S				
Cardiopteridaceae	Citronella suaveolens (Blume) Howard												S				S			
Cardiopteridaceae	Gonocaryum litorale (Blume) Sleumer									S	S	X	S	S						
Caricaceae	Carica papaya L.		S		S		S			S										
Caryophyllaceae	Drymaria cordata (L.) Willd. ex Roemer & Schult		S		S					S									X	
Casuarinaceae	Gymnostoma papuana (S. Moore) L.A.S. Johnson						S	X				S	S		S				S	
Celastraceae	Brassiantha pentamera A.C. Sm.							S								S				

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Celastraceae	Perrottetia alpestris (Blume) Loes.							S												
Celastraceae	Salacia erythrocarpa K. Schum.																S			
Chloranthaceae	Ascarina philippinensis C.B. Rob.							S								X				
Chloranthaceae	Ascarina sp.															X				
Chloranthaceae	Chloranthus erectus (Buch.-Ham.) Verdc.		S		S					S					S	S		X	S	
Chloranthaceae	Sarcandra glabra (Thunb.) Nakai																		X	
Chrysobalanaceae	Maranthes corymbosa Blume												S	S						
Chrysobalanaceae	Parastemon versteeghii Merr. & Perry						X									S	S			
Chrysobalanaceae	Parinari papuana C.T. White															S		X	S	
Clethraceae	Clethra canescens Reinw. ex Blume																		X	
Clusiaceae	Calophyllum papuanum Lauterb.			X	S	S														
Clusiaceae	Calophyllum soulattri Burm.				S	S						X			S	S				
Clusiaceae	Calophyllum sp.				S	S														
Clusiaceae	Garcinia celebica L.											X								
Clusiaceae	Garcinia cymosa (K. Schum.) I.M. Turner & P.F. Stevens								X											
Clusiaceae	Garcinia dulcis (Roxb.) Kurz														X	S				
Clusiaceae	Garcinia hollrungii Lauterb.		S									X		S		X				
Clusiaceae	Garcinia hunsteinii Lauterb.											X								
Clusiaceae	Garcinia sp., sect. Cambogia			S			S						S				X			
Clusiaceae	Garcinia spp.		S		X	S	X				S									
Combretaceae	Combretum tetralophum C.B. Clarke				S			S												
Combretaceae	Combretum trifoliatum Vent.		S					S												
Combretaceae	Quisqualis indica L.		X		S			S	S	S										
Combretaceae	Terminalia canaliculata Exell		S					S	S											
Combretaceae	Terminalia complanata K. Schum.		S					X	S	S				S	S					
Combretaceae	Terminalia impediens Coode						S			S										
Combretaceae	Terminalia oreadum Diels																	X		

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Combretaceae	Terminalia rubiginosa K. Schum.													X	S					
Connaraceae	Connarus sp., “semidecandrus group”								S						S					
Connaraceae	Rourea minor (Gaertn.) Leenh.							S												
Connaraceae	Rourea radlkoferiana K. Schum.															S				
Convolvulaceae	Ipomoea aquatica Forssk.		S		S		S	X												
Convolvulaceae	Ipomoea batatas (L.) Lam.		S				S			S									S	
Convolvulaceae	Ipomoea sp.		S				S		S											
Convolvulaceae	Lepistemon urceolatum (R. Br.) F. Muell.							S												
Convolvulaceae	Merremia gemella (Burm. f.) Hallier f.				S	S		S												
Convolvulaceae	Merremia peltata (L.) Merr.		S		S	S	S	S	S	S	S								S	
Convolvulaceae	Operculina sp.							S		S	S									
Cornaceae	Mastixia kaniensis Melch.					S							S		S	X	S			
Crypteroniaceae	Crypteronia cumingii (Planch.) Planch. ex Endl.											X	X		S	S			S	
Cucurbitaceae	Benincasa hispida (Thunb.) Cogn.		S																	
Cucurbitaceae	Citrullus vulgaris Schrad.		S																	
Cucurbitaceae	Cucumis sativus L.		S				S													
Cucurbitaceae	Neoalsomitra trifoliolata (F. Muell.) Hutch.					S	S	S	X											
Cucurbitaceae	Trichosanthes sp.								S			X						X	S	
Cucurbitaceae	Zanonia indica L.		X																	
Cucurbitaceae	Zehneria sp.					S	S	S						S				S		
Cunoniaceae	Acsmithia reticulata (Schltr.) Hoogland																	X		X
Cunoniaceae	Aistopetalum multiflorum Schltr.											X								
Cunoniaceae	Aistopetalum viticoides Schltr.															X		X		
Cunoniaceae	Ceratopetalum succirubrum C.T. White	VU								S						X		X		
Cunoniaceae	Gillbeea papuana Schltr.											S								
Cunoniaceae	Opocunonia nymanii (K. Schum.) Schltr.															X		X		X
Cunoniaceae	Pullea glabra Schltr.															X		X		X
Cunoniaceae	Schizomeria sp.															X			S	X

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Cunoniaceae	Weinmannia fraxinea (D. Don) Miq.							S	S		S			S		X		X	S	S
Cunoniaceae	Weinmannia urdanetensis Elmer																	S		X
Daphniphyllaceae	Daphniphyllum gracile Gage																	S		S
Datiscaceae	Octomeles sumatrana Miq.		S		S		S	S	S		S	S			S					
Dichapetalaceae	Dichapetalum papuanum (Becc.) Boerl.														X		X			
Dichapetalaceae	Dichapetalum sp.											S							S	
Dilleniaceae	Dillenia castaneifolia (Miq.) Martelli ex Dur. & Jacks.		X																	
Dilleniaceae	Dillenia montana Diels																	S		
Dilleniaceae	Dillenia sp.		S		S		S		S	S	S	S	S	S		S				
Dilleniaceae	Tetracera lanuginosa Diels		S															X	S	
Dilleniaceae	Tetracera nordtiana F.Muell.				X		S			S					X				S	
Dipterocarpaceae	Anisoptera thurifera (Blanco) Blume											X			S					
Dipterocarpaceae	Hopea iriana Slooten														X					
Dipterocarpaceae	Hopea sp.				S					S		S	S	S	S					
Dipterocarpaceae	Vatica rassak (Korth.) Blume		X	S	S	S	S	S	S	S	S		S	S	S					
Ebenaceae	Diospyros buxifolia (Blume) Hiern.						S	X		S										
Ebenaceae	Diospyros fusicarpa Bakh.											X			X					
Ebenaceae	Diospyros papuana Valeton		S					S		S		X		S						
Ebenaceae	Diospyros sp. nov.																	X		X
Elaeocarpaceae	Aceratium brassii A.C. Sm.																	X		X
Elaeocarpaceae	Aceratium cf. ledermannii Schltr.											X								
Elaeocarpaceae	Aceratium oppositifolium DC.					X		S		S			S	S	S	X				
Elaeocarpaceae	Aceratium pittosporoides Schltr.					X				X		X				X			S	
Elaeocarpaceae	Elaeocarpus angustifolius Blume		S				S	S		S	S	S		S	S	S				
Elaeocarpaceae	Elaeocarpus bilobatus Schltr.															X		X		
Elaeocarpaceae	Elaeocarpus branderhorstii Pulle							X												
Elaeocarpaceae	Elaeocarpus culminicola Warb.															S		S		S

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Elaeocarpaceae	Elaeocarpus dolichodactylis Schltr.											S	S		S		X			
Elaeocarpaceae	Elaeocarpus dolichostylis Schltr.		S					X												
Elaeocarpaceae	Elaeocarpus ledermannii Schltr.											X	X	S						
Elaeocarpaceae	Elaeocarpus miegei Weibel															X		X		
Elaeocarpaceae	Elaeocarpus peistocarpus Schltr.							X												
Elaeocarpaceae	Elaeocarpus polydactylis Schltr.																	X		
Elaeocarpaceae	Elaeocarpus prafiensis Weibel							X												
Elaeocarpaceae	Elaeocarpus schlechteranus A.C. Sm.																	X	X	
Elaeocarpaceae	Elaeocarpus sepikanus Schltr.		S			S				S			S			X				
Elaeocarpaceae	Sericolea micans Schltr.															X		S		X
Elaeocarpaceae	Sloanea cf. aberrans (Brandis) A.C. Sm.																	X	S	S
Elaeocarpaceae	Sloanea paradisearum F. Muell.											X								
Elaeocarpaceae	Sloanea pulchra (Schltr.) A.C. Sm.							X						S		S			S	
Elaeocarpaceae	Sloanea sogerensis Baker f.		S			S	S	X			S					S			S	
Elaeocarpaceae	Sloanea sp.		S													S		S		S
Ericaceae	Dimorphanthera brevipes Schltr.												X					X		X
Ericaceae	Dimorphanthera denticulifera Sleumer																	X		X
Ericaceae	Dimorphanthera kempteriana Schltr.																			X
Ericaceae	Diplycosia edulis Schltr.															X				X
Ericaceae	Diplycosia morobeensis Sleumer												X							
Ericaceae	Diplycosia rufescens Schltr.															X		X		X
Ericaceae	Rhododendron macgregoriae F. Muell.														S	X	S	X		X
Ericaceae	Rhododendron zoelleri Warb.															X				
Ericaceae	Vaccinium finisterrae Schltr.																	X		
Ericaceae	Vaccinium sp. A, sect. Oarianthe																	X		X
Ericaceae	Vaccinium sp. B, sect. Bracteata																	X		X
Erythroxylaceae	Erythroxylum ecarinatum Burck												X							
Euphorbiaceae	Acalypha hellwigii Warb.											X			X					

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Euphorbiaceae	Acalypha longispica Warb.																	X		
Euphorbiaceae	Actephila lindleyi (Steud.) Airy Shaw											X								
Euphorbiaceae	Agrostistachys borneensis Becc.					S			X	X						X				
Euphorbiaceae	Annesijoa novoguineensis Pax & Hoffm.												X							
Euphorbiaceae	Antidesma excavatum Miq.					S			X		X						X		X	
Euphorbiaceae	Antidesma rhynchophyllum K. Schum.			X																
Euphorbiaceae	Aporosa lamellata Airy Shaw											X								
Euphorbiaceae	Aporosa laxiflora Pax & Hoffm.							S				X								
Euphorbiaceae	Aporosa papuana Pax & Hoffm.						S			S		S	S							
Euphorbiaceae	Baccaurea papuana F.M. Bailey		X					S						S						
Euphorbiaceae	Breynia cernua (Poir.) Müll. Arg.		S		S		S	X		S						S				
Euphorbiaceae	Breynia vestita Warb.							X						X		X		S		
Euphorbiaceae	Bridelia penangiana Hook. f.		S									X								
Euphorbiaceae	Claoxylon sp.		S				X				X									
Euphorbiaceae	Cleistanthus sp.													S						
Euphorbiaceae	Codiaeum finisterrae Pax, or aff.							X												
Euphorbiaceae	Codiaeum variegatum (L.) Blume					S	S			X		S	S						S	
Euphorbiaceae	Croton muriculatus Airy Shaw							S				S								
Euphorbiaceae	Endospermum labios Schodde		S		S		S	S	S	S	S	S			S	S			X	
Euphorbiaceae	Euphorbia hirta L.				S		S			S										
Euphorbiaceae	Galearia celebica Koord.		X		S	X	S						X	S		S				S
Euphorbiaceae	Glochidion aff. chodrocarpum Airy Shaw		X						X											
Euphorbiaceae	Glochidion cf. fulvirameum Miq.														S	X				
Euphorbiaceae	Glochidion nesophilum Airy Shaw																X			
Euphorbiaceae	Glochidion novoguineense K. Schum.					S	S	X		S										
Euphorbiaceae	Glochidion perakense Hook. f.		S					X			S				X	X				
Euphorbiaceae	Glochidion sp. nov. aff. welzenii Takeuchi																	X	S	
Euphorbiaceae	Macaranga aleuritoides F. Muell.		S		S	S	S	S	S	S	S									

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Euphorbiaceae	Macaranga bifoveata J.J. Sm.				S											X			S	
Euphorbiaceae	Macaranga caudata Pax & Hoffm.							S						S		X				
Euphorbiaceae	Macaranga clavata Warb.											X				X				
Euphorbiaceae	Macaranga fallacina Pax & Hoffm.				S	S	S	X	X	S	S									
Euphorbiaceae	Macaranga gracilis Pax & Hoffm.																	X		X
Euphorbiaceae	Macaranga inermis Pax & Hoffm.				S	S	S											X	X	X
Euphorbiaceae	Macaranga lanceolata Pax & Hoffm.																	X		
Euphorbiaceae	Macaranga papuana (J.J. Sm.) Pax & Hoffm.				S		S						X	S						
Euphorbiaceae	Macaranga polyadenia Pax & Hoffm.															X		X		
Euphorbiaceae	Macaranga quadriglandulosa Warb.												S			S	X			
Euphorbiaceae	Macaranga reiteriana Pax & Hoffm.																			S
Euphorbiaceae	Macaranga strigosa Pax & Hoffm., or aff.								X		X	X							X	
Euphorbiaceae	Macaranga tessellata Gage				S	S				S			X					X	S	
Euphorbiaceae	Macaranga sp., "Longistipulata group"												S				S			
Euphorbiaceae	Mallotus floribundus (Blume) Müll. Arg.							S				X			X					
Euphorbiaceae	Mallotus paniculatus (Lam.) Müll. Arg.							S												
Euphorbiaceae	Mallotus peltatus (Geiseler) Müll. Arg.							S					S				S			
Euphorbiaceae	Mallotus penangensis Müll. Arg.											X								
Euphorbiaceae	Mallotus repandus (Rottler) Müll. Arg.							S				X								
Euphorbiaceae	Mallotus sp.					X														
Euphorbiaceae	Manihot esculenta Crantz		S		S	S	S			S									S	
Euphorbiaceae	Melanolepis multiglandulosa (Blume) Rchb. f. & Zoll.		S					S												
Euphorbiaceae	Octospermum pleiogynum (Pax & Hoffm.) Airy Shaw										S									
Euphorbiaceae	Omalanthus novoguineensis (Warb.) K. Schum.				S	S	S	S		S		X			X	S		S	S	
Euphorbiaceae	Phyllanthus ciccoides Müll. Arg.																	X		
Euphorbiaceae	Phyllanthus clamboides (F. Muell.) Diels							X												

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Euphorbiaceae	Phyllanthus rheophilus Airy Shaw						S			S		X	S		S	S			X	
Euphorbiaceae	Pimelodendron amboinicum Hassk.		S		S	S	S	S		S	S	S	S		S	S	S	S		
Euphorbiaceae	Spathiostemon javensis Bl.					X														
Euphorbiaceae	Syndrella? sp.							S												
Euphorbiaceae	Wetria insignis (Steud.) Airy Shaw											S								
Fabaceae	Abrus precatorius L.		S		S															
Fabaceae	Adenanthera novoguineensis Baker f.							X				S				S				
Fabaceae	Arachis hypogaea L.		S		S															
Fabaceae	Archidendron aruense (Warb.) de Wit							X				S			S					
Fabaceae	Archidendron clypearia (Jack) Nielsen		S			X	S	S		S		X		S	S	S		X		
Fabaceae	Archidendron lucyi F. Muell.		S		S	X	S			S					S					
Fabaceae	Archidendron sp. nov., aff. A. bellum Harms												S						X	
Fabaceae	Cassia alata L.		S		S		S	X		S										
Fabaceae	Clitorea ternatea L.		S																	
Fabaceae	Crotalaria pallida Ait.		S					S												
Fabaceae	Dahlbergia spp.		S				S	S		S				S						
Fabaceae	Derris elegans Grah. ex Benth.							S				S								
Fabaceae	Derris sp.					S	S													
Fabaceae	Desmodium ormocarpoides DC.					X	S					S								
Fabaceae	Desmodium sp.		S		S			S												
Fabaceae	Entada pursaetha DC.		S				S	S	S				S	S	S	S				
Fabaceae	Erythrina variegata L.				S		S													
Fabaceae	Inocarpus fagifer (Parkinson ex Z) Fosberg		X																	
Fabaceae	Intsia bijuga (Colebr.) Kuntze	VU	S		S	S	S	S	S	S	S	S			S		S			
Fabaceae	Kingiodendron alternifolium (Elmer) Merr. & Rolfe											X								
Fabaceae	Leucaena leucocephala (Lam.) de Wit						S			S										
Fabaceae	Maniltoa megacephala Harms		S					S					X							
Fabaceae	Maniltoa plurijuga Merr. & Perry		S					S						S	S	S				

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Fabaceae	Maniltoa psilogyne Harms				S	S	S	S		S				S						
Fabaceae	Maniltoa schefferi K. Schum. & Hollrung				S			X		S					X					
Fabaceae	Milletia pinnata (L.) Panigrahi		S			S	S	X	S	S	S	X								
Fabaceae	Mimosa pudica L.		S							S									S	
Fabaceae	Mucuna cyanosperma K. Schum.		X																	
Fabaceae	Mucuna novo-guineensis Scheff.		S		S		S	X	S	S	S	S	S	S	S					
Fabaceae	Paraserianthes falcataria (L.) Nielsen					S	S	X	S		S	S			S	S				
Fabaceae	Phaseolus vulgaris L.		S		S		S													
Fabaceae	Pterocarpus indicus Willd.	VU	S		S	S	S	S				S			S	S				
Fabaceae	Pueraria pulcherrima (Koord.) Koord.-Schumach.				S					S										
Fabaceae	Pueraria triloba sensu Makino					S	S	X						S						
Fabaceae	Rhynchosia acuminatissima Miq.				S		S	X												
Fabaceae	Strongylodon siderospermus Cordemoy		S					S	S		S									
Fabaceae	Tephrosia vogelii Hook. f.				S		S													
Fabaceae	Tephrosia sp.				S				S	S										
Fagaceae	Castanopsis acuminatissima (Blume) A. DC.									S						S	S	S	S	S
Fagaceae	Lithocarpus celebicus (Miq.) Rehder					S				S		X				S		X	S	S
Fagaceae	Lithocarpus rufovillosus (Markgr.) Rehder																	X	S	S
Fagaceae	Nothofagus flaviramea Steenis																	X		
Gesneriaceae	Aeschynanthus spp.						S	S		X	S	S	S	S	S	S	S	S	S	S
Gesneriaceae	Agalmyla sp.						S			X		X		S	S			X		S
Gesneriaceae	Cyrtandra bracteata Warb.					S	S			S	S	S		S	S					
Gesneriaceae	Cyrtandra cf. decurrens de Vriese															X				
Gesneriaceae	Cyrtandra fusco-vellea K. Schum.										S				X			X		
Gesneriaceae	Cyrtandra hispidissima Schltr.										S							S	S	S
Gesneriaceae	Cyrtandra janowskyi Schltr., or aff.																		X	
Gesneriaceae	Cyrtandra schumanniana Schltr.						S													
Gesneriaceae	Cyrtandra sp. nov. A											X	S							

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Gesneriaceae	Cyrtandra sp. B, sect. Geodesme													S				S	X	X
Gesneriaceae	Cyrtandra spp.				X	S		S			S	S	S	S	S	S	S	S	S	S
Goodeniaceae	Scaevola oppositifolia R. Br.						S				S	S			S	S		X	X	
Haloragaceae	Gonocarpus halconensis (Merr.) Orchard																	S		S
Haloragaceae	Gunnera macrophylla Blume																	S		S
Hernandiaceae	Hernandia ovigera L.		S					S			S		S	S	S					
Himantandraceae	Galbulimima belgraveana (F. Muell.) Sprague															X		X		S
Icacinaceae	Platea excelsa Blume					S			S		S	X		S	X					
Icacinaceae	Polyporandra scandens Becc.											X								
Icacinaceae	Rhyticaryum longifolium Lauterb. & K. Schum.		S	S			S			S	S							X		
Icacinaceae	Rhyticaryum novoguineense (Warb.) Sleumer																S			
Ixonanthaceae	Ixonanthes reticulata Jack														S			S	S	
Juglandaceae	Engelhardia rigida Blume												X							
Lamiaceae	Callicarpa longifolia Lam.		S				S		S	S								X		
Lamiaceae	Clerodendrum buruanum Miq.								S		S				X					
Lamiaceae	Clerodendrum porphyrocalyx Lauterb. & K. Schum.												S		S					
Lamiaceae	Clerodendrum tracyanum (F. Muell.) Benth.		S				S			S		X								
Lamiaceae	Faradaya splendida F. Muell.		S		S		S		S	S		X								
Lamiaceae	Geunsia pentandra (Roxb.) Merr.		S				S	S	S							X			X	
Lamiaceae	Gmelina cf. ledermanni H.J. Lam		S	S	S	S	S	X	S	S		X								
Lamiaceae	Gmelina cf. moluccana Backer ex K. Heyne												S		S		S			
Lamiaceae	Hyptis capitata Jacq.				S		S	X	S	S										
Lamiaceae	Ocimum gratissimum L.																		X	
Lamiaceae	Petraeovitex multiflora Merr.														X					
Lamiaceae	Plectranthus sp.																		X	
Lamiaceae	Premna serratifolia L.		S				S	X	S	S										
Lamiaceae	Stachytarpheta jamaicensis (L.) Vahl		S		S		S			S										
Lamiaceae	Teijsmanniodendron ahernianum (Merr.) Bakh.		S			S	S	X		S	S	S			X					

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Lamiaceae	Vitex cofassus Reinw. ex Blume					S		S						S						
Lauraceae	Actinodaphne nitida Teschner						S			S	S	S	S	S	S	S		S	S	
Lauraceae	Actinodaphne tomentosa Teschner											S				S			S	
Lauraceae	Alseodaphne sp.												S		S		S		S	
Lauraceae	Beilschmiedia acutifolia Teschner													X				X		
Lauraceae	Cinnamomum eugenoliferum Kosterm.												S		S					
Lauraceae	Cinnamomum spp.							S				S	S	S	S	S	S	S	S	S
Lauraceae	Cryptocarya multipaniculata Teschner, or aff.					S	S				S					X			X	
Lauraceae	Cryptocarya cf. pusilla Teschner																	X	X	S
Lauraceae	Cryptocarya spp.					S	S	S		S	S	S	S	S	S	S	S	S	S	S
Lauraceae	Endiandra sp.											S	S		X					
Lauraceae	Litsea guppyi (F. Muell.) F. Muell. ex Forman					S				S			X	X						
Lauraceae	Litsea ledermannii Teschner											X								
Lauraceae	Litsea spp.					S	S	S		S		S	S	S	S	S	S	S	S	S
Lauraceae	Persea americana L.		S							S										
Lauraceae	Phoebe forbesii Gamble															X	X			
Lecythidaceae	Barringtonia acutangula (L.) Gaertn.		X		S			S												
Lecythidaceae	Barringtonia calyptrata (Miers.) R. Br. ex. Benth.							S												
Lecythidaceae	Barringtonia calyptrocalyx K. Schum.												X		X					
Lecythidaceae	Barringtonia josephstaalensis Takeuchi				S							X								
Lecythidaceae	Barringtonia papuana Lauterb.								X	S										
Lecythidaceae	Barringtonia sepikensis Lauterb.		S		S		S					X								
Lecythidaceae	Planchonia papuana Merr. & Perry		S		S		S	X	S	S		X		S	X					
Lentibulariaceae	Utricularia striatula Sm.																	S		
Linaceae	Hugonia jenkinsii F.Muell.		X		S			X		S										
Loganiaceae	Fagraea amabilis S. Moore																	S		S
Loganiaceae	Fagraea berteroana A. Gray ex Benth.															X				
Loganiaceae	Fagraea bodenii Wernham																	S		

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Loganiaceae	Fagraea ceilanica Thunb.		S				S			S	S		S		X	X			X	
Loganiaceae	Fagraea elliptica Roxb.									S			X							
Loganiaceae	Fagraea racemosa Jack		S	S	S	S	S	S	S	S	S	S								
Loganiaceae	Geniostoma rupestre Forst.													X						
Loganiaceae	Geniostoma weinlandii K. Schum.										X		X		X					
Loganiaceae	Neuburgia corynocarpa (A. Gray) Leenh.		S		S	S	S	X		S	S			S					X	
Loganiaceae	Neuburgia rumphiana Leenh.							S												
Loganiaceae	Strychnos axillaris Colebr.														S					
Loganiaceae	Strychnos minor Dennst.				S			S						S						
Loranthaceae	Amyema friesiana (K. Schum.) Danser						S		S	S								X		
Loranthaceae	Amyema seemeniana (K. Schum.) Danser		X			S									X					
Loranthaceae	Amyema squarrosa Danser																	X		
Loranthaceae	Cecarria obtusifolia (Merr.) Barlow															S				
Loranthaceae	Decaisnina hollrungii (K. Schum.) Barlow		S					X		S	S			S	S			X		
Loranthaceae	Decaisnina sp.																		S	
Loranthaceae	Dendrophthoe curvata (Blume) Miq.		S					S												
Loranthaceae	Macrosolen cochinchinensis (Lour.) Tiegh.														S	X				
Lythraceae	Lagerstroemia piriformis Koehne		X					S												
Magnoliaceae	Elmerrillia tsiampacca (L.) Dandy																		S	
Malpighiaceae	Ryssopterys timoriensis (DC.) Jussieu		S					S												
Malvaceae	Abroma augusta L.		S				S	S		S										
Malvaceae	Commersonia bartramia (L.) Merr.		S					S		S					S					
Malvaceae	Hibiscus archboldianus Borss. Waalk.		S			S	S	X	S					S						
Malvaceae	Hibiscus cf. d'albertisii F. Muell.														X					
Malvaceae	Hibiscus ellipticifolius Borss. Waalk.							S				X		S						
Malvaceae	Hibiscus rosa-sinensis L.		S				S													
Malvaceae	Hibiscus tiliaceus L.		S					S	S	S	S									
Malvaceae	Kleinhovia hospita L.		S				S	S	S	S										

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Malvaceae	Melochia umbellata (Houtt.) Stapf.							S												
Malvaceae	Microcos chrysothyrsa Burret											X								
Malvaceae	Microcos grandiflora Burret														X					
Malvaceae	Pterocymbium beccarii K. Schum.												S							
Malvaceae	Sida rhombifolia L.		S				S			S										
Malvaceae	Sterculia ampla Baker f.		S					X	S		S			X						
Malvaceae	Sterculia macrophylla Vent.		S		S		S	S	S	S	S	X	S		X	X	S		S	
Malvaceae	Sterculia schumanniana (Lauterb.) Mildbr.		S		S		S			S						X		X	X	
Malvaceae	Sterculia shillinglawii F.Muell.							S					X	X	X					
Malvaceae	Theobroma cacao L.		S		S		S			S										
Malvaceae	Thespesia populnea (L.) Solander ex Correa				X			X												
Malvaceae	Trichospermum pleiostigma (F. Muell.) Kosterm.		S		S	S	S	X		S	S									
Malvaceae	Triumfetta pilosa Roth					S	S			S										
Melastomataceae	Astronia atro-viridis Mansf.																	X		X
Melastomataceae	Astronia crassiloba J.F. Maxwell																	X		
Melastomataceae	Astronia grandiflora J.F. Maxwell																	X		
Melastomataceae	Astronia hollrungii Cogn.																S		X	
Melastomataceae	Astronia rugata J.F. Maxwell							X												
Melastomataceae	Astronia sp.									X	X									
Melastomataceae	Beccarianthus sp. A																			S
Melastomataceae	Beccarianthus sp. B				S	S				S						S				
Melastomataceae	Catanthera longistylis (Mansf.) Nayar											S			X					
Melastomataceae	Catanthera paniculata (Nayar) Nayar																	S		S
Melastomataceae	Catanthera sp. nov.															S	X	S	X	
Melastomataceae	Creochiton novoguineensis (Baker f.) Veldkamp & Nayar															X				
Melastomataceae	Creochiton sp. nov.																		X	X
Melastomataceae	Diplectria divaricata (Willd.) Kuntze													X						

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Melastomataceae	Dissochaeta angiensis Ohwi											X								
Melastomataceae	Dissochaeta schumannii Cogn.										S							X		
Melastomataceae	Medinilla auriculata Lauterb., or aff.															X		X	X	
Melastomataceae	Medinilla aff. compacta Bakh. f.																	X		
Melastomataceae	Medinilla dentata Veldkamp											X						X	X	X
Melastomataceae	Medinilla rubrifructus Ohwi															X		X		
Melastomataceae	Medinilla teysmannii Miq.											S				S				
Melastomataceae	Medinilla triplinervia Cogn.													X						
Melastomataceae	Medinilla versteegii Mansf.												S		X					
Melastomataceae	Medinilla sp. A, aff. M. maluensis Mansf.							S								X		X	X	X
Melastomataceae	Medinilla sp. nov. B, sect. Heteroblemma															S		X		
Melastomataceae	Medinilla sp. nov. C, sect. Heteroblemma															S		X	X	
Melastomataceae	Medinilla sp. D, “quadrifolia group”			S		S	S				S	X						S	X	X
Melastomataceae	Melastoma malabathricum L.					S	S			S	S					S		X	X	
Melastomataceae	Memecylon cf. schraderbergense Mansf.					S	S					X				X				
Melastomataceae	Poikilogyne cordifolia (Cogn.) Mansf.															X			S	
Melastomataceae	Poikilogyne multiflora J.F. Maxwell															X				
Melastomataceae	Pternandra cf. galeata (Korth.) Ridl.				S	X	S			S						S		S	X	X
Melastomataceae	Sonerila papuana Cogn.						S						X			X				
Melastomataceae	genus nov.							X	X					X				X		
Meliaceae	Aglaia agglomerata Merr. & Perry	NT										X								
Meliaceae	Aglaia argentea Bl.						S			S										
Meliaceae	Aglaia euryanthera Harms												X							
Meliaceae	Aglaia lawii (Wight) Saldanha ex Ramamoorthy									S					X					
Meliaceae	Aglaia cf. lepiorrhachis Harms													S						
Meliaceae	Aglaia rimosa (Blanco) Merr.	NT	S				S			S	S	X								
Meliaceae	Aglaia sapindina (F. Muell.) Harms	NT								S					X					
Meliaceae	Aglaia subcuprea Merr. & Perry	NT													X					S

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Meliaceae	Aglaia subminutiflora C. DC.											X			X					
Meliaceae	Aglaia tomentosa Teijsm. & Binn.		S				S								X					
Meliaceae	Anthocarapa nitidula (Benth.) T.D. Penn. ex Mabb.		S					S			S			S						
Meliaceae	Aphanamixis polystachya (Wall.) R.N. Parker		S							S	S	S								
Meliaceae	Chisocheton ceramicus (Miq.) C. DC.							S				X		S	X					
Meliaceae	Chisocheton lasiocarpus (Miq.) Valeton, entity “weinlandi”		S				S			S				X						
Meliaceae	Chisocheton pohlianus Harms																S			
Meliaceae	Chisocheton sp. nov., aff. pachyrhachis Harms							S					X	S	X					
Meliaceae	Dysoxylum acutangulum Miq.												X							
Meliaceae	Dysoxylum alliaceum (Blume) Blume											S			S	X				
Meliaceae	Dysoxylum arborescens (Blume) Miq.											X					S			
Meliaceae	Dysoxylum brevipaniculum C. DC.							S						S						
Meliaceae	Dysoxylum excelsum Blume							S				S	X							
Meliaceae	Dysoxylum gaudichaudianum (A. Juss.) Miq.							S				S	S	X						
Meliaceae	Dysoxylum latifolium Benth.															S		S	X	
Meliaceae	Dysoxylum papuanum (Merr. & Perry) Mabb.														X					
Meliaceae	Dysoxylum parasiticum (Osb.) Kosterm.													X						
Meliaceae	Dysoxylum sparsiflorum Mabb.						X								X					
Meliaceae	Dysoxylum variabile Harms						S			S					S			X	S	
Meliaceae	Vavaea amicorum Benth.															S		S		
Menispermaceae	Chlaenandra ovata Miq.						S		S			S								
Menispermaceae	Hypserpa polyandra Becc.		S					X		S			X					X		
Menispermaceae	Legnephora minutiflora (K. Schum.) Diels																X			
Menispermaceae	Macrococculus pomiferus Becc.											S			X					
Menispermaceae	Parabaena tuberculata Becc.																X			
Menispermaceae	Pycnarrhena tumefacta Miers								X					X						
Menispermaceae	Stephania japonica (Thunb. ex Murr.) Miers				S		S									X			S	

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Menispermaceae	Stephania zippeliana Miq.											X								
Menispermaceae	Tinospora dissitiflora (Lauterb. & K. Schum.) Diels							S												
Monimiaceae	Kairoa villosa (Kaneh. & Hatus.) Renner & Takeuchi						S			X		X		S					X	
Monimiaceae	Kibara sp. nov.														X	X		X		
Monimiaceae	Kibara sp. A									S										
Monimiaceae	Levieria montana Becc.																	X		
Monimiaceae	Palmeria arfakiana Becc.															X		X		X
Monimiaceae	Palmeria hypargyrea Perkins																		X	
Monimiaceae	Steganthera dentata (Valeton) Kaneh. & Hatus.					S														
Monimiaceae	Steganthera hirsuta (Warb.) Perkins						S								S					
Monimiaceae	Steganthera hospitans (Becc.) Kaneh. & Hatus.		S				S				S	S	S		S	X	S		S	
Moraceae	Antiaropsis decipiens K. Schum.					S	X	S				S		S						
Moraceae	Artocarpus altilis (Parkins.) Fosb.		S		S		S	S		S	S									
Moraceae	Artocarpus vriesianus Miq.											S		S						
Moraceae	Broussonetia papyrifera (L.) Vent.		S						S											
Moraceae	Ficus adelpha Lauterb. & K. Schum.														X					
Moraceae	Ficus cf. adenosperma Miq.							S				X		S	S					
Moraceae	Ficus arbuscula Lauterb. & K. Schum.						S	S		S		X	S		X		S			
Moraceae	Ficus arfakensis King		S					S						S						
Moraceae	Ficus aff. aurita Reinw. ex Blume						S				S	X	S	S				X		
Moraceae	Ficus botryocarpa Miq.				S		S			S										
Moraceae	Ficus casearioides King													X						
Moraceae	Ficus chrysolepis Miq.															X				
Moraceae	Ficus copiosa Steud.											S							S	
Moraceae	Ficus disticha Blume														X					
Moraceae	Ficus glandulifera Wall. ex Miq.				S		S	S				S				S				
Moraceae	Ficus gul Lauterb. & K. Schum.				S		S									S			S	

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Moraceae	Ficus gymnorygma Summerh.													S					S	
Moraceae	Ficus cf. megalophylla Diels									X										
Moraceae	Ficus microcarpa L. f.				S															
Moraceae	Ficus mollior F. Muell. ex Benth.							X				X			S					
Moraceae	Ficus nasuta Summerh.		S					S												
Moraceae	Ficus nodosa Teijsm. & Binn.							S						S						
Moraceae	Ficus odoardi King											S		X						
Moraceae	Ficus phatnophylla Diels											X								
Moraceae	Ficus pungens Reinw. ex Blume				S		S				S	S			S					
Moraceae	Ficus septica Burm. f.				S		S			S									X	
Moraceae	Ficus subcuneata Miq.												X				X			
Moraceae	Ficus subtrinervia Lauterb. & K. Schum.						S	S		S		X				X			X	
Moraceae	Ficus subulata Blume				S		S	S		S	S	X			S					
Moraceae	Ficus trachypison K. Schum.											X								
Moraceae	Ficus virgata Reinw. ex Blume				S		S					S						X		
Moraceae	Ficus wassa Roxb.					S	S			S	S				S			X		
Moraceae	Ficus sp., "augusta facies"									S										
Moraceae	Ficus sp. A															X				
Moraceae	Ficus sp. B													X						
Moraceae	Parartocarpus venenosus (Zoll. & Moritzi) Becc.											S								
Moraceae	Prainea scandens King ex Hook. f.														X					
Moraceae	Streblus glaber (Merr.) Corner		X																X	X
Moraceae	Trophis scandens (Lour.) Hook. & Arn.							S												
Myristicaceae	Endocomia macrocoma (Miq.) de Wilde		S					S												
Myristicaceae	Gymnacranthera farquhariana Warb.		S			X	S	S	S		S	S								
Myristicaceae	Horsfieldia ampliformis de Wilde	VU																X		
Myristicaceae	Horsfieldia basifissa de Wilde							X						X						
Myristicaceae	Horsfieldia laevigata (Blume) Warb.		S		S	X		X					X							

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Myristicaceae	Horsfieldia pilifera Markgr.											X								
Myristicaceae	Horsfieldia schlechteri Warb.												X							
Myristicaceae	Horsfieldia sepikensis Markgr.	VU						X												
Myristicaceae	Horsfieldia subtilis (Miq.) Warb.					S	S	X						X	S					
Myristicaceae	Horsfieldia sylvestris (Houtt.) Warb.				S		S		S		S			S						
Myristicaceae	Myristica buchneriana Warb.	VU				X		X						X						
Myristicaceae	Myristica cornutiflora J. Sinclair													X						
Myristicaceae	Myristica dasyneura de Wilde									S										
Myristicaceae	Myristica fusca Markgr.														X					
Myristicaceae	Myristica globosa Warb.	NT										X	X		X					
Myristicaceae	Myristica lancifolia Poir.								S						X		S			
Myristicaceae	Myristica subalulata Miq.		S						S					S			S			
Myristicaceae	Myristica spp.					X	S				S									
Myrsinaceae	Ardisia forbesii S. Moore													X						
Myrsinaceae	Ardisia imperialis K. Schum.		X		S			S		X										
Myrsinaceae	Ardisia laciniata Mez																	S	X	
Myrsinaceae	Ardisia ternatensis Scheff.															X		X		
Myrsinaceae	Ardisia sp. nov. A, aff. A. forbesii S. Moore																		X	
Myrsinaceae	Ardisia sp. nov. B, aff. A. sogerensis S. Moore														X					X
Myrsinaceae	Ardisia sp. C								X											
Myrsinaceae	Conandrium polyanthum (Lauterb. & K. Schum.) Mez		S			X	S	S											S	
Myrsinaceae	Discocalyx latepetiolata (Mez) Sleumer															X		X		
Myrsinaceae	Discocalyx sp. nov., aff. D. orthioneura K. Schum.							S				X		X	X					
Myrsinaceae	Embelia cotinoides (S. Moore) Merr.							S						S				X		
Myrsinaceae	Fittingia tubiflora Mez																X			
Myrsinaceae	Maesa haplobotrys F. Muell.		S													S		S	X	X
Myrsinaceae	Maesa montis-wilhelmi P. Royen															X				

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Myrsinaceae	Myrsine acrosticta (Mez) Pipoly																	X		X
Myrsinaceae	Myrsine coriifolia (Sleumer) Pipoly																		X	
Myrsinaceae	Myrsine leucantha (K. Schum.) Pipoly															X		S	X	X
Myrtaceae	Decaspermum bracteatum (Roxb.) A.J. Scott		S			S		X												
Myrtaceae	Decaspermum sp.																			S
Myrtaceae	Kania eugenioides Schltr.															S		X	X	
Myrtaceae	Metrosideros eugenioides (Schltr.) Steenis																	X		
Myrtaceae	Metrosideros ramiflora Lauterb.							X				S				S				
Myrtaceae	Octamyrtus behrmannii Diels											S			S					
Myrtaceae	Octamyrtus pleiopetala (F. Muell.) Diels																	X		
Myrtaceae	Psidium guajava L.		S																	
Myrtaceae	Rhodomyrtus trineura (F. Muell.) F. Muell. ex Benth.															X			X	
Myrtaceae	Syzygium buettnerianum (K. Schum.) Niedenzu											X	S			S				
Myrtaceae	Syzygium cladopterum (Diels) Merr. & Perry													S						
Myrtaceae	Syzygium dictyophlebium Merr. & Perry															S		X	X	S
Myrtaceae	Syzygium effusum (A. Gray) C. Muell.			X	S		S				S	X			S				S	
Myrtaceae	Syzygium fastigiatum (Blume) Merr. & Perry														X			S		X
Myrtaceae	Syzygium furfuraceum Merr. & Perry						S												X	
Myrtaceae	Syzygium aff. hemilamprum (F. Muell. ex F.M. Bailey) Craven & Biffin			X																
Myrtaceae	Syzygium cf. hylophilum (Lauterb. & K. Schum.) Merr. & Perry													S						
Myrtaceae	Syzygium kipidamasii Takeuchi						S					X								
Myrtaceae	Syzygium lagerstroemioides Merr. & Perry															S	X		X	
Myrtaceae	Syzygium longipes Merr. & Perry				S		S	X			S	X								
Myrtaceae	Syzygium malaccense (L.) Merr. & Perry		S		S		S					X							X	

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Myrtaceae	Syzygium pachycladum (Lauterb. & K. Schum.) Merr. & Perry		S					S						S						
Myrtaceae	Syzygium plumeum (Ridl.) Merr. & Perry												S					X	S	X
Myrtaceae	Syzygium tympananthum (Diels) Merr. & Perry											X			X					
Myrtaceae	Syzygium versteegii (Lauterb.) Merr. & Perry		S		S															
Myrtaceae	Syzygium xylopiaceum (Diels) Merr. & Perry							X				X	S	S	S	X	S		X	
Myrtaceae	Syzygium spp.		S		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Myrtaceae	Xanthomyrtus cf. polyclada Diels																	X		X
Myrtaceae	Xanthomyrtus schlechteri Diels															X				
Myrtaceae	Xanthomyrtus scolopacina (Ridl.) Diels																	X	X	X
Nepenthaceae	Nepenthes ampullaria Jack			S	S	S	S			S						S		S		
Nepenthaceae	Nepenthes mirabilis (Lour.) Druce																	X		
Nepenthaceae	Nepenthes neo-guineensis Macfarlane															X		X		
Nyctaginaceae	Pisonia longirostris Teijsm. & Binn.		S		S	S	S	S		S	S	S	S	S	S	S				
Ochnaceae	Schuurmansia henningsii K. Schum.				S	S	S	S		S	S	S	S	S	S	S	S	S	S	S
Oleaceae	Chionanthus oxycarpus (Lingelsh.) Kiew																	X		
Oleaceae	Chionanthus ramiflorus Roxb.											S		S		X				
Oleaceae	Chionanthus salicifolius (Lingelsh.) Kiew											X								
Oleaceae	Chionanthus sessiliflorum (Hemsl.) Kiew						S		X			S			X					
Oleaceae	Jasminum schumannii Lingelsh.							S				X	S							
Oleaceae	Jasminum turneri C.T. White							X												
Onagraceae	Ludwigia adscendens (L.) Hara														X					
Onagraceae	Ludwigia hyssopifolia (D. Don) Exell				S		S	X	S	S										
Onagraceae	Ludwigia octovalvis (Jacq.) Raven		S		S				S	S		S						X	X	
Opiliaceae	Cansjera leptostachya Benth.											S			X					
Opiliaceae	Opilia amentacea Roxb.															X				
Oxalidaceae	Averrhoa bilimbi L.		S		S		S	X	S											
Oxalidaceae	Averrhoa carambola L.		S																	

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Oxalidaceae	Oxalis corniculata L.		S																	
Passifloraceae	Adenia heterophylla (Blume) Koord.		S		S			X	S	S										
Passifloraceae	Hollrungia aurantioides K. Schum.			S											X					
Passifloraceae	Passiflora foetida L.		S				S	X		S										
Pentaphragmataceae	Pentaphragma grandiflorum Kurz						S					S		S		S				
Piperaceae	Peperomia pellucida (L.) Kunth		S		S		S			S									X	
Piperaceae	Piper amboinense (Miq.) C. DC.				S										X					
Piperaceae	Piper betle L.		S		S		S			S									S	
Piperaceae	Piper caninum Blume		S		S		S			S	S	S	S	S	S	S				
Piperaceae	Piper celtidiforme Opiz, or aff.				S		S			S						X				
Piperaceae	Piper decumanum (Rumph.) L.											X			X					
Piperaceae	Piper interruptum Opiz															X				
Piperaceae	Piper macropiper Pennant				S	S	S	S		S	S	X		S	S	X				
Piperaceae	Piper majusculum Blume											X	X		S					
Piperaceae	Piper mestonii F.M. Bailey		S		S	S	S		S		S	X				X				
Piperaceae	Piper novo-guineense Warb.																	X		
Piperaceae	Piper pseudoamboinense C. DC.					S			S						X					
Piperaceae	Piper rodatzii K. Schum. & Lauterb.															X				
Piperaceae	Piper versteegii C. DC.																	X		
Pittosporaceae	Pittosporum pullifolium Burkill					S												X		X
Pittosporaceae	Pittosporum ramiflorum Zoll.																	X		X
Pittosporaceae	Pittosporum sinuatum Blume		S			S	S	S	S	S	S	S	S	S	S	S			S	
Polygalaceae	Epirixanthes cf. papuana J.J. Sm.																	X		
Polygalaceae	Eriandra fragrans P. Royen & Steenis								X							X				
Polygalaceae	Polygala paniculata L.		S																X	
Polygalaceae	Securidaca ecristata Kassau									X	S	X		S				X	X	
Polygalaceae	Xanthophyllum papuanum Whitm. ex Meijden											S			X	X				
Polygonaceae	Polygonum chinense L.				X															

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Polyosmaceae	Polyosma cf. cestroides Schltr.															X		X		X
Polyosmaceae	Polyosma cf. dentata Schltr.																	X		X
Polyosmaceae	Polyosma integrifolia Blume												X		X	X		S		
Polyosmaceae	Polyosma sp.																			S
Portulacaceae	Portulaca oleracea L.		S		S															
Proteaceae	Helicia odorata Diels															X		S	X	X
Proteaceae	Helicia oreadum Diels															X		X		X
Proteaceae	Helicia sp. nov., aff. H. macrostachya Lauterb.																	X	X	
Rhamnaceae	Alphitonia excelsa (Fenzl) Reiss. ex Endl.					S		S		S			X							
Rhamnaceae	Alphitonia macrocarpa Mansf.												S							
Rhamnaceae	Berchemia sp.																	S		
Rhamnaceae	Emmenosperma alphitonioides F. Muell.							S												
Rhamnaceae	Gouania microcarpa DC.							S							X	S				
Rhamnaceae	Rhamnus nipalensis (Wall.) Lawson ex Hook.															S		X	X	X
Rhamnaceae	Zizyphus angustifolius (Miq.) Hatus.		S		S			X		S										
Rhamnaceae	Zizyphus papuanus Lauterb.				S	S						S	S		S	S				
Rhizophoraceae	Carallia brachiata (Lour.) Merr.				S		S	S												
Rhizophoraceae	Gynotroches axillaris Blume		S						X	S		S	S	S	S	S			S	
Rosaceae	Prunus arborea (Blume) Kalkman								S	S	X					X		X	S	
Rosaceae	Prunus dolichobotrys (Lauterb. & K. Schum.) Kalkman									S		S	S		S		S		X	
Rosaceae	Prunus gazelle-peninsulae (Kaneh. & Hatus.) Kalkman															X				
Rosaceae	Prunus osiana Takeuchi																	X		
Rosaceae	Prunus cf. pullei (Koehne) Kalkman																	S		S
Rosaceae	Rubus moluccanus L.				S		S			S		S			S	S		S	S	S
Rosaceae	Rubus schlechteri (Koehne) Kalkman														X			S	X	

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Rousseaceae	Carpodetus arboreus (Lauterb. & K. Schum.) Schltr.												X							
Rubiaceae	Airosperma grandifolia Valeton				S	S	X					X		S	X		X			
Rubiaceae	Amaracarpus brassii Merr. & Perry																			X
Rubiaceae	Andira pseudoixoraeflora Ridsdale				S	S	X			S	S	X			X					
Rubiaceae	Antirhea sp.						X													
Rubiaceae	Argostemma bryophilum K. Schum.															X			X	
Rubiaceae	Argostemma cf. callitrichum Valeton																	X		X
Rubiaceae	Atractocarpus decorus (Valeton) C.F. Puttock											S	S	S	S	S				
Rubiaceae	Atractocarpus macarthurii (F. Muell.) C.F. Puttock											S		S			S			
Rubiaceae	Atractocarpus sessilis (F. Muell.) C.F. Puttock					S									X					
Rubiaceae	Caelospermum salomoniense (Engl.) J.T. Johansson														X			X		
Rubiaceae	Coffea arabica L.		S		S					S										
Rubiaceae	Coptosapelta fuscescens Valeton							X												
Rubiaceae	Coptosapelta hameliaeblasta (Wernham) Valeton											X								
Rubiaceae	Coptosapelta cf. maluensis Valeton													X						
Rubiaceae	Cyclophyllum cf. caudatum (Valeton) A.P. Davis & Ruhsam															X		X		
Rubiaceae	Cyclophyllum cf. longiflorum (Valeton) A.P. Davis & Ruhsam																		X	
Rubiaceae	Dolicholobium gertrudis K. Schum.							X		S										
Rubiaceae	Dolicholobium linearilobum M.E. Jansen															X		S		
Rubiaceae	Dolicholobium oxylobum K. Schum.									S					X					
Rubiaceae	Gardenia gjellerupii Valeton											X			X					
Rubiaceae	Gardenia lamingtonii F.M. Bailey												X			S				
Rubiaceae	Geophila repens (L.) I.M. Johnston													S		X				
Rubiaceae	Hedyotis lapeyrousii DC.				S	S			S		S	S		S	S	X			X	

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Rubiaceae	Hedyotis pubescens (Valeton) Merr. & Perry					S								X						
Rubiaceae	Hedyotis schlechteri (Valeton) Merr. & Perry															X				
Rubiaceae	Hydnophytum ?moseleyanum Becc.		S					S			S	S		S	S					
Rubiaceae	Hydnophytum sp.					S	S			S										
Rubiaceae	Ixora cf. leptopus Valeton												S	S						
Rubiaceae	Ixora sp.		X			S	S			S		S	S							
Rubiaceae	Lasianthus cyanocarpus Jack											X							X	
Rubiaceae	Mastixiodendron sp.					S		S		S										
Rubiaceae	Mitragyna speciosa Korth.											S			X					
Rubiaceae	Morinda bracteata Roxb.							X												
Rubiaceae	Morinda citrifolia L.		S																	
Rubiaceae	Morinda cf. glomerata (Blume) Miq.														S					
Rubiaceae	Morinda umbellata L.							S				S	S	S	S		S			
Rubiaceae	Mussaenda chrysotricha Valeton							S				S		X						
Rubiaceae	Mussaenda cylindrocarpa Burck										S				S					
Rubiaceae	Mussaenda ferruginea K. Schum.					S	S		S		S								X	
Rubiaceae	Mussaenda oreadum Wernham																	X		
Rubiaceae	Mussaenda scratchleyi Wernham								S				S							
Rubiaceae	Mycetia javanica (Blume) Reinw. ex Korth.							X			S	S			S			S	S	
Rubiaceae	Myrmecodia longissima Valeton																	X		
Rubiaceae	Myrmecodia cf. schlechteri Valeton														X					
Rubiaceae	Nauclea orientalis (L.) L.		S		S		S	S	S						S					
Rubiaceae	Nauclea sp.		S								S									
Rubiaceae	Neonauclea obversifolia (Valeton) Merr. & Perry							S						X						
Rubiaceae	Neonauclea sp.								S		S		S		S		S			
Rubiaceae	Ophiorrhiza spp.		S		S					S		S	S	S			S	S	X	
Rubiaceae	Pachystylus guelcherianus K. Schum.		S									S	S		S	S				
Rubiaceae	Pavetta platyclada Lauterb. & K. Schum.										X		X							

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Rubiaceae	Psychotria amplithyrsa Valeton		S	X				X	S										X	
Rubiaceae	Psychotria dieniensis Merr. & Perry									X										
Rubiaceae	Psychotria ectasiphylla Lauterb. & K. Schum.							S												
Rubiaceae	Psychotria leptothyrsa Miq.		S						S		X	X	S	X	X					
Rubiaceae	Psychotria leptothyrsa Miq.																	X	X	
Rubiaceae	Psychotria micrococca (Lauterb. & K. Schum.) Valeton					X						X	X		X					
Rubiaceae	Psychotria olivacea Valeton				S															
Rubiaceae	Psychotria petiolosa Valeton							X												
Rubiaceae	Psychotria ramulosa Merr. & Perry												S		X	S				
Rubiaceae	Psychotria sp. nov. A, aff. aquatilis Merr. & Perry											X		S			X			
Rubiaceae	Psychotria sp. nov. B											X						X	X	
Rubiaceae	Psychotria sp. nov. C							X						S						
Rubiaceae	Psychotria spp., climbers		S	X	X					X	S	X				X		X		X
Rubiaceae	Rothmannia macromera (Lauterb. & K. Schum.) Ridsdale												X		S					
Rubiaceae	Saprosma subrepandum (K. Schum. & Lauterb.) Valeton					S	S					X								
Rubiaceae	Schradera novoguineensis (Valeton) Puff, Buchner & Greimler			X	S	X														
Rubiaceae	Schradera ramiflora (Valeton) Puff, Buchner & Greimler									X							X			X
Rubiaceae	Tarenna buruensis (Miq.) Valeton							S												
Rubiaceae	Tarenna sp.					S	S									S				
Rubiaceae	Timonius avenis Valeton																	X		
Rubiaceae	Timonius caudatus Valeton, or aff.			X												X			X	X
Rubiaceae	Timonius flavescens (Jack) Baker																	S	X	
Rubiaceae	Timonius grandifolius Valeton				S		X	X	X	S	S	X		X				X		

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Rubiaceae	Timonius kaniensis Valeton		S			X	S							S		S				
Rubiaceae	Timonius oblongus Valeton																	X		
Rubiaceae	Timonius pubistipulis S. Darwin																	X		
Rubiaceae	Timonius secundiflorus S. Darwin													S		X			X	
Rubiaceae	Timonius subavenis (Valeton) S. Darwin							X												
Rubiaceae	Timonius timon (Spreng.) Merr.		S					S												
Rubiaceae	Timonius sp. nov., aff. grandifolius Valeton							X		S		X								
Rubiaceae	Uncaria calophylla Blume ex Korth.						S	S		S		S		S						
Rubiaceae	Uncaria cordata (Lour.) Merr.						S	S		S	X									
Rubiaceae	Uncaria lanosa Wall.		S		S	S		S	S		S	S	S	S	S	X				
Rubiaceae	Urophyllum britannicum Wernham					S					X	X								X
Rubiaceae	Urophyllum cf. glaucescens Valeton					S	S									X				
Rubiaceae	Versteegia cauliflora (Lauterb. & K. Schum.) Valeton												X							X
Rubiaceae	Versteegia ?minor Valeton																		X	
Rubiaceae	Wendlandia paniculata (Roxb.) DC.		S						S										X	
Rutaceae	Acronychia trifoliolata Zoll. & Mor.											S			X					
Rutaceae	Acronychia sp.																	S	S	S
Rutaceae	Euodia cuspidata K. Schum.											S			S					
Rutaceae	Flindersia pimenteliana F. Muell.	EN					S			S				X				X		
Rutaceae	Halfordia papuana Lauterb.	CE						X												
Rutaceae	Lunasia amara Blanco										S	S								
Rutaceae	Melicope elleryana (F. Muell.) T.G. Hartley					S		S		S		S	S	S	S	S	S			
Rutaceae	Melicope novoguineensis Valeton					S									X	X		X		
Rutaceae	Melicope xanthoxyloides (F. Muell.) T.G. Hartley											X								
Rutaceae	Melicope sp.																			S
Rutaceae	Micromelum minutum (Forst. f.) Wight & Arn.							S							X					
Rutaceae	Tetractomia tetrandrum (Roxb.) Merr.															X				
Rutaceae	Triphasia aff. brassii (C.T. White) Swingle		X																	

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Rutaceae	Wenzelia dolichophylla (Lauterb. & K. Schum.) Tanaka								X											
Sabiaceae	Meliosma pinnata (Roxb.) Maxim.		S												X	S				
Sabiaceae	Sabia pauciflora Blume						S					X								
Salicaceae	Casearia clutiaefolia Blume										S		S				S			
Salicaceae	Casearia macrantha Gilg											X								
Salicaceae	Flacourtia zippelii Slooten						S									S				
Salicaceae	Homalium foetidum (Roxb.) Benth.											S	S							
Salicaceae	Osmelia philippina (Turcz.) Benth.							S						S						
Salicaceae	Xylosma papuana Gilg															S				
Santalaceae	Cladomyza kaniensis (Pilg.) Stauffer																	X		
Santalaceae	Dendromyza sp.																	S		S
Santalaceae	Scleropyrum aurantiacum (Lauterb. & K. Schum.) Pilg.						S				S				X			X		
Sapindaceae	Alectryon sp.									X		S								
Sapindaceae	Cupaniopsis bilocularis Adema														X	X				
Sapindaceae	Cupaniopsis macropetala Radlk.							S												
Sapindaceae	Cupaniopsis stenopetala Radlk.															X			S	
Sapindaceae	Dictyoneura obtusa Blume								S			S	S							
Sapindaceae	Guioa sp.		X					S												
Sapindaceae	Harpullia arborea (Blanco) Radlk.						X					S								
Sapindaceae	Harpullia cf. cauliflora K. Schum. & Lauterb.														X	X				
Sapindaceae	Harpullia ramiflora Radlk.								S		S		S	S			S			
Sapindaceae	Jagera javanica (Blume) Kalkman		S	S	S	S										S				
Sapindaceae	Lepisanthes senegalensis (Poir.) Leenh.								X					S						
Sapindaceae	Mischocarpus sp.													S				S		S
Sapindaceae	Pometia pinnata Forst.		S		S	S	S	S	S	S	S	S	S	S	S	S	S			
Sapindaceae	Rhysotoechia sp.															S		S		

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Sapindaceae	Sarcopteryx squamosa (Roxb.) Radlk.															X				
Sapindaceae	Toechima erythrocarpum (F. Muell.) Radlk.													X						
Sapindaceae	Tristiropsis acutangula Radlk.														S					
Sapotaceae	Beccariella sp. nov.											X								
Sapotaceae	Palaquium sp.			X																
Sapotaceae	Planchonella anteridifera (C.T. White & W.D. Francis) H.J. Lam											X			X					
Sapotaceae	Planchonella firma (Miq.) Dubard												X							
Sapotaceae	Planchonella cf. obovoidea H.J. Lam											S	X				S		S	
Sapotaceae	Planchonella xylocarpa (C.T. White) Swenson															X			X	
Scrophulariaceae	Buddleja asiatica Lour.																		X	
Scrophulariaceae	Limnophila sp.						X													
Solanaceae	Capsicum anuum L.		S		S		S													
Solanaceae	Nicotiana tabacum L.		S		S		S												S	
Solanaceae	Physalis minima L.		S																S	
Solanaceae	Solanum lycopersicum L.		S				S													
Solanaceae	Solanum memecylonoides Bitter & Schltr.													S					X	
Solanaceae	Solanum oliverianum Lauterb. & K. Schum.				S	S	S						S					S	X	
Solanaceae	Solanum sp., subgenus Lycianthes									S										
Solanaceae	Solanum sp., subgenus Solanum						X													
Sonneratiaceae	Duabanga moluccana Blume				S	S		S												
Sphenostemonaceae	Quintinia ledermannii Schltr.															X		S		X
Sphenostemonaceae	Sphenostemon papuanum (Lauterb.) Steenis															S		S	S	S
Staphyleaceae	Turpinia pentandra (Schltr.) B.L. Linden														S					
Stemonuraceae	Gomphandra australiana F. Muell.						S								X	X				
Stemonuraceae	Gomphandra montana (Schellenb.) Sleumer																		X	
Stemonuraceae	Medusanthera laxiflora (Miers) Howard		S			S			X		S				S					
Stemonuraceae	Stemonurus monticolus (Schellenb.) Sleumer						X	S	X											

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Styracaceae	Bruinsmia styracoides Boerl. & Koords.																		S	S
Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore													S						
Tetrameristaceae	Tetramerista glabra Miq.			X	X	X														
Theaceae	Eurya tigang K. Schum. & Lauterb.											S				X				X
Theaceae	Eurya sp.																	S	S	S
Theaceae	Gordonia papuana Kobuski															S		S	S	S
Theaceae	Ternstroemia britteniana F. Muell.															X				
Theaceae	Ternstroemia cherryi (F.M. Bailey) Merr.																		X	
Theaceae	Ternstroemia merrilliana Kobuski													X		S				
Thymelaeaceae	Gyrinops ledermannii Domke							X						S				S		
Thymelaeaceae	Phaleria coccinea (Gaudich.) F. Muell.								X	S		X								
Thymelaeaceae	Phaleria macrocarpa (Scheff.) Boerl.							S												
Trimeniaceae	Trimenia papuana Ridl.									S						S		X	S	X
Ulmaceae	Celtis latifolia (Blume) Planch.											S		S	S					
Ulmaceae	Celtis philippensis Blanco						S						X	X						
Ulmaceae	Celtis rigescens (Miq.) Planch.															X		S		
Ulmaceae	Gironniera celtidifolia Gaudich.											X								
Ulmaceae	Gironniera hirta Ridl.											X			X					
Ulmaceae	Gironniera rhamnifolia Blume														X	S				
Ulmaceae	Gironniera subaequalis Planch.									S			S	S		S				
Ulmaceae	Parasponia sp.													S						
Ulmaceae	Trema cannabina Lour.						S	S		S					X					
Ulmaceae	Trema orientalis (L.) Blume											X								
Urticaceae	Cypholophus sp.														S					
Urticaceae	Dendrocnide sp.				S		S	S												
Urticaceae	Elatostema angulare H.J.P. Winkl.										S				X			S		
Urticaceae	Elatostema beccarii H. Schroet.													X						
Urticaceae	Elatostema macrophylla Brogn.									S	S									

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Urticaceae	Elatostema novo-guineense Warb.					S			S			S				S		S	S	
Urticaceae	Elatostema sesquifolium (Reinw.) Hassk.						S		S	S								S	S	
Urticaceae	Elatostema weinlandii K. Schum.										S	X								
Urticaceae	Elatostema spp.							S				S	S	S	S	S	S	S	X	S
Urticaceae	Laportea decumana (Roxb.) Wedd.		S		S	S	S					X							S	
Urticaceae	Leucosyke capitellata (Poir.) Chew		S		S		S	S			S		X							
Urticaceae	Nothocnide melastomatifolia (K. Schum.) Chew							X				X								
Urticaceae	Nothocnide repanda (Bl.) Bl.						X													
Urticaceae	Pilea sp.														S			S		
Urticaceae	Pipturus argenteus (Forst. f.) Wedd.										S			S						
Urticaceae	Poikilospermum amboinense Zipp. ex Miq.		S		S		S	S		S	S		X	S	S					
Urticaceae	Poikilospermum inaequale Chew																	S	X	
Urticaceae	Poikilospermum paxianum (H.J.P. Winkl.) Merr.																	S		
Urticaceae	Procris frutescens Blume										S	X			X					
Urticaceae	Procris gruningii H.J.P. Winkl.																		X	
Urticaceae	Villebrunea rubescens (Blume) Blume		S										X							
Violaceae	Rinorea horneri (Korth.) Kuntze														S					
Vitaceae	Ampelocissus muelleriana Planch.								X					S	S			S		
Vitaceae	Cayratia geniculata (Blume) Gagnep.					S									X					
Vitaceae	Cayratia japonica (Thunb.) Gagnep.		S		S						S				X					
Vitaceae	Cayratia trifolia (L.) Domin		S				S					X								
Vitaceae	Cissus aristata Blume							S							S					
Vitaceae	Cissus javana DC.				S							S								
Vitaceae	Leea coryphantha Lauterb.		S		S	S	S	S		S			X	S	S					
Vitaceae	Leea indica (Burm. f.) Merr.		S		S		S	S	S	S	S	S	S		S		S		S	
Vitaceae	Leea zippeliana Miq.		S								S		X	S	S					
Vitaceae	Nothocissus penninervis (F. Muell.) Latiff		S			S	S	S		S		S		S			X			
Vitaceae	Tetrastigma lauterbachianum Gilg		S		S		S	S		S	S	S	S	S	S				S	S

FAMILY	SPECIES	IUCN STATUS	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	NENA D2	HI	NENA BASE	NENA LIMESTONE
Winteraceae	Drimys piperita Hook. entity myrtoides Vink																			X
Winteraceae	Dryadodaphne novoguineensis (Perkins) A.C. Sm.																	S		S
Winteraceae	Zygogynum sp. nov. A						X						S		X		S			
Winteraceae	Zygogynum sp. B																	X	S	X
Winteraceae	Zygogynum sp. C								X											

note: entriesd are S = specimen collected, X = sighting. IUCN: CR - Critically Endangered, EN - endangered, VU - vulnerable, NT - not threatened.

Appendix 2.2. Modern Plant Records from the Ambunti-Hunstein District

TAXON	COMMENTS
Achariaceae	
Ryparosa sp. nov.	Hunstein; det. P.F. Stevens on Takeuchi 4817.
Annonaceae	
Pseuduvaria sp. nov.	Waskuk, det. R. Saunders on Takeuchi 17233 and 17430.
Apocynaceae	
Hoya sp. nov.	Hunstein, det. D. Liddle on Takeuchi 4546.
Marsdenia ambuntiensis P.I. Forst.	Ambunti, known only from the type (Hoogland & Craven 10163). Discussion in Forster (1995).
Clusiaceae	
Mammea papuana (Laut.) Kosterm.	Hunstein-April River, known from two collections. The species was described from Ledermann 9422 and rediscovered at nearby Mt Hunstein in 1966 (Stevens, 1974, 1995).
Elaeocarpaceae	
Elaeocarpus sp. nov.	Hunstein summit ridge, 4°30.39' S, 142°43.47' E; det. WT on Takeuchi 6806.
Euphorbiaceae	
Glochidion sp. nov.	Hunstein ridge, 4°31.44' S, 142°40.51' E; det. M. Balgooy on Takeuchi 6211.
Macaranga brachytricha Airy Shaw	Ambunti, 4°11'14" S, 142°44'55" E; previously known from two specimens; det. WT on Takeuchi 10154.
Fabaceae	
Acacia pluriglandulosa Verdc.	near Ambunti, typified from Hoogland & Craven 10334 (Verdcourt, 1978) but also with confirmed occurrences in the Jayapura area.
Derris sp. ?nov.	Waskuk, 4°11' S, 142°44' E (e.g., Regalado & Takeuchi 1487, Takeuchi 17831) and other districts, possibly new but status uncertain without fruits (Verdcourt, 1979; Adema, 2003). Listed as *Derris* sp. B in Verdcourt (1979).
Gesneriaceae	

Cyrtandra aff. *bracteata* Warb.	Waskuk, 4°11’ S, 142°44’ E, new subspecies; det. WT on Takeuchi 10126, 10148, 10180, 10181.
Cyrtandra sp. nov.	Hunstein ridge, scattered between 4°30.49’ S, 142°43.62’ E and 4°31.30’ S, 142°40.86’ E.
Sepikea cylindrocarpa Warb.	Hunstein ridge, scattered between 4°30.49’ S, 142°43.62’ E and 4°31.30’ S, 142°40.86’ E; rediscovery of lost endemic genus; det. B.L. Burtt onTakeuchi 5108, 5260.
Grammitidaceae	
Grammitis taeniophylla Parris	Mt Hunstein, typified from Hoogland & Craven 11034 in Parris (1983), also known from one collection in Irian Jaya.
Icacinaceae	
Medusanthera sp. nov. Takeuchi 6230.	Hunstein ridge, 4°30.39’ S, 142°43.51’ E; det. WT on
Loranthaceae	
Scurrula sp. Takeuchi 6905.	Hunstein, PNG generic record, det. P.F. Stevens on
Melastomataceae	
Astronidium circumscissum Maxw.	Mt Hunstein, E ridge 4°31’ S, 142°40’ E, type locality (Maxwell & Veldkamp, 1990), also occurs in Western Highlands Province.
Beccarianthus rufo-lanatus Maxw.	Mt Hunstein, E ridge 4°31’ S, 142°40’ E, known only from the type collection (Hoogland & Craven 10832). Discussion in Maxwell and Veldkamp (1990).
Creochiton ledermannii Mansf.	April River, apparently restricted to this area; det. WT on Takeuchi 6291. var. *turbinata* Maxw.
Pternandra sp. nov.	Bugabugi at Natawe, 4°33’11” S, 142°34’22” E; also at Okahsa, 4°33’22” S, 142°34’50” E; det. S. Renner (pers. comm., ca. May, 2002) on Takeuchi 10360.
Meliaceae	
Dysoxylum sparsiflorum Mabb.	Hunstein River, typified from Hoogland & Craven 10601 (Mabberley, 1994), also with one collection from Irian Jaya.
Myristicaceae	
Myristica dasycarpa de Wilde	Waskuk, 4°11’ S, 142°44’ E, typified from Regalado & Takeuchi 1520 (in de Wilde, 1998), common through area.
Myristica fasciculata de Wilde	Hunstein, described from Hoogland & Craven 10400 (in de Wilde, 1998), restricted to upper Sepik.
Paramyristica sepicana	monotypic genus known only from the Hunstein River; in de Wilde (1994).
Myrtaceae	
Syzygium lamprophyllum Diels	Hunstein, rediscovery of a Ledermann species lost at Berlin and unmatched by Hartley and Perry (1973); det. WT on Takeuchi 4913.
Syzygium purpuricarpum	known only from Mt Hunstein, typified from Takeuchi 5342 (Snow & Craven, in

	Snow & Craven press).
Syzygium sp. nov.	known only from Mt Hunstein; det. WT on Hoogland & Craven 10854.
Piperaceae	
Piper sp. nov.	Hunstein ridge, 4°30.49' S, 142°43.62' E; det. M. Jebb on Takeuchi 5070.
Proteaceae	
Bleasdalea papuana (Diels) Domin	Mt Hunstein, IUCN-listed as endangered, det. WT on Takeuchi 5107, 5336, 6284, 6956.
Rosaceae	
Prunus sp. nov.	Hunstein endemic, sp. D in Kalkman (1993), det. WT on Takeuchi 5111, 5232.
Rubiaceae	
Myrmephytum sp. nov.	Gahom, 4°37.81' S, 142°44.91' E; generic record for PNG, det. M. Jebb onTakeuchi 6661.
Psychotria yapaensis Sohmer	Hunstein River, typified from Hoogland & Craven 10802 (in Sohmer, 1988), also known from one collection in Irian Jaya.
Psychotria sp. nov.	Hunstein, det. WT on Takeuchi 4756.
Timonius longifolius Valeton	Hunstein River, rediscovery of lost Ledermann species, Hoogland & Craven 10663 designated as neotype (Darwin, 1994).
Genus nov. (distr. as "*Randia*")	Hunstein, a distinctive novelty with 8-ridged fruits recalling a cacao; det. WT on Takeuchi 4822, 6706, also represented by NGF 18025.
Sapotaceae	
Beccariella sp. nov.	Ambunti, det. U. Swenson on Takeuchi 17700.
Pouteria lamii Baehni	Hunstein summit ridge, 4°31.30' S, 142°40.86' E (Camp 4); rediscovery of lost German species, Takeuchi 6442 designated as neotype in Vink (2002).
Tectaria Group	
Chlamydogramme hollrungii	Waskuk, three collections known (Holttum, 1991a, b), det. WT on Takeuchi (Kuhn) Holttum 17176, 17741.
Winteraceae	
Zygogynum sp. nov.	Gipa, 4°28.11' S, 142°43.51' E, det. WT on Takeuchi 4811, 6104, distinctive sp. with large leaves and long pendulous inflorescence.

Chapter 3 Mammals

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A report prepared for Coffey Environments and

Frieda River Limited

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ACRONYMS, ABBREVIATIONS, DEFINITIONS AND NOMENCLATURE

Acronyms and abbreviations

CI RAP	Conservation International Rapid Assessment Programme
CR	Species classified as Critically Endangered by the 2011 IUCN Red List of threatened species (http://www.redlist.org/)
DD	Species classified as Data Deficient by the 2011 IUCN Red List of threatened species (http://www.redlist.org/)
EN	Species classified as Endangered by the 2011 IUCN Red List of threatened species (http://www.redlist.org/)
IUCN	International Union for Conservation of Nature
KICDP	Kikori Integrated Conservational and Development Project
LC	Species classified as Least Concern by the 2011 IUCN Red List of threatened species (http://www.redlist.org/)
LNG	liquefied natural gas
NE	Not evaluated for the 2011 IUCN Red List of threatened species
NT	Species classified as Near-threatened by the 2011 IUCN Red List of threatened species (http://www.redlist.org/)
P	Species classified as 'protected' under the PNG *Fauna (Protection and Control)Act 1966* .
ROW	Right-of-Way
sp.	Species
VU	Species classified as Vulnerable by the 2011 IUCN Red List of threatened species (http://www.redlist.org/)

Definitions

alluvial	a landform or process related to the activity of streams or rivers.
arboreal	living mainly above the ground, climbing in shrubs or trees.
colluvial	a landform or process related to the action of gravity and local runoff on hill slopes.
congener	a member of the same genus.
endemic	restricted to a certain area, e.g. endemic to New Ireland.
karst	a landscape that owes its character to solution by rainwater or groundwater, usually with a limestone substrate
Melanesia	the large island of New Guinea plus its satellite islands to the west and east, as far as New Caledonia.
metapopulation	a group of populations that are linked by regular two-way interchange of individuals by immigration/emigration.
New Guinea	the large island of New Guinea (PNG + Indonesian West Papua).
nocturnal	active between dusk and dawn.
non-volant	not capable of flight.
PNG	the Independent State of Papua New Guinea
PNG (mainland)	the mainland portion of PNG.
reproductive potential	the intrinsic capacity for a species to undergo population growth, determined by such factors as gestation period, number of young produced, period between pregnancies etc.
scansorial	essentially terrestrial but often climbing in low vegetation.

sympatric	living close together in the same locality.
terrestrial	living on the ground, non-climbing.
vicar	an ecological equivalent
volant	capable of flight.
WWF	World Wide Fund for Nature.

Nomenclature

The scientific names used in this report are generally those contained within the 2011 IUCN Red List of threatened species (http://www.redlist.org/; henceforth, the IUCN Red List). Where the usage departs from this listing, it is because recent taxonomic revision has favoured an alternative arrangement. In such cases, the more recent authority is cited.

There is no formal code that governs the use of English or 'common' names for species and hence, no standardisation of usage among different sources. The IUCN Red List includes a preferred English name but some of these are cumbersome and replace other names in general usage with no apparent reason, while some species are not assigned an English name. The tree kangaroo *Dendrolagus notatus* does not seem to have attracted a common name; we refer to it as the Western Montane Tree Kangaroo.

EXECUTIVE SUMMARY

This chapter contains a characterisation of the mammal fauna of the Study Area, including both terrestrial/ arboreal and volant groups. The characterisation contains two core components: 1) a biogeographic analysis of the regional mammal fauna, from which a list of potential 'Candidate Mammal List' is compiled for the Study Area; and 2) results of a systematic field survey at eighteen sites within the Study Area across an range of 30 – 1100 m elevation, supplemented with opportunistic observations at four other localities and information obtained through interviews with residents of five villages within the Study Area. The study represents the largest systematic survey undertaken to date of a lowland to Hill Zone mammal fauna in PNG.

The Study Area supports largely intact forest habitats with only small areas of disturbance including areas under traditional subsistence activities of local residents who live in small scattered villages.

The biogeographic analysis predicts that the Study Area could support up to 140 mammal species: 80 non volant mammals and 60 bats. The mammal faunas of the Study Area Lowland and Hill Zones are expected to have strong commonality with large regions of the northern lowlands and foothills of the Central Cordillera, spanning all three major drainage basins of northern New Guinea – the Mamberamo in the west, the Sepik River itself, and the Ramu to the east. The mammal fauna of the Study Area Montane Zone is expected to have close affinity with the montane mammal fauna of the Central Cordilleran ranges as a consequence of broad continuity of montane habitats during the last glacial period, with connectivity disrupted as frequently as 10,000 year ago with upslope expansion of Hill Zone habitats.

The biogeographic analysis further predicts that the Study Area is likely to support populations of 28 species listed as other than Least Concern in the 2011 IUCN Red List of threatened species (http://www.redlist.org/), and six species listed as Protected under the PNG *Fauna (Protection and Control)Act 1966.* This includes a Critically Endangered Long-beaked Echidna (*Zaglossus* sp.), the Black-spotted Cuscus (*Spilocuscus rufoniger*) the Telefomin Cuscus (*Phalanger matanim*) and Bulmer's Fruit Bat (*Aproteles bulmerae*); the Endangered Goodfellow's Tree Kangaroo (*Dendrolagus goodfellowi*); and the Vulnerable Western Montane Tree kangaroo (*Dendrolagus notatus*).

The survey activities produced a total of 81 species. There were confirmed records of 31 non-volant mammals and a further nine non-volant mammals are listed as likely to occur in the Study Area based on unambiguous and plausible accounts by local residents. 41 species of bats were recorded, twelve of which were documented only from unidentified acoustic recordings.

Most of the mammals detected in the Study Area were predicted by the biogeographic analysis. Exceptions include five previously unrecognised mammal species (two small rodents, one small marsupial and two bats), all of which are likely to have broader geographic distributions along the northern foothills of the Central Cordillera of New Guinea.

Mammal habitats in the Study Area are in very good condition, with only localised areas of human disturbance and low levels of human disturbance away from the immediate vicinity of villages. The low level of human disturbance of Lowland and Hill Zone habitats is reflected in high species diversity. Many species of non-volant mammals appear to be in naturally very low population densities. By contrast, species diversity and population densities were both exceptionally high for small fruit bats. This is interpreted as a likely reciprocal relationship due to competition for food resources, especially fruit and blossom produced in the forest canopy. The low natural abundance of non-volant mammals in these northern New Guinean forests has broad implications for conservation and for the design of specific mitigation activities in the Study Area. Very low capture rates for insectivorous bats reflects technical difficulties of capturing these elusive animals, and was contraindicated by frequent observations of insectivorous bats in flight, particularly over clearings and along tracks. Acoustic detection methods clearly demonstrate both high local diversity and abundance of echolocating bats at all elevations in the Study Area.

The Montane Zone in the Study Area is of high conservation significance due to the likely presence of multiple species listed in a conservation category. Moreover, it has a high vulnerability on account of the isolated nature of each patch of habitat.

Ten or 11 species of mammals were recorded that are listed as other than Least Concern by IUCN or are protected under the PNG *Fauna (Protection and Control) Act* 1996 and a further 15 or 16 could occur. The Critically Endangered Black-spotted Cuscus and the Endangered Goodfellow's Tree Kangaroo species are confirmed residents of the Study Area Lowland and Hill Zones, and Montane zones, respectively. The Critically Endangered Long-beaked Echidna and the Telefomin Cuscus, and the Vulnerable Western Montane Tree Kangaroo were among the species rated as occurring in the Study Area Montane Zone, based on unambiguous and plausible informants' accounts, supported by nearby capture records. The Critically Endangered Bulmer's Fruit Bat is listed as possibly occurring in the Study Area Montane Zone based on proximity to a modern capture locality and general suitability of habitat.

Special mitigation measures are warranted for the Critically Endangered Black-spotted Cuscus, for which the Study Area may constitute an important refuge area in PNG, and for the management of large colonies of the Great Fruit Bat (*Pteropus neohibernicus*) which occupy several large camp (numbering around 100,000 individuals, probably on a seasonal basis) within the Study Area Lowland Zone.

One exotic mammal species, the Black Rat (*Rattus rattus*) was detected within the Study Area Lowland Zone, possibly restricted thus far to a Project facility at Iniok Site. This invasive and potentially destructive species needs to be eradicated as an urgent priority, and measures taken to inhibit any future invasion by this and other exotic rodent pests.

1 INTRODUCTION

1.1 Background to the Mammal Fauna

The island of New Guinea hosts an exceptionally diverse mammal fauna with very high levels of endemism at both the genus and species level (Flannery 1995; Bonaccorso 1998; Helgen 2007a). This endemism is most pronounced for monotremes, marsupials and rodents, and is somewhat less so for bats. The majority of New Guinean mammal species are obligate forest dwellers and only a small subset are capable of adapting to major changes in vegetation structure such as conversion of forest to grassland or plantation habitats (Flannery 1995; Bonaccorso 1998). Several mammal species of Asian origin have been introduced to New Guinea in prehistoric to recent time, including various rats and domesticated pig and dog, both of which have become feral.

Table 1. Conservation classifications used by the *PNG Fauna (Protection and Control)* *Act 1966* **and IUCN**

PNG FAUNA (PROTECTION AND CONTROL) ACT	
Protected (P)	Taxa declared protected.
IUCN	
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is Endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.
Least Concern (LC)	Does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.
Not Evaluated (NE)	Not yet been evaluated against the criteria.

Notes: IUCN descriptions are abridged. For a detailed explanation see IUCN. (2001). IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp. (http://www.iucnredlist.org/technical-documents/categories-and-criteria).

A significant number of New Guinean mammal species have suffered major declines in population size and geographic ranges as a consequence of over-hunting and forest destruction, and a number of these included in the 2011 IUCN Red List of threatened species (http://www.redlist.org/), and/or are recorded under the PNG *Fauna (Protection and Control)Act 1966*. Table 1 presents the categories used by IUCN.

In contrast, relatively few New Guinean mammals appear to possess genuinely small natural ranges and most of these are restricted to small patches of subalpine habitat (e.g. Giluwe Rat, *Rattus giluwensis*; Alpine Woolly Rat, *Mallomys gunung*). Two notable exceptions are the Telefomin Cuscus (*Phalanger matanim*) and Champion's Tree Mouse, both of which are currently known from small areas in the vicinity of Telefomin (Flannery 1995).

Discovery of completely new species is still relatively commonplace in New Guinean mammal research, especially when surveys are conducted in previously under-investigated areas (e.g. Helgen 2007b; Aplin and Opiang 2011; Aplin and Kale 2011). Furthermore, many groups of New Guinean mammals remain poorly studied and new sampling often invites revision of previous collections. As an example, recent studies of New Guinean 'shrew-mice' (species of *Mayermys*, *Microhydromys, Pseudohydromys*) collected since the last major revision of the 1950s resulted in an increase from six to 15 species within this group (Helgen 2005a; Helgen 2007c; Helgen and Helgen 2009; Helgen *et al.* 2010). Taxonomic uncertainties of this kind can confound a regional assessment. However, with relevant expert knowledge of existing collections and regional biogeography, it is generally possible to foresee the impact of taxonomic changes on species distributions and conservation status within any particular group.

1.2 General Features of the Study Area

The Study Area is located in the northern foothills of the Central Cordillera of Papua New Guinea (PNG) within Sandaun and East Sepik Provinces and forms part of the watershed of the Sepik River (see Chapter 1 Figures 1 to 3).

Elevations within the Study Area range from approximately 30 m elevation on the bed of the Sepik River, to around 1,500 m elevation on isolated peaks and ridges within the Study Area itself. To the south, elevated ridges provide connectivity to extensive montane habitats of the Central Cordillera.

The Study Area has been divided for analytical purposes into three zones (Chapter 1).

Study Area Lowland Zone

This comprises alluvial landforms that result from past or present overbank flooding of the Sepik River and its major tributaries, and includes active floodplains of the major channels that are subject to inundation on a seasonal or multiannual basis; and various elevated landforms including river terraces and at least one substantial peat deposit accumulated in an area lacking significant surface drainage. The upper limit of active alluviation stands at around 35 m elevation on the Sepik River, 80 m elevation at the survey locality of Frieda Bend Site on the Frieda River, and 110 m elevation in the upper reaches of major tributary streams accessed from each of the Malia Site and Upper Ok Binai Site localities. For the present purposes, survey sites situated below 100 m elevation are treated as Lowland Zone sites.

Study Area Hill Zone

This zone comprises primary erosional and colluvial (i.e. slope deposit) landforms comprising the northern foothills of the Central Cordillera. Included are both continuous hills and ranges, and isolated hills surrounded by areas of active alluviation, such as at the site of the Kaugumi Site. Much of the topography is steep, with significant stretches of cliff-line habitat. Underlying geology is highly variable and spatially complex. Of particular significance are the areas of locally karstic limestone and calcareous mudstone. The karst habitat contains important roosting habitats for bats, including several major sinkholes and many smaller clefts, caverns and tunnel caves.

Study Area Montane Zone

This consists of primary erosional and colluvial (i.e. slope deposit) landforms comprising the northern foothills of the Central Cordillera above 1,000 m elevation and is a continuation of the Study Area Hill Zone.

Vegetation of the Study Area is presented in Chapters 1 and 2.

For the purposes of this report, survey sites situated between 100 m and 1,000 m elevation in the Study

Area are treated as Hill Zone sites, while the one sampling site situated above 1,000 m is treated as a Montane Zone site. An additional distinction is made in various parts of the report between the Hill Zone survey sites situated below and above 500 m elevation to explore whether or not the broad elevation range of the Hill Zone (100 – 1,000 m) conceals significant variation in mammal diversity.

1.3 Previous work in the Study Area and Surrounding Regions

The Study Area has not been subject to any previous systematic mammal survey or any significant casual visitation by mammalogists. To the best of our knowledge, a brief visit to the Frieda Base by Dr Patricia Woolley (La Trobe University) between 28 February and 4 March 1983 represents the only previous work by a professional mammalogist within the Study Area. Woolley was interested only in securing specimens of the Three Striped Dasyure (*Myoictis melas*) and was unsuccessful in this venture.

The anthropologist George Morren worked out of the Miyan village of Hotmin (on the western side of the Study Area) in the early 1970s, researching issues of human ecology in the Hill Forest habitat of PNG (Morren 1977, 1979, 1986). His output included a useful list of local mammals with local Miyan names (Morren 1989) and some information on traditional hunting techniques. Some of Morren's records are supported by voucher specimens now held by the PNG National Museum and Art Gallery.

Further afield, important sources of information include mammal survey work in the East Sepik Province in the 1960s by CSIRO collectors (McKean 1972), in the western Sepik lowlands and the North Coastal Ranges (Torricelli and Bewani mountains) in the mid 1980s to early 1990s by Flannery and others (Flannery and Seri 1990), in the vicinity of Telefomin by various workers from the American Museum of Natural History, Bernice P. Bishop Museum, the Australian Museum, and the PNG National Museum, in the Schrader Range (Western Highland Province) in the 1960s and 70s by Bulmer and others (Majnep and Bulmer 2007), and in the Mamberamo River basin of Indonesian West Papua in the last decade by Pattiselanno (2003). Recent work at the Mekil Research Station at 1,650 m elevation near Mt Stolle has produced some of the most detailed ecological studies conducted thus far on New Guinean mammals (e.g. Stephens 2005; Stephens *et al.* 2006); however, a general account of the local mammal community has not been forthcoming. Collectively, this body of previous work in the general region allows for development of a robust biogeographic framework for northern New Guinea.

2 OBJECTIVES AND PROJECT DESIGN

2.1 Objectives

The objectives of this assessment are to:

- Conduct mammal surveys in the Study Area.
- Characterise the mammalian fauna of the Study Area.
- Identify significant mammalian communities and habitats.
- Identify IUCN listed species and species listed as protected under the PNG *Fauna (Protection and Control)Act 1966*.
- Recommend suitable mitigations to reduce impacts on mammals.

2.2 Study Design

Comprehensive surveys of mammals in an area of the size and complexity of the Study Area would take several years of field work and is an unrealistic goal. Accordingly, an approach was formulated that made optimum use of prior knowledge of both the regional distribution of mammal species and communities, and of the susceptibility of individual mammal species and mammal communities to impacts of various kinds and severities. In this context, results of fieldwork activities can be seen as a 'test' of hypotheses generated from all available prior data.

The approach developed here begins with a biogeographic analysis of the northern foothills and lowlands of New Guinea, using knowledge of the complex geological and environmental history of the area to interpret the current pattern of distribution of mammal species and genera. This analysis generates a Candidate Mammals List for the Study Area, with separate predictions made for each of the Lowland Zone, the Hill Zone and the Montane Zone. For each zone, individual species are rated as *likely to occur, possibly occurring or unlikely to occur,* based on a range of ancillary information including details of elevational range, the area of available habitat, and likely patterns of co-occurrence within a single community.

The second step involves estimation of the likely susceptibility of individual mammal species and mammal communities to potential impacts within the Study Area, based on knowledge of what has occurred in other regions of New Guinea and elsewhere if relevant. An essential precursor to this step is identification of the potential direct and indirect impacts of the various Project activities.

The third step in the analysis involves a comparison between the Candidate Mammal List and the results of the field survey activities – with mammal species scored as either *confirmed* or *likely to occur* (e.g. based on an informant's account) within the Study Area. Through a process of reciprocal comparison, the Candidate Mammal List and the survey results can be used to assess the validity of the biogeographic hypothesis (i.e. Did the survey find any species that were not anticipated by the biogeographic analysis?) and to assess the degree of comprehensiveness of the field survey (i.e. How many predicted species were actually recorded?).

Aside from this general framework, special attention was directed at determining the status of regionally anticipated species with a 2011 IUCN Red List rating above Least Concern (Table 1 for definition of IUCN Red List categories) or a listing as Protected in the PNG *Fauna (Protection and Control)Act 1966.*

Table 2. Summary of the mammal survey effort expended at each of the survey sites in the Study Area.

	CAMP ELEVATION (M)	ELEVATION RANGE (M)	NIGHTS OF SAMPLING	NON-VOLANT MAMMAL SAMPLING EFFORT					BAT SAMPLING EFFORT					
				GROUND TRAP NIGHTS	CAGE TRAP NIGHTS	CAMERA TRAP NIGHTS	CAMERA TRAP HOURS	NIGHT TRANSECT (HRS)	MIST-NET NIGHTS	MIST-NET METRE-HRS	HARP TRAP NIGHTS	BAT DETECTOR SESSIONS	CAVE SEARCHES (CAVES)	CAVE SEARCHES (HRS)
LOWLAND ZONE SITES														
Iniok Site	45	28-50	5	584	0	9	224.25	12	21	3,384	6	4	0	0
East Sepik Site	45	35-55	5	512	15	33	685.5	13	39	4,430	7	6	0	0
Kubkain Site	50	30-135	5	190	0	21	511.25	12	6	144	0	9	0	0
Wogamush Site	55	45-120	5	57	0	24	606	12	6	144	0	10	0	0
Wario Site	65	40-335	4	124	0	17	417.5	12	24	384	0	9	0	0
Frieda Bend Site	80	77-103	5	537	15	14	540.25	12.5	40	5,247	10	9	0	0
Hotmin Village Site	83	83-100	0	0	0	0	0	0	0	0	0	0	3	2
Kaugumi Site	90	60-90	5	395	3	42	987	16	36	5,807	4	6	0	0
HILL ZONE SITES														
Ok Binai 1 Site	125	115-330	5	168	0	21	491	12	6	144	0	6	0	0
Ok Isai Site	135	100-145	6	560	14	38	891.75	14	52	6,331	12	12	0	0
Malia Site	290	281-326	8	983	14	110	2707	16.5	80	11,566	6	13	0	0
Nena D1 Site	400	376-450	3	289	8	8	182	12	19	2,500	3	8	0	0
Frieda Base	400	400-480	5	U	0	0	0	0	8	576	0	0	0	0
Upper Ok Binai Site	425	342-483	5	707	66	26	583.25	14	38	5187	9	10	0	0
Nena-Usage Site	440	380-413	1	20	0	3	55	4	2	237	1	3	0	0
Koki Site	560	530-615	5	739	17	23	526	13.5	43	6,470	3	10	0	0
HI Site	825	817-1,301	5	808	15	19	429.25	13	30	4,180	6	6	2	5
Nena Base Site	835	637-1,061	9	500	10	76	1,622.5	20	89	10,798.75	12	16	0	0
Nena Limestone Site	950	942-1,024	3	190	0	7	156.5	7	8	326	4	6	3	13
MONTANE ZONE SITES														
Nena Top Site	1,065	950-1,100	2	130	0	0	0	9	12	1,338	0	0	0	0
All Sites		**28-1,100**	**91**	**7,493**	**177**	**491**	**11,616**	**224.5**	**559**	**69,193.75**	**83**	**143**	**8**	**20**

Effort expended on village interviews is not included in this tabulation.

3 METHODS

3.1 Fieldwork Schedule and Locations

Fieldwork was conducted during four periods (Chapter 1). Most survey effort was expended at 18 systematic survey sites distributed across the Study Area (Chapter 1 Table 4), with each site surveyed for periods ranging between one and six nights. All but two sites received a minimum of three nights of effort. Information on mammal distributions was further gathered through opportunistic sampling at three other localities and through interviews with local residents of five villages in the Study Area.

Details of the effort expended at all mammal survey sites are given in Table 2 and the position of each site is shown in Chapter 1 Figures 4 and 5. In combination, the survey sites provided information on habitats situated between 30 m and approximately 1,300 m elevation; however, difficulty of access meant that no systematic sampling took place above 1,065 m elevation Information on the mammal fauna of higher elevation forests within and adjacent to the Study Area was obtained primarily from interviews conducted at the Miyan villages of Wameimin 1 and Wameimin 2.

The location of each systematic sampling site was decided after previous reconnaissance fieldwork, with the aim of providing access to all the major geomorphic and biotic zones within the Study Area, together with some of the more important proposed infrastructure elements. The area around each survey site was reconnoitred upon arrival and a sampling regime designed to accommodate observed diversity of habitat and microhabitat. The fieldwork on the first three trips was carried out by Ken Aplin, with assistance from Dr Michael Sale of Coffey Environments and various local Project staff. Mammal survey on the fourth trip was carried out by other team members (Stephen Richards and Chris Müller) together with the previously trained Project field staff. On all trips, other survey team members contributed reliable sight records for some species.

3.2 Survey Methods and Distribution of Effort

A variety of field methods were used with the general goal of detecting the greatest number of species:

- Trapping for non-volant mammals using various types of live and kill traps, mostly suited to capture of small non-volant mammals with body weight less than 1 kg; some larger cage traps were also deployed;
- Camera trapping for non-volant mammals (use combined with bird survey);
- Daytime patrols looking for signs and traces of mammal activity and for diurnal non-volant mammals;
- Night patrols with spotlights for nocturnal non-volant mammals;
- Interviews with experienced local hunters, both at villages and casually among field assistants employed by the Project but sourced from local villages;
- Examination of mammal remains kept in villages as hunting ‘trophies’ and of captive live animals held as pets;
- Searches for caves that might contain colonies of bats and/or predator prey remains;
- Setting of mist nets for bats;

- Setting of harp traps for bats (the same nets were commonly used for bird survey during the days); and

- Setting of AnaBat electronic bat echolocation call detectors.

Variation in effort between localities reflects judgement regarding the best use of available time at each site, given the overall study objectives and prior work within the Study Area. The following factors were taken into account:

- The degree of overlap with habitats surveyed at other sites;

- The capture returns within a given habitat or using a particular method (e.g. high returns from mist-netting on the first night might encourage the setting of additional nets);

- Distance required for travel to particular habitats; and

- Safety issues related to servicing of nets or trap lines, or daytime exploration and night patrolling.

The distribution of survey effort through the entire survey period is illustrated in Figure 1. The highest constancy of effort was maintained for night transects and AnaBat passive recording sessions. Ground and cage trapping and mist netting effort all increased during the period of the second and third survey periods (reflecting the increasing skilfulness of XFRL field assistants), and all decreased during the final survey period when the onus of mammal survey fell on other team members. Despite these fluctuations, the effort remained relatively even throughout the entire survey period for all methods.

3.2.1 Notes on Individual Survey Methods

3.2.1.1 Trapping for Non-volant Mammals

Four types of traps were used for non-volant mammals:

- Elliott live-capture traps (Figure 2a);

- Kill traps designed for domestic rat control (Snap-E Trap – rat; see Figure 2b);

- Kill traps designed for domestic mouse control (Snap-E Trap – mouse);

- Large cage traps (Figure 2c).

Traps were mostly set by Ken Aplin on Trip 1, by Ken Aplin and one or two local assistants on Trips 2 and 3, and by the same local assistants on Trip 4. A variety of baits were employed including pineapple, taro, sweet potato, rice mixed with tinned fish, rat meat, and peanut butter (usually smeared on taro or sweet potato). Traps were set in positions that were thought to be a focus of small mammal activity rather than on a regular grid or spacing. This involved searching for recent signs of small mammal activity, including active burrows or runways, feeding stations and faecal piles, as well as potential food resources such as fallen fruit. However, signs of recent activity were generally scarce and time constraints meant that many traps were placed in locations that lacked evidence of recent mammal activity. To avoid snap traps being triggered by rain, these often were placed in sheltered positions such as beneath logs.

Traps were set both on the ground and up to 2 m above ground on low tree branches, fallen trees etc. No attempt was made to place traps higher. To do so posed an unacceptable safety risk.

Total ground trapping effort across all trips and all localities amounted to 7,670 trap nights over 85 nights, including 127 cage trap nights (Table 2). More traps were set each night on the second and third trips than on the first, due to the longer time spent at camps and the higher level of local staff assistance.

3.2.1.2 Camera Trapping

Up to 12 digital camera-traps (Wildtrack Photography) were deployed each night. These were set either by ornithologist Iain Woxvold or by Ken Aplin. The majority was set on the ground along animal trails or beside forest floor pools or recent feeding debris, with a smaller number placed on fallen trees that crossed steep-sided gullies or streams. Once placed, most camera traps were left undisturbed for the duration of a campsite. Two camera traps placed at Malia Site during a reconnaissance trip in 2009 were recovered in December 2009 after an uncertain period of operation. For all other camera traps, the duration of the monitoring period was recorded, allowing imaging rates to be calculated with some precision. Details of camera trap deployment are presented in Appendix 3.1.

The total camera trapping effort (excluding the reconnaissance trip cameras set at Malia Site) amounted to 11,616 hours over 491 camera nights and at a total of 112 positions (Table 2).

Many of the mammals that might occur in the Study Area have one or more close relatives that cannot be distinguished reliably from a camera trap image. In these cases, identification is often possible to genus level only. In a few cases, identification to species level was achieved either because distinguishing features are visible in the image or because other species of the group can be discounted on distributional grounds.

3.2.1.3 Mist Nets, Harp Traps and Scoop Nets for Bats

Mist nets were used to survey both bats and birds (Figure 3), and their placement varied in accordance with this dual function. Details of mist net deployment are presented in Appendix 3.2.

For bats, mist nets are usually set to intersect flyways along streams, adjacent to rocky outcrop, along tracks, and at the edges of clearings. For birds, they are often set in dense undergrowth and at ground level. Nets set in all positions proved effective at catching bats, especially the smaller non-echolocating fruit bats which entered nets in large numbers, even those set in dense understorey. For practical reasons, nets were generally set a maximum basal height of 2m. No nets were placed in the canopy, although at Iniok Site two mist nets were set at greater height (basal heights of 3 m) on long bamboo poles, one set with a double tiered net to expand the surface area. One of these nets was placed alongside a camp facility spotlight that was seen to be attracting large numbers of insects and occasional insectivorous bats.

Two kinds of mist nets were employed; polyester nets used also for capturing birds and monofilament nets that are designed specifically for bats. The latter did not appear to be any more effective at catching echolocating insectivorous bats which seemed able to evade capture in nets.

Nets were generally checked several times in the evening through to early morning and then left open for the remainder of the night then visited within one or two hours of day break. Most captures were made in the first few hours after dusk. During Trip 4, nets were closed two hours after dusk. Mist nets were usually left in position for the duration of each camp, with effort put into erecting additional nets rather than moving nets.

At almost every site, one or two double-tiered harp traps were also employed (Figure 4). These were generally set on their legs in a narrow flyway (base of trap thus about 1 – 1.5 m above ground), with surrounding space filled by overhanging or specially cut and positioned vegetation. Harp traps were usually left in position for at least two nights. If unsuccessful over this period, they were moved to a new position. At Kaugumi Site, a harp trap was hauled by rope into the canopy in an effort to catch higher flying species. Harp traps were not employed at Kubkain Site, Wario Site, Wogamush Site and Ok Binai 1 Site. Details of harp trap deployment are presented in Appendix 3.3.

Scoop nets were used to attempt capture of bats flying at night through camp or along tracks. Although several bats were captured this way, the success rate was generally low with most species capable of avoiding a swung net.

The mist netting and harp trapping effort is summarised for each sampling locality and for the entire survey in Table 2. The combined total for all sites is 559 mist net nights (a total of 69,193 night time mist net metre-hours) and 83 harp trap nights.

3.2.1.4 Acoustic Recordings

Acoustic recordings were made with electronic bat detectors (AnaBat SD1and SD2; Titley Scientific). AnaBat SD1 and SD2 detectors were chosen over other equipment for several reasons, including their ease of use and deployment, the efficiency of data storage for long periods of survey and the efficiency of data analysis for recordings made in habitats with high levels of background noise. Full spectrum bat detectors capable of making unattended recordings and with appropriate hardware for sampling calls with a characteristic frequency over c.100 kHz became commercially available during the course of the field programme. While some testing of new models was undertaken on the two later trips, we here report only the AnaBat results to ensure standardisation across all systematic survey sites. Moreover, there is currently no published comparison of AnaBat and other newer full spectrum bat detectors which highlights the advantages of each, and we note that the response of the microphone and the sensitivity levels of each varies, making session replication and style of deployment equal in their importance to a consideration of the capabilities of the hardware.

Three AnaBat units were available for use during Trips 1–3, though on most nights only two were set, the third being held as a backup unit. On Trip 4, a fourth unit was available for use and up to three were set on any given night. They were waterproofed in plastic boxes, and microphones on an extension lead were placed in a funnel made from a plastic drink bottle, to reduce the chance of water exposure. Both regular (ST1 ‘low energy’) and Hi-Mic (‘green’) microphones were used. Details of AnaBat deployment are presented in Appendix 3.4.

The detectors were employed as passive stationary data recorders, being set in position at dusk and collected after dawn (Figure 5). The recorded bat calls are referred to here as ‘anonymously recorded’ because there is no *a priori* knowledge of the number and identity of contributing bats.

Bat detectors were placed in a variety of habitats including adjacent to streams, along tracks, on slopes facing into the forest canopy, and facing into both small and large clearings. The same position was sometimes sampled on several nights to account for different conditions (e.g. heavy or light rain).

For each AnaBat recording station a GPS position was recorded and notes made regarding the habitat in front of the unit. This was subsequently coded to produce nine habitat types, as follows:

- FC – forest canopy, usually sampled by facing the microphone downhill over a steep slope;
- FS – rapidly flowing streams within forest cover;
- FT – well-defined tracks passing below forest cover ;
- FU – understorey below forest cover;
- CL – large artificial clearings such as a helipad or major camp area;

- CR – open airspace above major river courses;
- CS – small clearings below forest cover;
- SS – slow flowing streams below forest cover; and
- SW – densely cluttered swamp habitat.

Echolocation signals were divided by a factor of 8, and stored automatically on a Compact Flash card, with each sequence of calls receiving a time and date stamp. Site details were associated with the serial number of the unit and recording date. The signals were downloaded using CFC Read 4.2a or 4.3r.

The recording effort is summarised for each sampling locality and for the entire survey in Table 2. The total recording effort on this survey was 143 AnaBat recording 'sessions' (one session is a full night's recording for one unit), which equates to an average of just under two sessions per night.

Whenever possible, reference echolocation calls were recorded from individuals captured during the survey. Recordings were made with AnaBat SD1 units, and also a Pettersson D240x time expansion recorder (Pettersson Electronics and Acoustics AB) connected to an Roland Edirol R-09HR digital recorder (sampling rate of 96 kHz, 16 bit resolution). For nasal-emitting bats that produce calls dominated by a constant frequency (CF) component, individuals were recorded while stationary and hanging freely in a voluminous mesh bag. When at rest and scanning their surroundings, CF-emitting bats produce calls where the dominant frequency is stable and almost matched to their acoustic fovea, and is therefore free from errors associated with Doppler shift that result from movement of the bat relative to the microphone, as well as the shifts in frequency that the bat makes in compensatory response to the Doppler shifted echoes it receives whilst in flight. This is a standard method for the research of echolocation in CF-emitting bats (e.g. review in Armstrong and Coles 2007). The microphone was held around 15 cm from the bat during recordings and only stable, high quality outputs were measured during the subsequent analysis. For mouth-emitting bats that produce flat or broadband frequency modulated (FM) search phase signals, these were recorded while they flew within a large hut, or as they flew in the open while attached to a long horizontal line ('zip-lining'; Parsons and Szewczak 2009). Neither method is ideal for recording high quality search phase pulses because FM bats typically switch to extremely short duration broadband 'clutter calls' under such conditions. Nevertheless, some idea of the characteristic frequency was obtained from the clutter calls. Unfortunately, too few echolocating bats were captured and their taxonomic identity too uncertain to use the alternative method of making recordings of free-flying bats after release. Measurements of reference calls were made in Cool Edit software. All bats for which reference calls were obtained were vouchered to allow precise taxonomic determination.

3.2.1.5 Day and Night Transects

At least four hours per day was spent walking within the forest habitats, either in the process of setting up, checking or retrieving traps and nets, or searching for caves and signs of mammal activity.

On most evenings three or more hours was spent walking slowly in the forest from usually after dusk (7–7.30 pm) to between 10 pm and 1 am. The night transect activities involved at least two, sometimes four or five people. Because the participants stayed relatively close together for safety reasons, the observations of each person cannot be counted as separate effort. However, there is no doubt that multiple sets of eyes (including those of local Miyan or Telefol men) increased the contact rates for mammals. This activity was carried out under clear conditions and in light rain; however, heavy rain obscures both vision and aural contact, and effort was usually suspended or abandoned under persistent heavy rain. Several mammals were either captured by hand or shot with a bow after being located during the course of night patrols.

Mammals were sometimes also observed (and occasionally photographed) by other team members, particularly herpetologist Stephen Richards who, with one or two local assistants, usually spent several hours each evening searching for amphibians. All of these sightings are included in the compilation, even if it was possible to identify the mammal only very generally.

The night time patrolling effort by the mammal survey group is summarised for each sampling locality and for the entire survey in Table 2; the time spent in night patrol by other team members is not counted in this tally because it was generally focussed on other tasks.

3.2.1.6 Cave Searches

Caves often contain roosting bats which can be captured in hand nets or by setting mist nets across entrances. Information that can be obtained from cave surveys includes:

- records of species that otherwise evade capture in nets and harp traps;
- valuable reference echolocation calls;
- an indication of species abundance within an area;
- information on breeding activity at the time of the visit;
- an indication of species vulnerability to cave disturbance; and
- discovery of important roosting sites that might be given special consideration during impact mitigation.

In addition, caves are sometimes used by predators such as owls, and these may produce accumulations of prey remains including the bones and teeth of mammals. Large accumulations of mammal bones are sometimes found in caves, and these provide an almost unparalleled source of information on the local small mammal community, including indications of relative abundance.

During the present survey, survey sites were typically positioned away from settlements, hence it was not possible to use local knowledge to locate caves. At several sites, Ken Aplin and field assistants searched obvious cliff-lines for caverns. The location of all caves located during the survey is given in Appendix 3.5.

3.2.1.7 Interviews and Inspection of Hunting Trophies

Formal interviews were conducted by Ken Aplin at two villages: Wameimin 2 on 3 December 2009 and Wameimin 1 on 21 February 2010 (accompanied by Community Affairs staff on both occasions). Although both visits were prearranged, the Sunday visit drew a much larger crowd of people than the mid-week daytime visit, at which time most people were absent from the village. At both villages, people were asked to exhibit collections of hunting trophies kept inside their houses. A visit to Hotmin Village on 26 February 2010 found almost the entire adult population absent at a community meeting; fortunately children knew of some nearby caves which were visited. On Trip 4, Stephen Richards conducted interviews with residents of Nekiei, Kubkain and Paru Villages, and was able to photograph hunter trophies from Nekiei and Paru Villages. These interviews were carried out in accordance with notes provided by Ken Aplin on cuscuses, wallabies and flying foxes.

The interviews used open-ended questions that encourage a respondent to make a statement (e.g. Tell me about the larger animals you find when hunting) rather than questions that only require confirmation or denial (e.g. Do you have tree kangaroos here?). Any statement was then challenged to determine whether it was a first-hand account as distinct from a general cultural awareness of the species (e.g. Have you ever caught a tree kangaroo?). Interviews were conducted with small groups of people (usually only men) and where possible, a request was made for people with particular interest and experience in hunting. Mamu *et al.* (2006) and Mamu (2008) discussed the potential pitfalls of using informant testimony as a source of survey data.

Photographic images are often used as a starting point for discussion but this can lead to many false records if not substantiated by tangential questioning to verify an informant's degree of familiarity with the species. During the interviews conducted at Wameimin 1 and 2, Flannery's (1995) *Mammals of New Guinea* was used only to clarify aspects of patterning and body form, with the question phrased as a choice (e.g. is the body pattern like A – spotted or B – striped; is the nose like A – pointed or B – snub). After the formal interviews were closed, people were asked to browse through the photographs in the book. This resulted in claims of local occurrence of various other species, some of which were extremely unlikely to occur in the Study Area on biogeographic grounds.

A large collection of hunting trophies was presented for identification by residents of Wameimin 2 (Figure 6) and a smaller number by residents of Wameimin 1, Nekiei and Paru. These were photographed and measured. The provenance of important specimens was discussed in detail to make sure that these were locally obtained and to identify the local habitat. Miyan names were employed in these discussions, as available through a published list (Morren 1989). An important observation was that the owner of a trophy specimen was usually able to correctly identify the species, according to Miyan classification. In contrast, they often gave incorrect names for other people's trophies, thereby demonstrating that the provenance information related to individual animals.

Additional discussions were held during Trip 1 with the Nena Base caretaker, an elderly Miyan man called Yamni who assisted with small mammal trapping and also possessed a small collection of hunting trophies derived from his own hunting and snaring, and from hunting by other people moving between Wameimin 2 and garden areas below Nena Base. Casual discussions also occurred throughout Trip 2 with various Miyan and Telefol field assistants provided by the Project. These discussions gave valuable insights into local hunting practices and the local abundance and ecology of several mammal species.

3.2.1.8 Helicopter Flyover

A helicopter transect of the Study Area Lowland Zone habitats, flown by ornithologist Iain Woxvold on 01 November 2010, resulted in observation of a large roosting congregation of flying foxes. The spatial extent of the colony was recorded through GPS points, an estimate made of the number of individuals present, and photographs taken of both roosting and flying bats.

3.2.2 Vouchering and Identification Methods

Most New Guinean mammals can be identified with confidence to generic level in the field. However, for only a small number of groups is it possible to make reliable species identifications based on external characteristics. More commonly, a reliable determination can only be made through examination of characteristics of the skull and teeth, and this can rarely be carried out on a live animal. Even then, there is a high likelihood of encountering entirely new species in any biologically unexplored context.

Voucher specimens were taken where necessary to obtain accurate taxonomic determinations. This did not include any species listed in a Threatened category, or listed as Near Threatened, by the IUCN. All vouchered individuals had DNA samples taken to maximise their immediate and future value for taxonomic research. Following approved export of the collections, identifications were refined through consultation of relevant literature and through direct comparison with relevant specimens in the Australian National Wildlife Collection, Canberra, and the Australian Museum, Sydney.

Detailed study of voucher specimens led to novel interpretations of species diversity in several genera, including blossom bats (*Syconycteris* spp.), tube-nosed bats (*Nyctimene* spp. and *Paranyctimene* spp.), long-eared bats (*Nyctophilus* spp.), feather-tailed possums (*Distoechurus* spp.), tree mice (*Pogonomys* spp.) and long-footed tree mice (*Lorentizimys* spp.). DNA sequencing was undertaken for one taxonomic group (the feather-tailed possums) to confirm the suspected distinctiveness of specimens from the Study Area.

3.2.3 Analysis of Acoustic Recordings

The first step in any analysis of acoustic recordings of bats is attributing anonymously recorded call types to individual species. This is usually done with the help of a reference library of good quality calls recorded from confidently identified bats. For New Guinean bats, published reference calls are available for only eight species of bats captured at sites in the Kikori basin, on the southern side of the Central Cordillera (Leary and Pennay *in press*). During the survey of the Study Area, reference calls were recorded for 12 different species (Appendix 3.6). Nine of these produced good quality reference calls, the remaining three gave only poor quality calls. Reference calls of a few other widely distributed species are available from compilations of calls from the northern and eastern Australia (Reinhold *et al.* 2001; Milne 2002; Pennay *et al.* 2004), but the application of these geographically remote libraries to a New Guinean context is questionable until such time as both the taxonomic unity of these species and the uniformity of echolocation calls over such large areas have been formally tested. Nevertheless, these more remote libraries are useful for narrowing down the possible identity of a call to genus or family level.

Given these limitations, it was decided to first develop a library of call types from the AnaBat recordings, and only then to attempt taxonomic identification of each call type. Anonymously recorded signals from the AnaBat detectors were examined in AnalookW 3.7w software, and discrete call types thought to represent search phase pulses from a single species were documented for each recording session. The call types were labelled according to a new scheme illustrated in Appendix 3.7; see Armstrong and Aplin (2011) for a published usage of the scheme.

A total of 24 different call types were recorded - 22 from the stationary session recordings and two from captured bats. For each call type measurements of pulse variables were made from a time-by-frequency display of echolocation sequences following Zero Crossings Analysis (ZCA). Three call variables were measured on good quality search phase pulses in representative call sequences: pulse duration (milliseconds), maximum frequency (kHz) and characteristic frequency (the point at the end of the flattest portion of a pulse before any terminal secondary frequency sweep; kHz). Summaries of pulse variables (Appendix 3.8) and representative sequence traces (Appendix 3.9) are presented in support of the analysis and identifications, as recommended by the Australasian Bat Society (ABS 2006).

Eleven of the call types are allocated to species through comparison with reference calls collected during the survey or reported by Leary and Pennay (*in press*). As noted above, similarity to calls recorded from Australian bats was taken as only indicative of taxonomic affinity, even where the same species is supposedly present. We also avoided the practice of identifying call types on the basis of general correlations between physical characteristics (e.g. forearm length, body weight) and echolocation call frequency (e.g. based on Jones, 1996; Robinson 1996; Bogdanowicz *et al.* 1999; Zhang *et al.* 2000; Feng *et al.* 2000, Richards 2005, 2008). Although this inferential method clearly has merit in some circumstances, in the present context we prefer to follow a more cautious, evidentiary approach that minimises the chance of calls being misidentified and action being taken on the basis of an incorrect determination. However, some effort was made to assess the possible source of taxonomically unassigned calls, based on general call attributes that tend to characterise bats of different genera and families. The evidentiary basis for all taxonomic allocations is documented in Appendix 3.10.

It is important to emphasise that our inability to taxonomically identity all call types does not automatically imply that we detected previously unknown species. On the contrary, the majority of the unassigned calls almost certainly belong to described species for which there are no verified echolocation reference calls.

As further reference calls become available, many of the unallocated calls will be identified retrospectively. Moreover, it should be noted that taxonomically unallocated call types are still useful for comparing trends in bat richness, relative abundance and community composition across sites and habitats. By using the call type as the unit of presentation and analysis, retrospective identifications can be applied through all site and habitat summaries, and all analyses.

Several further caveats need to be made in regard to the AnaBat acoustic dataset. The first is that the 24 documented call types may not simply equate to 24 bat species, for three reasons: 1) two or more closely related bat species may produce calls that are so similar that they cannot be distinguished reliably using the available methods (e.g. McKenzie and Muir 2000; Milne 2002); 2) the males and females of a few bat species are reported to produce calls with a slightly different mean characteristic frequency, albeit of comparable type (e.g. *Hipposideros semoni* in Australia: Coles 1993, de Oliveira and Schulz 1997; *Rhinolophus cornutus* in Japan: Yoshino *et al.* 2008); and 3) a single bat species may produce more than one call type (e.g. clutter calls, search phase calls, approach phase calls). With sufficient experience of related species, it is generally possible to control for the last of these factors, and to limit the analysis to the typically more diagnostic search phase calls. However, the other factors can only be controlled through development of an adequate reference library.

Finally, it should be noted that in all acoustic surveys (including AnaBat) the detectability of each species is determined to some extent by characteristics of its echolocation calls. In particular, species that produce ultra-high frequency (> 100 kHz) calls or those that produce calls with low amplitude (e.g. long-eared bats *Nyctophilus* spp.) will have relatively short detection distances, which will lead to their being under-represented or even missed altogether in an acoustic survey. Other factors that affect the detectability of different call types include the quality of the recording as determined by atmospheric conditions, most notably relative humidity and temperature that act together to attenuate ultrasound (e.g. Armstrong and Kerry 2011). Bats that are foraging in the immediate vicinity of the recording station are more likely to come within detection distance of the recording unit than those that might pass by only occasionally.

3.2.4 Inferences about Bat Community Structure

Two parameters are used to characterise bat community structure: call type richness and flight space composition.

Call type richness refers to the number of recognisably distinct call types. As noted above, it is possible that one call type might actually represent more than one species, and conversely that a single species might produce more than one call type, either due to differences in calls emitted by males and females of one species, or most likely, because of differences in the ecological function of emitted calls. Despite these caveats, there will be a strong correlation between the number of call types recorded and the number of species in the local community. Call type richness is thus a proxy for species diversity.

Flight space composition is the proportional representation of different functional categories of calls in any site or habitat. The functional categories are defined by various parameters of each echolocation call type which in turn, are thought to reflect flight space characteristics of the preferred foraging habitat of each bat species. The critical characteristic of a flight space is the distance between a foraging bat and its background environment, typically vegetation, which is termed ‘clutter’. Different call types vary in their effectiveness in discriminating prey items from ‘clutter echoes’. Three flight space types are distinguished here based on descriptions in Denzinger *et al.* (2004):

> **Open.** Uncluttered space, where clutter echoes are undetectable or clearly distinct from prey echoes. Such habitats include areas without tall forest, and spaces well above forest canopy. Bats that use open uncluttered spaces typically produce intense calls that have a narrowband, ‘flat’ FM structure, with relatively long duration, low duty cycle and large pulse intervals. Of the call types defined in this report, this would include the *sh.cFM* types at frequencies typically below 30 kHz.

Edge and gap. Background cluttered space, where prey echoes follow closely but do not overlap with clutter echoes. Such habitats include spaces adjacent to forest edges, large gaps within forest, spaces between different vegetation layers (e.g. canopy, subcanopy or understorey), and open space above water and forest canopy. Call types that are most effective in edge or gap habitats have high signal intensity, medium duration and frequency, and low duty cycle, and tend to have an initial steep broadband FM component followed by a longer duration narrowband shallow FM component. Of the call types defined in this report, this would include mainly *cFM* and *st.cFM* types, the call type *i.fFM.d* that has some resemblance to true constant frequency calls as emitted by Old World rhinolophoid bats, the high amplitude, short duration broadband types *st.bFM* and *st.sFM* characteristic of the genus *Myotis*, and relatively low (below 70 kHz) *sCF* types.

Clutter. Highly cluttered space, where prey echoes are confused with those from background clutter. Such habitats include spaces against vegetation, within small gaps in vegetation, and low over the ground. Calls produced in narrow spaces would include long or short (high or low duty cycle) CF-dominated calls, and short, broadband, uni or multi-harmonic FM calls with low intensity and low duty cycle. Of the call types defined in this report, this would include true constant frequency *sCF, mCF* and *lCF* types, plus *st.sFM* types characteristic of nyctophiline bats.

Absolute abundance of each call type at a site cannot be estimated from bat detector recordings because it is not possible to distinguish between relatively few bats passing the detector but contributing many calls, and a larger number of individuals passing the detector with each contributing relatively few calls. However, a measure of relative abundance of each call type can be derived from replicated recording sessions i.e. multiple bat detector sessions at a single site or in a given habitat. This value was calculated as the proportional occurrence of each call type across replicate recording sessions. For example, if call type 1 is detected on four of eight recording nights at one site, then its relative abundance score would be 0.5 for that site.

A call type that is detected during a high proportion of recording sessions at a particular site is taken as evidence of a locally abundant bat species. If the same call type is rarely recorded or absent at other sites, the simplest explanation is that the species is less abundant at those sites. Unfortunately, this logic cannot be extended to comparisons amongst call types because of their variable levels of detectability. Relative abundance scores thus allow meaningful comparisons between sites or habitats for a single call type but are more difficult to interpret between call types, even at a single site.

3.2.5 Assessment of Reliability of Records

Reliability of species records or inferences are expressed in different ways for each of the biogeographic analysis and the presentation of the survey results.

For the Candidate Mammal List each species rates as likely to occur or possibly present, depending on whether or not there are relevant local records and, in the case of the montane components of the fauna, whether they are likely to persist in small areas of habitat, based on knowledge of their natural population density or that of closely related forms. A species that is not assigned one of these values is regarded as unlikely to occur (i.e. to find it would be a real surprise).

For the survey results, the occurrence of each taxon is rated as *confirmed* or *likely* in the Study Area and in each of the three elevation zones, based on the following criteria:

confirmed – records are based on direct evidence, including captures, camera trap images, reliable sightings, recent hunting trophies, or acoustic recordings.

likely – records are based either on reliable informant testimony, meaning two or more independent confirmatory statements with sufficient detail to make an unambiguous identification, or on the grounds that the species is confirmed present in the Study Area and is judged likely to extend into a particular elevation zone based on wider distributional records.

Species that were included in the Candidate Mammal Species list but were not detected during the survey are treated as possible inhabitants of the Study Area.

For the acoustic survey of bat echolocation calls, the confidence in species identifications at each recording site or habitat is categorised according to one of the two following definitions:

H High. Unambiguous identification of the species or call type at the site based on measured call characteristics and comparison with available reference material. Greater confidence in this identification would come only after capture and supported by morphological measurements and/or genetic analysis.

NC Needs Confirmation. There are two grounds for this classification: 1. the recording quality was generally poor, which limited the variables available for facilitating identification; or 2. the recording was of reasonable quality but this call type resembles another, and the recording showed some ambiguous or incompletely diagnostic echolocation characteristics.

3.3 Biogeographic Analysis

A biogeographic analysis is only as good as each of its two major data sources – knowledge of the geological and climatic history of the region, and knowledge of the distribution and relationships of the organisms under consideration. Various biogeographic schemes have been proposed for the New Guinean biota (see review by Schodde 2006), most of which emphasise the historical merging of Asian and Australian elements to produce a complex and highly diverse amalgam.

Flannery (1989, see also 1995) made the first attempt to interpret New Guinean mammal biogeography in the context of the geological evolution of the region, based primarily on the series of palaeogeographic maps presented by Dow (1977). Although Flannery's model stimulated a significant body of biogeographic research, more recent geological work in the area has overturned some of the key conclusions of Dow (e.g. Abbott *et al.* 1994; Hall 2002; Cloos *et al*. 2005) and hence challenged some key foundations of Flannery's biogeographic model.

The biogeographic model employed here takes into account all pertinent sources of information, including:

- the most recent tectonic and lithostratigraphic interpretations (e.g. Abbott *et al.* 1994; Hall 2002; Cloos *et al*. 2005; Quarles van Ufford and Cloos 2005);
- the latest findings from palaeoclimatological research in the region (e.g. Hope *et al.* 2004; Haberle 2007);
- results of various distributional syntheses for multiple groups of organisms (e.g. Michaux 1994; Flannery 1995; de Boer and Duffels 1996; Aplin 1998; Bonaccorso 1998; Polhemus and Polhemus 1998; McGuigan *et al.* 2000; Heads 2001, 2002a, b; Helgen 2007a);
- results of molecular phylogenetic and phylogeographic studies on various groups of New Guinean vertebrates and invertebrates (McGuigan *et al.* 2000; Joseph *et al.* 2001; Rawlings and Donnellan 2003; Wüster *et al.* 2005; Zwiers *et al.* 2008; Malekian *et al.* 2010; Macqueen *et al*. 2011); and
- results of palaeoecological research on Quaternary mammal distributions in New Guinea and its satellite islands (Aplin *et al.* 1999; Pasveer and Aplin 1998; Aplin and Pasveer 2005; O'Connor *et al.* 2011);

3.4 Susceptibility Analysis

For the purposes of the impact assessment, each member of the Study Area Candidate Species List is given a subjective rating as to its susceptibility to forest removal and disturbance, and to hunting. The factors that need to be considered differ somewhat for non-volant (i.e. terrestrial and arboreal) mammals and volant mammals (i.e. bats).

3.4.1 Susceptibility Analysis for Non-volant Mammals

Disturbance in itself may have little impact on populations of non-volant mammals, unless a population is preconditioned against human presence on account of former hunting activity. More commonly, non-volant mammals experience population declines through habitat modification, direct predation by people or invasive predators, competition with other invasive species, or the introduction of exotic diseases or more often, through a combination of these factors. The capacity of a population to recover from a decline also depends on various factors, including its intrinsic reproductive potential, the capacity of individuals to disperse from a nearby source population, the presence of potential competitors (whether native or exotic), and the status of the factor that caused the initial decline (ongoing or not).

Population decline in the face of habitat modification alone is most likely to reflect the loss of suitable daytime retreat (den) sites (e.g. trees of sufficient age to contain hollows or support large epiphytes) and/or the loss of preferred or essential food resources. Declines may be avoided if suitable care is taken to preserve these key resources.

Population declines can occur through predation alone, with human hunting likely to have been the primary cause of some regional extinctions among New Guinean mammals (George 1979; Flannery and Seri 1990; Flannery 1995). However, hunting is generally targeted at larger mammals, with only casual exploitation of smaller species.

No population declines of New Guinean mammals are attributed to the influence of invasive predators, competitors or diseases. However, the long term ecological influence of the pig, dog and Pacific Rat (all introduced to New Guinea in prehistoric times; Flannery 1995) is not well documented, and the level of threat posed by newer invaders such as the Black Rat are entirely unknown.

In the absence of detailed studies of population dynamics for any of the non-volant mammals predicted to occur in the Study Area, the critical lines of evidence for assessing susceptibility are:

- General accounts of habitat use and reproductive biology of individual species (e.g. Hide *et al.* 1984; Dwyer 1990; Flannery 1995; Majnep and Bulmer 2007);
- Status of the species in regional areas where large scale conversion of primary forest into other vegetation communities (including secondary forest) has occurred (e.g. the Lower Ramu and Markham Valleys);
- Status of the species in forested areas adjacent to major regional human population centres (e.g. around Wewak, Telefomin); and
- Personal knowledge of the particular susceptibility of the species to hunting using either traditional or modern methods.

Susceptibility was rated as Low, Medium or High for each of the threatening factors of forest disturbance and hunting, according to criteria set out below:

Susceptibility to Forest Disturbance

LOW — species can persist in highly modified environments and/or early successional stages; species often has flexible nesting habits (e.g. tree hollows or leaf nests) and broad dietary range; species often with high reproductive potential hence able to rebuild population rapidly (e.g. many small rodents and marsupials).

MEDIUM — species can thrive in secondary as well as primary forests but is generally not present in early successional stages

HIGH — species is intolerant of disturbance and is generally found only in primary forest; species often with high reliance on tree hollow for nesting and/or specialised dietary requirements; species often with medium to low reproductive potential [e.g. long-beaked echidnas (*Zaglossus* spp.) and tree kangaroos (*Dendrolagus* spp.)]

Susceptibility to Hunting

LOW — species too small for targeted hunting and/or with high reproductive potential hence able to rebuild population rapidly (e.g. many small rodents and marsupials)

MEDIUM — species small but with low reproductive potential, hence unable to rebuild population rapidly (e.g. some small marsupials); species targeted but with high reproductive potential, hence able to rebuild population rapidly (e.g. some 'giant' rats and many bandicoots); species is targeted but is difficult to locate or catch, hence protected by evasion or natural rarity [e.g. larger carnivores such as New Guinean Quoll (*Dasyurus albopunctatus*), many arboreal marsupials]

HIGH — species is targeted for hunting, is easily located and captured, and has medium to low reproductive potential [e.g. long-beaked echidnas (*Zaglossus* spp.), tree kangaroos (*Dendrolagus* spp.)]

3.4.2 Susceptibility Analysis for Bats

For bats, the same general principles apply except that their mobility means that foraging and daytime retreat (roost) areas may be spatially separated by distances up to tens of kilometres for the larger bats. Moreover, for some species, complex social systems mean that large numbers of individuals congregate to mate or give birth at different times of year. This is particularly relevant to the larger fruit bats (*Dobsonia* and *Aproteles*) and flying foxes (*Pteropus* spp.) and to some groups of insectivorous bats (e.g. bent-winged bats *Miniopterus* spp.; some leaf-nosed and horseshoe bats, Hipposideridae and Rhinolophidae; species of *Emballonura*).

Bats are probably more resilient to general habitat modification than non-volant mammals because they have the capacity to shift their foraging areas to avoid areas of local disturbance. However, disturbance on a regional scale may cause significant declines of even the most mobile species (Richards 1990). Hunting of bats in most areas is restricted to the larger flying foxes (*Pteropus* spp.) and these will usually respond to excessive hunting by moving to alternative roost sites (Richards 1990; Eby *et al.* 1999). If this occurs during a critical stage in the reproductive cycle (e.g. at a maternity roost) the impact will be more severe. Bats that roost in caves are sometimes subjected to intensive hunting pressure, and even the smallest species are hunted if they can be killed in large enough numbers. For species that roost in tree hollows or in epiphytes, removal of larger trees is likely to be far more important than hunting.

Access to a suitable diurnal refuge or roost obviously represents a major factor in the ecology of many bat species and thus represents a key issue in assessing their susceptibility (Clements *et al.* 2006). Roosts offer protection from exposure to daytime ambient conditions, promote energy conservation, provide protection from predation and facilitate social interactions (Kunz and Lumsden 2003). Some bat species appear to have more specific roosting requirements than others, to the extent that they may be met by only a few particular caves within a given area. Other species might be found in virtually any cave deep enough to offer shelter from daylight, or utilise a variety of roost types including tree hollows or foliage, and artificial structures such as buildings and tunnels. A few species are known to use very specific roost sites outside of caves, such as abandoned bird nests (Reardon *et al.* 2008; Woodside *et al.* 2008). The specific roosting requirements of many New Guinean species are unknown (Flannery 1995; Bonaccorso 1998).

Some species of bats use different roosts at different times during their annual reproductive cycle. For example, several species of flying foxes (*Pteropus* spp.) in Australia congregate in very large numbers at two principal periods through the annual reproductive cycle (Hall and Richards 2000). The first involves adults of both sexes and facilitates complex courtship and mating behaviours which can extend over several months. The second involves mainly adult females that come together in 'maternity camps' to give birth and rear the young. Even more dramatic breeding congregations occur among the bent-winged bats (*Miniopterus* spp.) which show an unusual population biology that revolves around the use of traditional maternity roosts at which entire regional female populations (up to several 100,000s) congregate annually to give birth (Dwyer 1963, 1966, 1969; Hoye and Hall 2008). This can involve movements of several hundreds of kilometres, and more or less guarantees that each regional population is genetically isolated to from every other (Cardinal and Christidis 2000; Rodrigues *et al.* 2010). Outside of the breeding season, the females and young disperse widely and roost in much smaller congregations together with males.

Miniopterus species hold a further potential significance that derives from their capacity to alter the microclimate inside their maternity roost caves by virtue of the sheer numbers of roosting bats (Baudinette *et al.* 1994). This can provide roosting opportunities for other species of bats that might otherwise be unable to find a roost site with suitable microclimate. Other insectivorous bat species are often reported to share the maternity caves of *Miniopterus* species (Smith and Hood 1981; Bonaccorso 1998) but the extent to which they are truly reliant on these colonies is unknown.

Given all of these factors, the following susceptibility criteria were applied for bats:

Susceptibility of Bats to Forest Disturbance

LOW	species can persist in highly modified environments and/or early successional stages; species likely to be highly mobile.
MEDIUM	species can thrive in secondary as well as primary forests but is generally not present in early successional stages; species typically with lower mobility.
HIGH	species is intolerant of disturbance and is generally found only in primary forest; species typically with low mobility.

Susceptibility of Bats to Hunting

LOW	small species not targeted for systematic hunting; tending to roost in trees or epiphytes, hence are inaccessible to systematic hunting.
MEDIUM	small species tending to roost in small caves along with other sheltered places (e.g. inside logs), hence unlikely that hunting will result in heavy mortality; larger species that are difficult to hunt due to their solitary roosting habits (e.g. *Dobsonia minor*).
HIGH	large and small species with specific cave roost requirements and tending to congregate in large numbers; likely to suffer heavy mortality and major disturbance if hunted.

4 RESULTS - BIOGEOGRAPHIC ANALYSIS AND THE CANDIDATE MAMMAL LIST

4.1 Regional Biogeography

The New Guinean mammal fauna exhibits a high degree of zoogeographic structuring that reflects both the complex geological history of the island and the wide range of bioclimatic zones found across its wide elevation range of over 5,000 m. This structuring is particularly pronounced along the northern side of the Central Cordillera where two major geological provinces are joined – the New Guinean Fold Belt which forms most of the Central Cordilleran ranges, and the Northern Mobile Belt made up of numerous formerly discrete continental and oceanic landmasses, now welded to the main island but still recognisable as the topographically isolated North Coastal Ranges (from west to east, the Van Rees, Foya, Bewani, Torricelli, Prince Alexander, Adelbert, Saruwaged, and Finisterre ranges) (Pigram and Davies 1987; Hall 2002). Terrestrial mammals generally show more pronounced structuring than do the more mobile bats, and montane species more so than lowland forms. A few mammal species show much coarser patterning with geographic ranges that span wide geographic and/or elevational ranges. This is especially true among the bats but there are a few marsupials and rodents that also have exceptionally wide distributions. Typically, these occupy specialised niches (e.g. the New Guinean Quoll, *Dasyurus albopunctatus*, being the largest extant native carnivore in New Guinea) and the Ground Cuscus, *Phalanger gymnotis,* being the only primarily terrestrial cuscus).

For many lowland mammals, i.e. those found on the alluvial plains of the major rivers, the Central Cordillera separates northern lowland from southern lowland relatives, with distinctions found either at species or subspecies level (Flannery 1995; Aplin 1998; Helgen 2007a). Northern lowland mammals generally have geographic ranges that extend from the Vogelkop in the west to the Huon Peninsula in the east, including the drainage basins of the Mamberamo, Sepik and Ramu rivers, and sometimes also running along the northern side of the eastern 'tail' of New Guinea.

Mammals of the Cordilleran foothills generally show the same pattern as the lowland mammals. However, there are a small number of northern mammal species that appear to be restricted to the foothills of the North Coastal Ranges, most notably the Grizzled Tree Kangaroo (*Dendrolagus inustus*), Ziegler's Water Rat (*Hydromys ziegleri*) and possibly Edwards Hill's Leaf-nosed Bat (*Hipposideros edwardshilli*). At present, there are no mammals known to be confined to the northern Hill Forest (Hm) communities of the Central Cordillera. All species found in this area either extend into the true lowland habitats or else occur also in the foothills of the North Coastal Ranges.

Zoogeographic patterning is much stronger for mammals of the various montane forest communities of New Guinea. For many genera, the North Coastal Ranges host species that are quite distinct from those species found in the central ranges (Aplin 1998; Helgen 2005b, 2007a). Examples are the two endemic tree kangaroos of the Torricelli Range [Scott's Tree Kangaroo (*Dendrolagus scottae*), related to the *D. dorianus* group of the central ranges; and the Torricelli Tree Kangaroo (*D. pulcherimus*), related to the *D. goodfellowi* group], the Northern Glider (*Petaurus abidi*) of the Torricelli Range (which has no close relative on the central ranges), and the Northern Water Rat (*Paraleptomys rufilatus*) which has a congener in the Central Cordillera, the Short-haired Water Rat (*P. wilhelmina*). For many other montane mammals, the taxonomy remains crude and northern populations are not yet distinguished from those of the central ranges. However, in groups where more detailed studies are underway (e.g. the feather-tailed possums, genus *Distoechurus*; mosaic-tailed rats of the genus *Paramelomys*), the same pattern of North Coastal Ranges, montane endemism is generally observed.

Another component of zoogeographic structuring within the montane mammal fauna concerns a general east-west differentiation along the Central Cordillera, with many groups showing a changeover in species around the point where the great southern drainage system of the Strickland River approaches the headwaters of the north-flowing Sepik River (Helgen 2007a). Many species reach the limits of their distributions around this position (Flannery 1995), and the complex series of partially isolated ranges in this area (e.g. the Victor Emmanuel, Hindenburg and Mueller Ranges) also host a significant number of geographically restricted montane endemics including Champion's Tree Mouse (*Pogonomys championi*) and the Telefomin Cuscus (*Phalanger matanim*). The Study Area lies approximately 50 km north-northeast of Telefomin, and might be expected to support populations of some of the same species.

One final biogeographic consideration of importance for this assessment concerns the recent geological history of New Guinea, specifically the impact of Quaternary 'ice ages'. Despite being in equatorial position, the island of New Guinea was profoundly affected by the ice ages which occurred during periods of globally lower temperatures, causing expansion of ice sheets on the poles and on mountains worldwide and a coincident lowering of sea levels by 100 m or more. At the height of the last glacial phase, between 25,000 and 14,000 years ago, all of the higher mountains in New Guinea supported glaciers and tree growth was limited to areas below 2,000 m elevation Vegetation zones generally were depressed by as much as 1,000 m, and mammal species that are now found in lower montane forests were found at present day sea level (Pasveer and Aplin 1998). Although deglaciation commenced globally around 14,000 years ago, changes in plant and animal communities in New Guinea evidently lagged some thousands of years behind (Hope and Tulip 1994; Pasveer and Aplin 1998), perhaps due to persistently cloudy conditions through to around 8,000 years ago when sea level approached its current position.

The major implication is that until as recently as 10,000 years ago, much of the Study Area Hill Zone would have been covered in quite different forest types that more closely resembled lower montane forests in structure and composition, and further, would have displayed continuity with montane habitats of the central ranges. As conditions warmed, the montane communities of plants and animals would have retreated to progressively higher elevation, leaving small pockets of montane plants and animals stranded on the higher peaks and ridges. Over time, these relictl montane 'isolates' might experience local extinctions, with populations in smaller isolates generally being more vulnerable to stochastic events than populations in larger isolates. Other changes might include genetic drift, resulting in genetic divergence between the isolates and the main populations still found on the Central Cordilleran ranges, and the possible fixation of normally deleterious mutations (e.g. chromosomal rearrangements) due to the small population sizes (Lande 1985).

Based on these general biogeographic considerations, the mammal fauna of the Study Area is expected to contain four zoogeographic components: 1) widespread northern lowland mammal species; 2) northern foothill mammal species; 3) a subset of the montane mammal species of the Central Cordilleran ranges; and 4) some geographically widespread mammal species with wide elevational ranges.

4.2 The Candidate Mammal List

The Candidate Mammal List for the Study Area includes 140 mammal species, including three monotremes, 36 marsupials, 40 rodents, 60 bats, and the feral pig. The highest number of species (114 species) is predicted for the Hill Zone, with an even reduction at both lower (84 species) and higher elevations (87 species). If non-volant mammals are considered separately from bats, the Lowland Zone is predicted to be low in diversity (37 species) compared with either the Hill Zone (60 species) or the Montane Zone (70 species). The pattern for bats is the reverse with the Lowland and Hill Zones both with predicted diversity (47 and 54 species, respectively) and much lower diversity predicted for the Montane Zone (17 species). The very high predicted diversity of the Hill Zone is therefore due to the intersection of two contrasting trends, resulting in relatively high predicted diversity for each of non-volant mammals and bats. The pattern of sharing of these different faunal components is summarised in Table 3 and a full list of candidate mammals in Table 4.

Each species listed in Table 4 is provided with an 'endemism' value in accordance with a scheme employed for all taxa assessed during the survey. The result of this assessment, applied to the Candidate Mammal

List, is shown in Table 5. As would be expected, the Lowland Zone mammal fauna contains the largest proportion of widespread Indo-Pacific species (29%), with a progressive fall in the representation of this group in the Hill Zone (21%) and the Montane Zone (9%). Contrariwise, the Lowland Zone mammal fauna contains the lowest proportion of mainland New Guinean endemics (44%) with a progressive rise in the Hill Zone (55%) and the Montane Zone (76%). Less predictably, northern mainland New Guinea endemics are almost equally represented in the mammal fauna of all zones – Lowland (10%), Hill (9%), Montane (8%) – a pattern that is owed to the presence of several species with very restricted distributions centred on the Telefomin area. The significant proportion of northern mainland New Guinea endemics (9% overall) is a particularly noteworthy feature of the candidate mammal list for the Study Area.

The Candidate Mammal List for the Study Area (Table 4) includes 28 species that appear on the IUCN Red List of threatened species (http://www.redlist.org/) with ranking other than Least Concern, and six that are listed as Protected under the PNG *Fauna (Protection and Control)Act 1966*.

Table 3. Potential occurrence of 'candidate' mammal species in the Study Area

OCCURRENCE BY ZONE	NON-VOLANT MAMMALS	BATS	ALL MAMMALS
Found in all zones	28	9	37
Found in Lowland Zone only	0	5	5
Found in Lowland + Hill Zones only	9	33	42
Found in Hill Zones only	1	5	6
Found in Hill + Montane Zones only	22	7	29
Found in Montane Zone only	20	1	21
Total number in Lowland Zone	37	47	84
Total number in Hill Zone	60	54	114
Total number in Montane Zone	42	17	87
GRAND TOTAL for Study Area	80	60	140

Note: Entries are numbers of species.

Table 4. The Candidate Mammal List for the Study Area.

FAMILY	SUBFAMILY	GENUS AND SPECIES	ENGLISH NAME	MINIMUM ELEVATION	MAXIMUM ELEVATION	ENDEMICITY1	IUCN LISTED2	PNG FAUNA ACT LISTED	INTRODUCED TO PNG	LOWLAND ZONE	HILL ZONE	MONTANE ZONE	SUSCEPTIBILITY TO DISTURBANCE	SUSCEPTIBILITY TO HUNTING
Tachyglossidae		*Tachyglossus aculeatus*	Short-beaked Echidna	0	1700	1				-	P	-	M	H
		Zaglossus attenboroughi	Sir David's Long-beaked Echidna	100	1600	6	CR	P		-	P	P	H	H
		Zaglossus bartoni	Eastern Long-beaked Echidna	0	4150	4	CR	P		-	P	L	H	H
Dasyuridae	Dasyurinae	*Dasyurus albopunctatus*	New Guinean Quoll	0	4000	4	NT			L	L	L	M	M
		Myoictis melas	Three-striped Dasyure	0	1800	4				L	L	L	M	L
		Neophascogale lorentzi	Speckled Dasyure	1200	3900	4				-	-	P	U	L
		Phascolosorex dorsalis	Narrow-striped Marsupial Shrew	1600	2500	4				-	-	P	M	L
	Muricinae	*Micromurexia habbema*	Habbema Dasyure	2700	2800	4				-	-	P	U	L
		Murexechinus melanurus	Black-tailed Dasyure	0	2000	4				L	L	L	M	L
		Murexia longicaudata	Short-furred Dasyure	0	1800	4				L	L	L	M	L
		Phascomurexia naso	Long-nosed Dasyure	1400	2800	4				-	P	L	M	L
Peramelidae	Peroryctinae	*Peroryctes raffrayana*	Raffray's Bandicoot	0	4000	4				-	L	L	M	M
	Echymiperinae	*Echymipera clara*	Clara's Spiny Bandicoot	0	1700	5				L	L	-	M	M
		Echymipera kalubu	Common Spiny Bandicoot	0	1200	4				L	L	L	M	M
		Echymipera rufescens	Long-nosed Spiny Bandicoot	0	2100	4				L	L	P	M	M
		Microperoryctes longicauda	Striped Bandicoot	1,000	3600	4				-	-	L	M	M
Burramyidae		*Cercartetus caudatus*	Long-tailed Pygmy Possum	1,000	3700	4				-	P	L	M	L
Phalangeridae	Phalangerinae	*Phalanger carmelitae*	Mountain Cuscus	1350	3800	4				-	P	L	M	M
		Phalanger gymnotis	Ground Cuscus	0	2700	4				L	L	L	M	M
		Phalanger matanim	Telefomin Cuscus	1550	2600	6	CR	P		-	P	L	H	M
		Phalanger orientalis	Northern Common Cuscus	0	1500	2				L	L	L	M	M
		Phalanger vestitus	Stein's Cuscus	1200	2200	4				-	L	L	M	M

FAMILY	SUBFAMILY	GENUS AND SPECIES	ENGLISH NAME	MINIMUM ELEVATION	MAXIMUM ELEVATION	ENDEMICITY1	IUCN LISTED2	PNG FAUNA ACT LISTED	INTRODUCED TO PNG	LOWLAND ZONE	HILL ZONE	MONTANE ZONE	SUSCEPTIBILITY TO DISTURBANCE	SUSCEPTIBILITY TO HUNTING
Phalangeridae	Phalangerinae	*Spilocuscus maculatus*	Common Spotted Cuscus	0	1400	4		P		L	L	L	M	H
		Spilocuscus rufoniger	Black-spotted Cuscus	0	1200	5	CR			L	L	-	H	H
Pseudocheiridae	Pseudocheirinae	*Pseudochirulus canescens*	Lowland Ringtail Possum	0	1700	4				L	L	-	M	M
		Pseudochirulus larvatus	Masked Ringtail Possum	450	3800	4				-	L	L	M	M
		Pseudochirulus mayeri	Pygmy Ringtail Possum	1200	4200	4				-	-	P	M	L
	Pseudochiropinae	*Pseudochirops corinnae*	Plush-coated Ringtail Possum	900	2900	4	VU			-	P	L	M	M
		Pseudochirops cupreus	Coppery Ringtail Possum	1350	4000	4				-	-	L	M	M
Petauridae	Dactylopsilinae	*Dactylopsila megalura*	Great-tailed Triok	1,000	2300	4				-	-	P	M	M
		Dactylopsila palpator	Long-fingered Triok	850	3000	4				-	-	P	M	M
		Dactylopsila trivirgata	Striped Possum	0	2400	1				L	L	P	M	M
	Petaurinae	*Petaurus breviceps*	Sugar Glider	0	3000	1				L	L	L	M	L
Acrobatidae		*Distoechurus pennatus*	New Guinean Feather-tailed Possum	0	1900	4				L	L	L	M	L
Macropodidae	Macropodinae	*Dendrolagus notatus*	Western Montane Tree Kangaroo	600	3300	4	VU	P		-	-	P	H	H
		Dendrolagus goodfellowi	Goodfellow's Tree Kangaroo	680	2865	4	EN	P		-	P	L	H	H
		Dorcopsis hageni	White-striped Dorcopsis	0	800	5				L	L	-	M	M
		Dorcopsulus vanheurni	Small Mountain Dorcopsis	800	3200	4	NT			-	P	L	M	M
		Thylogale browni	Brown's Pademelon	0	2300	4	VU			L	L	P	M	M
Muridae	Murinae	*Abeomelomys sevia*	Highland Brush Mouse	1400	3100	4				-	P	L	M	L
		Anisomys imitator	Squirrel-toothed Rat	1200	2900	4				-	P	L	M	M
		Baiyankamys shawmayeri	Shaw Mayer's Water Rat	2000	2200	4				-	-	P	U	L
		Coccymys shawmayeri	Shawmayer's Brush Mouse	1600	3700	4				-	-	P	U	L
		Crossomys moncktoni	Earless Water Rat	1200	3500	4				-	-	P	U	L
		Hydromys chrysogaster	Water Rat	0	1900	1				L	L	L	M	L

FAMILY	SUBFAMILY	GENUS AND SPECIES	ENGLISH NAME	MINIMUM ELEVATION	MAXIMUM ELEVATION	ENDEMICITY1	IUCN LISTED2	PNG FAUNA ACT LISTED	INTRODUCED TO PNG	LOWLAND ZONE	HILL ZONE	MONTANE ZONE	SUSCEPTIBILITY TO DISTURBANCE	SUSCEPTIBILITY TO HUNTING
Muridae	Murinae	*Hyomys dammermani*	Western White-eared Giant Rat	1400	4000	4				-	-	P	M	M
		Hyomys goliath	Eastern White-eared Giant Rat	1500	2800	4				-	-	P	M	M
		Lorentzimys nouhuysi	Long-footed Tree Mouse	80	2700	4				L	L	L	M	M
		Mallomys aroaensis	De Vis's Woolly Rat	1100	2900	4				-	-	P	M	M
		Mallomys rothschildi	Rothschild's Woolly Rat	1200	3700	4				-	-	P	M	M
		Mammelomys lanosus	Montane Mammelomys	1500	2800	5				-	-	P	M	L
		Mammelomys rattoides	Lowland Mammelomys	320	1400	5				L	L	P	M	L
		Melomys gracilis	Slender Mosaic-tailed Rat	1,000	1800	4				-	P	P	M	L
		Melomys rufescens	Black-tailed Melomys	0	2400	4				L	L	P	M	L
		Microhydromys richardsoni	Northern Groove-toothed Shrew Mouse	0	1500	5	DD			L	L	L	U	L
		Paramelomys lorentzii	Lorentz's Mosaic-tailed Rat	0	900	4				L	L	P	M	L
		Paramelomys mollis	Thomas's Mosaic-tailed Rat	1200	2500	4				-	P	L	M	L
		Paramelomys moncktoni	Monckton's Mosaic-tailed Rat	0	1400	4				L	L	P	M	L
		Paramelomys platyops	Lowland Mosaic-tailed Rat	0	1500	3				L	L	P	M	L
		Paramelomys rubex	Mountain Mosaic-tailed Rat	900	3000	4				-	P	L	M	L
		Parahydromys asper	New Guinea Waterside Rat	0	2800	4				P	P	-	M	L
		Paraleptomys wilhelmina	Short-haired Water Rat	1600	2800	4	DD			-	-	P	U	L
		Pogonomelomys bruijni	Lowland Brush Mouse	60	600	4	NT			P	P	-	U	L
		Pogonomelomys mayeri	Shaw Mayer's Brush Mouse	0	1800	4				-	P	L	M	L
		Pogonomys championi	Champion's Tree Mouse	1400	2300	6	DD			-	P	P	M	L
		Pogonomys loriae	Large Tree Mouse	0	800	4				P	P	-	M	L
		Pogonomys mollipilosus	Large Tree Mouse	0	2000	4				L	L	L	M	L
		Pogonomys macrourus	Chestnut Tree Mouse	0	2000	4				L	L	P	M	L

FAMILY	SUBFAMILY	GENUS AND SPECIES	ENGLISH NAME	MINIMUM ELEVATION	MAXIMUM ELEVATION	ENDEMICITY1	IUCN LISTED2	PNG FAUNA ACT LISTED	INTRODUCED TO PNG	LOWLAND ZONE	HILL ZONE	MONTANE ZONE	SUSCEPTIBILITY TO DISTURBANCE	SUSCEPTIBILITY TO HUNTING
Muridae	Murinae	*Pseudohydromys fuscus*	Mottled-tailed Shrew Mouse	1600	3660	4				-	-	P	U	L
		Pseudohydromys occidentalis	Western Shrew Mouse	2300	3800	4	DD			-	-	P	U	L
		Rattus exulans	Polynesian Rat	0	2000	1			+	P	P	-	L	L
		Rattus niobe	Moss-forest Rat	762	4050	4				-	P	L	M	L
		Rattus praetor	Spiny Rat	0	1500	4				L	L	P	L	L
		Rattus rattus	Black Rat	0	750	1			+	P	P	-	L	L
		Rattus steini	Stein's Rat	850	2850	4				L	L	L	L	L
		Rattus verecundus	Slender Rat	150	2750	4				-	P	L	M	L
		Uromys anak	Giant naked-tailed Rat	850	3000	4				-	P	L	M	M
		Uromys caudimaculatus[7]	Giant White-tailed Rat	0	1925	4				L	L	P	L	M
		Xenuromys barbatus	Rock-dwelling Rat	75	1600	4				L	L	P	U	M
Suidae	Suinae	*Sus scrofa*	Feral Pig	0	3000	1			+	L	L	P	L	M
Emballonuridae	Emballonurinae	*Emballonura beccarii*	Beccari's Sheath-tailed Bat	0	1500	2				L	L	-	M	H
		Emballonura furax	New Guinea Sheath-tailed Bat	0	1200	4	DD			P	P	-	U	H
		Emballonura raffrayana	Raffray's Sheath-tailed Bat	0	1600	2				P	P	-	M	H
Emballonuridae	Emballonurinae	*Mosia nigrescens*	Lesser Sheath-tailed Bat	0	1600	2				L	L	-	L	L
		Saccolaimus saccolaimus	Naked-rumped Sheath-tailed Bat	0	200	1				P	P	-	U	L
Hipposideridae		*Aselliscus tricuspidatus*	Trident Leaf-nosed Bat	0	600	2				L	L	-	M	H
		Hipposideros ater	Dusky Leaf-nosed Bat	0	1700	1				L	L	-	M	M
		Hipposideros calcaratus	Spurred Leaf-nosed Bat	0	600	2				L	L	-	M	H
		Hipposideros cervinus	Fawn Leaf-nosed Bat	0	1400	2				L	L	-	M	H
		Hipposideros corynophyllus	Telefomin Leaf-nosed Bat	1400	2700	4	DD				P	-	U	H
		Hipposideros diadema	Diadem Leaf-nosed Bat	0	1300	1				L	L	-	M	H

FAMILY	SUBFAMILY	GENUS AND SPECIES	ENGLISH NAME	MINIMUM ELEVATION	MAXIMUM ELEVATION	ENDEMICITY1	IUCN LISTED2	PNG FAUNA ACT LISTED	INTRODUCED TO PNG	LOWLAND ZONE	HILL ZONE	MONTANE ZONE	SUSCEPTIBILITY TO DISTURBANCE	SUSCEPTIBILITY TO HUNTING
Hipposideridae		*Hipposideros edwardshilli*	Hill's Leaf-nosed Bat	240	250	6	DD			P	-	-	U	H
		Hipposideros maggietaylorae	Maggie Taylor's Leaf-nosed Bat	0	300	1				L	-	-	M	H
		Hipposideros muscinus	Fly River Leaf-nosed Bat	0	600	4	DD			P	-	-	U	M
		Hipposideros semoni	Semon's Leaf-nosed Bat	600	1400	1	DD			-	P	-	U	M
		Hipposideros wollastoni	Wollaston's Leaf-nosed Bat	0	800	4				-	L	-	M	H
Molossidae	Molossinae	*Mormopterus beccarii*	Beccari's Free-tailed Bat	0	300	1				L	L	-	M	L
		Otomops papuensis	Papuan Free-tailed Bat	0	300	4	DD			P	P	-	U	L
		Otomops secundus	Mantled Free-tailed Bat	0	1980	4	DD			-	P	P	U	L
		Tadarida kuboriensis	New Guinea Free-tailed Bat	1900	3000	4				-	P	P	U	L
Miniopteridae		*Miniopterus australis*	Little Long-fingered Bat	0	1500	1				P	P	-	M	H
		Miniopterus macrocneme	Small Melanesian Bent-winged Bat	0	3200	1	DD			L	L	L	U	H
		Miniopterus magnater	Large Bent-winged Bat	0	2000	4				L	L	L	M	H
		Miniopterus medius	Medium Bent-winged Bat	360	1360	4				P	P	P	M	H
		Miniopterus oceanensis	Australasian Bent-winged Bat	0	2900	1				P	P	P	M	H
		Miniopterus tristis	Great Long-fingered Bat	0	1600	1				P	P	-	M	H
Pteropodidae	Macroglossinae	*Macroglossus minimus*	Long-nosed Blossom Bat	0	1200	1				L	L	P	L	L
		*Syconycteris australis***	Common Blossom Bat	0	3000	1				L	L	L	L	L
		*Syconycteris cf. finschii***	Bismarck Blossom Bat	0	3000	2				P	-	-	L	L
		Syconycteris hobbit	Moss-forest Blossom Bat	1800	2800	4	VU			-	-	P	U	L
	Nyctimeninae	*Nyctimene aello*	Broad-striped Tube-nosed Fruit Bat	0	1,000	4				L	P	-	L	M
		*Nyctimene albiventer group***	Common Tube-nosed Fruit Bats	0	1900	2				L	L	L	M	L
		Nyctimene certans	Mountain Tube-nosed Fruit Bat	780	2300	4				-	P	L	U	L
		Nyctimene draconilla	Lesser Tube-nosed Fruit Bat	0	100	4	DD			L	L	-	U	L

FAMILY	SUBFAMILY	GENUS AND SPECIES	ENGLISH NAME	MINIMUM ELEVATION	MAXIMUM ELEVATION	ENDEMICITY1	IUCN LISTED2	PNG FAUNA ACT LISTED	INTRODUCED TO PNG	LOWLAND ZONE	HILL ZONE	MONTANE ZONE	SUSCEPTIBILITY TO DISTURBANCE	SUSCEPTIBILITY TO HUNTING
Pteropodidae	Nyctimeninae	*Paranyctimene raptor*	Green Tube-nosed Fruit Bat	0	1200	4				P	P	-	M	L
		Paranyctimene tenax	Steadfast Tube-nosed Fruit Bat	0	1600	4				P	P	-	M	L
	Pteropodinae Pteropodinae	*Aproteles bulmerae*	Bulmer's Fruit Bat	1760	2400	4	CR			-	P	P	U	H
		Dobsonia minor	Lesser Naked-backed Fruit Bat	0	700	4				L	L	-	L	L
		Dobsonia moluccensis	Moluccan Naked-backed Fruit Bat	0	2700	3				L	L	L	L	H
		Pteropus alecto	Black Flying Fox	0	60	1				L	P	-	M	L
		Pteropus conspicillatus	Spectacled Flying Fox	0	1,000	1				P	P	-	M	L
		Pteropus hypomelanus	Small Flying Fox	0	20	1				P	P	-	M	L
		Pteropus macrotis	Large-eared Flying Fox	0	500	4				P	P	-	M	L
		Pteropus neohibernicus	Great Flying Fox	0	1400	4				L	L	-	M	L
		Rousettus amplexicaudatus	Common Rousette Bat	0	2200	1				L	L	-	L	L
Rhinolophidae		*Rhinolophus arcuatus*	Arcuate Horseshoe Bat	360	1600	2				-	P		M	H
		Rhinolophus euryotis	New Guinea Horseshoe Bat	0	1800	2				P	P	-	M	H
		Rhinolophus megaphyllus	Eastern Horseshoe Bat	260	360	1				P	P	-	M	H
		Rhinolophus philippinensis	Large-eared Horseshoe Bat	0	1300	1				-	P	-	U	H
Vespertilionidae	Kerivoulinae	*Kerivoula muscina*	Fly River Woolly Bat	20	1600	4				L	L	-	U	L
	Murininae	*Murina florium*	Flute-nosed Bat	0	2800	2				-	P	P	U	L
	Myotinae	*Myotis moluccarum*	Moluccan Myotis	0	1200	2				L	L	-	M	L
	Nyctophilinae	*Nyctophilus bifax*	Eastern Long-eared Bat	0	1500	1				P	-	-	U	L
		Nyctophilus microdon	Small-toothed Long-eared Bat	1900	2150	4	DD			-	P	P	U	L
		Nyctophilus microtis	Papuan Long-eared Bat	0	2600	4				L	L	-	M	L
		*Nyctophilus affin. microtis***	Papuan Long-eared Bat	0	2600	5				L	L	-	M	L

FAMILY	SUBFAMILY	GENUS AND SPECIES	ENGLISH NAME	MINIMUM ELEVATION	MAXIMUM ELEVATION	ENDEMICITY1	IUCN LISTED2	PNG FAUNA ACT LISTED	INTRODUCED TO PNG	LOWLAND ZONE	HILL ZONE	MONTANE ZONE	SUSCEPTIBILITY TO DISTURBANCE	SUSCEPTIBILITY TO HUNTING
Vespertilionidae	Vespertilioninae	*Philetor brachypterus*	Short-winged Pipistrelle	0	2100	1				L	L	-	M	L
		Pipistrellus angulatus	New Guinean Pipistrelle	0	2400	2				L	L	L	M	L
		Pipistrellus collinus	Mountain Pipistrelle	700	3000	4				-	P	P	M	L
		Pipistrellus papuanus	Lesser Papuan Pipistrelle	0	1300	2				L	L	-	M	L

Notes: The occurrence of each taxon is inferred in each of the three zones within the Study Area with two levels of confidence: L = likely to occur, P = possibly present. Codes for Endemicity: 1 = Occurs more widely in the Indo-Pacific; 2 = Endemic to New Guinea, its satellite islands, the Bismarcks and Maluku; 3 = Endemic to New Guinea and its satellite islands (Waigeo, Misol, Yapen, Biak, Aru, d'Entrecasteaux and Louisiades); 4 = Endemic to mainland New Guinea; 5 = Endemic to northern mainland New Guinea, north of the Central Cordillera; 6 = Endemic to small areas of northern mainland New Guinea. Values for the IUCN categories are explained in Table 1. Listings under the PNG Fauna Act: P = Protected, Codes for Susceptibility: L = Low, M = Moderate, H = high, U - Unknown; **taxonomically complex groups.

Table 5. Summary of patterns of endemicity among the 'candidate' mammal fauna of the Study Area as predicted by the biogeographic analysis.

ENDEMICITY	ALL ELEVATIONS		LOWLAND ZONE		HILL ZONE		MONTANE ZONE	
1	27	19%	24	29%	24	21%	8	9%
2	15	11%	13	15%	14	13%	4	5%
3	2	1%	2	2%	2	2%	2	2%
4	84	60%	37	44%	62	55%	66	76%
5	8	6%	7	8%	7	6%	4	5%
6	4	3%	1	1%	3	3%	3	3%
5+6	12	9%	8	10%	10	9%	7	8%
No of Species	140		84		112		87	

Endemicity codes:

1 - Occurs more widely in the Indo-Pacific

2 - Endemic to New Guinea, its satellite islands, the Bismarcks and Maluku

3 - Endemic to New Guinea and its satellite islands (Waigeo, Misol, Yapen, Biak, Aru, d'Entrecasteaux and Louisiades)

4 - Endemic to mainland New Guinea

5 - Endemic to northern mainland New Guinea, north of the Central Cordillera

6 - Endemic to small areas of northern mainland New Guinea

5 SURVEY RESULTS

5.1 Overview

A total of 69 mammal species was documented during the survey, along with 12 taxonomically unallocated bat call types that probably represent the same number of additional bat species (Table 6). The combined tally is thus likely to be 81 species, of which 72 are rated as confirmed for the Study Area as a whole, and 9 rated as likely to occur in the Study Area. This tally counts *Zaglossus* sp. as one species only.

The Lowland Zone produced confirmed records of 49 species (including unallocated bat call types) and likely records of 16 species. The Hill Zone produced confirmed records of 62 species (including unallocated bat call types) and likely records of 11 species. The Montane Zone produced confirmed records of only six species (no acoustic survey) and likely records of 50 species. The marked disparity in the ratio of confirmed to likely records in the Montane Zone (6:50) compared with each of the Lowland Zone (49:16) and Hill Zone (62:11) reflects the markedly different systematic survey effort in these parts of the Study Area, with only one systematic survey site and no acoustic bat survey in the Montane Zone.

Five undescribed species were recorded - one marsupial, two rodents, and two bats. The two rodents may represent entirely new discoveries and their status outside of the Study Area is unknown. The other species are represented in prior collections from other localities in PNG but they have evaded taxonomic attention for various reasons. All five are likely to occur more widely in the northern foothills and lowlands of New Guinea.

With the exception of five newly recognised mammal species, the inventory produced by the survey is a strict subset of the Candidate Mammal List produced from the biogeographic analysis. The survey results thus represent a strong validation of the biogeographic analysis. Confidence is obviously highest for the Study Area Lowland and Hill Zones, where more than half of the predicted mammal species were detected, but information obtained for the Study Area Montane Zone from interviews with local hunters also supports the essential validity of all elements of the biogeographic analysis. This is an important conclusion because it not only allows risk analyses to proceed on the basis of a robust predictive model of mammal communities within the Study Area but it also provides an historical biogeographic context for assessing the significance of populations of individual mammal species within the Study Area.

5.2 Results of Individual Survey Methods

The success of each of the main survey methods is reviewed below, prior to integration and interpretation of the results for each of the main taxonomic groups – non-volant mammals (monotremes, marsupials and rodents); non-echolocating bats (Pteropodidae); and insectivorous bats. The review of separate methods serves to clarify the contribution of different survey methods to the overall assessment, which in turn informs on the overall effectiveness of the survey, and assist with the development of appropriate effective monitoring protocols.

5.2.1 Ground and Understorey Trapping

The total trapping effort across all systematic survey sites amounted to 7,670 trap nights including 127 large cage trap nights (Table 2). This effort was fairly evenly distributed between the Lowland Zone sites (2,432 trap nights) and two elevation blocks within the Hill Zone – below 500 m elevation (2,829 trap nights) and above 500 m elevation (2,409 trap nights). A much smaller effort was expended in the Montane Zone (130 trap nights at Nena Top Site).

A total of 53 individuals representing 12 different species were captured in traps (Table 7). The majority of captures were made in kill traps, with three captures in live-capture Elliott traps (one juvenile *Echymipera*

Table 6. Occurrence by sampling site of mammal species recorded during in the Study Area.

SCIENTIFIC NAME	ENGLISH NAME	IUCN STATUS[1]	PNG FAUNA ACT [2]	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	HI	NENA BASE	NENA LIMESTONE	NENA TOP	FRIEDA BASE	NENA BASE	HOTMIN VILLAGE	KUBKAIN VILLAGE	PARU VILLAGE	NEKIEI VILLAGE	FLYING FOX CAMP*	WAMEIMIN 1 VILLAGE	WAMEIMIN 2 VILLAGE	ENTIRE STUDY AREA	LOWLAND ZONE	HILL ZONE	MONTANE ZONE
Tachyglossidae																																		
Zaglossus sp.[1]	A Long-beaked Echidna	CR	P																										I	I	**L**		**L**	**L**
Dasyuridae																																		
Dasyurus albopunctatus	New Guinean Quoll	NT																											I	I	**L**	**L**	**L**	**L**
Myoictis melas	Three-striped Dasyure														G														I	I	**C**	**L**	**C**	**L**
Murexia longicaudata	Short-furred Dasyure														CG			G											I	I	**C**	**L**	**C**	**L**
Peramelidae																																		
Peroryctes raffrayana	Raffray's Bandicoot											C						C													**C**		**C**	**L**
Echymipera clara	Clara's Spiny Bandicoot								Sc				Sc																	T	**C**	**C**	**C**	
Echymipera kalubu	Common Spiny Bandicoot									Sc	Sc	Sc		Sc			G		L				T						T	T	**C**	**C**	**C**	**L**
Echymipera rufescens	Long-nosed Spiny Bandicoot				Sc					Sc		Sc																		T	**C**	**C**	**C**	
Echymipera sp.[2]	A Spiny Bandicoot				S				C	C			C					C																
Microperoryctes longicauda	Striped Bandicoot																												I	I	**L**			**L**
Phalangeridae																																		
Phalanger cf. carmelitae	Mountain Cuscus																		S										I	I	**L**		**C**	**L**
Phalanger gymnotis	Ground Cuscus					C				C								C	L				L						TI	TI	**C**	**C**	**C**	**L**
Phalanger matanim	Telefomin Cuscus	CR	P																										I		**L**			**L**
Phalanger orientalis	Northern Common Cuscus						Sp																T		I	I	I		I	TI	**C**	**C**	**L**	
Spilocuscus maculatus	Common Spotted Cuscus		P	TL																			T		I	I	I		I	TI	**C**	**C**	**C**	
Spilocuscus rufoniger	Black-spotted Cuscus	CR																								I	TI				**C**	**L**	**C**	

SCIENTIFIC NAME	ENGLISH NAME	IUCN STATUS[1]	PNG FAUNA ACT [2]	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	HI	NENA BASE	NENA LIMESTONE	NENA TOP	FRIEDA BASE	NENA BASE	HOTMIN VILLAGE	KUBKAIN VILLAGE	PARU VILLAGE	NEKIEI VILLAGE	FLYING FOX CAMP*	WAMEIMIN 1 VILLAGE	WAMEIMIN 2 VILLAGE	ENTIRE STUDY AREA	LOWLAND ZONE	HILL ZONE	MONTANE ZONE
Pseudocheiridae																																		
Pseudochirulus canescens	Lowland Ringtail Possum																		Sc		Sc										**C**		**C**	**C**
Petauridae																																		
Dactylopsila trivirgata	Striped Possum																										I		I		**L**	**L**	**L**	**L**
Petaurus breviceps	Sugar Glider																												I	I	**L**	**L**	**L**	**L**
Acrobatidae																																		
Distoechurus sp.[3]	a Feather-tailed Possum			Sc	Sc																								I		**C**	**C**	**L**	
Macropodidae																																		
Dendrolagus notatus	Western Montane Tree Kangaroo	VU	P																										I	I	**L**			**L**
Dendrolagus goodfellowi	Goodfellow's Tree Kangaroo	EN	P																										I	TI	**C**			**C**
Dorcopsis hageni	White-striped Dorcopsis								C	C			C					C										T	I	TI	**C**	**C**	**C**	
Dorcopsulus sp.[3]	Small Mountain Dorcopsis	NT																											I	I	**L**			**L**
Thylogale browni	Brown's Pademelon	VU											S																I		**C**	**L**	**C**	
Muridae																																		
Hydromys chrysogaster	Water Rat												Sc					GC													**C**	**L**	**C**	**L**
Lorentzimys sp.[3]	Long-footed Tree Mouse												G																		**C**	**L**	**C**	
Mammelomys rattoides	Lowland Mammelomys								G				Sc	S			G	G	C		G									T	**C**	**C**	**C**	**C**
Melomys rufescens	Black-tailed Melomys										G	M																			**C**	**L**	**C**	
Microhydromys richardsoni	Northern Groove-toothed Shrew Mouse	DD												G																	**C**	**L**	**C**	**L**
Paramelomys platyops	Lowland Mosaic-tailed Rat				G			G	G	G	G	G	ScG		ScG			G	G		G										**C**	**C**	**C**	**C**
Pogonomys cf. *loriae*[3]	a Large Tree Mouse									Sc																					**C**	**C**	**L**	

SCIENTIFIC NAME	ENGLISH NAME	IUCN STATUS[1]	PNG FAUNA ACT [2]	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	HI	NENA BASE	NENA LIMESTONE	NENA TOP	FRIEDA BASE	NENA BASE	HOTMIN VILLAGE	KUBKAIN VILLAGE	PARU VILLAGE	NEKIEI VILLAGE	FLYING FOX CAMP*	WAMEIMIN 1 VILLAGE	WAMEIMIN 2 VILLAGE	ENTIRE STUDY AREA	LOWLAND ZONE	HILL ZONE	MONTANE ZONE
Pogonomys cf. *mollipilosus*[3]	a Large Tree Mouse	NE											Sc																		**C**	**L**	**C**	**L**
Pogonomys macrourus	Chestnut Tree Mouse														Sc																**C**	**L**	**C**	
Rattus praetor	Spiny rat																G		G			G									**C**	**L**	**C**	
Rattus rattus	Black Rat			S																											**C**	**C**		
Rattus steini	Stein's Rat																		G												**C**		**C**	**L**
Uromys affin. *caudimaculatus*[3]	Giant White-tailed Rat								C	ScC			SC		S														TI	TI	**C**	**C**	**C**	**L**
Xenuromys barbatus	Rock-dwelling Rat																												I	TI	**C**		**C**	**L**
Suidae																																		
Sus scrofa	Feral Pig					C	C		C	C		C						C											I	TI	**C**	**C**	**C**	**L**
Emballonuridae																																		
Mosia nigrescens (64 sCF / i.cvFM)	Lesser Sheath-tailed Bat			A	A	A	A	A	ANS	A	A	A	A	A	MA	A	A	A	A	A		NA									**C**	**C**	**C**	**L**
Hipposideridae																																		
As. tricuspidatus (112 sCF)	Trident Leaf-nosed Bat			HAN	A		A	A		A	A	A	A	A	HA		A		A		M										**C**	**C**	**C**	**C**
Hipposideros ater	Dusky Leaf-nosed Bat												R											R							**C**	**L**	**C**	**L**
Hipposideros cervinus	Fawn Leaf-nosed Bat								H				H		H																**C**	**C**	**C**	**L**
Hipposideros diadema (58 mCF)	Diadem Leaf-nosed Bat			A	A	A	A	A	MA	A	A	A		A	A		A		A	A											**C**	**C**	**C**	**L**
H. maggietaylorae (124 sCF)	Maggie Taylor's Leaf-nosed Bat							M				A		H	R																**C**	**C**	**C**	**L**
Hipposideros wollastoni (82 mCF)	Wollaston's Leaf-nosed Bat								A		A				A		HA	A	HA												**C**	**C**	**C**	**L**
Miniopterus magnater (37 st.cFM)	Large Bent-winged Bat			MA	A	A	A	A	A	A	A	A	A	A	A	A	A	A	MA	A											**C**	**C**	**C**	**L**

SCIENTIFIC NAME	ENGLISH NAME	IUCN STATUS[1]	PNG FAUNA ACT [2]	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	HI	NENA BASE	NENA LIMESTONE	NENA TOP	FRIEDA BASE	NENA BASE	HOTMIN VILLAGE	KUBKAIN VILLAGE	PARU VILLAGE	NEKIEI VILLAGE	FLYING FOX CAMP*	WAMEIMIN 1 VILLAGE	WAMEIMIN 2 VILLAGE	ENTIRE STUDY AREA	LOWLAND ZONE	HILL ZONE	MONTANE ZONE
Pteropodidae																																		
Macroglossus minimus	Long-nosed Blossom Bat			M					M	M		M																			C	C	C	L
Syconycteris australis	Common Blossom Bat			M	M	M	M	M	M	M	M	M	M	M	MH	M	M	M	M	MH	M	M									C	C	C	C
Syconycteris cf. *finschi*[3]	Bismarck Blossom Bat	NE			M	M		M	M			M			M		M		M												C	C	C	
Nyctimene aello	Broad-striped Tube-nosed Fruit Bat			M				MSc		M		M																			C	C	C	
Nyctimene draconilla	Lesser Tube-nosed Fruit Bat	DD		M	M		M	M	M	M		M	M	M	M		M														C	C	C	L
Nyctimene albiventer papuanus[5]	Tube-nosed Fruit Bat												M	M	M		M	M	M	M											C		C	L
Nyctimene sp. A[3]	Tube-nosed Fruit Bat	NE		M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M		M									C	C	C	L
Nyctimene sp. B[3]	Tube-nosed Fruit Bat	NE												M			M	M	M	M											C		C	L
Paranyctimene raptor	Green Tube-nosed Fruit Bat			M							M	M																			C	C	C	
Paranyctimene tenax	Steadfast Tube-nosed Fruit Bat			M					M	M		M	M	M	M																C	C	C	
Dobsonia minor	Lesser Naked-backed Fruit Bat			MH			M		M	M		M	M																		C	C	C	
Dobsonia moluccensis	Moluccan Naked-backed Fruit Bat															M			S										I	I	C	L	C	L
Pteropus macrotis	Large-eared Flying Fox			M																											C	C	L	
Pteropus neohibernicus	Great Flying Fox																								I	I	TI	Sp			C	C	L	
Pteropus sp. (large)*	A large Flying Fox			S					S																									
Rhinolophidae																																		
Rhinolophus philippinensis	Large-eared Horseshoe Bat															A			A	A											C		C	L
Vespertillionidae																																		
Myotis moluccarum	Moluccan Myotis			A					A	A		A	MA		A																C	C	C	L

SCIENTIFIC NAME	ENGLISH NAME	IUCN STATUS[1]	PNG FAUNA ACT [2]	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	FRIEDA BEND	KAUGUMI	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	KOKI	HI	NENA BASE	NENA LIMESTONE	NENA TOP	FRIEDA BASE	NENA BASE	HOTMIN VILLAGE	KUBKAIN VILLAGE	PARU VILLAGE	NEKIEI VILLAGE	FLYING FOX CAMP*	WAMEIMIN 1 VILLAGE	WAMEIMIN 2 VILLAGE	ENTIRE STUDY AREA	LOWLAND ZONE	HILL ZONE	MONTANE ZONE
Nyctophilus microtis	Papuan Long-eared Bat			H																											C	C	L	L
N. affin. *microtis*	Papuan Long-eared Bat	NE		MH		A																									C	C	L	L
Pipistrellus angulatus	New Guinean Pipistrelle			A	HA	A	A	A	A	A	A	A	A	A	A	A	A	A	A												C	C	C	L
Pipistrellus papuanus	Lesser Papuan Pipistrelle															M															C	C	C	L
Unallocated bat call types																																		
17 sh.cFM (Saccolaimus sp. or molossid)									A										A												C	C	C	L
20 cFM (Saccolaimus sp. or molossid)				A				A		A				A			A		A												C	C	C	L
24 cFM (Saccolaimus sp.)						A	A	A				A	A	A		A		A	A												C	C	C	L
27 sh.cFM.d (Emballonura sp.)				A						A		A			A																C	C	C	
30 st.cFM (Saccolaimus sp. or molossid?						A		A												A											C	C	C	L
34 i.fFM.d / sCF (Emballonura sp.)							A	A											A	A											C	C	C	L
42 cFM (a vespertilionid?)				A	A	A	A	A	A	A	A	A	A	A	A	A	A		A	A											C	C	C	L
42 i.fFM.d (Emballonura sp.)								A				A				A															C	C	C	
47 sCF / i.fFM.d (Emballonura sp.)				A	A	A	A	A	A	A	A	A	A		A	A	A		A	A											C	C	C	L
55 st.cFM.d / cFM (a vespertilionid)												A				A		A	A	A											C	C	C	L
75 mCF (*Hipposideros semoni* or *H. muscinus*)						A	A	A		A					A				A												C	C	C	L
90 mCF (*Hipposideros semoni* or *H. muscinus*)					A		A	A	A	A	A	A	A	A			A														C	C	C	L

Notes: Entries in taxon/site cells represent the method by which a taxon is recorded: A = acoustic detection, C = camera trap, G = ground trap, H = harp trap, I = reliable informant account, L = live village captive, M = mist net, N = hand net, R = at roost, S = sighting, Sc = sighting + capture, Sp = sighting + photograph, T = trophy. Entries in final four summary columns are: C = confirmed present; L = likely to be present (reliable informant testimony); Values for the IUCN categories are explained in Table 1; Listings under the PNG *Fauna (Protection and Control)Act 1966*: P = Protected.

1. The exact species present in the Study Area could not be determined; the record is counted in the species totals.

2. The record is inadequate to distinguish between several locally occurring species but represents an additional taxon for the individual sampling site. It is counted in site totals but not in totals for the zones or the Study Area.

3. Taxonomically undescribed or otherwise complex species.

* Flying Fox camp found during helicopter survey

kalubu, one *Paramelomys platyops*, and one *M. rufescens*,) and one in a cage trap (*Murexia longicaudata*). Approximately ten times as many kill traps were set as Elliott traps; hence, the capture rate for kill traps was almost double that for the Elliott traps.

Trap success (% of traps that returned a capture) was extremely low at all sites, with an overall trap success of 0.7% (i.e. less than one capture per 150 traps set; Table 7). The highest trap success (still only 1.6%) was obtained at Nena Base Site where a few traps set close to buildings caught two native *Rattus* species with reasonable frequency, thereby elevating the capture rate. Sites in the Lowland Zone had the lowest capture rate (0.5% across all sites; one capture per 200 traps set), and there was a slight but progressive increase to the Hill Zone (0.8%) and the Montane Zone (1.5%). Traps set by Miyan and Telefol assistants failed to produce any more captures than those set by Ken Aplin. The total number of captures is too low to allow meaningful assessment of relative efficacy of trap or bait types for capturing different kinds of mammals.

As mentioned before, a few traps set close to buildings at Nena Base Site on each of 7 nights returned a total of 7 rodents [all Spiny Rat (*Rattus praetor*) and Stein's Rat (*R. steini*)]. Similarly, traps set by Project staff in buildings at Frieda Base also produced regular captures of the Spiny Rat.

The total trapping effort in the Study Area (7,670 trap nights over 91 nights) represents the largest systematic trapping effort ever employed in a regional mammal survey in PNG, at least since the completion of the Archbold Expeditions of the 1930s to 1960s. By way of comparison, Leary and Seri (1997) reported setting 2,262 traps over 40 nights during a survey of the Kikori Integrated Conservation and Development Project. For surveys associated with the PNG LNG Project, Mamu *et al.* (2006) and Mamu (2008) reported a combined effort of 1,526 trap nights over 61 nights for both survey periods. Helgen (2007a) reported a total of 605 trap nights over the 14 day survey of the Kaijende highlands area near Porgera, Enga Province. Dawson *et al.* (2009) reported a total trapping effort of 5,760 trap nights at 12 sites with three 4-day survey periods per site in the Waria Valley, Morobe Province. Aplin and Opiang (2011) set 1,440 traps over 20 nights on the CI RAP Survey of the Nakanai Plateau of East New Britain Province, while Aplin and Kale (2011) set 2,134 traps over 25 nights in the CI RAP Survey of the Muller Range, Western Province. Flannery and Seri (1990) did not specify the total trapping effort for their multiple field surveys in the Sandaun region but it is clear that far greater reliance was placed on captures by local people rather than trapping.

5.2.2 Camera Trapping

A total of 68 camera trap photographs contained images of mammals (Table 8). All but one of these images could be identified at least to family level. Results obtained with individual cameras are presented in Appendix 3.9. The image capture rate (images per 100 camera traps hours) calculated across all sites is 0.59 (Table 8). Since the majority of mammal activity occurs at night, this is perhaps more meaningfully expressed as images per camera night or images per camera position, in which case the survey wide tally is one image per 7.22 camera nights and one image for every 1.85 camera positions.

At least 11 different mammal species were recorded by the camera trap units (Table 8). The most commonly photographed mammals were feral pigs (*Sus scrofa*; see Figure 7) with 20 images, spiny bandicoots (*Echymipera* spp.; see Figure 8) with 13 images; and Lowland Mammelomys (*Mammelomys rattoides*; Figure 9), White-striped Dorcopsis (*Dorcopsis hageni*; Figure 10) and Giant White-tailed Rat *Uromys* affin. *caudimaculatus*; Figure 11), each with seven images. Cuscuses were photographed walking on the ground on five occasions. Three of these images are definitely of a Ground Cuscus (*Phalanger gymnotis*; Figure 12), while the others could not be identified to species.

Raffray's Bandicoot (*Peroryctes raffrayana*) was captured in camera trap images at Ok Isai Site and HI Site (Figure 13). This species was not otherwise recorded during the survey but it is known from higher elevations in the general region (Morren 1989; Flannery and Seri 1990). Pigs were imaged by camera

Table 7. Capture rates for ground traps.

SURVEY SITE	INIOK SITE	EAST SEPIK SITE	KUBKAIN SITE	WOGAMUSH SITE	WARIO SITE	FRIEDA BEND SITE	KAUGUMI SITE	ALL STUDY AREA LOWLAND ZONE	OK BINAI 1 SITE	OK ISAI SITE	MALIA SITE	UPPER OK BINAI SITE	NENA D1 SITE	FRIEDA BASE	NENA-USAGE SITE	ALL STUDY AREA HILL ZONE (<500 M)	KOKI SITE	HI SITE	NENA BASE SITE	NENA LIMESTONE SITE	ALL STUDY AREA HILL ZONE (>500 M)	NENA TOP SITE	ALL SURVEY SITES
Myoictis melas												1				**1**					**0**		**1**
Murexia longicaudata												1				**1**		3			**3**		**4**
Echymipera kalubu												2				**2**	1				**1**		**3**
Hydromys chrysogaster																		1			**1**		**1**
Lorentzimys sp.											1					**1**							**1**
Mammelomys rattoides						1		**1**			3		1			**4**	2				**2**	1	**8**
Melomys rufescens									1							**1**							**1**
Microhydromys richardsoni													1			**1**							**1**
Paramelomys platyops		6				1	4	**11**	1	5	2	3				**11**		1	1		**2**	1	**25**
Rattus praetor														2					1		**1**		**1**
Rattus steini														1			1		4		**5**		**5**
Rattus praetor/ steini														2					2		**2**		**2**
Total captures	0	6	0	0	0	2	4	**12**	2	5	6	7	2	5	0	**22**	4	5	8	0	**17**	2	**53**
Capture rate (individuals/trap night)	0.000	0.011	0.000	0.000	0.000	0.004	0.010	**0.005**	0.012	0.009	0.006	0.010	0.007		0.000	**0.008**	0.005	0.006	0.016	0.000	**0.007**	0.015	**0.007**

Notes: entries are number of animals caught.

Table 8. Camera trapping results.

SAMPLING SITE	INIOK SITE	EAST SEPIK SITE	KUBKAIN SITE	WOGAMUSH SITE	WARIO SITE	FRIEDA BEND SITE	KAUGUMI SITE	ALL STUDY AREA LOWLAND ZONE SITES	OK BINAI 1 SITE	OK ISAI SITE	MALIA SITE	NENA D1 SITE	UPPER OK BINAI SITE	NENA-USAGE SITE	ALL STUDY AREA HILL ZONE (<500 M) SITES	KOKI SITE	HI SITE	NENA BASE SITE	NENA LIMESTONE SITE	ALL STUDY AREA HILL ZONE (>500 M)	ALL SAMPLING SITES
Murexia longicaudata								**0**					1		**1**					**0**	**1**
Echymipera sp.						1	8	**9**		1	2		1		**4**					**0**	**13**
Peroryctes raffrayana								**0**		1			1		**2**					**0**	**2**
Peralemidae indet.								**0**							**0**		1			**1**	**1**
Phalanger sp.							1	**1**							**0**		1			**1**	**2**
Phalanger gymnotis			1				1	**2**					1		**1**					**0**	**3**
Dorcopsis hageni						1	1	**2**			2		3		**5**					**0**	**7**
Hydromys chrysogaster								**0**							**0**		1			**1**	**1**
Mammelomys rattoides								**0**				1	2		**3**	1		3		**4**	**7**
Uromys affin. *caudimaculatus*						3	2	**5**			2				**2**					**0**	**7**
cf *Paramelomys* sp.						1		**1**							**0**		1			**1**	**2**
Sus scrofa	2	0	1	2	0	4	5	**14**	0	1	0	0	0	0	**1**	5	0	0	0	**5**	**20**
Canis lupus domesticus							1	**1**							**0**					**0**	**1**
Indetet, medium-mammal								**0**							**0**					**0**	**0**
Total no of images	2	1	2	2	0	10	19	**36**	0	3	6	1	9	0	**19**	6	4	3	0	**13**	**68**
Total no of species	1	1	2	1	0	4	6	**7**	0	3	3	1	6	0	**8**	2	4	1	0	**5**	**20**
No images/100 CT hr	0.89	0.12	0.39	0.33	0.00	2.88	1.79	**0.84**	0.00	0.34	0.26	0.55	1.54	0.00	**0.42**	1.14	0.93	0.18	0.00	**0.48**	**0.59**
No Species*/100 CT hr	0.45	0.12	0.39	0.17	0.00	1.15	0.57	**0.16**	0.00	0.34	0.13	0.55	1.03	0.00	**0.18**	0.38	0.93	0.06	0.00	**0.18**	**0.17**
No pig images/100 CT hr	0.89	0.00	0.20	0.33	0.00	1.15	0.47	**0.33**	0.00	0.11	0.00	0.00	0.00	0.00	**0.02**	0.95	0.00	0.00	0.00	**0.18**	**0.17**
No other mammal images/100 CT hrs	0.00	0.12	0.20	0.00	0.00	1.73	1.32	**0.51**	0.00	0.22	0.26	0.55	1.54	0.00	**0.40**	0.19	0.93	0.18	0.00	**0.29**	**0.42**

Notes: Entries are number of animals and Imaging rates (calculated per 100 camera trap (CT) hours). Images identified as *Phalanger* sp. and Peramelidae indet. are non-diagnostic below this level and they are not counted in species tallies if a more diagnostic record is also included (e.g. *P. gymnotis*; *Echymipera* sp.)

traps more than any other mammal in the Lowland Zone sites but generally not at Hill Zone sites (Figure 14). The one exception is the Koki Site where two cameras set in quite separate positions caught multiple images over two nights of what could be the same pig, a mature female with non-swollen teats. Images from the sites in the Lowland Zone include several of small groups of pigs, including females with young as well as mature males.

Image capture rates for other mammals show no systematic relationship with site elevation (Figure 14). However, if data are pooled for each of the elevation zones, there is a decrease from 0.51 images/100 CT hrs in the Lowland Zone to 0.40 images/100 CT hrs in the Hill Zone below 500 m elevation, and to 0.29 images/100 CT hrs in the Hill Zone above 500 m elevation (Table 8).

The camera trapping effort in the Study Area (11,616 camera trap hours including 491 camera trap nights) represents the largest effort of its kind in a PNG mammal survey. The total camera trapping effort during surveys associated with the PNG LNG Project was reported as 57 nights for surveys in 2005 (Mamu *et al.* 2006: Table 2) and 3,274 hours for surveys in 2007 (Mamu 2008: Table 2). The present survey thus achieved more than three times that applied during the previous largest effort.

5.2.3 Mist Netting

Mist netting was highly productive at all elevations, with a total of 737 bats captured in the 546 mist net nights that were applied across the 18 systematic survey sites (Table 9). A small number of bats were also netted at the opportunistic sampling site of Frieda Base but these are not included in the quantitative analysis.

The taxonomic composition of the mist net captures across the 18 systematic survey sites is shown in Table 9. A total of 13 pteropodid species and seven insectivorous bats were captured.

The great majority of mist net captures were of non-echolocating pteropodid bats (blossom bats, tube-nosed bats, fruit bats and flying foxes), with fewer captures of echolocating insectivorous bats. This contrast undoubtedly reflects the capacity of most insectivorous bats to avoid even the finer monofilament nets that were used during the survey. Insectivorous bats also tend to be adept at chewing themselves free from nets, and occasional holes in mist nets attested to escapees. Capture rates of insectivorous bats would be improved by attending the net through the evening, so that bats can be retained before they chew free. However, with multiple nets to check and the added workload of night transects for non-volant mammals, this was not a practical option. Instead, harp traps were employed as a potentially more effective means of capturing insectivorous bats.

Mist net capture rates are summarised in Table 9 and Figure 15 as captures per mist net night and as captures per 1,000 mist net metre hours. Capture rates for pteropodid bats were substantially higher in Lowland Zone sites than elsewhere, and there is an overall trend of declining capture rates with increasing elevation (Figure 15). However, Nena Limestone Site, situated at 950 m elevation at the upper limit of the Hill Zone, had a capture rate that exceeded some lowland sites and thus negates any generality in this trend. The other outlier point on these plots is Nena-Usage Site where a small netting effort (237 net metre hours) resulted in capture of a Moluccan Bare-backed Fruit Bat (*Dobsonia moluccensis*).

Capture rates for insectivorous bats also tend to be very slightly higher in the Lowland Zone (Table 10); Nena-Usage Site again is a striking outlier due to capture of one insectivorous bat.

There are few comparative data on sampling effort available for bat surveys in PNG. Leary and Seri (1997) indicated that they set a total of 109 mist nets on poles and a further 94 in the canopy during their 40-day survey of the Kikori ICDP area. Helgen (2007a) mentioned that mist netting effort was shared with bird surveyors during the 14-day survey of the Kaijende highlands area near Porgera, Enga Province but the number of nets is not specified. Richards (2005, 2008) also shared nets with the bird survey team during

Table 9. Mist netting results for all survey sites.

SAMPLING SITE	INIOK SITE	EAST SEPIK SITE	KUBKAIN SITE*	WOGAMUSH SITE*	WARIO SITE*	FRIEDA BEND SITE	KAUGUMI SITE	OK BINAI 1 SITE*	OK ISAI SITE	MALIA SITE	UPPER OK BINAI SITE	NENA D1 SITE	NENA-USAGE SITE	KOKI SITE	HI SITE	NENA BASE SITE	NENA LIMESTONE SITE	NENA TOP SITE
Number of nets	9	13	2	2	6	11	12	2	15	15	11	6	2	10	10	9	4	6
Hours open	282	446.00	6	6	113.25	469.75	553.50	6	620.75	934.50	450.00	210.625	17.50	513.25	348.75	999.25	109	134.00
Net-metre hours	3384	4430	144	144	384	5247	5807	144	6331	11566	5187	2500	237	6740	4180	9303	1157	1338
Net Nights	21	39	6	6	24	40	36	6	52	80	38	19	2	43	30	82	10	12
Dobsonia minor	1			1		1	3		4	1								
Dobsonia moluccensis													1					
Macroglossus minimus	9					13	1		3									
Nyctimene aello	9				1		2		1									
Nyctimene draconilla	11	15		2	1	6	11		5	5	2			2				
Nyctimene papuanus										5	2	2		10	8	10	6	
Nyctimene sp. A*	36	29	18	6	11	27	84	1	4	23	4	5		16	1	2	1	
Nyctimene sp.B*												1		1	1	1	3	
Paranyctimene raptor	4							1	1									
Paranyctimene tenax	2					1	1		1	1	1	2						
Pteropus macrotis	12																	
Syconycteris australis	11	18	3	3	1	25	24	3	11	35	13	5	2	12	15	21	13	10
Syconycteris cf. *finschii*		1	1		1	5			37		1			1		1		
Nyctophilus affin. *microtis*	1																	
Pipistrellus papuanus													1					
Miniopterus magnater	1															1		
Mosia nigrescens											1							
Aselliscus tricuspidatus																		1

SAMPLING SITE	INIOK SITE	EAST SEPIK SITE	KUBKAIN SITE*	WOGAMUSH SITE*	WARIO SITE*	FRIEDA BEND SITE	KAUGUMI SITE	OK BINAI 1 SITE*	OK ISAI SITE	MALIA SITE	UPPER OK BINAI SITE	NENA D1 SITE	NENA-USAGE SITE	KOKI SITE	HI SITE	NENA BASE SITE	NENA LIMESTONE SITE	NENA TOP SITE
Hipposideros diadema						1												
Hipposideros maggietaylorae					1													
Total Pteropodids	**95**	**63**	**22**	**12**	**15**	**78**	**126**	**5**	**67**	**70**	**23**	**15**	**3**	**42**	**25**	**35**	**23**	**10**
Total Insectivorous bats	**2**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**
All bats	**97**	**63**	**22**	**12**	**16**	**79**	**126**	**5**	**67**	**70**	**24**	**15**	**4**	**42**	**25**	**36**	**23**	**11**
Pteropodid captures per net night	**4.52**	**1.62**	**3.67**	**2.00**	**0.63**	**1.95**	**3.50**	**0.83**	**1.29**	**0.88**	**0.61**	**0.79**	**1.50**	**0.98**	**0.83**	**0.43**	**2.30**	**0.83**
Pteropodid captures per 1,000 Net-metre hrs	**28.07**	**14.22**	**152.78**	**83.33**	**39.06**	**14.87**	**21.70**	**34.72**	**10.58**	**6.05**	**4.43**	**6.00**	**12.66**	**6.23**	**5.98**	**3.76**	**19.88**	**7.47**
Insectivorous bat captures per net night	**0.10**	**0.00**	**0.00**	**0.00**	**0.04**	**0.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.00**	**0.50**	**0.00**	**0.00**	**0.01**	**0.00**	**0.08**
Insectivorous bat captures per 1,000 Net-metre hrs	**0.59**	**0.00**	**0.00**	**0.00**	**2.60**	**0.19**	**0.00**	**0.00**	**0.00**	**0.00**	**0.19**	**0.00**	**4.22**	**0.00**	**0.00**	**0.11**	**0.00**	**0.75**
All bat captures per net night	**4.62**	**1.62**	**3.67**	**2.00**	**0.67**	**1.98**	**3.50**	**0.83**	**1.29**	**0.88**	**0.63**	**0.79**	**2.00**	**0.98**	**0.83**	**0.44**	**2.30**	**0.92**
All bat captures per 1,000 Net-metre hrs	**28.66**	**14.22**	**152.78**	**83.33**	**41.67**	**15.06**	**21.70**	**34.72**	**10.58**	**6.05**	**4.63**	**6.00**	**16.88**	**6.23**	**5.98**	**3.87**	**19.88**	**8.22**

Notes: Entries for species are numbers caught. Sites indicated with an * were surveyed in a different way to the others and the quantitative results are not directly comparable.

the PNG LNG Project but also did not quantify the netting effort or captures from mist nets. Dawson *et al.* (2009) reported a mist netting effort of 725 – 750 mist net metre-hours at each of 12 sites in the Waria Valley. This amounts to 9,000 net metre hours, or a fraction of the effort allocated to this method during the present survey. Aplin and Opiang (2011) reported a total of 158 mist net nights over 20 nights on the CI RAP Survey of the Nakanai Plateau of East New Britain Province. Armstrong and Aplin (2011) reported a total of 266 mist net nights over 25 nights in the CI RAP Survey of the Muller Range, Western Province.

Table 10. Mist net bat capture rates summarised by zone

	CAPTURES PER NET NIGHTS					CAPTURES PER 1,000 NET-METRE HRS				
	LOWLAND ZONE	HIILL ZONE (<500 M)	HILL ZONE (>500 M)	MONTANE ZONE	ALL STUDY AREA	LOWLAND ZONE	HILL ZONE (<500 M)	HILL ZONE (>500 M)	MONTANE ZONE	ALL STUDY AREA
Number of nets	45	49	33	6	145	45	49	33	6	145
Hours open	1751.3	2233.4	1970.3	134.00	6220.1	1751.3	2233.4	1970.3	134.00	6220.1
Net-metre hours	18868	25821	21380	1338	68223	18868	25821	21380	1338	68223
Net Nights	136	191	165	12	546	136	191	165	12	546
Dobsonia minor	0.03	0.03			0.02	0.21	0.19			0.16
Dobsonia moluccensis		0.01			0.00		0.04			0.01
Macroglossus minimus	0.17	0.02			0.05	1.22	0.12			0.38
Nyctimene aello	0.08	0.01			0.02	0.58	0.04			0.19
Nyctimene draconilla	0.32	0.06	0.01		0.11	2.28	0.46	0.09		0.88
Nyctimene papuanus		0.05	0.21		0.08		0.35	1.59		0.63
Nyctimene sp. A	1.29	0.17	0.12		0.49	9.33	1.28	0.94		3.93
Nyctimene sp. B		0.01	0.04		0.01		0.04	0.28		0.10
Paranyctimene raptor	0.03	0.01			0.01	0.21	0.04			0.09
Paranyctimene tenax	0.03	0.03			0.02	0.21	0.19			0.13
Pteropus macrotis	0.09				0.02	0.64				0.18
Syconycteris australis	0.58	0.35	0.37	0.83	0.41	4.19	2.56	2.85	7.47	3.30
Syconycteris cf. finschii	0.04	0.20	0.01		0.09	0.32	1.47	0.09		0.70
Nyctophilus affin. microtis	0.01				0.00	0.05				0.01
Pipistrellus papuanus		0.01			0.00		0.04			0.01
Miniopterus magnater	0.01		0.01		0.00	0.05		0.05		0.03
Mosia nigrescens		0.01			0.00		0.04			0.01
Aselliscus tricuspidatus				0.08	0.00				0.75	0.01
Hipposideros diadema	0.01				0.00	0.05				0.01
Hipposideros maggietaylorae					0.00					0.01
Total Pteropodids	2.66	0.92	0.76	0.83	1.34	19.19	6.78	5.85	7.47	10.69
Total Insectivorous bats	0.02	0.01	0.01	0.08	0.01	0.16	0.08	0.05	0.75	0.12
All bats	2.68	0.93	0.76	0.92	1.35	19.34	6.85	5.89	8.22	10.80

Notes: Values for the Lowland Zone do not include data from Wario, Wogamush or Kubkain Sites. Values for the Hill Zone <500 m do not include data from Ok Binai Site. Empty cells are null values.

5.2.4 Harp Traps

The 83 harp trap nights produced a total of 20 captures, comprising three small pteropodid bats belonging to two species, and 17 insectivorous bats representing nine species (Table 11). The overall capture rate was 0.24 bats per harp trap night or one bat for every 4.2 harp trap nights. The capture rate for insectivorous bats was 0.20 and that of small pteropodids was 0.04. Remarkably, no tube-nosed bats

Table 11. Harp trap results for all survey sites.

	LOWLAND ZONE							HILL ZONE (<500 M)						HILL ZONE (>500 M)				ALL SITES	CAPTURES PER HARP TRAP NIGHT
	INIOK SITE	EAST SEPIK SITE	KUBKAIN SITE	WOGAMUSH SITE	WARIO SITE	FRIEDA BEND SITE	KAUGUMI SITE	OK BINAI 1 SITE	OK ISAI SITE	MALIA SITE	UPPER OK BINAI SITE	NENA D1 SITE	NENA-USAGE SITE	KOKI SITE	HI SITE	NENA BASE SITE	NENA LIMESTONE SITE		
Dobsonia minor	1																	**1**	**0.01**
Syconycteris australis											1						1	**2**	**0.02**
Myotis moluccarum										1								**1**	**0.01**
Nyctophilus microtis	1																	**1**	**0.01**
Nyctophilus affin. microtis	1																	**1**	**0.01**
Pipistrellus angulatus		1																**1**	**0.01**
Miniopterus medius	1																	**1**	**0.01**
Aselliscus tricuspidatus	2										1							**3**	**0.04**
Hipposideros cervinus						1				1	1							**3**	**0.04**
Hipposideros maggietaylorae												4						**4**	**0.05**
Hipposideros wollastoni														1		1		**2**	**0.02**
Total pteropodid bats	1										1						1	**3**	**0.04**
Total Insectivorous bats	5	1				1				2	2	4		1		1		**17**	**0.20**
All bats	6	1				1				2	3	4		1		1	1	**20**	**0.24**

Notes: Entries are number of animals caught.

were captured in harp traps, despite the high representation of this group in mist net captures. Harp traps are clearly ineffective for surveying non-echolocating bats in the Study Area but why this should be so is unclear.

Despite the low numbers of captures, the harp traps made a valuable contribution to our survey insofar as they contributed the only capture records of six species of insectivorous bats and provided individuals of eight species from which echolocation reference calls were obtained.

Harp traps have only occasionally been used in a systematic way in New Guinea mammal survey. Leary and Seri (1997) reported a total of 36 harp trap nights over their 40-day survey of the Kikori ICDP area. Helgen (2007a) mentioned a total of 7 harp trap nights over the 14-day survey of the Kaijende highlands area near Porgera, Enga Province. Aplin and Opiang (2011) reported a total of 38 harp trap nights over 20 nights on the CI RAP Survey of the Nakanai Plateau of East New Britain Province. Armstrong and Aplin (2011) reported a total of 16 harp trap nights over 25 nights in the CI RAP Survey of the Muller Range, Western Province.

Harp traps have a proven track record for capturing insectivorous bats in closed forests in Australia (Duffy *et a*l. 2000) and in Southeast Asia (Kingston *et al*. 2003; Armstrong 2006). However, they never seem to be particularly successful when deployed in New Guinean closed forest habitats. Apart from the present study, poor returns from harp traps have been reported by Richards (2008; who had no captures from 20-30 trap nights in primary forest), Armstrong and Aplin (2011; no captures from 16 harp trap nights), Helgen (*pers. comm*. to Aplin May 2010; no captures), and Leary (*pers. comm*. to Aplin May 2010). Aplin and Opiang (2011) had somewhat better success in East New Britain with 17 captures from 38 harp trap nights.

5.2.5 Acoustic Bat Survey

5.2.5.1 Reference Calls

Reference calls were recorded from 18 individuals of 10 different species of insectivorous bats, using a variety of different methods (Appendix 3.6). In addition, recordings were made of a bat feeding congregation around a building light at Frieda Base. The identity of the swarming bats was confirmed by hand netting of several individuals of the Lesser Sheath-tailed Bat (*Mosia nigrescens*).

5.2.5.2 Anabat Recording Sessions

A total of 138 informative AnaBat sessions were obtained (Appendix 3.4). All but one of these represents a full night of passive stationary recording at one of the systematic survey sites. The exception was a brief session recorded at Frieda Base on the occasion of a feeding swarm of Lesser Sheath-tailed Bats, as noted above.

A total of 22 different call types were distinguished on the passive AnaBat recording stations (Table 12), with two further types only recorded as hand held reference calls from captured bats using the Pettersson D240x detector (Appendix 3.6). The total might be revised upward slightly in the future, once echolocation calls of additional species present in the Study Area have been characterised. Ten call types could be allocated to species through comparison with vouchered reference calls. The remaining 12 call types were tentatively assigned to either genus or family level on the basis of diagnostic call characteristics. Appendix 3.7 contains a summary of echolocation pulse parameters for all call types and Appendix 3.9 shows representative call sequences for each type

The highest frequency call type recorded in a passive recording session was around 124 kHz (identified as the *124 sCF* call of the Maggie Taylor's Leaf-nosed Bat, *Hipposideros maggietaylorae*). Two of the species for which reference calls were made following capture (Fawn Leaf-nosed Bat, *H. cervinus* and

Dusky Leaf-nosed Bat, *H. ater*) produced calls with an even higher characteristic frequency, which have a limited range of detection using AnaBat units, possibly within 1 – 2 m. Both of these species were captured in close proximity to AnaBat recording sites, hence it is likely that they passed in the vicinity of the units without being detected. The same is true of the two species of long-eared bats (*Nyctophilus* spp.) captured in a harp trap at Iniok Village Site very close to a recording AnaBat unit. High frequency calls such as those emitted by the *Hipposideros* species, as well as low amplitude broadband calls of the kind emitted by *Nyctophilus* spp., have relatively short detection distances, and species that emit such calls are almost certainly underestimated on the recording sessions. The 143 recording sessions made on the Project survey represents the largest acoustic survey investment to date in PNG. In the only other large scale use of acoustic recording methods in PNG, Richards (2005; 2008) reported a total of 68 AnaBat recording sessions over 18 days field survey in 2005, and 50 recording sessions over 22 days field survey in 2008. Dawson *et al.* (2009) reported using an acoustic method to record bat calls in their survey of the Waria Valley, Morobe Province. However, the total effort was small, with only 3 hours recording for each of two nights per site, and they were able to distinguish only six call types. Armstrong and Aplin (2011) reported a total of 21 AnaBat recording sessions over 25 nights in the CI RAP Survey of the Muller Range, Western Province.

5.2.6 Night Transects

Night transects amounted to a total of 224.8 hours (Table 2), of which 89.5 hours were expended in Lowland Zone sites, 72.5 hours in Hill Zone sites below 500 m elevation, 53.5 hours in Hill Zone sites above 500 m elevation, and 9 hours in the Montane Zone site. The time spent at each site varied from 4 hours (Nena-Usage Site) to 20 hours (Nena Base Site), with most sites receiving 12-14 hours of effort.

A total of 29 terrestrial mammal sightings and 17 arboreal mammal sightings were made across all sites (Table 13). Contact rates (number of sightings per transect hour; s/hr) were uniformly low at all sites, with an overall average of 0.13 s/hr for terrestrial mammals and 0.08 s/hr for arboreal mammals. The highest contact rates for terrestrial mammals were experienced in Lowland Zone sites such as East Sepik Site (0.38 s/hr) and Frieda Bend Site (0.32 s/hr), and in lower elevation Hill Zone sites such as Malia Site (0.30 s/hr) and Nena D1 Site (0.42 s/hr). For arboreal mammals, the highest contact rate was experienced at Nena Top Site (0.33 s/hr) with the highest rates in the Lowland Zone at Kaugumi Site (0.19 s/hr) and Iniok Site (0.17 s/hr), and at Malia Site (0.18 s/hr) in the Hill Zone.

Fourteen different non-volant mammals species were observed and identified to species during night patrols. A further seven were identified to genus or family. For 13 of these species, the encounters resulted in capture of the individuals. One species (Northern Common Cuscus *Phalanger orientalis*) could be identified from photographs taken at night by Stephen Richards (Figure 16) and three other species were observed well enough for reliable identification.

Species representation is relatively even in the sightings, with each species accounting for between one and four observations. The most commonly observed group of mammals was terrestrial rodents (n = 18), followed by bandicoots (n = 11), possums (n = 9) and arboreal rodents (n = 8). One particularly significant sighting was made of a montane cuscus (probably Mountain Cuscus, *Phalanger carmelitae*; it was sitting 4 m above ground but evaded capture) at approximately 900 m elevation Previous records of this species are all from above 1300 m elevation (Helgen 2007a) and the Nena Base site sighting illustrates well the capacity for New Guinean montane mammals to extend to lower elevations in response to local influences of topography and microclimate.

The high contact rate at Nena Top Site mainly involved the Lowland Ringtail Possum *Pseudochirulus canescens* which was also observed at Nena Base Site (Figure 17).

Only five of the species in Table 13 were also trapped (*Echymipera kalubu, Hydromys chrysogaster, Mammelomys rattoides, Melomys rufescens, Paramelomys platyops*). The relatively low overlap between

Table 12. Summary of occurrence of bat call types recorded during AnaBat passive recording sessions at each sampling site.

	INIOK SITE	EAST SEPIK SITE	KUBKAIN SITE	WOGAMUSH SITE	WARIO SITE	FRIEDA BEND SITE	FRIEDA BASE	KAUGUMI SITE	OK BINAI 1 SITE	OK ISAI SITE	MALIA SITE	NENA D1 SITE	UPPER OK BINAI SITE	NENA-USAGE SITE	KOKI SITE	HI SITE	NENA BASE SITE	NENA LIMESTONE SITE	*ELEVATION RANGE (M)*
17 sh.cFM	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	H	—	*77–927*
20 cFM	H	—	—	—	H	—	—	Nc	—	—	—	H	—	—	H	—	H	—	*28–927*
24 cFM Saccolaimus sp.	—	—	H	H	H	—	—	—	—	H	H	H	—	H	—	H	H	—	*54–1036*
27 sh.cFM.d Emballonura sp.	H	—	—	—	—	—	—	H	—	H	—	—	H	—	—	—	—	—	*28–459*
30 st.cFM	—	—	H	—	H	—	—	—	—	—	—	—	—	—	—	—	—	H	*54–997*
34 i.fFM.d / sCF Emballonura sp.	—	—	—	H	H	—	—	—	—	—	—	—	—	—	—	—	H	Nc	*54–927*
37 st.cFM M. magnater	H	H	H	H	H	H	—	H	H	H	H	H	H	H	H	H	H	H	*28–1036*
40 st.bFM /st.sFM.d M. moluccarum	H	—	—	—	—	H	—	H	—	H	H	—	H	—	—	—	—	—	*28–459*
42 cFM	H	H	H	H	H	H	—	H	H	H	Nc	H	H	H	H	—	H	H	*28–997*
42 lCF R. philippinensis	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	Nc	*398–927*
42 i.fFM.d Emballonura sp.	—	—	—	—	H	—	—	—	—	H	—	—	—	Nc	—	—	—	—	*54–185*
47 sCF / i.fFM.d Emballonura sp.	H	H	H	H	H	H	—	H	H	H	H	—	H	H	H	—	H	H	*28–997*
47 st.cFM.h P. angulatus	H	H	H	H	H	H	—	H	H	H	H	H	H	H	H	H	H	—	*28–1036*
55 st.cFM.d / cFM	—	—	—	—	—	—	—	—	—	H	—	—	—	H	—	H	H	—	*103–1036*
55 st.bFM Nyctophilus microtis	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*54–*
58 mCF Hipposideros diadema	H	H	H	H	H	H	—	H	H	H	—	H	H	—	H	—	Nc	H	*28–997*
64 sCF / i.cvFM M. nigrescens	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	*28–1036*
75 mCF	—	—	H	H	H	—	—	Nc	—	—	—	—	H	—	—	—	H	—	*54–927*
82 mCF H. wollastoni	—	—	—	—	—	H	—	—	H	—	—	—	H	—	H	H	H	—	*54–1036*
90 mCF	—	H	—	H	H	H	—	H	H	H	H	H	—	—	H	—	—	—	*41–615*
112 sCF A. tricuspidatus	H	H	—	H	H	—	—	H	H	H	H	H	H	—	H	—	H	—	*28–927*
124 sCF H. maggietaylorae	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	*103–185*
Total of call types	**10**	**8**	**10**	**11**	**14**	**10**	**1**	**12**	**9**	**14**	**9**	**9**	**11**	**9**	**10**	**6**	**15**	**8**	
Anabat nights	**4**	**5**	**9**	**10**	**9**	**9**	**1**	**6**	**5**	**12**	**13**	**8**	**11**	**3**	**10**	**7**	**14**	**6**	

Notes: Cell entries are: H = high reliability; Nc = needs confirmation; dash = not detected. The elevation range of records for each call type is shown, based on the location of actual AnaBat passive recording sessions. The two call types recorded from captured and identified bats are not included.

trapping and night transect results highlights the importance of using multiple methods for mammal survey in PNG, especially where both trap success and transect contact rates are low.

Relatively large numbers of insectivorous bats were seen flying at dusk at some sites (e.g. Frieda Bend Site, Frieda Base), and on most night transects a few bats were observed flying through forest understorey. A count of these observations was made each night and this information is reported in Table 13. At several sites, large variation was noted from night to night in the number of insectivorous bats seen flying in the lower canopy. This might reflect variable levels of insect activity which itself could be determined by subtle variations in atmospheric conditions.

On nights with heavy rain, small pteropodid bats (blossom bats and tube-nosed bats) were noted to be more abundant in the lower canopy, and this was noted also in elevated capture rates on nights with significant rainfall. It is postulated that in heavy rain these species might spend more time in the lower canopy to avoid the adverse conditions of the upper canopy.

Night transect effort is not generally quantified for New Guinean mammal surveys. As explained earlier, the number of transect hours recorded for the present survey is an approximation of the actual effort because the number of people involved in the transect activity varied from a minimum of two up to occasional parties of four or five people walking together.

5.2.7 Daytime Observation of Animal Tracks and Signs

Mammal activity in a forest environment is usually indicated by the presence of obvious burrows and trackways, piles of feeding debris under logs and among roots, tooth marks on fallen fruit or on nut casings, isolated or concentrated faecal pellets (depending on species' habits), and sometimes also odour where urine has not been washed away by rain. Footprints might be visible alongside waterways or on tracks where mud is exposed. Feral pig (*Sus scrofa*) activity is also indicated by their deeper footprints, often on well-marked trails, and by areas of rooted up ground where they have been searching for fungi or worms.

At most sites, there was very little evidence of mammal activity. Active searching only rarely turned up a definite mammal burrow or well used trackway apart from those in use by pigs, and feeding debris was most often limited to old fragments of nuts (often of Fagaceae) showing rodent tooth marks; these clearly persist for many months or even years and thus give a cumulative record of activity over prolonged periods.

Signs of pig activity were noted frequently at all sites on the Sepik Plains sites except East Sepik Site, where they were conspicuously absent, perhaps reflecting the inferred low productivity of the Peat Forest environment. Significant pig activity, mainly in the form of well-marked track-ways, was noted in low hills immediately flanking this zone, such as occurs at each of Frieda Bend Site, Kaugumi Site and Malia Site. All sites above 400 m elevation showed little evidence of pig activity, including Koki Site where at least one pig was caught in camera traps. We infer that feral pigs in the Study Area are primarily using the resources of the lowland swamp and floodplain habitats, at least through December to June, with much less emphasis given to the resources of the Hill Forest zone.

Very few mammals were sighted during day time walking. One good sighting was made by Chris Muller who followed a wallaby for some distance near Malia Site. Based on his description, this animal is identified with a high degree of certainty as a Brown's Pademelon, *Thylogale browni*. This species was not recorded directly in any other way, though Miyan hunters gave good descriptions of this species as a resident of their hunting territories.

Table 13. Night transect results for all survey sites.

	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	KAUGUMI	FRIEDA BEND	LOWLAND ZONE	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	HILL ZONE (<500 M)	KOKI	HI	NENA BASE	NENA LIMESTONE	HILL ZONE (>500 M)	NENA TOP	ALL SAMPLES
Terrestial marsupials																						
Echymipera clara							1	**1**														**1**
Echymipera kalubu		1				1		**2**	1			1			**2**							**4**
Echymipera rufescens		1						**1**			1				**1**							**2**
Echymipera sp. Indet.		3						**3**				1			**1**							**4**
Thylogale browni											1*											
Terrestrial rodents																						
Hydromys chrysogaster											1				**1**							**1**
Mammelomys rattoides											1	1			**2**							**2**
Paramelomys platyops											1		1		**2**							**2**
Rattus rattus	1							**1**														**1**
Unidentified terrestrial rodent						1	3	**4**			1	2			**3**	1	2	2		**5**		**12**
Arboreal marsupials																						
Distoechurus sp.	2	1						**3**														**3**
Phalanger carmelitae																		1		**1**		**1**
Phalanger orientalis				1				**1**														**1**
Phalanger sp.																					1	**1**
Pseudochirulus canescens																		1		**1**	2	**3**
Arboreal rodents																						
Melomys rufescens									1						**1**							**1**
Pogonomys cf. *loriae*						2		**2**														**2**
Pogonomys cf. *mollipilosus*											1				**1**							**1**
Pogonomys macrourus											1				**1**							**1**

	INIOK	EAST SEPIK	KUBKAIN	WOGAMUSH	WARIO	KAUGUMI	FRIEDA BEND	LOWLAND ZONE	OK BINAI 1	OK ISAI	MALIA	NENA D1	UPPER OK BINAI	NENA-USAGE	HILL ZONE (<500 M)	KOKI	HI	NENA BASE	NENA LIMESTONE	HILL ZONE (>500 M)	NENA TOP	ALL SAMPLES
Uromys caudimaculatus						1		**1**			1				**1**							**2**
Unidentified arboreal murid																1				**1**		**1**
Pteropodid bats																						
Dobsonia minor							1	**1**														**1**
Dobsonia moluccensis																		1		**1**		**1**
Nyctimene aello					1			**1**														**1**
Nyctimene sp.	1	2				4	3	**10**	1		2	2			**5**	1		3		**4**		**19**
Pteropus macrotis	2							**2**														**2**
Pteropus sp. (large)							2	**2**														**2**
Syconycteris sp.		2				2	2	**6**		2	4	2	2	1	**11**	2	1	4	1	**8**	2	**27**
Insectivorous bats																						
Mosia nigrescens							1	**1**														**1**
Hipposideros ater											2				**2**							**2**
Unidentified Insectivorous bats	12	8				13	14	**47**		5	11	22	13	4	**55**	14	10	24		**48**	18	**168**
Total sightings																						
Terrestrial mammals	1	5	0	0	0	2	4	**12**	1	0	5	5	1	0	**12**	1	2	2	0	**5**	0	**29**
Arboreal mammals	2	1	0	1	0	3	0	**7**	1	0	3	0	0	0	**4**	1	0	2	0	**3**	3	**17**
Pteropodid bats	3	4	0	0	1	6	8	**22**	1	2	6	4	2	1	**16**	3	1	8	1	**13**	2	**53**
Insectivorous bats	12	8	0	0	0	13	15	**48**	0	5	13	22	13	4	**58**	14	10	24	0	**48**	18	**172**
Sighting rates (no per transect hour)																						
Terrestrial mammals	0.08	0.38	0.00	0.00	0.00	0.13	0.32	**0.13**	0.08	0.00	0.30	0.42	0.07	0.00	**0.17**	0.07	0.15	0.10	0.00	**0.09**	0.00	**0.13**
Arboreal mammals	0.17	0.08	0.00	0.08	0.00	0.19	0.00	**0.13**	0.08	0.00	0.18	0.00	0.00	0.00	**0.06**	0.07	0.00	0.10	0.00	**0.05**	0.33	**0.08**
Pteropodid bats	0.25	0.31	0.00	0.00	0.08	0.38	0.64	**0.13**	0.08	0.14	0.36	0.33	0.14	0.25	**0.22**	0.22	0.08	0.40	0.11	**0.23**	0.22	**0.23**
Insectivorous bats	1.00	0.62	0.00	0.00	0.00	0.81	1.20	**0.13**	0.00	0.36	0.79	1.83	0.93	1.00	**0.80**	1.04	0.77	1.20	0.00	**0.86**	2.00	**0.76**

Notes: Entries are number of animals. *Entry for *Thylogale browni* represents a daytime sighting and is not counted in the contact totals or calculation of contact rates.

5.2.8 Village Interviews and Hunting Trophies

A significant body of information on the larger mammals of the Study Area was obtained from interviews with residents of five villages and examination of hunting trophies from four villages. This information is summarised in Table 6 and presented in more detail in Appendix 3.12 and Miyan names for mammals in Appendix 3.13.

The largest collection of hunting trophies, examined at Wameimin 2 Village at 637 m elevation below the southern flank of the Nena Limestone Plateau, included specimens of ten mammal species (Figure 6). The most significant item was a tail of the *Endangered* Goodfellow's Tree Kangaroo (*Dendrolagus goodfellowi*), said to have been obtained locally on the Nena Limestone Plateau. A small collection of hunting trophies from Nekiei Village on the Sepik Floodplain contained an adult lower jaw of the Critically Endangered Black-spotted Cuscus *Spilocuscus rufoniger* (Figure 18).

Three topics of particular significance were given special attention during the course of these discussions, 1) the status in the Study Area of various Montane Zone mammals; 2) the status in the Study Area of the Black-spotted Cuscus; and 3) the location and pattern of usage of large flying fox camps.

5.2.8.1 Mammals in the Study Area Montane Zone

Informants at Wameimin 1 and 2 villages repeatedly mentioned several mammal species that occur in the Study Area Montane Zone, including the Critically Endangered Long-beaked Echidna (*Zaglossus* sp.), a second species of tree kangaroo [most likely the Vulnerable Western Montane Tree Kangaroo (*Dendrolagus notatus*)], the Critically Endangered Telefomin Cuscus (*Phalanger matanim*), and a small wallaby, probably the Near Threatened Small Mountain Dorcopsis (*Dorcopsulus vanheurni*). A possum-sized rat with grey fur was mentioned by several informants as an occupant of the highest forests in the Study Area. This most likely refers to either the Squirrel-toothed Rat (*Anisomys imitator*), a species of White-eared Giant Rat (*Hyomys* sp.), or a Woolly Rat (*Mallomys* sp.). The biogeographic analysis determined all of these taxa as possibly occurring in the Study Area (Table 4).

The Telefomin Cuscus is endemic to PNG and is only known from five specimens from two localities, Telefomin and Urapmin, about 50 km south-southwest of the Study Area. It is recorded from Lower Montane Forest (L ± c) between 1,400 and 2,600 m elevation. It superficially resembles Stein's Cuscus (*Phalanger vestitus*) and to a lesser extent the Ground Cuscus (*Phalanger gymnotis*). Telefol hunters, who happened to be passing through while a village interview was underway at Wameimin 1 in February 2010 stated that 'Matan' (= Telefol name for Telefomin Cuscus) has been caught close to the Telefol village of Eliptamin which is 40 km south-southwest of the Study Area. Miyan hunters involved in the same discussion followed up this statement with the information that the same species is known by the Miyan name 'Nelem' and can be caught even closer (20 to 30 km) to the Study Area. They accurately described two features that distinguish the Telefomin Cuscus from its relatives, namely its unusually short tail and its stocky build.

The Western Montane Tree Kangaroo is endemic to the Central Cordillera of PNG from 900 m to 3,100 m elevation, west of the Strickland River (Leary *et al.* 2008). It occurs in Hill Forest (Hm), Lower Montane Forest (L ± c) and Montane Forest, and occasionally ranges into alpine habitats. Miyan informants interviewed at Wameimin 1 and 2 villages clearly distinguished two kinds of tree kangaroos, known locally as 'Yema' and 'Debalmin'. 'Yema' is identified with confidence as a form of *D. goodfellowi*, based on Morren's (1989) records and the tail of a juvenile animal kept as a trophy in the Wameimin 2 Village. 'Debalmin' was described by hunters as large with 'black' (= dark) fur and a 'black' tail. The dark tail effectively rules out *D. stellarum*, described by Flannery and Seri (1990) from high elevations in the Star Mountains but is consistent with *D. notatus*. 'Debalmin' was also recorded by Morren (1989: 128) who stated that it could be found in "from the undisturbed montane forests of the upper slopes of Mt Stolle". The Miyan hunters interviewed at Wameimin 1 and 2 Villages were adamant that this species could also be caught locally within the Study Area, in the same places that supported ‘Yema’.

Small forest wallabies of the genus *Dorcopsulus* are widespread on the main island of New Guinea, from the lower montane zone up to the limit of tree cover (Flannery 1995). They occur both on the Central Cordillera and on many of the isolated ranges, in forests between about 800 and 3,100 m elevation They may have once been more widespread - according to Leary *et al.* (2008) “It has been extirpated from the Hunstein, Schrader, and the Torricelli Ranges, and probably the Adelberts”. Although they occur mainly in primary forests, small forest wallabies will utilize secondary forest and gardens where these abut large stands of forest.

Morren (1989: 129) recorded a species of *Dorcopsulus* in Miyanmin hunting territory (as ‘Sumul’, a name shared with other wallabies) and stated that it was “common in undisturbed mid-montane forest above 1600 m”. Miyanmin hunters interviewed at Wameimin 1 and 2 villages during the Project survey described a small montane forest wallaby under the name ‘Soyabu’. They stated that it was present at high elevations in the Study Area as well as on the more distant, larger mountains. It was said to be moderately common in the Study Area, and easily hunted with dogs. No trophy jaws of this species were presented. Flannery and Seri (1990: 186) recorded a Small Forest Wallaby (as *Dorcopsulus vanheurni*) in Miyanmin territory down to 1,000 m, and as “common in montane forests between 1,300 and 2,300 m”.

5.2.8.2 The Black-spotted Cuscus in the Study Area

The trophy jaw photographed at Nekei Village on 27 February 2011 provides the first confirmed record of the Black-spotted Cuscus in the Study Area. However, its presence was anticipated on general distributional data, the occurrence of large areas of suitable habitat, and information obtained from Miyan hunters. The anthropologist George Morren who worked mainly out of Miyanmim and Hotmin villages in the 1980s, reported “one trophy skin and a skull purchased in 1968. According to informants, it is found in the May River valley” (Morren 1989: 127). Morren also recorded the Miyan names ‘Tekep Derakeman’ for males and ‘Tekep Asul’ for females. These names were familiar to Miyan hunters interviewed at Wameimin 1 and 2 villages during the Project survey and the species was stated to be present throughout the area and across a wide elevational range.

Hunters at Nekei Village (speakers of Sanio-Hiyowe) were interviewed by Steve Richards with assistance from Project field staff members Simeon Dalap and Terence Orien. The name ‘Abiae’ was used for members of the Spotted Cuscus group (genus *Spilocuscus*), with three kinds of Abiae mentioned:

- ‘Abiae Mo-Unae’ – white animals (adults of both sexes of the local race of the Common Cuscus *S. maculatus* are often white or pale ginger).

- ‘Abiae Aili’ – black and brown animals with a little white (consistent with immature animals of both sexes and some adult males of the local race of *S. maculatus*).

- ‘Abiae Iwari’ – applied to a photograph (Flannery 1995: 187) of the Black-spotted Cuscus *S. rufoniger*. Said to be slightly larger than the other types, which is consistent with *S. rufoniger* (the local race of *S. maculatus* is particularly small).

Nekei hunters were not asked about the relative abundance of the different forms.

Hunters from Paru Village (speakers of Yahe) distinguished two kinds of spotted cuscus, ‘Hati-Wari’ (= White cuscus) and ‘Hati-Turu’ = (more coloured) with ‘Hati-Turu’ said to be larger. Both were said to be common but difficult to catch. A haul of 12 white cuscus were reported for April-May 2010, at the end of the wet season, with one each of the white and more coloured varieties in Sepmber and November 2010, respectively.

At Kubkain Village (Wogamusin speakers) the spotted cuscuses are known collectively as ‘Wub’. Three kinds are distinguished: ‘Wub-will’ are white, ‘Wub-kob’ are white and brown and “Wub-ndol’ are all brown. These names were said to represent different colour forms of the same species, which is consistent with known colour variation within the local race of *S. maculatus* (Flannery 1994). We could not determine if the Black-spotted Cuscus is referred to as “Wub-kob” or not. Cuscus were said to be hunted intensively during times of high flood water, by spotting them from canoes and using bow-and arrow. As many as 100 are said to be killed each year by the villagers combined, and the last one was brought in early March 2011.

Although information obtained from interviews must be treated with caution, the results are suggestive of the continued presence of Black-spotted Cuscus in the Study Area, with a possible geographic focus on the foot Hill Zone rather than the inundated floodplain zone. The limited capture data obtained from the Paru Village hunters suggest that the Black-spotted Cuscus may be either less abundant or less readily captured than the Common Cuscus.

The major threats to this species are forest removal and disturbance, and increased hunting activity, especially where this included the use of firearms (Flannery 1994, 1995, Leary *et al.* 2008). Flannery (1994) suggested the species has been exterminated in the eastern parts of its range and it is severely impacted by hunting. Suitable habitat is abundant and widespread in the Study Area and beyond. Indeed, the Study Area, with its large areas of relatively undisturbed Hill Forest and low human population density, may represent a significant refuge for the species.

5.2.9 Discovery and Characterisation of Bat Roosting Sites

5.2.9.1 Cave Roosts

Six caves were found to contain evidence of roosting bats and two other large cave roosts were reported by informants during village interviews but not visited (Table 14). No bone accumulations were found.

Roosting pteropodids were located in two caves along cliff lines visible from tracks emanating from the Koki Site. Cave 1 was a narrow but deep cleft in a low cliff line that contained four or five bats that flew out the cave as it was entered by one of the field assistants; the bats were consistent in size with the Moluccan Naked-backed Fruit Bat (*Dobsonia moluccensis*) or Bulmer’s Fruit Bat (*Aproteles bulmerae*).

The second cave in the vicinity of Koki Site was difficult to access. It is situated at the top of a near vertical cleft (Figure 19) and has an associated deep shaft that is subject to continual water spray from above. The roost was located after *Dobsonia*-sized bats were seen flying around the entrance during the late afternoon. The approach to the roost showed no evidence of recent human visitation in the form of an access path or hunting debris (usually wooden poles and charcoal from torches). Several hundred individuals were present but lack of access to the roosting surfaces made it impossible to get an accurate count or a firm identification of the species involved. Samples of urine and faecal deposits were taken for possible future DNA analysis.

During the visit to Wameimin 2 Village, information was obtained about two large colonies of ‘flying foxes’ resident in sinkholes called Inikia and Abo, each located on the Nena Limestone Plateau. To reach the caves involves a full day’s walk from Wameimin 2 Village and requires an overnight stay. Either of these sinkholes could harbour colonies of the Critically Endangered Bulmer’s Fruit Bat (*Aproteles bulmerae*) in addition to the widespread and Common Naked-backed Fruit Bat (*Dobsonia moluccensis*). People at Wameimin 2 did not have any trophy specimens of pteropodid bats and it was not possible to visit the sites during the field survey period.

Other small caves located near Hotmin Village, on the western side of the Study Area, and at the Nena Limestone Site, contained evidence of small numbers of roosting bats. The locality near Hotmin Village is a series of small cavernous overhangs part way up a steep scarp. Two pairs of Dusky Horse-shoe

Bats (*Hipposideros ater*) were observed roosting in semi-dark conditions in low crevices at the rear of the caverns and one pair was captured in a mist net to record echolocation calls. The site is visited regularly by children from Hotmin Village to ambush birds that visit mineral licks in the floor of the cave and it is clear that the bats, despite their minute size, are also hunted during these visits. *Hipposideros ater* is reported to use a wide variety of small roosts (Flannery 1995; Bonaccorso 1998) and the present observations are consistent with this prior information.

Table 14. Location, physical characteristics and contents of potential bat roosting sites.

NEAREST SURVEY SITE OR VILLAGE	DATE VISITED	KARST FEATURE	EASTING, NORTHING	ELEVATION (M)	CONTENTS
Koki Site cave 1	17/02/2010	Tunnel cave in low limestone cliff	583079, 9481290	1,150 m	4-5 large pteropodids; consistent with *Dobsonia moluccensis* or *Aproteles bulmerae*
Koki Site cave 2	17/02/2010	Large fissure in high limestone cliff with associated caves of unknown depth	583162, 9481185	1,124 m	Several hundred large pteropodids; identity not confirmed but consistent with *Dobsonia moluccensis* or *Aproteles bulmerae*; no sign of recent human visitation
Nena Limestone Site cave 1	10/12/2009	Waterfall caves in limestone	575451, 9486962	942 m	No evidence of usage by bats but flushed regularly by stream
Nena Limestone Site cave 2	11/12/2009	Shallow overhang in limestone	575347, 9486544	959 m	A single microchiropteran bat flushed on entry; no other evidence of usage
Nena Limestone Site cave 3	11/12/2009	Small fissure cave in limestone	575329	967 m	Scattered bat faecal piles in deep fissure with low ceiling
Hotmin Village Site	26/02/2010	Series of shallow overhangs below a calcareous mudstone scarp	562170	155 m	Two pairs of *Hipposideros ater* located in each of two different overhangs; signs of bat hunting activity

Note: coordinates in PNG MG94 zone 54

Two small cave systems at Nena Limestone Site contained small piles of insectivorous bat faeces indicating occasional use by bats. The entrance of one of the caves was blocked overnight with mist nets but this failed to produce any captures; hence, it seems likely that this particular cave was not in active use.

5.2.9.2 Flying Fox ‘Camps’

A large roosting congregation or ‘camp’ of flying foxes was observed on 01 November 2010 during a helicopter transect of Study Area Lowland Zone by Iain Woxvold. Interviews with residents of three villages in the vicinity of the flying fox camp revealed the existence of several additional flying fox camps within the Study Area. As explained below, these camps are probably semi-permanent fixtures in the landscape, at least on a decadal time scale, and must be treated as potentially significant for conservation of the resident flying fox species and for conservation of ecosystem services on a regional scale. This camp had moved several months later (M. Hawkins *pers. comm*.)

The flying fox roosting congregation (henceforth ‘the Wogamush flying fox camp’) observed from the air was located approximately 4 km north-northeast of the Wogamush Site, It extended for approximately 1.5 km on both sides of a large meander cutoff of the Wario River, along an ecotone between Lowland Open

Forest (Po) and Herbaceous Swamp (Hsw) (Figure 20a). Trees along the ecotone showed extensive defoliation (Figure 20b), as commonly noted for flying fox camps in Australia and elsewhere, and this can be used to infer the extent of the flying fox camp, even when the bats are absent. Placement along an ecotone between open and forest habitat is also a common feature of flying fox camps as it allows the bats to move freely along the margin of the congregation and gives easy access to the roosting trees.

Photographs of bats in flight at the Wogamush flying fox camp show features diagnostic of the Great Flying Fox *Pteropus neohibernicus*, including a sparsely furred back and a patch of yellow to golden fur on the lower back (Figure 21). Estimates by Iain Woxvold of wingspans well in excess of 1 m are also consistent with this determination.

Close-up photographs of the colony appear to show only adult bats. Despite this fact, the Wogamush flying fox camp is identified with some confidence as a maternity camp of the Great Flying Fox, a site where females congregate annually to give birth and rear their young through the first 4-5 months until they become independent. In Sandaun Province, female Great Flying Foxes were reported to be carrying late term embryos in January and to have dependent young of 250-320 g in late February (Flannery 1995). If the breeding schedule in the Study Area is the same as that recorded by Flannery, the majority of individuals in late December might be expected to be in advanced pregnancy or carrying new born young that would be difficult to see in the photographs. Other possible alternatives are that the congregation was of males and/or of young animals, although the latter option is contraindicated by the uniform size of the photographed bats. Flying foxes also congregate for one or more months during the mating season but with late pregnancies recorded locally in January and a likely gestation period of 6 months, mating congregations are more likely to occur in June or July.

Further information on flying fox camps was obtained during subsequent interviews with inhabitants of three villages with hunting territories covering parts of the Wario River and Wogamush River floodplains. This information probably relates to colonies of both the Great Flying Fox and the Big-eared Flying Fox *P. macrotis*, which is also abundant in the same general area.

- Hunters from Paru Village, which is located only 4-5 km from the Wogamush flying fox camp, reported three main flying fox camps in the vicinity of the village. The three camps were said to be quite variable in situation – one is next to the lake, one is near the village in forest (i.e. not near water), and the other is next to a river. The camps were said to be occupied at different times, with each camp used for 1-3 months before the bats depart. According to Stephen Richards, who conducted this interview, the hunters claimed that there is no predictable season, rather “they keep an eye out and when the flying foxes turn up, they hunt them”. However, they also said that the same three camps have been in existence since the earliest memories of the oldest informant (50+ years). The camps were said to be hunted intensively when they are occupied, with bow and arrows, and by felling of trees. This latter method would be effective only at maternity sites where it can be used to harvest immature bats too large to be carried by the females, but it is unclear whether the maternity camp in mention is the same as the Wogamush flying fox camp. The last major hunt was said to be in November 2010 when each hunter was said to have killed between 6 and 30-40 each (age and sex of bats was not specified). Hunts were conducted by individuals or small groups.

- At Kubkain Village, located approximately 14 km north-northeast of the Wogamush flying fox camp, hunters reported five main flying fox camps in the area. These were said to be occupied only seasonally, which is during high floods and when the bread-fruit is ripening, and located either near or far from water. Different trees were said to be selected as roosts each year. When present, flying foxes are intensely hunted with shotguns and bow and arrow. Despite the hunting, flying foxes were said to remain common in the area and no reductions in overall abundance were noted. Indeed, they reported that some camps were so dense that the leaves of the trees cannot be seen.

- At Nekiei Village, situated approximately 17 km southwest of the Wogamush flying fox camp and closer to the Hill Zone, people insisted that no large flying fox colonies occurred within hunting distance of the village. However, flying foxes were hunted whenever they fly into the area to feed, which they might do at any time of year.

The informants' accounts are consistent with the notion that the Lowland Zone of the Study Area contains one or more large flying fox camps, apart from the Wogamush flying fox camp observed in late December 2010, and that the same camp locations are used repeatedly over the course of multiple years. The other camps mentioned by informants might include additional maternity camps but probably also include courtship/mating camps or camps occupied by adolescent bats or males. Some camps presumably are occupied by the other common species of flying fox in the area, the Big-eared Flying Fox *P. macrotis*. The interpretation based on statements by Paru informants that the camps are "not used in predictable seasons" is here taken to mean that the camps are not all used in the same season, and possibly also that there are a number of alternative camp locations for any given seasonal activity (i.e. there may be several possible maternity camps, with no way of predicting which one will be used in a given year. Either of these inferences would be consistent with what is known of flying fox biology in northern Australia (e.g. Tidemann *et al.* 1999).

5.2.9.3 Other bat roost sites

One specimen of the Dusky Leaf-nosed Bat (*Hipposideros ater*) was found roosting inside a large fallen hollow log at Malia Site. A few days earlier Steve Richards had observed several small bats flying in and out of this log at dusk.

Several groups of the Lesser Sheath-tailed Bats (*Mosia nigrescens*) were observed roosting under palm leaves at Frieda Bend Site, in each case hanging approximately 4 m above the ground. This is consistent with previous accounts of roosting behaviour for this species (Flannery 1995; Bonaccorso 1998; Richards 2008).

Several tube-nosed bats (genus *Nyctimene*) and one Lesser Naked-backed Fruit Bat (*Dobsonia minor*) were observed at dusk, hanging in understorey vegetation. Although it cannot be certain that these represented the daytime retreats of the animals, in each case it is consistent with previous information on roosting behaviour of these species (Flannery 1995; Bonaccorso 1998).

5.3 Newly Discovered and/or Undescribed Species

Five of the mammal species recorded in the survey are undescribed, i.e. they are distinct species that have not been given scientific names. Two of these species appear not to have been collected previously and thus, are entirely new to science. The other three are very likely represented in previous regional collections but have remained undescribed due to a lack of sufficient taxonomic scrutiny of their group.

5.3.1 Species New to Science

Lorentzimys sp. - A Long-footed Tree Mouse

This genus is currently thought to contain a single species (Flannery 1995; Musser and Carleton 2005), albeit with acknowledgement of the need for further taxonomic study. Ongoing taxonomic studies by Ken Aplin suggest that the genus contains multiple well-differentiated species.

One specimen of *Lorentzimys* was collected at Malia Site. This specimen differs from all others examined by Ken Aplin, including animals from each of the Torricelli Range, localities in the western part of the Central Cordillera of Papua New Guinea (e.g. Porgera; Telefomin, Muller Range), and localities in Morobe Province to the east (e.g. Wau). While it certain that the species is new to science, its potential geographic distribution is far less certain. To date the northern foothills of the Central Cordillera of New Guinea have produced only a handful of specimens of *Lorentzimys*, including one record from the Torricelli Range which represents a different species to that collected at Malia Site. Available evidence does not preclude the Malia Site species having a broad distribution along the northern foothills of the Central Cordillera.

Pogonomys sp.* - A large Tree Mouse possibly related to *P. loriae

This species was detected only at Kaugumi Site where two individuals were shot with a bow at night after being observed climbing together in a low understorey tree. The capture site was inside Swampy Forest and the ground was waterlogged for several hundreds of metres in all directions. All members of this genus are thought to live communally in elaborate burrow systems (Flannery 1995; Winter et al. 2008). This clearly could not be the case for the Kaugumi Site animals that must have been utilising elevated daytime retreats due to the locally waterlogged conditions.

Morphologically, the Kaugumi Site *Pogonomys* appears to be most closely related to *P. loriae* of hill forest elevations (c. 500 – 700 m elevation) in the Owen Stanley Range. The Owen Stanley species is itself clearly distinct from a more widely distributed white bellied *Pogonomys* of moderate to large body size for which the name *P. mollipilosus* is probably applicable. At present *P. loriae* and *P. mollipilosus* are grouped as one species which is thought to occur across most of New Guinea and across a wide elevational range (Flannery 1995; Musser and Carleton 2005). A specimen tentatively identified as *P. mollipilosus* was obtained at Malia Site. In the Owen Stanley Range true *P. loriae* and *P. mollipilosus* occur together or in close proximity. In the Study Area, *P.* cf. *loriae* and *P.* cf. *mollipilosus* were collected at different sites, though only separated by a few hundred metres of elevation. To our knowledge, the larger of the two *Pogonomys* species has not been collected previously in northern New Guinea. The few regional records of '*P. loriae*' (Flannery 1995) are referrable to *P.* cf. *mollipilosus*.

Genetic studies currently underway will clarify the identity of the various *Pogonomys* species recorded in the Study Area. Until those results become available, the large *Pogonyoms* from Kaugumi Site should be treated as a potentially new species that is not known from any other locality. If, on the other hand, the Kaugumi population turns out to be referrable to *P. loriae*, then this will represent a very significant range extension and almost certainly a geographically isolated population.

5.3.2 Previously Recorded but Undescribed Species

***Distoechurus* sp. - a Feather-tailed Possum**

This species was detected at East Sepik Site and Iniok Site (Figure 22). The genus *Distoechurus* is usually treated as monotypic, with an altitudinal range from sea level to 1,900 m (Flannery 1995). However, ongoing genetic and morphological studies by the authors of this report favour the recognition of multiple well-differentiated species, each probably occupying a discrete geographic area on the main island of New Guinea. The Feather-tailed Possum from the Study Area differs in both external features and cranio-dental morphology from specimens examined from each of the Vogelkop to the west (typical *D. pennatus*) and Morobe Province to the east but is similar to two specimens in the Australian Museum from localities in West Sepik Province and the Torricelli Range. A pilot DNA assessment using mitochondrial 12S rDNA sequences (Aplin and Armstrong unpublished) also suggests close affinity between the Frieda, West Sepik and Torricelli populations, with a high level of divergence between this group and populations in the Ramu-Markham Basins the east and to the south of the Central Cordillera. Flannery (1995: 190) notes that "specimens from the Sepik are somewhat more brightly coloured than others" and this is true for the Study Area specimens. To date, no name has been proposed for this regionally endemic species. A *Distoechurus* photographed by Jim Thomas (Tenkile Alliance) in the Torricelli Range is also consistent with this form.

On available evidence, we conclude that the Sepik Basin *Distoechurus* is an undescribed species with a relatively large geographic range that includes the Torricelli Range. It appears to be locally quite common (two individuals were located during night patrols at Iniok Site) and occurs in both primary peat forest habitat (at East Sepik camp) and in heavily disturbed and secondary riverine forest communities (at Iniok Site). Our local assistants were mostly unfamiliar with this species, which is too small to be of much interest to hunters and probably spends most of its time in the forest canopy. In contrast, people at Wamiemin 1 and 2 seemed to be familiar with *Distoechurus* and claimed it to be common in both garden and forest habitats across a broad altitudinal range. Confusion between *Distoechurus* and the Sugar Glider (*Petaurus breviceps*) may account for some of this ambiguity – the Miyan name *mayfagam* seems to apply to both, while the name *kuriyang* was also offered for a '*mayfagam* without wings'. Morren (1989) recorded the Miyan name *mamsenabu* for this species but this name was not used by anyone interviewed during our survey. It is possible that any *Distoechurus* population at higher elevations in the Study Area may be distinct from the species that occurs at the low elevation sites.

***Nyctimene* species A and B – two undescribed Tube-nosed Fruit Bats**

The genus *Nyctimene* (Tube-nosed Fruit Bats) proved exceptionally abundant and taxonomically diverse within the survey area (Figures 23 and 24). Five species are distinguished on external and cranio-dental criteria. Only two of these can be assigned scientific names with any confidence – *N. aello* for the largest species and *N. draconilla* for the smallest. All of the remaining diversity falls into the current concept of *N. albiventer* which is widely acknowledged to be a taxonomic morass (Donnellan *et al.* 1995; Flannery 1995; Bonaccorso 1998).

A total of three species are clearly present in the sample of '*N. albiventer*' from the Study Area. These fall into two quite different groups based on cranial criteria – one species with a narrow V-shaped palate, similar to but larger than *N. draconilla*, and two species with broad U-shaped palates and thus similar to *N. albiventer* of eastern Indonesia and to *N. cyclotis* and *N. certans* (two poorly known species of montane forests in New Guinea). The two species with U-shaped palates from the Study Area differ significantly in body weights and external measurements, as well as in fur texture and patterning, and they have contrasting altitudinal distributions.

The smaller of the two Study Area taxa with the U-shaped palate is tentatively referred to the taxon *papuanus* described from Milne Bay Province (Figure 24; Andersen 1912). Flannery (1975) and Bonaccorso (1998) treat *papuanus* as a subspecies of *albiventer*, a view which is provisionally followed here. At present it is not possible to associate scientific names with either the taxon with the V-shaped palate (Figure 23) or the larger taxon with the U-shaped palate (Figure 23). Both are quite likely unnamed and they are listed here as *Nyctimene sp.* A and *Nyctimene sp.* B, respectively (e.g. Tables 6 and 10). *Nyctimene sp* B (Figure 23) averages slightly larger-bodied and longer winged than *Nyctimene albiventer papuanus*.

Preliminary studies of CSIRO collections from sites in both the northern and southern lowlands suggest that *N. albiventer papuanus* and *Nyctimene* sp. A both have wide geographic ranges, possibly extending even to the lowlands and foothills of southern New Guinea. On the other hand, *Nyctimene* sp. B, which was recorded only from higher elevation sites in the Study Area Hill Zone, is not matched by specimens examined from any other collecting locality. More exhaustive studies of existing museum collections are needed to establish the wider distribution of this taxon. Within the Study Area it appears to be common at Nena Limestone Site and it seems likely to occur more widely, though possibly with an association with limestone karst habitat.

5.3.1 Other Taxonomically Labile Groups

At least three other groups of mammals recorded in the Study Area contain as yet unresolved taxonomic complexity. These are highlighted here either because the taxonomic nomenclature employed in this report differs from that featured on the current IUCN Red List of Mammals, or because taxonomic studies in the near future are likely to result in the recognition of additional mammal species with potentially restricted geographic ranges in the Study Area.

The Papuan Long-eared Bats - N. microtis *and* N. *affin.* microtis

Three adult long-eared bats were captured at Iniok Site. Although all have the general morphological features of the Papuan Long-eared Bat, *N. microtis* (Bonaccorso 1998), one of the three is not only considerably more gracile than the others (6.8 g vs 12.8 – 13.2 g; forearm lengths are comparable) but also differs in cranial shape and dental morphology. Previous regional collections from the Sepik River Basin also include two recognisable forms of the Papuan Long-eared Bat (*Nyctophilus microtis*) that differ in cranial robusticity (H. Parnaby, *pers. comm.* to Ken Aplin, August 2010) but it is not yet clear which form represents *N. microtis* or whether the second species has a prior name. On the other hand, it is very likely that both of the *Nyctophilus* species captured at Iniok Site are more widely distributed, at least within the Sepik River Basin.

Giant White-tailed Rats - Uromys *affin.* caudimaculatus

Uromys caudimaculatus is currently thought to have a wide distribution that includes all of mainland New Guinea up to lower montane elevations, as well as rainforest habitats in northeast Australia. Ongoing morphological and genetic studies by the authors, Kris Helgen (Smithsonian Institution) and others have revealed multiple species in this group, with as many as four occurring in New Guinea. *Uromys caudimaculatus* is essentially an Australian species but it does occur in rainforest patches on the Fly Plateau of Western Province. Two or more related species occur on the northern side of the Central Cordillera but it is unclear at present what names might be applied to these taxa and how they are distributed, especially in the western half of the island. At present, it does not appear as though any of the species of this group are very restricted in their distribution.

Blossom Bats – *Syconycteris* spp. Only one species of the blossom bat genus *Syconycteris* is currently recognised in lowland New Guinea and this is among the most commonly caught of all New Guinean bats (Flannery 1995; Bonaccorso 1998). Many individuals were captured during this survey and considerable variation was noted in both body size and dental morphology. This variation resolved into two species, each showing some sexual dimorphism. The larger species is identified as the Common Blossom Bat (*S. australis*). The smaller species is tentatively identified as the Bismarck Blossom Bat, usually distinguished from the typical Common Blossom Bat *Syconycteris australis* only at sub-specific level – as *Syconycteris australis finschi* (e.g. Bonaccorso 1998). However, both forms were captured at many sites (Table 6) and it is clear that they are two distinct biological species - here denoted as *Syconycteris australis* and *Syconycteris* cf. *finschi.* Detailed comparisons are now required to establish the identity of the Sepik population with the typical *finschi* of the Bismarck Archipelago. The likely presence of *S. australis finschi* on mainland northern New Guinea has been noted previously by K. Helgen (Smithsonian Institution; pers. comm. to Ken Aplin, May 2010) based on one specimen collected near Lae in Morobe Province.

The proportion of the two species in the sample is not yet quantified as this requires the removal and cleaning of large numbers of skulls and extensive genetic analysis. However, it is clear that *Syconycteris* cf. *finschi* was caught more frequently at sites in the Study Area Lowland Zone, and less commonly at higher elevation sites. The highest elevation record of *Syconycteris* cf. *finschi* appears to come from a net set at 750 m elevation, below the large clearing at Nena Base Site.

5.4 Assessment of Survey Adequacy

Sampling adequacy of the Study Area survey is assessed here in three ways:

- by comparing the survey results with the Candidate Mammal List produced from the biogeographic analysis

- by examining taxon cumulative accumulation curves for individual survey sites and/or elevational zones, as recorded by the various survey methods

- by examining the canonical distribution of species or bat call types across the various survey sites.

5.4.1 Comparison of the Survey Results with the Candidate Mammal List

The Candidate Mammal List and survey results are compared in Table 15 for the Survey Area as a whole and for each of the three elevation zones, with the results broken down into major taxonomic/ecological categories. For the survey results, the tabulation includes those taxa rated either as confirmed or likely to be present.

Table 15. Quantitative comparison of the Candidate Mammal List derived from the biogeographic analysis with the results of the field survey

		ALL MAMMALS	MONOTREMES	MARSUPIALS	RODENTS	PTEROPODID BATS	INSECTIVOROUS BATS
Candidate Mammal List	All Study Area	139	3	36	40	19	41
	Lowland Zone	83	0	17	19	16	31
	Hill Zone	112	2	27	29	17	37
	Montane Zone	85	1	32	35	7	10
Survey results (including likely records)	All Study Area	80	1	25	14	14	26
	Lowland Zone	64	0	15	12	12	25
	Hill Zone	72	1	18	13	14	26
	Montane Zone	55	1	15	8	7	24
Deficit (potentially undetected species) or excess (unanticipated species)	All Study Area	58	1	11	26	5	15
	Lowland Zone	19	0	2	7	4	6
	Hill Zone	40	1	9	16	3	11
	Montane Zone	30	0	17	27	0	-14
Survey result as % of Candidate List	All Study Area	58%	50%	69%	35%	74%	63%
	Lowland Zone	77%	-	88%	63%	75%	81%
	Hill Zone	64%	50%	67%	45%	82%	70%
	Montane Zone	65%	100%	47%	23%	100%	240%

Notes: Data are presented for all sites combined and for each of three main elevation zones in the Study Area (Lowland Zone, Hill Zone and Montane Zone). Feral pig excluded from table.

For all groups of mammals combined, the comparison suggests that the survey may have detected less than 60% of locally occurring species, with the lowest apparent detection rates being for monotremes (50%) and rodents (35%). When the mammal fauna of different elevation zones is considered individually, the apparent detection rate rises to over 63% for all groups and to over 75% for all groups except rodents. For the Hill Zone, the values exceed 66% for all groups except monotremes (50%) and rodents (45%). For the Montane Zone, apparent detection rates are highly polarised, being quite low for marsupials (47%) and rodents (23%) but very high for monotremes (100%), pteropodid bats (100%), and particularly insectivorous bats (240%; i.e. more than twice the expected number).

The overall low apparent detection rates for rodents and marsupials may be a genuine feature of the results – it probably reflects the difficulty of capturing many New Guinean small non-volant mammals, either because they are genuinely rare or because they are difficult to capture or observe using conventional methods. While the decrease in apparent detection rates for these groups at higher elevations presumably reflects the progressively lower amount of trapping carried out in these zones.

Pteropodid bats appear to show the reverse trend, with apparent detection rates at a minimum (75%) in the Lowland Zone and rising to 100% in the Montane Zone. For this group, the Candidate Mammal List contains a number of wide-ranging 'supertramp' species (*sensu* Diamond 1974) that have their main distribution on offshore islands but might include all or part of the Study Area within their foraging range or seasonal movements. These species include a number of the larger flying foxes and they were unlikely to be recorded using the methods employed.

The acoustic detection in the Montane Zone of 14 more species of insectivorous bats than expected is an interesting result that finds parallel in other recent surveys (Armstrong and Aplin 2011). In our view this phenomenon is attributable to the small amount of systematic bat survey that has been carried out in the Hill Zone and the lower part of the Montane Zone in New Guinea, compared with the Lowland Zone and the mid to higher elevations in the Montane Zone. Species that were thought to be restricted to lower elevations are being found to extend up to elevations in excess of 1,000 m elevation A good example from this study was the acoustic detection of the Trident Leaf-nosed Bat (*Aselliscus tricuspidatus*) up to 925 m elevation and its capture in a mist net set at 1,065 m elevation, compared with a previously reported ceiling at 600 m elevation (Bonaccorso 1998; Helgen 2007a).

For the non-volant mammals there are no striking discrepancies between the Candidate Mammal List and the survey results. No species was notable in its absence, and only one species can be said to have been genuinely 'unexpected'. This 'mammal surprise' was the Large Tree Mouse *Pogonomys* cf. *loriae* that most closely resembles *Pogonomys loriae* of Hill Forest elevations (c. 500 – 700 m elevation) in the Owen Stanley Range.

For pteropodid bats the major discrepancy between the Candidate Mammal List and the survey results concerns the higher than anticipated diversity among the Tube-nosed fruit bats (*Nyctimene* and *Paranyctimene*). The biogeographic analysis rated a total of four species as likely and two as possible for the Study Area. The survey recorded seven species; moreover, one of those rated as likely in the Candidate Mammal List (the Mountain Tube-nosed Fruit Bat *N. certans*) was not recorded, probably due to insufficient mist netting effort in the Montane Zone. The true total diversity in the Study Area thus may be eight species of tube-nosed fruits bats. Two of these are undescribed species (*Nyctimene* sp. A and *Nyctimene* sp. B) and one of these (*Nyctimene* sp. B) appears to be currently known only from the Study Area.

One notable absence among the pteropodids recorded during the survey results is the Common Rousette Bat (*Rousettus amplexicaudatus*). This species is known from lowland habitats in the general region and it is also susceptible to mist netting (Bonaccorso 1998). However, this typically Lowland Zone species probably roosts exclusively in caves and failure to detect it in the Study Area most likely reflects the absence of limestone karst habitats at low elevations.

Among the echolocating bats, all of the species captured in mist nets or harp traps were anticipated by the biogeographic analysis. However, the acoustic recordings produced several unanticipated results. Foremost among these was the potentially high diversity among members of the genus *Emballonura*. In all, four taxonomically unallocated call types were tentatively assigned to members of this genus (*27 sh.cFM.d*, *34 i.fFM.d*, *42 i.fFM.d* and *47 sCF / i.fFM.d*), whereas the biogeographic analysis suggested the occurrence of only three species within the Study Area. This might be due to the presence of additional complexity within this rather poorly studied genus (especially given the wide range of variation in characteristic frequency in the *47 sCF / i.fFM.d* type) or due to several of the call types being referrable to one species with sexual dimorphism in characteristic frequency.

These minor discrepancies aside, the generally high degree of correspondence between the survey results and the Candidate Mammal List also provides a strong validation of the biogeographic analysis. This is strongest for the Study Area Lowland and Hill Zones, where the highest proportion of all candidate mammal species were detected. However, results obtained for the Study Area Montane Zone also support the essential validity of this component of the biogeographic analysis. This conclusion is important for two reasons: 1) it allows risk analyses to proceed on the basis of a robust predictive model of mammal communities within the Study Area; and 2) it provides a detailed historical biogeographic framework for assessing the significance of populations of individual mammal species within the Study Area.

5.4.2 Taxon Cumulative Accumulation Curves

Another measure of survey completeness is obtained by plotting the accumulation of new species records through the duration of a survey, either based on individual survey methods or by combining records derived from all methods (Figure 25 to 27). This can be done at a single site level, or by zones, depending on the quantity of data obtained. A survey using a particular method is likely to be complete or nearly so if the taxon accumulation curve reaches a ‘data plateau’ with no additional taxa added despite considerable further sampling effort.

5.4.2.1 Non-volant Mammals

Data accumulation plots for all sites combined show an apparent data plateau effect for camera trapping (Figure 26), a suggestion of a data plateau for ground trapping (Figure 25), and no data plateau for night transects (Figure 27). However, when the data is plotted separately for each of the major zones there are no compelling data plateaux for any method (Figures 25 to 27). The data plateau for camera trapping across all sites may be an artefact of the fact that the last major period of fieldwork was carried out in the Lowland Zone where the species accumulation plots for all methods combined can only be plotted against the common factor of number of sampling nights, rather than the actual measure of effort such as trap nights, transect hours etc. However, the survey effort was relatively even throughout the entire survey period. The plot for all sites combined shows a gradual decrease in slope suggestive of approach to a genuine plateau (Figure 28a). However, plots for each of the elevation zones suggests a possible approach to a genuine plateau for the Lowland Zone but not for the Hill Zone, whether this is taken as a whole or analysed separately for the sites above and below 500 m (Figure 28b).

5.4.2.2 Bats

Data accumulation plots for the results of mist netting show no data plateaux whether or not the data are combined across all sites or pooled within each of the major zones (Figure 29a-b). As expected, the slope of the relationship is steepest for the Lowland Zone where bat diversity is highest, and progressively lower for each of the Hill Zone < 500m elevation and the Hill Zone > 500m elevation Insufficient data were obtained from the Montane Zone to include it in this analysis.

Equivalent plots for the results of harp trapping show a similar pattern albeit with lower total numbers of captured species (Figure 30a-b).

Accumulation plots for the AnaBat passive recording data show a gradual decrease in slope, suggestive of approach to a genuine plateau, irrespective of whether the data are combined across all sites or pooled within each of the major zones (Figure 31a-b). However, additional bat call types were recorded close to the end of the survey effort both in the Lowland Zone and in the Hill Zone, and it is by no means certain that the full diversity of bat call types was recorded in either context.

The AnaBat datasets are sufficiently data rich to support a more detailed analysis on an individual site basis. Accumulation curves for bat call types are plotted using the cumulative number of AnaBat acoustic sessions in Figure 32 and using the cumulative number of acoustic survey nights in Figure 33. At Wogamush Site in the Lowland Zone, and Malia Site in the Hill Zone <500m elevation, and at Koki Site, HI Site and Nena Limestone Site in the Hill Zone >500m elevation, the accumulation curves suggest that most species had been adequately sampled with 3 – 7 AnaBat sessions over 3 – 5 nights. However, in the remaining sites, there are no obvious plateaux in species number. Most notably, the accumulation curves for Nena Base Site, Nena D1 Site and Ok Isai Site do not appear to have attained a plateau even after 5 – 8 survey nights (11 – 14 sessions). These results suggest that the acoustic survey effort was sufficient to detect the more abundant insectivorous bat species at each site but probably not all of the rarer species (or those that have relatively low detectability).

5.4.3 Canonical Distribution Plots

Canonical distribution plots illustrate the extent to which taxa are shared between different systematic survey sites within the Survey Area, and are often used as a measure of rarity or commonness within a community (Preston 1962). For a mammal community that is not comprehensively surveyed, such as in the present context, they represent a measure of sampling adequacy.

Canonical plots for non-volant mammals and for bats recorded through direct capture methods show classic J-shaped curves which indicate that a large number of taxa were recorded only at a small number of sites, with relatively few recorded from multiple sites (Figure 34a). In contrast, the plot for bat call types recorded by AnaBat passive recording sessions shows a more complex pattern with an apparent dichotomy between taxa recorded at six or fewer sites and those recorded at more than nine sites (Figure 34b). This pattern may reflect a genuine feature of bat community structure in the Study Area, with a contrast between a suite of widespread and relatively abundant species, and a second suite of either less abundant or more restricted species.

5.4.4 Relative Effectiveness of Different Survey Methods

The relative effectiveness of different methods can be assessed in terms of several parameters:

- The total number of species records contributed by each method;
- The number of unique species records contributed by each method;
- The number of species of special conservation concern contributed by each method; and
- The relative cost of this information in terms of effort expended in the field.

The relevant data are summarised in matrix form in Table 16, Table 17 compares efficiency of the different survey methods and Appendix 3.14 shows which species were caught by which methods.

5.4.4.1 Total Number of Species Records

No single method detected more than 28% of the total mammal species records (Table 16). However, a more useful measure is the effective contribution of each method in detecting its principal target group (generally non-volant mammals or bats). Analysed in this way, the maximum individual contributions of the most informative methods rise to 46 - 56% of target species.

The largest number of species was detected by the acoustic bat survey (22), followed by mist netting (21), informant interviews (19), night transects (18), inspection of hunter trophies (14), ground trapping (11) and harp traps (10). Other methods contributed between one and nine species records.

Table 16. Relative effectiveness of each mammal survey method in detecting mammals.

	GROUND TRAPPING	CAMERA TRAPPING	NIGHT TRANSECT	DAY PATROL	AERIAL SURVEY	INFORMANT INTERVIEWS	HUNTER TROPHY	MIST NETTING	HARP TRAPPING	SCOOP NET	CAVE SEARCHES	ACOUSTIC SURVEY	NUMBER OF SPECIES DETECTED BY METHOD	% OF ALL MAMMALS SPECIES
Ground trapping	4												11	14%
Camera trapping	3	1											9	11%
Night transect	3	2	6										18	22%
Day patrol		1		2									4	5%
Aerial survey					0								1	1%
Informant interviews	3	5	1	2		8							19	23%
Hunter trophy	2	5	5	1	1	7	1						14	17%
Mist netting	1		4					10					21	26%
Harp trapping			1					5	2				10	12%
Scoop net			1					2	1	0			2	2%
Cave searches			1					1			0		1	1%
Acoustic survey			2					6	6	2		12	22	27%
Total for all methods	81													

Values in cells along the diagonal are number of species uniquely detected by an individual method. Values below the diagonal are number of species detected in common by each pair of methods.

For non-volant mammals there is particularly strong overlap between the records contributed by informant interviews (and hunter trophies, which formed the basis for much discussion) compared with camera trapping and night transects. An interesting observation is that most species detected by ground trapping (a particularly laborious activity) were also detected by one or more of camera trapping, night transects or informant interviews.

There is significant overlap between the contributions of the major bat detection methods of mist netting, harp trapping and acoustic survey. For the insectivorous bats, the degree of overlap reflects the extent to which we were successful in obtaining reference echolocation calls from captured bats. With sufficient effort to complete this task for the Study Area, it is likely that the appropriate use of acoustic survey methods would make direct capture of insectivorous bats almost entirely redundant as a survey method, as has occurred to a large extent in Australia and some other parts of the world. However, it is important to stress that this method relies for its effectiveness not only on established call libraries but also on a solid taxonomic foundation, with accurate delineation of species. Neither condition is currently met for any group of New Guinean insectivorous bats.

For the diverse assemblage of non-echolocating small pteropodid bats, the use of mist netting represents the only effective survey method at the present time, with harp trapping and observations of roosting bats during day or night transects contributing only occasional records.

5.4.4.2 Unique Species Records

The largest number of unique species records was contributed by the acoustic survey (12), followed by

Table 17. Relative efficiency of main mammal survey methods.

SURVEY METHOD	FIELD EFFORT REQUIRED	TOTAL NUMBER OF SPECIES	NUMBER OF UNIQUE RECORDS	NUMBER OF LISTED SPECIES
Ground traps	High	11	4	1
Mist nets	Moderate	21	10	1
Night transects	Moderate	18	6	0
Acoustic bat survey	Low in field, but requires significant post-fieldwork analysis by a specialist	22	12	0
Camera traps	Low	9	1	0
Harp traps	Low	10	2	0
Informant interview / hunter trophy	Low	19	9	8

Notes: Listed species are those listed above Least Concern in the IUCN Red List or as protected in the PNG *Fauna (Protection and Control)Act 1966*.

mist netting (10), informant interviews + hunter trophies (9), night transects (6), ground trapping (4), harp traps (2) and camera trapping (1) (Table 16).

The large number of unique records from the acoustic bat survey is a reflection of the difficulty of capturing many insectivorous bats. Very large effort with mist nets and harp traps would be needed to replicate the dataset obtained through acoustic survey methods. As noted above, mist netting currently represents the only effective way of sampling non-echolocating small pteropodid bats.

For non-volant mammals, informant interviews and night patrols provided many unique records and it is likely that some of these records (e.g. small ringtail possums, tree mice) would not be replicated by other techniques such as trapping and camera trapping unless these could be safely translated into the arboreal realm. Ground trapping produced unique records of four rodent species. For the two *Rattus* species uniquely recorded this way, a camera trap image or other remote sighting would not allow discrimination of the two species which are morphologically very similar. The other two rodent species are very small and it is questionable whether they would trigger a camera trap or if they did, that their image would be detectable. A sighting during night transect is more likely to provide a record for the very small non-volant mammals such as tiny bodied rodents (e.g. moss mice) and dasyurid marsupials, and hand capture is often possible under such circumstances. Pit trapping, a technique not employed on this survey, represents an alternative for capture of very small terrestrial mammals. However, this method is difficult to employ in high rainfall areas where the pits tend to rise from the ground during the course of a night.

5.4.4.3 Species of Conservation Concern

Species of conservation concern were recorded primarily on the basis of informant interviews. Significant exceptions are: Critically Endangered Black Spotted Cuscus (*Spilocuscus rufoniger*) and Endangered Goodfellow's Tree (*Dendrolagus goodfellowi*) – both recorded also from trophy specimens; Vulnerable Brown's Pademelon (*Thylogale brownii*) - detected by a daytime sighting; Data Deficient Lesser Tube-nosed Fruit Bat (*Nyctimene draconilla*) - detected by mist netting; and Data Deficient Northern Groove-toothed Shrew Mouse (*Microhydromys richardsoni*) - detected by ground trapping. Lack of detection of other species of conservation concern during the survey is no doubt due in part to the low natural population densities of these species. However, in the case of primarily montane-dwelling taxa like the Long-beaked Echidnas (*Zaglossus* spp.) and the Western Montane Tree Kangaroo (*Dendrolagus notatus*), it also reflected the elevational emphasis of the survey on the Lowland and Hill Zones, where the bulk of potential projects impacts would be concentrated. It should be noted here that the effort in the Montane Zone reflected the limited Project disturbance area within this zone.

5.4.5 Summary of Sampling Adequacy

The various analyses reported in this section all indicate that further survey effort in any of the major elevational zones in the Study Area would lead to the recording of additional species of mammals. This is particularly so for the arboreal mammal fauna, slightly less so for the terrestrial mammals, and less so again for bats. Among the non-echolocating pteropodid bats, species inventory of the smaller blossom bats and tube-nosed fruit bats is probably complete, but the full local diversity of the larger fruits bats is almost certainly not so. For the echolocating insectivorous bats, further acoustic survey work is unlikely to detect many more call types in the relatively well-surveyed Lowland and Hill Zones, but almost certainly would detect additional call types in the Montane Zone. Many of these elusive insectivorous bats remain known for the Study Area only by their calls and the taxonomic identity of these call types will remain uncertain until such time as they can be captured and reference calls taken.

Based on the biogeographic analysis, the actual total of mammal species in the Study Area might be close to double the number recorded during the survey, with many more species of small rodents in particular still to be detected. Higher than recorded diversity is especially likely in the Montane Zone which received comparatively less survey effort, concordant with the predicted low impact of Project activities in this zone.

Although more survey effort would undoubtedly detect additional species, it is important to highlight the fact that this was not for want of effort – our survey of the Study Area involved not only a wider range of methods than any other recent mammal survey in PNG but also a larger effort for each and every one of these individual methods. Instead, complete inventory of a mammal fauna across an elevational gradient in PNG must be seen as an almost unattainable goal, unless survey effort can be sustained over many years. As an illustration, the survey of the mammals of Sandaun Province by Flannery and Seri (1990) involved a prolonged field effort spread across multiple years and also involved much involvement by local hunters, yet it failed to detect a number of species that turned up on the present survey (e.g. *Microhydromys richardsoni*, *Pogonomys* sp. cf. *loriae*, *Nyctophilus macrotis, Hipposideros ater*).

Furthermore, despite the undoubted gaps in the present mammal inventory, it is clear that the body of knowledge obtained during the survey is sufficient to shed new light on the composition and distribution of local mammal communities, on their pattern of altitudinal zonation, and on some of the ecological factors that determine the distribution and abundance of key individual species, including the critical set of mammals of conservation concern as determined by IUCN and/or accorded Protected status by the PNG *Fauna (Protection and Control)Act 1966*. These issues are discussed further in the following section.

6 INTERPRETATION OF THE SURVEY RESULTS

The survey results have important bearing on six principal issues of relevance for the environmental assessment:

1. The pattern of distribution of mammal species diversity on the transect from the Sepik River floodplain to the foothills and outlier montane peaks of the Central Cordillera;

2. Mammal community structure and function within each of the major Study Area Zones, with special attention to habitat use and the issue of natural rarity;

3. The status of mammal species of special conservation concern in the Study Area;

4. Identification of mammal communities of conservation significance in the Study Area;

5. The status of invasive species in the Study Area; and

6. The cultural significance of the mammal fauna.

6.1 Elevational Occurrence

The fairly even spread of systematic sampling localities between 45 m elevation and 1065 m elevation allows the elevation ranges of mammal species in the Lowland and Hill Zones of the Study Area to be determined with a high degree of confidence, and some inferences to be made regarding patterns of habitat use within the various elevation zones. This fills a significant void in knowledge of mammal distribution and ecology of northern New Guinea, where the bulk of prior work has focussed on the Sepik Floodplain or at higher elevations in the Central Cordillera (McKean 1972; Flannery and Seri 1990). In contrast, Hill Forest (Hm) habitat, in which most of the Project infrastructure will be sited, has attracted little attention due to its remoteness from major human settlements and consequent inaccessibility.

Understanding the elevational distribution of biological diversity in the Study Area also addresses two question of special relevance to the environmental assessment process, namely:

1) To what extent are the Lowland, Hill and Montane zones biologically distinct within the Study Area?

2) Can either of the Lowland or Hill Zones of the Study Area be treated as a single ecological and biodiversity unit for risk assessment and impact mitigation purposes?

Examination of patterns of habitat use within each elevational zone addresses the additional question of whether or not there are habitats or sites of particular conservation significance in the Study Area.

6.1.1 Non-volant Mammals

The majority of non-volant mammal species produced too few records to support any conclusions regarding either elevational distribution or patterns of habitat usage. Among the small number of more ‘common’ species, the Lowland Mosaic-tailed Rat (*Paramelomys platyops*) was trapped at almost equal rates in the Lowland Zone and Hill Zone < 500 m, and less frequently in the Hill Zone > 500 m (Table 7). Lowland Mammelomys (*Mammelomys rattoides*) appears to be restricted to the Hill Zone where it was trapped at similar rates across the full elevation range from 45 m to 1,065 m. The one record of this species in the Lowland Zone comes from Frieda Bend but at this site it was trapped in low hills rather than the inundated habitat near the river. Flannery and Seri (1990) concluded that these morphologically similar species are ecological vicars showing elevational replacement. However, at least in the Study Area, they are broadly co-occurring in the Hill Zone and presumably show some subtle ecological differentiation.

Bandicoots were detected more frequently by a variety of methods in the Lowland and Hill Zone < 500 m elevation, and less often in the Hill Zone > 500 m elevation. The Lowland Zone records are exclusively of Spiny Bandicoots (*Echymipera* spp., with three species represented), while the Hill Zone > 500 m elevation also produced records of Raffray's Bandicoot (*Peroryctes raffrayana*). This species is known from higher elevations in the general region (Morren 1989; Flannery and Seri 1990) and has a broader elevation range on New Guinea of 0 – 4000 m (Helgen 2007a). Informant interviews suggested that Clara's Spiny Bandicoot (*Echymipera clara*) is confined to lower elevations within the Hill Zone, consistent with suggestions made by Flannery and Seri (1990). The one definite sighting of this species during this survey was made in a true Lowland Zone habitat, adjacent to the Frieda River at Frieda Bend (seeTable 5), but it is possible that this species is absent from inundated Lowland Zone habitats further removed from the foot hills.

The White-striped Dorcopsis (*Dorcopsis hageni*) and the Ground Cuscus were both recorded by camera traps (Table 8) only in the Lowland Zone and Hill Zone < 500 m elevation than at higher elevations in the Study Area. The White-striped Dorcopsis has been recorded from as high as 800 m elevation at other locations in northern New Guinea and could be expected to be less abundant at higher elevations. The Ground Cuscus has one of the broadest elevation ranges of all New Guinean mammals but does seem to be everywhere more abundant below approximately 1500 m elevation where the diversity of other cuscus species is not as high as above that elevation.

Among the strictly arboreal mammals, the Lowland Ringtail Possum (*Pseudochirulus canescens*) appears to be relatively common at the higher elevations, with one capture at Nena Base Site and two on one night at the Nena Top Site (Table 6). Flannery (1995a: 221) reported this species to be "widespread throughout lowland New Guinea but .. rare or uncommon over most of its range". Most recent records of the species actually come from elevations above 500 m elevation and it is recorded as high as 1,700 m elevation (Helgen 2007a). It thus might be better named the 'Hill Forest Ringtail' and its apparent rarity attributed to the generally poor survey effort in Hill Forest (Hm) habitats across New Guinea. Certainly, it seems to be moderately abundant at higher elevations in the Hill Zone and Montane Zone habitats of the Study Area.

The undescribed species of Feather-tailed Possum (*Distoechurus* sp.) was encountered only in the seasonally inundated floodplain forest and Peat Forest of the Lowland Zone (Table 6). Informant testimony suggests that this (or a closely related) species might also occur in the upper Hill Zone.

Feral pigs (*Sus scrofa*) probably occur throughout the Study Area. However, signs of pig activity were only abundant at the lower elevation localities – Malia Site at 290 m elevation in the Study Area Hill Zone and at the Lowland Zone sites of Frieda Bend, Ok Isai, Kaugumi Site and Iniok (information not available for Ok Binai 1, Wario, Wogamush and Kubkain Sites). At each of these sites, large areas of rooting damage were observed, especially on alluvial terraces alongside both large and small watercourses, and in swamp habitats. Away from these habitats, there was less evidence of extensive rooting behaviour. However, numerous track ways and occasional definite pig footprints and faeces attested to the regular movement of pigs through these areas. The East Sepik Camp site was anomalous in having no evidence of pig activity; this may reflect the inferred low productivity of the Peat Forest biotype (Chapter 2).

At the higher elevation sites, remote from areas of alluvial or swamp habitat, there was much less evidence of feral pig activity and camera traps recorded pigs at one site only, Koki Site at 560 m elevation Whether or not the occurrence of pigs at Koki Site is due to the history of former disturbance at this location cannot be ascertained; however, it is notable that Koki Site along with the other 'disturbed' localities of Nena Base Site and Frieda Base, also all produced records of the disturbance tolerant Stein's Rat (*Rattus steini*).

6.1.2 Fruit-and Nectar-Eating Bats

Capture records of the small necta-and fruit-eating pteropodid bats provide the most compelling evidence of elevational zonation in the mammal fauna of the Study Area. Three pteropodid species appear to be restricted to the Study Area Lowland Zone: Long-nosed Blossom Bat, *Macroglossus minimus*; Broad-striped Tube-nosed Fruit Bat, *Nyctimene aello*; and Green Tube-nosed Bat, *Paranyctimene raptor*. Four others show higher abundance in this zone and extend only to lower elevations within the Study Area Hill Zone: Bismarck Blossom Bat, *Syconycteris* cf. *finschi*; Lesser Tube-nosed Fruit Bat*, Nyctimene draconilla*; Steadfast Tube-nosed Bat, *Paranyctimene tenax*; and Lesser Bare-backed Fruit Bat, *Dobsonia minor*. Contrariwise, two species appear to be restricted to the Study Area Hill Zone in the Study Area: the Tube-nosed Fruit Bats *Nyctimene* sp. A and *Nyctimene* sp. B.

Blossom bats of the genus *Syconycteris* were captured at all sites (Tables 6 and 9). The proportion of the two species of *Syconycteris* in each sample is not yet quantified, as this will rely on a detailed morphological and genetic analysis. However, it is clear that the Bismarck Blossom Bat *Syconycteris* cf. *finschi* was caught at most sites in the Study Area Lowland Zone but only occasionally at higher elevation sites. The highest elevation record of *Syconycteris* cf. *finschi* probably comes from a net set at 750 m elevation, below the large clearing at Nena Base Site.

The various smaller tube-nosed fruit bat species appear to show reciprocally inverse patterns of occurrence. The Lesser Tube-nosed Fruit Bat (*Nyctimene draconilla*) was most abundant at lower elevations and was not caught above 560 m elevation Among the suite of 'Common' Tube-nosed Fruit Bats, *Nyctimene sp. A* was most abundant at lower elevations but extended at least to 750 m elevation In contrast, *Nyctimene albiventer papuanus* appears to be rare or absent below 300 m elevation and abundant at mid to higher elevations in the Study Area Hill Zone. *Nyctimene* sp. B was most abundant at Nena Limestone Site but was caught as low as 560 m elevation. Rather surprisingly, no tube-nosed fruit bats were captured during two nights of mist-netting at the Nena Top Site.

Species of the unstriped tube-nosed fruit bat genus *Paranyctimene* were only captured at sites below 450 m elevation (Table 6). The survey produced the first evidence of sympatry between Green Tube-nosed Fruit Bat (*P. raptor*) and Steadfast Tube-nosed Fruit Bat (*P. tenax*), confirming the prediction of Bergmans (2001) that they would occur together. Neither species appears to be very common in the Study Area but the small numbers of captures suggest that Green Tube-nosed Fruit Bat (*P. raptor*) is confined locally to Study Area Lowland Zone habitats, while Steadfast Tube-nosed Fruit Bat (*P. tenax*) extends at least part way up into the Study Area Hill Zone. The highest elevation records of the genus in New Guinea come from nearly 1500 m elevation (Bonaccorso 1998), though it is not known which species is involved. Large series of *Paranyctimene* are present in the CSIRO collection, mainly derived from very low elevation localities in East Sepik Province (e.g. around Ambunti and Maprik), and these also contain individuals of both species.

For several species, the local elevational ranges differ markedly from those recorded across their broader distributions (Flannery 1995; Bonaccorso 1998; Helgen 2007a). The Broad-striped Tube-nosed Fruit Bat (*Nyctimene aello*) was captured regularly in mist nets at sites in the Study Area Lowland Zone but was not encountered at all in the Hill Zone sites. Elsewhere in New Guinea this distinctive species has been recorded from as high as 1,000 m elevation. The Lesser Naked-backed Fruit Bat (*Dobsonia minor*) and the Long-nosed Blossom Bat (*Macroglossus minimus*) have broader elevation ranges of 0 – 700 m and 0 – 1,500 m, respectively. Both were captured only at sites in the Study Area Lowland Zone (Table 6). When present, the Long-nosed Blossom Bat was relatively abundant; hence, failure to capture this species at any Study Area Hill Zone site is taken as a true absence.

The relatively sharp discrimination in the Study Area between the pteropodid faunas of the Lowland and Hill Zone is unusual in the wider New Guinean context. In our view, the most likely explanation is that species such as Long-nosed Blossom Bat, Broad-striped Tube-nosed Fruit Bat, Green Tube-nosed Bat, Bismarck

Blossom Bat and Lesser Bare-backed Fruit Bat are naturally absent or rare in relatively undisturbed Hill and Montane Zone forests, such as occur in the Study Area, but have penetrated to higher elevations elsewhere in New Guinea as a result of widespread human disturbance and the creation of anthropogenic habitats. On a local scale, the anomalously high record of Bismarck Blossom Bat (*Syconycteris* cf. *finschi*) at Nena Base Site might be due to upslope colonisation of this site which has been an anthropogenic clearing for several decades. Another possible explanation is that there is either a seasonal movement between lower and higher elevations or a seasonal expansion and contraction of elevational range. This possibility can only be tested through fieldwork across several entire years. However, it is regarded as unlikely given the presence at higher elevations during the survey period of other, closely related species [e.g. Common Blossom Bat (*Syconycteris australis*) and other species of tube-nosed fruit bat].

6.1.3 Insectivorous Bats

Insectivorous bats were captured too infrequently to infer elevational ranges for any species. In contrast, the acoustic survey provided a rich source of evidence and some significant insights into elevational occurrence.

Most bat species (including taxonomically unallocated bat call types) were detected across a wide elevation range within the Study Area (Table 6). Three species/call types were only recorded below 430 m elevation: the Moluccan Myotis (*Myotis moluccarum*), the Papuan Long-eared Bat (*Nyctophilus microtis*), and call type *27 sh.cFM.d*, currently unassigned. The Moluccan Myotis has been recorded as high as 1,400 m in PNG, though it is considered to be more common at lower elevations (Bonaccorso 1998). The more restricted occurrence observed in the present survey may be the result of incomplete sampling or it may parallel the situation observed for several small pteropodids where the local elevational limit is substantially lower than reported for elsewhere in New Guinea. The Papuan Long-eared Bat was also only recorded at low elevation; however, it produces a low amplitude call with relatively low detectability and its true distribution and abundance cannot be inferred from the acoustic survey data. It appeared to be moderately abundant at Iniok Site, with captures in both mist net and harp trap.

Two call types were only recorded above 800 m elevation: *42 lCF* referred to the Large-eared Horseshoe Bat (*Rhinolophus philippinensis*) and *124 sCF* referred to Maggie Taylor's Leaf-nosed Bat (*Hipposideros maggietaylorae*). The Large-eared Horseshoe Bat is captured rarely in PNG but two records come from elevations of 1,200 – 1,300 m (Bonaccorso 1998); its echolocation calls have been reported from 900 – 1,400 m in the Southern Highlands (Richards 2005, 2008). Regionally, there are confirmed records of this or a closely related species at elevations below 500 m (e.g. Indonesia: Bonaccorso 1998; Timor-Leste: Armstrong 2006; Australia: Churchill 2008). Maggie Taylor's Leaf-nosed Bat has a high frequency call with relatively low detectability. It was captured in the Study Area in mist nets and harp traps at various sites between 55 m and 850 m elevation

Two unallocated call types show an unusual pattern of occurrence, with records from multiple sites at the Lowland Zone and the highest elevations in the Hill Zone but not in between. These are *30 st.cFM* possibly a species of *Mormopterus*, and *34 i.fFM.d / sCF,* referred to a species of *Emballonura*. The reason for this bimodal distribution is not known, though it might simply be an artefact of sampling.

The patterns of relative abundance of each species, calculated as the proportion of AnaBat sessions per site where each species was recorded, show some patterns suggestive of elevational patterning (Table 18). Many species seem to have higher relative abundances at lower elevations, including the Diadem Leaf-nosed Bat (*Hipposideros diadema*), the Trident Leaf-nosed Bat (*Aselliscus tricuspidatus*), the New Guinean Pipistrelle (*Pipistrellus angulatus*), the Lesser Sheath-tailed Bat (*Mosia nigrescens*), and unassigned call types *42 cFM* and *90 mCF*. Two species, the Large-eared Horseshoe Bat (*Rhinolophus philippinensis*) and Wollaston's Leaf-nosed Bat (*Hipposideros wollastoni*), showed the opposite pattern, with there highest relative abundance at higher elevations.

Table 18. Relative abundance of each bat species / call type at each site.

BAT SPECIES / CALL TYPE	LOWLAND ZONE SITES									HILL ZONE SITES							
	INIOK SITE	EAST SEPIK SITE	KUBKAIN SITE	WOGAMUSH SITE	WARIO SITE	FRIEDA BEND SITE	KAUGUMI SITE	OK BINAI 1 SITE	OK ISAI SITE	MALIA SITE	NENA D1 SITE	UPPER OK BINAI SITE	NENA-USAGE SITE	KOKI SITE	HI SITE	NENA BASE SITE	NENA LIMESTONE SITE
17 sh.cFM						0.1										0.1	
20 cFM	0.3				0.2		0.2				0.1			0.1		0.1	
24 cFM Saccolaimus sp.			0.2	0.3	0.3				0.1	0.1	0.1		0.3		0.1	0.1	
27 sh.cFM.d Emballonura sp.	0.3						0.2		0.1			0.2					
30 st.cFM			0.1		0.3												0.3
34 i.fFM.d / sCF Emballonura sp.				0.1	0.2											0.2	0.2
37 st.cFM M. magnater	0.3	0.6	0.3	0.4	0.7	0.1	0.3	0.6	0.3	0.2	0.3	0.2	0.7	0.1	0.3	0.5	0.3
40 st.bFM /st.sFM.d M. moluccarum	0.3					0.2	0.3		0.3	0.1		0.2					
42 cFM	0.3	0.6	0.4	0.6	0.7	0.1	0.5	0.4	0.5	0.1	0.4	0.2	0.3	0.1		0.1	0.3
42 ICF R. philippinensis													0.3			0.4	0.3
42 i.fFM.d Emballonura sp.					0.1				0.2				0.3				
47 sCF / i.fFM.d Emballonura sp.	0.3	0.2	0.1	0.1	0.6	0.1	0.2	0.6	0.3	0.1		0.2	0.7	0.3		0.5	0.3
47 st.cFM.h P. angulatus	0.3	1.0	0.8	0.8	0.9	0.1	0.8	0.4	0.6	0.2	0.1	0.2	0.7	0.1	0.3	0.5	
55 st.cFM.d / cFM									0.2				0.3		0.1	0.1	
55 st.bFM N. microtis			0.1														
58 mCF H. diadema	0.3	0.6	0.3	0.5	0.4	0.4	0.5	0.4	0.6		0.1	0.1		0.1		0.1	0.2
64 sCF / i.cvFM M. nigrescens	0.8	0.8	0.9	0.8	0.9	0.3	0.8	0.8	0.7	0.2	0.5	0.2	0.7	0.2	0.3	0.6	0.5
75 mCF			0.2	0.4	0.3		0.2					0.4				0.1	
82 mCF H. wollastoni						0.4		0.2				0.2		0.3	0.3	0.5	
90 mCF		0.4		0.7	0.2	0.2	0.3	0.4	0.4	0.4	0.1			0.2			
112 sCF A. tricuspidatus	0.5	0.4		0.1	0.1		0.3	0.6	0.3	0.1	0.1	0.2		0.1		0.1	
124 sCF H. maggietaylorae									0.1								

Key	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1

Notes: Calculated as the proportion of occurrences in the total number of AnaBat nights per site.

Species diversity of insectivorous bats in New Guinea is generally thought to be highest in the lowlands and to show a general decline with elevation, with the most abrupt fall in diversity being at elevations in excess of 1,500 m (Bonaccorso 1998). Our acoustic survey results show a wide range of richness values across the full elevation range surveyed (Figure 35). However, maximum richness does shows a slight decline with increasing elevation, from 12 species at low elevation sites (28–185 m), to 10 species at mid elevations (281–596 m), and 8 species at the highest elevation survey sites (737–1,036 m). Too few replicated recordings were obtained at the higher end of the richness scale for the results to be statistically significant.

6.1.4 Summary of Elevational Patterns

As anticipated by the findings of the biogeographic analysis, the survey results demonstrate clear differences between the mammal faunas of the Study Area Lowland and Hill Zones. Moreover, the survey results suggest some elevational differentiation within the mammal fauna of the Hill Zone, with the maximum species turnover probably occurring around 400 – 500 m.

The contrast between the Lowland Zone and the Hill Zone is best illustrated by the small nectar-and fruit-eating pteropodid bats, with some support from the non-volant mammals. Differentiation within the Hill Zone is also evident in these groups, but with added support from the acoustic survey data for insectivorous bats.

The lower part of the Hill Zone, up to approximately 400 m elevation might be thought of as a zone of interaction between Lowland and true Hill Zone mammal faunas. At lower elevations, up to around 400 m, the bat community includes several species that might be regarded as typical Lowland Zone taxa e.g. the Lesser Tube-nosed Fruit Bat, the Steadfast Tube-nosed Fruit Bat and the Lesser Naked-backed Fruit Bat. Sites above 400 m lack these species but do contain a number of species that are quite conspicuous in their absence from all Study Area Lowland Zone sites. Most notable of these are two species of tube-nosed fruit bats, *Nyctimene albiventer papuanus* and *Nyctimene* sp. B.

Both these species both possess broad U-shaped palates and relatively large cheekteeth and this may indicate preferred food items with physical characteristics different from those found at lower elevations. Whether or not these species extend to even higher elevations with the Study Area Montane Zone, remains to be determined. However, it is relevant to note that the Mountain Tube-nosed Fruit Bat (*Nyctimene certans*), a woolly furred bat of montane forests, bears a close resemblance in dental morphology and body size to each of *Nyctimene* sp. A and *Nyctimene* sp. B, and it is likely to represent an elevational replacement of one or both of the species recorded in the Study Area. This species has been recorded at Telefomin, at an elevation of around 1,500 m, and may well occur in the Montane Zone of the Study Area.

Two insectivorous bats that might be locally confined to the upper part of the Study Area Hill Zone are the Large-eared Horseshoe Bat (*Rhinolophus philippinensis*) and the bat responsible for call type *34 i.fFM.d / sCF* at these sites, which might be attributed to a species of sheath-tailed bat (*Emballonura* sp.). Beccari's Sheath-tailed Bat (*Emballonura beccarii*) is said to be more common above 500 m than below, with elevation records extending to 1,500 m (Bonaccorso 1998); it is possible that call type *34 i.fFM.d / sCF* relates to this taxon.

A more complete and instructive picture of elevational zonation within the Hill Zone biota will no doubt emerge from integration of the mammal survey results with data from other animal groups and plants.

6.2 Mammal Community Structure and Habitat Use

Mammal community structure and function can be explored by considering the relative abundances in the community of different groups of mammals, and of different species within each group.

6.2.1 Relative Abundance of Major Groups

A dominant feature of the survey results is the contrast between very low contact rates for all groups of non-volant mammals (whether through trapping, camera traps or direct observation) and the moderate to high capture rates for bats, particularly the small nectar-and fruit-eating pteropodid bats. This observation applies equally across all sites in both the Lowland and Hill Zones, and for the one site in the Montane Zone, and thus may be regarded as a general characteristic of the forest habitats of the Study Area.

The contact rates experienced during the Study Area survey are contrasted in Table 19 and Figure 36 with comparable data from other regional surveys in New Guinea. The comparative data come from the Kikori ICDP survey in the Lowland to Montane zones of the Kikori River basin (Leary and Seri 1997), the Waria Valley survey in the Lowland and Hill Zones in Morobe Province (Dawson *et al.* 2009), and the CI RAP surveys of the Nakanai Plateau, East New Britain Province (Aplin and Opiang 2011) and of the Muller Range, Western Province (Aplin and Kale 2011; Armstrong and Aplin 2011). Although these data are limited in the number of regions being compared, they are strongly suggestive of a systematic contrast between the mammal communities on either side of the Central Cordillera of New Guinea.

Table 19. Comparison of ground mammal and bat capture rates among various localities and elevation zones across PNG.

REGION/LOCALITY	ZONE	NO OF SITES (ELEVATION RANGE)	HABITATS	TOTAL TRAP NIGHTS	TOTAL TRAP CAPTURES	% TRAP SUCCESS	TOTAL MIST NET NIGHTS	TOTAL MIST NET CAPTURES	MIST NET SUCCESS BATS/NET NIGHT
Kikori basin	Lowland Zone	2 (15-35 m)	primary forest	424	25	5.90%	42	72	1.71
	Hill Zone	3 (170-1,000 m)	primary forest	1422	56	3.94%	129	141	1.09
	Montane Zone	3 (1,050-1,350 m)	primary forest	416	19	4.57%	31	34	1.10
Muller Range	Hill Zone	515	primary forest	904	23	2.54%	90	18	0.20
	Montane Zone	2 (1,587-2,875 m)	primary forest	1230	48	3.90%	176	18	0.10
Nakanai Plateau	Lowland Zone	200	primary forest	432	0	0.00%	55	47	0.85
	Hill Zone	859	primary forest	576	11	1.91%	78	33	0.42
	Montane Zone	1,590	primary forest	432	4	0.93%	25	5	0.20
Waria Valley	Lowland Zone	3 (10-15 m)	gardens	1389	44	3.17%	48	160	3.33
	Lowland Zone	3 (15-80 m)	secondary forest	1456	13	0.89%	48	196	4.08
	Lowland Zone	5 (32-95 m)	primary forest edge	2249	40	1.78%	80	215	2.69
	Hill Zone	200 m	primary forest	472	3	0.64%	16	25	1.56
Study Area	Lowland Zone	7 (45-90 m)	primary forest	2399	12	0.50%	172	415	2.41
	Hill Zone	10 (125-925 m)	primary and secondary forest	4964	39	0.79%	362	311	0.86
	Montane Zone	1,065	primary forest	130	2	1.54%	12	11	0.92

Data sources are: Kikori basin: Leary and Seri (1990); Muller Range: Aplin and Kale (2011), Nakanai Plateau: Aplin and Opiang (2011); Waria Valley; Dawson et al. 2009); Study Area (this report).

Sites from north of the Central Cordillera (including East New Britain) show uniformly low captures for ground mammals (usually below 1%, only exceeding 2% in garden habitat) combined with more variable but often quite high capture rates for small pteropodid bats, especially in the Lowland Zone where capture rates of 2.41 – 4.08 bats/net night are recorded. In contrast, sites on the southern side show high ground capture rates both in the Lowland Zone (5.9%) and in the Hill Zone (2.54 – 3.94%), combined with low to moderate mist net capture rates (1.1 – 1.71 bats/net night in Lowland Zone; 0.2 – 1.09 bats/net night in the Hill Zone).

Kikkawa and Dwyer (1992) made the observation that well-developed, complex rain forests of humid lowlands in all parts of the world seem to support lower than expected populations of animals compared with other kinds of forest. They note that only ants and termites, among insects, are consistently common on the forest floor, and these may be preyed upon by specialist insectivores. Terrestrial herbivores and frugivores are generally scarce, as are insectivores that feed on leaf-eating insects. Kikkawa and Dwyer (1992) attribute these patterns to a combination of relatively low net primary productivity of undisturbed mature lowland rainforests, coupled with a rapid rate of decomposition of forest litter.

We offer a similar though more specific interpretation of the dual phenomenon of the low abundance of non-volant mammals coupled with high abundance of nectar-and fruit-eating bats in the Study Area Lowland and Hill Zones. We attribute these community characteristics to the interplay of various factors, including:

1. Low productivity of palatable fruits within the forest canopy. Few trees seemed to be producing fruit during any of the survey periods; moreover, when fruiting trees were located these often seemed to show no evidence of consumption except by fruit bats prior to fruit fall. Several different fruits shown to the team botanist were said to be highly toxic and not suitable for human consumption.

2. High densities of leaf-eating insects at all levels in the understorey and canopy, providing highly effective competition for any mammal species that might feed on young leaves or shoots.

3. High diversity and abundance of Hymenoptera, notably large stinging ants that live under moss layers on trees as well as within the forest floor, and wasps suspended below leaves and fallen trees. Under such conditions there may be heavy predation on small non-volant mammals, especially of rodent young that must be left unattended in burrows or nests while the mother forages.

4. Competition for scarce arboreal food resources from fruit-eating pteropodids. If fruiting is sporadic and widely scattered across the forest canopy, as suggested above, this resource might still be available for effective utilisation by pteropodids because of their mobility, hence even less available for utilisation by more sedentary rodents and marsupials.

5. For the parts of the Study Area Lowland Zone that are subject to regular inundation by floodwaters, there is very likely a significant reduction in population densities of terrestrial species during the inundation periods. Complete elimination of terrestrial mammals during flooding events is less likely however, as the majority of New Guinean 'terrestrial' mammals are quite capable of climbing into low bushes and sub-canopy trees to escape floodwater. Even bandicoots are probably capable of surviving flood events in this way, and both bandicoots and wallabies are good swimmers and thus able to search for suitable refuge. Although no study has been constructed of mammal population responses to flooding in PNG, we suspect that population densities for many lowland mammals probably show strongly cyclic patterns, with a low point during flooding, followed by quite rapid recovery after flood water recedes and new grasses and herbaceous plants respond with a flush of growth.

Three other observations support this hypothesis. First, a similar pattern of rare non-volant mammals and abundant pteropodids has been observed elsewhere in Melanesia (e.g. Nakanai Plateau of East New Britain, Aplin and Opiang 2011) and this demonstrates that the phenomenon is one with more general rather than purely local causes. Second, non-volant mammal abundances are usually considerably higher in montane forests than in Hill Forests, irrespective of the degree of disturbance, with peak capture and contact rates often met with at elevations of 2 – 3,000 m elevation. Significantly, at these high elevations there are generally few if any hymenopterans, fewer leaf eating insects in evidence, and a much lower diversity and abundance of bats. And third, the contrast noted above between northern and southern Lowland and Hill Zone faunas points to a reciprocally competitive relationship between small pteropodid and terrestrial mammals, with the key resource presumably being fruit which can either be consumed in the canopy or on the ground, depending on population levels of volant vs non-volant mammals. What factors might limit the population density of small pteropodids in the southern Lowland and Hill Zones is a separate question that begs investigation.

6.2.2 Non-volant Mammals

Many animal and plant communities show a bimodality in the pattern of individual species abundances – species either tend to be ‘common’ or ‘rare’, with fewer being of intermediate abundance (Kunin and Gaston 1993; Harcourt 2006). The survey results for non-volant mammals in the Study Area are consistent with this general pattern.

Among the smaller-bodied non-volant mammals, two species of rats accounted for more than half of all trapping captures – the Lowland Mosaic-tailed Rat (*Paramelomys platyops*) and the Lowland Mammelomys (*Mammelomys rattoides*). These rats are probably the most ‘common’ non-volant mammals in the Lowland and Hill Zone communities, respectively. Among the medium-sized non-volant mammals, spiny bandicoots (*Echymipera* spp.) and Giant White-tailed Rats (*Uromys* affin. *caudimaculatus*) accounted for the majority of sightings and camera trap images, and they too probably rate as ‘common’ species. Among the largest terrestrial mammals, the frequency of camera trap images indicate that the White-striped Dorcopsis (*Dorcopsis hageni*) and feral pigs (*Sus scrofa*) are both ‘common’ in the Lowland Zone and lower Hill Zone habitats, whilst Brown’s Pademelon (*Thylogale browni*) is comparatively rare. All other small to medium-sized non-volant mammal species in the Study Area also might be regarded as ‘rare’, although some, such as the highly arboreal Tree Mice (*Pogonomys* spp.), may spend much of their time in the high canopy and could be under-represented in the survey results. Not surprisingly, each of the ‘common’ species was also recorded more consistently across the survey sites.

An unexpected survey result was the rarity of native *Rattus* species in all relatively undisturbed forests of the Study Area – so rare in fact they were not caught at all in these contexts. In contrast, one or two native *Rattus* species (Spiny Rat *Rattus praetor*; and Stein’s Rat *Rattus steini*) were captured at each of three localities with a history of past or ongoing habitat disturbance: Nena Camp Site, Koki Site and Frieda Base. Species of *Rattus* are usually among the most abundant ground mammal captures during surveys in PNG, and the two species recorded in the Study Area are said to occur in all habitats at moderate to high abundance (Flannery and Seri 1990; Flannery 1995). We attribute their rarity in the Study Area to an ecological affinity with disturbance. Almost all species of the genus *Rattus* have high reproductive potential and the majority seem to be dietary generalists, and this combination of attributes allows them to take advantage of short term opportunities in the environment, such as clearings created by landslides, flood events etc. In less disturbed contexts, however, they seem to be less competitive and they generally decline in abundance as forests regenerate (e.g. Dwyer 1978). The extreme rarity of *Rattus* in the forests of the Study Area is a strong indicator of the generally very low level of disturbance. Contrariwise, the presence of *Rattus* spp. in any abundance can be taken as a very strong indicator of habitat disturbance or degradation, and thus represents a potentially powerful tool for monitoring activities.

Based on informant testimony, it is expected to be diverse and to include several larger species such as tree kangaroos and a long-beaked echidna, all probably at very low density.

Low natural abundances of non-volant mammals in the context of primary forest has implications for conservation biology and potentially, for design of monitoring activities and mitigation measures.

1. The mammal community within any one patch of forest may be ‘incomplete’ due to local declines and extinctions that occur as a stochastic consequence of natural rarity alone. Accordingly, it might not be possible to reliably predict species occurrence based on habitat parameters alone, except on large spatial scales.

2. Effective conservation of the mammal community in such a forest may require protection of much larger areas than might normally be considered to be adequate. This also has implications for our perception of the conservation value of the seemingly extensive tracts of intact or only lightly disturbed Hill Forest that run along the northern foothills of New Guinea – for some groups of organisms, they may not be quite as extensive as they first appear.

3. Monitoring activities might be extremely difficult due to low contact rates using any method, making it difficult to know whether mitigation measures are being effective on any scale.

4. For some species, total regional population size may be much smaller than might be thought based on the areal extent of ‘suitable’ habitat. The conservation ‘value’ of individual animals therefore might be such as to encourage mitigation measures to ensure individual survival as well as population persistence (e.g. relocation of individuals threatened by Project activities).

6.2.3 Fruit-and Nectar-Eating Bats

The relative abundance of the various small nectar-and fruit-eating pteropodid bats varies considerably among the survey sites of the Study Area, as shown graphically in Figure 37. The most commonly caught pteropodids were various blossom bats (*Syconycteris* spp. and *Macroglossus minimus*) and tube-nosed bats (*Paranyctimene* spp. and *Nyctimene* spp.). These groups are so abundant that they must play a central role in many aspects of forest ecology, including pollination, seed dispersal and nutrient cycling. To date, this role remains almost entirely undocumented.

Species of *Syconycteris* dominate the small pteropodid community except for at the very lowest elevations. At these sites the Long-nosed Blossom Bat (*Macroglossus minimus*) typically also occurs together with the two *Syconycteris* species, and the blossom bats as a whole are less dominant. The strictly nectar-feeding Long-nosed Blossom Bat was not captured in the Peat Forest at East Sepik Site, presumably due to the low incidence of flowering at this unusual site. *Syconycteris* are more catholic in their diet and both species of this genus occurred together with two species of tube-nosed fruit bats at East Sepik Site. Remarkably, the capture rates of *Syconycteris* spp. and the smaller *Nyctimene* species were no lower at this site than several others in the Study Area Lowland Zone (Table 10).

The diversity of tube-nosed fruit bats is a striking feature of the Study Area pteropodid bat community. A total of five different species of the genus *Nyctimene* and two of *Paranyctimene* were captured, with a maximum of five species occurring together at each of Iniok and Kaugumi Sites in the Lowland Zone, and at Ok Isai Site in the Hill Zone. Most well-surveyed sites in the Lowland and Hill Zones supported four species of tube-nosed bats but this reduced to three species in sites above 800 m elevation The Study Area provides the first certain instances of strict sympatry between the two species of *Paranyctimene*, with examples at both Iniok Site and Ok Isai Site. The Steadfast Unstriped Tube-nosed Fruit Bat (*P. tenax*) appears to be slightly more abundant in the Study Area than the Green Unstriped Tube-nosed Fruit Bat (*P. raptor*).

Capture rates of members of the *Nyctimene* ‘*albiventer’* group show a noteworthy pattern – highest in the inundated swamp forest habitats of the Study Area Lowland Zone, lower across all sites in the Study Area Hill Zone, but moderately high again at Nena Limestone Site (Table 10; Figure 38), where captures were otherwise dominated by *Nyctimene* sp. B. Despite this trend, no tube-nosed fruit bats were captured during two nights of mist-netting at the Nena Top Site.

Apart from these elevational trends, there is little indication of differential habitat use among the pteropodid bats. However, more detailed studies of movement and foraging behaviour might reveal subtle differences in habitat use by these abundant and undoubtedly, ecologically important mammals.

Larger pteropodid bats tend to feed in the upper canopy and are captured infrequently by nets set in the understorey or across small, enclosed streams. The Moluccan Naked-backed Fruit Bat (*Dobsonia moluccensis*) was netted over a wide stream at Nena-Usage Site and its characteristic, slow wing beat was heard over the Hill Forest (Hm) canopy upslope of Nena Base Site on several nights. The Lesser Naked-backed Fruit Bat (*Dobsonia minor*) is more active within the understorey and was captured at several of the sites in the Study Area Lowland Zone as well as at Ok Isia and Malia Sites (Table 9) in the Hill Zone.

Larger fruit bats (*Pteropus* spp.) were heard quite regularly at night at the majority of the Lowland Sites, the exception being East Sepik Site where the Peat Forest may not provide sufficient resources to attract these larger species. Two size classes could be detected among these larger bats. At Iniok Site, a double-tiered mist net set above garden regrowth captured 12 individuals on a single night of the Big-eared Flying Fox (*Pteropus macrotis*). This species was active at all levels in the canopy and was often disturbed during night patrols at this site. Occasional individuals of a larger species were observed in the upper canopy at Iniok Site, and also observed flying high above the Sepik River at Iniok Site and the Frieda River at Frieda Bend Site.

Large roosting congregations of flying foxes (*Pteropus* spp.) are reported by informants and one of these was observed and photographed from the air on the 1st November 2010. This congregation involved tens of thousands of Great Flying Foxes (*Pteropus neohibernicus*). The likely ecology of this species and other congeners in the Study Area is discussed further in Section 6.4.1. Here we need only repeat the observation that large flying foxes, by virtue of their size, mobility and sheer numbers in many Old World tropical forests, are acknowledged to play significant roles in pollination and seed dispersal within forest communities (Pierson and Rainey 1992; Richards 1995). Their removal from a mammalian community has been postulated to have wider and potentially cascading ecological impacts (Cox *et al.* 1991; Richards 1995).

6.2.4 Insectivorous Bats

The relative abundance of the three functional call types in each of the 17 systematic survey sites is summarised in Table 20 and illustrated in Figure 39a. Table 21 summarises the occurrence of each of the 24 different bat call types/species among the nine habitat types distinguished in the survey area; this data is illustrated graphically in Figure 32b.

Six call types were only recorded in relatively open habitats (away from clutter or over the canopy). Significantly, most of these were relatively narrowband call types with the lowest mean characteristic call frequencies, ranging from 17 kHz to 34 kHz, and all are likely to be derived from either free-tailed bats (Family Molossidae) or sheath-tailed bats of the genera *Saccolaimus* and *Emballonura*.

All of the major habitat types had approximately equal representation of species that forage along edges or in gaps, and in narrow spaces within vegetation (Figure 39b). Not surprisingly, call types suited for foraging in open spaces were generally recorded from the more open habitats. The proportional representation of open, edge and gap, and clutter species was relatively similar at each survey site, suggesting that the placement of bat detectors had been successful in sampling a range of foraging (flight space) habitats in each case. Habitats with dense understorey, including a sago swamp, produced only one exclusive call type (*124 sCF*) identified as that of Maggie Taylor's Leaf-nosed Bat (*Hipposideros maggietaylorae*).

Table 20. Summary of bat functional call type representation at each site.

SITE	TOTAL	OPEN FORAGER SPECIES	EDGE FORAGER SPECIES	CLUTTER FORAGERS
Iniok	10	1	8	1
East Sepik	8	0	6	2
Kubkain	10	1	7	2
Wogamush	11	1	7	3
Wario	14	2	9	3
Frieda Bend	10	1	7	2
Kaugumi	12	1	8	3
Ok Binai 1	9	0	6	3
Ok Isai	14	1	10	3
Malia	9	1	6	2
Nena D1	9	2	5	2
Upper Ok Binai	11	0	8	3
Nena-Usage	9	1	7	1
Koki	10	1	6	3
HI	6	1	4	1
Nena Base	15	3	8	4
Nena Limestone	8	0	7	1

Note: entries are number of call types.

However, the detection distance of such a characteristic frequency is relatively low, given the response of the AnaBat microphone and the high atmospheric relative humidity in PNG that attenuates high frequency signals quickly. The species itself was captured at several sites in the Study Area Hill Zone, and in both dense and open understorey. The infrequent recording of this species is thus explicable in terms of its relatively low detectability.

The greatest number of bat call types (16-18 of 22 types) (see Table 21) was recorded by AnaBat detectors positioned on steep slopes, facing down into the canopy below , or other open habitats. These units probably sample a greater area because they can detect bats flying above the canopy, as well as in the spaces beneath the canopy, and lower down in the mid storey. Moderate richness was recorded in forest understorey with small clearings or flyways such as tracks or streams (up to 13) and relatively few call types (six) were recorded in swamp habitats. In summary, it seems that the highest richness was obtained when bat detectors were able to sample several types of flight space within a single vegetation habitat, and were within the detection range of both relatively powerful calls of species that forage in open habitats and calls with high attenuation rates (typically *CF* type calls) made by bats that forage within vegetation.

Acoustic bat survey by Richards (2008) at sites in Southern Highlands Province found both species diversity and the total number of acoustic recordings to be highest in open areas rather than within closed forest habitats. The findings of the present study suggest that the most abundant and diverse aggregations of bats might occur along the periphery of the denser sections of canopy, either along an edge bordering onto a clearing or along the under surface of the canopy, as surveyed here by detector placements in the forest canopy category.

Table 21. Pattern of occurrence of bat call types among bat foraging habitats

	FUNCTIONAL GROUP	CL—LARGE CLEARING	CR—CLEARING ON RIVER	CS—SMALL CLEARING	FC—FOREST CANOPY	FS—FAST STREAM IN FOREST	FT—FOREST TRACK	FU—FOREST UNDERSTOREY	SS—SLOW STREAM IN FOREST	SW—SWAMP
17 sh.cFM	O	—	H	—	—	—	—	—	—	—
20 cFM	O	H	H	—	H	—	—	—	—	—
24 cFM *Saccolaimus* sp.	O	H	H	H	H	—	—	—	—	—
27 sh.cFM.d *Emballonura* sp.	E	H	—	—	—	—	H	—	—	—
30 st.cFM	E	H	H	H	H	—	—	—	—	—
34 i.fFM.d / sCF *Emballonura* sp.	E	H	H	—	Nc	—	—	—	—	—
37 st.cFM *M. magnater*	E	H	H	H	H	H	H	H	—	—
40 st.bFM /st.sFM.d *M. moluccarum*	E	H	H	Nc	—	—	—	Nc	—	—
42 cFM	E	H	H	H	H	H	H	H	H	H
42 lCF *R. philippinensis*	N	—	H	—	H	Nc	H	—	—	—
42 i.fFM.d *Emballonura* sp.	E	H	H	—	—	Nc	—	—	—	—
47 sCF / i.fFM.d *Emballonura* sp.	E	H	H	H	H	H	Nc	—	—	—
47 st.cFM.h *P. angulatus*	E	H	H	H	H	H	H	H	H	H
55 st.cFM.d / cFM	E	H	—	—	H	H	—	—	—	—
55 st.bFM *N. microdon*	N	—	—	—	—	—	H	—	—	—
58 mCF *H. diadema*	E	H	H	H	H	H	H	H	H	H
64 sCF / i.cvFM *M. nigrescens*	E	H	H	H	H	H	H	H	H	H
75 mCF	N	H	H	H	H	H	H	H	H	H
82 mCF *H. wollastoni*	N	H	H	H	H	H	H	—	H	—
90 mCF	N	H	H	H	H	H	H	H	H	H
112 sCF *A. tricuspidatus*	N	H	H	H	H	H	H	H	H	—
124 sCF *H. maggietaylorae*	N	—	—	—	—	—	—	H	—	—
137 sCF *H. cervinus*	N	—	—	—	—	—	—	—	—	—
144 sCF *H. ater*	N	—	—	—	—	—	—	—	—	—
Richness Total		**18**	**18**	**13**	**16**	**13**	**13**	**10**	**8**	**6**
Richness Open Space foragers	**O**	**2**	**3**	**1**	**2**	**0**	**0**	**0**	**0**	**0**
Richness Edge/Gap foragers	**E**	**12**	**10**	**8**	**9**	**8**	**7**	**6**	**4**	**4**
Richness Clutter foragers	**N**	**4**	**5**	**4**	**5**	**5**	**6**	**4**	**4**	**2**
% Open Space foragers	**O**	**11**	**17**	**8**	**13**	**0**	**0**	**0**	**0**	**0**
% Edge/Gap foragers	**E**	**67**	**56**	**62**	**56**	**62**	**54**	**60**	**50**	**67**
% Clutter foragers	**N**	**22**	**28**	**31**	**31**	**38**	**46**	**40**	**50**	**33**

Notes: Codes for Functional Group: O = Open space forager; E = Edge and gap forager; N = clutter or narrow space forager. Codes for reliability of record: H = High; NC = Needs confirmation.

6.3 Species of Conservation Concern

6.3.1 IUCN and PNG Fauna (Protection and Control)*Act 1966* Listed Species confirmed or Likely to Occur in the Study Area

A total of 10 or 11 non-volant mammal species and one bat species of conszervatikon concern are either *confirmed* present (**C**) or *likely* to be present (**L**) within the Study Area (Table 6). All are included on the 2011 IUCN Red List; four or five are also listed under the PNG *Fauna (Protection and Control)Act 1966*. In order of IUCN threat level, these are:

- *Critically Endangered* – Black Spotted Cuscus (*Spilocuscus rufoniger*) **L**
- *Critically Endangered* – Long-beaked Echinda (*Zaglossus bartoni* and/or *Z. attenboroughi*); also Protected under the PNG *Fauna (Protection and Control)Act 1966* **L**
- *Critically Endangered* – Telefomin Cuscus (*Phalanger matanim*); also Protected under the PNG *Fauna (Protection and Control)Act 1966* **L**
- *Endangered* – Goodfellow's Tree Kangaroo (*Dendrolagus goodfellowi)*; also Protected under the PNG *Fauna (Protection and Control)Act 1966.* **C**
- *Vulnerable* – Brown's Pademelon (*Thylogale browni*) **C**
- *Vulnerable* – Western Montane Tree Kangaroo (*Dendrolagus notatus*); also Protected under the PNG *Fauna (Protection and Control)Act 1966*. **L**
- *Near Threatened* - New Guinean Quoll (*Dasyurus albopuntatus*) **L**
- *Near Threatened* - Small Mountain Dorcopsis (*Dorcopsulus sp.*) **L**
- *Data Deficient* – Northern Groove-toothed Shrew Mouse (*Microhydromys richardsoni*) **C**
- *Data Deficient* – Lesser Tube-nosed Fruit Bat (*Nyctimene draconilla*) **C**

Informant interviews suggest that the population of Black-spotted Cuscus in the Study Area is either confined to or most abundant in the Hill Zone, where it is an uncommon animal. This species has been recorded only twice in the last two decades and there are no populations known to occur in protected areas. Black-spotted Cuscus probably relies for its survival on the persistence of relatively undisturbed forest with low human population density (Flannery 1994). Any substantial stretch of good quality Hill Forest (Hm) under low hunting pressure is potentially significant for the long term survival for this species. The population of Black-spotted Cuscus in the Study Area must be regarded as being of the highest conservation significance.

Long-beaked Echidnas, Telefomin Cuscus, Goodfellow's Tree Kangaroo and Western Montane Tree Kangaroo are very likely confined within the Study Area to the patches of montane forest that top the higher ridges and peaks. These populations are probably quite small and are very likely isolated from each other, and thus present a very high level of vulnerability. Their only protection derives from the remoteness and ruggedness of these habitats. The species is hunted occasionally, as shown by the trophy tail seen at Wameimin 2 and said to have come from the nearby Nena Limestone Plateau.

Brown's Pademelon (*Thylogale browni*) is a widespread species of lowland and Hill Forest habitats (Flannery 1995). Hunters in the Lowland Zone villages of Nekiei, Paru and Kubkain, and at the Hill Zone village of Wameimin 2 were familiar with this species and it probably occurs at low to moderate abundance across all elevations within the Study Area, protected by the low human population density and remoteness from settlements of much of the region.

The Northern Groove-toothed Shrew Mouse is probably one of the most elusive of New Guinean rodent species. A recent review of the genus by Helgen *et al.* (2010) distinguished *M. richardsoni* of northern New Guinea from the closely related *M. argenteus* of southern New Guinea, and clarified the distributions of both species. This species was trapped only once in the Study Area, hence there is little basis for judging its true abundance.

The status of the Lesser Tube-nosed Fruit Bat has been obscured by taxonomic issues (Bonaccorso 1998); Flannery (1995) even questioned its distinction from *N. albiventer.* Recent re-examination of collections held by CSIRO and the Australian Museum suggest that many specimens of this species are currently held in collections, the majority misidentified as Common Tube-nosed Fruit Bats (*N. albiventer*).

The species potentially new to science or undescribed are listed in Table 6 under the category Not Evaluated. Of these potentially new taxa, the Tree Mouse (*Pogonomys* cf. *loriae*), the Long-footed Tree Mouse (*Lorentzimys* sp.) and the tube-nosed bat (*Nyctimene* sp. B) are likely to receive IUCN listing of *Data Deficient* on account of the incomplete knowledge of their geographic distribution in the poorly surveyed northern New Guinean Hill Zone. *Nyctimene* sp. A is widespread and abundant and has only evaded formal description through prior confusion with *Nyctimene albiventer papuanus*. The undescribed Feather-tail Possum (*Distoechurus* sp.) is not subject to hunting pressure and has a moderately large geographic range that covers at least part of the Sepik River Basin and the Torricelli Range, and includes the regionally dominant Swamp Forest habitat represented at Iniok Site. Although its distribution and ecology are not well-known, it would most likely attract an IUCN listing of Least Concern.

Dossiers on all these species, including details of habitat requirements and range, will be presented in the EIS.

6.3.2 IUCN and PNG Fauna (Protection and Control) *Act 1966* Listed Species that are Possible Inhabitants of the Study Area

A further 15 or 16 species of conservation interest are regarded as possible inhabitants of the Study Area. These are included in the Candidate Mammal List (Table 4) generated by the biogeographic analysis but were not detected during the survey. In order of IUCN threat level, these are:

- *Critically Endangered* – Bulmer's Fruit Bat (*Aproteles bulmerae*)
- *Vulnerable* – Moss Forest Blossom Bat (*Syconycteris hobbit*)
- *Near Threatened* – Plush-coated Ringtail Possum (*Pseudochirops corinnae*)
- *Near Threatened* – Bruijn's Pogonomelomys (*Pogonomelomys bruijni*)
- *Data Deficient* – Short-haired Water Rat (*Paraleptomys wilhelmina*)
- *Data Deficient* – Champion's Tree Mouse (*Pogonomys championi*)
- *Data Deficient* – Western Shrew Mouse (*Pseudohydromys occidentalis*)
- *Data Deficient* – Telefomin Leaf-nosed Bat (*Hipposideros corynophyllus*)

- *Data Deficient* – Hill’s Leaf-nosed Bat (*Hipposideros edwardshilli*)
- *Data Deficient* – New Guinea Sheath-tailed Bat (*Emballonura furax*)
- *Data Deficient* – Fly River Leaf-nosed Bat (*Hipposideros muscinus*)
- *Data Deficient* – Semon’s Leaf-nosed Bat *Hipposideros semoni*)
- *Data Deficient* – Free-tailed Bats (*Otomops papuanesis* and/or *O. secundus*.)
- *Data Deficient* – Small Melanesian Bent-winged Bat (*Miniopterus macrocneme*)
- *Data Deficient* – Small-toothed Long-eared Bat (*Nyctophilus microdon*)

The Critically Endangered Bulmer’s Fruit Bat (*Aproteles bulmerae*) is included as a possible inhabitant of the Hill and Montane zones of the Study Area on the following grounds:

1. Modern records of the species come from widely separated localities along the Central Cordillera and indicate a formerly extensive range which is now fragmented into an unknown number of refugia;
2. It is recorded from localities on the Central Cordillera, including the vicinity of Telefomin, around 50 km from the Study Area;
3. While this distance probably exceeds the foraging range of an individual bat, it is certainly within the dispersal range of a large-bodied fruit bat (Hall and Richards 2000);
4. It is known to roost in large limestone sinkholes of the kind found within the large limestone plateau of the Study Area; and
5. It is known to be sensitive to hunting disturbance and to frequent karst areas that are inaccessible and rarely visited by people (the large sinkholes in the Study Area conform to this profile).

As for the other threatened Montane Zone mammals, the survival of Bulmer’s Fruit Bat will depend in large part on preserving the remoteness of its critical habitats, in this case the primary roosting sites. Special measures are warranted to identify and avoid or mitigate potential impacts on any population of Bulmer’s Fruit Bat that utilises any part of the Study Area, either for roosting or as part of a wider foraging zone.

Other possible inhabitants of the Montane Zone in the Study Area are the Vulnerable Moss Forest Blossom Bat, and the Near Threatened Small Mountain Dorcopsis, Plush-coated Ringtail Possum and the Data Deficient Champion’s Tree Mouse, Short-haired Water Rat and Western Shrew Mouse. The Small Mountain Dorcopsis and Plush-coated Ringtail Possum are potential targets for hunting but have wide distributions along the Central Cordillera of New Guinea. Champion’s Tree Mouse is currently only known from the Telefomin area (Flannery 1995). It has a known geographic range of less than 250 km^2 and the extent and quality of its habitat around Telefomin is probably declining. However, it is known to be locally common and to persist in the face of local forest disturbance and subsistence hunting. Any population within the Study Area would represent a significant addition to its known range and be of considerable conservation significance.

The Near Threatened Lowland Brush Mouse (*Pogonomelomys bruijni*) is a poorly known species recorded from widely scattered localities in lowland rainforest, up to maximum elevation of 200 m elevation Whilst it is not recorded from anywhere in the northern lowlands, the few locality records are so widely scattered that its presence cannot be discounted. Nothing is known of its ecological requirements.

Eleven Data Deficient bat species are possible inhabitants of the Study Area. All are listed as Data Deficient either on account of taxonomic issues (e.g. the Small Melanesian Bent-winged Bat, *Miniopterus macrocneme*; Appleton *et al.* 2004) or primarily because they are difficult to detect (e.g. the Free-tailed Bats, *Otomops* spp.). Only the Telefomin Leaf-nosed Bat (*Hipposideros corynophyllus*) and Hill's Leaf-nosed Bat (*Hipposideros edwardshilli*) might be construed as having a potentially small geographic range. The former species would most likely be found in the small patches of Study Area Montane Zone habitat; the latter species possibly in the Lowland Zone or Hill Zone.

Dossiers on all these species, including details of habitat requirements and range, will be presented in the EIS.

6.4 Mammal Communities of Conservation Significance

6.4.1 Mammal Communities of the Study Area Lowland Zone

The extensive alluvial plains of northern New Guinea support a diverse and distinctive but for the most part, widely distributed non-volant mammal community. The majority of its component species are found throughout all three of the major northern basins – Mamberamo, Sepik and Ramu –and many also extend upwards at least onto the lower flanks of the northern Cordilleran foothills. Indeed, relatively few mammal species appear to be restricted to the lowland alluvial environment. Within the Study Area, three species were recorded exclusively at sites in the Study Area Lowland Zone: the Long-nosed Spiny Bandicoot (*Echymipera rufescens*); the Large Tree Mouse (*Pogonomys* cf. *loriae*); and the Feather-tailed Possum (*Distoechurus* sp.). Of these, the bandicoot and possum most likely extend to higher elevations, while the Tree Mouse genus as a whole was recorded too infrequently within the Study Area to estimate the elevational range of any particular species.

Among the large number of bat species found in the Study Area Lowland Zone, several of the smaller pteropodid species appear to be locally restricted to the inundated swamp habitats, namely the Wide-striped Tube-nosed Fruit Bat (*Nyctimene aello*), the Green Tube-nosed Bat (*Paranyctimene raptor*) and the Long-nosed Blossom Bat (*Macroglossus minimus*) – these were not captured in the Peat Forest at East Sepik Site nor at sites within the Study Area Hill Zone. By contrast, with the possible exception of one or both of the *Nyctophilus* species captured at Iniok Site, no insectivorous bat species seems to be restricted to the Study Area Lowland Zone – the majority extend at least into the lower Study Area Hill Zone, some even to higher elevations.

While bat endemism thus appears low in the Study Area Lowland Zone, the bat communities are nonetheless remarkable for the diversity and sheer abundance of Pteropodidae, particularly among the blossom bats (with three species) and the tube-nosed fruit bats (with five species). These groups are so abundant that they must play a central role in many aspects of forest ecology, including pollination, seed dispersal and nutrient cycling.

The distinctive Peat Forest community at East Sepik Site did not produce any unusual mammal records. The site was notable, however, for the absence of several pteropodid species found at all other Study Area Lowland Zone sites (e.g. *Nyctimene aello*, *Macroglossus minimus*), for having the lowest insectivorous bat call type diversity of all Study Area Lowland Zone habitats (8 species vs 10 – 14), and for the apparent absence or rarity of both feral pigs and wallabies. These indicators of a reduced mammalian diversity are consistent with the general conclusion that this represents a nutritionally impoverished habitat with overall low biodiversity. Somewhat surprisingly, the capture rates of *Syconycteris* spp. and the smaller *Nyctimene* species were no lower at this site than several others in the Study Area Lowland Zone. Once again, this highlights the contrasting opportunities available to a mobile volant mammal as against the restrictions faced by a more sedentary terrestrial mammal in dealing with sparse and scattered resources.

At least two species of flying foxes (Great Flying Fox *Pteropus neohibernicus*; and Big-eared Flying Fox

Pteropus macrotis) are abundant members of the Lowland Zone mammal community, and several others (e.g. Black Flying Fox *Pteropus alecto*) are probably occasional visitors from more permanent territories located closer to the coast.

The Great Flying Fox is a widespread Melanesian species with scattered records from New Guinea up to 1,700 m elevation and from the Bismarck Archipelago (Bonaccorso 1998). Flannery (1995) mentioned the occurrence of “massive camps” in the swamp forests of the Upper Sepik River Basin but did not provide details of localities. No major congregations of this species are recorded outside of the Sepik River Basin. A large seasonal congregation in Madang township referred to this species by Smith and Hood (1981) and Flannery (1995) was later identified by Bonaccorso (1998: 138) as involving a different species, the Spectacled Flying Fox *Pteropus conspicillatus*. Smith and Hood (1981) recorded numerous small congregations (500-600 bats) of Great Flying Fox on New Britain and New Ireland. Little else is recorded of the biology of the species, though there are accounts of it feeding heavily on fruits including figs, and of it using nectar from blossoms (Bonaccorso 1998: 138).

Even less is known about the Big-eared Flying Fox, despite the fact that it is widely distributed on the main island of New Guinea up to 500 m elevation and locally common (Bonaccorso 1998).

The pattern of reproduction, roosting behaviour and movement has not been documented in any detail for any endemic Melanesian species of flying fox. However, there is a high degree of similarity among all well-documented species of the flying fox genus *Pteropus* (Pierson and Rainey 1992; Hall and Richards 2000) and it is reasonable to assume that Melanesian endemic species will conform to the general pattern.

Large flying foxes typically have a gestation period of around six months, with the single young carried for about 6 weeks after birth. The young are flightless for a further 3 months but are left at the maternity roost while the female forages. Lactation ceases about 4-5 months after parturition and young become independent soon thereafter. Females may be capable of breeding at one year of age but first breeding at 2-3 years of age is probably more usual. Average lifespan is probably less than a decade but wild-living individuals have been known to live up to 18 years.

All Australian flying fox species have restricted breeding seasons and there is a high degree of synchrony between species. The Grey-headed Flying Fox *Pteropus poliocephalus* of eastern Australia mates in March and April, with single young born in mid-September to mid-December (Martin *et al.* 1987). The Spectacled Flying Fox *P. conspicillatus* of rainforest habitats in north Queensland mates for a prolonged period (January to June) but most young are born between October and December. The more widely distributed Black Flying Fox *P. alecto* mates in March-April on the east coast (Vardon and Tidemann 1998) but in January-February in the Northern Territory (Markus *et al.* 2008), with births occurring six months later in each case. The smaller Little Red Flying Fox *P. scapulatus* also shows highly seasonal breeding but there is less synchrony with the other species – it mates in November to January in eastern Australia, with births in April and May. In the Northern Territory births are recorded from early March.

Breeding schedules may be somewhat more variable in Melanesia than in Australia, even within shared species. For example, an annual congregation of Spectacled Flying Foxes (*Pteropus conspicillatus*) at Madang in Morobe Province results in the birth of young in July-August (i.e. 3 months earlier than in north Queensland; Bonaccorso 1998). Variation in the time of breeding is also observed between different localities for Melanesian endemics. For the Admiralty Flying Fox *Pteropus admiraltum*, pregnancies have been recorded in June in the Admiralty Islands but in January on Tabar Island to the northeast of New Ireland (Bonaccorso 1998). Similarly, the Masked Flying Fox *Pteropus capistratus* has been recorded with young in each of January and July in New Britain. This greater variability in the timing of reproduction in Melanesia may reflect greater intrinsic temporal variation in resource availability, compared with the more strongly seasonal environments of northern and eastern Australia. Whether this translates to greater inter-annual variation in any one region, as well as between regions, is not known.

Most flying foxes spend the daytime hours in the canopy of trees, forming roosting congregations or 'camps' of varying size and composition. Tidemann *et al.* (1999) distinguished 'main camps' with >1,000 individuals which are important sites for mating and parturition, from 'satellite camps' with <1,000 individuals, the latter often comprised of males and/or subadults. This categorization does not capture all of the complexity of the complex population dynamics of camps, but it is a useful basis for discussing the possible significance of roosting sites in the Study Area.

Among the well-studied Australian flying foxes, congregations in 'main camps' occur at two principal periods through the annual reproductive cycle (Hall and Richards 2000). The first involves adults of both sexes and facilitates complex courtship and mating behaviours which can extend over several months. The second involves mainly adult females that come together in 'maternity camps' to give birth and rear the young. Several different species may sometimes use the same maternity camp though they tend to be overwhelmingly dominated by one species. The 'main camp' localities may be deserted outside of these periods, or may be used for general roosting by smaller numbers of individuals. Smaller congregations of variable size and composition occur at all times, often involving groups of males or adolescent bats.

Large congregations of flying foxes can involve significant proportions of total populations and the same camp locations are typically used over periods of many decades or longer, provided surrounding foraging areas remain productive and disturbance of the colony is not excessive. Surveys of camp use in New South Wales in July 1998 found 99% of the estimated resident state population of 85,400 *P. poliocephalus* to be using 9 out of a total of 11 camps in use at that time (Eby *et al.* 1999), with a similar level of spatial clumping of *P. alecto* populations at the same time. A Study Area maternity colony in the order of 100,000 adult females of the Great Flying Fox could represent a significant fraction of regionally occurring breeding-age females. To provide perspective, Garnett *et al.* (1999) estimated the total population size of the Spectacled Flying Fox in Australia in March 1998 at 153,000 individuals, while Eby *et al.* (1999) estimated the total population of the Grey-headed Flying Fox in Australia in 1998 at around 400,000 individuals.

More or less continuous annual use of some Australian flying fox camps is documented back to the earliest historical records. Establishment of new camps has also been observed, especially following recent southern range expansion of the Grey-headed Flying Fox. Although many camps are now located close to areas of regular human activity, including patches of remnant forest in towns, camp persistence seems to be determined more by continued access to adequate foraging resources than to any other factor (Richards 1990). However, excessive disturbance by shooting etc. can lead to abandonment of long-occupied camps.

The direction and extent of dispersal of flying foxes around their 'main camps' appears to be determined by spatial and temporal patterns of food availability (Eby 1991; Palmer and Woinarski 1999), with no overall migratory component as suggested by some early workers (e.g. Radcliffe 1931). In areas with more or less continuously available but dispersed resources, short term and even seasonal movements may be restricted to some tens of kilometres. In contrast, areas with more localised and irregular resources will see large groups of bats moving tens to hundreds of kilometres over quite short periods. In all situations, occasional to regular long distance movement of individuals and small groups takes place between roosting sites (Spencer *et al.* 1991), and this results in a high degree of genetic uniformity over large areas (Webb and Tidemann 1996). Daily flights of 20 km or more between roosting and foraging areas are reported for many species (Nelson 1964, Spencer *et al.* 1991; Tidemann and Nelson 2004).

A maternity colony in the order of 100,000 individuals could represent a significant fraction of regionally occurring breeding age females. To provide perspective, Garnett *et al.* (1999) estimated the total population size of the Spectacled Flying Fox in Australia in March 1998 at 153,000 individuals, while Eby *et al.* (1999) estimated the total population of the Grey-headed Flying Fox in Australia in 1998 at around 400,000 individuals.

Flying foxes are acknowledged to play significant roles in pollination and seed dispersal within forest communities (Pierson and Rainey 1992; Richards 1995), and their removal from a mammalian community has been postulated to have wider and potentially cascading ecological impacts (Cox *et al.* 1991; Richards 1995).

6.4.2 Mammal Communities of the Study Area Hill Zone

The Study Area Hill Zone supports a rich mammal community that includes a confirmed population of the Critically Endangered Black-spotted Cuscus (*Spilocuscus rufoniger*) and the Data Deficient Northern Groove-toothed Shrew Mouse (*Microhydromys richardsoni*). Very few mammal species appear to be confined to this zone, the majority either extending downward into the Lowland Zone, or upward into the Montane Zone. Two exceptions are the Black-spotted Cuscus that seems to avoid the inundated habitats of alluvial floodplains, and the Lowland Mammelomys (*Mammelomys rattoides*) which appears to be restricted to Hill Forest habitats of the Mamberamo, Sepik and Ramu drainage basins (Flannery 1995), with an ecological replacement species (Montane Mammelomys, *M. lanosus*) in regional Montane Zone forests. Another candidate for a restricted endemic of the Study Area Hill Zone is the unusual Long-footed Tree Mouse (*Lorentzimys* sp.) captured at Malia Site. However, very few specimens of this genus are known from the northern lowlands of New Guinea, and it is likely that the species detected in the Study Area has a broader geographic range extending along the northern foothills of the Central Cordillera. This will need to be confirmed by wider survey effort outside of the Study Area.

Bats of the northern foothills of the Central Cordillera were largely unsurveyed prior to this study. One of the more striking results of this survey is the discovery of an exceptionally diverse and abundant community of nectar-and fruit-eating Pteropodidae, with extremely high local diversity of tube-nosed fruit bats (*Nyctimene* and *Paranyctimene*) and blossom bats (*Syconycteris*), including two tube-nosed fruit bats (*Nyctimene albiventer papuanus* and *Nyctimene* sp. B) that may be restricted to the Hill Zone. The abundance of *Nyctimene* in the study area finds parallels in regional collections from localities in the northern foothills, including sites in Morobe Province (Dawson *et al.* 2009). For reasons that are presently unclear, tube-nosed fruit bats appear to be far less abundant in sites south of the Central Cordillera (e.g. Armstrong and Aplin 2011).

With the possible exception of the Long-footed Tree Mouse (*Lorentzimys* sp.), all of the Hill Forest mammal species recorded in the Study Area are known to be widely distributed along the northern slopes of the cordillera, the majority extending throughout the watershed catchments of the Mamberamo, Sepik and Ramu River systems (Flannery 1995; Bonaccorso 1998). The significance of the Study Area Hill Zone is that it is relatively undisturbed compared to many other catchments in Indonesia and further eastward towards the Bismarck Range. The author considers this to be particularly significant for the Critically Endangered Black-spotted Cuscus which has declined so much throughout its range.

Communities of the Study Area Montane Zone

There is compelling evidence from informants' testimony that high elevation peaks and ridges within the Study Area support isolates of a montane mammal community that includes a Critically Endangered Long-beaked Echidna (*Zaglossus* sp.), two species of tree kangaroos (*Dendrolagus* spp., listed as Endangered and Vulnerable), a Near Threatened Small Dorcopsis (*Dorcopsulus* sp.), a striped bandicoot (*Microperoryctes* sp.), several species of montane cuscus (probably including the Critically Endangered Telefomin Cuscus *Phalanger matanim*), and at least one giant montane rat that cannot be more precisely identified from informants testimony. Many other smaller mammal species typical of Lower Montane Forest (L ± c) are also expected to occur in these areas, and rugged karst habitat on the Nena Limestone Plateau and some other high peaks might represent roosting sites for the Critically Endangered Bulmer's Fruit Bat (*Aproteles bulmeri*).

The presence of this mammal community on isolated peaks is readily explained in terms of the climatic and vegetation history of New Guinea which saw montane mammal communities brought down to current Hill Forest elevations during glacial episodes (Aplin 1998), the most recent of which terminated around 14,000 years ago (Hope *et al.* 2004). As climate warmed through the last 14,000 years, the montane mammal community retreated to higher elevations, leaving behind pockets of this community on the higher peaks and ridges above 1,000 m in the Study Area. Since that time, these isolated montane communities have probably undergone a process of simplification through local extinction of some species. Additionally, component species may have been subject to genetic drift, thereby distinguishing each isolated population from each other, and from the larger population that today occupies the ranges of the Central Cordillera.

The lower elevation boundary of the Montane Zone of 1,000 m is an arbitrary one that does not necessarily reflect any strict elevation limit of individual species. For example, a montane cuscus (probably the Mountain Cuscus, *Phalanger carmelitae*) was observed at approximately 900 m elevation at Nena Site, and other montane mammal species could be expected to occur in the upper reaches of the Hill Zone either as individuals utilising sub-optimal habitat (perhaps on account of social sub-dominance) or as dispersing individuals in search of new territories. Habitat continuity is necessary for such behaviour which is a critical component of population dynamics. Degradation of intervening habitat, particularly for strictly arboreal species, would likely result in reducing this connectivity and increasing isolation of these patches. Ongoing dispersal between isolates, even at low frequency of occurrence, is thought to be critical to the maintenance of viable metapopulations in the case of long-term habitat fragments separated by otherwise impassable barriers (Taylor and Goldingay 2009).

The significance of the montane mammal community isolates within the Study Area thus relates to:

- the likely presence in these isolates of several mammals listed by IUCN as Critically Endangered, Endangered and Vulnerable;
- their degree of protection from exploitation by virtue of remoteness of these habitats;
- the general pattern of decline through the greater part of their distribution along the Central Cordillera of PNG due to overhunting and habitat modification;
- the possibility that these populations have diverged from the Central Cordilleran populations through local adaptation or genetic drift; and
- the possibility that the isolates might preserve components of genetic diversity that have been subsequently lost through extinction in the larger cordilleran populations.

6.5 Invasive Mammal Species within the Study Area

Populations of two invasive mammals were detected in the Study Area.

The European Black Rat (*Rattus rattus*) was observed at night climbing on a facility building at Iniok Site. The rat was observed at close range and identified with confidence based on its relatively long tail, broad feet, and fur texture. Project staff reported seeing rats climbing in the roof of the building on numerous occasions, and these are also likely to relate to *R. rattus* rather than a native species of *Rattus*, all of which are less adept climbers. Traps were set around the building for several nights but failed to make a capture. Black rats are often wary of traps.

Project staff at Frieda Base also reported seeing rats inside buildings, though only on the ground in this case. They were given traps to set inside the buildings and captured a total of five specimens of a native rat, *Rattus praetor*. This and another species of native rat (Stein’s Rat, *Rattus steini*), were also captured around the buildings at Nena Base Site.

Several buildings at each of Frieda Base and Nena Base Sites were carefully examined by Aplin for signs of arboreal rat activity, which might be indicative of Black Rat populations. No such signs were observed and it seems likely than the Black Rat is not yet established at these sites. However, with regular movement of cargo by air and canoe between the barge landing at Iniok Site and the other infrastructure sites, there is a high risk of Black Rat colonisation into all major infrastructure sites.

Black Rats have been present regionally in the Sepik River Basin since at least the mid-1960s – the CSIRO collection holds specimens from Ambunti and Angoram, collected at that time.

The second invasive mammal in the Study Area is the feral pig, a prehistoric invader to New Guinea but one that is probably still penetrating and degrading new habitats as opportunity presents. Aspects of its distribution and ecological role in the Study Area have been described in above.

No evidence was found of Polynesian Rats (*Rattus exulans*) at any site. This smaller-bodied rat is widespread in New Guinea and is often found in villages and gardens. People at Wameimin 1 and 2 described small rats sometimes found living in the roof of houses but these were described as having white belly fur, suggesting either Black Rats or the Black-tailed Melomys (*Melomys rufescens*), rather than *R. exulans* which is grey or tan-bellied. Flannery (1995) reported Black-tailed Melomys as a common inhabitant of Miyan villages in Sandaun Province.

6.6 Cultural Significance of the Mammal Fauna

It is beyond our expertise to provide more than a few general remarks on this important topic. A detailed anthropological study is warranted, especially in regard to the development of any mitigation strategies that require landowners to modify their traditional patterns of behaviour toward particular species or habitats.

In our limited experience of the resident peoples of the Study Area, it is likely that all groups have a strong cultural association with wildlife that includes but does not end at its use as a food resource. This is most thoroughly documented for local Miyan communities through the detailed studies of Morren (1977, 1979, 1986, 1989); however, there is no reason to doubt that similar economic and cultural relationships exist for all other local groups as well.

Current levels of exploitation of wildlife resources are not yet documented in any detail. Informant interviews indicated that people of all villages hunt occasionally but people with access to Hill Zone habitats probably hunt more frequently and on a more continuous basis than people who live in the seasonally inundated environment of the alluvial floodplains. Hunting appears to be largely opportunistic and any reasonable prey item that is encountered might be taken. The extent of any hunting or dietary taboos was not investigated in any detail due to lack of appropriate background information on social organisations through which to interpret any information offered.

Targeted hunting trips to large roosting caves of bats were mentioned but the frequency of such trips was not ascertained. Specific mention was made of hunting of flying fox populations in the Study Area. These may represent a significant food resource for local people who harvest them from roosts as well as during their foraging activity that brings them into villages and gardens. Judging from the informants' responses, the numbers of animals consumed does not appear to be great but the timing as well as the quantity of any protein resource may be significant. It is not known whether the flying fox colonies have any other cultural significance.

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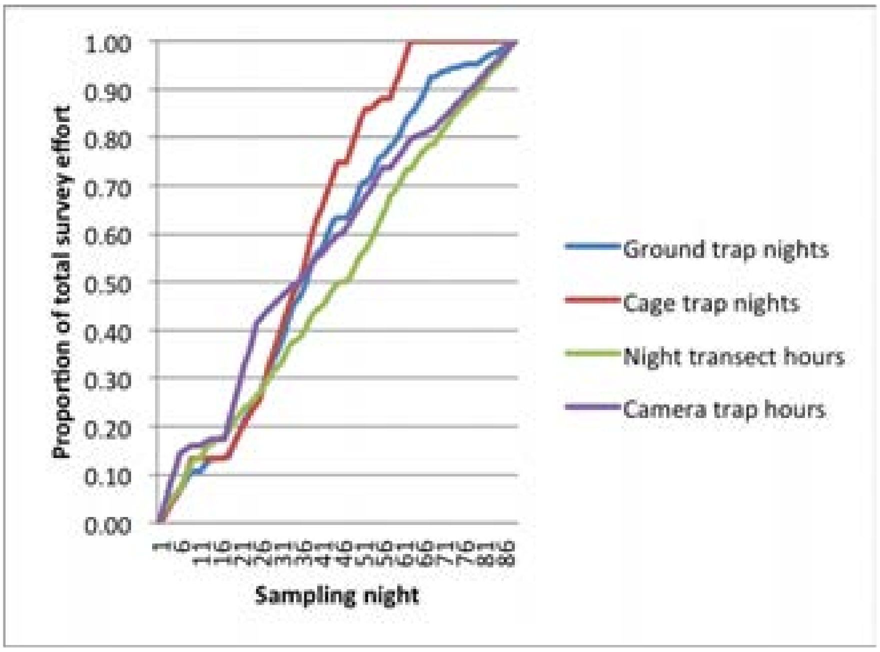
The initial consultancy for this work was undertaken by CSIRO Division of Sustainable Ecosystems and reported in full to Coffey Environments in September 2010. The content of this report was made available to the present authors by Coffey Environments to incorporate into this final report on all phases of work.

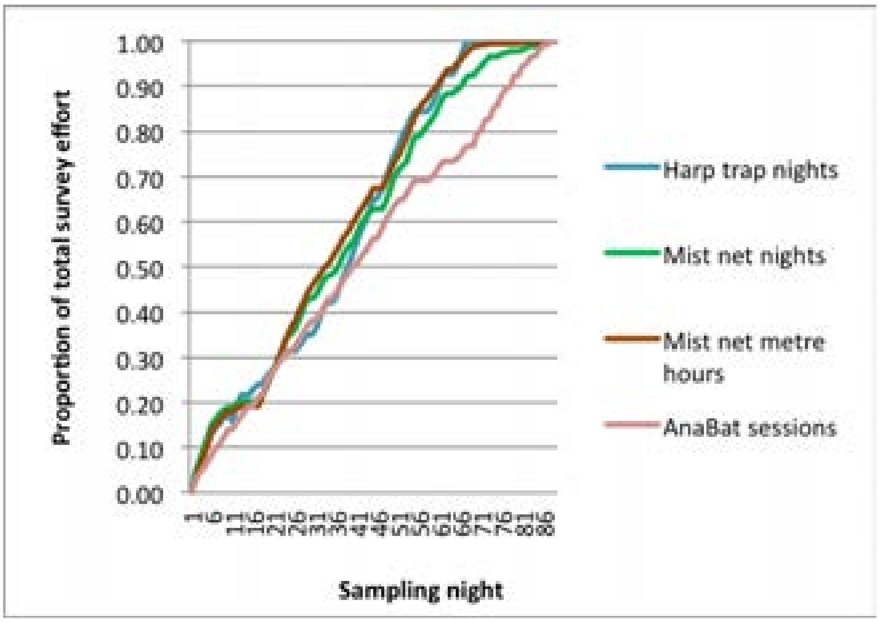
Dr Ken Aplin carried out the fieldwork on Trips 1 – 3 with assistance from Dr Michael Sale of Coffey Environments, other members of the field team, and various local staff provided by the proponent. Aplin is responsible for all mammal identifications other than those made on the basis of acoustic records, and for the general analytical and interpretive framework.

Dr Kyle Armstrong provided all electronic and some trapping equipment to the field survey, provided advice in the use of equipment, undertook all acoustic analyses of the AnaBat recorded data, and contributed text on the insectivorous bats. A capability statement outlining the skills and experience of Dr Armstrong is available at URL: http://www.gaiaresources.com.au/sz

FIGURES



A. Non-volant mammals



B. Bats

Figure 1. The distribution of mammal sampling effort over the period of the field survey.

Elliott trap set on a mammal runway passing beneath a boulder.

Large snap trap set on a fallen tree crossing a deep gully.

Cat trap set under a fallen tree where a large mammal has taken shelter.

Figure 2. Three kinds of traps employed during the survey.

A. Mist net set across a shallow stream at Nena-Usage Site. A Papuan Pipistrelle (*Pipistrellus papuanus*) and a Bare-backed Fruit Bat (*Dobsonia moluccensis*) were both captured in this net.

B. Mist net set in forest understorey at East Sepik Site. Large numbers of tube-nosed fruit bats (*Nyctimene* spp.) were captured in this habitat.

Figure 3. Examples of mist net position within contrasting habitat types.

A. Harp trap set on ground and blocking a narrow flyway where a forest stream enters a clearing at Nena Base Site.

B. Harp trap suspended in the forest canopy on a rope at Kaugumi Site.

Figure 4. Examples of harp trap set in contrasting positions to target different species of insectivorous bats.

Figure 5. Method of deployment of an AnaBat SD1 unit for passive acoustic recording of insectivorous bats. The microphone is located within the plastic cone which protects it from rain.

A.Fatiap, village head of Wameimin 2.

B. Trophy bones of locally hunted animals including wild pigs, a cassowary, and numerous bandicoots, possums and giant rats.

Figure 6. Hunting trophy collection examined at the Miyan village of Wameimin 2 on 3 December 2009.

Figure 7. Feral pig *(Sus scrofa)* captured by camera trap on 5 May 2010 at Kaugumi Site.

Figure 8. Spiny Bandicoot (*Echymipera* sp.) captured by camera trap on 6 June 2010 at Kaugumi Site.

(The three species of this genus are difficult to distinguish from camera trap images unless the age and sex can be determined.)

Figure 9. Lowland Mammelomys (*Mammelomys rattoides*) captured by camera trap on 22 February 2010 at Upper Ok Binai Site.

Figure 10. White-striped Forest Wallaby (*Dorcopsis hageni)* captured by camera trap on 22 February 2010, Upper Ok Binai Site.

Figure 11. Giant White-tailed Rat (*Uromys* affin. *caudimaculatus*) captured by camera trap at Kaugumi Site on 3 June 2010.

Figure 12. Ground Cuscus (*Phalanger gymnotis*) captured by camera trap at Ok Isai Site on 21 February 2010.

A. Image taken on 12 May 2010 at Ok Esai Camp. Image cropped to show detail.

B. Image taken on 22 February at Ok Binai Camp Image cropped to show detail.

Figure 13. Camera trap images of Raffray's Bandicoots (*Peroryctes raffrayana*).

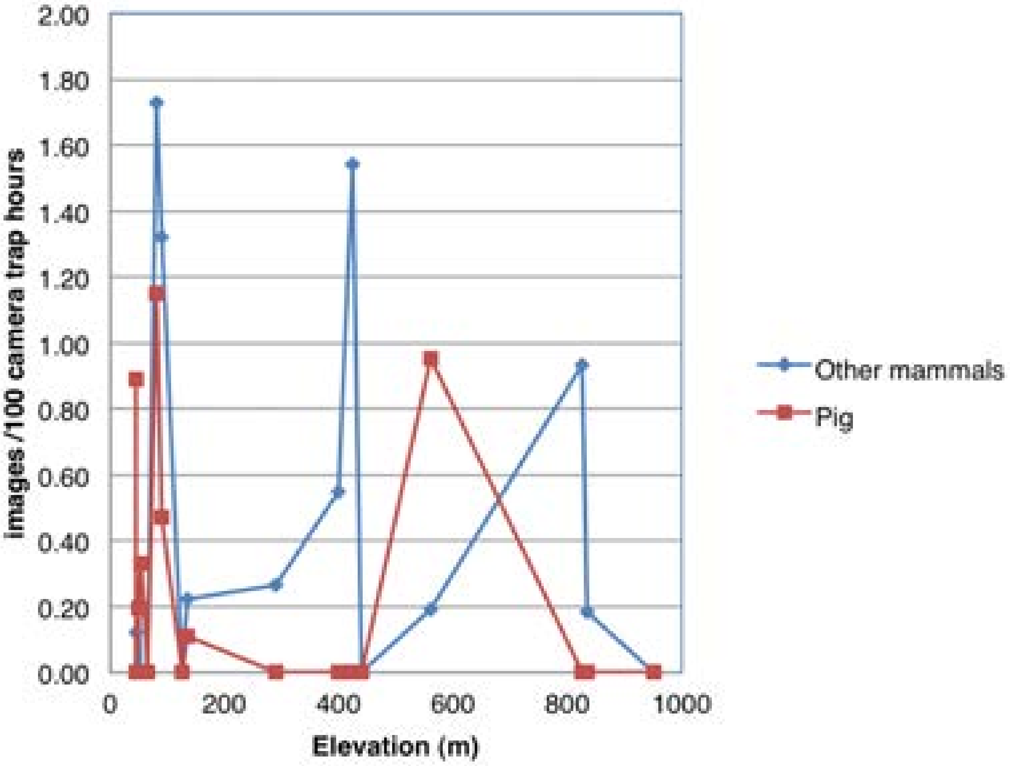
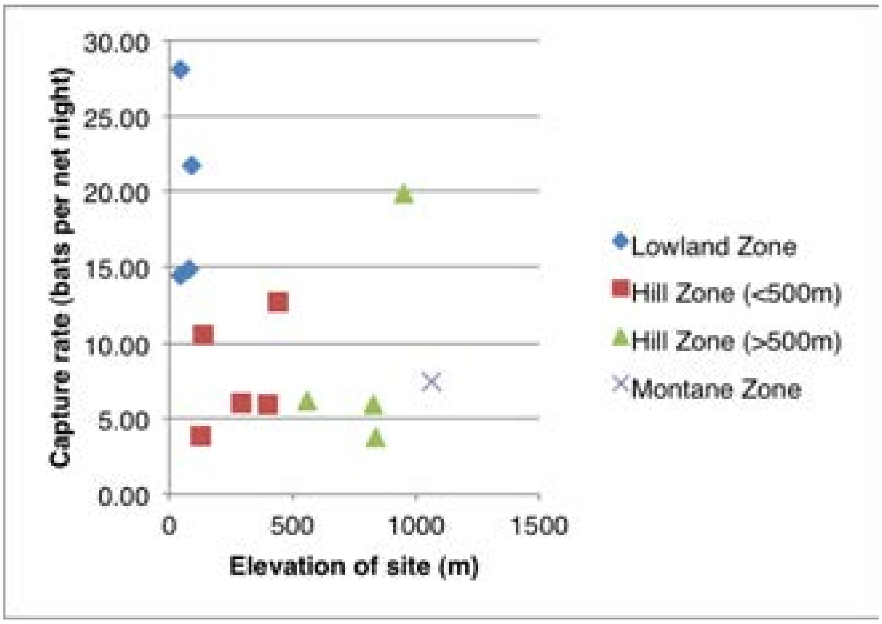
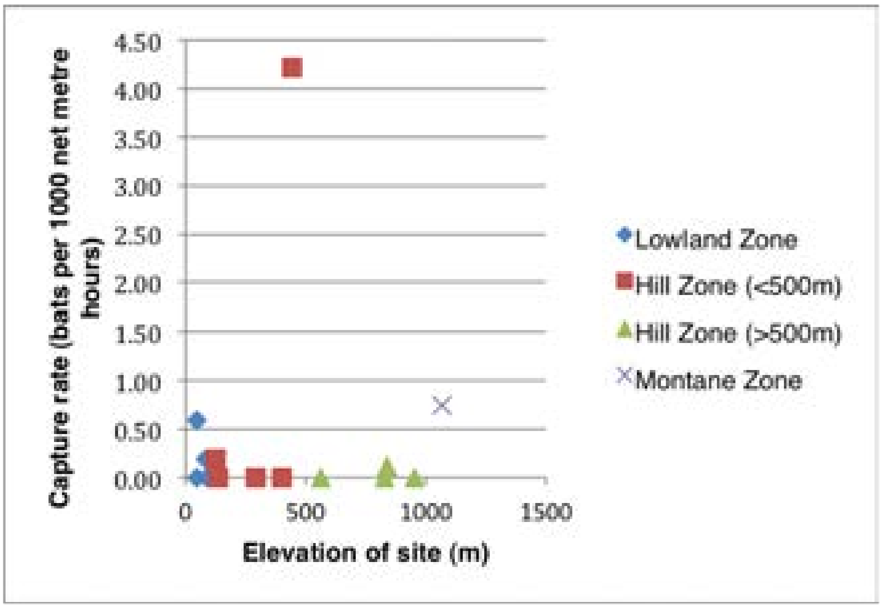


Figure 14. Variation in camera trap image capture rates for pigs and other non-volant mammals along the elevational gradient in the Study Area.



A. Capture rates calculated as bats per mist net night.



B. Capture rates calculated as bats per 1,000 mist net metre hours.

Figure 15. Elevational variation in pteropodid bat capture rate.

Figure 16. A female Northern Common Cuscus photographed during a night transect at Wogamush Site on 4 March 2011 (photo. S. J. Richards).

Figure 17. A Lowland Ringtail Possum located during a night transect at Nena Base Site on 2 December 2009 (photo. S. J. Richards).

Figure 18. A lower jaw of the Black-spotted Cuscus (*Spilocuscus rufoniger*) photographed at Nekiei Village on 27 February 2011. (photo. S. J. Richards).

Figure 19. Site of a significant fruit bat cave roost near Koki Site.

A. General view showing the location of the camp along on both sides of a large meander cutoff of the Wario River. The extent of the camp is indicated by the defoliated trees.

B. Bats roosting in the defoliated trees along the ecotone between Lowland Open Forest (Po) and Herbaceous Swamp (Hsw).

Figure 20. Views of the Wogamush flying fox camp, taken on 30th December 2010 during a helicopter flyover (photos I. Woxvold).

Figure 21. Bats in flight, illustrating the distinctive features of the Great Flying Fox *(Pteropus neohibernicus)*.

Figure 22. An undescribed species of Feather-tail Possum, *Distoechurus* sp., photographed at Iniok Site on the evening of 16th June 2010. This immature male was active in the second level of a multi-layered secondary forest on the Sepik River floodplain. (photo S. J. Richards).

Nyctimene sp. A mist-netted at Nena D1 Site (photo S. J. Richards).

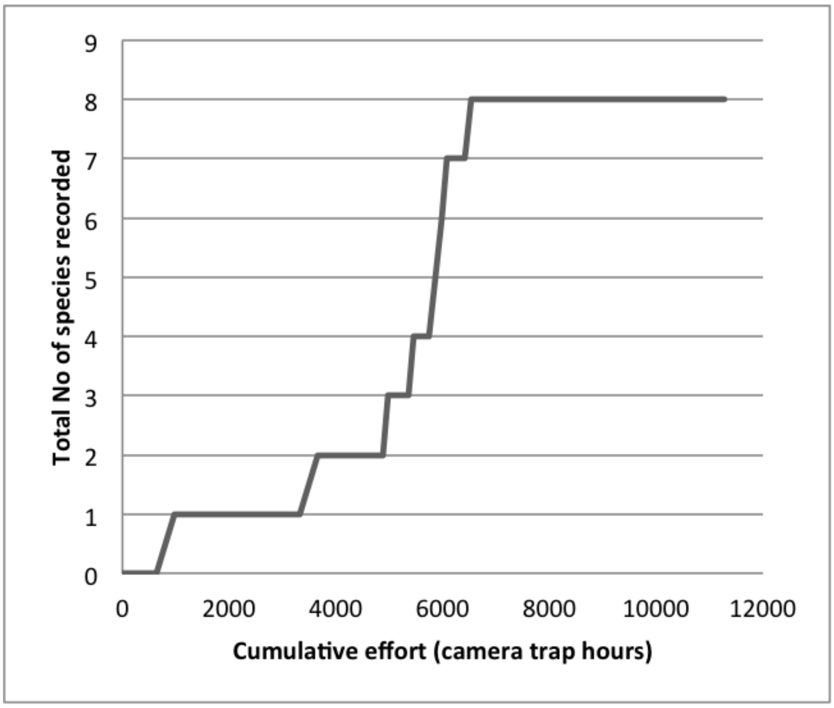
Nyctimene sp.B mist-netted at Malia Site (photo S. J. Richards). The gingery head and yellow ears are distinctive features.

Figure 23. Taxonomic diversity within *Nyctimene* in the Study Area I.

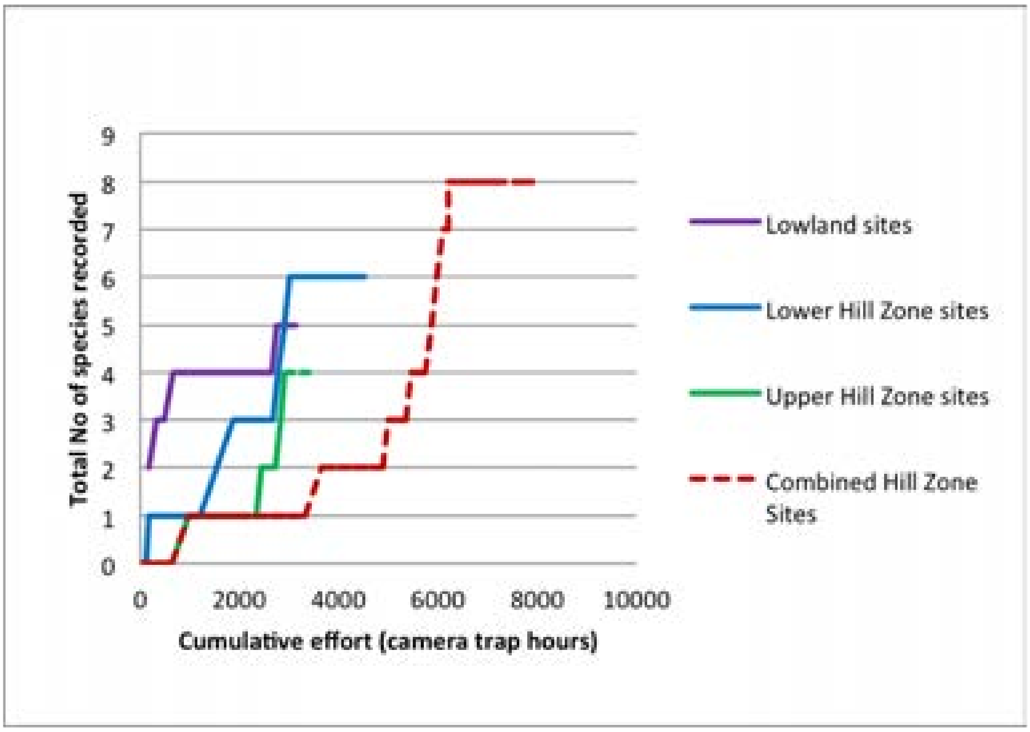
A. *Nyctimene draconilla* mist-netted at Upper Ok Binai Site (photo S. J. Richards).

B. *Nyctimene albiventer papuanus* mist-netted at Koki Site (photo S. J. Richards).

Figure 24. Taxonomic diversity within *Nyctimene* in the Study Area II.

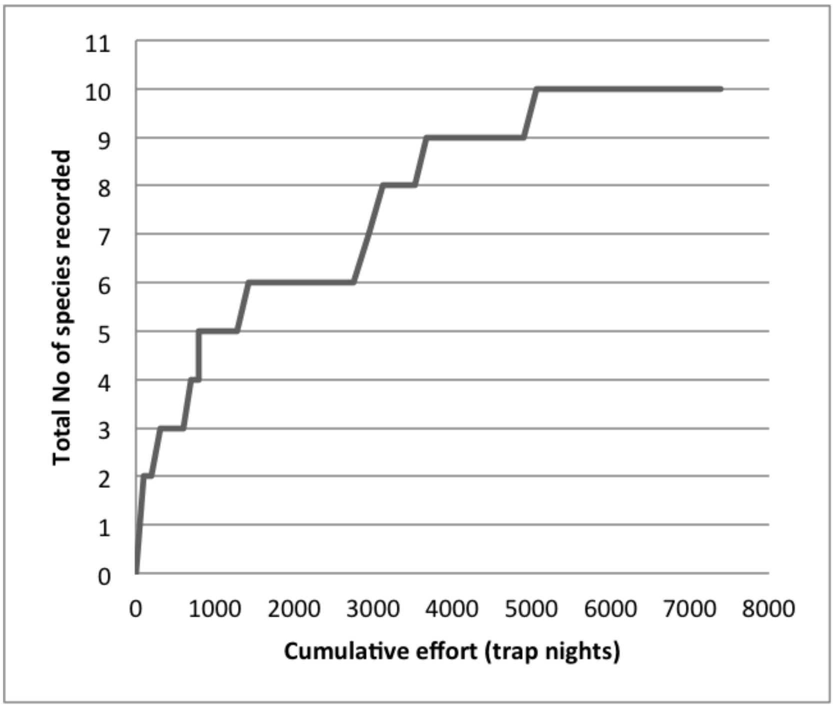


Camera trapping with data combined across all sites.

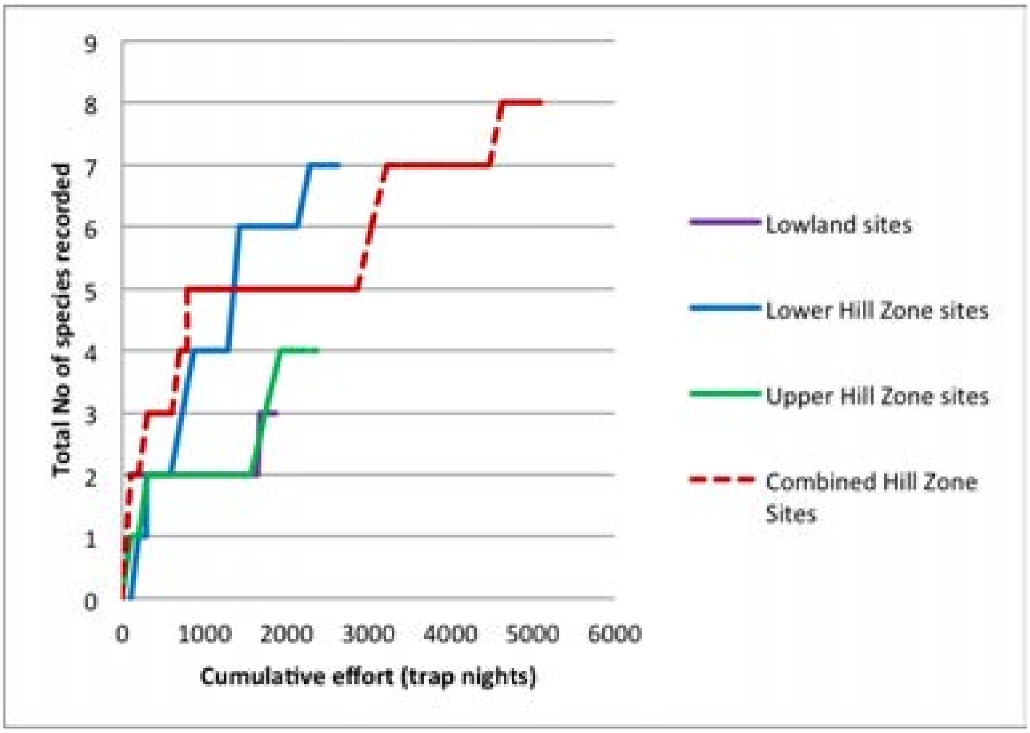


Camera trapping with sites grouped by elevation zone

Figure 25. Taxon accumulation curves for the main methods of detecting non-volant mammals - camera trps.

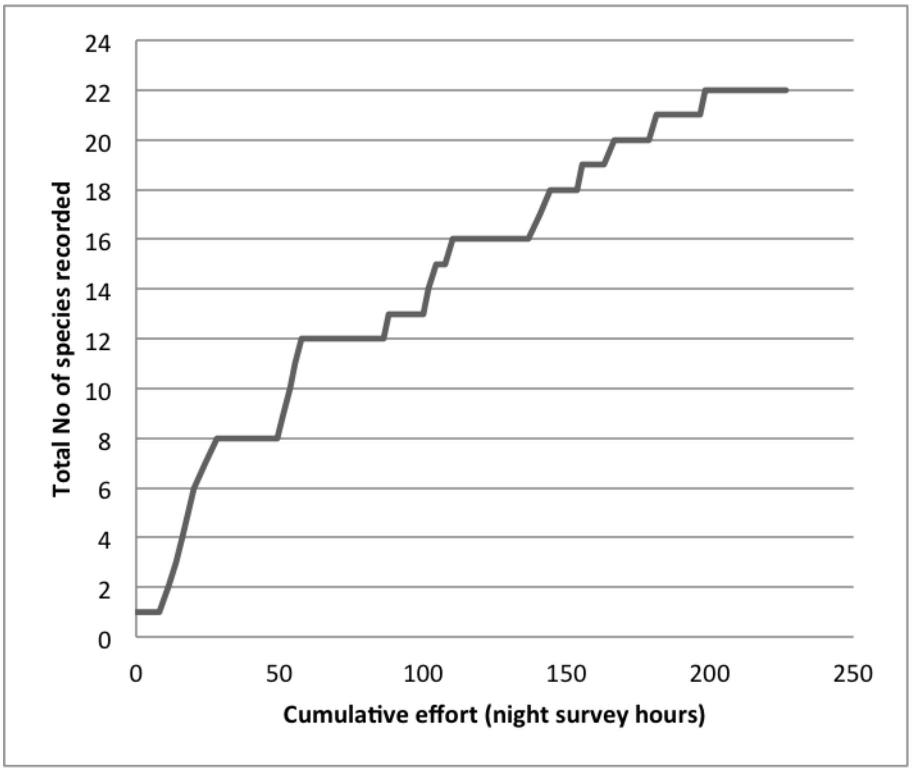


Ground trapping with data combined across all sites.

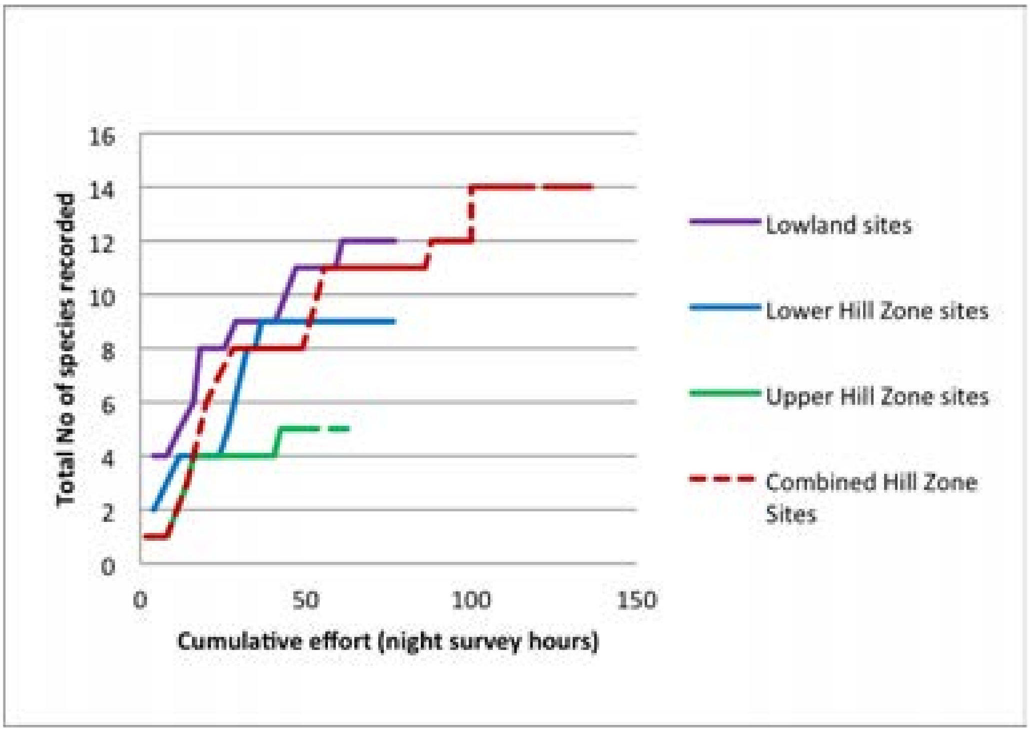


Ground trapping with sites grouped by elevation zone.

Figure 26. Taxon accumulation curves for the main methods of detecting non-volant mammals - ground traps.

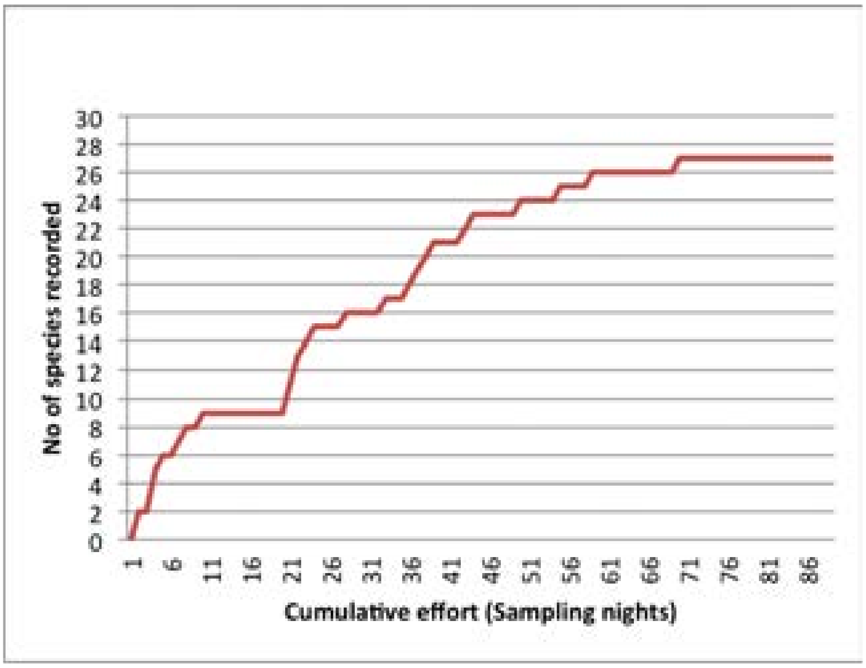


C. Night transects with data combined across all sites

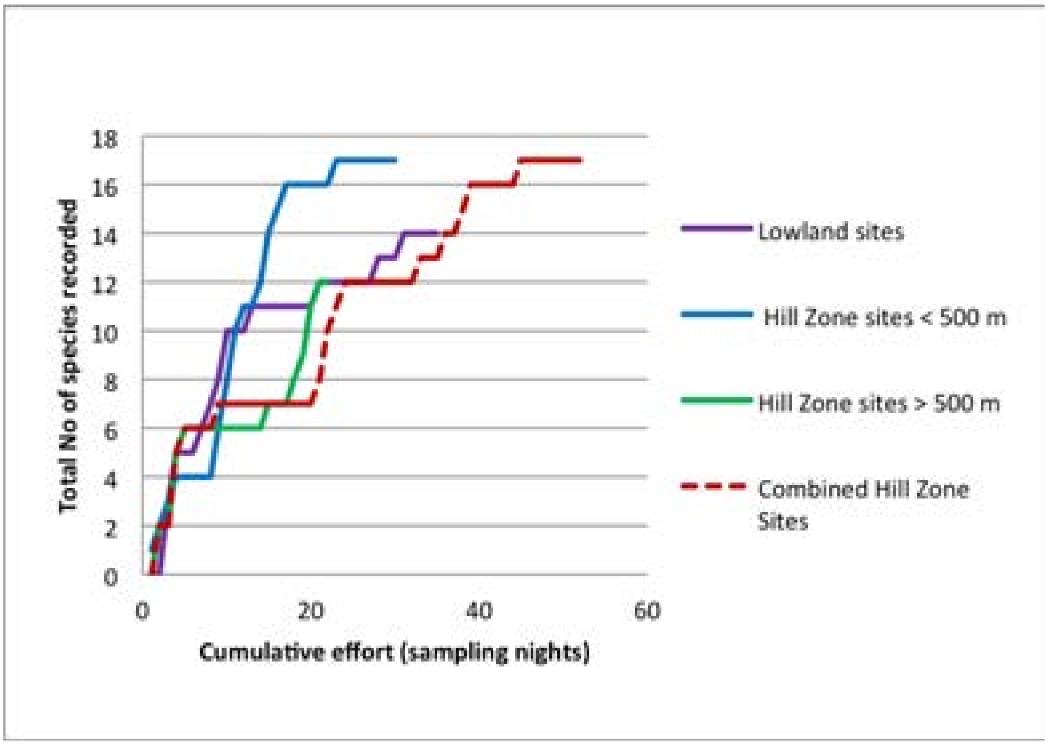


F. Night transects with sites grouped by elevation zone.

Figure 27. Taxon accumulation curves for the main methods of detecting non-volant mammals - night transects.

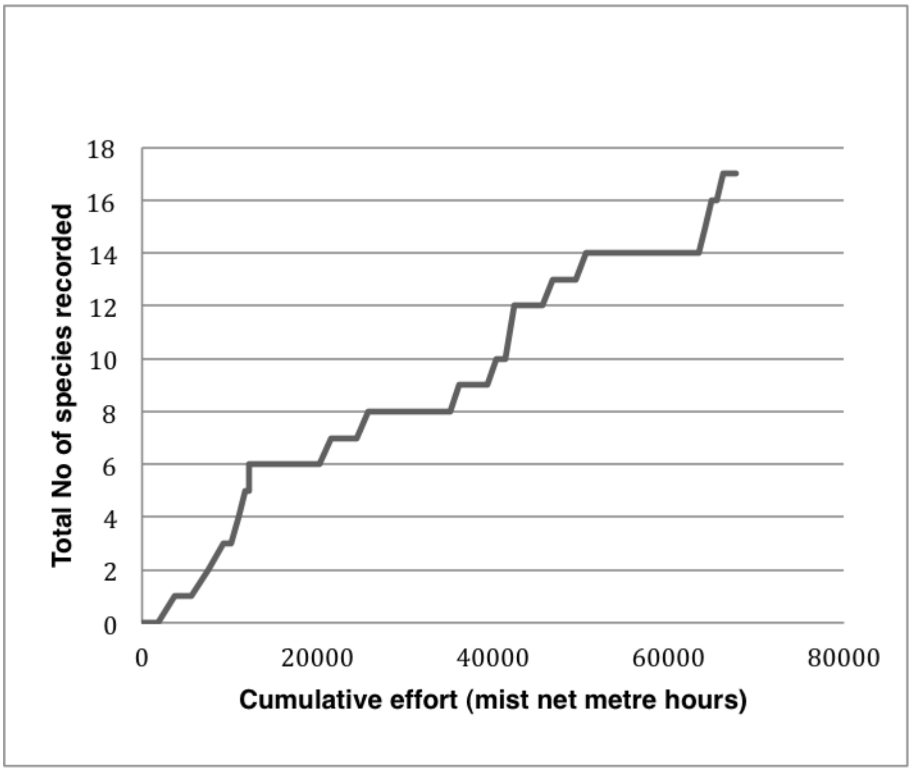


A. All methods with data combined across all sites

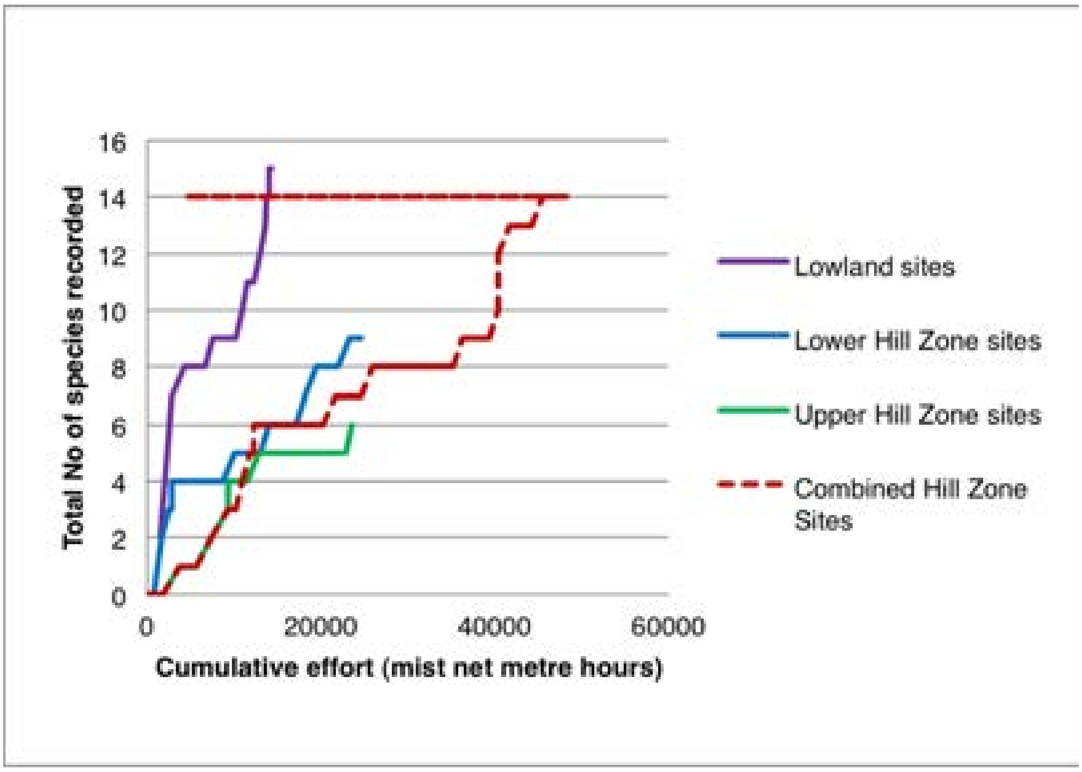


B. All methods with sites grouped by Zone

Figure 28. Taxon accumulation curves for the combination of all main methods of detecting non-volant mammals (camera traps, ground traps and night transects).

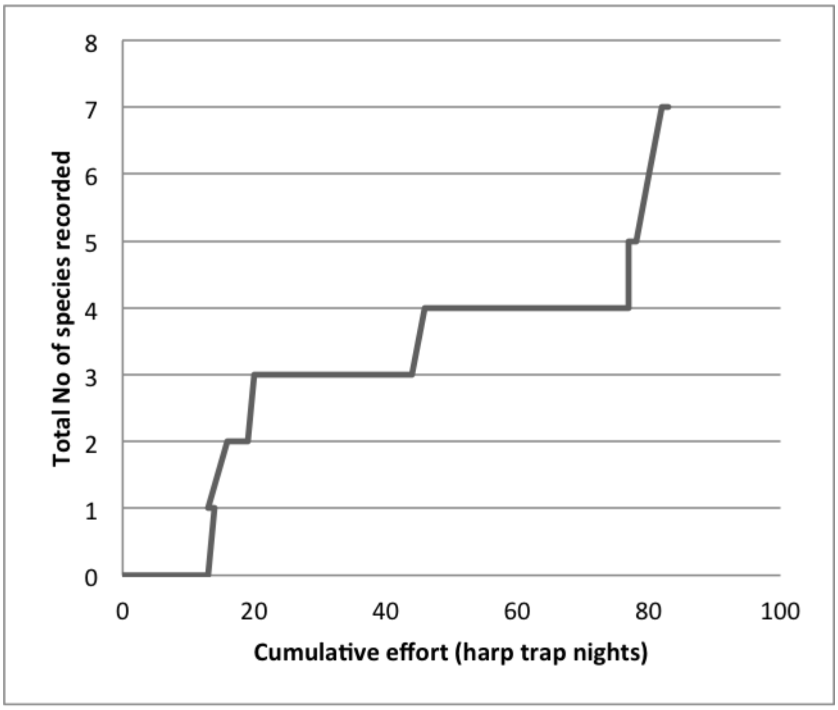


A. Mist netting with all sites combined.

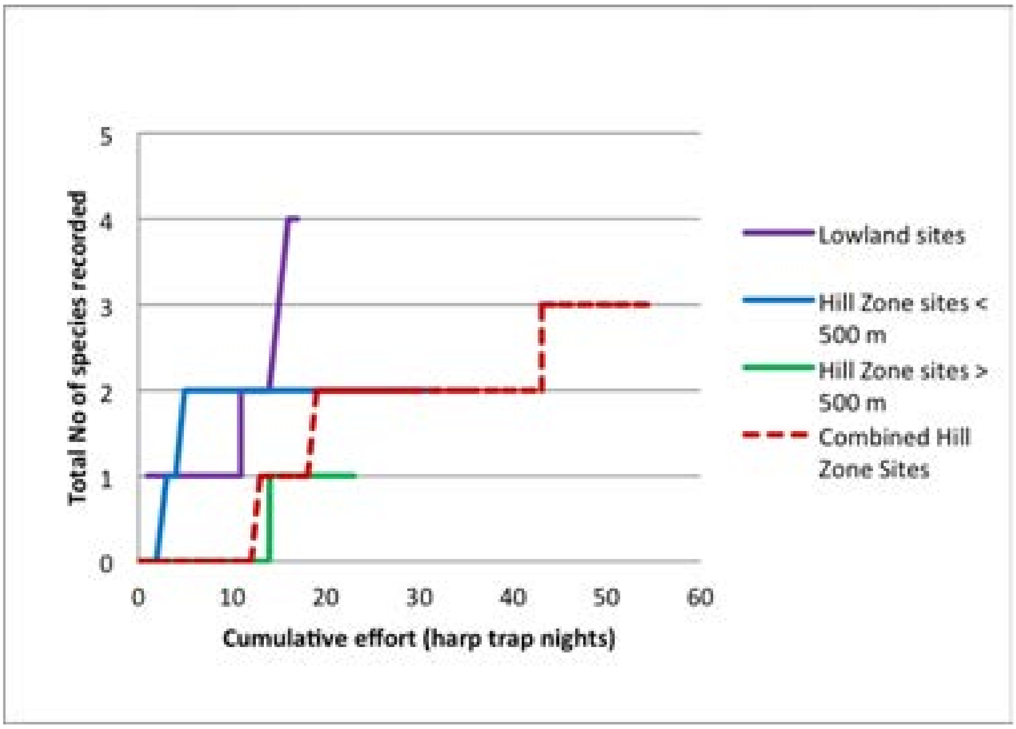


B. Mist netting with sites grouped by Zone.

Figure 29. Taxon accumulation curves for mist netting.

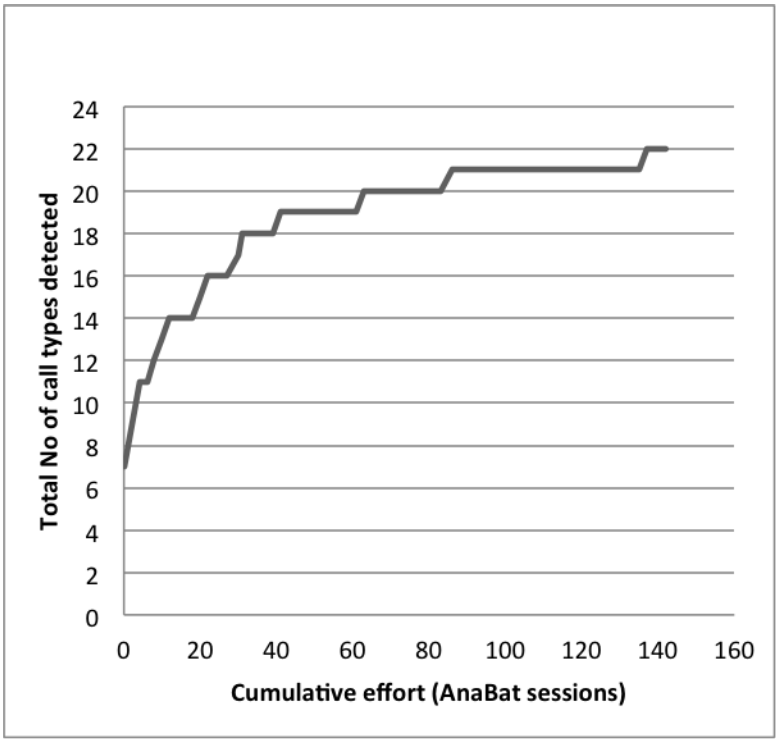


A. Harp trapping with all sites combined.

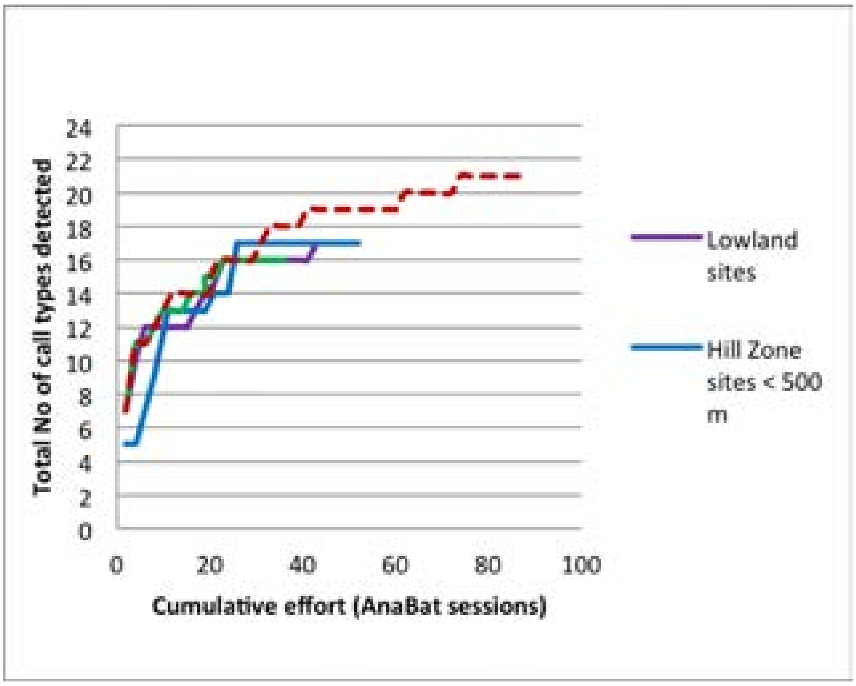


B. Harp trapping with sites grouped by Zone

Figure 30. Taxon accumulation curves for harp trapping.

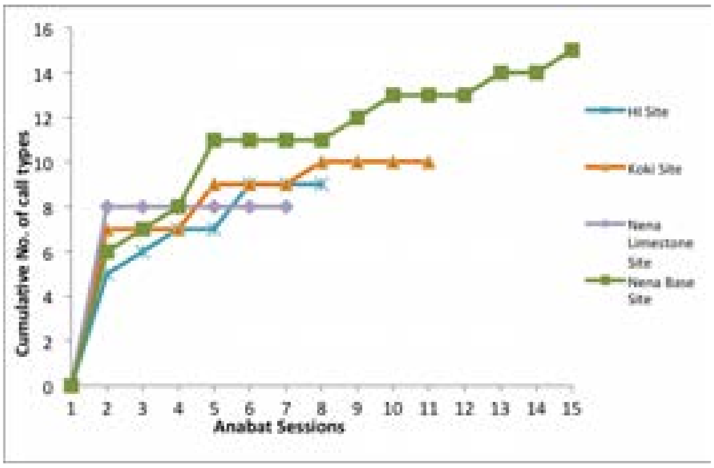


A. Call type accumulation curves with all sites combined.

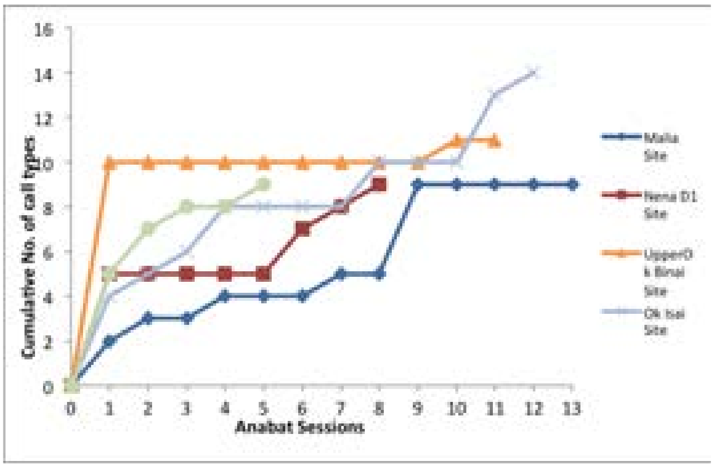


B. Call type accumulation curves with sites grouped by Zone.

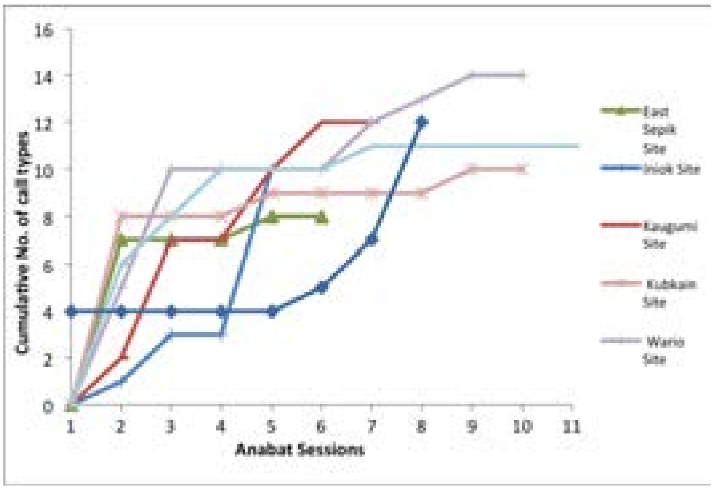
Figure 31. Call type accumulation curves for AnaBat passive recording sessions.



A. Call type accumulation curves for all Lowland Zone Sites.

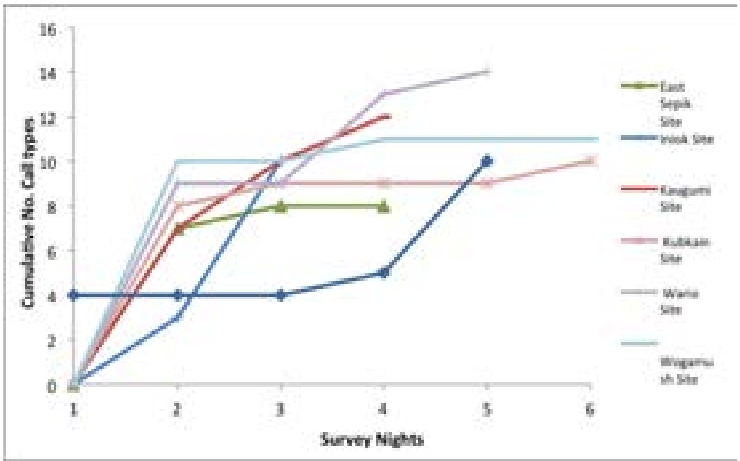


B. Call type accumulation curves for Hill Zone Sites < 500 m.

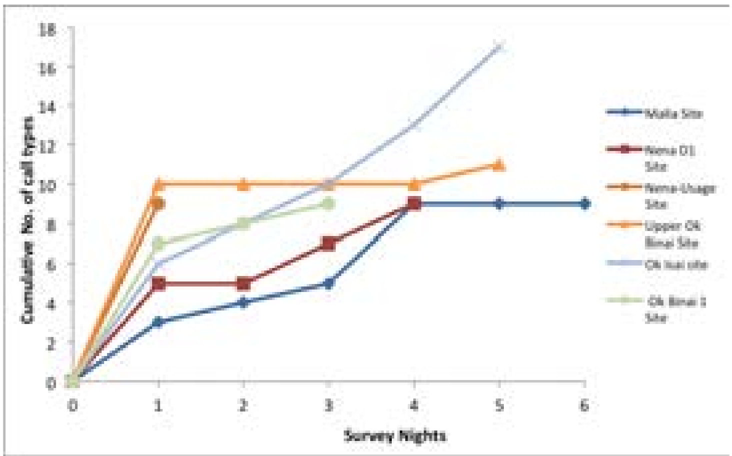


C. Call type accumulation curves for Hill Zone Sites > 500 m.

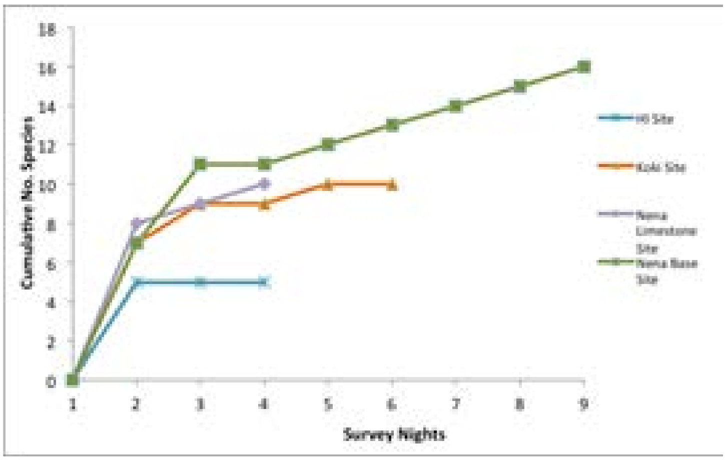
Figure 32. Call type accumulation curves for three elevation zones in the Study Area, based on cumulative number of AnaBat passive recording sessions.



A. Call type accumulation curves for all Lowland Zone Sites.

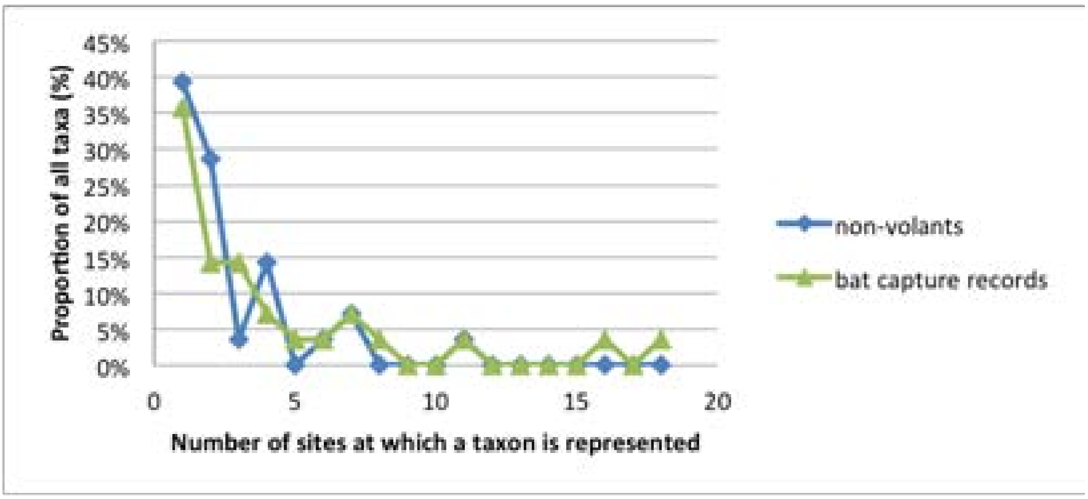


B. Call type accumulation curves for Hill Zone Sites < 500 m.

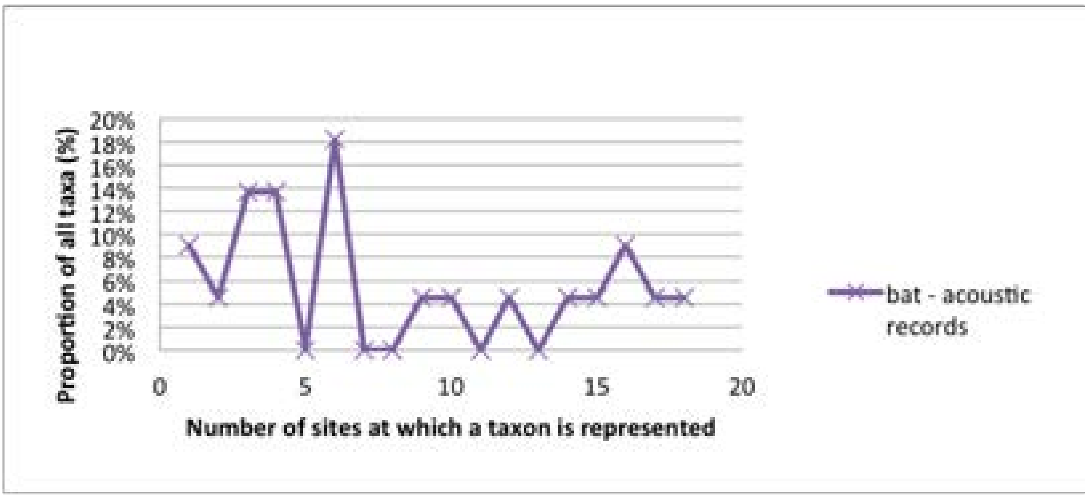


C. Call type accumulation curves for Hill Zone Sites > 500 m.

Figure 33. Call type accumulation curves for three elevation zones in the Study Area, based on cumulative number of AnaBat recording nights.



A. Canonical distribution for non-volant mammals and bat capture records (primarily pteropodid bats).



B. Canonical distribution for insectivorous bats based on acoustic passive recording sessions.

Figure 34. Canonical distribution plots of the major groups of mammals in the Study Area, based on contrasting survey methods.

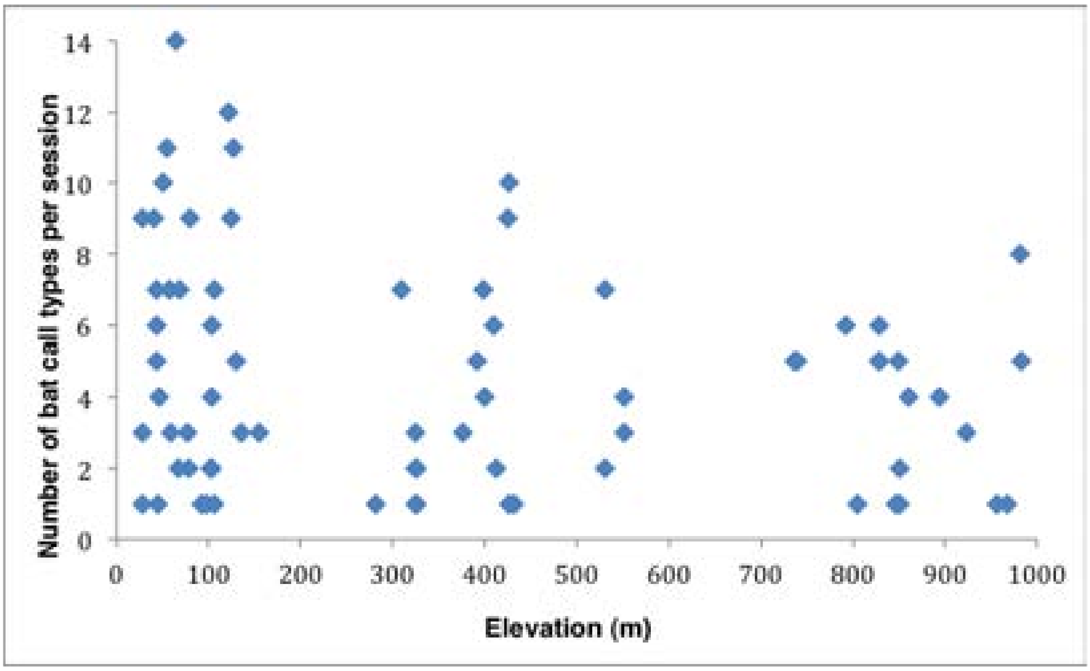
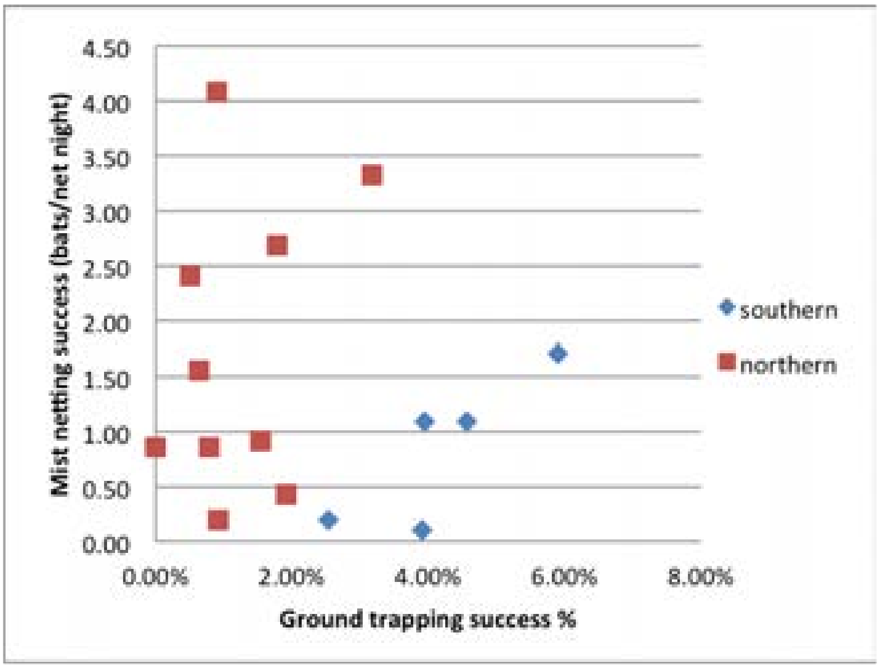
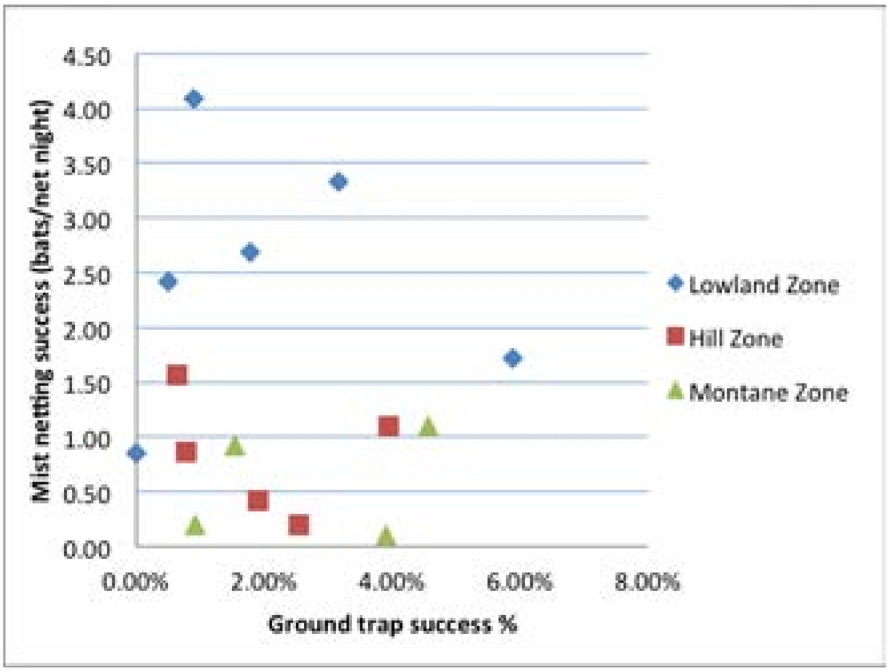


Figure 35. Variation in richness of bat call types along the elevational gradient in the Study Area. Richness values for individual AnaBat sessions are plotted against the elevation at which the recording was made.



A. Data points labelled to differentiate those from north *vs* south of the Central Cordillera of PNG.



B. Data points labelled to differentiate those pertaining to major elevation zones, irrespective or where they come from in PNG.

Figure 36. Comparison of capture rate data for ground trapping and mist netting, using data from four regional study sites in PNG. The dataset includes sites both north and south of the Central Cordillera and from Lowland, Hill and Montane Zone habitats.

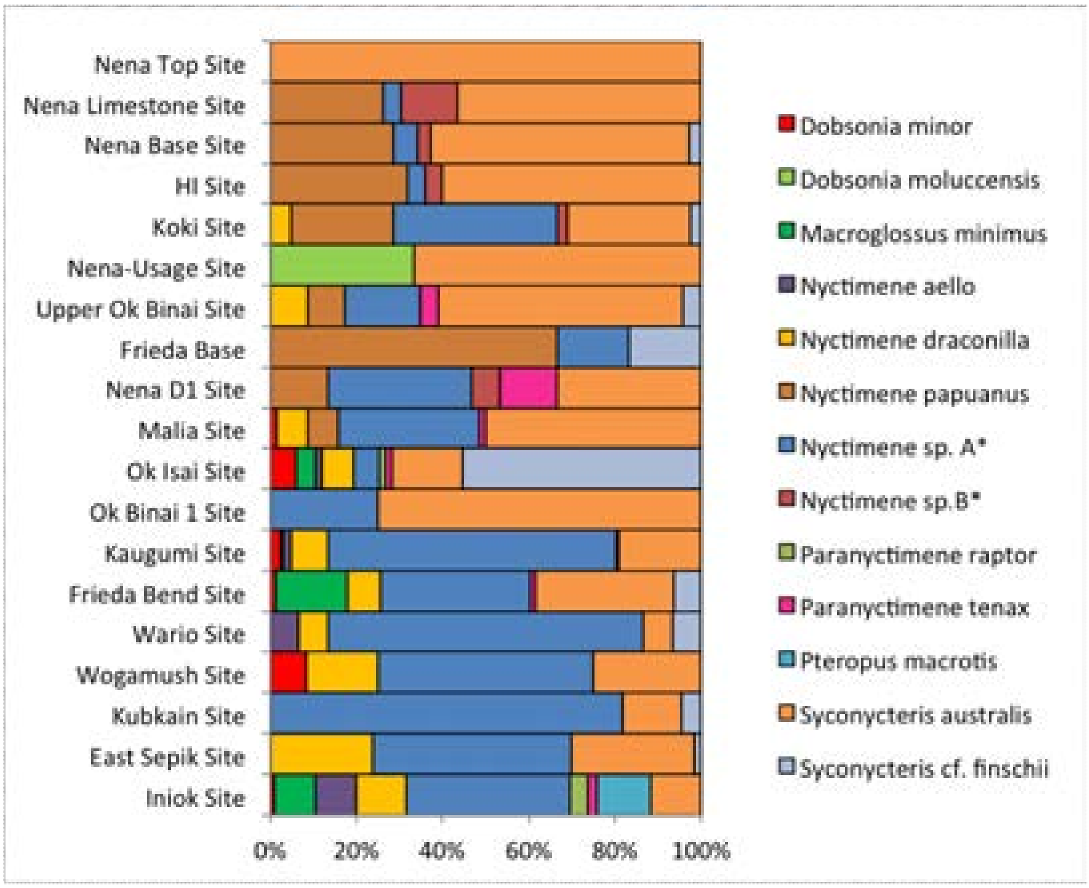


Figure 37. Variation in relative abundance of different species of pteropodid according to elevation in the Study Area.

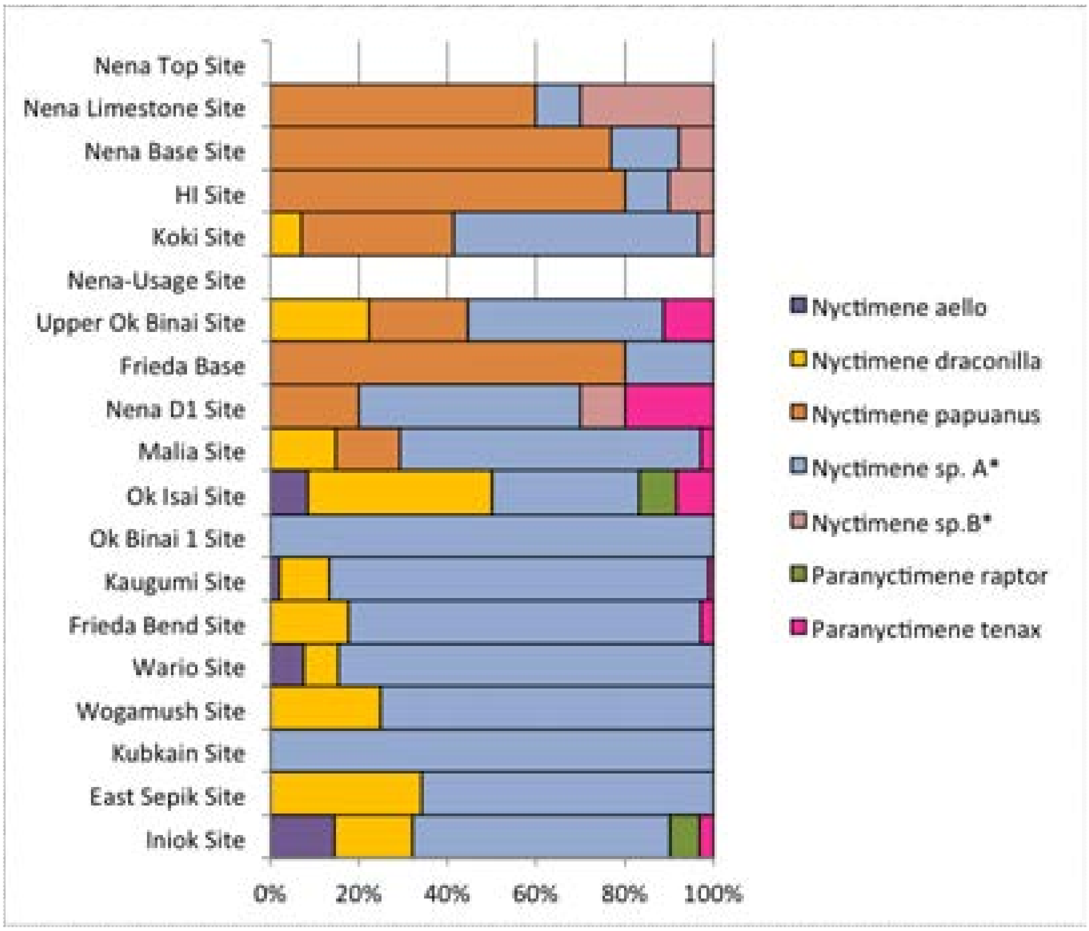
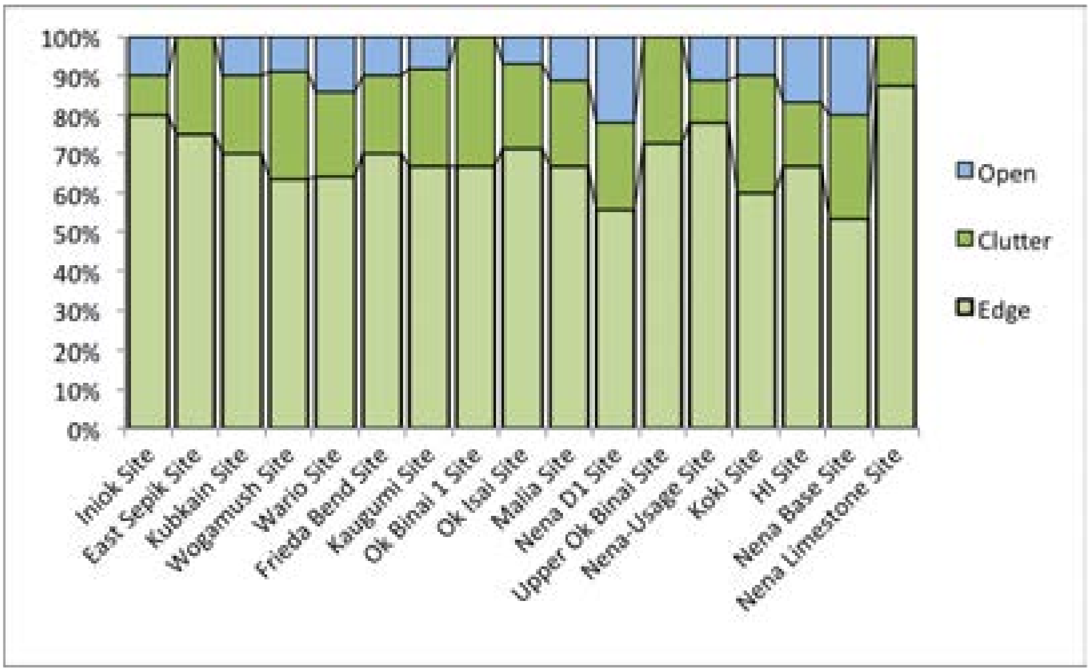
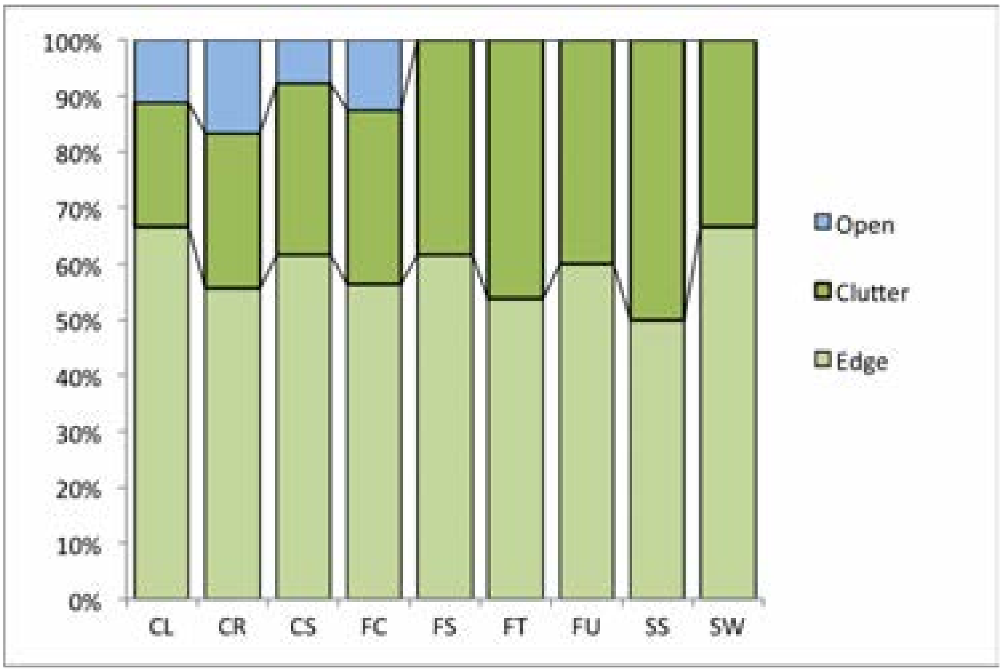


Figure 38. Variation in the relative abundance of different species of tube-nosed fruit bats to elevation in the Study Area.



A. Proportion of functional foraging group representation in each survey site.



B. Proportion of functional foraging group representation in each survey habitat.

Habitat codes: CL—Large Clearing; CR—Clearing on River; CS—Small Clearing; FC—Forest Canopy; FS—Fast Stream in Forest; FT—Forest Track; FU—Forest Understorey; SS—Slow Stream in Forest; SW—Swamp.

Figure 39. Microchiropteran bat community composition in the Study Area.

APPENDICES

Appendix 3.1. Camera trap locations and effort at each survey site.

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
Trip 1								
Nena Base Site	1	580151	9485812	890	30 Nov 09, 08h30	14 Dec 09, 13h30	341.00	Rainforest (RF) slope.
	2	579757	9485848	1,000	30 Nov 09, 12h45	14 Dec 09, 12h45	336.00	RF slope.
	3	579880	9485875	963	30 Nov 09, 13h15	14 Dec 09, 12h45	335.50	RF slope.
	4	579859	9485859	961	30 Nov 09, 13h30	14 Dec 09, 12h45	335.25	Small RF terrace on slope near stream.
	5	580053	9485849	934	1 Dec 09, 13h00	5 Dec 09, 9h00	92.00	RF.
	6	580029	9485964	930	1 Dec 09, 14h00	5 Dec 09, 9h30	91.50	Fallen fruits with rodent gnawing on trail.
	7	580044	9485957	929	1 Dec 09, 14h30	5 Dec 09, 9h45	91.25	Fallen *Garcinia* fruits with rodent gnawing.
Nena D1 Site	1	582197	9487044	440	5 Dec 09, 14h00	9 Dec 09, 9h00	91.00	Alongside rockshelter.
	2	582203	9487015	439	5 Dec 09, 14h00	9 Dec 09, 9h00	91.00	Into small cave below rockshelter.
Nena Limestone Site	1	575424	9486617	957	9 Dec 09, 10h15	12 Dec 09, 9h30	71.25	Log high acoss fast stream
	2	575404	9486442	981	10 Dec 09, 15h45	12 Dec 09, 10h30	42.75	Undulating RF valley, on small slope at foot of limestone wall. Closed 18–25 m canopy, open understorey.
	3	575420	9486402	984	10 Dec 09, 16h00	12 Dec 09, 10h30	42.50	Same as no. 1, but on small alluvial terrace.
Nena-Usage Site	1	576410	9489151	388	13 Dec 09, 13h30	14 Dec 09, 9h00	19.50	Streamside burrow.
	2	576347	9489124	403	13 Dec 09, 14h30	14 Dec 09, 9h00	18.50	Fallen figs.
	3	576430	9489183	399	13 Dec 09, 17h00	14 Dec 09, 10h00	17.00	High log crossing valley.
Trip 2								
Malia Site	1	588426	9486688	365	17 Oct 09 09 2009, 10h00	Nov-Dec 09[2]	750+	RF on low ridge.
	2	588312	9486744	383	17 Oct 09 2009, 10h30	Nov-Dec 09[2]	750+	RF on low ridge.
	3	588657	9485830	317	3 Feb 10, 10h20	4 Feb 10, 12h05	25.75	Small stature RF on flat terrain, 15-20 m canopy, sparse canopy, dense understorey.
	4	588513	9485967	309	3 Feb 10, 11h00	4 Feb 10, 14h00	27.00	Same as previous.
	5	588374	9486548	355	5 Feb 10, 08h45	7 Feb 10, 14h30	53.75	15 m small stature RF, 20-25 m emergents, on alluvial terrace adjacent to small stream.
	6,7	588760	9485268	264	3 Feb 10, 12h20	7 Feb 10, 12h20	192.00	Small stature RF next to small stream, edge of peneplain forest before steep descent to Nena River.
	8	588530	9485903	313	4 Feb 10, 12h35	8 Feb 10, 08h35	92.00	Steep forested slope between ridge and stream terrace.
	9	588406	9485900	329	4 Feb 10, 13h30	8 Feb 10, 07h45	90.25	RF on low ridge, 15-25 m canopy.

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
	10	588288	9486326	352	3 Feb 10, 09h45	8 Feb 10, 11h00	121.25	Shallow ephemeral pool on forested ridge
	11	588371	9486223	340	3 Feb 10, 10h00	28 Feb 10, 15h00	605.00	Shallow ephemeral pool on forested ridge
Koki Site	1,2	585586	9482678	537	9 Feb 10, 10h00	12 Feb 10, 11h15	146.50	18-25 m canopy shallow gully RF next to small stream.
	3	585792	9482663	552	9 Feb 10, 11h20	12 Feb 10, 10h50	71.50	20-25(30) m canopy RF on broad ridge; fairly dense ground layer.
	4	585760	9482602	556	9 Feb 10, 12h00	12 Feb 10, 10h30	70.50	Same as previous.
	5	585011	9482496	596	9 Feb 10, 17h15	12 Feb 10, 08h45	63.50	15-20 m small crowned mossy forest with ferns and dense leaf litter.
	6	584977	9482508	596	9 Feb 10, 17h40	12 Feb 10, 08h55	63.25	Same as previous.
	7	585024	9482525	587	9 Feb 10, 18h00	12 Feb 10, 09h00	63.00	Same as previous.
	8	585784	9482492	568	10 Feb 10, 10h35	12 Feb 10, 10h20	47.75	20 m canopy with 25-30 m emergents on gully ledge next to stream; fruit and animal sign about.
HI Site	1,2	583408	9481080	963	14 Feb 10, 15h00	18 Feb 10, 07h45	177.50	RF on broad,sloping ridge with palm and fern understorey, 8-15 m canopy, 20-30 m emergents.
	3	583291	9481157	1,003	15 Feb 10, 16h50	18 Feb 10, 07h20	62.50	Same as previous.
	4	583372	9481032	909	14 Feb 10, 10h00	17 Feb 10, 10h30	72.50	Floor of shallow cave under large rock
	5	582800	9481365	1289	15 Feb 10, 15h00	17 Feb 10, 12h00	45.00	Small-stature, montane cliff-top vegetation.
	6	583371	9481085	917	14 Feb 10, 10h30	17 Feb 10, 10h15	71.75	Slope below shallow cave
Upper Ok Binai Site	1,2	587210	9477733	382	19 Feb 10, 10h45	23 Feb 10, 07h30	185.50	RF on slope, 8-15 m canopy, 20-25 m emergents.
	3	587218	9477667	405	19 Feb 10, 11h15	23 Feb 10, 07h15	92.00	Same as previous.
	4,5	587342	9477368	464	19 Feb 10, 15h25	23 Feb 10, 08h25	178.00	Level shelf in Hill Forest, 15-20 m canopy, 25-30 m emergents.
	6	587346	9477345	470	19 Feb 10, 17h15	23 Feb 10, 08h30	87.25	Same as previous.
	7	587521	9477298	464	21 Feb 10, 15h45	23 Feb 10, 08h15	40.50	Hole under small rock ledge on RF slope, ~10 m from fast flowing, steep forest stream.
Frieda Bend Site	1,2	602139	9485670	97	24 Feb 10, 08h45	28 Feb 10, 08h15	191.00	25 m canopy, level RF with open understorey, soak depressions and trees with aerial root structures (wet floor adaptations).
	3	602180	9485699	100	24 Feb 10, 09h00	28 Feb 10, 08h15	95.25	Same as previous, though drier ground & associated vegetation.
	4,5	601764	9485767	116	24 Feb 10, 10h30	28 Feb 10, 07h45	93.25	10-15 m canopy RF, 20-25 m emergents, open understorey, level ground.
	6	601803	9485726	116	24 Feb 10, 12h30	28 Feb 10, 07h45	91.25	Same as previous.
	7	602348	9485785	97	24 Feb 10, 17h45	27Feb 10, 15h15	69.50	Lowland peneplain RF, wet soils, 8-15 m canopy, 20+ m emergents, fairly open understorey. Cassowary sign & baited with fruit.
Trip 3								

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
Ok Isai Site	1,2	602503	9479335	113	27 May 10, 09h30	1 Jun 10, 07h15	235.50	Disturbed swamp forest, 15 m canopy, 25-30 m emergents, dense understorey with lianes and rattan, stream and pools on wet mud.
	3,4,5	602539	9479358	120	27 May, 10h00	31 May, 11h15	291.75	Same as previous, but no adjacent stream.
	6,7	602558	9479314	117	28 May, 09h30	1 Jun 10, 07h15	187.50	Same as previous.
	8,9	602493	9478978	125	28 May, 15h15	1 Jun 10, 07h45	177.00	Small statured footHill Forest, 10-15 m canpoy, 20-25 m emergents.
Kaugumi Site	1	606417	9497393	70	1 Jun 10, 14h30	6 Jun 10, 14h30	120.00	Swamp forest with sago, 15-20 m canopy, shallow muds.
	2	606363	9497323	65	1 Jun 10, 15h00	6 Jun 10, 14h30	119.50	Same as previous.
	3	606315	9497303	66	1 Jun 10, 15h15	6 Jun 10, 14h45	119.50	Same as previous.
	4	606511	9497254	69	2 Jun 10, 10h15	5 Jun 10, 08h45	70.50	Same as previous.
	5,6	606475	9497270	78	2 Jun 10, 11h00	6 Jun 10, 12h00	194.00	Same as previous.
	7,8	606519	9497320	65	2 Jun 10, 15h15	5 Jun 10, 08h45	131.00	Same as previous.
	9,10	606490	9497192	75	2 Jun 10, 16h15	6 Jun 10, 12h00	183.50	Same as previous.
	11	606202	9496995	69	5 Jun 10, 11h00	6 Jun 10, 11h15	24.25	Small statured Sago swamp forest.
	12	606363	9497135	71	5 Jun 10, 10h15	6 Jun 10, 11h00	24.75	Stream crossing in swamp forest.
East Sepik Site	1,2	616550	9513107	63	8 Jun 10, 11h45	11 Jun 10, 16h30	153.50	Peat forest.
	3	616330	9513188	61	8 Jun 10, 12h00	11 Jun 10, 16h00	76.00	Peat forest.
	4	616253	9513176	61	8 Jun 10, 12h15	11 Jun 10, 15h45	75.50	Peat forest.
	5,6	615719	9513007	56	8 Jun 10, 15h30	12 Jun 10, 13h00	187.00	Peat forest.
	6	616684	9513178	58	9 Jun 10, 10h00	11 Jun 10, 17h00	55.00	Peat forest.
	7,8	615700	9513121	55	9 Jun 10, 17h15	12 Jun 10, 14h30	138.50	Peat forest.
Iniok Site	1	613734	9526152	41	14 Jun 10, 13h00	17 Jun 10, 16h00	75.00	Disturbed riparian forest, near scrubfowl mound.
	2	613841	9526133	41	14 Jun 10, 13h15	17 Jun 10, 16h00	74.75	Disturbed riparian forest.
	3	613843	9526154	44	14 Jun 10, 13h30	17 Jun 10, 16h00	74.50	Disturbed riparian forest, near scrubfowl mound.
Trip 4								
Wario Site	1	626182	9499604	120	24 Feb 11,16h15	27 Feb 11, 11h15	67.00	Small statured (15 m canopy) ridge forest amid taller (35 m+) slope and gully forest.
	2	626167	9499590	116	24 Feb 11,16h20	27 Feb 11, 11h20	67.00	Forest, 30 m canopy, on small terrace on foothill slope.
	3	625792	9499230	52 (SR)	24 Feb 11, 15h30	27 Feb 11, 18h30	75.00	Riparian forest on alluvial flats.
	4,5	625882	9499404	59	25 Feb 11, 09h45	27 Feb 11, 14h30	105.50	Next to stream winding through riparian forest on alluvial flats.
	6	625735	9499264	56	25 Feb 11, 15h15	27 Feb 11, 18h45	51.50	Riparian forest on alluvial flats.

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
	7	625666	9499261	56	25 Feb 11, 15h30	27 Feb 11, 19h00	51.50	Riparian forest on alluvial flats.
Wogamush Site	1	643372	9512475	56	1 Mar 11, 10h30	4 Mar 11, 15h45	77.25	FootHill Forest.
	2	643351	9512448	65	1 Mar 11, 10h45	4 Mar 11, 15h45	77.00	FootHill Forest.
	3	643376	9512342	75	1 Mar 11, 11h15	4 Mar 11, 16h00	76.75	FootHill Forest.
	4	643496	9512251	81	1 Mar 11, 11h45	4 Mar 11, 16h15	76.50	FootHill Forest.
	5	643548	9512377	58	1 Mar 11, 12h10	4 Mar 11, 15h10	75.00	FootHill Forest.
	6	643540	9512403	58	1 Mar 11, 12h15	4 Mar 11, 15h15	75.00	FootHill Forest.
	7	643607	9512332	46	1 Mar 11, 13h00	4 Mar 11, 15h15	74.25	Sago swamp forest.
	8	643584	9512372	50	1 Mar 11, 13h15	4 Mar 11, 15h30	74.25	FootHill Forest.
Kubkain Site	1	648033	9521818	56	6 Mar 11, 14h00	9 Mar 11, 15h30	73.50	FootHill Forest.
	2	648061	9521827	64	6 Mar 11, 14h15	9 Mar 11, 15h30	73.25	FootHill Forest.
	3	648050	9521860	66	6 Mar 11, 14h15	9 Mar 11, 15h30	73.25	FootHill Forest.
	4	648223	9521785	54	6 Mar 11, 14h45	9 Mar 11, 15h45	73.00	FootHill Forest.
	5	648246	9521760	52	6 Mar 11, 15h00	9 Mar 11, 15h45	72.75	FootHill Forest.
	6	648300	9521823	63	6 Mar 11, 15h15	9 Mar 11, 16h15	73.00	FootHill Forest.
	7	648263	9521864	67	6 Mar 11, 15h45	9 Mar 11, 16h15	72.50	FootHill Forest.
Ok Binai 1 Site	1	593014	9480601	166	11 Mar 11, 14h00	14 Mar 11, 15h00	73.00	Hill Forest.
	2	593066	9480532	166	11 Mar 11, 14h15	14 Mar 11, 15h15	73.00	Hill Forest.
	3	593078	9480515	165	11 Mar 11, 14h30	14 Mar 11, 15h30	73.00	Hill Forest.
	4	593866	9480127	156	11 Mar 11, 16h30	14 Mar 11, 12h45	68.25	Hill Forest.
	5	593869	9480090	148	11 Mar 11, 16h45	14 Mar 11, 12h30	67.75	Hill Forest.
	6	593936	9480097	154	11 Mar 11, 17h00	14 Mar 11, 13h00	68.00	Hill Forest.
	7	593991	9480135	158	11 Mar 11, 17h15	14 Mar 11, 13h15	68.00	Hill Forest.
Total							11,616.00+	

[1] Unless otherwise stated, all dates for Trips 1–3 are for the year 2010, and for Trip 4 are for 2011.

[2] Camera-traps set at Malia Site in October 2009 ran continually until batteries expired. Total hours estimated from average camera life of one month. The few images obtained from these cameras do not add any new records for the survey or the site and are excluded from all quantitative analyses of survey results.

Appendix 3.2. Mist-netting location and effort at each survey site.

	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
Trip1									
Nena Base Site	1	9	580153	9485696	871	122.375	1101.375	10	Early stage secondary forest (3–5 m) next to stream.
	2	12	580163	9485714	873	122	1464	10	Early stage secondary forest (3–5 m) and scrub near stream.
	3	9	580137	9485765	892	105.125	946.125	8	Primary rainforest (RF) with numerous saplings and ferns on flat terrace.
	4	9	580079	9485767	892	104.625	941.625	8	Primary RF along low ridge between stream and deeper valley of small river.
	5	12	580071	9485813	922	107.625	1291.5	9	Primary RF along ridge beside walking trail.
	6	6	580071	9485813	922	113.5	681	9	Perpendicular to net no. 5, across trail and end of ridge.
	7	12	580137	9485765	895	99.5	1194	8	Adjacent and parallel to net no. 3.
	8	6	580522	9485941	792	112.25	673.5	10	Across fast flowing stream.
	9	9	580441	9485752	805	112.25	1010.25	10	Across fast flowing stream, above cascade.
Nena D1 Site	1	9	582397	9486888	430	43.5	391.5	4	Primary RF (15–20 m), fairly dense understorey with numerous saplings.
	2	9	582464	9486814	416	33.625	302.625	3	Gallery forest (8–15 m) adjacent to river.
	3	12	582348	9486905	432	32.875	394.5	3	Same as net no. 1.
	4	15	582393	9486876	406	34	510	3	Break in slope, forest above stream.
	5	15	582346	9486920	410	33.875	508.125	3	Break in slope, forest above stream.
	6	12	582203	9487015	439	32.75	393	3	Along front of rockshelter.
Nena Limestone Site	1	12	575311	9486692	968	32.25	387	3	Primary RF on gentle slope, fairly open understorey with numerous small trees.
	2	9	575385	9486570	972	31.875	286.875	3	Primary RF ridge, dense understorey of climbing bamboo *Nastus productus.*
	3	12	575424	9486617	957	35.625	427.5	3	High, across wide, shallow stream.
	4	6	575328	9486592	967	9.25	55.5	1	Blocking cave mouth.
Nena-Usage Site	1	12	576477	9489124	407	8.5	102	1	Across stream.
	2	15	576482	9489118	403	9	135	1	In forest understorey.
Trip 2									
Malia Site	1	12	588580	9486318	328	72	864	6	Primary RF on flat terrain, 20-25 m canopy, dense ground cover of young saplings, dense mid-storey of young trees.

	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
	2	9	588608	9486323	327	72	648	6	Extension of net 1, adjacent to stream on lower terrace, more open ground layer.
	3	12	588624	9486204	315	71	852	6	Same as net 1.
	4	9	588624	9486204	315	71	639	6	Same as net 1.
	5	15	588405	9486358	338	69	1035	6	Mid-slope, dense understorey
	6	12	588419	9486345	325	68.5	822	6	Upper slope, moderate dense understorey
	7	15	588411	9486318	328	68	1020	6	Cross slope from net 6
	8	15	588409	9486376	330	67.5	1012.5	6	Alluvial bench beside stream, open understorey
	9	12	588461	9486313	325	67	804	6	Crossing small stream
	10	15	588409	9486312	340	60	900	5	Along small interfluve, relatively open understorey
	11	10	588361	9486339	346	59.5	595	5	Moderate dense understorey on ridge
	12	12	588535	9486127	327	59	708	5	Flat waterlogged area, relatively open understorey
	13	12	588484	9486206	326	58.5	702	5	Top of slope above ago swamp
	14	12	588469	9485915	330	36	432	3	Across shallow stream
	15	15	588469	9485915	330	35.5	532.5	3	Oblique crossing stream, near net 14
Koki Site	1	12	585273	9482603	560	57	684	5	Alongside fast narrow stream
	2	12	585254	9482606	566	56.75	681	5	Cross slope, dense understorey
	3	15	585238	9482582	569	56.5	847.5	5	Cross slope, dense understorey
	4	9	585212	9482568	566	50	450	4	Flat bench, open understorey
	5	12	585231	9482574	562	49.5	594	4	Mid-slope, dense understorey
	6	12	585535	9482755	507	49.5	594	4	Stream side, dense understorey
	7	15	585535	9482755	508	49	735	4	Lower slope
	8	12	585212	9482568	566	48.5	582	4	Upper slope
	9	12	585614	9482748	520	48.5	582	4	Lower slope
	10	15	585271	9482580	557	48	720	4	Upper slope
Frieda Base Site	1	12	586447	9480160	480	14	168	1	Small stature forest on limestone, dense understorey and ground layers, many ferns and lianes.
	2	12	586447	9480160	480	14	168	1	Same as net 1.
	3	12	586447	9480160	480	14	168	1	Same as net 1.
	4	6	586447	9480160	480	14	84	1	Same as net 1.

	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
HI Site	1	12	583518	9481113	872	36	432	3	dense understorey
	2	12	583536	9481092	862	35.75	429	3	dense understorey
	3	9	583608	9480943	832	35.5	319.5	3	open area beside path
	4	12	583628	9480895	824	35.25	423	3	across narrow valley
	5	12	583691	9480853	820	35	420	3	crossing small stream
	6	12	583473	9481218	881	34.75	417	3	beside track
	7	12	583473	9481218	881	34.5	414	3	ridge with Nastus bamboo
	8	12	583487	9481192	877	34.25	411	3	across dry stream in regrowth
	9	12	583498	9481147	871	34	408	3	shrubby regrowth beside track
	10	15	583498	9481120	871	33.75	506.25	3	parallel to small stream
Uriabe Site	1	15	582897	9481048	1375	8	120	1	sub-montane forest on ridge with stunted trees and dense coral fern ground layer
Upper Ok Binai Site	1	12	587183	9477437	399	48	576	4	dense understorey beside stream
	2	12	587184	9477437	399	47.75	573	4	dense understorey beside stream
	3	12	587223	9477438	452	47.5	570	4	mid-slope, dense understorey
	4	12	587211	9477398	468	47.25	567	4	top of steep slope
	5	12	587229	9477392	467	47	564	4	top of steep slope
	6	9	587242	9477401	465	36	324	3	top of steep slope
	7	12	587248	9477436	457	35.75	429	3	mid-slope, dense understorey
	8	12	587260	9477429	455	35.5	426	3	mid-slope, dense understorey
	9	12	587338	9477427	464	35.25	423	3	top of steep slope
	10	9	587327	9477419	467	35	315	3	top of steep slope
	11	12	587358	9477410	458	35	420	3	mid-slope, dense understorey
Frieda Bend Site	1	12	602410	9485849	76	36	432	3	swamp, open understorey
	2	15	602390	9485799	76	35.75	536.25	3	swamp, open understorey
	3	6	602379	9485751	78	35.5	213	3	beside swamp, dense scrub
	4	12	602355	9485698	74	35.25	423	3	crossing stream
	5	9	602223	9485665	82	47.5	427.5	4	Hill Forest
	6	9	602203	9485687	82	47.25	425.25	4	Hill Forest
	7	15	602200	9485667	81	47	705	4	Hill Forest

	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
	8	9	602193	9485697	82	46.75	420.75	4	beside stream, Hill Forest
	9	9	602173	9485708	83	46.5	418.5	4	Hill Forest
	10	15	602163	9485695	83	46.25	693.75	4	Hill Forest
	11	12	602141	9485757	88	46	552	4	Hill Forest
Trip 3									
Ok Isai Site	1	12	602551	9479475	118	47.5	570	4	swamp forest
	2	12	602565	9479479	109	47.25	567	4	swamp forest
	3	12	602552	9479520	109	47	564	4	across shallow stream
	4	12	602518	9479498	108	46.75	561	4	across shallow stream
	5	12	602565	9479351	112	46.5	558	4	swamp to Hill Forest transition
	6	6	602531	9479302	101	46.25	277.5	4	swamp forest
	7	6	602532	9479010	103	46	276	4	swamp to Hill Forest transition
	8	9	602532	9479010	103	45.75	411.75	4	swamp to Hill Forest transition
	9	9	602512	9479211	103	36	324	3	swamp to Hill Forest transition
	10	6	602512	9479211	103	35.75	214.5	3	swamp to Hill Forest transition
	11	12	602597	9478771	135	35.5	426	3	Hill Forest
	12	12	602672	9478776	144	35.25	423	2	crossing stream
	13	12	602672	9478776	144	35.25	423	2	alongside stream
	14	12	602672	9478776	144	35	420	2	crossing stream
	15	9	602644	9478852	122	35	315	2	Hill Forest above stream
Kaugumi Site	1	12	606392	9497578	60	47.5	570	4	swamp forest
	2	9	606356	9497562	58	47.25	425.25	4	swamp forest
	3	9	606368	9497525	58	47	423	4	swamp forest
	4	12	606370	9497495	58	46.75	561	4	swamp forest
	5	9	606354	9497438	54	46.5	418.5	4	swamp forest
	6	9	606343	9497397	55	46.25	416.25	4	swamp forest
	7	12	606461	9497476	75	46	552	4	edge of helipad clearing
	8	9	606463	9497515	78	45.75	411.75	4	hill top, open understorey
	9	9	606447	9497543	75	45.5	409.5	4	mid-slope, open understorey
	10	12	606459	9497547	73	45.25	543	4	mid-slope, open understorey

	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
	11	12	606480	9497543	76	45	540	4	mid-slope, open understorey
	12	12	606477	9497552	71	44.75	537	4	mid-slope, open understorey
Nena Top Site	1	12	579454	9485964	1064	23	276	2	tree fall clearing under Nothofagus
	2	6	579454	9485964	1064	23	138	2	aligned with net 1
	3	12	579463	9485997	1067	22.5	270	2	beside tree fall clearing under Nothofagus
	4	6	579500	9485843	1076	22	132	2	along track on ridge crest
	5	12	579500	9485843	1076	22	264	2	along track on ridge crest
	6	12	579390	9485846	1060	21.5	258	2	along track through swampy patch in forest
East Sepik Site	1	9	615327	9512489	45	35	315	3	Peat Forest, dense understorey
	2	15	615372	9512540	45	34.75	521.25	3	Peat Forest, dense understorey
	3	6	615384	9512611	45	34.5	207	3	Peat Forest, dense understorey
	4	9	615402	9512636	45	34.25	308.25	3	Peat Forest, dense understorey
	5	12	615494	9512692	45	34	408	3	Peat Forest, dense understorey
	6	6	615592	9512711	45	33.75	202.5	3	Peat Forest, dense understorey
	7	12	615942	9513033	44	35	420	3	Peat Forest, dense understorey
	8	12	615927	9513091	40	34.75	417	3	Peat Forest, dense understorey
	9	9	615880	9513097	42	34.5	310.5	3	Peat Forest, dense understorey
	10	9	615814	9513103	44	34.25	308.25	3	Peat Forest, dense understorey
	11	9	615758	9513125	44	34	306	3	Peat Forest, dense understorey
	12	12	615758	9513125	44	33.75	405	3	Peat Forest, dense understorey
	13	9	615694	9513122	45	33.5	301.5	3	Peat Forest, dense understorey
Iniok Site	1	24	613223	9526034	30	9	216	1	high above regrowth scrub
	2	15	613850	9526227	47	35	525	3	mature floodlplain forest, open understorey
	3	9	613850	9526227	47	34.75	312.75	3	mature floodlplain forest, open understorey
	4	6	613692	9526092	47	34.5	207	3	early stage regrowth forest, dense pitpit understorey
	5	12	613692	9526092	47	34.25	411	3	early stage regrowth forest, dense pitpit understorey
	6	9	613426	9525935	43	34	306	3	early stage regrowth forest, dense pitpit understorey
	7	12	613426	9525935	43	33.75	405	3	early stage regrowth forest, dense pitpit understorey
	8	15	613201	9525938	34	33.5	502.5	2	camp clearing
	9	15	613201	9525938	34	33.25	498.75	2	camp clearing

	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
Trip 4									
Wario Site	1	9	625792	9499230	52	12.6875	114.1875	4	Riparian forest on alluvial flats alongside Wario River.
	2	12	625792	9499230	52	9.8125	117.75	4	Riparian forest on alluvial flats alongside Wario River.
	3	12	625735	9499264	56	9.625	115.5	4	Riparian forest on alluvial flats alongside Wario River.
	4	9	625735	9499264	56	10.125	91.125	4	Riparian forest on alluvial flats alongside Wario River.
	5	12	625666	9499261	56	7.25	87	4	Riparian forest on alluvial flats alongside Wario River.
	6	12	625666	9499261	56	7.125	85.5	4	Riparian forest on alluvial flats alongside Wario River.
Wogamush Site	1	12	643607	9512332	46	6	72	3	Swamp forest.
	2	12	643372	9512475	56	6	72	3	Hill forest.
Kubkain Site	1	12	648246	9521760	52	6	72	3	Swamp forest.
	2	12	648061	9521827	64	6	72	3	Hill forest.
Ok Binai 1 Site	1	12	593645	9480197	120	6	72	3	Hill forest at camp.
	2	12	593645	9480197	120	6	72	3	Hill forest at camp.
Survey Totals						6,245.50	68,887.56	562	

Appendix 3.3. Harp trap location and effort at each survey site

SITE	HARP TRAP NO	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIMING		NIGHTS OPEN	HABITAT AND POSITIONING
		EASTING	NORTHING		SET UP	TAKEN DOWN		
Nena Base Site	1	580153	9485696	871	1/12/2009	6/12/2009	5	Across narrow Upland Low Gradient Stream emerging from Lightly disturbed Hill Forest into clearing
Nena Base Site	2	580441	9485752	805	1/12/2009	6/12/2009	5	Across path overlooking wide Upland Torrential Stream, Lightly disturbed Hill Forest.
Nena D1 Site	3	582397	9486888	430	6/12/2009	10/12/2009	4	Beside large boulder in Early successional Hill Forest in clearing.
Nena Limestone Site	4	575328	9486592	967	10/12/2009	12/12/2009	2	Across narrow Upland Low Gradient Stream flowing over benched rocky surface, Mature Hill Forest.
Nena-Usage Site	5	576477	9489124	407	13/12/2009	14/12/2009	1	Across shallow Lowland Low Gradient Stream in steep-sided gully with overhanging vegetation, Mature Hill Forest.
Malia Site	6	588409	9486376	330	5/02/2010	8/02/2010	3	Across narrow Lowland Low Gradient Stream in Mature Hill Forest.
Malia Site	7	588409	9486376	330	5/02/2010	8/02/2010	3	Across narrow Lowland Low Gradient Stream in Mature Hill Forest.
Koki Site	8	585273	9482603	560	9/02/2010	13/02/2010	4	Across narrow Upland Low Gradient Stream, in Mature Hill Forest.
HI Site	9	583557	9480843	835	14/02/2010	16/02/2010	2	Tree-fall clearing to Mature Hill Forest beside camp clearing.
HI Site	10	583536	9481092	862	15/02/2010	18/02/2010	3	Across narrow Upland Low Gradient Stream flowing over benched rocky surface, Mature Hill Forest.
HI Site	11	588624	9486204	315	16/02/2010	18/02/2010	2	Across narrow Upland Low Gradient Stream in steep-sided gully with overhanging vegetation, Mature Hill Forest.
Upper Ok Binai Site	12	587358	9477410	458	18/02/2010	23/02/2010	5	Across narrow Lowland Low Gradient Stream in steep-sided gully with overhanging vegetation, Mature Hill Forest.
Upper Ok Binai Site	13	587184	9477437	399	19/02/2010	23/02/2010	4	Small, shallow Lowland Low Gradient Stream in narrow gully, Mature Hill Forest.
Frieda Bend Site	14	602379	9485751	78	23/02/2010	28/02/2010	5	Small, shallow Lowland Low Gradient Stream in broad gully, Mature Hill Forest .
Frieda Bend Site	15	602364	9485624	80	23/02/2010	28/02/2010	5	Track in Heavily disturbed Hill Forest near camp.
Ok Isai Site	16	602552	9479520	109	26/05/2010	30/05/2010	4	Shallow Lowland Low Gradient Stream in narrow gully, Mature Hill Forest.
Ok Isai Site	17	602552	9479520	109	26/05/2010	30/05/2010	4	Shallow Lowland Low Gradient Stream in narrow gully, Mature Hill Forest.
Ok Isai Site	18	602672	9478776	144	30/05/2010	1/06/2010	2	Across shallow Lowland Low Gradient Stream, Mature Hill Forest.
Ok Isai Site	19	602672	9478776	144	30/05/2010	1/06/2010	2	Across shallow Lowland Low Gradient Stream, Mature Hill Forest.
Kaugumi Site	20	606472	9497488	90	4/06/2010	6/06/2010	2	Suspended 7m in canopy on edge of helipad clearing, Mature Hill Forest.
Kaugumi Site	21	606477	9497552	71	5/06/2010	6/06/2010	1	On track through Mature Hill Forest, at base of hill.
East Sepik Site	22	615978	9512957	45	9/06/2010	13/06/2010	4	Opening in Peat Forest at edge of helipad.
East Sepik Site	23	615978	9512957	45	10/06/2010	13/06/2010	3	Opening in Peat Forest at edge of helipad.

SITE	HARP TRAP NO	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIMING		NIGHTS OPEN	HABITAT AND POSITIONING
		EASTING	NORTHING		SET UP	TAKEN DOWN		
Iniok Site	24	613850	9526227	47	15/06/2010	19/06/2010	4	Mature Swampy Forest, open understorey
Iniok Site	25	613426	9525935	43	15/06/2010	19/06/2010	4	Early successional Swampy Forest, dense pit-pit understorey
Total							83	

Appendix 3.4. AnaBat passive recording sessions: location, date and habitat recorded.

SITE	ANABAT SESSION #	POSITION (PNG MG94 ZONE 54)		DATE OF EVENING SETUP	ELEVATION M (ELEVATION)	HABITAT CODE	LOCATION
		EASTING	NORTHING				
Nena Base Site	AN01	9485702	580352	29/11/2009	828	CR	Overlooking stream beside Nena Camp
Nena Base Site	AN02	9485703	580336	29/11/2009	829	CR	Overlooking stream beside Nena Camp
Nena Base Site	AN03	9485942	580523	30/11/2009	792	SF	Overlooking stream cascade, lower stream
Nena Base Site	AN04	9485752	580441	30/11/2009	805	SF	Path overlooking stream, below cascade
Nena Base Site	AN05	9485668	580168	1/12/2009	851	SF	On bridge, looking downstream into densely vegetated narrow stream
Nena Base Site	AN06	9485705	580158	1/12/2009	861	CS	Looking into garden clearing, surrounded by forest
Nena Base Site	AN07	9485941	580470	2/12/2009	740	FC	Overlooking forested valley, lower track
Nena Base Site	AN08	9485872	580496	2/12/2009	737	FT	Along forested track into clearing
Nena Base Site	AN09	9485828	580074	3/12/2009	927	FC	Hill track, looking down into lower canopy
Nena Base Site	AN10	9485766	580126	3/12/2009	894	FC	Hill track, looking down into lower canopy
Nena Base Site	AN11	9485690	580409	4/12/2009	811	CL	On track below camp, overlooking regrowth
Nena Base Site	AN12	9485693	580122	4/12/2009	874	FC	Hill track, looking down into lower canopy
Nena D1 Site	AN13	9486774	582454	5/12/2009	391	FC	On helipad, overlooking densely vegetated confluence of streams
Nena D1 Site	AN14	9486862	582421	5/12/2009	407	SF	In forest, above stream
Nena D1 Site	AN15	9487045	582197	6/12/2009	440	CS	Overlooking rockshelter and regrowth in clearing
Nena D1 Site	AN16	9487016	582203	6/12/2009	439	SF	Overlooking small stream in forest
Nena D1 Site	AN17	9487104	582126	7/12/2009	450	FC	Low hill overlooking forest in valley
Nena D1 Site	AN18	9487110	582123	7/12/2009	437	FU	In narrow forested valley
Nena Limestone Site	AN19	9486772	582449	8/12/2009	376	FC	On helipad, overlooking smaller of two streams
Nena Limestone Site	AN20	9486840	582479	8/12/2009	400	FC	Looking over larger stream to NE of helipad
Nena Limestone Site	AN21	9486657	575335	9/12/2009	983	FC	On helipad, facing NE over forest
Nena Limestone Site	AN22	9486657	575315	9/12/2009	981	FC	On helipad, facing SW over forest
Nena Limestone Site	AN23	9486637	575395	10/12/2009	959	FC	Overlooking forest, alongside stream
Nena Limestone Site	AN24	9486617	575466	10/12/2009	957	FS	Looking downstream
Nena Limestone Site	AN25	9486592	575329	11/12/2009	967	FS	Overlooking small cave complex and stream
Nena Limestone Site	AN26	9486410	575426	11/12/2009	997	FU	Under forest canopy, flat area near low cliffs
Nena-Usage Site	AN27	9489146	576445	13/12/2009	409	SF	Under forest canopy, facing down small stream

SITE	ANABAT SESSION #	POSITION (PNG MG94 ZONE 54)		DATE OF EVENING SETUP	ELEVATION M (ELEVATION)	HABITAT CODE	LOCATION
		EASTING	NORTHING				
Nena-Usage Site	AN28	9489125	576477	12/12/2009	407	SF	Above stream, looking upstream
Nena-Usage Site	AN29	9489182	576526	14/12/2009	398	CR	Looking upstream, mostly dry river bed, large boulders, 100m wide gap in canopy
Nena Base Site	AN30	9485702	580352	13/12/2009	828	CR	Overlooking valley beside Nena Camp
Nena Base Site	AN31	9485668	580168	13/12/2009	851	CL	Overlooking Nena Camp
Malia Site	AN32	9486313	588461	2/02/2010	325	FU	Forested small depression above creek
Malia Site	AN33	9486348	588434	2/02/2010	326	FU	Forest understorey above creek
Malia Site	AN34	9486313	588461	3/02/2010	325	FU	Forested small depression above creek
Malia Site	AN35	9486348	588434	3/02/2010	326	FU	Forest understorey above creek
Malia Site	AN36	9486139	588539	4/02/2010	327	FC	Tall forest with low open understorey
Malia Site	AN37	9485905	588517	4/02/2010	281	SW	Overlooking sago swamp
Malia Site	AN38	9485905	588517	5/02/2010	281	SW	Overlooking sago swamp
Malia Site	AN39	9486280	588505	5/02/2010	309	CL	Across helipad clearing
Malia Site	AN40	9485896	588502	6/02/2010	325	SS	Along shallow gravelly stream in forest
Malia Site	AN41	9485896	588502	7/02/2010	325	SS	Along shallow gravelly stream in forest
Malia Site	AN42	9485886	588536	7/02/2010	319	FC	Into canopy over forested stream
Koki Site	AN43	9482710	585414	8/02/2010	530	CR	Edge of helipad but looking into riparian forest
Koki Site	AN44	9482710	585414	8/02/2010	530	CL	Across helipad clearing
Koki Site	AN45	9482639	585267	9/02/2010	531	FT	Along track in forest
Koki Site	AN46	9482646	585287	9/02/2010	530	FU	Inside dense understorey
Koki Site	AN47	9482409	584936	10/02/2010	615	CS	Drill-pad clearing on ridge
Koki Site	AN48	9482490	585026	10/02/2010	596	FC	Slope above forested torrent
Koki Site	AN49	9482673	585750	11/02/2010	551	FT	Along survey transect cut in forest
Koki Site	AN50	9482719	585725	11/02/2010	539	CS	small clearing beside small stream
Koki Site	AN51	9482656	585328	12/02/2010	552	CS	Clearing behind camp
Koki Site	AN52	9482687	585340	12/02/2010	550	FT	Path leading to river
HI Site	AN53	9480829	583557	14/02/2010	849	CL	Beside helipad clearing
HI Site	AN54	9480866	583536	14/02/2010	860	CL	Overlooking camp clearing
HI Site	AN55	9480762	583550	15/02/2010	846	FC	Dense regrowth forest on ridge
HI Site	AN56	9480789	583542	15/02/2010	840	FU	Dense gully forest
HI Site	AN57	9481034	583349	16/02/2010	923	FC	Forest canopy on ridge
HI Site	AN58	9481271	583126	16/02/2010	1036	FC	Forest canopy on ridge
Upper Ok Binai Site	AN59	9477338	587143	18/02/2010	428	CR	Overlooking stream in clearing
Upper Ok Binai Site	AN60	9477389	587115	18/02/2010	427	CL	Across helipad clearing
Upper Ok Binai Site	AN61	9477313	587449	19/02/2010	450	SS	Forested stream in valley

SITE	ANABAT SESSION #	POSITION (PNG MG94 ZONE 54)		DATE OF EVENING SETUP	ELEVATION M (ELEVATION)	HABITAT CODE	LOCATION
		EASTING	NORTHING				
Upper Ok Binai Site	AN62	9477361	587408	19/02/2010	440	FU	Forest understorey away from stream
Upper Ok Binai Site	AN63	9477400	587244	20/02/2010	459	FU	Into forest understorey
Upper Ok Binai Site	AN64	9477478	587188	20/02/2010	426	CR	Overlooking stream in clearing
Upper Ok Binai Site	AN65	9477525	587318	21/02/2010	432	FC	Looking into forest along stream in valley
Upper Ok Binai Site	AN66	9477761	587033	21/02/2010	342	FC	Looking into forest along stream in valley
Upper Ok Binai Site	AN67	9477450	587096	22/02/2010	413	FC	Down steep forested slope
Upper Ok Binai Site	AN68	9477417	587114	22/02/2010	425	CL	Across helipad clearing
Frieda Bend Site	AN69	9485814	602043	23/02/2010	102	SS	Slow stream in small gully
Frieda Bend Site	AN70	9485762	602142	23/02/2010	103	FC	Forested slope above stream
Frieda Bend Site	AN71	9485755	602334	24/02/2010	84	SW	Swamp on river terrace
Frieda Bend Site	AN72	9485727	602309	24/02/2010	83	SS	Shallow stream in gully through river terrace
Frieda Bend Site	AN73	9485860	602184	25/02/2010	93	FS	Small stream in Hill Forest
Frieda Bend Site	AN74	9485729	602160	25/02/2010	98	FT	On track in Hill Forest
Frieda Bend Site	AN75	9485730	602387	26/02/2010	78	CS	Grassy clearing on river terrace
Frieda Bend Site	AN76	9485763	602403	26/02/2010	77	CS	Grassy clearing on river terrace
Frieda Bend Site	AN77	9485731	602385	27/02/2010	80	CR	*Pandanus* grove fringing river
Ok Isai Site	AN78	9479010	602532	27/05/2010	103	FU	forest understorey
Ok Isai Site	AN79	9479010	602532	27/05/2010	103	FS	small stream in forest
Ok Isai Site	AN80	9478855	602597	27/05/2010	135	CL	helipad clearing
Ok Isai Site	AN81	9479011	602599	28/05/2010	107	FU	forest understorey
Ok Isai Site	AN82	9479239	602551	28/05/2010	106	CS	small clearing, edge of swamp
Ok Isai Site	AN83	9479298	602518	28/05/2010	104	FS	small stream in forest
Ok Isai Site	AN84	9478771	602597	29/05/2010	185	FU	on hill, into dense understorey
Ok Isai Site	AN85	9478865	602605	29/05/2010	130	CL	helipad clearing
Ok Isai Site	AN86	9478802	602533	30/05/2010	155	FS	small stream in forest
Ok Isai Site	AN87	9478776	602672	30/05/2010	144	FS	small stream in forest
Ok Isai Site	AN88	9478835	602579	31/05/2010	127	CL	helipad clearing
Ok Isai Site	AN89	9478840	602622	31/05/2010	121	CL	camp clearing
Kaugumi Site	AN90	9497523	606448	1/06/2010	69	FT	wide track in Hill Forest, open understorey
Kaugumi Site	AN91	9497463	606466	1/06/2010	67	FC	into canopy, edge of helipad
Kaugumi Site	AN92	9497497	606591	3/06/2010	58	LC	large clearing beside stream
Kaugumi Site	AN93	9497448	606554	3/06/2010	59	FC	overlooking sago palm swamp
Kaugumi Site	AN94	9497585	606429	5/06/2010	41	CR	20 m wide river, incomplete canopy
Kaugumi Site	AN95	9497579	606373	5/06/2010	44	FT	track in swamp forest, dense understorey
East Sepik Site	AN96	9512964	616046	8/06/2010	46	FU	Peat Forest understorey
East Sepik Site	AN97	9512489	615327	8/06/2010	63	CL	helipad clearing
East Sepik Site	AN98	9512912	615970	9/06/2010	45	FU	Peat Forest understorey

SITE	ANABAT SESSION #	POSITION (PNG MG94 ZONE 54)		DATE OF EVENING SETUP	ELEVATION M (ELEVATION)	HABITAT CODE	LOCATION
		EASTING	NORTHING				
East Sepik Site	AN99	9512990	615967	9/06/2010	44	CL	helipad clearing
East Sepik Site	AN100	9512969	615986	12/06/2010	71	CL	helipad clearing
Iniok Site	AN102	9526092	613692	15/06/2010	47	FT	track in swamp forest, open understorey
Iniok Site	AN103	9526093	613691	15/06/2010	28	FT	track in swamp forest, pit-pit grass understorey
Iniok Site	AN104	9526092	613694	16/06/2010	28	CL	edge of camp clearing
Iniok Site	AN105	9526094	613692	16/06/2010	28	CL	edge of camp clearing
Wario Site	AN106	9499570	625865	24/02/2011	54	CL	edge of clearing
Wario Site	AN107	9499596	625875	24/02/2011	54	CR	clearing overlooking ravine
Wario Site	AN108	9499591	625903	24/02/2011	54	CS	small clearing in Swampy Forest
Wario Site	AN109	9499598	625928	24/02/2011	54	FU	forest understorey
Wario Site	AN110	9499598	625928	25/02/2011	54	FU	forest understorey
Wario Site	AN111	9499570	625865	26/02/2011	54	CL	edge of clearing
Wario Site	AN112	9499596	625875	26/02/2011	54	CR	clearing overlooking ravine
Wario Site	AN113	9499473	625959	26/02/2011	54	SS	narrow slow stream, full canopy
Wario Site	AN114	9499675	626066	27/02/2011	54	FT	narrow track along ridge top
Wogamush Site	AN115	9513062	643434	28/02/2011	54	CS	small clearing in swamp forest
Wogamush Site	AN116	9513289	643541	28/02/2011	54	CL	helipad clearing in swamp forest
Wogamush Site	AN117	9513042	643440	28/02/2011	54	CS	small clearing in swamp forest
Wogamush Site	AN118	nr	nr	1/032011	nr	FT	track through forest
Wogamush Site	AN119	9513062	643434	2/03/2011	54	CS	small clearing in swamp forest
Wogamush Site	AN120	9513289	643541	2/03/2011	54	CL	helipad clearing in swamp forest
Wogamush Site	AN121	9513042	643440	2/03/2011	54	CS	small clearing in swamp forest
Wogamush Site	AN122	9513826	643370	3/03/2011	54	SW	Inside swamp
Wogamush Site	AN123	9512802	643293	3/03/2011	54	FT	track on ridge top
Wogamush Site	AN124	9513148	643260	3/03/2011	54	SW	track on palm swamp
Kubkain Site	AN125	9521816	647073	5/03/2011	54	FU	dry open regrowth forest, faint track
Kubkain Site	AN126	9521771	647047	5/03/2011	54	FU	forest understorey
Kubkain Site	AN127	9521818	646995	5/03/2011	54	CL	helipad clearing in swamp forest
Kubkain Site	AN128	9521816	647073	7/03/2011	54	FU	dry open regrowth forest, faint track
Kubkain Site	AN129	9521771	647047	7/03/2011	54	FU	forest understorey
Kubkain Site	AN130	9521818	646995	7/03/2011	54	CL	helipad clearing in swamp forest
Kubkain Site	AN131	9521815	647553	8/03/2011	54	SW	large clearing
Kubkain Site	AN132	9521703	647086	9/03/2011	54	SW	swamp edge with Hill Forest
Kubkain Site	AN133	9521875	646864	9/03/2011	54	FT	on knoll
Ok Binai 1 Site	AN134	9480323	593425	10/03/2011	54	CR	overlooking river
Ok Binai 1 Site	AN135	9480294	593365	10/03/2011	54	CL	large garden bordering river
Ok Binai 1 Site	AN136	9480323	593425	11/03/2011	54	CR	overlooking river

SITE	ANABAT SESSION #	POSITION (PNG MG94 ZONE 54)		DATE OF EVENING SETUP	ELEVATION M (ELEVATION)	HABITAT CODE	LOCATION
		EASTING	NORTHING				
Ok Binai 1 Site	AN137	9480023	593321	11/03/2011	54	CL	large man made clearing bordering swamp forest
Ok Binai 1 Site	AN138	9480239	593407	13/03/2011	54	FS	small stream in forest

Habitat codes: CL—Large Clearing; CR—Clearing on River; CS—Small Clearing; FC—Forest Canopy; FS—Fast Stream in forest; FT—Forest Track; FU—Forest Understorey; SS—Slow Stream in forest; SW—Swamp.

Appendix 3.5. Acoustic records for each AnaBat session.

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
ANABAT SESSION	ANABAT SERIAL	DATE	*17 sh.cFM*	*20 cFM*	*24 cFM Saccolaimus sp.*	*27 sh.cFM.d Emballonura sp.*	*30 st.cFM*	*34 i.fFM.d / sCF Emballonura sp.*	*37 st.cFM M. magnater*	*40 st.bFM /st.sFM.d M. moluccarum*	*42 cFM*	*42 lCF R. philippinensis**	*42 i.fFM.d Emballonura sp.*	*47 sCF / i.fFM.d Emballonura sp.*	*47 st.cFM.h P. angulatus*	*55 st.cFM.d / cFM*	*55 st.bFM N. microdon*	*58 mCF H. diadema*	*64 sCF / i.cvFM M. nigrescens*	*75 mCF*	*82 mCF H. wollastoni*	*90 mCF*	*112 sCF A. tricuspidatus*	*124 sCF H. maggietaylorae*	*137 sCF **H. cervinus*	*144 sCF **H. ater*
AN01	5334	29/11/2009	—	H	—	—	—	Nc	H	—	H	—	—	H	H	—	—	—	—	—	—	—	—	—	—	—
AN02	5395	29/11/2009	—	—	—	—	—	H	H	—	—	—	—	H	H	—	—	—	H	—	—	—	—	—	—	—
AN03	5395	30/11/2009	—	—	—	—	—	—	H	—	—	Nc	—	—	H	H	—	—	—	H	H	—	—	—	—	—
AN04	5334	30/11/2009	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN05	5334	1/12/2009	—	—	—	—	—	—	H	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
AN06	5395	1/12/2009	—	—	—	—	—	—	H	—	—	—	—	H	—	—	—	—	H	—	H	—	—	—	—	—
AN07	5395	3/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN08	5334	3/12/2009	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	H	—	H	—	H	—	—	—
AN09	5395	2/12/2009	—	—	—	—	—	—	—	—	—	H	—	—	H	—	—	Nc	H	—	H	—	—	—	—	—
AN10	5334	2/12/2009	—	—	—	—	—	—	—	—	H	H	—	—	H	—	—	—	H	—	H	—	—	—	—	—
AN11	5395	4/12/2009	—	—	H	—	—	H	H	—	—	—	—	H	—	—	—	—	H	—	H	—	—	—	—	—
AN12	5334	4/12/2009	—	—	—	—	—	—	—	—	—	H	—	Nc	—	—	—	—	H	—	H	—	—	—	—	—
AN13	5334	5/12/2009	—	H	H	—	—	—	H	—	H	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—
AN14	5395	5/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN15	5395	6/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN16	5334	6/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN17	5395	7/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	H	—	H	—	H	—	—	—	—	—	—	—
AN18	5334	7/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN19	5334	8/12/2009	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	H	—	—	H	—	—	—	—

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
AN20	5395	8/12/2009	—	—	—	—	—	—	H	—	H	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—
AN21	5395	9/12/2009	—	—	—	—	H	—	H	—	H	—	—	H	—	—	—	—	H	—	—	—	—	—	—	—
AN22	5334	9/12/2009	—	—	—	—	H	Nc	H	—	H	Nc	—	H	—	—	—	H	H	—	—	—	—	—	—	—
AN23	5334	10/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN24	5395	10/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—
AN25	5334	11/12/2009	—	—	—	—	—	—	—	—	—	Nc	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN26	5395	11/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN27	5215	13/12/2009	—	—	—	—	—	—	H	—	—	—	Nc	H	H	H	—	—	H	—	—	—	—	—	—	—
AN28	5334	12/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—
AN29	5395	14/12/2009	H	—	—	—	—	—	H	—	—	—	—	H	H	—	—	—	H	—	—	—	—	—	—	—
AN30	5395	13/12/2009	—	—	H	—	—	—	H	—	H	H	—	H	H	—	—	—	H	—	—	—	—	—	—	—
AN31	5334	13/12/2009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN32	5215	2/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	H	—	—	—	—
AN33	5334	2/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	H	—	—	—
AN34	5215	3/02/2010	—	—	—	—	—	—	H	—	—	—	—	—	H	—	—	—	—	—	—	H	—	—	—	—
AN35	5334	3/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—
AN36	5334	4/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN37	5215	4/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—
AN38	5334	5/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN39	5215	5/02/2010	—	—	H	—	—	—	H	H	Nc	—	—	H	H	—	—	—	H	—	—	—	—	—	—	—
AN40	5215	6/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN41	5215	7/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—
AN42	5334	7/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN43	5395	8/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN44	5215	8/02/2010	—	H	—	—	—	—	H	—	H	—	—	H	H	—	—	H	H	—	—	—	—	—	—	—
AN45	5395	9/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	H	—	—	—	—
AN46	5215	9/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN47	5215	10/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN48	5395	10/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
AN49	5215	11/02/2010	—	—	—	—	—	—	—	—	—	—	—	Nc	—	—	—	—	—	—	H	H	H	—	—	—
AN50	5395	11/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN51	5215	12/02/2010	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	H	—	H	—	—	—	—	—
AN52	5395	12/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN53	5215	14/02/2010	—	—	H	—	—	—	H	—	—	—	—	—	H	—	—	—	H	—	H	—	—	—	—	—
AN54	5334	14/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN55	5215	15/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—
AN56	5334	15/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN57	5215	16/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	H	H	—	—	H	—	—	—	—	—	—	—
AN58	5395	16/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN59	5395	18/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN60	5334	18/02/2010	—	—	—	H	—	—	H	H	H	—	—	H	H	—	—	—	H	H	H	—	H	—	—	—
AN61	5334	19/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN62	5395	19/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN63	5334	20/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN64	5395	20/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—
AN65	5334	21/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—
AN66	5395	21/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN67	5395	22/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	—	—	—
AN68	5334	22/02/2010	—	—	—	H	—	—	H	H	H	—	—	H	H	—	—	H	H	H	—	—	—	—	—	—
AN69	5395	23/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	H	—	—	—	—
AN70	5334	23/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	H	—	—	—	—	—	—	—
AN71	5395	24/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN72	5334	24/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN73	5334	25/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—
AN74	5395	25/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—
AN75	5395	26/02/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	—	—	—	—	—
AN76	5334	26/02/2010	—	—	—	—	—	—	—	Nc	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	—

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
AN77	5334	27/02/2010	H	—	—	—	—	—	H	H	H	—	—	H	H	—	—	H	H	—	H	—	—	—	—	—
AN78	5215	27/05/2010	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	H	H	—	—	H	—	—	—	—
AN79	5395	27/05/2010	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	H	H	—	—	H	H	—	—	—
AN80	5334	27/05/2010	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	H	—	—	—	—	—	—	—
AN81	5215	28/05/2010	—	—	—	—	—	—	—	Nc	—	—	—	—	H	—	—	H	H	—	—	H	H	H	—	—
AN82	5395	28/05/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—
AN83	5334	28/05/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN84	5215	29/05/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN85	5395	29/05/2010	—	—	—	—	—	—	H	—	H	—	—	H	H	—	—	—	H	—	—	—	—	—	—	—
AN86	5395	30/05/2010	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	H	—	—	—	—	—	—	—
AN87	5215	30/05/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN88	5215	31/05/2010	—	—	H	—	—	—	H	Nc	H	—	H	H	H	H	—	H	H	—	—	H	—	—	—	—
AN89	5395	31/05/2010	—	—	—	H	—	—	H	H	H	—	H	H	H	H	—	H	H	—	—	H	H	—	—	—
AN90	5395	1/06/2010	—	—	—	H	—	—	—	—	H	—	—	—	H	—	—	H	H	—	—	H	H	—	—	—
AN91	5334	1/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	—	—	—	—
AN92	5395	3/06/2010	—	Nc	—	—	—	—	H	H	H	—	—	—	H	—	—	—	H	—	—	—	H	—	—	—
AN93	5334	3/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	H	—	—	—	—	—	—	—
AN94	5334	5/06/2010	—	—	—	—	—	—	H	H	H	—	—	H	H	—	—	H	H	Nc	—	H	—	—	—	—
AN95	5395	5/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN96	5395	8/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	H	H	—	—	—
AN97	5334	8/06/2010	—	—	—	—	—	—	H	—	Nc	—	—	—	H	—	—	H	H	—	—	H	H	—	—	—
AN98	5334	9/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—
AN99	5395	9/06/2010	—	—	—	—	—	—	H	—	H	—	—	H	H	—	—	H	H	—	—	—	—	—	—	—
AN100	5395	12/06/2010	—	—	—	—	—	—	H	—	H	—	—	—	H	—	—	H	H	—	—	—	—	—	—	—
AN102	5334	15/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—
AN103	5395	15/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	H	—	—	—	H	—	—	—
AN104	5334	16/06/2010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AN105	5395	16/06/2010	—	H	—	H	—	—	H	H	H	—	—	H	H	—	—	H		—	—	—	H	—	—	—
AN106	80100	24/02/2011	—	—	H	—	H	—	H	—	H	—	—	H	H	—	—	—	H	—	—	—	—	—	—	—

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
AN107	80156	24/02/2011	—	—	H	—	H	—	H	—	H	—	—	H	H	—	—	H	H	—	—	—	—	—	—	—
AN108	81220	24/02/2011	—	—	—	—	H	—	H	—	H	—	—	H	H	—	—	H	H	—	—	—	—	—	—	—
AN109	80095	24/02/2011	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	H	H	—	H	—	—	—	—
AN110	80095	25/02/2011	—	—	—	—	—	—	H	—	—	—	—	—	H	—	—	—	H	H	—	—	—	—	—	—
AN111	80100	26/02/2011	—	H	—	—	—	H	H	—	H	—	—	H	H	—	—	—	H	—	—	—	—	—	—	—
AN112	80156	26/02/2011	—	H	H	—	—	H	H	—	H	—	H	H	H	—	—	—	H	—	—	—	—	—	—	—
AN113	81220	26/02/2011	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	H	H	—	—	H	—	—	—
AN114	80095	27/02/2011	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	—
AN115	80100	28/02/2011	—	—	H	—	—	—	—	—	H	—	—	—	H	—	—	H	H	—	—	H	—	—	—	—
AN116	80156	28/02/2011	—	—	H	—	—	—	H	—	H	—	—	H	H	—	—	—	H	—	—	H	—	—	—	—
AN117	81220	28/02/2011	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	H	H	H	—	H	H	—	—	—
AN118	80095	28/02/2011	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	H	H	—	—	—	—	—	—
AN119	80100	2/03/2011	—	—	H	—	—	—	H	—	H	—	—	—	H	—	—	—	H	—	—	H	—	—	—	—
AN120	80156	2/03/2011	—	—	—	—	—	H	H	—	H	—	—	—	H	—	—	H	H	—	—	—	—	—	—	—
AN121	81220	2/03/2011	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	H	H	H	—	H	—	—	—	—
AN122	80100	3/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	H	—	—	—	—
AN124	80095	3/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	—	—	—	—
AN125	80100	5/03/2011	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—
AN126	81220	5/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	—	—	—	—
AN127	80095	5/03/2011	—	—	H	—	—	—	H	—	H	—	—	H	H	—	—	H	H	H	—	—	—	—	—	—
AN128	80100	7/03/2011	—	—	—	—	—	—	H	—	—	—	—	—	H	—	—	—	H	—	—	—	—	—	—	—
AN129	81220	7/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	—	—	—	—
AN130	80095	7/03/2011	—	—	H	—	H	—	H	—	H	—	—	—	H	—	—	H	H	—	—	—	—	—	—	—
AN131	80100	8/03/2011	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	H	H	H	—	—	—	—	—	—
AN132	81220	9/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	H	—	—	—	—	—	—	—
AN133	80095	9/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—
AN134	80100	10/03/2011	—	—	—	—	—	—	H	—	H	—	—	H	—	—	—	—	H	—	—	—	H	—	—	—
AN135	81220	10/03/2011	—	—	—	—	—	—	H	—	—	—	—	H	H	—	—	—	H	—	—	H	—	—	—	—
AN136	80100	11/03/2011	—	—	—	—	—	—	H	—	H	—	—	H	—	—	—	H	H	—	—	—	H	—	—	—

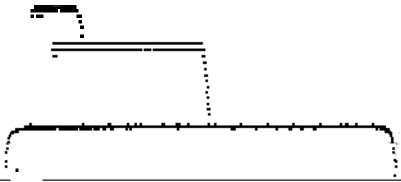
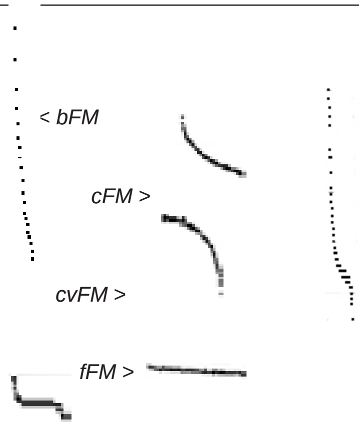
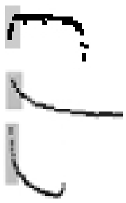
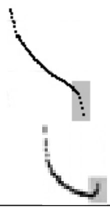
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
AN137	80095	11/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	H	—	—	H	H	—	—	—	—	—	—	—
AN138	80095	13/03/2011	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H	H	H	—	—	—

Notes: Details of AnaBat placement (location, date, habitat) are provided in Appendix 4. Cell entries: H (High) = Unambiguous identification of the species or *call type* at the site based on measured call characteristics and comparison with available reference material. Greater confidence in this identification would come only after capture and supported by morphological measurements and/or genetic analysis. NC (Needs Confirmation): There are two grounds for this classification: 1. the recording quality was generally poor, which limited the variables available for facilitating identification; or 2. the recording was of reasonable quality but this call type resembles another, and the recording showed some ambiguous or incompletely diagnostic echolocation characteristics.

Appendix 3.6. List of vouchered reference calls recorded during the survey.

FIELD NO	SPECIES	SEX	DATE	RECORDING UNIT	HOW RECORDED	FOREARM LENGTH (MM)	BODY WEIGHT (GM)	CALL QUALITY
FR68	*Hipposideros maggietaylorae*	M	7/12/2009	AnaBat	inside mesh bag	57.3	17.8	poor
FR73	*Hipposideros maggietaylorae*	M	7/12/2009	AnaBat	inside mesh bag	57.4	15.9	poor
FR75	*Hipposideros maggietaylorae*	M	8/12/2009	AnaBat	inside mesh bag	54.1	15.2	poor
FR76	*Hipposideros maggietaylorae*	F	8/12/2009	AnaBat	inside mesh bag	56.4	16.6	poor
FR87	*Hipposideros wollastoni*	F	9/12/2009	AnaBat	inside mesh bag	44.6	5.6	poor
FR88	*Miniopterus magnater*	F	9/12/2009	AnaBat	flying along fixed line	48.9	16	poor
FR116	*Pipistrellus papuanus*	F	13/12/2009	AnaBat	flying along fixed line	27.5	5	poor
FR116	*Pipistrellus papuanus*	F	13/12/2009	AnaBat	flying inside small room	27.5	5	poor
FR186	*Hipposideros cervinus*	F	6/02/2010	Petersson	inside mesh bag	49.7	7.5	good
FR186	*Hipposideros cervinus*	F	6/02/2010	AnaBat	inside mesh bag	49.7	7.5	good
FR186	*Hipposideros cervinus*	F	6/02/2010	AnaBat	flying in mosquito net	49.7	7.5	good
FR210	*Myotis moluccarum*	F	8/02/2010	AnaBat	flying in large hut	39.8	8.2	poor
FR249	*Hipposideros wollastoni*	F	11/02/2010	Petersson	inside mesh bag	44.8	6.8	good
FR307	*Mosia nigrescens*	M	19/02/2010	Petersson	flying in small tent	33.9	3	good
FR308	*Hipposideros maggietaylorae*	Fjuv	19/02/2010	Petersson	hand held	34.9	8.2	good
FR338	*Ascelliscus tricuspidatus*	M	23/02/2010	Petersson	inside mesh bag	42.8	3.6	good
FR338	*Ascelliscus tricuspidatus*	M	23/02/2010	AnaBat	inside mesh bag	42.8	3.6	good
FR339	*Hipposideros cervinus*	F	23/02/2010	Petersson	inside mesh bag	47	8.1	good
FR339	*Hipposideros cervinus*	F	23/02/2010	AnaBat	inside mesh bag	47	8.1	good
FR368	*Hipposideros diadema*	M	25/02/2010	Petersson	inside mesh bag	77.7	35.3	good
FR368	*Hipposideros diadema*	M	25/02/2010	AnaBat	inside mesh bag	77.7	35.3	good
FR403	*Hipposideros ater*	F	26/02/2010	AnaBat	inside mesh bag	41.9	5.9	poor
FR404	*Hipposideros ater*	M	26/02/2010	AnaBat	inside mesh bag	40	5.7	poor
FR427	*Hipposideros ater*	M	28/02/2010	AnaBat	inside mesh bag	42.3	6.9	poor
FR427	*Hipposideros ater*	M	28/02/2010	AnaBat	flying in large hut	42.3	6.9	poor
FR1022	*Pipistrellus angulatus*	F	12/06/2010	Petersson	flying in small tent	34.5	4.3	good
FR1032	*Nyctophilus microtis*	M	15/06/2010	Petersson	flying in small tent	40.4	6.8	good
FR1031	*Ascelliscus tricuspidatus*	M	15/06/2010	Petersson	inside mesh bag	42.1	3.9	good
FR1124	*Miniopterus magnater*	M	17/06/2010	Petersson	flying along fixed line	51.7	16.8	good
Lost	*Mosia nigrescens*	M/F	19/06/2010	Petersson	feeding swarm around light			good

Appendix 3.7. Echolocation call categories

CODE	DESCRIPTION	EXAMPLE
CF	Constant Frequency main Body Sub Type (BST)	
sCF	Short duration (<15 ms)	
mCF	Medium duration (15 – 30 ms)	
lCF	Long duration (>30 ms)	
FM	Frequency Modulated main Body Sub Type (BST)	
bFM	Broadband, slightest degree of curvature only, no significant development of serpentine component (*sFM*)	< *bFM*
cFM	Curved, simple or curvilinear trace	*cFM* >
cvFM	Convex curved, essentially cFM rotated 180°	*cvFM* >
fFM	Flat or with a very slight curve, narrowband, not *CF*	*fFM* >
sFM	Serpentine, generally S-shaped	< *sFM* >
	Initial Frequency Sweep (IFS)	
i.	Inclined, a narrowband increasing frequency sweep	
sh.	Short, shallow or narrowband frequency sweep	
st.	Steeply decreasing, broadband frequency sweep	
	Terminating Frequency Sweep (TFS)	
.d	Drooped, decreasing frequency sweep following the characteristic frequency in the main body of the call	
.h	Hooked, increasing in frequency	

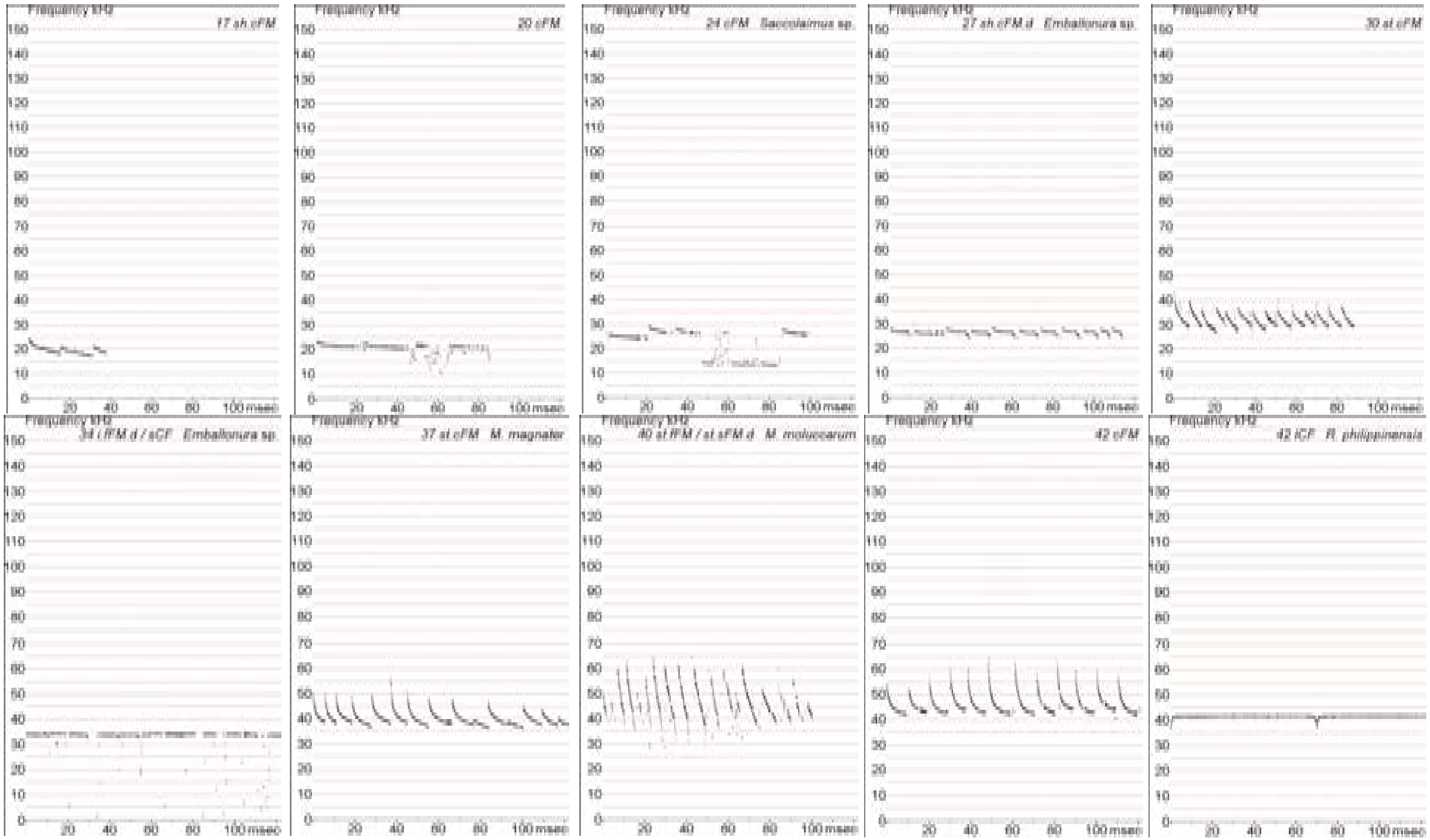
Based on the morphology of the dominant type or types of single search-phase pulses in high quality sequences (adapted from de Oliveira (1998a,b) and Corben and O'Farrell (1999) by Armstrong and Aplin (in prep.); examples are not scaled equally). Pulses generally consist of three main sections: an initial 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 mean characteristic frequency in kHz. Note that most CF pulses have an initial upward frequency sweep, and all have a recognisable terminating frequency sweep, so the TFS descriptors are not used for this Body Sub Type.

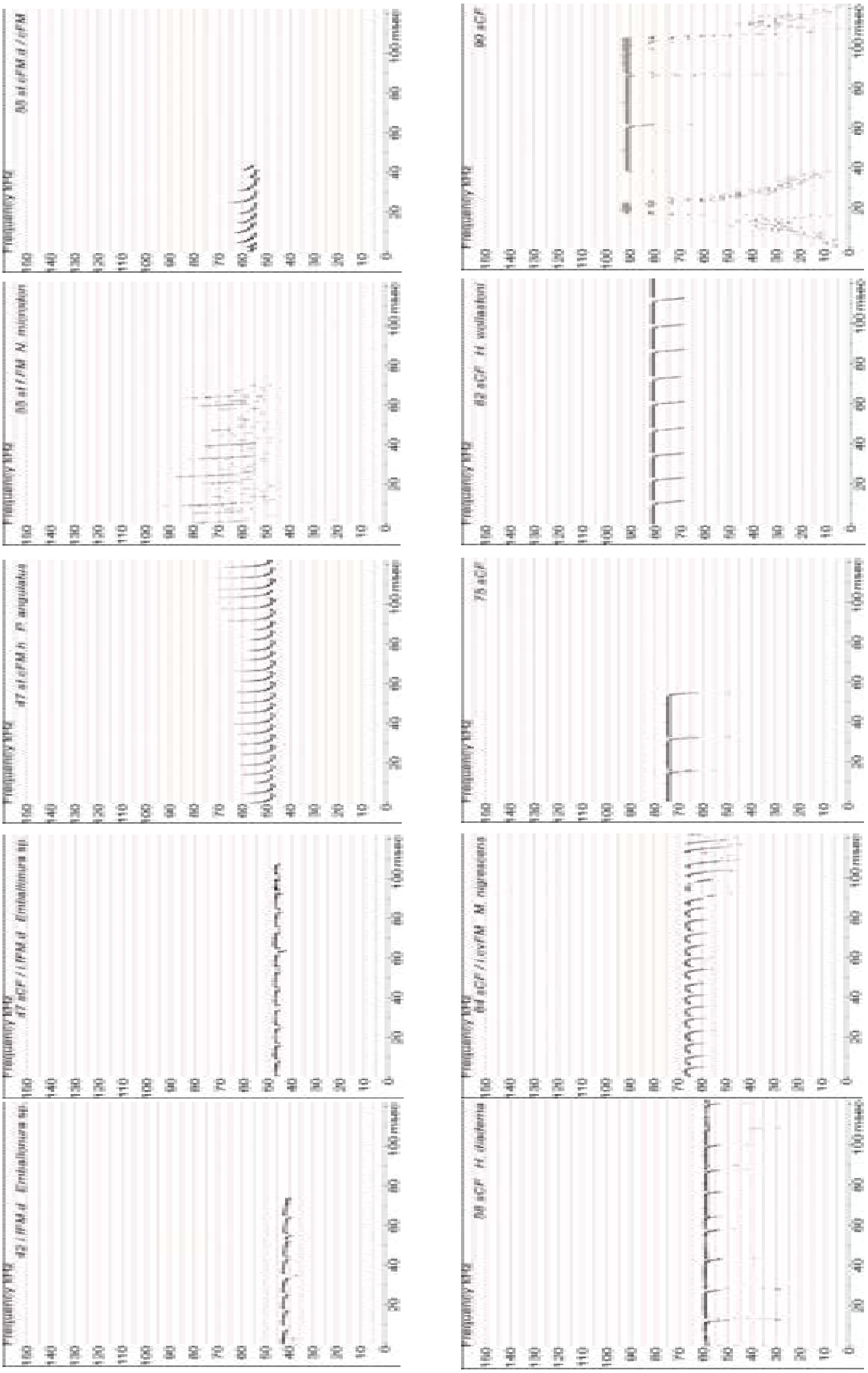
Appendix 3.8. Summary of variables from representative and reference call sequences

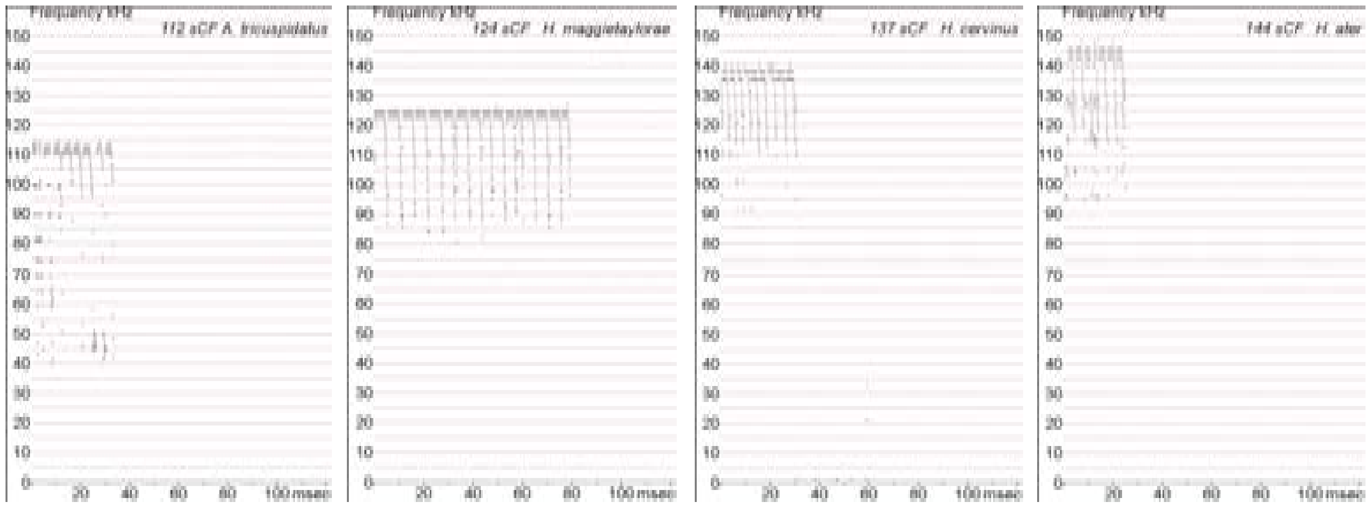
CALL TYPE	TAXON	S,P[1]	DURATION (MSEC)[2]	MAX FREQUENCY (KHZ)[2]	CHAR FREQUENCY (KHZ)[2]
17 sh.cFM	Saccolaimus sp. or molossid?	1,4	3.3 ± 0.5	17.3 ± 0.2	16.7 ± 0.3
			2.9 – 3.9	17.1 – 17.5	16.4 – 17.0
20 cFM	Saccolaimus sp. or molossid?	2,12	7.2 ± 1.2	27.4 ± 2.8	22.0 ± 1.1
			6.0 – 9.6	23.1 – 31.4	20.0 – 23.6
24 cFM	Saccolaimus sp.	1,5	7.8 ± 1.2	30.2 ± 0.2	23.9 ± 0.3
			6.0 – 8.6	30.1 – 30.5	23.5 – 24.2
27 sh.cFM.d	Emballonura sp.	3,30	10.9 ± 2.9	28.9 ± 0.7	27.1 ± 0.3
			6.7 – 16.5	28.0 – 30.3	26.7 – 27.7
30 st.cFM	Mormopterus or Emballonura sp.	1,13	7.0 ± 1.7	31.5 ± 10.5	24.5 ± 9.6
			5.4 – 10.5	6.4 – 39.8	3.7 – 31.8
34 i.fFM.d / sCF	Emballonura sp.	6,27	8.5 ± 2.1	33.4 ± 1.0	33.0 ± 1.1
			6.0 – 13.1	31.6 – 35.1	31.1 – 34.8
37 st.cFM	Miniopterus magnater	11,66	6.0 ± 2.0	48.2 ± 5.6	38.5 ± 1.0
			2.7 – 11.4	39.6 – 63.5	36.4 – 41.7
40 st.bFM / st.sFM.d	Myotis moluccarum	11,88	2.4 ± 0.9	57.7 ± 7.2	46.6 ± 6.2
			1.0 – 4.7	46.5 – 77.7	38.5 – 63.0
42 cFM	possibly a vespertilionid	6,40	5.9 ± 3.0	48.1 ± 2.9	42.6 ± 1.3
			2.5 – 18.5	43.0 – 54.1	40.6 – 46.0
42 lCF	Rhinolophus philippinensis	2,29	69.6 ± 12.9	—	41.7 ± 0.1
			27.5 – 83.7		41.6 – 41.9
42 i.fFM.d	Emballonura sp.	1,4	6.0 ± 2.5	41.9 ± 0.9	40.9 ± 0.4
			3.2 – 8.2	40.6 – 42.6	40.6 – 41.4
47 sCF / i.fFM.d	Emballonura sp.	14,97	6.8 ± 1.4	50.2 ± 3.1	49.7 ± 3.1
			3.8 – 12.3	45.2 – 54.8	44.2 – 54.1
47 st.cFM.h	Pipistrellus angulatus	7,84	5.0 ± 2.7	58.0 ± 6.9	47.3 ± 0.6
			2.7 – 26.5	50.3 – 84.2	45.7 – 48.8
53 st.fFM	Nyctophilus aff. microdon[3]	3,11	0.9 ± 0.5	115.9 ± 7.6	53.5 ± 2.6
			0.4 – 1.6	104.0 – 131.0	48.0 – 58.0
55 st.cFM.d / cFM	vespertilionid?	5,23	4.4 ± 0.9	62.2 ± 3.7	55.2 ± 0.5
			2.5 – 6.4	56.7 – 71.4	54.4 – 56.3
58 mCF	Hipposideros diadema	3,86	11.1 ± 1.6	59.4 ± 0.2	59.1 ± 0.3
			7.7 – 14.7	58.8 – 59.7	58.0 – 59.7
64 sCF / i.cvFM	Mosia nigrescens	6,65	4.7 ± 0.7	—	64.4 ± 1.9
			3.7 – 6.6		62.1 – 68.4
75 mCF	Hipposideros semoni or H. muscinus?	3,8	19.0 ± 2.1	—	74.0 ± 0.6
			15.9 – 22.4		73.4 – 74.9
82 mCF	Hipposideros wollastoni	7,77	16.3 ± 4.9	—	81.1 ± 0.8
			10.2 – 31.5		80.7 – 84.2
90 mCF	Hipposideros semoni or H. muscinus?	10,14	18.0 ± 4.9	—	92.3 ± 0.7
			10.8 – 24.5		90.8 – 93.1
112 sCF	Aselliscus tricuspidatus	8,31	2.9 ± 0.5	—	111.7 ± 5.2
			2.1 – 4.2		101.3 – 117.7
124 sCF	Hipposideros maggietaylorae	4,35	4.7 ± 0.6	—	125.1 ± 0.6
			3.3 – 5.7		124.9 – 126.9
137 sCF	Hipposideros cervinus	1,9	3.1 ± 0.5	—	138.0 ± 0
			2.4 – 3.9		138.0 – 138.0
144 sCF	Hipposideros ater	7,36	3.2 ± 0.6	—	143.2 ± 1.8
			1.9 – 4.4		140.4 – 145.5

Notes: S,P is the number of sequences measured and the combined total number of pulses respectively.

Appendix 3.9. Representative call sequences of the insectivorous bat call types identified







Time is compressed between pulses. Species-level names are given if a reference call was recorded from a vouchered individual or if it could be allocated with high confidence based on reference material from other sources; genus level names were given to emballonurids based on pulse and harmonic structure.

Appendix 3.10. Notes on the taxonomic determination of the 24 insectivorous bat call types documented during the field survey.

17 sh.cFM	Attributable to one of the three *Saccolaimus* species, based on pulse structure and characteristic frequency (examples in Milne 2002, 2008), possibly also *Otomops* spp.
20 cFM	Attributable to one of the three *Saccolaimus* species, based on pulse structure and characteristic frequency (examples in Milne 2002, 2008), possibly also *Chaerephon jobensis, Mormopterus beccarii*, or *Otomops* spp.
***24 cFM Saccolaimus* sp.**	Attributable to a species of *Saccolaimus* based on one observed sequence with both the rarely observed lower fundamental, and the dominant first harmonic.
***27 sh.cFM.d Emballonura* sp.**	Call shape (with terminal droops) and harmonic structure typical of *Emballonura*, based on similar morphology from elsewhere (e.g. Pottie et al. 2005; other unpublished sources).
30 st.cFM	One of several candidate species, perhaps *Mormopterus,* or else attack phase calls of *27 sh.cFM.d Emballonura* sp.
***34 i.fFM.d / sCF Emballonura* sp.**	Call shape (with terminal droops) typical of *Emballonura*, based on similar morphology from elsewhere (e.g. Pottie et al. 2005; other unpublished sources).
37 st.cFM Miniopterus magnater	Attributable with high confidence based on reference calls collected on the survey.
40 st.bFM / st.sFM.d Myotis moluccarum	Most likely from *Myotis moluccarum*, which was captured on the survey and gave similar call sequences
42 lCF Rhinolophus philippinensis	Attributable with high confidence to *Rhinolophus philippinensis* based on similarity to the remarkably low frequency, long duration (high duty cycle) calls seen in the Australian forms. The recorded form is similar in frequency to the undescribed 'intermediate' (*sensu* Cooper et al. 1998) of Australia (Churchill 2008; review in DEWHA 2010).
42 cFM	Likely to be one of several candidate species in the Vespertilionidae.
***42 i.fFM.d Emballonura* sp.**	Call shape (with terminal droops) typical of *Emballonura*, based on similar morphology from elsewhere (e.g. Pottie et al. 2005; other unpublished sources).
***47 sCF / i.fFM.d Emballonura* sp.**	Call shape (with terminal droops) typical of *Emballonura*, based on similar morphology from elsewhere (e.g. Pottie et al. 2005; other unpublished sources). The representative sequence trace shows pulses with a characteristic frequency of c. 47 kHz, but pulses were often up to c. 10 kHz higher. There was some indication that a higher and lower phonic type were present, but they have been lumped into the same call category because many contemporaneous (i.e. overlapping) examples of both types were observed from several sites.
47 st.cFM.h Pipistrellus angulatus	Attributable with high confidence based on reference calls collected on the survey. Call attributes may overlap with other vespertilionid species, but there was not obvious indication that more than one contributor was present in the Study Area.
53 st.fFM Nyctophilus* aff. *microdon	Attributable with high confidence based on reference calls collected on the survey, however it is likely to be confused with other species that produce short duration broadband calls in clutter.
55 st.cFM.d / cFM	Likely to be one of several candidate species in the Vespertilionidae.
55 st.bFM N. microdon	Identified as *Nyctophilus microdon* based on comnparison with the reference call recorded from one individual captured on the survey.
58 mCF Hipposideros diadema	Attributable with high confidence based on reference calls collected on the survey.
64 sCF / i.cvFM Mosia nigrescens	Attributable with high confidence based on reference calls collected on the survey.
75 mCF	Possibly attributable to females of *Hipposideros semoni*, given the relatively long pulse duration, which was similar to CF calls made by *H. wollastoni*. These two species are close relatives (*cyclops* group; Hill 1963). The calls of male and female *H. semoni* are thought to be very different in Australia (de Oliveira and Schulz 1997; Churchill 2008), but *H. muscinus* is also a possibility.
82 mCF Hipposideros wollastoni	Attributable with high confidence based on reference calls collected on the survey. Unlikely to be confused with another species because of both the characteristic frequency and the relatively long duration (for a hipposiderid).
90 mCF	Possibly attributable to males of *Hipposideros semoni*, given the apparent sexual dimorphism in call frequency in this species (de Oliveira and Schulz 1997; Churchill 2008), but *H. muscinus* is also a possibility.
112 sCF Aselliscus tricuspidatus	Attributable with high confidence based on reference calls collected on the survey.
124 sCF Hipposideros maggietaylorae	Attributable with high confidence based on reference calls collected on the survey.
137 sCF Hipposideros cervinus	Attributable with high confidence based on reference calls collected on the survey.
144 sCF Hipposideros ater	Attributable with high confidence based on reference calls collected on the survey.

Appendix 3.11. Results of camera trapping activities in the Study Area.

SAMPLING SITE	Camera position No.	*Murexia longicaudata*	*Echymipera* sp.	*Peroryctes raffrayana*	Peralemidae indet.	*Phalanger* sp.	*Phalanger gymnotis*	*Dorcopsis hageni*	*Hydromys chrysogaster*	*Mammelomys* sp.	*Uromys caudimaculatus*	cf *Paramelomys* sp.	*Sus scrofa*	*Canis lupus domesticus*	Indeterminate medium-sized mammal	Total images	Total mammal species	Images/100 camera trap hour
Nena Base Site	1															0	0	0.0
Nena Base Site	2															0	0	0.0
Nena Base Site	3															0	0	0.0
Nena Base Site	4															0	0	0.0
Nena Base Site	5															0	0	0.0
Nena Base Site	6															0	0	0.0
Nena Base Site	7									3 2/12/'09						3	1	3.3
Nena D1 Site	1															0	0	0.0
Nena D1 Site	2									1 7/12/'09						1	1	1.1
Nena Limestone Site	1															0	0	0.0
Nena Limestone Site	2															0	0	0.0
Nena Limestone Site	3															0	0	0.0
Malia Site	3															0	0	0.0
Malia Site	4															0	0	0.0
Malia Site	5															0	0	0.0
Malia Site	6							1 5/02/'10								1	1	1.2
Malia Site	7							1 5/02/'10								1	1	1.2
Malia Site	8															0	0	0.0
Malia Site	9															0	0	0.0
Malia Site	10															0	0	0.0
Malia Site	11															0	0	0.0
Malia Site	12		2 16/02/'10								2 27/02/'10					4	2	0.4

SAMPLING SITE	Camera position No.	*Murexia longicaudata*	*Echymipera sp.*	*Peroryctes raffrayana*	Peralemidae indet.	*Phalanger sp.*	*Phalanger gymnotis*	*Dorcopsis hageni*	*Hydromys chrysogaster*	*Mammelomys sp.*	*Uromys caudimaculatus*	cf *Paramelomys sp.*	*Sus scrofa*	*Canis lupus domesticus*	Indeterminate medium-sized mammal	Total images	Total mammal species	Images/100 camera trap hour
Koki Site	8												3 11+12/2/'10			3	1	6.3
HI Site	1				1? 17/3/'10	1 17/3/'10										2	1	2.3
HI Site	2															0	0	0.0
HI Site	3															0	0	0.0
HI Site	4															0	0	0.0
HI Site	5															0	0	0.0
HI Site	6								1 15/2/'10			1 15/2/'10				2	2	2.8
Upper Ok Binai Site	1	1 20/2/'10					1 21/2/'10									2	2	2.2
Upper Ok Binai Site	2							2 22/2/'10								2	1	2.2
Upper Ok Binai Site	3							1 22/2/'10								1	1	1.1
Upper Ok Binai Site	4			1 22/2/'10						2 22/2/'10						3	2	3.4
Upper Ok Binai Site	5															0	0	0.0
Upper Ok Binai Site	6															0	0	0.0
Upper Ok Binai Site	7		1 22/2/'10													1	1	2.5
Frieda Bend Site	1		1? 26/2/'10								1 26/2/'10	1 28/2/'10				3	2	3.1
Frieda Bend Site	2															0	0	0.0
Frieda Bend Site	3										1 26/2/'10					1	1	1.0
Frieda Bend Site	4							1 28/2/'10			1 25/2/'10		2 26/2/'10			4	3	4.3
Frieda Bend Site	5												1 26/2/'10			1	1	1.1
Frieda Bend Site	6												1 25/2/'10			1	1	1.1
Frieda Bend Site	7															0	0	0.0
Ok Isai Site	1															0	0	0.0
Ok Isai Site	2															0	0	0.0

SAMPLING SITE	**Camera position No.**	*Murexia longicaudata*	*Echymipera sp.*	*Peroryctes raffrayana*	Peralemidae indet.	*Phalanger sp.*	*Phalanger gymnotis*	*Dorcopsis hageni*	*Hydromys chrysogaster*	*Mammelomys sp.*	*Uromys caudimaculatus*	cf *Paramelomys* sp.	*Sus scrofa*	*Canis lupus domesticus*	Indeterminate medium-sized mammal	Total images	Total mammal species	Images/100 camera trap hour
Ok Isai Site	3												1 29/5/'10			1	1	1.0
Ok Isai Site	4		1 29/5/'10													1	1	1.0
Ok Isai Site	5															0	0	0.0
Ok Isai Site	6			1 28/5/'10												1	1	1.1
Ok Isai Site	7															0	0	0.0
Ok Isai Site	8															0	0	0.0
Ok Isai Site	9															0	0	0.0
Kaugumi Site	1		5 3+5+6/6/'10										4 1+3+4/6/'10			9	2	7.5
Kaugumi Site	2															0	0	0.0
Kaugumi Site	3		3 1+5+6/6/'10			1 2/6/'10					1 3/6/'10		1 5/6/'10			6	4	5.0
Kaugumi Site	4															0	0	0.0
Kaugumi Site	4						1 4/6/'10				1 5/6/'10					2	2	2.2
Kaugumi Site	5															0	0	0.0
Kaugumi Site	6															0	0	0.0
Kaugumi Site	7															0	0	0.0
Kaugumi Site	8													1 2/6/'10		1	1	1.5
Kaugumi Site	9															0	0	0.0
Kaugumi Site	10							1 5/6/'10								1	1	1.1
Kaugumi Site	11															0	0	0.0
Kaugumi Site	12															0	0	0.0
East Sepik Site	1															0	0	0.0
East Sepik Site	2															0	0	0.0
East Sepik Site	3															0	0	0.0

SAMPLING SITE	Camera position No.	*Murexia longicaudata*	*Echymipera sp.*	*Peroryctes raffrayana*	Peralemidae indet.	*Phalanger sp.*	*Phalanger gymnotis*	*Dorcopsis hageni*	*Hydromys chrysogaster*	*Mammelomys sp.*	*Uromys caudimaculatus*	cf *Paramelomys* sp.	*Sus scrofa*	*Canis lupus domesticus*	Indeterminate medium-sized mammal	Total images	Total mammal species	Images/100 camera trap hour
East Sepik Site	4															0	0	0.0
East Sepik Site	5														1 9/6/'10	1	1	1.1
East Sepik Site	6															0	0	0.0
East Sepik Site	7															0	0	0.0
East Sepik Site	8															0	0	0.0
East Sepik Site	6a															0	0	0.0
Iniok Site	1															0	0	0.0
Iniok Site	2												2 15/6/'10			2	1	2.7
Iniok Site	3															0	0	0.0
Wario Site	1															0	0	0.0
Wario Site	2															0	0	0.0
Wario Site	3															0	0	0.0
Wario Site	4															0	0	0.0
Wario Site	5															0	0	0.0
Wario Site	6															0	0	0.0
Wario Site	7															0	0	0.0
Wogamush Site	1															0	0	0.0
Wogamush Site	2															0	0	0.0
Wogamush Site	3															0	0	0.0
Wogamush Site	4															0	0	0.0
Wogamush Site	5															0	0	0.0
Wogamush Site	6															0	0	0.0
Wogamush Site	7															0	0	0.0

SAMPLING SITE	**Camera position No.**	*Murexia longicaudata*	*Echymipera sp.*	*Peroryctes raffrayana*	Peralemidae indet.	*Phalanger sp.*	*Phalanger gymnotis*	*Dorcopsis hageni*	*Hydromys chrysogaster*	*Mammelomys sp.*	*Uromys caudimaculatus*	cf *Paramelomys sp.*	*Sus scrofa*	*Canis lupus domesticus*	Indeterminate medium-sized mammal	Total images	Total mammal species	Images/100 camera trap hour
Wogamush Site	8												2 4/3/'11			2	1	2.7
Kubkain Site	1															0	0	0.0
Kubkain Site	2												1 7/3/'11			1	1	1.4
Kubkain Site	3															0	0	0.0
Kubkain Site	4															0	0	0.0
Kubkain Site	5						1 6/3/'11									1	1	1.4
Kubkain Site	6															0	0	0.0
Kubkain Site	7															0	0	0.0
Ok Binai 1 Site	1															0	0	0.0
Ok Binai 1 Site	2															0	0	0.0
Ok Binai 1 Site	3															0	0	0.0
Ok Binai 1 Site	4															0	0	0.0
Ok Binai 1 Site	5															0	0	0.0
Ok Binai 1 Site	6															0	0	0.0
Ok Binai 1 Site	7															0	0	0.0
Reconnaissance cameras																		
Malia Site	1															0	0	
Malia Site	2				1											1	1	

Cell entries are the number of images and the date on which they were taken. Data on the location, habitat, and duration of each camera isNotes: contained in Appendix 3.1.

Appendix 3.12. Details of informant testimony and hunter trophies obtained during the survey.

GENUS AND SPECIES	ENGLISH NAME	IUCN[2]	PNG[3]	NENA BASE SITE	KUBKAIN VILLAGE SITE	PARU VILLAGE SITE	NEKIEI VILLAGE	WAMEIMIN 1 VILLAGE SITE	WAMEIMIN 2 VILLAGE SITE	BASIS FOR ACCEPTANCE OF RECORD
Tachyglossidae										
Zaglossus sp.	A Long-beaked Echidna	CR	P					I	I	unambiguous descriptions, including nose, spines, size
Dasyuridae										
Dasyurus albopunctatus	New Guinean Quoll	NT						I	I	unambiguous description including carnivory and spots
Myoictis melas	Three-striped Dasyure							I	I	good description of plain body and size
Murexia longicaudata	Short-furred Dasyure							I	I	good description including stripes and diurnal activity
Peramelidae										
Echymipera clara	Clara's Spiny Bandicoot								T	one dentary at Wameimin 2
Echymipera kalubu	Common Spiny Bandicoot			T				T	T	14 dentaries at Wameimin 2; 1 at Nena Base
Echymipera rufescens	Long-nosed Spiny Bandicoot								T	8 dentaries at Wameimin 2
Microperoryctes longicauda	Striped Bandicoot							I	I	good description including stripes
Phalangeridae										
Phalanger cf. carmelitae	Mountain Cuscus							I	I	good description of fur colour and tail
Phalanger gymnotis	Ground Cuscus			L				TI	TI	5 dentaries at Wameimin 2
Phalanger matanim	Telefomin Cuscus	CR	P					I		good description including short tail and 'plumpness'; linked Miyan and Telefol names
Phalanger orientalis	Northern Common Cuscus			T	I	I	I	I	TI	7 dentaries at Wameimin 2; 2 at Nena Base; good description of sexual dichromatism
Spilocuscus maculatus	Common Spotted Cuscus		P	T	I	I	I	I	TI	1 dentaries at Wameimin 2; 1 at Nena Base; 1 skin at Iniok; good descriptions of sexual dichromatism
Spilocuscus rufoniger	Black-spotted Cuscus	CR				I	TI			1 dentary at Nekiei; good descriptions of colour pattern
Petauridae										
Dactylopsila trivirgata	Striped Possum						I	I		unambiguous description, including stripes
Petaurus breviceps	Sugar Glider							I	I	unambiguous description, including gliding membranes and vocalisation
Acrobatidae										
Distoechurus sp.	a Feather-tailed Possum							I		good description including facial stripes and musky smell
Macropodidae										
Dendrolagus notatus	Western Montane Tree Kangaroo	VU	P					I	I	good description of body and tail colouration

GENUS AND SPECIES	ENGLISH NAME	IUCN[2]	PNG[3]	NENA BASE SITE	KUBKAIN VILLAGE SITE	PARU VILLAGE SITE	NEKIEI VILLAGE	WAMEIMIN 1 VILLAGE SITE	WAMEIMIN 2 VILLAGE SITE	BASIS FOR ACCEPTANCE OF RECORD
Dendrolagus goodfellowi	Goodfellow's Tree Kangaroo	EN	P					I	TI	tail of juvenile at Wameimin 2; pelvic bone of *Dendrolagus* sp. at W1; unambiguous descriptions
Dorcopsis hageni	White-striped Dorcopsis					T		I	TI	1 dentary at each of Wameimin 2 and Paru; unambiguous descriptions including vertical tail resting position
Dorcopsulus vanheurni	Small Mountain Dorcopsis	NT						I	I	good description of plain body and small size
Thylogale browni	Brown's Pademelon	VU						I		good description of plain body and larger size; flat tail resting position
Muridae										
Mammelomys rattoides	Lowland Mammelomys								T	1 dentary at Wameimin 2
Uromys affin. *caudimaculatus*	Giant White-tailed Rat							TI	TI	3 dentaries at Wameimin 2
Xenuromys barbatus	Rock-dwelling Rat							I	TI	3 dentaries at Wameimin 2
Suidae										
Sus scrofa	Feral Pig							I	TI	7 dentaries at Wameimin 2
Pteropodidae										
Dobsonia moluccensis	Moluccan Naked-backed Fruit Bat							I	I	general description, could also apply to *Aproteles bulmerae*
Pteropus neohibernicus	Great Flying Fox				I	I	TI			1 dentary from Paru

Notes: Values for the IUCN categories are explained in Table 1. Listings under the PNG *Fauna Act*: P = Protected. Cell values are: T = trophy examined; I = informant testimony.

Appendix 3.13. Miyan names for native mammals.

FAMILY/ENGLISH NAME	SCIENTIFIC NAME	MORREN (1989)	FLANNERY (1995)	APLIN (FIELD SURVEY)	MORREN (1989) NOTES	APLIN NOTES
Tachyglossidae						
Long-beaked Echidna	*Zaglossus* sp.	*No Takel*	*Yakeil*		"relatively rare … and taken opportunistically typically above 1,000 m" p.123	Not hunted from Wameimin 2 but found using dogs in 'cold' forests
Dasyuridae						
New Guinean Quoll	*Dasyurus albopunctatus*		*Tangtangib*	*Tangtangibo Hom*		
Three-striped Dasyure	*Myoictis melas*	*No Tangtangibo Hom*	*Hom*	*Tangtangibo Hom**		
Black-tailed Dasyure	*Murexechinus melanurus*	*No Temiyap*	*Bumtaing*		"occurs in small numbers everywhere" p.124	
Short-furred Dasyure	*Murexia longicaudata*	*No Tangtangibo*		*Tangtangibo**	"Informants associate it with the May River" p.123 (i.e. lower elevations)	
Peramelidae						
Raffray's Bandicoot	*Peroryctes raffrayana*	*No Duwin*	*Duwin*	*Duwin*	"only encountered occasionally" p. 125	
Clara's Spiny Bandicoot	*Echymipera clara*	*No Kiyok*	*Kiyok*	*Kiyok**	"uncommon in the Miyanmin range" p. 124	Said to be most often caught at lower elevations. Rare in trophy jaw collection
Common Spiny Bandicoot	*Echymipera kalubu*	*No Aiyal*	*Aiyal*	*Aiyal**	"very common … encountered in gardens" p. 124	Most abundant species in trophy jaws
Long-nosed Spiny Bandicoot	*Echymipera rufescens*		*Aiyal*	*Aiyal**		Second most abundant species in trophy jaws
Striped Bandicoot	*Microperoryctes longicauda*			*Duwin*		
Phalangeridae						
Mountain Cuscus	*Phalanger carmelitae*	*No Satol*		*Satol*		
Ground Cuscus	*Phalanger gymnotis*	*No Kwiyam*	*Quoyam*	*Kwiyam***	"a common cuscus said to be present in forest above 1,000 m but most commonly encountered in secondary growth and other disturbed areas below that elevation" p. 125	Said to be common at all elevations
Telefomin Cuscus	*Phalanger matanim*			*Nelem*		Said to be the same taxon as *matan* of Telefol people; found locally in Miyan territory. Note that *Nelem* listed by Flannery (1995) as a Telefol name for *Phalanger vestitus*
Southern Common Cuscus	*Phalanger orientalis*	*No Ibim (male); No Ariken (female)*	*Maetol; Aligin; Ibim*	*Aligin*; Ibim**	"very common . almost always taken in 5 – 10 year second growth" p. 125	Most abundant cuscus species in trophy collections
Stein's Cuscus	*Phalanger vestitus*			*Nelem*		
Common Spotted Cuscus	*Spilocuscus maculatus*	*No Tekep Duruku or No Tekep Nema (male); No Tekep Gaong (female)*	*Tekeib*	*Tekep**	"mid-elevation . centred on 1,000 m, and *P. rufoniger* as a lowland species" p. 126	

FAMILY/ENGLISH NAME	SCIENTIFIC NAME	MORREN (1989)	FLANNERY (1995)	APLIN (FIELD SURVEY)	MORREN (1989) NOTES	APLIN NOTES
Black-spotted Cuscus	*Spilocuscus rufoniger*	*No Tekep Derakeman (male); No Tekep Asul (female)*	*Tekeib?*	*Tekep**	"one trophy skin and a skull purchased in 1968. According to informants, it is found in the May River valley" p. 127	Not represented in trophy collection at Wameimin 2. Trophy jaw photographed at Nekiei Village.
Pseudocheiridae						
Lowland Ringtail Possum	*Pseudochirulus canescens*		*Sobim*	*Sobim*; Befagam**		Said to be common, especially in sago swamps. Note that *Sobim* listed by Flannery (1995) as a Telefol name for *P. forbesi*
Masked Ringtail Possum	*Pseudochirulus larvatus*	*No Tifon (male?); No Sobim (female?)*			"common in forest above 1,000 m and occurs sporadically below that elevation" p. 127	
Coppery Ringtail Possum	*Pseudochirops cupreus*	*No Nenem (male?); No Kiyong (female?)*			"common above 2000 m"	
Petauridae						
Striped Possum	*Dactylopsila trivirgata*	*No Kwidiaim*	*Kwidiaim*	*Kwidiaim*		Said to be common at all elevations
Sugar Glider	*Petaurus breviceps*	*No Befagam*	*Mayfagam*	*Befagam*	"probably common but no one bothers to hunt these tiny animals systematically" p. 128	
Acrobatidae						
A Feather-tail Possum	*Distoechurus* sp.	*No Mamsenabu*	*Mayfagam*	*Mamsenabu**		Said to be common in gardens and forest around Wameimin 2 but not present locally around Wameimin 1
Macropodidae						
Doria's Tree Kangaroo	*Dendrolagus notatus*	*No Debalim Asul/Melil*		*Debalim*	"known from the undisturbed montane forests of the upper slopes of Mt Stolle" p. 128	Said to be found in 'cold' forests, together with Yema
Goodfellow's Tree Kangaroo	*Dendrolagus goodfellowi*	*No Yema*	*Yemma; Timboyok*	*Yema***	"The geographic spread of the specimens is extensive. … from the Donner Range above 2000 m . others came from the May, San and upper Uk valleys" p. 129	Trophy tail said to come from the Nena limestone plateau, otherwise common in 'cold' forests
White-striped Dorcopsis	*Dorcopsis hageni*	*No Sumul Soiyabu*	*Soyabu*	*Sumul*; Bitinawi**	"They know it from the hunting territories of the small lowland Miyanmin groups such as the Hotmin … where it inhabits the scrub vegetation subject to inundation as well as adjacent foothills" p. 129	Said to be common in lowlands, along big rivers
Small Mountain Dorcopsis	*Dorcopsulus vanheurni*	*No Sumul*		*Soyabu*	"common in undisturbed mid-montane forest above 1600 m" p. 129	Said to be common in 'cold' forests
Brown's Pademelon	*Thylogale browni*		*Sumul*	*Sumul*		Said to be found In hills, below *soyabu*
Muridae						
Water Rat	*Hydromys chrysogaster*	*No Aiyam*	*Ayam*	*Ayam**		

FAMILY/ENGLISH NAME	SCIENTIFIC NAME	MORREN (1989)	FLANNERY (1995)	APLIN (FIELD SURVEY)	MORREN (1989) NOTES	APLIN NOTES
Eastern White-eared Giant Rat	*Hyomys goliath*	*No Afut (male?); No Debam (female?)_*			"encountered only above approximately 1600 m where small numbers are taken opportunistically" p. 131	
Lowland Mammelomys	*Mammelomys rattoides*	*No Temeya*	*Temeya*	*Temeya**	"common forest dweller … occupies ground burrows communally" p. 133	
Black-tailed Mosaic-tailed Rat	*Melomys rufescens*	*No Abul, No Abul Sombo*	*Dawan*		"abundant … forest gaps, abandoned gardens, vacant settlements, uninhabited houses and grassy areas" p. 132.	
Northern Groove-toothed Shrew Mouse	*Microhydromys richardsoni*			*Briazu**		
Lowland Mosaic-tailed Rat	*Paramelomys platyops*	*No Briazu; No Briazu Dowan*	*Abul*		"common inhabitant of the edges of natural and man-made gaps in the forest" p. 133	
Mountain Mosaic-tailed Rat	*Paramelomys rubex*		*Briazu*			
Chestnut Tree Mouse	*Pogonomys macrourus*	*No Idam*			"occurs near human settlement as well as in the bush … makes ground burrows" p. 133	
Spiny Rat and/or Stein's Rat	*Rattus praetor and/or Rattus steini*	*No Sanuk*	*Senok*	*Sanuk**	"common ,,, the village rat … also common in productive or recently harvested gardens and, according to informants, in the bush" p. 132	
Giant naked-tailed Rat	*Uromys anak*			*Kwaimo*		
Giant White-tailed Rat	*Uromys* affin. *caudimaculatus*[8]	*No Kwateribo*	*Quaterib*	*Kwateribo**	"relatively common in lowland and lower montane forest … occasionally ventures into gardens and plantations" p. 131.	Said to be common everywhere; climbing
Rock-dwelling Rat	*Xenuromys barbatus*	*No Bobol*	*Boboyamin*	*Bobo***	"partly aquatic, "nesting under stones or in burrows beside streams" p. 132	Said to be less common than Kwateribo and to spend more time on the ground; living among rocks
Unidentified "tiny forest rat"		*No Titiyabu*			"elusive and only rarely encountered" p. 133	
Suidae						
Feral Pig	*Sus scrofa*	*El Halap*			Halap	
Pteropodidae						
Lesser Naked-backed Fruit Bat	*Dobsonia minor*			*Katep**		
Moluccan Naked-backed Fruit Bat	*Dobsonia moluccensis*	*Wan Katep*	*Ketab*	*Katep**		
Broad-striped Tube-nosed Fruit Bat	*Nyctimene aello*		*Uleuelabu*			
Common Tube-nosed Fruit Bats	*Nyctimene albiventer* group	*Wan Timinim*	*Raulabo*	*Raulabo*; Wan Katep**		
Green Tube-nosed Fruit Bat	*Paranyctimene raptor*	*Wan Uleulalabu*	*Raulabo*			
Bismarck Flying-fox	*Pteropus neohibernicus*		*Sewio*			

FAMILY/ENGLISH NAME	SCIENTIFIC NAME	MORREN (1989)	FLANNERY (1995)	APLIN (FIELD SURVEY)	MORREN (1989) NOTES	APLIN NOTES
Unidentified Flying Fox	*Pteropus sp.*	*Wan Sewi*		*Sewi*		
Long-nosed Blossum Bat	*Macroglossus minimus*		*Timinim*			
Common Blossom Bat	*Syconycteris australis*	*Wan Timinim Wafume*	*Timinim*	*Timinim**		
Emballonuridae						
Lesser Sheath-tailed Bat	*Mosia nigrescens*	*Wan Uleulalabu*	*Heba-heba*	*Heba-heba**		
Hipposideridae						
Diadem Leaf-nosed Bat	*Hipposideros diadema*		*Tibinim*			
Fly River Leaf-nosed Bat	*Hipposideros muscinus*	*Wan Timinim*				
Vespertilionidae						
New Guinea Pipistrelle	*Pipistrellus angulatus*	*Wan Timinim*				

Notes: Included are additional notes derived from informants' testimony and previous ethnographic literature. Names and information are derived from three sources: Morren (1989), Flannery (1995), and village interviews and casual discussion with XFRL field staff during the field survey. Some of Flannery's names may be sourced from Morren but the contrasting spelling suggests otherwise. Names marked with a single asterisk in the 'Aplin field survey' column were verified by using freshly dead specimens; a double asterisk indicates verification using a trophy jaw/skull, or a tail/piece of skin.

Appendix 3.14. Summary of the methods by which each mammal species was detected

TAXON			STATUS			NON-VOLANT MAMMALS							BATS					NUMBER OF DIFFERENT METHODS
FAMILY	GENUS AND SPECIES	ENGLISH NAME	IUCN	PNG	INTRODUCED TO PNG	GROUND TRAPPING	CAMERA TRAPPING	NIGHT TRANSECT	DAY PATROL	AERIAL SURVEY	INFORMANT INTERVIEWS	HUNTER TROPHY	MIST NETTING	HARP TRAPPING	SCOOP NET	CAVE SEARCHES	ACOUSTIC SURVEY	
Tachyglossidae	*Zaglossus* sp.	A Long-beaked Echidna	CR	P							+							1
Dasyuridae	*Dasyurus albopunctatus*	New Guinean Quoll	NT								+							1
	Myoictis melas	Three-striped Dasyure				+					+							2
	Murexia longicaudata	Short-furred Dasyure				+	+				+							3
Peramelidae	*Peroryctes raffrayana*	Raffray's Bandicoot					+											1
Peramelidae	*Echymipera clara*	Clara's Spiny Bandicoot						+				+						2
	Echymipera kalubu	Common Spiny Bandicoot				+		+				+						3
	Echymipera rufescens	Long-nosed Spiny Bandicoot						+				+						2
	Echymipera sp. indet.	A Spiny Bandicoot					+	+										2
	Microperoryctes longicauda	Striped Bandicoot									+							1
Phalangeridae	*Phalanger cf. carmelitae*	Mountain Cuscus						+										1
	Phalanger gymnotis	Ground Cuscus					+				+	+						3
	Phalanger matanim	Telefomin Cuscus	CR	P							+							1
	Phalanger orientalis	Northern Common Cuscus						+			+	+						3
	Spilocuscus maculatus	Common Spotted Cuscus		P							+	+						2
	Spilocuscus rufoniger	Black-spotted Cuscus	CR								+	+						2
Pseudocheiridae	*Pseudochirulus canescens*	Lowland Ringtail Possum						+										1
	Dactylopsila trivirgata	Striped Possum									+							1
Petauridae	*Petaurus breviceps*	Sugar Glider									+							1
Acrobatidae	*Distoechurus* sp.	Feather-tailed Possum						+										1
Macropodidae	*Dendrolagus notatus*	Doria's Tree Kangaroo	VU	P							+							1
	Dendrolagus goodfellowi	Goodfellow's Tree Kangaroo	EN	P							+	+						2

TAXON			STATUS			NON-VOLANT MAMMALS							BATS					NUMBER OF DIFFERENT METHODS
FAMILY	GENUS AND SPECIES	ENGLISH NAME	IUCN	PNG	INTRODUCED TO PNG	GROUND TRAPPING	CAMERA TRAPPING	NIGHT TRANSECT	DAY PATROL	AERIAL SURVEY	INFORMANT INTERVIEWS	HUNTER TROPHY	MIST NETTING	HARP TRAPPING	SCOOP NET	CAVE SEARCHES	ACOUSTIC SURVEY	
	Dorcopsis hageni	White-striped Dorcopsis					+				+	+						3
	Dorcopsulus vanheurni	Small Mountain Dorcopsis	NT								+							1
	Thylogale browni	Brown's Pademelon	VU						+		+							2
Muridae	*Hydromys chrysogaster*	Water Rat				+	+				+							3
	Lorentzimys sp.	Long-footed Tree Mouse				+												1
	Mammelomys rattoides	Lowland Mammelomys				+	+	+				+						4
	Melomys rufescens	Black-tailed Melomys				+							+					2
	Microhydromys richardsoni	Northern Groove-toothed Shrew Mouse	DD			+												1
	Paramelomys platyops	Lowland Mosaic-tailed Rat				+		+										2
	Pogonomys cf. *loriae*	Large Tree Mouse						+										1
	Pogonomys cf. *mollipilosus*	Large Tree Mouse	NE					+										1
	Pogonomys macrourus	Chestnut Tree Mouse						+										1
	Rattus praetor	Spiny rat				+												1
	Rattus rattus	Black Rat			yes			+										1
	Rattus steini	Stein's Rat				+												1
	Uromys affin. *caudimaculatus*	Giant White-tailed Rat					+					+						2
	Xenuromys barbatus	Rock-dwelling Rat										+						1
Suidae	*Sus scrofa*	Feral Pig			yes		+		+		+	+						4
Emballonuridae	*Mosia nigrescens*	Lesser Sheath-tailed Bat						+					+		+		+	4
Hipposideridae	*Aselliscus tricuspidatus*	Trident Leaf-nosed Bat											+	+	+		+	4
	Hipposideros ater	Dusky Leaf-nosed Bat							+									1
	Hipposideros cervinus	Fawn Leaf-nosed Bat												+				1
	Hipposideros diadema	Diadem Leaf-nosed Bat											+				+	2

TAXON			STATUS			NON-VOLANT MAMMALS						BATS					NUMBER OF DIFFERENT METHODS
FAMILY	GENUS AND SPECIES	ENGLISH NAME	IUCN	PNG	INTRODUCED TO PNG	GROUND TRAPPING	CAMERA TRAPPING	NIGHT TRANSECT	DAY PATROL	AERIAL SURVEY	INFORMANT INTERVIEWS	HUNTER TROPHY	MIST NETTING	HARP TRAPPING	SCOOP NET	CAVE SEARCHES	ACOUSTIC SURVEY	
	Hipposideros maggietaylorae	Maggie Taylor's Leaf-nosed Bat						+					+	+			+	4
	Hipposideros wollastoni	Wollaston's Leaf-nosed Bat												+			+	2
	Miniopterus magnater	Large Bent-winged Bat	DD										+				+	2
Pteropodidae	*Macroglossus minimus*	Long-nosed Blossom Bat											+					1
	Syconycteris australis	Common Blossom Bat											+	+				2
	Syconycteris cf. *finschii*	Bismarck Blossom Bat	NE										+					1
	Nyctimene aello	Broad-striped Tube-nosed Fruit Bat						+					+					2
	Nyctimene draconilla	Lesser Tube-nosed Fruit Bat	DD										+					1
	Nyctimene albiventer papuanus	Tube-nosed Fruit Bat											+					1
	Nyctimene sp. A	Tube-nosed Fruit Bat	NE										+					1
	Nyctimene sp. B	Tube-nosed Fruit Bat	NE										+					1
	Paranyctimene raptor	Green Tube-nosed Fruit Bat											+					1
	Paranyctimene tenax	Steadfast Tube-nosed Fruit Bat											+					1
	Dobsonia minor	Lesser Naked-backed Fruit Bat											+	+				2
	Dobsonia moluccensis	Moluccan Naked-backed Fruit Bat						+					+			+		3
	Pteropus macrotis	Large-eared Flying Fox											+					1
	Pteropus neohibernicus	Great Flying Fox								+		+						2
	Pteropus sp. (large)	A large Flying Fox							+									1
Rhinolophidae	*Rhinolophus philippinensis*	Large-eared Horseshoe Bat															+	1
Vespertillionidae	*Myotis moluccarum*	Moluccan Myotis												+			+	2
	Nyctophilus microtis	Papuan Long-eared Bat												+				1
	Nyctophilus affin. *microtis*	Papuan Long-eared Bat	NE										+	+			+	3

TAXON			STATUS			NON-VOLANT MAMMALS							BATS					NUMBER OF DIFFERENT METHODS
FAMILY	GENUS AND SPECIES	ENGLISH NAME	IUCN	PNG	INTRODUCED TO PNG	GROUND TRAPPING	CAMERA TRAPPING	NIGHT TRANSECT	DAY PATROL	AERIAL SURVEY	INFORMANT INTERVIEWS	HUNTER TROPHY	MIST NETTING	HARP TRAPPING	SCOOP NET	CAVE SEARCHES	ACOUSTIC SURVEY	
	Pipistrellus angulatus	New Guinean Pipistrelle												+			+	2
	Pipistrellus papuanus	Lesser Papuan Pipistrelle											+					1
Unallocated bat call types	*17 sh.cFM (Saccolaimus sp. or molossid?)*																+	1
	20 cFM (Saccolaimus sp. or molossid?)																+	1
	24 cFM (Saccolaimus sp.)																+	1
	27 sh.cFM.d (Emballonura sp.)																+	1
	30 st.cFM (Saccolaimus sp. or molossid?)																+	1
	34 i.fFM.d / sCF (Emballonura sp.)																+	1
	42 cFM (a vespertilionid)																+	1
	42 i.fFM.d (Emballonura sp.)																+	1
	47 sCF / i.fFM.d (Emballonura sp.)																+	1
	55 st.cFM.d / cFM (a vespertilionid)																+	1
	75 mCF (Hipposideros semoni or H. muscinus)																+	1
	90 mCF (Hipposideros semoni or H. muscinus)																+	1
Total species per method						**11**	**9**	**18**	**4**	**1**	**19**	**14**	**21**	**10**	**2**	**1**	**22**	

Notes: each entry denotes that that the species was detected by that method together with total number of methods the species was detected with. Values for the IUCN categories are explained in Table 1. Listings under the PNG *Fauna Act*: P = Protected

Chapter 4 Birds

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A report prepared for Coffey Environments and

Frieda River Limited

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ABBREVIATIONS USED

ca.	Approximately
cf.	Compare
cm	Centimetres
CR	Critically Endangered (IUCN threat category)
DD	Data Deficient (IUCN threat category)
EAAF	East Asian-Australasian Flyway
EN	Endangered (IUCN threat category)
EBA	Endemic Bird Area
FIMS	Forest Inventory Mapping System
ha	Hectares
IUCN	International Union for Conservation of Nature and Natural Resources
IUCN species	A species listed in the IUCN Red List as other than Least Concerned
km	Kilometres
LC	Least Concern (IUCN threat category)
m	Metres
NT	Near Threatened (IUCN threat category)
P	Species protected under the PNG *Fauna (Protection & Control)Act 1966*
PNG	Papua New Guinea
sp.	Species (singular)
spp.	Species (plural)
VU	Vulnerable (IUCN threat category)

EXECUTIVE SUMMARY

As part of an environmental impact assessment of the Frieda River Copper-Gold Project (the Project), this reportexamines the results of bird surveys conducted within a *ca.* 350,000 ha Study Area in Sandaun and East Sepik Provinces, Papua New Guinea (PNG) in 2009–11. These are the first major avifauna surveys to have been conducted within the Study Area.

For the purposes of this report, the Study Area is divided into three biogeographically distinct sectors: (1) the Study Area Lowland Zone, comprising lowland alluvial habitats of the upper Sepik River Basin, is here defined as all lands below 100 m elevation; (2) the Study Area Hill Zone comprises the northern foothills of the Central Cordillera between 100 and 1,000 m elevation; and (3) the Study Area Montane Zone comprises the northern slopes of the Central Cordillera above 1,000 m elevation.

Formal surveys were conducted in four stages. Trip 1 surveys were conducted from five locations centred on the Nena River catchment (Hill Zone) between 29 November and 15 December 2009. Trip 2 surveys were conducted from eight sites in the Project's mine area (Hill Zone) and Frieda River drainage between 1 February and 3 March 2010. Trip 3 surveys were conducted from five sites in the Frieda River drainage and the Study Area Lowland Zone between 26 May and 18 June 2010. Trip 4 surveys were conducted from two sites in the Study Area Lowland Zone from 23 February to 2 March 2011. Data from these surveys are supplemented with observations made at various locations during reconnaissance of the Study Area during 7–20 October 2009 and on 1 November 2010.

Survey sites were positioned to cover a representative sample of the elevations and the habitats present throughout the Study Area. The bird surveys were deemed sufficient to document a high proportion of the avifauna likely to occur in the Study Area Hill and Lowland zones, though a number will have gone undetected in these areas and more species may be expected to occur in the Study Area Montane Zone.

A total of 220 bird species from 44 families was recorded. The highest number of species was recorded from Iniok Site (93), Wario Site (90), Nena Base Site (87), Kaugumi Site (84), Upper Ok Binai Site (81), Malia Site (80), Frieda Bend Site (76), Ok Isai Site (73) and at Hauna (and lakes) Site (72).

Of the species recorded thus far, 23 are of global and/or national conservation significance, including 10 listed by the IUCN as Vulnerable (Northern Cassowary, Pesquet's Parrot, Victoria Crowned-Pigeon, New Guinea Eagle), Near Threatened (Dwarf Cassowary, New Guinea Flightless Rail, Doria's Goshawk, Forest Bittern) or Data Deficient ([Blue-black Kingfisher], [Wallace's Owlet-Nightjar]). No Critically Endangered or Endangered birds were recorded during the surveys or are expected to occur. Two of these species are Protected under the PNG *Fauna (Protection and Control)Act 1966*, and a further 13 species are listed under the Act but are listed as of Least Concern by IUCN.

A cluster analysis comparing species composition among sites showed that most survey sites separated into two clusters corresponding with a bioregional distinction between (1) the Study Area Hill and Montane zones and (2) the Frieda River drainage and Study Area Lowland Zone. Within the first group there was further separation between mid-elevation sites and upland sites. At a finer scale a number of site-pairs yielded similar bird communities, most notably the Malia–Upper Ok Binai Sites, Ok Isai–Kaugumi Sites, Wario–Wogamush Sites, Frieda Base–Nena D1 Sites and the Nena Base–Nena Limestone Sites. The most distinctive bird communities were recorded at HI Site/Ubiame Site, East Sepik Site and Iniok Site.

Within the Study Area Hill Zone, despite an almost continuous cover of intact forest, individual species were not distributed evenly across the landscape. Rather, many birds were distributed patchily between sites in response to spatial variation in habitat features (e.g. elevation, terrain, floristic structure and composition) and temporal variation in resource availability (e.g. fruits and flowers).

In the Study Area Lowland Zone, the East Sepik Site was located in Peat Forest, a habitat hitherto undetected in PNG and little known in Indonesian Papua. Although species-poor, the bird community was highly distinctive, not only in relation to other habitats within the Study Area but also to those elsewhere in New Guinea.

Half of all bird species recorded in the Study Area were recorded at the Iniok and Hauna (and lakes) Sites. Extensive and diverse wetlands present at these sites provide important foraging and breeding habitat for many waterbirds, contributing significantly to the overall diversity to the Study Area and to the upper Sepik River Basin as a whole. Unfortunately, evidence suggests that local waterbird populations have declined significantly in recent years. The scale and mechanisms of these declines are poorly known.

An additional 195 species not yet recorded may occur in the Study Area in light of current information on distribution and habitat preference. Possible additional species include 11 birds listed by the IUCN as Vulnerable, Near Threatened or Data Deficient, and nine species Protected under the PNG *Fauna (Protection and Control)Act 1966*.

The Study Area is of high conservation value due to its large size, remoteness and high degree of connectivity among a variety of intact/undisturbed habitats that span a broad elevation range and a variety of topographies and soil types. Accordingly, the Study Area still supports a diverse and predominantly intact avifauna, including viable populations of a number of hunting-sensitive species now scarce or absent in the vicinity of many settled areas.

1 INTRODUCTION

1.1 Avian Diversity in New Guinea

New Guinea is among the most biologically diverse and endemically rich regions on Earth (Olson and Dinerstein 1998; Brooks *et al.* 2006). The world's second largest island, it supports the third largest block of unbroken tropical rainforest (behind the Amazon and the Congo) and the largest tract of primary rainforest remaining in the Asia-Pacific region (Beehler 2007a; Shearman *et al.* 2009). New Guinea's forests support more than five percent of the world's plant and animal species on less than one percent of its land surface (Faith *et al.* 2001). Moreover, with an isolated and complex biogeographic history, some two thirds of New Guinea's biota is endemic.

New Guinea and its satellite islands have been the centre of diversity for numerous avian taxa. The region supports most of the world's species of birds-of-paradise (Corvidae: Paradisaeini), bowerbirds (Ptilorhynchidae), 'Australasian' robins (Petroicidae), cassowaries (Casuariidae) and owlet-nightjars (Aegothelidae), and is the only place in which berrypeckers and longbills (Melanocharitidae) and pitohuis are found (del Hoyo *et al.* 1999, 2007, 2008; Mack and Dumbacher 2007). Of the more than 800 bird species recorded in New Guinea some 330 (*ca.* 41%) are endemic (Coates 1985; Beehler *et al.* 1986).

Despite the diversity and high public profile of New Guinea's unique birdlife, and the high global conservation value of its tropical forests, relatively little is known of the distribution and ecology of avifauna across much of the island. Biological exploration has been limited by logistic constraints, poor weather, difficult terrain and/or law and order issues such that available information remains piecemeal. Consequently, many regions have not been surveyed for the better part of a century or remain entirely unexplored, with new bird species being discovered on the island as recently as 2006 (Beehler *et al.* 2007a).

1.2 The Frieda River Copper-Gold Project and the Study Area

The Frieda River Copper-Gold Project (the Project) is located in north-west mainland Papua New Guinea (PNG)and covers a variety of terrains that support a wide range of predominantly undisturbed habitats. As currently planned, Project components and infrastructure will traverse across the Sandaun and East Sepik provinces, from the location of the Horse-Ivaal-Trukai, Ekwai and Koki copper and gold deposits in the northern hills of the Central Cordillera north-east to the Sepik River.

The Project disturbance area lies within a ca. 350,000 ha biodiversity Study Area (hereafter Study Area) defined for the purpose of studying the terrestrial biotic communities within the Project disturbance area and surrounds. The Study Area is bounded to the north by the Sepik River, to the west by the Saniap, Usake and Upper May rivers, to the east by the Wogamush, Hewe, Miwe and Tau rivers, and to the south by the 1,500 m elevation contour (Figures 2 and 3 in Chapter 1).

The Study Area spans two major, distinct terrain features:

- The upper Sepik River Basin.
- The north-central slopes of the Central Cordillera.

For the purposes of this study, the Study Area is further divided into the following three biogeographically distinct sectors.

1.2.1 Study Area Lowland Zone

The Study Area Lowland Zone comprises lowland alluvial habitats of the upper Sepik River Basin. With a catchment of more than 80,000 km^2 (Revenga *et al.* 2003) the Sepik River Basin is the largest river system in PNG (Osborne 1989; Miller *et al.* 1994) and is regarded as the largest and least contaminated freshwater system in the Asia-Pacific region (WWF 1999). The Study Area traverses approximately 30 km north across the Sepik River Basin from the Study Area Hill Zone to the upper Sepik River. Most of this region is flat, lies below 80 m elevation and is subject to flooding, particularly during the November–March wet season. Isolated small hills occur as outliers of the Central Cordillera.

The Study Area Lowland Zone consists of depositional landforms below 100 m elevation resulting from past or present overbank flooding of the Sepik River and its major tributaries. This zone is one of flat lands forming river floodplains and excludes the isolated hills that jut out of the plains even where these hills do not reach 100 m elevation; these hills are rightly regarded part of the Study Area Hill Zone (Section 1.2.2) as their vegetation is not subject to the effects of overbank river flooding due to the abrupt gradient change at their bases.

Vegetation of the Study Area Lowland Zone is dominated by large tracts of Mixed Swamp Forest (Fsw), Swamp Woodland (Wsw), Alluvial Wooded Swamp Complexes (Wsw/Fsw), Lowland Open Forest (Po) and Peat Forest. Freshwater habitats include the Sepik River and its many permanent tributaries, the larger of which include the Frieda, Wario, Wogamush and Saniap rivers, and numerous permanent, standing water-bodies such as oxbow and tributary lakes. Lake Warangai and Lake Warwi are the largest natural lakes present within the Study Area, the former located 5 km west of Frieda River, the latter between the Frieda and Wario rivers. Large areas of natural disturbance are present alongside the major water-bodies where flooding and shifting river flows have resulted in mobile successions. Habitats in these areas comprise a series of Riverine Mixed Successions (Fri/Wri) and include mudflats, floodplain grasslands and secondary forest at varying stages of regeneration grading into riparian Lowland Open Forest (Po).

The Study Area Lowland Zone supports ca. 20 villages, most of which occur on or east of the Wario River or on the Sepik River. The area south of the Sepik River and between the Saniap and Wario rivers, which makes up most of the Study Area Lowland Zone, is only sparsely populated, the only settlements there being Auom 3 on the south-western shores of Lake Warangai, Paupe on the Frieda River immediately downstream of Frieda Airstrip and Hauna near Lake Warwi.

1.2.2 Study Area Hill Zone

The Study Area Hill Zone comprises that part of the Study Area overlying the north-central slopes of the Central Cordillera up to 1,000 m elevation. It spans ca. 70 km east-west between the Tau and Upper May rivers, and extends ca. 35 km south from the Study Area Lowland Zone, from below 100 m elevation in the foothills immediately above the Sepik River Basin south to the 1,000 m contour. At its western extremity it incorporates the Mianmin Divide east of the Upper May River. The Study Area Hill Zone is dominated by steep terrain and consists of primary erosional and colluvial (i.e. slope deposit) landforms. It includes not only those continuous hills and ranges of the Central Cordillera proper, but also those isolated hills surrounded by areas of active alluviation in the Study Area Lowland Zone.

The mineral deposits and the majority of areas development of the Project may occur are situated within the Frieda River catchment in the Study Area Hill Zone. Within this catchment, the Nena and Niar rivers meet to form the Frieda River, which, along with the Wario and Wogamush rivers to the east and the Saniap and May rivers to the west, drains north into the upper reaches of the Sepik River.

Habitat in the Study Area Hill Zone is dominated by undisturbed and little-disturbed Hill Forest (Hm) and includes numerous waterways from small, temporary streams to medium-large, permanent rivers (e.g. Nena, Niar and Frieda rivers) that drain and flow across a variety of terrains and geological substrates.

The Study Area Hill Zone is very sparsely populated. Ok Isai and Wabia are located on the Niar River within the Frieda River drainage. To the west, and beyond the Project disturbance area, Wameimin 2 lies approximately 7 km north-west of the Horse-Ival-Trukai deposit, Hotmin, Amaromin and Mabwaimin are on the Upper May River, and Urepmitabip and Wameimin 1 lie south-west of Wameimin 2. There are no settlements mapped within the Study Area Hill Zone east of the Frieda River drainage.

Disturbed habitats are largely restricted to areas around human settlement and mining exploration activities, such as around logistic and accommodation centres (e.g. Frieda Base Site) and at past and present drill sites (Nena and Horse-Ivaal-Trukai deposits). Minor areas of clearance and degradation are scattered across the Study Area Hill Zone in the form of (e.g.) helipads, drill pads, fly-camps and at temporary camps established by local residents while mining for alluvial gold.

1.2.3 Study Area Montane Zone

The Study Area Montane Zone comprises that part of the Study Area overlying the north-central slopes of the Central Cordillera between 1,000 m and 1,500 m elevation. It is dominated by steep terrain and consists of primary erosional and colluvial (i.e. slope deposit) landforms.

Habitat in the Study Area Montane Zone is dominated by undisturbed Lower Montane Forest (L ± c) traversed by numerous permanent and temporary streams. There are no permanent settlements within the Study Area Montane Zone.

In relation to the more notable peaks and ranges occurring in this sector of the Central Cordillera, the Drei Zinnen Mountains/Thurnwald Range, Gratzack Range and Star Mountains lie west-southwest of the Study Area Montane Zone (ca. 50 km, 75 km and 80 km respectively), the Donner Mountains about 45 km to the south-west, beyond them the Star Mountains and the Hindenburg Range, the Victor Emmanuel Range some 65 km to the south and the Schatteburg Mountains about 40 km to the south-east. Mount Stolle, an isolated peak that rises to over 2,800 m elevation, and the only peak above ca. 2,200 m present within the immediate vicinity, lies less than 5 km south and west of the Study Area Montane Zone (Figures 2 and 3 in Chapter 1).

1.3 Existing Information

Basic knowledge of the distribution and status of major plant and vertebrate taxa is severely limited for much of New Guinea (Beehler 2007b; Frodin 2007). In PNG this situation is most prevalent in the west (Heads 2002).

Despite being one of the best known of all vertebrate taxa, almost no bird surveys have been conducted within the Study Area itself. The most relevant studies were conducted by Joseph Bürgers, who collected some birds along the May, Frieda, Wario and April rivers and in the Lordberg and Hunstein Ranges during the German Augustafluss Expedition of 1912–13. These were later written up by Erwin Stresemann. Table 1 gives the location of sites where Bürgers collected birds from within or near the Study Area.

Elsewhere along the Central Cordillera, ornithologists have worked most closely to the Study Area at the nearby Mekil Biological Research Station on Mount Stolle. In addition to compiling a basic species inventory, detailed investigations into the behaviour and ecology of select species have also been conducted there (e.g. Carola's Parotia, Scholes 2005, 2006). Although of general interest, most or all of the work on Mount Stolle has been conducted at over 1,700 m elevation and is therefore of limited relevance to bird communities in the Study Area, particularly those of the Study Area Hill and Lowland zones.

While collecting mammals from Sandaun Province, Tim Flannery and Lester Seri made some incidental bird collections from relevant elevations west of the Study Area, most notably along the August River and

Table 1. The location of sites in or near the Study Area at which birds were collected during the 1912–13 German Sepik (Ausgustafluss) Expedition.

LOCALITY	NEAREST PROJECT SITE	DISTANCE (KM)	BEARING (DEGREES)
Maeanderberg (Mt. Meander)	Iniok Site	45.7	305
Maifluss (May River)	Iniok Site	15.2	272
Pionierlager (on/near Sepik River)	Iniok Site	6.5	292
April Fluss (April River)	Iniok Site	44.1	94
Standlager (on April River)	Iniok Site	61.4	116
Etappenberg (between April and Wario rivers)	Frieda Airstrip	58.0	93
Lordberg (Durchblick)	Frieda Airstrip	70.1	110
Hunsteinspitze (Mt. Hunstein)	Frieda Airstrip	78.8	83

* As indicated in Stresemann (1923) and Veldkamp *et al.* (1988).

tributaries (100–700 m elevation) and on the northern slopes of the Thurnwald (east Drei Zinnen) Range (ca. 1,000+ m elevation) (summarised in Rowland 1995).

Further south-west, and on the southern slopes of the Central Cordillera, a good deal of work has been conducted around the Tabubil and Ok Tedi valley areas (e.g. Gregory 1995). Bell (1969) and Murray (1988) worked the south-eastern slopes of the Star Mountains and the south-western slopes of the Hindenburg Range at elevations between ca. 100 and 1,600 m elevation, Gilliard and LeCroy (1961) worked the northern Hindenburg slopes and the eastern portion of the Victor Emanuel Mountains above 1,000 m elevation.

Other researchers (and in addition to Dr Bürgers) have worked on the Hunstein Range, an isolated range lying north of the Central Cordillera and some 55 km east of the Study Area's eastern boundary along the Hewe River. As part of the CSIRO regional surveys, Lyn Craven (botanist) collected some birds from the Hunstein Range (L. Craven, In litt. 2009), and Andrew Mack, Allen Allison and D. Wright collected specimens for the Bishop Museum there in 1989.

In the lowlands north of the Central Cordillera, a number of ornithologists have travelled along the Sepik River, some of whom have collected and/or published their records. Most (e.g. Crome and Swainson 1974; Lister 1977; Stringer 1977; Gregory 1996) did not travel upstream of Ambunti, the unofficial border separating the 'middle' and 'upper' sectors of the Sepik River. Under German administration, Carl Hunstein worked along the lower and middle Sepik River in the late 1880s. Thomas Gilliard and Mary LeCroy surveyed birds along the Sepik River from its mouth to Ambunti and in the Wewak area during the American Museum of Natural History (AMNH) expedition of 1953–54 (Gilliard and LeCroy 1966).

Further upstream, Leonhard Schulze-Jena travelled along the Sepik River to beyond the Study Area in 1909–10. P. Temple (Bishop Museum) collected birds from the upper Sepik River Basin, including the May River (and the Telefomin area) in 1963. Relatively few recreational ornithologists have published lists from the upper Sepik River Basin, and these typically only after short stays (e.g. May River area, Tolhurst 1993).

North of the Sepik River, birds have been surveyed in the North Coastal Ranges in the Torricelli Mountains (e.g. Diamond 1967, 1969; Diamond and Terborgh 1968; Hulme 1977) and in the adjacent Prince Alexander and Bewani Mountains (e.g. Pearson 1975; Beehler and Beehler 1986; Whitney 1987). Some ornithologists have published lists or records from sites around Maprik (e.g. Pearson 1975; Tolhurst 1993) and the Vanimo area (e.g. Palliser 1989; Shany 1995; Richards and Rowland 1995).

Almost all of the surveys listed above are of limited relevance to the present surveys due to their distance from the Study Area and/or occurrence in biogeographically distinct areas (e.g. North Coastal Ranges). Consequently, the information available on avifauna present in the vicinity of the Study Area is poor for the Lowland Zone and almost totally lacking for the Study Area Hill and Montane zones.

Accordingly, in 1993 the PNG Conservation Needs Assessment (CNA) defined this part of the Central Cordillera that rises south of the Sepik River Basin as one of the country's 'major terrestrial unknowns'; more specifically, that it is one of "16 major geographic areas within Papua New Guinea for which the present lack of scientific information is particularly serious" (Swartzendruber 1993).

2 OBJECTIVES

A series of biodiversity surveys was conducted throughout the Study Area in order to characterise the biodiversity values present and to identify any risks associated with Project development and operations in relation to the viability of plant and animal populations currently present in the area. This report details and discusses the results of bird surveys conducted as part of the Project surveys.

The objectives of the study were to:

1. Collate and assess existing information relevant to bird communities in the vicinity of the Study Area.

2. Survey bird communities present across the Study Area and provide expert advice on their status and conservation value.

3. Report on the status of conservationally significant bird species recorded or potentially present within the Study Area, and on their habitat requirements and the viability and importance of existing populations in a local, regional and global context.

4. Discuss the susceptibility of conservationally significant bird species to future developments of the Project.

5. Assist in the development of recommendations relevant to the protection of vulnerable taxa and/or bird communities.

This report details and discusses the results of bird surveys in relation to objectives 1–3 outlined above. Objective 3 is treated further, together with objectives 4 and 5, in the EIS.

3 SURVEY SITES AND TIMING

3.1 Overview

The major bird surveys were conducted in four stages:

- Trip 1 – Nena Surveys: 29 November to 15 December 2009. The 2009 Nena Surveys were conducted from five locations in the headwaters of the Nena (Frieda River catchment) and Usake (May River catchment) rivers.

- Trip 2 – The mine and Frieda River drainage: 1 February to 3 March 2010. The 2010 Trip 2 surveys were conducted from seven sites centred on the mine and Frieda River drainage in the Study Area Hill Zone. Surveys focused on the proposed open pit area and Koki, and other sites earmarked for development of associated logistics and infrastructure centres during the early stages of Project design. One site was surveyed in the Frieda River drainage. All of the Trip 2 survey sites were located within the Frieda River catchment.

- Trip 3 – Study Area Lowland Zone and Frieda River drainage: 26 May to 20 June 2010. The 2010 Trip 3 surveys were conducted from one site in the Frieda River drainage and five sites in the Study Area Lowland Zone. Most sites were situated in the Frieda River catchment. Surveys of the Hauna area were conducted in the April River catchment.

- Trip 4 – Study Area Lowland Zone: 23 February to 16 March 2011. The 2011 Trip 4 surveys were conducted from two sites in the Study Area Lowland Zone in the Wario and Wogamush River catchments. Limited observations were also made from Frieda Airstrip (Frieda Strip Site).

Additional data on birds were collected opportunistically during two reconnaissance visits undertaken in preparation for subsequent detailed biodiversity surveys.

- Trip 1 Reconnaissance: 7–20 October 2009. Birds were recorded at various locations in the Study Area Hill and Lowland zones while on reconnaissance for the Trip 1–3 biodiversity surveys.

- Trip 4 Reconnaissance: 1 November 2010. Birds were recorded in the Study Area Lowland Zone during a brief stop-over at Kubkain Site in preparation for the Trip 4 biodiversity surveys.

Appendix 4.1 lists the survey dates, base co-ordinates and elevations covered at each of the survey sites during each of the survey periods. The location of each survey site is shown in Figures 4 and 5 in Chapter 1.

All biotic communities undergo marked changes in species composition with change in elevation and habitat. Survey sites were positioned to cover a representative sample of the elevations and the habitats present throughout the Study Area.

A description of the FIMS vegetation within the Study Area and at each of the survey sites is presented in Chapter 2. A brief description of each study site and the habitats surveyed for birds is given below.

Table 2 lists the various non-anthropogenic habitats mentioned in the text and shows how they relate to the PNG Forest Inventory Mapping System (FIMS) vegetation types present within the Study Area. In terms of bird community structure, the FIMS coding system classifies habitats rather broadly. Consequently, some FIMS types included multiple habitat sub-categories that influence the distribution and abundance of various bird species (see Chapter 1 for vegetation terms used by the zoological chapters).

Table 2. Vegetation types present wihin the Study Area.

FIMS CODE	FIMS TYPE	TERMS USED (SEE CHAPTER 1)
HILL ZONE AND MONTANE ZONE HABITATS		
Hm	Medium crowned upland (hill) forest	Hill Forest (Hm)
		Hill Forest (Hm) below *ca.* 250 m asl
L, Lc and LN	Small crowned lower montane forest and complexes and small crowned lower montane forest with conifers and small crowned lower montane forest with *Nothofagus.*	Lower Montane Forest (L ± c)
Hm and Lc	Hill Forest (Hm) or Lower Montane Forest (L ± c) immediately adjacent to waterways (> ca. 4m wide at least flow) within continously forested areas.	Riparian Forest
STUDY AREA LOWLAND ZONE HABITATS		
Fri and Wri	Riverine Mixed Successions and Riverine successions dominated by woodland	Grassland
		Mudflats
		Riverine Mixed Successions (Fri/Wri) and Riverine Mixed Successions (Fri/Wri) with *Barringtonia/ Neonauclea*
		Riparian Forest
Po	Open low-elevation forest on (alluvial) plains and fans	Lowland Open Forest (Po)
		Lowland Open Forest (Po) with a very wet floor
Po	Lowland Open Forest (Po) immediately adjacent to waterways (> ca. 4m wide at least flow) within continously forested areas.	Riparian Forest
Fsw	Mixed Swamp Forest	Mixed Swamp Forest (Fsw)
		Mixed Swamp Forest (Fsw) with sago
Wsw	Swamp woodland	Swamp Woodland (Wsw)
	General category to refer to Swamp Woodland and Mixed Swamp Forest	Swampy Forest
N/A	Unclassified	Peat Forest

3.2 Trip 1

Nena Base Site

The base camp for the Trip 1 surveys was situated in an historic mining camp. Habitat throughout the area is dominated by Hill Forest (Hm) from ca. 750 to 1,100 m elevation. Forest in the immediate vicinity of the mining camp had been cleared some decades previously, and at the time of our survey these areas supported actively maintained lawns and gardens, and pioneer and secondary forest at varying stages of regeneration. Birds were surveyed along a pre-existing walking trail that connects Wameimin 2 with the abandoned ‘Nena bottom camp’ situated between the Nena base camp and Nena D1 Site. During the Trip 1 surveys, this trail was walked repeatedly during the main survey period (Appendix 4.1) and at times between visits to other sites.

Data on birds were collected twice from Nena Base Site outside of the Nena Survey period:

- During the Trip 1 Reconnaissance, when the author and Dr M. Sale visited the site on the morning of 15 October 2009.
- During the Trip 3 surveys, when Dr. K. Aplin camped and mist-netted at Nena Top Site on the south-west ridge (1,065 m elevation) on 6–8 June (Appendix 4.1).

Although the results of Aplin’s surveys at Nena Top Site are treated separately in Chapter 3, they are here incorporated into the results of the Nena Base Site surveys because (a) the Nena Top Site is located a short walk from the Nena Base Site, and (b) only a small number of bird species (n = 13) were recorded there (mostly by mist-netting).

Nena D2 Site

Nena D2 Site covers ca. 95 ha in a steep forested valley (Hill Forest (Hm)) at elevations between ca. 600 and 840 m elevation. Despite little or no human activity in the valley, the terrain and vegetation reflect a heavy disturbance history, with the steep, unstable slopes prone to landslip and evidence of frequent flooding present in the valley bottom. Birds were surveyed over a 24-hour period along the valley bottom.

Nena D1 Site

Situated immediately north-east and below the Nena Base Site, Nena D1 Site was situated alongside a northern tributary of the upper Nena River at 400 m elevation. Birds were surveyed over three days between ca. 365 and 500 m elevation in undisturbed Hill Forest (Hm) on terraced alluvial terrain close to and along the valley bottom.

Nena Limestone Site

Birds were surveyed over three days on a limestone plateau in the vicinity of a site formerly proposed for the development of a limestone quarry. Habitat consisted of undisturbed small-crowned Lower Montane Forest (L ± Lc) with prolific mosses and dense thickets of climbing bamboo (*Nastus productus*) present on the ridges. Other than a small, pre-existing hunting trail that led south to Wameimin 2 village, there was little evidence of human activity in this area.

Nena-Usage Site

The Nena-Usage Site was located in the headwaters of the Usake River catchment, close to the ridge that separates the May River and Frieda River catchments. Surveys were conducted over two days along a steep river valley and in undisturbed Hill Forest (Hm) on adjacent steep terrain. The river here flowed quickly through a deep, wide ravine littered with large boulders, scree, clay, timber and ephemeral weeds. Riparian Forest was absent, with Hill Forest (Hm) on slopes presenting right to the edge of precipitous river banks abutting the surge zone. A number of smaller, forested streams drained into the main river.

Warangai South Site

The Warangai South Site is located ca. 5 km south-east of Auom 3 village and west of the Frieda River. This site was surveyed for birds by the author and M. Sale during the Trip 1 Reconnaissance on 16 and 18 October 2009. The vegetation was a complex of undisturbed Swamp Woodland (Wsw) and Swamp Forest (Fsw) on alluvial terrain and Hill Forest (Hm) on isolated hills.

3.3 Trip 2

Malia Site

The base camp for the Trip 2 surveys was situated in undisturbed Hill Forest (Hm) adjacent to the middle reaches of the Nena River.

Compared to most other Study Area Hill and Montane Zone sites, this area was notable for its gentle terrain, making it a suitable location for a large accommodation and logistics centre. Birds were surveyed over eight days. Habitats surveyed included the Nena River and associated Riparian Forest at ca. 225 m elevation, and Hill Forest (Hm) and associated streams to ca. 400 m elevation.

In addition to the Trip 2 surveys the Malia Site was visited twice during the Trip 1 Reconnaissance (14 and 17 October 2009).

Koki Site

Birds were surveyed over four days in Hill Forest (Hm) on limestone and clays that ranged in elevation from ca. 510–660 m elevation. Secondary forest was present around the Koki Site, probably as a result of earlier exploration and mining activities. Hill Forest (Hm) on limestone was of a notably distinct structural and floristic character.

Frieda Base Site

During the Trip 2 surveys, two days were spent surveying birds in Hill Forest (Hm) along the track between Frieda Base Site and Horse-Ivaal-Trukai mining camp (HI Track). Partial days were also spent surveying birds along HI Track during the Trip 1 Reconnaissance (8, 9, 11, 13 and 19 October 2009).

HI Site

The Horse-Ivaal-Trukai open pit is predicted to cover an area that ranges in elevation from ca. 450 m to over 1,100 m at its western edge. Much of the area has been subjected to recent and intensive drilling exploration activities, and at the time of our visit much of the habitat, especially on the lower slopes, was disturbed and included cleared areas, pioneer and secondary Hill Forest (Hm) at various stages of regeneration. The HI Site was situated on the upper north-west slopes of the deposit, near the northern base of a cliff that runs along the deposit's western boundary, and provided access to both disturbed and remnant undisturbed habitats. Undisturbed forest generally persisted on very steep terrain that included sharp ridges and steep ravines, and included Hill Forest (Hm) and Lower Montane Forest (L ± c). Surveys were conducted over three days, mostly along a pre-existing trail that leads north from the HI Site to Wameimin 2 village.

Ubiame Site

One night was spent at Ubiame Site, the site of a communications repeater station at the summit of Ekwai de Bom, on the western edge of the proposed open pit. At over 1,350 m elevation, the habitat consisted of Lower Montane Forest with conifers (Lc).

Upper Ok Binai Site

Habitat at this site comprised undisturbed Hill Forest (Hm) on fairly steep terrain with small areas of regrowth from natural disturbance events. Surveys were conducted over five days and covered habitats from the Ok Binai (Binai River) in the valley bottom to Hill Forest ca. 250 m upslope to the south.

Frieda Bend Site

Surveys of the Frieda River were conducted during Trip 2 from a camp on the northern bank of the Nena River near its confluence with the Niar River. Surveys were conducted over five days, on foot through forest upstream of the Frieda Bend Site, and by boat along the Niar and Frieda sections of the main river between the gorge area of the Frieda River and a point immediately upstream of Wabia village. Habitats covered include undisturbed Hill Forest (Hm), Lowland Open Forest (Po) and Riverine Mixed Successions (Fri/Wri).

In addition to the main survey period, the Frieda and Niar River sections were surveyed by canoe between Frieda Strip Site and Wabia on 10 October 2009 during the Trip 1 Reconnaissance. From the 2009 canoe survey, records of birds from upstream of the gorge area of the Frieda River are included here with subsequent records from Frieda Bend Site. Records from between Frieda Airstrip and the gorge area of the Frieda River are included with records from the Frieda Strip Site (Section 3.5).

3.4 Trip 3

Ok Isai Site

The Ok Isai Site was located in Hill Forest (Hm) south of the Niar River and approximately half-way between the villages of Ok Isai and Wabia. Surveys were conducted over six days in undisturbed Hill Forest (Hm) and Lowland Open Forest (Po) with a very wet floor between camp and the Niar River. Lowland Open Forest (Po) here varied widely in stature and structural composition according to changes in flooding/inundation patterns; forest was generally taller and drier underfoot closer to the foothills. These swampy habitats showed little sign of human activity, despite their proximity to Ok Isai and Wabia (<5 km from both). North of the site, taro gardens (probably accessed by boat) were maintained on the banks of the Niar River. Gardens (taro and banana), pioneer and early successional secondary Hill Forest (Hm) were also surveyed closer to Ok Isai village.

Kaugumi Site

Kaugumi Site was located west of Frieda River and ca. 7 km north of Frieda Strip Site on a small hill amidst a mosaic of sago-rich (*Metroxylon sagu*) Swamp Woodland (Wsw) and Mixed Swamp Forest (Fsw) on flat, alluvial terrain. Birds were surveyed over six days in Swampy Forest and in Riparian Forest along a river that ran (ca.) east-west immediately north of camp.

East Sepik Site

The East Sepik Site was located ca. 5 km east of the Frieda River, 25 km north-northeast of Frieda Strip Site and 13 km south of Iniok Site. Habitat consisted of Peat Forest (Chapter 2). Birds were surveyed over five days.

Iniok Site, Hauna and Lakes

Riparian and wetland habitats along the Sepik River and adjacent lakes and waterways were surveyed on foot and by canoe from Iniok and Hauna villages. While based at Hauna guest-house (ca. 20 km east of Iniok Site), birds were surveyed over a 24-hour period on Lake Warwi, Lake Narisin, along the tributaries linking the lakes with Hauna and the Sepik River, and along the Sepik River upstream to Iniok Site. From Iniok Site birds were surveyed over five days, with significant time spent on and around Lake Warangai and the Hueap Creek (connecting Lake Warangai with the Sepik River) and in gardens and riparian habitats accessible on foot from Iniok Site (including Iniok Wi, a small lake immediately north of the village).

Natural vegetation abutting the lakes and rivers was dominated by complex Riverine Mixed Successions (Fri/Wri). These are described in detail in Chapter 2, and included areas of tussock grassland and various arborescent associations whose floristics and structure are determined by flooding patterns and shifting channel courses. A distinct form of flooded woodland, here termed Riverine Mixed Succession (Fri/Wri) with *Barringtonia/Neonauclea,* was surveyed on the eastern shores of Lake Warangai. Anthropogenic habitats were common along the navigable waterways, and included extensive gardens and numerous permanent and temporary settlements.

3.5 Trip 4

Wario Site

Wario Site was located on the eastern bank of the Wario River approximately 1 km upstream from Nekiei village. Birds were surveyed over four days in a variety of habitats, including Hill Forest (Hm), Riparian Forest (Po) alongside the Wario River, sago-rich Swamp Woodland (Wsw) and Mixed Swamp Forest (Fsw) east of Nekiei, Riverine Mixed Successions (Fri/Wri) including grassland and pioneer and secondary forest (Po), anthropogenic gardens, the Wario River and an adjacent oxbow lake immediately east of Nekiei.

Wogamush Site

Wogamush Site was located in the Wogamush River catchment ca. 4 km west of the Wogamush River and 1 km west of Lake Wati (Chapter 1 Figure 4). The camp was located on a small, isolated range of hills and immediately above the alluvial plains of the Study Area Lowland Zone. Birds were surveyed over two days in undisturbed Hill Forest (Hm), sago-rich Swamp Woodland (Wsw) and Mixed Swamp Forest (Fsw).

Kubkain Site

Kubkain Site was located on a small, isolated hill ca. 1 km south of Kubkain village on the Sepik River. Habitats include of Hill Forest (Hm) on the hill slopes, sago-rich Swamp Woodland (Wsw), Riverine Mixed Successions (Fri/Wri) and anthropogenic habitats near the Sepik River.

Kubkain Site was surveyed by the biodiversity team on 5–10 March 2011. Although no ornithologist was present during that period, casual observations by other team members and bird records from their camera-trapping and mist-netting programs are reported here. These are combined with aural and visual records collected opportunistically by the author during a brief stop-over (30 minutes) on the camp hill on 1 November 2010 during the Trip 4 Reconnaissance.

Ok Binai 1 site

Ok Binai 1 Site was located at the site of the pre-existing Ok Binai 1 fly-camp alongside the Ok Binai River. Habitats include Hill Forest (Hm), Riverine Mixed Successions (Fri/Wri) alongside the Ok Binai River and areas of disturbance created by local residents mining for alluvial gold.

Ok Binai 1 Site was surveyed by the biodiversity team on 10–15 March 2011. Although no ornithologist was present during that period, casual observations by other team members and bird records from their camera-trapping and mist-netting programs are reported here.

In addition to the main survey period, birds were surveyed by the author and M. Sale during the Trip 1 Reconnaissance on 20 October 2009.

Frieda Strip Site

Surveys of the Frieda Strip Site were made from the Frieda Airstrip and accommodation facility alongside the Frieda River. Habitats include Hill Forest (Hm), Lowland Open Forest (Po), Riparian Forest and Riverine Mixed Successions (Fri/Wri). Formal surveys were limited, being restricted to a canoe survey along the Frieda River between Frieda Airstrip and the between the gorge area of the Frieda River (Section 3.3 Frieda Bend Site) and two short surveys along the banks of the Frieda River while based at Frieda Airstrip at the beginning of the Trip 4 surveys. Results of these surveys were combined with casual observations made while waiting for transport at Frieda Airstrip at other times (Trips 1–3 and reconnaissance trips).

4 METHODS

Survey methods included transect searches, mist-netting, camera traps, call playbacks and interviews with local hunters and are discussed below. These techniques were combined to maximise the bird species inventory and the likelihood of locating rare and threatened taxa in the time available. The total effort of the various survey methods is summarised for each site in Table 3.

Table 3. Total and per-site survey effort summaries.

SITE	TRANSECT SURVEYS (MAN HOURS)	MIST-NETS (NET- METRE HOURS)	CAMERA-TRAPS (HOURS)	SOUND RECORDINGS	
				NO.	MINS
Nena Base Site	31.25	21,282.75	1,622.50	26	51.85
Nena D2 Site	12.00				
Nena D1 Site	25.25	4,999.50	182.00	25	34.57
Nena Limestone Site	27.00	2,313.75	156.50	28	35.35
Nena-Usage Site	16.50	474.00	55.00	2	0.50
Malia Site	54.00	23,132.00	2,707.00+	27	38.43
Koki Site	22.50	12,939.00	526.00		
Frieda Base	23.25	1,176.00		16	37.53
HI Site	16.50	8,359.50	429.25	11	12.68
Ubiame Site	9.00	240.00		2	4.25
Upper Ok Binai Site	36.00	10,374.00	583.25	19	34.40
Ok Binai 1 Site	4.50	144.00	491.00	1	2.02
Frieda Bend Site	36.00	10,494.00	540.25	7	11.72
Ok Isai Site	34.25	12,661.50	891.75	10	28.25
Frieda Strip Site	5.00				
Kaugumi Site	41.00	11,614.50	987.00	29	39.57
East Sepik Site	27.75	8,860.50	685.50	19	22.57
Hauna (and lakes) Site	10.50			13	6.10
Iniok Site	30.00	6,768.00	224.25	24	64.12
Warangai South Site	10.25			13	27.32
Wario Site	29.00	2,444.25	417.50	36	57.78
Wogamush Site	14.50	144.00	606.00	17	28.18
Kubkain Site	0.50	144.00	511.25		
Total	516.50	138,565.25	11,616.00+	325	537.19

4.1 Transect Surveys

Each morning and afternoon birds were surveyed on foot along walking trails or by canoe along navigable waterways. Birds were identified either visually using binoculars or by their calls. Surveys commenced at or prior to dawn on most mornings (05h15–06h15) and regularly continued until after dusk to cover active periods of both diurnal and nocturnal birds. Survey trails are shown in Figures 4 and 5 of Chapter 1.

4.2 Mist-nets

Mist-nets ranging in size from 6 to 15 m (31 mm mesh) were deployed at most sites in a variety of habitats. Mist-net locations and trapping effort are summarised for each site in Appendix 4.2. Most nets were erected close to the ground (<6 m high) on trimmed saplings, were left open continuously (day and night) and were checked at least every 1.5 hours over the period from dawn to some hours after dusk. Some nets were furled during periods of heavy rain or a few hours after nightfall and reopened at dawn. Most birds were identified and released immediately at the capture site. Some birds were brought back to camp and stored in the shade in calico bags to photograph and measure to confirm identifications.

4.3 Camera-traps

Twelve digital camera-traps (Wildtrack Photography) were deployed along animal trails and at apparent feeding stations at various sites in an effort to photograph mammals and ground birds. Units were deployed for a total of more than 11,500 camera-trap-hours (Table 3). Camera-trap locations and trapping effort are summarised for each site in Appendix 4.3.

4.4 Sound Recordings and Playbacks

Unfamiliar calls were routinely recorded while walking transects and during informal survey periods. Calls were recorded digitally on a Sony PCM-D50 Linear PCM Recorder with or without a Sennheiser ME66 cardioid microphone. Recorded calls were later matched against an extensive database of PNG bird calls. Birdsongs of positively identified species were also recorded to be later added to this growing database for future reference. Selected calls were played aloud using a 5-watt portable amplifier in an effort to elucidate a response from shy, cryptic, rare or threatened species that may be present (including, among others, pigeons, pittas, jewel-babblers, robins, owls, frogmouths, owlet-nightjars).

4.5 Hunter Interviews

Further data were collected by interviewing local landowners. Many records were provided by Yamlin Sipmap, an Ababel sub-group member and local resident from Sokamin (Wamintri) employed as a caretaker at Nena Base Site. On being shown images of birds in Beehler *et al.* (1986), Sipmap displayed a detailed and relatively accurate knowledge of the local avifauna (including, in many instances, their vocalisations) and provided an extensive list of local language names for species in and beyond the Study Area (provided in Appendix 4.4).

Additional information was collected while working with local residents who were employed by the proponent and assigned to assist with the biodiversity surveys. Relevant information was gathered opportunistically during conversations with residents of Ok Isai, Wameimin 2, Auom 3, Wabia, Hauna, Hotmin and Nekiei.

4.6 Taxonomy and Conservation Status

Nomenclature (common and scientific names) and family arrangements follow the Sibley and Monroe system (Sibley and Monroe 1990, 1993; Monroe and Sibley 1993) for most species. Birds-of-paradise follow Frith and Beehler (1998), bowerbirds Frith and Frith (2004), megapodes Jones *et al.* (1995) and cuckoos Payne (2005). Other recently accepted taxonomic changes incorporated into this report include that of Gjershaug *et al.* (2009) for Pygmy Eagle *Aquila (Hieraaetus) weiskei*, and those accepted by Christidis and Boles (2008) for Eastern Great Egret *Ardea modesta* and Variable Goshawk *Accipiter hiogaster*.

The global conservation status of all species was taken from the 2011 International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (IUCN 2011).

IUCN conservation categories rank the relative risk of individual taxa becoming extinct in the wild based on a set of standardised criteria. These categories and the conservation classifications under the PNG *Fauna (Protection & Control)Act 1966* are shown in Table 4.

Table 4. Conservation classifications used by the *PNG Fauna (Protection and Control)* *Act 1966* **and IUCN.**

PNG FAUNA (PROTECTION AND CONTROL) ACT	
Protected (P)	Taxa declared protected.
IUCN	
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.
Least Concern (LC)	Does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Abridged. For a detailed explanation see IUCN. (2001). IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp. (http://www.iucnredlist.org/technical-documents/categories-and-criteria).

Species that are listed as other than Least Concern by the IUCN are defined here as being species of international conservation significance. They are hereafter termed 'IUCN species'.

The Study Area lies across two Endemic Bird Areas (EBAs) – the Central Papuan Mountains and North Papuan Lowlands (Section 5.5). Intended to delineate centres of bird endemism, EBAs are defined by BirdLife International as distinct geographical regions that support populations of at least two Restricted Range species (total global breeding range less than 50,000 km2; Stattersfield *et al.* 1998).

In the text below, only the common names are used for those species appearing in various appendices (particularly Appendices 4.5 and 4.7); scientific names can be found in the appendices and in tables presented within the text. For species not listed in the appendices, the scientific name appears with the common name on first mention in the text, and only the common name is used thereafter.

Species appearing in square brackets (in text, tables and appendices) were only provisionally identified to species level.

4.7 Analysis

Species accumulation curves were generated for each site and for the survey as a whole.

A cluster analysis was used to explore avian community structure across the Study Area. Survey sites were clustered according to similarity in species composition by means of a hierarchical (agglomerative) cluster analysis using the SPSS (Statistical Package for the Social Sciences) version 12.0 statistical package. Statistical methods follow those described in Kattan *et al.* (2006), with a dendrogram generated from presence/absence data using the centroid method and Jaccard's similarity index. Incomplete surveys at individual sites influence the results of similarity tests. Consequently, only those sites that were surveyed over a period of at least four days were included in the cluster analysis. Records from HI Site and Ubiame Site were combined owing to their proximity, contiguity in elevation and habitat, and similar treatment in other specialist reports. The swiftlet complex *Aerodramus hirundinaceus-vanikorensis-(nuditarsus-papuensis*), the Yellow-billed and Mountain Kingfishers, Pygmy-Parrots, Fig-Parrots (*Cyclopsitta/ Psittaculirostris* spp.), Goshawks (*Accipiter* spp.), Puff-backed and Mimic Honeyeaters, and the Crinkle-collared and Jobi Manucodes, were combined as single entities due to the similar ecological requirements of the congeneric taxa and/or the difficulty in separating birds to the species level in the field (visually and/ or by call). By contrast, *Meliphaga* honeyeaters not identified to species level were removed from the data set prior to performing cluster analysis.

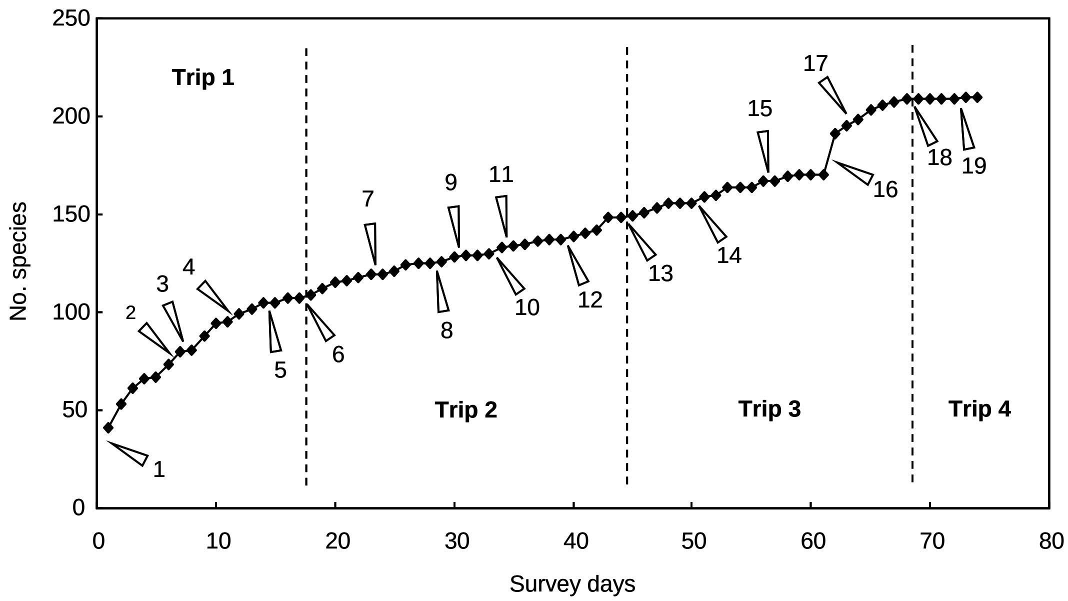
5 RESULTS

5.1 Survey Totals

A total of 220 bird species from 44 families was recorded from the Study Area. These are listed in Appendix 4.5 together with their conservation status. Most were seen or heard during transect surveys. Sixty three species (374 individual birds) were mist-netted and 12 species (34 individuals) photographed by camera-trap and/or captured by hand (at night while roosting or on the nest: 7 birds, 6 species). These are listed separately in Appendix 4.6. The majority are shown in Plates 1–12.

Of 168 species recorded in the Study Area Lowland Zone, 62 were recorded there exclusively (i.e. not recorded in the Hill or Montane zones). A total of 159 species was recorded in the Study Area Hill and Montane zones, 52 exclusively. The highest number of species was recorded at Iniok Site (93), Wario Site (90), Nena Base Site (87), Kaugumi Site (84), Upper Ok Binai Site (81), Malia Site (80), Frieda Bend Site (76), Ok Isai Site (73) and at Hauna (and lakes) Site (72).

The rate at which individual species were discovered throughout the surveys (excluding reconnaissance trips) is shown in Figure 1. Excluding trapping data, species discovery curves for each of the Phase II survey sites are shown in Figure 2.



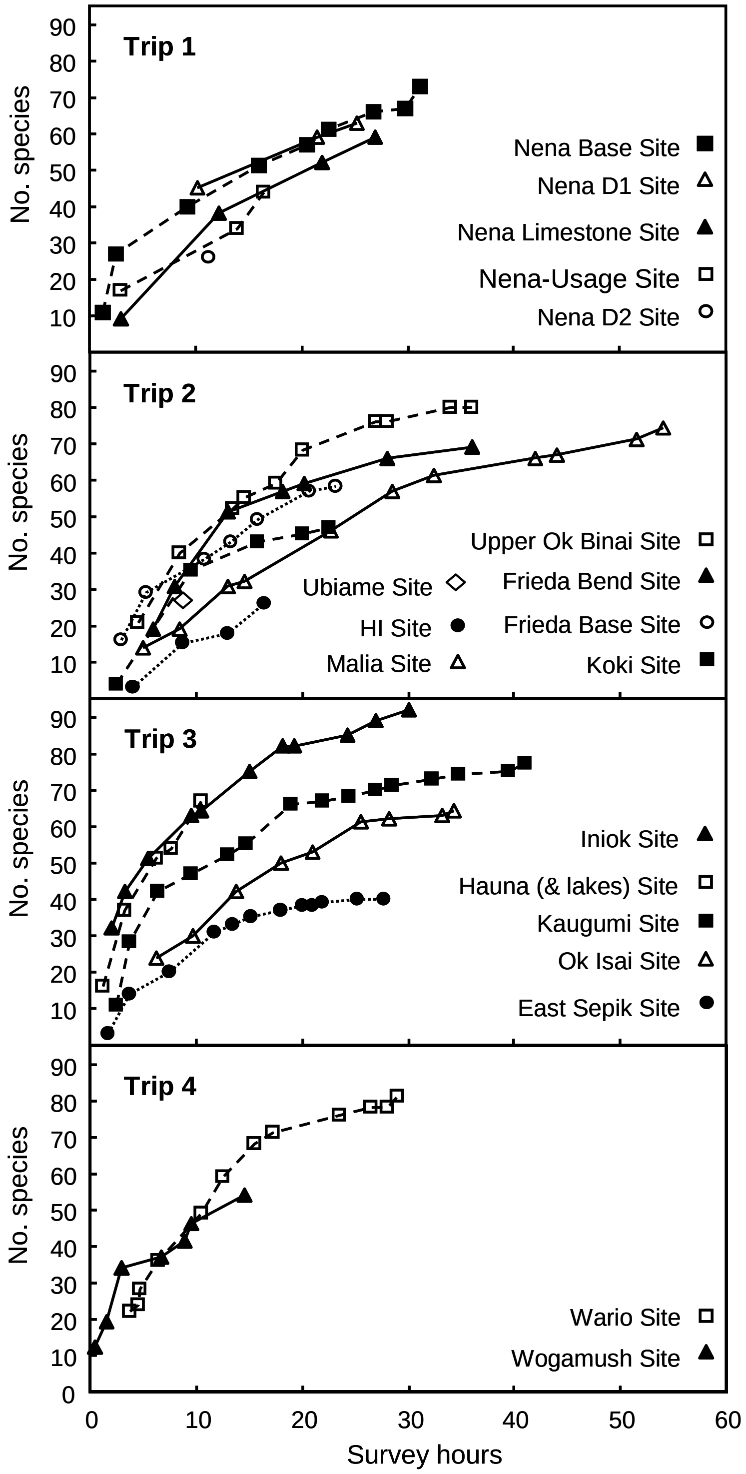
Data include species detected during active formal surveys (transects) and informal observations (trapping data excluded). Arrows indicate arrival at: Nena Base Site (1); Nena D2 Site (2); Nena D1 Site (3); Nena Limestone Site (4); Nena-Usage Site (5); Malia Site (6); Koki Site (7); Frieda Base Site (8); HI Site (9); Ubiame Site (10); Upper Ok Binai Site (11); Frieda Bend Site (12); Ok Isai Site (13); Kaugumi Site (14); East Sepik Site (15); Hauna (& lakes) Site (16); Iniok Site (17); Wario Site (18); Wogamush Site (19). (reconnaissance trips excluded)

Figure 1. Species discovery curve for all sites combined.

5.2 Widespread and Rarely Recorded Species

Of the 220 species recorded, more than one third were found at only one (50 species; 22.7%) or two (36 species; 16.4%) of the survey sites listed in Appendix 4.5.

Forty-two species (19.1%) were recorded at 12 or more (>50%) sites. Table 5 lists the 24 species that were most widespread, being recorded at 15 or more sites. The four most widespread species were Blyth's Hornbill, Black-capped Lory, Rainbow Lorikeet and Banded Imperial-Pigeon.



Data include species detected during transect surveys (trapping data excluded).

Figure 2. Species discovery curves for each of the sites surveyed during the Project surveys.

Table 5. The Study Area's most widespread bird species.

ENGLISH NAME	TOTAL SITES	LOWLAND ZONE	HILL & MONTANE ZONES
Blyth's Hornbill *Aceros plicatus*	20	10	10
Variable Kingfisher *Ceyx lepidus*	15	5	10
Rufous-bellied Kookaburra *Dacelo gaudichaud*	18	8	10
Greater Black Coucal *Centropus menbeki*	16	8	8
Rainbow Lorikeet *Trichoglossus haematodus*	21	9	12
Black-capped Lory *Lorius lory*	21	9	12
Eclectus Parrot *Eclectus roratus*	17	8	9
Palm Cockatoo *Probosciger aterrimus*	15	8	7
Sulphur-crested Cockatoo *Cacatua galerita*	19	8	11
Swiftlet sp(p). *Aerodramus* sp(p).	17	7	10
Superb Fruit-Dove Ptilinopus superbus	15	6	9
Coroneted Fruit-Dove Ptilinopus coronulatus	17	8	9
Banded Imperial-Pigeon *Ducula zoeae*	20	9	11
Tawny-breasted Honeyeater *Xanthotis flaviventer*	19	8	11
New Guinea Friarbird *Philemon novaeguineae*	19	9	10
Rusty Mouse-warbler *Crateroscelis murina*	16	5	11
Black-sided Robin *Poecilodryas hypoleuca*	15	7	8
Variable Pitohui *Pitohui kirhocephalus*	18	6	12
Grey Crow *Corvus tristis*	16	6	10
Grey-headed Cuckooshrike *Coracina schisticeps*	18	6	12
Black-browed Triller *Lalage atrovirens*	16	9	7
Spangled Drongo *Dicrurus bracteatus*	18	8	10
Yellow-faced Myna *Mino dumontii*	18	9	9
Black Sunbird *Nectarinia aspasia*	16	6	10

Figures show the number of sites each species was recorded from

5.3 Listed Species

Appendix 4.5 includes 23 species that are IUCN species and/or Protected under the PNG *Fauna (Protection and Control)Act 1966*. These are listed separately in Table 6, and include 10 species listed by the IUCN as Globally Threatened (Vulnerable: Northern Cassowary, Pesquet's Parrot, Victoria Crowned-Pigeon, New Guinea Eagle), Near Threatened (Dwarf Cassowary, New Guinea Flightless Rail, Doria's Goshawk, Forest Bittern) or Data Deficient (Blue-black Kingfisher and Wallace's Owlet-Nightjar). Fifteen species are listed as Protected under PNG legislation.

Dossiers on all these species, including details of habitat requirements and range, will be presented in the EIS.

No IUCN-listed Critically Endangered or Endangered birds were recorded during the surveys.

Table 6. Species of conservation significance recorded from the Study Area.

SPECIES	IUCN	PNG
Dwarf Cassowary *Casuarius bennetti*	NT	
Northern Cassowary *Casuarius unappendiculatus*	VU	
Blyth's Hornbill *Aceros plicatus*		P
[Blue-black Kingfisher *Todirhamphus nigrocyaneus]*	DD	
Pesquet's Parrot *Psittrichas fulgidus*	VU	
Palm Cockatoo *Probosciger aterrimus*		P
[Wallace's Owlet-Nightjar *Aegotheles wallacii*]	DD	
Victoria Crowned-*Pigeon Goura victoria*	VU	P
New Guinea Flightless Rail *Megacrex inepta*	NT	
Doria's Goshawk *Megatriorchis doriae*	NT	
New Guinea Eagle *Harpyopsis novaeguineae*	VU	P
Little Egret *Egretta garzetta*		P
Eastern Great Egret *Ardea modesta*		P
Intermediate Egret *Mesophoyx intermedia*		P
Forest Bittern *Zonerodius heliosylus*	NT	
Crinkle-collared/Jobi Manucode *Manucodia chalybata/jobiensis*		P
Glossy-mantled/Jobi Manucode *Manucodia atra/jobiensis*		P
Carola's Parotia *Parotia carolae*		P
Magnificent Riflebird *Ptiloris magnificus*		P
Magnificent Bird-of-paradise *Cicinnurus magnificus*		P
King Bird-of-paradise *Cicinnurus regius*		P
Twelve-wired Bird-of-paradise *Seleucidis melanoleuca*		P
Lesser Bird-of-paradise *Paradisaea minor*		P

Notes: IUCN categories are VU - Vulnerable, NT - Near Threatened and DD - Data Deficient. PNG: P - protected under the PNG *Fauna (Protection and Control)Act 1966.*

5.4 Migratory species

Most of the birds recorded in the Study Area are resident breeding species (204/220; 92.7%). Migratory species recorded in the Study Area are listed in Table 7. These include 12 species occurring in New Guinea only as non-breeding migrants, four species recorded only as migrants but that may also breed in New Guinea, and six species consisting of breeding residents with numbers seasonally augmented by non-breeding migrant visitors.

Migratory birds recorded and potentially occurring in the Study Area are discussed in detail in below (Section 9).

Table 7. Migratory species recorded from the Study Area.

SPECIES	MIGRATORY STATUS
Dollarbird *Eurystomus orientalis*	BR+M
Sacred Kingfisher *Todirhamphus sanctus*	M
Buff-breasted Paradise-Kingfisher *Tanysiptera sylvia*	M
Rainbow Bee-eater *Merops ornatus*	M
Oriental (/Himalayan) Cuckoo *Cuculus optatus(/saturatus)*	M
Brush Cuckoo *Cacomantis variolosus*	BR+M
Channel-billed Cuckoo *Scythrops novaehollandiae*	M
White-throated Needletail *Hirundapus caudacutus*	M
Common Sandpiper *Actitis hypoleucos*	M
Wader sp. [Sharp-tailed Sandpiper *Calidris acuminate*]	M
Whiskered Tern *Chlidonias hybridus*	M
Little Pied Cormorant *Phalacrocorax melanoleucos*	BR+M
Little Black Cormorant *Phalacrocorax sulcirostris*	BR+M
Great Cormorant *Phalacrocorax carbo*	R
Pied Heron *Ardea picata*	M(+BR?)
Little Egret *Egretta garzetta*	M(+BR?)
Great Egret *Ardea alba*	BR+M
Intermediate Egret *Mesophoyx intermedia*	M(+BR?)
Yellow(/Little) Bittern *Ixobrychus sinensis(/minutus)*	M(+BR?)
Spangled Drongo *Dicrurus bracteatus*	BR+M
Satin Flycatcher *Myiagra cyanoleuca*	M
Grey Wagtail *Motacilla cinerea*	M

Migratory status taken from Coates (1985, 1990). Migratory status indicates: M – species that occur in New Guinea only as non-breeding migrants; BR+M – breeding residents with populations seasonally augmented by non-breeding visitors; R – rarely recorded non-breeding vagrants; M(+BR?) – non-breeding migrants with possible breeding populations in New Guinea.

5.5 Endemic and Restricted Range Species

Nearly half of the bird species recorded in the Study Area (102/220, 46.4%) are found only in New Guinea and its satellite islands[1]. This represents more than one third (~37%) of the 275 or so species that are endemic to the region (Beehler *et al.* 1986; Coates 1985, 1990). Twenty-six (26) of these are restricted to the island of New Guinea.

Two Restricted Range species were recorded, Brown Lory (*Chalcopsotta duivenbodii*) and Edward's Fig-Parrot (*Psittaculirostris edwardsii*) , both endemic to the North Papuan Lowlands EBA.

1 Including the Aru Islands but not New Britain or New Ireland.

Edward’s Fig-Parrot is a locally common resident of the northern lowlands and hills (up to ca. 800 m elevation) between Jayapura and the Huon Gulf (Coates 1985; Juniper and Parr 1998). This species was common at Kaugumi Site, where groups of up to six birds were seen or heard daily and a pair was seen investigating a potential nest cavity high in a tall tree near camp. A group of four was also observed in the Frieda River during the Trip 2 surveys, and a pair was seen at Wario Site during Trip 4. Fig-parrots not identified to species level and that may have been Edward’s Fig-parrot were seen briefly at Malia Site, Ok Isai Site and Wogamush Site.

The Brown Lory is an uncommon resident of northern lowland forests (to 150 m elevation) between the Memberamo River area and Astrolabe Bay in the east. It was reasonably common at Kaugumi Site, where single birds and groups of up to five birds were seen in flight on 1, 3 and 4 June 2010, and a flock of 27 was observed on 4 June 2010. Lories not identified to species level and that may have been Brown Lories were seen flying overhead at Iniok Site, Frieda Strip Site and (by C. Muller) at Kubkain Site.

No bird species endemic to the Central Papuan Mountains EBA were recorded during the surveys.

5.6 New or Undescribed Taxa

No new or otherwise undescribed species or subspecies were definitively recorded during the surveys, although the following record is of potential taxonomic interest.

At Nena Limestone Site a pair of owlet-nightjars was heard calling at close range over two nights (8–9 December 2009) and their calls were recorded. The birds were not seen, but are believed on the basis of their vocalizations and behaviour most likely to be Wallace’s Owlet-Nightjars, and are therefore provisionally recorded as such in this report. However, the possibility of an as yet undescribed taxon at the subspecies, or even species, level cannot be ruled out. Relevant behavioural and taxonomic information is summarised here.

At ca. 20h30 on 9 December 2009 a series of pre-recorded calls was played aloud in an effort to elucidate a response from the birds. After no response to playback of Barred or Mountain Owlet-Nightjar recordings, calls of Wallace’s Owlet-Nightjar from Ketu River (a tributary of Elevala River, Western Province, PNG) were played and drew an immediate and intense response from the two birds that called repeatedly and excitedly for some minutes while flying overhead across the helipad clearing.

Comparison with other recordings available for *Aegotheles* species indicates that the vocalisations of the birds at Nena Limestone Site are (1) very similar to those of Wallace’s Owlet-Nightjar, and (2) unlike those recorded from most other species known from New Guinea, including Feline, Barred, Mountain and Starry Owlet-Nightjars.

Among currently described taxa known from New Guinea, there remains potential for confusion with Archbold’s Owlet-Nightjar and race *affinis* of Barred Owlet-Nightjar, neither of whose calls have been described (Cleere 2010). Some authors argue that the latter is best treated as a full species (Dumbacher *et al.* 2003; Cleere 2010). However, it is reasonable to conclude that the birds at Nena Limestone Site were more likely to be Wallace’s Owlet-Nightjar given:

- Their strong and sustained behavioural response to recordings of Wallace’s Owlet-Nightjar.

- That Archbold’s Owlet-Nightjar forms a superspecies with Mountain Owlet-Nightjar, with which it was formerly considered conspecific, that Archbold’s and Mountain Owlet-Nightjar are morphologically and genetically similar to one another but distinct from Wallace’s Owlet-Nightjar (Dumbacher *et al.* 2003; Cleere 2010), and that calls of Archbold’s Owlet-Nightjar may therefore be expected to sound most similar to Mountain Owlet-Nightjar.

- That the Nena Limestone Site is within the known elevation range for Wallace's Owlet-Nightjar, whereas Archbold's Owlet-Nightjar is known only from a handful of sites at elevations above 1,450 m elevation (Cleere and Nurney 1998) and mostly above 2,000 m (Cleere 2010).

- That race *affinis* of Barred Owlet-Nightjar is much more similar, morphologically and genetically, to other races of that species than it is to Wallace's Owlet-Nightjar (Dumbacher *et al.* 2003; Cleere 2010), and may therefore be expected to sound most similar to Barred Owlet-Nightjar.

- The taxonomy of owlet-nightjars is still unresolved (e.g. Dumbacher *et al.* 2003), and while the birds encountered are most likely to be Wallace's Owlet-Nightjar, their affinities within this taxon remain unknown, and the possibility remains that they represent an as yet undescribed subspecies. Of the three subspecies currently known, two occur in PNG – *Aegotheles wallaci wallaci* from the southern slopes of the Central Cordillera, and *A. w. manni* from the North Coastal Ranges (Cleere 2010). If the birds at Nena Limestone Site are in fact Wallace's Owlet-Nightjars, this would be the first record of this species from the northern slopes of the Central Cordillera anywhere in New Guinea. Among New Guinea's hill-dwelling avifauna it is common for northern and southern populations to belong to different subspecies.

Finally, the possibility that the Nena Limestone Site owlet-nightjars represent an undescribed species cannot be definitively ruled out, especially given that a number of new owlet-nightjar species have recently been described (Pratt 2000) or suggested (Dumbacher *et al.* 2003) from already known subpopulations.

The taxonomy of the birds at Nena Limestone Site can only be determined with further research, including capture and sampling of individuals in the field. Capturing birds will be possible by exploiting their strong territorial response to call playbacks.

6 AVIAN COMMUNITY STRUCTURE

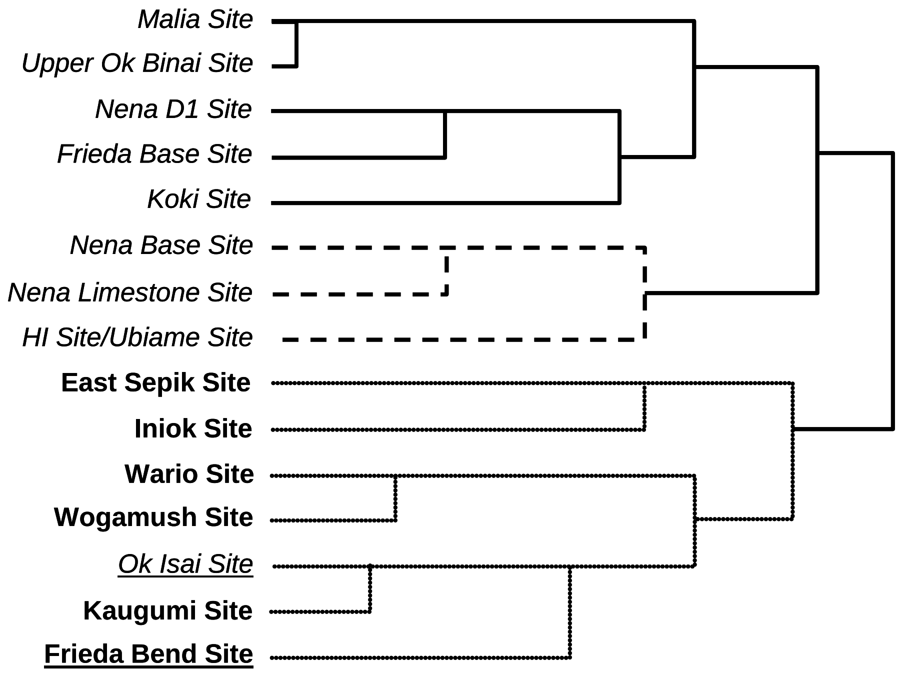
The Study Area presently supports a nearly continuous matrix of undisturbed forest, and bird species are therefore assumed to be capable of moving freely across the landscape and between survey sites. Despite these conditions, bird species richness and composition is rarely (if ever) homogeneous at the landscape level, and this was certainly evident during the present surveys.

6.1 Community Composition Across Zones and Sites

Figure 3 shows how the various survey sites clustered according to the degree of similarity in their recorded bird communities. At the broadest scale, most survey sites separated into two clusters corresponding with a bioregional distinction between (1) the Study Area Hill and Montane zones and (2) the Frieda River drainage and Study Area Lowland Zone. Within the first group there was further separation between mid-elevation sites and upland sites (see below). At a finer scale a number of site-pairs yielded similar bird communities, most notably the Malia–Upper Ok Binai Sites, Ok Isai–Kaugumi Sites, Wario–Wogamush Sites, Frieda Base–Nena D1 Sites and the Nena Base–Nena Limestone Sites. No ‘tight’ clusters of more than two sites were produced. The most distinctive bird communities were recorded at HI Site/Ubiame Site, East Sepik Site and Iniok Site.

Birds respond to a wide variety of environmental variables, including broad-scale habitat changes (e.g. forest, wetlands, open and disturbed areas), elevation, seasonal changes in food availability (e.g. flowers, fruit) and a suite of more subtle ecological signals, including fine-scale changes in forest structure and floristics. The cluster analysis provides a useful tool with which to discuss how the habitats and conditions present at each site/area influence bird species composition and various feeding guilds.

In the following discussion (Sections 6.2–6.4), avian community structure is described and compared among sites within each of the three broadest clusters defined in Figure 3. Sites that were not included in the cluster analysis are introduced into the discussion according to their occurrence in each of the bioregions defined by these clusters.



The three broadest clusters are differentiated by line-style. Study Area Hill and Montane Zone sites are written in italics, sites in the Frieda drainage upstream of the gorge are underlined, and those in the Study Area Lowland Zone sites are written in bold. Only the most extensively surveyed sites are shown (Section 4.7 for methodology).

Figure 3. Dendrogram of similarity of survey sites based on bird species composition.

6.2 Mid Elevation Hill Zone

Hill Forest (Hm) and Lower Montane Forest (L ± c) within the Study Area are likely to support a number of bird species that do not extend to habitats in the Study Area Lowland Zone. This is largely because there is a suite of species associated with hill and montane forest habitats that readily descend to 'foothill' elevations but do not extend their distribution to forest on lowland alluvial terrain (Coates 1985, 1990; Beehler *et al.* 1986). Consistent with this, of the 52 species recorded only in the Study Area Hill and Montane zones, more than three quarters (40 species; 76.9%) are forest-dependent residents.

The first of the three broadest clusters illustrated in Figure 3 comprises the mid-elevation Study Area Hill Zone sites of Malia Site, Upper Ok Binai Site, Nena D1 Site, Frieda Base Site and Koki Site. The general similarity among the bird communities recorded at these sites, and their distinction from those encountered elsewhere in the Study Area (Figure 3), is attributable to their sharing the following important features.

- The habitat surveyed at each of these sites was dominated by undisturbed forest.

- There was significant overlap in elevation covered at these sites (Malia Site: 225–400 m elevation; Upper Ok Binai Site: 325–575 m elevation; Nena D1 Site: 365–500 m elevation; Frieda Base Site: 390–515 m elevation; Koki Site: 510–660 m elevation). Elevation exerts a marked influence on forest structure and floristics, and also on the structure of tropical bird communities (e.g. Kattan *et al.* 2006), including those in New Guinea (Diamond 1972; Beehler 1982; Woxvold 2008). While a number of forest bird species occur over a broad elevation range, others are more or less restricted to habitats in one or two broad elevation zones. At these sites bird surveys were conducted well below the zone of transition to sub-montane habitats and their associated bird communities, and above the lowland and alluvial habitats present elsewhere in Study Area Lowland Zone.

6.2.1 Malia Site and Upper Ok Binai Site

Of all sites analysed, Malia Site and Upper Ok Binai Site shared the most similar bird communities (Figure 3): 65 of the 96 species (67.7%) recorded at these sites were encountered at both, while 15 were unique to Malia Site and 16 were recorded only at Upper Ok Binai Site.

The high degree of similarity among the Malia Site–Upper Ok Binai Site bird communities, and their distinction from those recorded at the Frieda Base, Nena D1 and Koki Sites, is at least partly attributable to phenology (plant fruiting and flowering cycles), which strongly influences the distribution and abundance of those birds that include fruit, nectar and/or pollen as a major component of their diet.

Even compared to other tropical regions, New Guinea's avifauna includes a remarkably high proportion of frugivorous species (Pearson 1977; Mack and Dumbacher 2007). Frugivorous avifauna in New Guinea include the cassowaries (Casuariidae), Blyth's Hornbill (Bucerotidae), pigeons and doves (Columbidae), a variety of parrots (Psittacidae: including within the Study Area Pesquet's Parrot, fig-parrots, Palm and Sulphur-crested Cockatoos, Eclectus Parrot, Geoffroyus parrots and Papuan King-Parrot), flowerpeckers (Nactariniidae: *Dicaeum* spp.), short-billed berrypeckers (Melanocharitidae: *Melanocharis*; Paramythiidae), starlings and mynas (Sturnidae), bowerbirds (Ptilonorhynchidae) and most birds-of-paradise (Corvidae: Paradisaeini) (Coates 1985, 1990). Nectarivores also comprise a significant component of New Guinea's avifauna, with relevant and speciose taxa including the honeyeaters (Meliphagidae) and lories (Psittacidae: Loriinae).

Both the frugivore and nectarivore guilds include a suite of species that are nomadic to varying degrees. Such species are not migratory per se in that they do not undergo well defined, seasonal movements into and out of New Guinea. Rather, they move about the landscape in response to seasonal cycles of fruiting and flowering plants (e.g. Bell 1982). Phenological patterns are poorly understood and difficult to predict (W. Takeuchi, pers. comm., 11 February 2010), particularly in low elevation forests where most plants have shorter flowering periods than montane taxa (Takeuchi 2007). As a result, encountering nomadic frugivores and/or nectarivores at any particular locality is often an unpredictable process.

At the time of the bird surveys the density of fruiting trees was notably higher at Malia Site and Upper Ok Binai Site than at the Frieda Base, Nena D1 and Koki Sites. Accordingly, this site-pair displayed the following distinct patterns in frugivore abundance and diversity:

- Of 18 species of pigeons and doves recorded in the Study Area Hill Zone, the highest diversity was found at Malia Site and Upper Ok Binai Site (12 and 13 species respectively), and these were the only two sites at which all six of the commonly recorded hill-dwelling fruit-doves were recorded (Wompoo, Pink-spotted, Superb, Coroneted, Orange-bellied and Dwarf Fruit-Dove).

- The highest diversity of frugivorous parrots was recorded at Malia Site and Upper Ok Binai Site (seven and six species respectively), and these were the only Study Area Hill Zone sites at which both mainland New Guinean Geoffroyus (Red-cheeked and Blue-collared) parrots were recorded.

- The Malia and Upper Ok Binai Sites shared the equal highest diversity (with Koki Site) of birds-of-paradise, with the same four species recorded at both sites: Magnificent Riflebird, Magnificent, King and Lesser Bird-of-Paradise.

Other patterns are more difficult to explain, and may reflect locally patchy distributions in response to poorly understood microhabitat requirements in structurally and floristically complex forests. Among insectivores for example, Malia Site and Upper Ok Binai Site were the only Study Area Hill Zone sites at which all four dry-land, forest-dwelling monarch flycatchers (Spot-winged, Hooded, Golden and Rufous-collared Monarchs) were recorded (these species were also recorded together at Wario Site in the Study Area Lowland Zone).

Among other examples, White-crowned Koel and Yellow-breasted Boatbill were recorded at both Nena D1 Site and Frieda Base Site but not at Malia Site or Upper Ok Binai Site, while Brown-collared Brush-turkey and Yellow-billed Kingfisher were recorded at the latter two sites but not the former. These records are puzzling, particularly given apparently suitable habitat at all four sites and the general ease of detection of each of these conspicuously vocal species. During a comparable survey of the Lakekamu basin, Beehler and Mack (1999) also found that Yellow-breasted Boatbill and some forest-dwelling kingfisher species were patchily distributed among their survey sites.

IUCN species recorded at Malia Site and/or Upper Ok Bini Site include cassowaries (Northern Cassowary (VU) at Malia Site and [Dwarf] Cassowary (NT) at Upper Ok Binai Site), Pesquet's Parrot (VU), Victoria Crowned-Pigeon (VU) and Forest Bittern (NT).

6.2.2 Nena D1 Site and Frieda Base Site

Of 84 species recorded at Nena D1 Site and Frieda Base Site, 40 (47.6%) were found at both sites, 24 were recorded only at Nena D1 Site and 20 only at Frieda Base Site.

The density of fruiting trees was lower at these sites than at Malia Site and Upper Ok Binai Site. Accordingly, at Nena D1 Site and Frieda Base Site fewer pigeons and doves (six and six respectively), frugivorous parrots (three and four) and birds-of-paradise (three and one) were recorded.

In contrast to fruiting patterns, a number of woody plant species were flowering profusely at Nena D1 Site and Frieda Base Site, including *Melicope elleryana* and *Dimorphentera* sp. [*keysseri*], whereas flowering was not particularly prevalent at Malia Site or Upper Ok Binai Site. Accordingly, a number of nomadic nectarivores not encountered at Malia Site–Upper Ok Binai Site were recorded at Frieda Base Site and/or Nena D1 Site, including Red-fronted and Red-flanked Lorikeets, Red-throated and Black(/Red) Myzomelas.

IUCN species recorded at one or more of these sites include Pesquet's Parrot (VU), Doria's Goshawk (NT) and [New Guinea Eagle] (VU).

6.2.3 Koki Site

Despite its geographical proximity to the previous sites and the similar elevations covered (510–660 m), the cluster analysis revealed the bird community at Koki Site to be the most distinct from other mid elevation Study Area Hill Zone sites (Figure 3).

A total of 55 species was recorded over four days at Koki Site, comparatively fewer than at most other Hill Forest sites following similar survey effort (Figure 1). A notable feature at this site was the extensive presence of silicified limestone with an overlying forest poor in fleshy-fruiting trees. The upper stratum was Cunoniaceae dominant, whose capsular fruits with wind-dispersed seeds neither rely on nor have evolved to attract fruit-eating or seed-dispersing birds (W. Takeuchi, pers. comm., 11 February 2010). By contrast, the more fertile soils on the eastern track supported a plant community with more baccate (berry-like) fruit-bearing taxa. Accordingly, there were few frugivorous birds in Hill Forest (Hm) on limestone at Koki Site; many of the pigeons and fruit-doves recorded at Koki Site were heard only in forest along the eastern track, and those that were present in Hill Forest (Hm) on limestone were encountered less often.

Close to the campsite a number of *Melicope elleryana* trees were in flower. These attracted many nectarivores, including Red-throated and Black(/Red) Myzomelas, Obscure Honeyeater, Rainbow Lorikeet and large numbers of Red-flanked and Red-fronted Lorikeets (flocks of 30+ comprised of these two species).

Camera-trapping showed pigs were common at this site. Some authors (e.g. Kocher Schmid 1993) have suggested that brush-turkeys are scarce in places where wild pigs are active. Contrary to this opinion Koki Site supported at least two species of megapode, the Brown-collared and Wattled Brush-Turkeys. Wattled Brush-Turkeys were photographed remotely by two separate camera-traps, providing a mainland record at an unusually low elevation for this species.

IUCN species recorded at Koki Site include [Dwarf] Cassowary (NT) and Pesquet's Parrot (VU).

6.2.4 Nena D2 Site and Nena-Usage Site

Short survey times yielded low species counts at Nena D2 Site (27 species) and Nena-Usage Site (43 species). These mid-elevation Study Area Hill Zone sites were therefore not included in the cluster analysis.

While the low tally at Nena D2 Site is partly attributable to the short time spent there (24 hours), bird diversity and abundance were also noticeably low. This appeared partly attributable to the steep and unstable terrain. Camping along the valley bottom and surrounded by steep valley walls, surveys were limited to habitat alongside the small but fast-flowing river and adjacent lower slopes. The soils were mostly pebbly clays released from landslip and frequently washed by water-flow over the steep surface. The humus layer was sparse or absent, and there were numerous fallen trees and very dense undergrowth.

Habitat was unsuitable for many of the local ground birds; Rusty Mouse-warblers, common elsewhere, were scarce, and the relatively widespread and conspicuous brush-turkeys and jewel-babblers were unrecorded. Forest structure may also have been unsuitable for a number of sedentary insectivores. No fantails, monarch flycatchers or forest-dwelling petroicid robins were recorded, although Torrent Robin was present along the river.

Frugivores were also notably scarce. Only one columbid was recorded, a Slender-billed Cuckoo-Dove, and this was the only site surveyed at which no fruit-doves or imperial-pigeons were found. However, there was some frugivore activity higher upslope, with Pesquet's and Eclectus Parrots, Sulphur-crested Cockatoo, Lesser Bird-of-Paradise and a pair of manucodes (Crinkle-collared or Jobi Manucode) occasionally traversing the valley from slope to slope. Fruit-doves and imperial-pigeons are generally less visible as they tend not to fly about so often and remain hidden in the canopy for long periods. Their presence may have gone undetected.

Bird diversity and abundance was also relatively low in habitats surveyed at Nena-Usage Site. Terrain was somewhat similar to that at Nena D2 Site, with surveys again restricted to the bottom of a steep, forested valley adjacent to a fast-flowing river. The deeply gouged ravine was littered with large boulders, scree and clay and vegetated with ephemeral weeds. The precipitous banks lacked well-formed riparian vegetation.

Columbids were scarce despite the presence of fruiting trees; cuckoo-doves and Superb Fruit-dove were unrecorded, the latter common at most other Study Area Hill Zone sites. Variable Pitohui, conspicuous at all other Study Area Hill Zone sites through their loud and distinctive calls, were neither seen nor heard. Honeyeater numbers were also conspicuously low. Streak-headed Honeyeater and Meyer's Friarbird were unrecorded (normally vocal and easy to detect), and while Helmeted Friarbird, Obscure and Tawny-breasted Honeyeaters were occasionally heard, they appeared to be present in smaller numbers than at most other Study Area Hill Zone sites (cf. HI Site).

The survey here was too brief (two days) to confirm these observations as characteristic. Columbids and at least some honeyeaters are nomadic within a landscape in response to seasonal patterns in food availability. Moreover, most species were recorded in forest some distance from the noisy river, and further survey there would no doubt record additional species. A variety of negative consequences may be associated with interference to birds acoustic signalling, and there is growing evidence that many bird species are less abundant in noisy areas (e.g. Parris and Schneider 2008; Slabbekoorn and Ripmeester

2008).

One terrain feature at Nena-Usage Site did appear to be of importance to some local birds: the steep, forested slopes and ridge-line immediately to the east of the river and opposite the survey site was nightly used as a roosting site by numbers of large parrots and multiple hornbill pairs. Parrots arriving to roost in the evening included Sulphur-crested Cockatoos (>25), Eclectus Parrots (≥4), Palm Cockatoos (2), and Pesquet's Parrots (≥14). Numbers were estimated conservatively to avoid double counting, and other birds were occasionally seen rising above the ridge-line from the slopes on the opposite side of the ridge.

Pesquet's Parrot (VU) was the only IUCN species recorded at these sites.

6.3 Upper Hill Zone and Montane Zone

The second of the three broadest clusters illustrated in Figure 3 comprises the upper-elevation Study Area Hill and Montane Zone sites of Nena Base Site, Nena Limestone Site and HI Site/Ubiame Site. The clustering of these sites in terms of bird community structure, and their distinction from communities recorded elsewhere (Figure 3), can be largely explained by the higher elevations surveyed (Appendix 4.1). While Hill Forest (Hm) was still a notable habitat component at Nena Base Site and HI Site, all sites supported tracts of Lower Montane Forest (L ± c), Nena Limestone Site and Ubiame Site exclusively so (Chapter 2). Accordingly, a number of the birds recorded only at one or more of these sites are exclusively or strongly associated with upper Hill Forest (Hm) and/or Lower Montane Forest (L ± c), including White-eared Bronze-Cuckoo, [Wallace's] Owlet-Nightjar, Goldenface, [Sclater's] Whistler, Rusty Whistler, Tropical/Beccari's Scrubwren, White-faced Robin, Spotted Catbird, Stout-billed and Black-bellied Cuckooshrike, Mountain Peltops and Carola's Parotia. Conversely, a suite of species common at other Study Area Hill Zone locations were absent from these sites, including Red-cheeked Parrot, Wompoo Fruit-Dove, Streak-headed Honeyeater, Black and Hooded Butcherbirds, Boyer's Cuckooshrike, and Spot-winged and Hooded Monarchs. The influence of elevation on species composition is clearly shown by the separation of Nena Base Site from Nena D1 Site in Figure 3, the camps of which were only 2.5 km apart.

6.3.1 Nena Base Site and Nena Limestone Site

Among these sites, Nena Base Site and Nena Limestone Site shared the most similar bird communities. Of 101 species recorded at these sites, 48 (47.5%) were encountered at both, while 39 were unique to Nena Base Site and 14 were recorded only at Nena Limestone Site.

Nena Base Site was among the most extensively surveyed Study Area Hill Zone sites and yielded the highest number of species (87) from this sector. Comparison of the discovery curves for these sites (Figure 1) shows a similar rate of species accrual after an initially steeper rise at Nena Base Site. This may reflect lower species richness in forests growing on a lower nutrient base at the Nena Limestone Site plateau. Such alkaline substrates typically have a marked effect on the overlying flora, which often shows a species complement reminiscent of higher elevation flora and a reduced density of fruiting trees. Accordingly, columbid diversity was higher at Nena Base Site than at Nena Limestone Site (11:7 species).

IUCN species recorded at these sites include Dwarf Cassowary (NT), Pesquet's Parrot (VU), [New Guinea Eagle] (VU), and at Nena Limestone Site a pair of [Wallace's] Owlet-nightjar (DD), a rare night-bird previously unknown from the northern slopes of the Central Cordillera (Section 5.6).

6.3.2 HI Site and Ubiame Site

HI Site and Ubiame Site were highly distinct in terms of terrain, habitat and bird community structure (Figure 3). The upper slopes of HI Site were clearly depauperate in terms of both species richness and the number of individual birds that were present (or at least detectable), not only in relation to other sites surveyed within the Study Area, but also in comparison with most other sites surveyed by the author elsewhere within PNG. HI Site yielded the lowest total number of species per unit survey effort of all sites (Figure 1), even after including species recorded in heavily disturbed habitats surveyed on the lower slopes. In three days spent at this site a total of only 34 species was recorded, significantly fewer than the diversity recorded at Nena Limestone Site and Nena D1 Site over similar periods, and 10 less than were encountered over two days at Nena-Usage Site.

Forest species common at other sites were scarce or absent in forest on the steep upper slopes at HI Site. Notable examples included an almost total lack of columbids (including none of the fruit-doves present at other sites, some of which were among the most obvious birds present), no Lesser Bird-of-Paradise, no berrypeckers, very few of the more common and vocal honeyeaters (no Tawny-breasted or Streak-headed Honeyeaters, no Meyer’s or New Guinea Friarbirds) and no gerygones, fantails, monarchs or robins (a single Black-sided Robin was heard in remnant disturbed forest close to drilling pads on the lower slopes). Moreover, of those forest species that were recorded, many were encountered as single birds or pairs only in the vicinity of two abutting fruiting figs (Dwarf Koel, a pair of Crinkle-collared/Jobi Manucodes, a small group of Pesquest’s Parrots, Magnificent Bird-of-Paradise, Banded Imperial-pigeon, White-bibbed Fruit-dove). Among the few species that were present in numbers were the Rusty Mouse-warbler, Long-billed Honeyeater, Variable Pitohui and Little Shrike-thrush. Low bird diversity and abundance here may have been due to (inter alia) the steep terrain, noisy, fast-flowing rivers and general lack of fruiting or flowering plants.

Other parts of the HI Site area that were not surveyed for birds may support a higher diversity and abundance of forest-dwelling species. Moreover, at times when phenological patterns are more favourable, the area around our survey camp may also support higher numbers of frugivores and nectarivores. Nevertheless, it is also clear that the bird community persisting in the heavily disturbed lower sections of the HI Pit is depauperate in terms of the diversity and abundance of forest-dwelling species that would originally have occurred.

A total of 29 species was recorded over a 24-hour period spent near the repeater tower at Ubiame Site. This low figure is partly attributable to the difficulty in accessing the forest interior at this site, with surveys restricted to ca. 250 m of a rough, ridge-line path adjacent and parallel to the cliff edge. Consequently, most birds were recorded by listening to calls in the forest behind and below the survey track on a single morning.

Despite these limitations, it was immediately clear that the bird community present at this site was distinct from other parts of the Study Area as it included a number of species strongly or exclusively associated with (lower-)montane habitats, including Mountain Peltops, Carola’s Parotia, Black-bellied Cuckooshrike, Stout-billed Cuckooshrike, Goldenface and Spotted Catbird, the first three of which were encountered only at Ubiame Site.

Pesquet’s Parrot (VU) was the only IUCN species recorded at HI Site and Ubiame Site.

6.4 Study Area Lowland Zone and Frieda River

The last of the three broadest clusters illustrated in Figure 3 grouped the Study Area Lowland Zone sites, excluding Hauna (and lakes) Site, Frieda Strip Site and Warangai South Site that had too few data, with the two sites in the Frieda River drainage (Ok Isai Site and Frieda Bend Site) that had sufficient data for analysis. Although Ok Isai Site is technically part of the Study Area Hill Zone, and in espite of the presence of Hill Forest (Hm) at both Frieda Bend and Ok Isai Sites, this is attributable to the lower elevations surveyed at these sites (65–150 m elevation) and to the predominance of habitats more closely allied with those surveyed at other lowland sites in the Study Area Lowland Zone, including broad, midreach stretches of the Nena and Niar rivers, associated riverine successions (including tall grasses, scrub and secondary vegetation in various stages of regrowth) and Lowland Open Forest (Po).

Lowland alluvial forests support a relatively limited endemic vertebrate fauna, and most animal species occurring in Study Area Lowland Zone forest habitats are also likely to occur in Hill Forest (Hm) (though in many cases at lower densities) (Coates 1985, 1990; Flannery 1995; Menzies 2006). Accordingly, of the 62 species recorded only in the Study Area Lowland Zone, only 12 (19.4%) are residents dependent on mature forest habitats (New Guinea Scrubfowl, [Blue-black Kingfisher], Long-billed Cuckoo, Brown Lory, Edwards's Fig-Parrot, Collared Imperial-Pigeon, Rufous Owl, New Guinea Flightless Rail, Red-bellied Pitta, Green-backed Honeyeater, Emperor Fairywren, Twelve-wired Bird-of-paradise). Among these, at least two that are resident in the Study Area Lowland Zone's Swampy Forests are likely to be restricted to these habitats, both of which are of conservation significance: the New Guinea Flightless Rail (NT) and the Twelve-wired Bird-of-paradise (P). Other birds more or less restricted to forests of the Study Area Lowland Zone may also be present in Hill Forest (Hm), as shown by Northern Cassowary, albeit in lower numbers.

The remaining species recorded only in the Study Area Lowland Zone are birds of rivers and wetlands and/or open and disturbed habitats. While many of these also occur at higher elevations elsewhere in New Guinea, the distribution of these habitats within the Study Area is currently heavily skewed towards the Study Area Lowland Zone.

Within this broad cluster there were few closely related site-pairs (Figure 3), and many of the Study Area Lowland Zone sites supported rather distinct bird communities.

6.4.1 East Sepik Site: A Peat Forest Bird Community

Most of the world's tropical peatlands occur in Borneo, Sumatra and the Malay Peninsula (collectively Sundaland). Their presence in New Guinea was heretofore recorded only in parts of Indonesian Papua (consistent with the absence of a FIMS code for this forest type in PNG) (Page *et al.* 2004; Chapter 2). Vegetation communities in Sundaic Peat Forest have been documented to some degree, though data on animals is sparse. Comparable surveys of New Guinean Peat Forest are almost totally lacking, and there are no pre-existing accounts of bird surveys being conducted in Peat Forest on the island.

Given the distinctiveness, apparent rarity and lack of previous data regarding New Guinea Peat Forest, it is useful to list some of its features, both in general and at East Sepik Site, that are pertinent to bird communities:

- Peat substrates are highly acidic and nutrient-poor and most Peat Forests (including at East Sepik Site) are ombrotrophic systems, with nutrients added only via precipitation (i.e. no nutrient-rich overflow from adjacent major rivers).

- These traits strongly influence the productivity, structure and floristics of the overlying vegetation and associated fauna (Janzen 1974; Gaither 1994; Whitten *et al.* 2000). Vegetation at East Sepik Site was stunted, plant diversity was extremely low and subcanopy layers were reduced (Chapter 2).

- No flowing water was located within the survey area; rainwater sank directly into the porous soils and accumulated in the water table which, at the time of our survey, lay ca. 20–50 cm below the surface.

- The survey area, and presumably similar surrounding habitat, was almost entirely undisturbed by humans. Gary Nugom, a local resident of Hauna, indicated that no one travelled through this kind of forest as there was no water to drink (except from the *Nepenthes* pitchers) and that it was easy to become lost. There was no sign of pre-existing trails, and a number of bird species exhibited uncharacteristic boldness (e.g. Emperor Fairywren, Hooded Monarch).

- Wayne Takeuchi and Chris Muller mapped the extent of the Peat Forest present south of the Sepik River and between the Frieda River and Wogamush River via aerial reconnaissance during the Trip 4 surveys. It was determined that Peat Forest covers ca. 2,800 ha around the East Sepik Site and that no other areas of Peat Forest are present in this area.

Consistent with the distinctiveness of this habitat, the cluster analysis ranked the East Sepik Site bird community as among the most distinct recorded within the Study Area.

Species richness and bird abundance were notably low at East Sepik Site. With only 40 species recorded over 5 days, the rate of accrual was significantly lower than that of most other survey sites, including all other sites in the Study Area Lowland Zone (Figure 1). Moreover, the curve in Figure 1 approaches a distinct asymptote, indicating that very few novel species were recorded during the last half of the survey and suggesting that relatively few remained undetected. In addition to the low plant diversity, these results are consistent with those of other faunal surveys carried out at this site.

Few plants were in fruit at the time of the survey, and frugivore/nectarivore diversity and abundance were correspondingly low. Of the four columbids recorded, only two were encountered regularly (Coroneted Fruit-Dove, Banded Imperial-Pigeon), with records of Superb and Orange-bellied Fruit-Doves involving single birds. Of only four parrot species, most were recorded as overflights (use of Peat Forest not confirmed), and many large frugivorous parrots widespread or common at other lowland sites were unrecorded (Sulphur-crested Cockatoo, Eclectus Parrot, Palm Cockatoo). In addition to these nomadic species, sedentary frugivores were also scarce or absent. Among birds-of-paradise, one manucode (Jobi/Crinkle-collared) was heard, while single birds or duos of King Bird-of-paradise were recorded at a single locality on multiple days. A number of sedentary frugivore/frugivore-insectivores common or widespread at other lowland forest sites were conspicuously absent, including Victoria Crowned-Pigeon, Boyer's Cuckooshrike, White-eared Catbird, Grey Crow, Variable Pitohui and Lesser Bird-of-paradise.

The canopy at the East Sepik Site did include numerous fleshy-fruiting tree taxa (e.g. *Calophyllum, Garcinia*, baccate Myrtaceae etc.; W. Takeuchi, In Litt. 2010). It is therefore possible (or likely) that avian frugivore diversity and abundance would be seasonally higher at other times.

Sedentary insectivore/nectarivore-insectivores were also scarce. Notable absences included a number of species that forage in sub-canopy strata (including terrestrial/understorey birds): Hook-billed Kingfisher, Rusty Mouse-warbler, Yellow-bellied Gerygone, Red-capped Flowerpecker, Black Sunbird, Green-crowned Longbill. The foliage of Peat Forest is generally nutrient poor and chemically well defended against herbivory, presumably influencing insect biomass (Janzen 1974; Whitten *et al.* 2000).

In addition to the scarcities, those species that were present in good numbers combined to form a very distinctive bird community, not only in relation to other habitats within the Study Area but also to those elsewhere New Guinea. The most abundant species within the forest (in descending order) were a *Meliphaga* honeyeater (species undetermined), Coroneted Fruit-Dove, Emperor Fairywren, Little Shrike-thrush, Hooded Monarch and White-bellied Thicket-fantail. Outside of Peat Forest the Emperor Fairywren is normally a bird of thickets in secondary forest, riversides, forest edge or interior openings (Beehler *et al.* 1986; Coates 1990; Rowley and Russell 2007), in stark contrast to the open lower storeys at East Sepik Site. The Hooded Monarch is uncommon and patchy elsewhere in New Guinea – though fairly common at some Study Area Hill Zone sites, nowhere was it as common and conspicuous as at East Sepik Site.

Gaither (1994) recorded a similar pattern in Borneo, where most sedentary, understorey insectivores were notably less abundant in Peat Forest compared with adjacent dipterocarp forest, while two species displayed a reverse trend, rising to become dominant members of a rather unique though depauperate avian community.

The abundance of *Meliphaga* honeyeaters was higher than at almost any other survey site (equal to Mixed Swamp Forest (Fsw) at Wogamush Site). This genus presents the most difficult problem of field identification of any bird group in New Guinea, with many species requiring capture for confirmation of presence. Understorey mist-netting indicated that Mimic Honeyeater was present at East Sepik Site. This species was present at a number of Study Area Hill Zone sites though usually outnumbered by the congeneric Puff-backed Honeyeater which was not recorded at East Sepik Site. It was not confirmed with certainty that Mimic Honeyeater was the *Meliphaga* species abundant in the Peat Forest canopy, where it gave frequent and distinctive calls (and the same as those at Wogamush Site). These calls were not recognised by the author or by other, independent experts. Although most likely to be Mimic Honeyeaters, it would be useful to mist-net some of the canopy *Meliphaga* honeyeaters at this site to ascertain this. Although few tree species were in flower, *Meliphaga* honeyeaters were taking nectar from flowering *Planchonella*, a co-dominant canopy tree at this site.

Northern Cassowary (VU) was the only IUCN species recorded at this site.

6.4.2 Iniok Site, Hauna (and lakes) Site and Kubkain Site

Large areas of wetland and Riverine Mixed Succession (Fri/Wri) habitats were surveyed on foot and by motorised canoe around Iniok Site (including Lake Warangai) and around Hauna village and nearby lakes. These habitats also occur around Kubkain Site. Only surveys conducted at Iniok Site were sufficiently extensive to include in the cluster analysis.

Half of all bird species recorded in the Study Area were recorded from these sites (110/220, including 109 at Iniok and Hauna (and lakes) Site), contributing significantly to the overall total for the Study Area and making the Iniok Site bird community among the most distinct (Figure 3).

The wetlands here are extensive and diverse. They include the Sepik River, numerous tributaries, backwaters and oxbow lakes, and a number of large basin lakes south of the Sepik such as Lake Warangai and Lake Warwi. These provide important foraging and breeding habitat for many waterbirds, contributing significantly to the overall diversity of the Study Area. Of 33 species recorded only at these sites, 12 (36.4%) were wetland birds: Spotted Whistling-Duck, Rufous-tailed Waterhen, Purple Swamphen, Wader sp(p)., White-headed Stilt, Whiskered Tern, Little Egret, Great-billed Heron, Pied Heron, Rufous Night-Heron, Yellow(/Little) Bittern and Black Bittern. Most of the waterbirds recorded at other sites, especially in the Frieda River drainage and at Wario Site, were also recorded at Iniok Site/Hauna (and lakes) (e.g. White-bellied Sea-Eagle, Australian Darter, Little Pied and Little Black Cormorant, Masked Lapwing, Eastern Great Egret, Intermediate Egret). Further survey would likely have revealed additional species (Figure 1) (Section 8.4.2).

Little information is available regarding the numbers of waterbirds that breed in the Sepik River Basin. Large rookeries have been reported for some species (e.g. Intermediate Egret, Spotted Whistling-Duck: Gilliard and LeCroy 1966), and the 21,000-ha Chambri Lake (PNG's second largest lake after Lake Murray) hosts large numbers of waterbirds, many of which breed there. The number of species and individuals that breed in wetlands within and around the Study Area remains unknown.

Unfortunately, evidence suggests that local waterbird populations have declined significantly in recent years. Local residents indicated that this was associated with marked losses in floating and lakeside vegetation over the previous 10–15 years, thereby reducing habitat required for breeding, foraging and/or sheltering by many waterbirds, including grebes, ducks, rails and jacanas. Significant declines were reported by locals for various ducks and jacanas (e.g. Cotton Pygmy-Goose and Comb-crested Jacana, formerly common but now rare and unrecorded during the Project surveys). A suite of exotic fish species, one of which is known locally as 'ball-cutter', was introduced into the Sepik between 1987 and 1997 (Dudgeon and Smith 2006) and shortly before these changes were noted by local residents. A connection between these events was voiced by our informants.

A rather distinct bird community was recorded in the Riverine Mixed Succession (Fri/Wri) with *Barringtonia/ Neonauclea*, an open woodland formation on exposed mudflats around the north-eastern edge of Lake Warangai. Dominant species here included Rufous-banded Honeyeater, Grey Shrike-thrush and Willie-wagtail, with numbers of Silver-eared Honeyeater, Brown Oriole and Orange-fronted Fruit-Dove (inter alia). These are the first records of Rufous-banded and Silver-eared Honeyeater for the Upper Sepik River Basin, extending their known range some 100 km or more upstream.

Interestingly, a number of hunting-sensitive species were recorded in good numbers in gardens and disturbed riparian forest around Iniok Site, including plantations on the outskirts of the village itself. New Guinea Scrubfowl were commonly heard and observed, and numerous active nest mounds were located. Gilliard and LeCroy (1966) found a similar situation at Kanganaman village on the middle Sepik River, where villagers claimed ownership of individual mounds, harvesting the eggs and protecting adult birds from injury. While adult scrubfowl are also left unmolested at Iniok Site, Gary Nugom indicated that both eggs and birds were taken by residents of Hauna.

Also in gardens immediately behind Iniok Site, Chris Muller observed two Victoria Crowned-Pigeons at close range. Normally considered a forest bird (Coates 1985; Baptista *et al.* 1997), there is growing evidence (e.g. Mack *et al.* 2000) to suggest that in the absence of hunting it can persist in more disturbed environments.

Other birds recorded only at Iniok Site and Hauna (and lakes) Site include a suite of species that are closely associated with open and disturbed habitats: Sacred Kingfisher, [Pheasant Coucal], [Emerald Dove], Black Kite, White-bellied Cuckooshrike, Golden-headed Cisticola, Metallic and Singing Starling, White-breasted Woodswallow, Olive-backed Sunbird, Streak-headed and Hooded Munias.

IUCN species recorded at these sites include Northern Cassowary (VU) and Victoria Crowned-Pigeon (VU).

6.4.3 Wario Site and Wogamush Site

Ninety species were recorded at Wario Site - the highest diversity of birds recorded at any site during the Project surveys. Although significantly fewer species were recorded at Wogamush Site (57), of all sites analysed Wario Site and Wogamush Site shared the third most similar bird communities (Figure 3). Of 96 species recorded at Wario Site and Wogamush Site, 50 (52.1%) were recorded at both, 40 were unique to Wario Site and 6 were recorded only at Wogamush Site.

The high species count at Wario Site is attributable to the wide range of habitats present within a fairly small area, including undisturbed Hill Forest (Hm), Riparian Forest (Po) alongside the Wario River, Swampy Forests east of Nekiei, Riverine Mixed Successions (Fri/Wri) including grassland and pioneer and secondary forest (Po), anthropogenic gardens, the Wario River and an adjacent oxbow lake immediately east of Nekiei. Wario Site yielded the equal highest diversity of pigeons and doves (14 species), six wetland bird species (Pacific Black Duck, Masked Lapwing, Brahminy Kite, White-bellied Fish-Eagle, Eastern Great Egret, Intermediate Egret), Swampy Forest specialists such as the New Guinea Flightless Rail and Red-necked Crake, and it was the only Study Area Lowland Zone site at which all four dry-land, forest-dwelling monarch flycatchers (Spot-winged, Hooded, Golden and Rufous-collared Monarchs) were recorded.

Riparian forest at the Wario Site provided a locally important roosting site for Blyth's Hornbill. Dozens of hornbills roosted each night opposite camp on the western bank of the Wario River, at least 56 in the one favoured roosting tree.

IUCN species recorded at Wario Site include Northern Cassowary (VU), Victoria-crowned Pigeon (VU) and New Guinea Flightless Rail (NT).

The lower count at Wogamush Site is attributable to the fewer habitats present and to the shorter time spent surveying birds there. Predominantly a site of undisturbed forest without streams or rivers, Wogamush Site provided the greatest access to Mixed Swamp Forest (Fsw) of all survey sites. Other habitats included sago-rich Swamp Woodland (Wsw) and Hill Forest (Hm) below ca. 250 m elevation on the isolated hills. Although a walking track linking nearby villages passed through our camp, the area was predominantly undisturbed. Although only ca. 5 km walk from the nearest villages, the lack of flowing water rendered Wogamush Site unsuitable for extended visits by local residents. Thus there were no signs of gardens present and some evidence to show that hunting in the area was minimal – Northern Cassowary and Victoria Crowned-Pigeon were fairly common and detectable at this site. In addition, sapling growth in the Hill Forest (Hm) understorey indicated that disturbance by Feral Pigs (*Sus scrofa* x *celebensis*) was minimal. All of these signs are consistent with the likely presence of an intact bird community little-affected by human interference.

IUCN species recorded at Wogamush Site include Northern Cassowary (VU) and Victoria-crowned Pigeon (VU).

6.4.4 Ok Isai Site and Kaugumi Site

Kaugumi Site yielded among the highest recorded species totals, with 84 species recorded over six days. Moreover, with no standing-water wetlands and only minor areas of forest disturbance, Kaugumi Site yielded the second highest diversity of forest-dependent bird species behind Nena Base Site, and the highest diversity of lowland forest birds recorded during the Project surveys. The Kaugumi Site list includes two of New Guinea's rarest and least known lowland forest birds – the Long-billed Cuckoo and [Blue-black Kingfisher].

Fruiting trees were abundant at Kaugumi Site, and the highest diversity of a number of frugivorous taxa were recorded here, including parrots (12 species, this being the only site where both Restricted Range species were recorded: Brown Lory, Edward's Fig-Parrot) and pigeons and doves (14 species). Among terrestrial (at least partial) frugivores, and despite the regular occurrence of hunters and their dogs, cassowaries, probably all Northern Cassowary, were common, and this was the only site at which Brown-collared Brush-turkey and New Guinea Scrubfowl were proven to co-occur.

The cluster analysis (Figure 3) revealed that the Ok Isai and Kaugumi Sites shared the second most similar bird communities of all sites analysed. Of 99 species recorded at Kaugumi Site and Ok Isai Site, 57 (57.6%) were found at both sites, 27 were unique to Kaugumi Site and 15 were unique to Ok Isai Site. In addition to the low elevations covered at these sites (Ok Isai Site: 100–145 m elevation; Kaugumi Site: 60–90 m elevation), this similarity can be partly attributed to shared habitats and survey timing.

The shared presence of (1) Hill Forest (Hm) below ca. 250 m elevation and (2) wet-floor forest habitats (Swampy Forest (Wsw/Fsw) at Kaugumi Site, Lowland Open Forest (Po) with a very wet floor at Ok Isai Site) yielded similarities in the forest bird communities present at these sites and helped to distinguish that of Ok Isai Site from those of other Study Area Hill Zone Sites. Relevant species in this respect include Buff-faced Pygmy-Parrot, Stephan's Dove, Victoria Crowned-Pigeon, Red-necked Crake, White-bellied Thicket-Fantail and Shining Flycatcher. These species were present at both Ok Isai and Kaugumi Sites, were scarce or absent at other Study Area Hill Zone sites (only Victoria Crowned-Pigeon and Shining Flycatcher at Malia Site), and were all recorded in suitable habitat elsewhere in the Study Area Lowland

Zone.

The absence of extensive wetland habitats and limited survey of riverine habitats further linked these sites and helped to distinguish these sites from some other Study Area Lowland Zone sites such as Frieda Bend Site, Iniok Site and Wario Site. Although the Niar River was reached during surveys at Ok Isai Site, the little time spent there was limited to the middle, hottest part of the day when bird activity is at its lowest.

Survey timing further linked Ok Isai Site with Kaugumi Site (and other Study Area Lowland Zone sites surveyed during Trip 3). While the Trip 1, Trip 2 and Trip 4 surveys were all conducted during the austral summer, the Trip 3 surveys of Ok Isai Site and the Study Area Lowland Zone were better timed to coincide with non-breeding southern migrants. Consequently, records of Dollarbird and Rainbow Bee-eater were restricted to Ok Isai Site and all four Trip 3 Study Area Lowland Zone sites (Kaugumi Site, East Sepik Site, Hauna (and lakes) Site, Iniok Site).

The diversity and species composition of pigeons and doves recorded at these sites was also very similar, with 12 of the 14 species recorded at Kaugumi Site also occurring at Ok Isai Site. Survey timing may have influenced this pattern through seasonal effects on phenology, rainfall and/or species detectability (e.g. seasonal changes in the tendency to vocalise).

IUCN species recorded at Ok Isai Site and/or Kaugumi Site include Northern Cassowary (VU), [Blue-black Kingfisher] (DD), Pesquet's Parrot (VU), Victoria-crowned Pigeon (VU) and New Guinea Eagle (VU).

6.4.5 Frieda Bend Site

While technically part of the Study Area Lowland Zone, elevation coverage (65–150 m) and habitats at Frieda Bend Site shared affinities with both the Study Area Lowland and Hill Zones, resulting in a rather distinct bird community at this site.

Surveys at Frieda Bend Site involved extensive coverage of riverine and adjacent open/disturbed habitats; these included two surveys by canoe, during the Trip 1 Reconnaissance and during Trip 2, along the Niar and Frieda rivers between the gorge area of the Frieda River and a point immediately upstream of Wabia village. These habitats were either not present or were far less prevalent at Kaugumi Site and at sites in the Study Area Hill and Montane zones. Accordingly, a number of species recorded in these habitats at Frieda Bend Site (White-bellied Fish-Eagle, Little Pied Cormorant, Great Cormorant, Eastern Great Egret, Little Ringed Plover, [Silver-eared Honeyeater], Willie-wagtail) were not recorded in the Study Area Hill and Montane zones or at Kaugumi Site, or in the Study Area Hill Zone were recorded only at Ok Isai Site (Whistling Kite, Little Black Cormorant, Pacific Swallow). While most of these species were also found in suitable habitat elsewhere in the Study Area Lowland Zone, Great Cormorant (a rare vagrant) and Little Ringed Plover were only recorded at Frieda Bend Site, and the Silver-eared Honeyeater was otherwise recorded only on the shores of Lake Warangai (Iniok Site).

While species of riverine and Lowland Open Forest (Po) habitats provided a link with the Study Area Lowland Zone, others were more characteristic of the Study Area Hill Zone. In particular, the distinction of Frieda Bend Site from other Study Area Lowland Zone sites was driven partly by the presence of hill-dwelling forest species that were not recorded at other Lowland Zone sites (Pale-billed Scrubwren, Obscure Honeyeater, Rufous-backed Fantail, Sooty Thicket-Fantail) or elsewhere in the Study Area Lowland Zone were recorded only in Hill Forest (Hm) on the low elevation slopes at Wario Site (Spot-winged Monarch, Black Berrypecker).

IUCN species recorded at Frieda Bend Site include Northern Cassowary (VU), Pesquet's Parrot (VU) and Victoria Crowned-Pigeon (VU).

6.4.6 Ok Binai 1 Site and Warangai South Site

Limited survey time at Ok Binai 1 Site (Section 3.5) yielded an incomplete list of only 31 species, and the results from this site were therefore excluded from the cluster analysis. The bird community at Ok Binai 1 Site is expected to be similar to those occurring at the Frieda Bend and Ok Isai Sites, given their geographic proximity and the broad overlap in elevation range and habitats present at each of these sites. Accordingly, most of the species recorded at Ok Binai 1 Site were also recorded at Frieda Bend Site and/or Ok Isai Site (28/31 species). The three species recorded at Ok Binai 1 Site and not at Frieda Bend Site or Ok Isai Site were Channel-billed Cuckoo, Pygmy Eagle and White-throated Needletail. Each of these species was generally scarce or patchily distributed across the Study Area, and the latter two are migratory species and therefore unlikely to have been present during either the Frieda Bend Site (Channel-billed Cuckoo) or Ok Isai Site (White-throated Needletail) surveys.

Northern Cassowary (VU) was the only IUCN species recorded at Ok Binai 1 Site.

Habitat surveyed at Warangai South Site comprised a mosaic of Swamp Woodland (Wsw), Mixed Swamp Forest (Fsw) and Hill Forest (Hm) below ca. 250 m elevation, and was similar to that surveyed in most other forest-dominated Study Area Lowland Zone sites (Kaugumi Site, Wario Site and Wogamush Site, but cf. East Sepik Site (Section 6.4.1). Forty-four species were recorded at Warangai South Site over two visits (10 hours total) during the Trip 1 Reconnaissance. While these surveys were not extensive enough to warrant inclusion in the cluster analysis, the similarity with comparable Study Area Lowland Zone sites was clear: most species (43/44) recorded here were also found at Kaugumi Site and/or Wario Site, the only addition being Pesquet's Parrot.

IUCN species recorded at Warangai South Site include Northern Cassowary (VU), Pesquet's Parrot (VU) and Victoria-crowned Pigeon (VU).

7 COMPLETENESS OF THE SURVEY

7.1 Overview

The Project surveys were sufficiently extensive to document a high proportion of the avifauna that is likely to occur in the Project disturbance area and throughout the Study Area Hill and Lowland zones (i.e. <1,000 m elevation).

No single-visit rapid assessment survey can be expected to result in a complete inventory of the avifauna regularly occurring at an individual site, consequently, a full census at each site was not the objective. Rather, these surveys were aimed at documenting as many of those species present as possible in the time available at each site, with a special focus on determining the status of those conservationally significant species that may be present. A variety of survey techniques were combined in an effort to achieve these goals, including aural and visual detection, mist-netting, camera-trapping, hunter interviews and call recording and playbacks.

Variation in survey time influenced the completeness of inventories at individual sites. Shorter survey periods at some locations (e.g. Nena D2 Site, Nena-Usage Site, Ubiame Site, Kubkain Site, Ok Binai 1 Site) yielded lists that fall well short of a full census. Despite more extensive surveys at other locations, additional bird species were still being recorded towards the end of most surveys, and few of the curves in Figure 5.1 approach an asymptote. Heavy rain during periods of peak bird activity (dawn and dusk) during the wet season surveys (Trip 2) further limited the time available to survey birds at optimum times.

Despite these restrictions, given the significant overlap in species composition among clustered sites, and in terms of (1) the number of study sites per unit area, (2) overall time spent in the field and (3) the pattern of visitation at different times of the year (dry season and wet season surveys, austral winter and summer), a high proportion of those bird species residing or regularly occurring in the Study Area Hill and Lowland zones appear to have been documented.

7.2 Study Area Hill and Montane zones

Within the Study Area Hill Zone, total species accumulation had slowed significantly towards the end of the Trip 2 surveys. Few or no additional species were recorded on most days at the last few Study Area Hill Zone sites (sites 9–11 in Figure 2), with only one species (Little Bronze-Cuckoo) added to the overall Study Area Hill Zone list during the Upper Ok Binai Site survey. Moreover, most of the additional species recorded at these sites were encountered in appreciably different habitat at Ubiame Site. Ubiame Site provided the only access to truly montane vegetation and associated bird communities. Despite the short survey period and inability to access the forest interior, a number of montane bird species were encountered only at this site (Mountain Peltops, Carola’s Parotia, Black-bellied Cuckooshrike).

Following the Trip 2 surveys, the only additional Study Area Hill Zone survey[2] was conducted at Ok Isai Site during the austral winter. Although a number of species recorded at Ok Isai Site were new for the Study Area (Figure 2), only one (Golden Myna) was a resident Hill Forest (Hm) species, the others being an austral migrant occurring only at this time of year (Rainbow Bee-eater) and two species preferring wet-floor forest that were recorded only in Lowland Open Forest (Po) (Red-necked Crake, Hooded Pitta).

Avifauna in the Study Area Montane Zone was less well covered, and a number of additional species may be found there (Section 8). Additional work at Ubiame Site, and/or at other Study Area Montane Zone sites, would undoubtedly reveal the presence of additional, previously unrecorded bird species. However, most additional species occurring in the Study Area Montane Zone are likely to be largely restricted to elevations above those predicted to be influenced by disturbances associated with Project development.

2 Excluding records from low elevation Hill Forest (Hm) on hill slopes projecting above the Sepik River Basin at various lowland Zone sites.

7.3 Study Area Lowland Zone

Towards the end of Trip 2, surveys of the Frieda Bend Site accessed habitats in the Frieda River drainage that included Lowland Open Forest (Po), riverine habitats and associated grassland and regrowth in extensive flood zones. Bird species observed only at this site during the final days of the survey include a number that are exclusively or closely associated with these habitats (e.g. Little Ringed Plover, Whistling Kite, White-bellied Sea-Eagle, Little Pied, Little Black and Great Cormorants, Great Egret, Silver-eared Honeyeater, Willie-wagtail, White-bellied Thicket-Fantail).

Resumption of species accumulation during Trip 3 is attributable to unprecedented access to forest on the lowlands of the Sepik River Basin, and at Hauna (and lakes) and Iniok Sites, to riparian, anthropogenic and wetland habitats (including grasslands, mudflats and flooded woodlands). Of 62 species recorded only in the Study Area Lowland Zone, some 38 (61.3%) are largely or entirely restricted to these habitats (Section 6.4). Figure 2 shows a steady increase in species accumulation at Hauna (and lakes) and Iniok Sites, reflecting the many habitats available and an ability to efficiently cover large areas using motorised canoe.

As with Study Area Hill Zone species, the majority of birds likely to occur in the Study Area Lowland Zone were recorded during the Trip 3 surveys. Accordingly, only two species were added to the total for the Study Area during the Trip 4 surveys at Wario Site (New Guinea Flightless Rail) and Wogamush Site (Red-bellied Pitta). Most of the Trip 4 survey time was spent in forest habitats (Swampy Forests, Lowland Open Forest (Po), Hill Forest (Hm) below ca. 250 m elevation), and most resident Study Area Lowland Zone forest species are likely to have been recorded.

By contrast, the wetland and Riverine Mixed Succession (Fri/Wri) habitats associated with the Sepik River and nearby lakes were poorly represented at Wario Site and Wogamush Site. The continual accrual of novel species at Hauna (and lakes) Site and Iniok Site during Trip 3 suggests that a complete census of these habitats had not been achieved and that more species can therefore be expected to occur, including a number of migratory wetland species (Sections 8.4.2 and 9.2.3).

8 POSSIBLE ADDITIONAL SPECIES

8.1 Totals

Excluding vagrants to New Guinea, an additional 195 species that have not yet been recorded may occur in the Study Area in light of current information on distribution and habitat preference. These are listed in Appendix 4.7 together with their conservation and residence/migratory status, their elevation range, habitat preference and potential for occurrence in the Study Area zones.

Appendix 4.7 includes 165 species (84.6%) that are New Guinea mainland breeding residents, three of which have their populations supplemented by non-breeding visitors from Australia. Thirty species (15.4%) are known to occur in New Guinea only as non-breeding migrants. Possible additional migratory species are discussed in detail below (Section 9). More than half of the birds listed in Appendix 4.7 (117; 60.0%) are forest-dependent species, 32 (16.4%) utilise more open and/or disturbed habitats (aerial foragers and birds of grasslands, marshes, urban and agricultural areas), and the remaining 46 (23.6 %) are wetland birds found only in lakes, rivers, streams and associated wetland vegetation.

8.2 Additional Listed Species

Seventeen possible additional species are of global and/or national conservation significance (Table 8). These include two Globally Threatened (Vulnerable) species (Salvadori's Teal, Black Sicklebill), nine species listed by the IUCN as Near Threatened or Data Deficient, and nine nationally Protected species. No Critically Endangered or Endangered birds are likely to occur within the Study Area.

Table 8. Additional IUCN and nationally listed bird species not yet recorded but potentially occurring within the Study Area.

COMMON NAME (*SCIENTIFIC NAME*)	**IUCN**	**PNG**	**LOWLAND ZONE**	**HILL & MONTANE ZONES**
Salvadori's Teal *Salvadorina waigiuensis*	VU	P		X
Papuan Swiftlet *Aerodramus papuensis*	DD		X	X
Papuan Hawk-Owl *Uroglaux dimorpha*	DD		X	X
Black-tailed Godwit *Limosa limosa*	NT		X	
Chestnut-shouldered Goshawk *Erythrotriorchis buergersi*	DD			X
Gurney's Eagle *Aquila gurneyi*	NT		X	X
Olive-yellow Robin *Poecilodryas placens*	NT			X
Papuan Whipbird *Androphobus viridis*	DD			X
Yellow-breasted Bird-of-paradise *Loboparadisea sericea*	NT	P		X
Loria's Bird-of-paradise *Cnemophilus loriae*		P		X
Trumpet Manucode *Manucodia keraudrenii*		P		X
Short-tailed Paradigalla *Paradigalla brevicauda*		P		X
Black Sicklebill *Epimachus fastuosus*	VU	P		X
Black-billed Sicklebill *Epimachus albertisi*		P		X
Superb Bird-of-paradise *Lophorina superba*		P		X
King-of-Saxony Bird-of-paradise *Pteridophora alberti*		P		X
Obscure Berrypecker *Melanocharis arfakiana*	DD			X

Notes: IUCN categories are VU - Vulnerable, NT - Near Threatened and DD - Data Deficient. PNG: P - protected under the PNG *Fauna (Protection and Control)Act 1966.*

Sixteen species listed in Table 8 may occur in the Study Area Hill and/or Montane zones, while only four are likely in the Study Area Lowland Zone. Many of the species listed in Table 8, including the Papuan Whipbird and all of the birds-of-paradise, are likely to occur in the Study Area, if at all, only in the Study Area Montane Zone (Section 8.3).

Detailed information on their distribution, habitat requirements and general conservation status will be given for each species individually in the EIS.

8.3 Additional Study Area Hill and Montane Zone Species

More than three quarters of the birds listed in Appendix 4.7 (151; 77.4%) may occur within the Study Area Hill and/or Montane zones. At first glance this is incongruous with the conclusion stated above (Section 7) that surveys conducted to date have been sufficient to document the majority of avifauna likely to occur in the Study Area Hill Zone. However, Appendix 4.7 was compiled using a conservative, inclusive approach that considered the broadest range of distributional and elevation records (sometimes aberrant) available for each species. Consequently, though their presence (at least occasionally) cannot be ruled out, many of the species listed in Appendix 4.7 may be unlikely to occur in the Study Area or be present only irregularly or as scarce and/or difficult to detect visitors or residents.

Appendix 4.7 includes 73 montane[3] species (marked therein), accounting for nearly half (48.3%) of the birds that may yet prove present within the Study Area Hill and Montane zones. None of these are normally found below 1,000 m elevation, and all are therefore most likely to occur only in the Study Area Montane Zone and outside of the Project disturbance area. Moreover, nearly half of the montane species (32/73; 43.8%) are not normally found below 1,500 m elevation, the upper elevation limit of the Study Area, though their presence cannot be ruled out as they have, at least occasionally, been recorded at lower elevations. A number are also nomadic in response to seasonal changes in food availability. Consequently, and particularly given that only a small section of the Study Area reaches above 1,000 m, many of the species listed in Appendix 4.7 are likely to be scarce, occur only in small numbers from time to time, or prove absent altogether. Nevertheless, without further work their presence in the Study Area cannot be ruled out.

Some other hill-dwelling species are generally uncommon and patchily distributed at the regional/ landscape level. Though the Study Area is located within (or close to) their known range they may be scarce or absent for a variety of reasons, including competitive exclusion with ecologically similar congeners. Relevant species include the Olive-yellow, White-rumped and Green-backed Robins and the Leaden Honeyeater (also a montane species). The shy, patchily distributed and apparently rare Greater Melampitta may occur wherever suitable limestone karst terrain occurs (and on other terrain: see Richards and Rowland 1995), though this appears not to be extensive within the Study Area. The Hooded Pitohui is reportedly less common where the Variable Pitohui is present (Coates 1990). The latter species is very common throughout the Study Area, and the Hooded Pitohui may be scarce or absent due to competition for local resources.

Other birds that may have been present are typically difficult to detect. These include genuinely rare and/ or inconspicuous birds, such as nocturnal predators (e.g. owls, nightjars and owlet-nightjars), Bare-legged and Papuan Swiftlets, Yellow-gaped Honeyeater and Masked Bowerbird (a lower montane species). In their Lake Kamu Basin surveys, Beehler and Mack (1999) reported that Yellow-gaped Honeyeater, Oriental Hobby and Papuan Hawk-Owl were only recorded in the final survey of a series of 10, and that the Barred Owlet-nightjar was still unrecorded at that time.

Other species are harder to detect at certain times of year. Most birds are considerably more vocal immediately prior to and during breeding, and some (e.g. nightjars, cuckoos) are almost silent outside these times. Seasonal changes in frequency and/or type of vocalisation have been noted among various

3 Here defined as species normally recorded above 1,000 m elevation.

rails (Rallidae), pigeons (Columbidae), pittas (Pittidae) and a number of arboreal passerines including certain flycatchers, whistlers, cuckooshrikes and birds-of-paradise (e.g. Diamond and Bishop 2003). These phenomena are relatively well understood in Asia (McClure 1974) and Australia (Crome 1993; Nix 1993), though they have not been studied to the same extent in PNG. Particularly in forest, many more birds are found by ear than by eye, and the presence of relatively cryptic species may easily be overlooked. Unfortunately, without repeat surveys conducted at the same sites at different times of year, seasonal patterns of vocalisation among birds present within the Study Area cannot be determined.

8.4 Additional Study Area Lowland Zone Species

Although most species likely to occur in the Study Area Lowland Zone were recorded during the Trip 3 surveys, more can be expected to occur given:

- The continual accrual of species at Hauna (and lakes) and Iniok Site (Figure 2).
- The fact that the Trip 3 surveys were not timed to coincide with northern hemisphere migrants likely to occur predominantly or solely in wetlands of the Study Area Lowland Zone.
- The lack of survey in Study Area Lowland Zone wetlands during the austral summer Trip 4 surveys.

Eighty-five additional species may occur in the Study Area Lowland Zone (Appendix 4.7), more than half of which (44 species; 51.8%) are not expected to occur in the Study Area Hill or Montane zones. Possible additional Study Area Lowland Zone species include 55 breeding residents and all of the migrants listed in Appendix 4.7 (30 species; see Section 9).

8.4.1 Land Birds

Only 15 Study Area Lowland Zone land birds listed in Appendix 4.7 are forest-dependent species that do not regularly occur in open habitats. Most of these are rare and/or inconspicuous at certain times of year, including New Guinea Bronzewing, White-bibbed and Thick-billed Ground-Pigeons, Metallic Pigeon, Bare-eyed Rail, Gurney's Eagle, Papuan Hawk-Owl, Barred Owlet-Nightjar, Tawny Straightbill, Yellow-gaped Honeyeater. Of these, only Bare-eyed Rail is not expected to also occur in the Study Area Hill Zone.

Open and disturbed habitats are far more extensive in the Study Area Lowland Zone than in the Study Area Hill and Montane zones. Of 36 non-forest land birds listed in Appendix 4.7, all but two (Bare-legged Swiftlet, Great Woodswallow) are expected to occur in the Study Area Lowland Zone. Of 23 potentially occurring in both sectors, all are expected to be most prevalent in the Study Area Lowland Zone. Surveys in most suitable habitat (suitable habitat was limited at Wario Site) were not timed to locate Barn Swallow (a northern migrant), but all other open habitat birds are either resident or austral migrants. A number are rare, patchy or previously unrecorded in the middle or upper Sepik River Basin, so that their presence in the Study Area is uncertain and their detection during a single survey is hit-or-miss (e.g. Black-winged Kite, Little Curlew, Oriental Plover, White-throated Eared-Nightjar, Papuan Swiftlet, Forest Kingfisher, Blue-tailed Bee-eater, Golden-backed and White-bellied Whistler, Lemon-bellied Flyrobin, Pied Bushchat, Australasian Lark).

More regularly occurring species include a number of inconspicuous and/or sparsely distributed night-birds (Barn Owl, Barking Owl), diurnal raptors (Oriental Hobby, Brown Falcon) and quail (Brown and Blue-breasted).

8.4.2 Wetland Birds

The freshwater wetlands of the Sepik River Basin support important resident waterbird populations and a suite of migratory species (Osborne 1989; UNESCO 2010). Detailed investigation into the distribution and status of waterbirds in the Sepik River Basin has not been undertaken, though a number of observers have published lists of species encountered in various localities (e.g. Stresemann 1923; Gilliard and LeCroy 1966; Lister 1977; Stringer 1977; Tolhurst 1993; Gregory 1996).

While wetland birds were a major component of the avifauna around Iniok Site and Hauna (and lakes) Site (Section 6.4.2), a number of additional species are likely to occur; wetland birds comprise nearly half of the Study Area Lowland Zone birds listed in Appendix 4.7 (38 species; 44.7%) and account for most of the migratory species listed in Appendix 4.7 (21/30 species; 70.0%; see Section 9).

Seventeen additional resident waterbirds may occur, including two kingfishers, five crakes and rails, four ducks, two grebes, two herons and the Comb-crested Jacana. The recent loss of breeding, foraging and/or sheltering habitat required by most of these species has been described above (Section 6.4.2). The scope of the problem cannot be quantified as no waterbird or vegetation surveys were previously conducted in the area. The present survey provides a useful baseline. Additional, periodic censuses at various times of year would be useful.

A number of resident waterbirds listed in Appendix 4.7 are rare in the Sepik River Basin and may not occur in the Study Area, though their presence cannot be ruled out (e.g. Grey Teal, Common Coot, Baillon's Crake, Striated and White-faced Heron, Common Kingfisher, Clamorous Reed-Warbler).

Possible additional migratory waterbirds are discussed below (Section 9.2.3).

9 MIGRATORY SPECIES IN THE STUDY AREA

New Guinea's avifauna includes some 60 migrant species that breed in the northern hemisphere (Eurasia) and around 30 species that breed to the south in Australia and New Zealand.

Published estimates vary of the number of migrants from the northern hemisphere; Dingle (2004) conservatively listed some 40 species as migrating to the Australo-Papuan region from breeding grounds in Eurasia, while Mack and Dumbacher (2007) noted that 75 species are listed under treaties designed to protect birds migrating between Australia and Japan (Japan-Australia Migratory Bird Agreement) and Australia and China (China-Australia Migratory Bird Agreement), all of which have been recorded or may be expected to occur in New Guinea (as a destination or en route to Australia).

Northern migrants are present in greatest numbers during the austral summer from September to April, while southern migrants are most common between May and October. The Trip 1, 2 and 4 surveys were thus best timed to detect northern migrants, while the Trip 3 surveys coincided with a peak in southern migrants.

Of 220 species recorded in the Study Area, at least 16 are migatory species and a further six are breeding residents whose numbers are seasonally augmented by non-breeding visitors (Table 7). Thirty additional migratory species may occur (Appendix 4.7).

9.1 Migratory Land Birds

9.1.1 Australian Migrants Recorded

Most migratory land birds breed in Australia and are therefore present during the austral winter. Eight southern migrant land-birds have been recorded in the Study Area, four of which were recorded only in the Study Area Lowland Zone during Trip 3 (Sacred Kingfisher, Buff-breasted Paradise-Kingfisher, Rainbow Bee-eater, Satin Flycatcher). Some of these may also occur in the Study Area Hill Zone, though surveys at those sites were poorly timed for detecting southern migrants.

Dollarbirds were regularly recorded at all sites during Trip 3, and a single bird was observed along the Niar River on 10 October 2009 during the Phase 1 Reconnaissance. All instances most likely involved migrant birds; the resident race *waigiouensis* is scarce in the north while the Australian-breeding race *pacificus* occurs there in large numbers from March to November (Coates 1985; Dingle 2004). Brush Cuckoos of both the resident north New Guinea race *infaustus* and the Australian migratory race *variolosus* may have been encountered but are indistinguishable in the field (Coates 1985; Payne 2005).

Migrant Spangled Drongos may not reach the Study Area. Members of the migratory Australian subspecies *bracteatus* (and possibly *atrabectus*) are known only from the southern watershed and almost exclusively from the Trans-Fly (Beehler *et al.* 1986; Coates 1990; Higgins *et al.* 2006). Notwithstanding heretofore undetected movements, and consistent with vocalisations heard during the surveys, birds from the Study Area almost certainly are all members of the resident subspecies *carbonarius*.

9.1.2 Northern Migrants Recorded

Fewer Eurasian land-birds visit New Guinea. Of only four species that regularly visit the eastern half of the island (Dingle 2004), three were recorded in the Study Area Hill and Montane zones: Oriental Cuckoo (although confirmation would require measurement of captured birds, the birds observed at HI Site and Upper Ok Binai Site were most likely this species. The Himalayan Cuckoo is known with certainty from New Guinea only from the western half of Papua (Payne 2005).White-throated Needletail and Grey Wagtail. The fourth Eurasian migrant land-bird, the Fork-tailed Swift, is unlikely to occur regularly in the

Study Area as most records of this species in New Guinea are from the southern watershed (Coates 1985; Beehler *et al.* 1986).

9.1.3 Possible Additional Migrant Land Birds

Seven additional migratory land birds may occur in the Study Area, all of which are expected to be most numerous in open and disturbed habitats in the Study Area Lowland Zone. Four of these are southern migrants. Though unrecorded during the Trip 3 surveys, the Tree Martin and Shining Bronze-Cuckoo are likely to be regular visitors. The White-throated Eared-Nightjar and Forest Kingfisher are as yet unknown from the Sepik River Basin (Coates 1985; Cleere and Nurney 1998; Coates and Peekover 2001; Cleere 2010), so that their occurrence in the Study Area is uncertain but cannot be ruled out.

Most Study Area Lowland Zone surveys (Trip 3) were not timed to locate northern migrants. The Oriental Plover and Little Curlew are rare in the Sepik River Basin but may occur on grassy and open ground from time to time (Coates 1985). The Barn Swallow may be a regular visitor in small numbers.

9.2 Migratory Waterbirds

Most migratory waterbirds visit New Guinea's coasts and wetlands rather than the interior.

9.2.1 Australian Migrants Recorded

Each year there is a significant exchange of waterbirds between Australia and New Guinea, though for many species patterns of movement and breeding are still poorly known (Dingle 2004).

Whiskered Terns, Little Pied and Little Black Cormorants, Intermediate and Eastern Great Egrets were all regularly encountered along rivers and lakes in the Study Area Lowland Zone. The cormorants and Eastern Great Egret were also recorded on the Niar River in the Frieda River drainage. Pied Herons were seen in good numbers from the air on Lakes Warwi and Warangai in October 2009, but only one was seen on Lake Warangai in June 2010. Less common species included a single Great Cormorant (a rare vagrant in New Guinea) on the Niar River in February 2010, and a single Little Egret at the junction of Hueap Creek and the Sepik River in June 2010. Most records likely involved Australian-breeding birds, though individuals of some species (e.g. Little Pied and Little Black Cormorants, Pied Heron and all three egret species) may breed in the area. Additional surveys would be required to determine the importance of the Study Area's wetlands to breeding waterbirds.

9.2.2 Northern Migrants Recorded

Northern migrants include a large number of Eurasian-breeding waders (Scolopacidae, Charadriidae) that visit tidal and coastal mudflats during the austral summer. Small groups of Eurasian waders, almost certainly including and probably exclusively comprised of Sharp-tailed Sandpiper, were seen during aerial reconnaissance of Lake Warwi and Lake Warangai in October 2009. Common Sandpipers were recorded along the Nena River (1 bird) and Niar River (2 birds) in February 2010 (Trip 2).

A single *Ixobrychus bittern*, probably Yellow Bittern, was seen along the Hueap Creek in June 2010. The Yellow Bittern is known in New Guinea only as a northern migrant during the austral summer, although there is a resident breeding population on Bougainville and winter records consistent with breeding from New Britain and the Ninigo Islands (Coates 1985). This individual may have been a migrant Yellow Bittern that did not make the return journey north for the 2010 breeding season, part of an unrecorded population of breeding resident Yellow Bitterns, or a southern migrant Little Bittern, though these are rare in northern New Guinea and the plumage characters fit the former species more closely.

9.2.3 Possible Additional Migrant Waterbirds

In addition to those already recorded, a further seven southern migrant waterbirds may occur in the Study Area. Of these, only the Gull-billed Tern is likely to be a regular visitor; Little Tern, Hardhead, Australian Pelican, Royal Spoonbill, Glossy and Australian Ibis may occur only rarely, most likely during periods of severe drought in Australia. One such event in 1977–78 coincided with a major irruption of Australian Pelicans in New Guinea, and perhaps into the Study Area. Residents of Hauna recognised this species from a single event "many years ago" when numbers of birds arrived on the lakes. Gary Nugom, a small boy at the time, recalled that local residents did not recognise the birds and were afraid that they may eat their children. A number of pelicans were killed.

An additional 18 species of waterbird that breed in the northern hemisphere may occur in the Study Area's wetlands during the austral summer (Appendix 4.7). These include two terns (Common and White-winged Terns) and 16 migratory Palaearctic waders (Scolopacidae, Charadriidae).

9.2.4 Palaearctic Waders

The conservation of Palaearctic waders and their habitats is the focus of elevated international concern, since many of the species are in decline and continue to be threatened by a wide range of environmental changes and human-related activities (Barrett *et al.* 2003; Meltofte *et al.* 2004; Gosbell and Clemens 2006). Each year the birds travel long distances between their northern hemisphere breeding grounds and wintering areas in Australia and New Zealand. The energy required for migration comes primarily from fat stored at wintering grounds and stopover points (Finn 2007). Consequently, disruptions to their foraging behaviour and/or habitat can have serious consequences for their survival.

Situated in the southern half of the East Asian-Australasian Flyway (EAAF), the Study Area includes suitable foraging habitat as exposed mudflats, vegetated swamps and shallow edges to lakes and rivers. Most of the migratory waders listed in Appendix 4.7 prefer coastal or sub-coastal, tidal wetland habitats, and are likely therefore to be most prevalent in sub-coastal wetlands of the lower Sepik River Basin, and therefore outside of the Project disturbance area. However, they also commonly occur or are at least occasionally recorded in interior freshwater wetlands (Geering *et al.* 2007). The species most common in the middle and upper Sepik River Basin are the Pacific Golden Plover and the Sharp-tailed Sandpiper (Coates 1985). Others recorded from the floodplains of the Sepik and Ramu rivers include Black-tailed and Bar-tailed Godwits, Whimbrel, Marsh and Wood Sandpipers, Grey-tailed Tattler, Red-necked Stint and Latham's and Swinhoe's Snipe (Osborne 1989). Yet others potentially occurring but not yet recorded in the region may include Common Greenshank, Little and Long-toed Stints, Pectoral, Curlew and Broad-billed Sandpipers.

Falls in reporting rates in Australia suggest that many of these species are experiencing population declines, including Sharp-tailed Sandpiper, both godwits, Grey-tailed Tattler, Curlew Sandpiper, Red-necked Stint, Common Greenshank and Pacific Golden Plover (Barrett *et al.* 2003; Gosbell and Clemens 2006; Harding *et al.* 2007). Loss or degradation of foraging and roosting wetland habitat in the Sepik River Basin may place additional pressure on these taxa and thereby affect their global populations. Ultimately, the magnitude of the potential threat will be proportional to the importance of Sepik River Basin habitats to each species, either as a wintering station or staging point, details which remain unknown and warrant further investigation.

10 CONSERVATION VALUE OF THE STUDY AREA AND ITS AVIFAUNA

A variety of factors combine to determine the conservation value of an area's habitats and the biotic communities they support. Factors influencing the significance of bird communities include but may not be restricted to:

- The relative size of the area under investigation, and the quality, diversity and contiguity of habitats supported therein.
- The presence of similar or better quality (e.g. less degraded) habitats elsewhere locally and/or regionally.
- Intactness and diversity of the local bird communities.
- The number of endemic, rare and sensitive (e.g. IUCN) species present.
- The persistence and status of these species elsewhere locally and/or regionally.
- The stability of the situation described by the conditions above, including the outlook for ongoing viability of habitats and the biota they support.

The Study Area is of high conservation value due to its large size, remoteness and high degree of connectivity among a variety of intact habitats that span a broad elevation range of nearly 1,500 m and a variety of topographies and soil types. Habitats present include significant tracts of lowland and Hill Forest, including dry-land forest, swamp forest and riparian forest, and numerous rivers, streams and standing water wetlands. Accordingly, the Study Area still supports a diverse and predominantly intact avifauna. Our surveys indicate that in most parts of the Study Area Lowland and Hill Zones most or all bird species that would naturally have occurred in the absence of extensive human occupation are still to be found, and moreover appear to be present in or close to their natural abundance. Exceptions to this pattern are largely restricted to the vicinity of local villages, past mineral exploration activities, and, to a lesser degree, in hunting areas located some distance from local settlements (e.g. at Malia Site, which is about 2 days walk from Wameimin 2).

In addition to its overall intact state, the Study Area's avifauna is presently known to include 23 species that are IUCN species and/or listed as Proteced under the PNG *Fauna (Protection & Control)Act 1966* (Table 6), and a number of additional, as yet undetected IUCN species are also likely to occur (Section 8.2). Most IUCN species present within the Study Area also occur fairly widely across New Guinea, are known from widely scattered localities across the island, or have a broad distribution across its northern lowland forests (e.g. Northern Cassowary, Victoria Crowned-Pigeon, New Guinea Flightless Rail). Viable populations therefore also persist in other areas of intact and sparsely populated forest, and in a number of cases these areas are presently expansive.

Compared to other tropical regions, most notably South-east Asia, New Guinea's forests are still relatively intact; the island still supports the world's third largest continuous tract of tropical forest behind the Amazon and the Congo (Beehler 2007a; Shearman *et al.* 2009). Moreover, New Guinea is still relatively sparsely populated and infrastructure-poor, so that much of its tropical lowland and Hill Forests, typically the most accessible and heavily exploited, are thus far relatively free of large-scale conversion pressures (Sekhran and Miller 1994; Anggraeni 2007; FAO 2007). However, recent analysis of satellite imagery has shown that estimates of forest loss and conversion have been underestimated (Shearman *et al.* 2009).

Taking a regional perspective, the Study Area incorporates part of two distinct avifaunal regions: the hills and lower mountains of the Central Cordillera (Study Area Hill and Montane zones) and the north Papuan lowlands (Study Area Lowland Zone). The Study Area is situated more or less in the centre of an approximately 1,200-km-long interface between these two extensive areas. Most of these areas, and their zones of intersection, still support significant tracts of remote and intact habitat. The Sepik River catchment is itself regarded as probably the largest and least contaminated freshwater system present in the Asia-Pacific realm (WWF 1999), with forest cover in the Sepik River Basin currently estimated at more than 75% (Revenga *et al.* 2003, Sherman *et al.* 2009). Its western complement, Papua's Memberano basin, is still more than 90% forested (Frazier 2007).

Despite this persistence of intact faunal communities across large parts of New Guinea, the Study Area's avifauna is still to be regarded as being of high conservation value at both the national and international levels.

The present remoteness of New Guinea's forests and their biota does not mean that they are permanently secure. Unexploited natural resources still abundant in New Guinea include expansive tracts of forest, land for commercial agriculture ventures (particularly Oil Palm) and mineral and energy reserves (New Guinea is one of the world's highest mineralization zones) (Anggraeni 2007; Cannon 2007). Between 2000 and 2005, PNG accounted for the third highest loss of primary forest from any country in the world (FAO 2007). Combined with the fact that the highest global loss of primary forest occurred in Indonesia and that much of that was in Papua, the situation in New Guinea is serious. These processes are set to continue as large areas of forest are currently included within logging concessions or have been slated for conversion to large-scale commercial agriculture. For example, PNG currently exports about two million cubic metres of logs annually, making it the world's second largest exporter of tropical logs behind Malaysia. Numerous additional forestry projects are in various stages of development, including at least three in Sandaun Province that cover a total land area of more than 400,000 ha (PNG Forest Authority 2007).

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PLATES

Unless otherwise stated, all birds were mist-netted and all photos copyright Iain Woxvold.

Plate 1. (A) An immature Northern Cassowary (*Casuarius unappendiculatus*) camera-trapped at Malia Site; (B) A Northern Cassowary camera-trapped at Ok Binai 1 Site; (C) A captive juvenile Dwarf Cassowary (*C. bennetti*) at Frieda Base Site; (D) Wattled Brush-turkey (*Aepypodius arfakianus*) camera-trapped at Koki Site; (E) Brown-collared Brush-turkey (*Talegalla jobiensis*) camera-trapped at Upper Ok Binai Site; (F) New Guinea Scrubfowl (*Megapodius decollatus*) camera-trapped at Kaugumi Site.

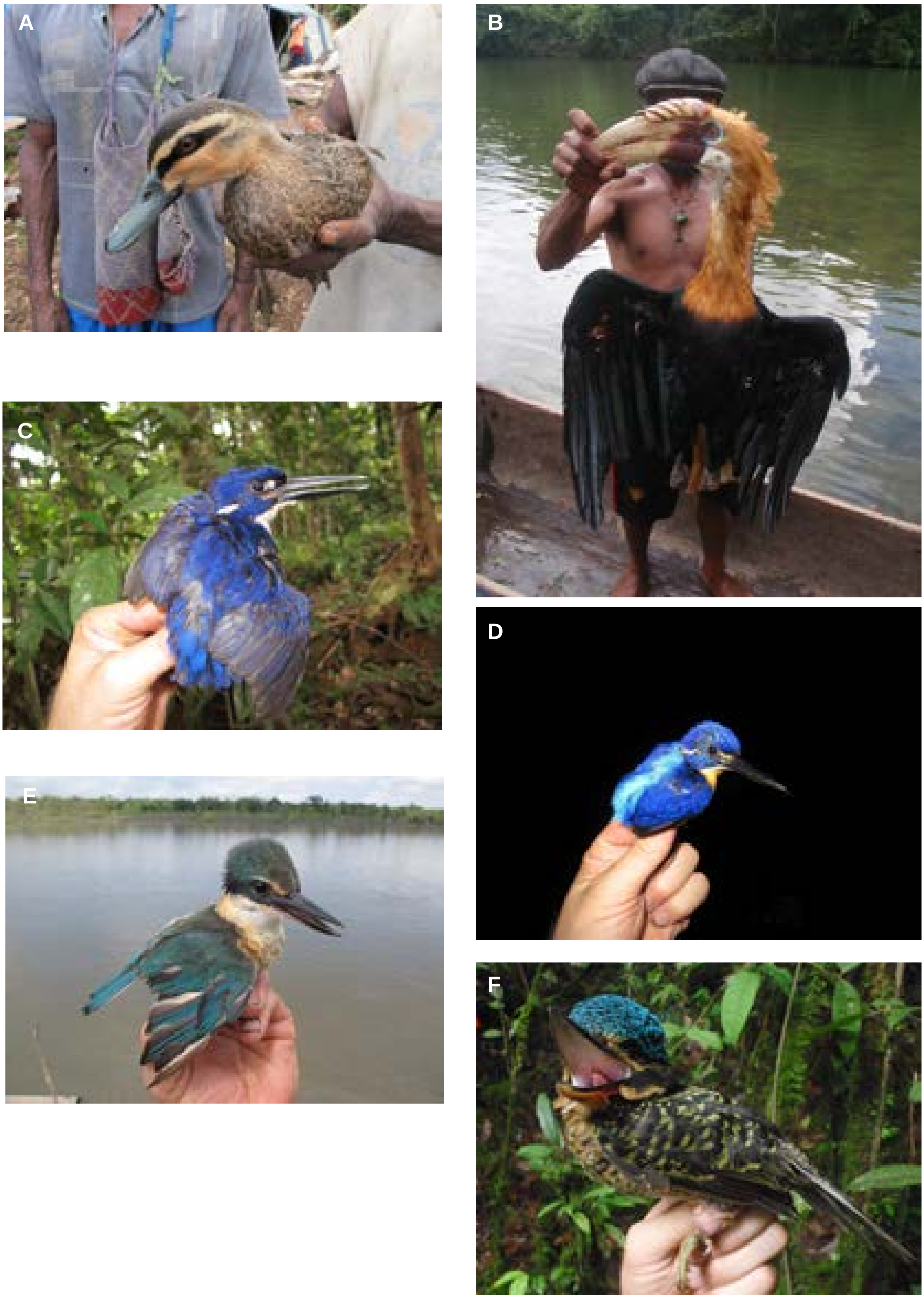

Plate 2. (A) Pacific Black Duck (*Anas superciliosa*) captured by a local resident at Wario Site; (B) male Blyth's Hornbill (*Aceros plicatus*) killed by a dog near Frieda Bend Site (C) Azure Kingfisher (*Alcedo azurea*); (D) Variable Kingfisher (*Ceyx lepidus*); (E) Sacred Kingfisher (*Todirhamphus sanctus*); (F) Hook-billed Kingfisher (*Melidora macrorrhina*).

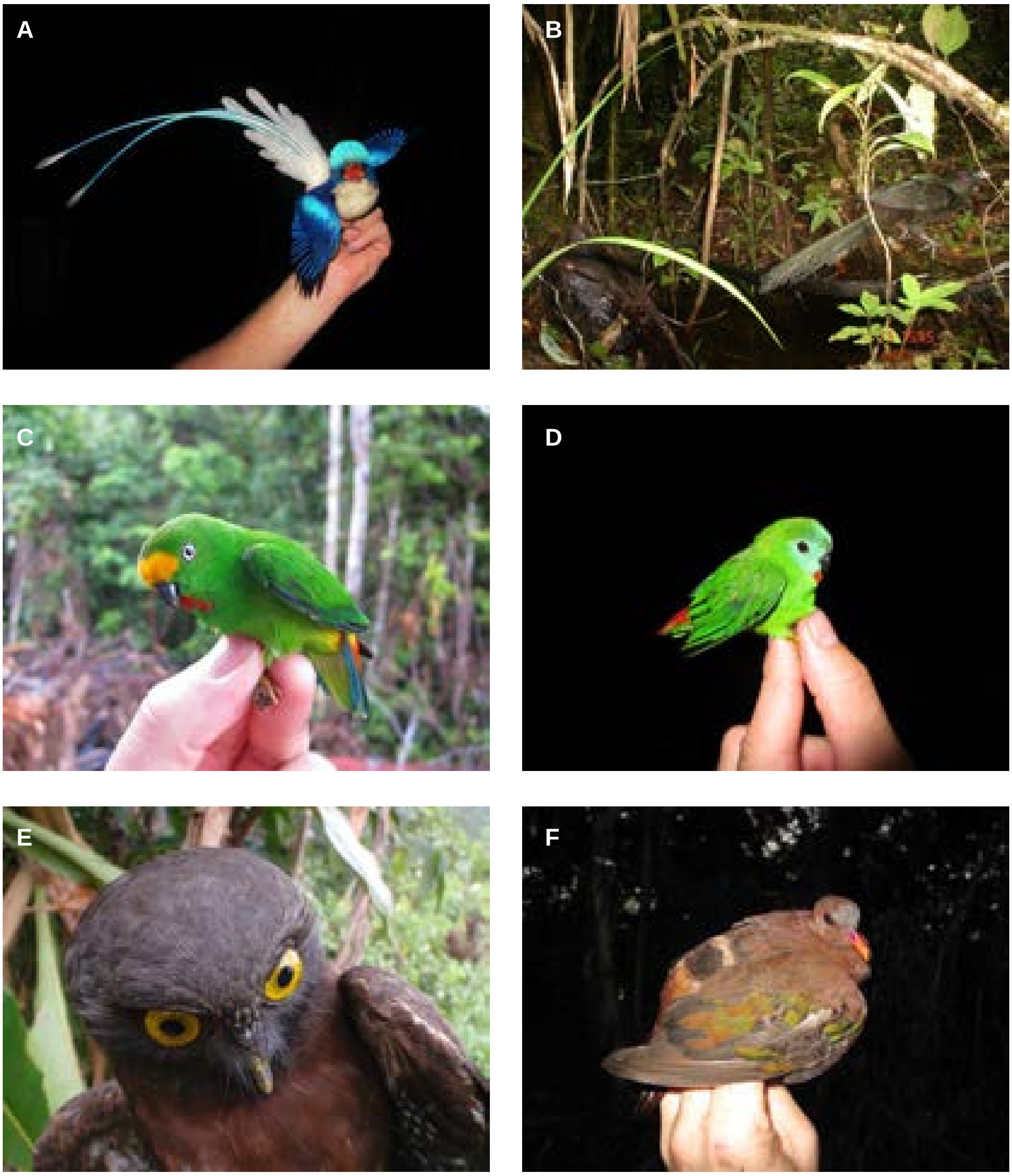

Plate 3. (A) Common Paradise-Kingfisher (*Tanysiptera galatea*); (B) Greater Black Coucal (*Centropus menbeki*) camera-trapped at Malia Site; (C) male and (D) female Orange-fronted Hanging-Parrot (*Loriculus aurantiifrons*); (E) Jungle Hawk-Owl (*Ninox theomacha*); (F) juvenile Stephan's Dove (*Chalcophaps stephani*).

Plate 4. (A) Cinnamon Ground-Dove (*Gallicolumba rufigula*); (B) juvenile Ornate Fruit-Dove (*Ptilinopus ornatus*) captured by hand at Nena Base Site (C) Coroneted Fruit-Dove (*Ptilinopus coronulatus*); (D) Red-necked Crake (*Rallina tricolor*) camera-trapped at Ok Isai Camp.

Plate 5. Two species of international conservation significance, camera-trapped at Malia Site: (A) the hunting-sensitive Victoria Crowned-Pigeon (*Goura victoria*) (IUCN: Vulnerable); (B) the rare Forest Bittern (*Zonerodius heliosylus*) (IUCN: Near Threatened)

Plate 6. (A) White-eared Catbird (*Ailuroedus buccoides*); (B) Long-billed Honeyeater (*Melilestes megarhynchus*); (C) Green-backed Honeyeater (*Glycichaera fallax*); (D) Forest Honeyeater (*Meliphaga montana*); (E) Puff-backed Honeyeater (*M. aruensis*); (F) Mimic Honeyeater (*M. analoga*).

Plate 7. (A) Obscure Honeyeater (Lichenostomus obscurus); (B) Tawny-breasted Honeyeater (*Xanthotis flaviventer*); (C) Plain Honeyeater (*Pycnopygius ixoides*) (photo: K. Aplin); (D) Rusty Mouse-warbler (*Crateroscelis murina*). (E) Pale-billed Scrubwren (*Sericornis spilodera*); (F) Yellow-bellied Gerygone (*Gerygone chrysogaster*).

Plate 8. (A) Large-billed Gerygone (*Gerygone magnirostris*); (B) White-faced Robin (*Tregellasia leucops*) (photo: K. Aplin); (C) Black-chinned Robin (*Poecilodryas brachyura*); (D) New Guinea Babbler (*Pomatostomus isidorei*); (E) Blue Jewel-babbler (*Ptilorrhoa caerulescens*); (E) Chestnut-backed Jewel-babbler (*P. castanonota*).

Plate 9. (A) Goldenface (*Pachycare flavogrisea*) (photo: K. Aplin); (B) Rusty Whistler (*Pachycephala hyperythra*) (photo: K. Aplin); (C) Little Shrike-thrush (*Colluricincla megarhyncha*); (D) Variable Pitohui (*Pitohui kirhocephalus*); (E) Rusty Pitohui (*P. ferrugineus*).

Plate 10. **(A–B) Male, and (C) female Magnificent Bird-of-paradise (*Cicinnurus magnificus*); (D) female King Bird-of-paradise (*C. regius*) (photo: S. Richards); (E) White-bellied Thicket-Fantail (*Rhipidura leucothorax*); (F) Rufous-backed Fantail (*R. rufidorsa*).**

Plate 11. (A) Spot-winged Monarch (*Monarcha guttulus*); (B) Hooded Monarch (*M. manadensis*); (C) female Golden Monarch (*M. chrysomela*); (D) male Rufous-collared Monarch (*Arses insularis*) (photo: S. Richards); (E) male, and (F) female Shining Flycatcher (*Myiagra alecto*).

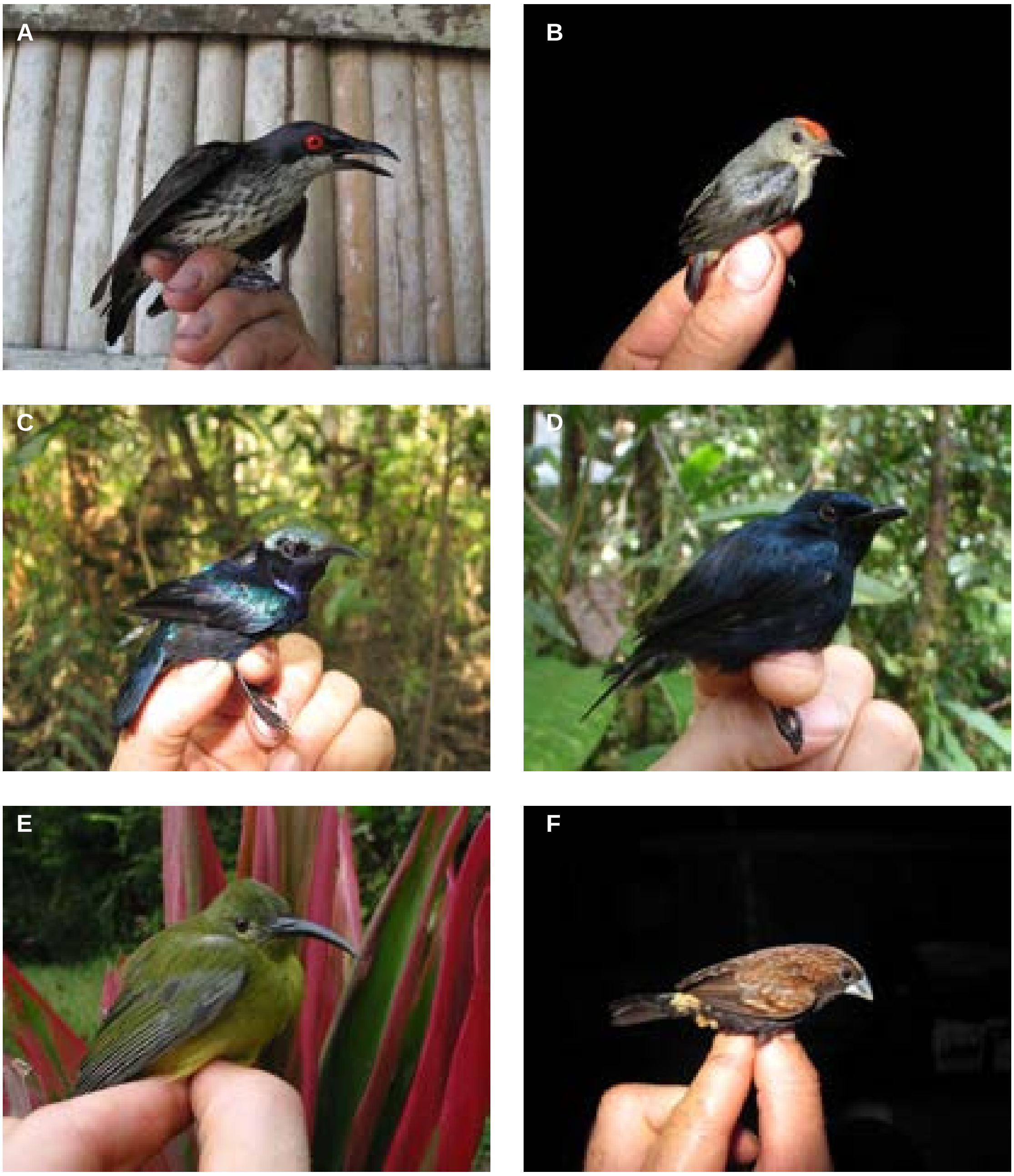

Plate 12. (A) An immature Metallic Starling (*Aplonis metallica*); (B) female Red-capped Flowerpecker (*Dicaeum geelvinkianum*); (C) male (Papuan) Black Sunbird (*Nectarinia aspasia*); (D) male Black Berrypecker (Melanocharis nigra); (E) Green-crowned Longbill (*Toxorhamphus novaeguineae*) (F) Streak-headed Munia (*Lonchura tristissima*).

APPENDICES

Appendix 4.1 The location of each survey site and the duration and coverage of bird surveys.

SITE	NORTHING	EASTING	LAT (S)	LONG (E)	ELEVATION (M)	TRIP #	SURVEY DATES
Biodiversity survey sites							
Hauna (& lakes) Site	633102	9521859	4°19.492	142°11.968	30 (35 - 50)	3	12 - 13 Jun ‘10
Warangai South Site	604838	9508484	4°26.772	141°56.696	40 (40 - 55)	R	16 Oct ‘09; 18 Oct ‘09;
East Sepik Site	615978	9512957	4°24.337	142°02.716	45 (35 - 55)	3,4	07 – 12 Jun ’10; 14 Mar ‘11
Iniok Site	613257	9525933	4°17.296	142°01.236	45 (35 - 50)	3	13 -18 Jun ‘10
Kubkain Site	647022	9521801	4°19.510	142°19.493	50 (30 - 135)	R,4	01 Nov ‘10; 05 – 10 Mar ‘11
Wogamush Site	643437	9513096	S 04° 24.238’	142° 17.563’	55 (45 - 120)	4	28 Feb – 05 Mar ‘11
Frieda Strip Site	606679	9490687	4°36.430	141°57.704	60 (60 - 60)	R, 1, 2, 3, 4	brief transits
Wario Site	625869	9499578	04° 31.589’	142° 08.076’	65 (40 - 335)	4	24 – 28 Feb ‘11
Frieda Bend Site	602364	9485624	4°39.181	141°55.374	80 (65 - 150)	R, 2	10 Oct ‘09; 23 - 28 Feb ‘10
Kaugumi Site	606472	9497488	4°32.739	141°57.588	90 (60 - 90)	3	01 – 07 Jun ‘10
Ok Binai 1 Site	593391	9480315	4°42.068	141°50.524	125 (115 - 330)	R, 4	20 Oct ‘09; 10 - 15 Mar ‘11
Ok Isai Site	602620	9478846	4°42.859	141°55.517	135 (100 - 145)	3	26 May – 01 Jun ‘10
Malia Site	588503	9486267	4°38.841	141°47.876	290 (225 - 400)	R, 2	14 Oct ‘09; 17 Oct ‘09; 2 – 8 Feb ‘10 28 Feb - 02 Mar ‘10
Nena D1 Site	582451	9486788	4°38.562	141°44.602	400 (365 - 500)	1	5 – 8 Dec ‘09
Frieda Base	587095	9480591	4°41.923	141°47.118	400 (390 - 515)	R, 2	8 - 19 Oct ‘09; 12 – 14 Feb ‘10
Upper Ok Binai Site	587128	9477389	4°43.660	141°47.138	425 (325 - 575)	2	18 – 23 Feb ‘10
Nena-Usage Site	576498	9489217	4°37.247	141°41.380	440 (305 - 460)	1	12 – 14 Dec ‘09
Koki Site	585378	9482657	4°40.802	141°46.188	560 (510 - 660)	2	8 – 12 Feb ‘10
Nena D2 Site	580804	9489145	4°37.283	141°43.710	655 (640 - 685)	1	3 – 4 Dec ‘09

SITE	NORTHING	EASTING	LAT (S)	LONG (E)	ELEVATION (M)	TRIP #	SURVEY DATES
HI Site	583557	9480843	4°41.788	141°45.204	825 (610 - 1305)	2	14 – 18 Feb ‘10
Nena Base Site	580316	9485643	4°39.185	141°43.448	835 (750 - 1030)	R, 1	15 Oct ‘09; 29 Nov – 14 Dec ‘09
Nena Limestone Site	575324	9486656	4°38.637	141°40.747	950 (880 - 1055)	1	8 – 11 Dec ‘09
Nena Top Site	579516	9485824	4°39.087	141°43.015	1065 (950 - 1100)	3	06 – 08 Jun
Ubiame Site	582960	9480935	4°41.738	141°44.881	1380 (1360 - 1385)	2	16 – 17 Feb ‘10
Village interview sites							
Hotmin Village Site	561993	9493904	4°34.710	141°33.533	83 (83 - 155)	2	26 Feb ‘10
Wameimin 1 Village Site	565138	9476150	4°44.429	141°35.177	500 (500 - 500)	2	21 Feb ‘10
Wameimin 2 Village Site	577335	9484453	4°39.832	141°41.836	637	1	03 Dec ‘09
Nekiei Village	626130	9500220	4°31.24	141°8.648	45	4	27 Feb ‘11
Kubkain village	647416	9523164	4°18.77	141°19.705	50	4	09 Mar ‘11
Paru Village (interviews at Wogamush site)	646118	9515964	4°22.678	141°19.1	45	4	03 Mar ‘11

Note: eastings and northings in PNG MG94 Zone 54. Trips are R: recconniasance 7-20 Oct ‘09 and 1 Nov ‘10. Trip 1: 29 Nov - 15 Dec ‘09. Trip 2: 01 Feb ‘10 - 03 Mar ‘10. Trip 3: 26 May - 20 Jun ‘10. Trip 4: 23 Feb - 16 Mar ‘11.

Frieda Base site consisted of artial-day surveys conducted on 8, 9, 11, 13 and 19 October 2009.

Frieda Strip Site: casual observations over multiple days while waiting at Frieda Airstrip.

Frieda bend Site included a canoe survey between Frieda Airstrip and Wabia Village and between the hydro-power dam and Wabia Village.

During the Trip 1 Surveys, all time was spent at Nena Base Site when not at other survey sites.

Appendix 4.2 Mist-netting effort and location at each survey site.

SITE	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M))	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
Trip1									
Nena Base Site	1	9	580153	9485696	871	244.75	2202.75	10	Early stage secondary Hill Forest (Hm) (3–5 m) next to stream.
	2	12	580163	9485714	873	244.00	2928.00	10	Pioneer and early stage secondary Hill Forest (Hm) (3–5 m) and scrub near stream.
	3	9	580137	9485765	892	210.25	1892.25	8	Undisturbed Hill Forest (Hm) with numerous saplings and ferns on flat terrace.
	4	9	580079	9485767	892	209.25	1883.25	8	Undisturbed Hill Forest (Hm) along low ridge between stream and deeper valley of small river.
	5	12	580071	9485813	922	215.25	2583.00	9	Undisturbed Hill Forest (Hm) along ridge beside walking trail.
	6	6	580071	9485813	922	227.00	1362.00	9	Perpendicular to net no. 5, across trail and end of ridge.
	7	12	580137	9485765	895	199.00	2388.00	8	Adjacent and parallel to net no. 3.
	8	6	580522	9485941	792	224.50	1347.00	10	Across fast flowing stream.
	9	9	580441	9485752	805	224.50	2020.50	10	Across fast flowing stream, above cascade.
Nena D1 Site	1	9	582397	9486888	430	87.00	783.00	4	Undisturbed Hill Forest (Hm) (15–20 m), fairly dense understorey with numerous saplings.
	2	9	582464	9486814	416	67.25	605.25	3	Riparian Forest (Hm) (8–15 m) adjacent to river.
	3	12	582348	9486905	432	65.75	789.00	3	Same as net no. 1.
	4	15	582393	9486876	406	68.00	1020.00	3	Break in slope, Hill Forest (Hm) above stream.
	5	15	582346	9486920	410	67.75	1016.25	3	Break in slope, Hill Forest (Hm) above stream.
	6	12	582203	9487015	439	65.50	786.00	3	Along front of rockshelter.
Nena Limestone Site	1	12	575311	9486692	968	64.50	774.00	3	Undisturbed Hill Forest (Hm) on gentle slope, fairly open understorey with numerous small trees.
	2	9	575385	9486570	972	63.75	573.75	3	Undisturbed Hill Forest (Hm) ridge, dense understorey of climbing bamboo *Nastus productus*.
	3	12	575424	9486617	957	71.25	855.00	3	High, across wide, shallow stream.
	4	6	575328	9486592	967	18.50	111.00	1	Blocking cave mouth.
Nena-Usage Site	1	12	576477	9489124	407	17.00	204.00	1	Hill Forest (Hm) across stream.
	2	15	576482	9489118	403	18.00	270.00	1	In Hill Forest (Hm) understorey.
Trip 2									

SITE	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M))	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
Malia Site	1	12	588580	9486318	328	144.00	1728.00	6	Undisturbed Hill Forest (Hm) on flat terrain, 20-25 m canopy, dense ground cover of young saplings, dense mid-storey of young trees.
	2	9	588608	9486323	327	144.00	1296.00	6	Extension of net 1, adjacent to stream on lower terrace, more open ground layer.
	3	12	588624	9486204	315	142.00	1704.00	6	Same as net 1.
	4	9	588624	9486204	315	142.00	1278.00	6	Same as net 1.
	5	15	588405	9486358	338	138.00	2070.00	6	Mid-slope, dense understorey
	6	12	588419	9486345	325	137.00	1644.00	6	Upper slope, moderate dense understorey
	7	15	588411	9486318	328	136.00	2040.00	6	Cross slope from net 6
	8	15	588409	9486376	330	135.00	2025.00	6	Alluvial bench beside stream, open understorey
	9	12	588461	9486313	325	134.00	1608.00	6	Crossing small stream
	10	15	588409	9486312	340	120.00	1800.00	5	Along small interfluve, relatively open understorey
	11	10	588361	9486339	346	119.00	1190.00	5	Moderate dense understorey on ridge
	12	12	588535	9486127	327	118.00	1416.00	5	Flat waterlogged area, relatively open understorey
	13	12	588484	9486206	326	117.00	1404.00	5	Top of slope above ago swamp
	14	12	588469	9485915	330	72.00	864.00	3	Across shallow stream
	15	15	588469	9485915	330	71.00	1065.00	3	Oblique crossing stream, near net 14
Koki Site	1	12	585273	9482603	560	114.00	1368.00	5	Undisturbed Hill Forest (Hm) alongside fast narrow stream
	2	12	585254	9482606	566	113.50	1362.00	5	Cross slope, dense understorey
	3	15	585238	9482582	569	113.00	1695.00	5	Cross slope, dense understorey
	4	9	585212	9482568	566	100.00	900.00	4	Flat bench, open understorey
	5	12	585231	9482574	562	99.00	1188.00	4	Mid-slope, dense understorey
	6	12	585535	9482755	507	99.00	1188.00	4	Stream side, dense understorey
	7	15	585535	9482755	508	98.00	1470.00	4	Lower slope
	8	12	585212	9482568	566	97.00	1164.00	4	Upper slope
	9	12	585614	9482748	520	97.00	1164.00	4	Lower slope
	10	15	585271	9482580	557	96.00	1440.00	4	Upper slope
Frieda Base Site	1	12	586447	9480160	480	28.00	336.00	1	Small stature Hill Forest (Hm) on limestone, dense understorey and ground layers, many ferns and lianes.
	2	12	586447	9480160	480	28.00	336.00	1	Same as net 1.

SITE	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M))	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
	3	12	586447	9480160	480	28.00	336.00	1	Same as net 1.
	4	6	586447	9480160	480	28.00	168.00	1	Same as net 1.
HI Site	1	12	583518	9481113	872	72.00	864.00	3	Undisturbed Hill Forest (Hm), dense understorey
	2	12	583536	9481092	862	71.50	858.00	3	Dense understorey
	3	9	583608	9480943	832	71.00	639.00	3	Open area beside path
	4	12	583628	9480895	824	70.50	846.00	3	Across narrow valley
	5	12	583691	9480853	820	70.00	840.00	3	Crossing small stream
	6	12	583473	9481218	881	69.50	834.00	3	Beside track
	7	12	583473	9481218	881	69.00	828.00	3	Ridge with *Nastus* bamboo
	8	12	583487	9481192	877	68.50	822.00	3	Across dry stream in regrowth
	9	12	583498	9481147	871	68.00	816.00	3	Shrubby regrowth beside track
	10	15	583498	9481120	871	67.50	1012.50	3	Parallel to small stream
Ubiame Site	1	15	582897	9481048	1375	16.00	240.00	1	Lower Montane Forest (L ± c) on ridge with stunted trees and dense coral fern ground layer
Upper Ok Binai Site	1	12	587183	9477437	399	96.00	1152.00	4	Undisturbed Hill Forest (Hm), dense understorey beside stream
	2	12	587184	9477437	399	95.50	1146.00	4	Dense understorey beside stream
	3	12	587223	9477438	452	95.00	1140.00	4	Mid-slope, dense understorey
	4	12	587211	9477398	468	94.50	1134.00	4	Top of steep slope
	5	12	587229	9477392	467	94.00	1128.00	4	Top of steep slope
	6	9	587242	9477401	465	72.00	648.00	3	Top of steep slope
	7	12	587248	9477436	457	71.50	858.00	3	Mid-slope, dense understorey
	8	12	587260	9477429	455	71.00	852.00	3	Mid-slope, dense understorey
	9	12	587338	9477427	464	70.50	846.00	3	Top of steep slope
	10	9	587327	9477419	467	70.00	630.00	3	Top of steep slope
	11	12	587358	9477410	458	70.00	840.00	3	Mid-slope, dense understorey
Frieda Bend Site	1	12	602410	9485849	76	72.00	864.00	3	Lowland Open Forest (Po) with a very wet floor, open understorey
	2	15	602390	9485799	76	71.50	1072.50	3	Lowland Open Forest (Po) with a very wet floor, open understorey
	3	6	602379	9485751	78	71.00	426.00	3	Beside Lowland Open Forest (Po) with a very wet floor, dense scrub
	4	12	602355	9485698	74	70.50	846.00	3	Crossing stream

SITE	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M))	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
	5	9	602223	9485665	82	95.00	855.00	4	Hill Forest (Hm)
	6	9	602203	9485687	82	94.50	850.50	4	Hill Forest (Hm)
	7	15	602200	9485667	81	94.00	1410.00	4	Hill Forest (Hm)
	8	9	602193	9485697	82	93.50	841.50	4	Hill Forest (Hm) beside stream
	9	9	602173	9485708	83	93.00	837.00	4	Hill Forest (Hm)
	10	15	602163	9485695	83	92.50	1387.50	4	Hill Forest (Hm)
	11	12	602141	9485757	88	92.00	1104.00	4	Hill Forest (Hm)
Trip 3									
Ok Isai Site	1	12	602551	9479475	118	95.00	1140.00	4	Lowland Open Forest (Po) with a very wet floor
	2	12	602565	9479479	109	94.50	1134.00	4	Lowland Open Forest (Po) with a very wet floor
	3	12	602552	9479520	109	94.00	1128.00	4	Across shallow stream
	4	12	602518	9479498	108	93.50	1122.00	4	Across shallow stream
	5	12	602565	9479351	112	93.00	1116.00	4	Lowland Open Forest (Po) with a very wet floor to Hill Forest (Hm) transition
	6	6	602531	9479302	101	92.50	555.00	4	Lowland Open Forest (Po) with a very wet floor
	7	6	602532	9479010	103	92.00	552.00	4	As for net 5
	8	9	602532	9479010	103	91.50	823.50	4	As for net 5
	9	9	602512	9479211	103	72.00	648.00	3	As for net 5
	10	6	602512	9479211	103	71.50	429.00	3	As for net 5
	11	12	602597	9478771	135	71.00	852.00	3	Hill Forest (Hm)
	12	12	602672	9478776	144	70.50	846.00	2	Crossing stream
	13	12	602672	9478776	144	70.50	846.00	2	Alongside stream
	14	12	602672	9478776	144	70.00	840.00	2	Crossing stream
	15	9	602644	9478852	122	70.00	630.00	2	Hill Forest (Hm) above stream
Kaugumi Site	1	12	606392	9497578	60	95.00	1140.00	4	Swamp Woodland (Wsw)
	2	9	606356	9497562	58	94.50	850.50	4	Swamp Woodland (Wsw)
	3	9	606368	9497525	58	94.00	846.00	4	Swamp Woodland (Wsw)
	4	12	606370	9497495	58	93.50	1122.00	4	Swamp Woodland (Wsw)
	5	9	606354	9497438	54	93.00	837.00	4	Swamp Woodland (Wsw)
	6	9	606343	9497397	55	92.50	832.50	4	Swamp Woodland (Wsw)

SITE	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M))	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
	7	12	606461	9497476	75	92.00	1104.00	4	Hill Forest (Hm), edge of helipad clearing
	8	9	606463	9497515	78	91.50	823.50	4	Hill Forest (Hm) hill top, open understorey
	9	9	606447	9497543	75	91.00	819.00	4	Hill Forest (Hm) mid-slope, open understorey
	10	12	606459	9497547	73	90.50	1086.00	4	Hill Forest (Hm) mid-slope, open understorey
	11	12	606480	9497543	76	90.00	1080.00	4	Hill Forest (Hm) mid-slope, open understorey
	12	12	606477	9497552	71	89.50	1074.00	4	Hill Forest (Hm) mid-slope, open understorey
Nena Top Site	1	12	579454	9485964	1064	46.00	552.00	2	Lower Montane Forest (L ± c) tree fall clearing under *Nothofagus*
	2	6	579454	9485964	1064	46.00	276.00	2	Aligned with net 1
	3	12	579463	9485997	1067	45.00	540.00	2	Beside tree fall clearing under Nothofagus
	4	6	579500	9485843	1076	44.00	264.00	2	Along track on ridge crest
	5	12	579500	9485843	1076	44.00	528.00	2	Along track on ridge crest
	6	12	579390	9485846	1060	43.00	516.00	2	Along track through swampy patch in forest
East Sepik Site	1	9	615327	9512489	45	70.00	630.00	3	Peat Forest, dense understorey
	2	15	615372	9512540	45	69.50	1042.50	3	Peat Forest, dense understorey
	3	6	615384	9512611	45	69.00	414.00	3	Peat Forest, dense understorey
	4	9	615402	9512636	45	68.50	616.50	3	Peat Forest, dense understorey
	5	12	615494	9512692	45	68.00	816.00	3	Peat Forest, dense understorey
	6	6	615592	9512711	45	67.50	405.00	3	Peat Forest, dense understorey
	7	12	615942	9513033	44	70.00	840.00	3	Peat Forest, dense understorey
	8	12	615927	9513091	40	69.50	834.00	3	Peat Forest, dense understorey
	9	9	615880	9513097	42	69.00	621.00	3	Peat Forest, dense understorey
	10	9	615814	9513103	44	68.50	616.50	3	Peat Forest, dense understorey
	11	9	615758	9513125	44	68.00	612.00	3	Peat Forest, dense understorey
	12	12	615758	9513125	44	67.50	810.00	3	Peat Forest, dense understorey
	13	9	615694	9513122	45	67.00	603.00	3	Peat Forest, dense understorey
Iniok Site	1	24	613223	9526034	30	18.00	432.00	1	High above pioneer Lowland Open Forest (Po)
	2	15	613850	9526227	47	70.00	1050.00	3	Lowland Open Forest (Po), open understorey
	3	9	613850	9526227	47	69.50	625.50	3	Lowland Open Forest (Po), open understorey
	4	6	613692	9526092	47	69.00	414.00	3	Pioneer Lowland Open Forest (Po), dense pitpit understorey
	5	12	613692	9526092	47	68.50	822.00	3	As for net 4

SITE	NET NO.	LENGTH (M)	POSITION (PNG MG94 ZONE 54)		ELEVATION (M))	HOURS OPEN	NET-METRE HOURS	NIGHTS OPEN	HABITAT
			EASTING	NORTHING					
	6	9	613426	9525935	43	68.00	612.00	3	As for net 4
	7	12	613426	9525935	43	67.50	810.00	3	As for net 4
	8	15	613201	9525938	34	67.00	1005.00	2	Camp clearing
	9	15	613201	9525938	34	66.50	997.50	2	Camp clearing
Trip 4									
Wario Site	1	9	625792	9499230	52	50.75	456.75	4	Riparian Forest (Po) on alluvial flats alongside Wario River
	2	12	625792	9499230	52	39.25	471.00	4	As for net 1
	3	12	625735	9499264	56	38.50	462.00	4	As for net 1
	4	9	625735	9499264	56	40.50	364.50	4	As for net 1
	5	12	625666	9499261	56	29.00	348.00	4	As for net 1
	6	12	625666	9499261	56	28.50	342.00	4	As for net 1
Wogamush Site	1	12	643607	9512332	46	6.00	72.00	3	Swamp Woodland (Wsw)
	2	12	643372	9512475	56	6.00	72.00	3	Hill Forest (Hm)
Kubkain Site	1	12	648246	9521760	52	6.00	72.00	3	Swamp Woodland (Wsw)
	2	12	648061	9521827	64	6.00	72.00	3	Hill Forest (Hm)
Ok Binai 1 Site	1	12	593645	9480197	120	6.00	72.00	3	Hill Forest (Hm)at camp
	2	12	593645	9480197	120	6.00	72.00	3	Hill Forest (Hm)at camp
Total						12,568.25	138,565.25	562.00	

Appendix 4.3 Camera-trap locations and trapping effort at each survey site.

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
Trip 1								
Nena Base Site	1	580151	9485812	890	30 Nov 09, 08h30	14 Dec 09, 13h30	341.00	Rainforest (RF) slope.
	2	579757	9485848	1,000	30 Nov 09, 12h45	14 Dec 09, 12h45	336.00	RF slope.
	3	579880	9485875	963	30 Nov 09, 13h15	14 Dec 09, 12h45	335.50	RF slope.
	4	579859	9485859	961	30 Nov 09, 13h30	14 Dec 09, 12h45	335.25	Small RF terrace on slope near stream.
	5	580053	9485849	934	1 Dec 09, 13h00	5 Dec 09, 9h00	92.00	RF.
	6	580029	9485964	930	1 Dec 09, 14h00	5 Dec 09, 9h30	91.50	Fallen fruits with rodent gnawing on trail.
	7	580044	9485957	929	1 Dec 09, 14h30	5 Dec 09, 9h45	91.25	Fallen *Garcinia* fruits with rodent gnawing.
Nena D1 Site	1	582197	9487044	440	5 Dec 09, 14h00	9 Dec 09, 9h00	91.00	Alongside rockshelter.
	2	582203	9487015	439	5 Dec 09, 14h00	9 Dec 09, 9h00	91.00	Into small cave below rockshelter.
Nena Limestone Site	1	575424	9486617	957	9 Dec 09, 10h15	12 Dec 09, 9h30	71.25	Log high acoss fast stream
	2	575404	9486442	981	10 Dec 09, 15h45	12 Dec 09, 10h30	42.75	Undulating RF valley, on small slope at foot of limestone wall. Closed 18–25 m canopy, open understorey.
	3	575420	9486402	984	10 Dec 09, 16h00	12 Dec 09, 10h30	42.50	Same as no. 1, but on small alluvial terrace.
Nena-Usage Site	1	576410	9489151	388	13 Dec 09, 13h30	14 Dec 09, 9h00	19.50	Streamside burrow.
	2	576347	9489124	403	13 Dec 09, 14h30	14 Dec 09, 9h00	18.50	Fallen figs.
	3	576430	9489183	399	13 Dec 09, 17h00	14 Dec 09, 10h00	17.00	High log crossing valley.
Trip 2								
Malia Site	1	588426	9486688	365	17 Oct 09 09 2009, 10h00	Nov-Dec[2]	750+	RF on low ridge.
	2	588312	9486744	383	17 Oct 09 2009, 10h30	Nov-Dec[2]	750+	RF on low ridge.
	3	588657	9485830	317	3 Feb 10, 10h20	4 Feb 10, 12h05	25.75	Small stature RF on flat terrain, 15-20 m canopy, sparse canopy, dense understorey.
	4	588513	9485967	309	3 Feb 10, 11h00	4 Feb 10, 14h00	27.00	Same as previous.
	5	588374	9486548	355	5 Feb 10, 08h45	7 Feb 10, 14h30	53.75	15 m small stature RF, 20-25 m emergents, on alluvial terrace adjacent to small stream.
	6,7	588760	9485268	264	3 Feb 10, 12h20	7 Feb 10, 12h20	192.00	Small stature RF next to small stream, edge of peneplain forest before steep descent to Nena River.
	8	588530	9485903	313	4 Feb 10, 12h35	8 Feb 10, 08h35	92.00	Steep forested slope between ridge and stream terrace.
	9	588406	9485900	329	4 Feb 10, 13h30	8 Feb 10, 07h45	90.25	RF on low ridge, 15-25 m canopy.

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
	10	588288	9486326	352	3 Feb 10, 09h45	8 Feb 10, 11h00	121.25	Shallow ephemeral pool on forested ridge
	11	588371	9486223	340	3 Feb 10, 10h00	28 Feb 10, 15h00	605.00	Shallow ephemeral pool on forested ridge
Koki Site	1,2	585586	9482678	537	9 Feb 10, 10h00	12 Feb 10, 11h15	146.50	18-25 m canopy shallow gully RF next to small stream.
	3	585792	9482663	552	9 Feb 10, 11h20	12 Feb 10, 10h50	71.50	20-25(30) m canopy RF on broad ridge; fairly dense ground layer.
	4	585760	9482602	556	9 Feb 10, 12h00	12 Feb 10, 10h30	70.50	Same as previous.
	5	585011	9482496	596	9 Feb 10, 17h15	12 Feb 10, 08h45	63.50	15-20 m small crowned mossy forest with ferns and dense leaf litter.
	6	584977	9482508	596	9 Feb 10, 17h40	12 Feb 10, 08h55	63.25	Same as previous.
	7	585024	9482525	587	9 Feb 10, 18h00	12 Feb 10, 09h00	63.00	Same as previous.
	8	585784	9482492	568	10 Feb 10, 10h35	12 Feb 10, 10h20	47.75	20 m canopy with 25-30 m emergents on gully ledge next to stream; fruit and animal sign about.
HI Site	1,2	583408	9481080	963	14 Feb 10, 15h00	18 Feb 10, 07h45	177.50	RF on broad,sloping ridge with palm and fern understorey, 8-15 m canopy, 20-30 m emergents.
	3	583291	9481157	1,003	15 Feb 10, 16h50	18 Feb 10, 07h20	62.50	Same as previous.
	4	583372	9481032	909	14 Feb 10, 10h00	17 Feb 10, 10h30	72.50	Floor of shallow cave under large rock
	5	582800	9481365	1289	15 Feb 10, 15h00	17 Feb 10, 12h00	45.00	Small-stature, montane cliff-top vegetation.
	6	583371	9481085	917	14 Feb 10, 10h30	17 Feb 10, 10h15	71.75	Slope below shallow cave
Upper Ok Binai Site	1,2	587210	9477733	382	19 Feb 10, 10h45	23 Feb 10, 07h30	185.50	RF on slope, 8-15 m canopy, 20-25 m emergents.
	3	587218	9477667	405	19 Feb 10, 11h15	23 Feb 10, 07h15	92.00	Same as previous.
	4,5	587342	9477368	464	19 Feb 10, 15h25	23 Feb 10, 08h25	178.00	Level shelf in Hill Forest, 15-20 m canopy, 25-30 m emergents.
	6	587346	9477345	470	19 Feb 10, 17h15	23 Feb 10, 08h30	87.25	Same as previous.
	7	587521	9477298	464	21 Feb 10, 15h45	23 Feb 10, 08h15	40.50	Hole under small rock ledge on RF slope, ~10 m from fast flowing, steep forest stream.
Frieda Bend Site	1,2	602139	9485670	97	24 Feb 10, 08h45	28 Feb 10, 08h15	191.00	25 m canopy, level RF with open understorey, soak depressions and trees with aerial root structures (wet floor adaptations).
	3	602180	9485699	100	24 Feb 10, 09h00	28 Feb 10, 08h15	95.25	Same as previous, though drier ground & associated vegetation.
	4,5	601764	9485767	116	24 Feb 10, 10h30	28 Feb 10, 07h45	93.25	10-15 m canopy RF, 20-25 m emergents, open understorey, level ground.
	6	601803	9485726	116	24 Feb 10, 12h30	28 Feb 10, 07h45	91.25	Same as previous.
	7	602348	9485785	97	24 Feb 10, 17h45	27Feb 10, 15h15	69.50	Lowland peneplain RF, wet soils, 8-15 m canopy, 20+ m emergents, fairly open understorey. Cassowary sign & baited with fruit.
Trip 3								

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
Ok Isai Site	1,2	602503	9479335	113	27 May 10, 09h30	1 Jun 10, 07h15	235.50	Disturbed swamp forest, 15 m canopy, 25-30 m emergents, dense understorey with lianes and rattan, stream and pools on wet mud.
	3,4,5	602539	9479358	120	27 May, 10h00	31 May, 11h15	291.75	Same as previous, but no adjacent stream.
	6,7	602558	9479314	117	28 May, 09h30	1 Jun 10, 07h15	187.50	Same as previous.
	8,9	602493	9478978	125	28 May, 15h15	1 Jun 10, 07h45	177.00	Small statured footHill Forest, 10-15 m canpoy, 20-25 m emergents.
Kaugumi Site	1	606417	9497393	70	1 Jun 10, 14h30	6 Jun 10, 14h30	120.00	Swamp forest with sago, 15-20 m canopy, shallow muds.
	2	606363	9497323	65	1 Jun 10, 15h00	6 Jun 10, 14h30	119.50	Same as previous.
	3	606315	9497303	66	1 Jun 10, 15h15	6 Jun 10, 14h45	119.50	Same as previous.
	4	606511	9497254	69	2 Jun 10, 10h15	5 Jun 10, 08h45	70.50	Same as previous.
	5,6	606475	9497270	78	2 Jun 10, 11h00	6 Jun 10, 12h00	194.00	Same as previous.
	7,8	606519	9497320	65	2 Jun 10, 15h15	5 Jun 10, 08h45	131.00	Same as previous.
	9,10	606490	9497192	75	2 Jun 10, 16h15	6 Jun 10, 12h00	183.50	Same as previous.
	11	606202	9496995	69	5 Jun 10, 11h00	6 Jun 10, 11h15	24.25	Small statured Sago swamp forest.
	12	606363	9497135	71	5 Jun 10, 10h15	6 Jun 10, 11h00	24.75	Stream crossing in swamp forest.
East Sepik Site	1,2	616550	9513107	63	8 Jun 10, 11h45	11 Jun 10, 16h30	153.50	Peat forest.
	3	616330	9513188	61	8 Jun 10, 12h00	11 Jun 10, 16h00	76.00	Peat forest.
	4	616253	9513176	61	8 Jun 10, 12h15	11 Jun 10, 15h45	75.50	Peat forest.
	5,6	615719	9513007	56	8 Jun 10, 15h30	12 Jun 10, 13h00	187.00	Peat forest.
	6	616684	9513178	58	9 Jun 10, 10h00	11 Jun 10, 17h00	55.00	Peat forest.
	7,8	615700	9513121	55	9 Jun 10, 17h15	12 Jun 10, 14h30	138.50	Peat forest.
Iniok Site	1	613734	9526152	41	14 Jun 10, 13h00	17 Jun 10, 16h00	75.00	Disturbed riparian forest, near scrubfowl mound.
	2	613841	9526133	41	14 Jun 10, 13h15	17 Jun 10, 16h00	74.75	Disturbed riparian forest.
	3	613843	9526154	44	14 Jun 10, 13h30	17 Jun 10, 16h00	74.50	Disturbed riparian forest, near scrubfowl mound.
Trip 4								
Wario Site	1	626182	9499604	120	24 Feb 11,16h15	27 Feb 11, 11h15	67.00	Small statured (15 m canopy) ridge forest amid taller (35 m+) slope and gully forest.
	2	626167	9499590	116	24 Feb 11,16h20	27 Feb 11, 11h20	67.00	Forest, 30 m canopy, on small terrace on foothill slope.
	3	625792	9499230	52 (SR)	24 Feb 11, 15h30	27 Feb 11, 18h30	75.00	Riparian forest on alluvial flats.
	4,5	625882	9499404	59	25 Feb 11, 09h45	27 Feb 11, 14h30	105.50	Next to stream winding through riparian forest on alluvial flats.
	6	625735	9499264	56	25 Feb 11, 15h15	27 Feb 11, 18h45	51.50	Riparian forest on alluvial flats.

SITE	NO.	POSITION (PNG MG94 ZONE 54)		ELEVATION (M)	TIME ON[1]	TIME OFF[1]	TOTAL HOURS	LOCATION
		EASTING	NORTHING					
	7	625666	9499261	56	25 Feb 11, 15h30	27 Feb 11, 19h00	51.50	Riparian forest on alluvial flats.
Wogamush Site	1	643372	9512475	56	1 Mar 11, 10h30	4 Mar 11, 15h45	77.25	FootHill Forest.
	2	643351	9512448	65	1 Mar 11, 10h45	4 Mar 11, 15h45	77.00	FootHill Forest.
	3	643376	9512342	75	1 Mar 11, 11h15	4 Mar 11, 16h00	76.75	FootHill Forest.
	4	643496	9512251	81	1 Mar 11, 11h45	4 Mar 11, 16h15	76.50	FootHill Forest.
	5	643548	9512377	58	1 Mar 11, 12h10	4 Mar 11, 15h10	75.00	FootHill Forest.
	6	643540	9512403	58	1 Mar 11, 12h15	4 Mar 11, 15h15	75.00	FootHill Forest.
	7	643607	9512332	46	1 Mar 11, 13h00	4 Mar 11, 15h15	74.25	Sago swamp forest.
	8	643584	9512372	50	1 Mar 11, 13h15	4 Mar 11, 15h30	74.25	FootHill Forest.
Kubkain Site	1	648033	9521818	56	6 Mar 11, 14h00	9 Mar 11, 15h30	73.50	FootHill Forest.
	2	648061	9521827	64	6 Mar 11, 14h15	9 Mar 11, 15h30	73.25	FootHill Forest.
	3	648050	9521860	66	6 Mar 11, 14h15	9 Mar 11, 15h30	73.25	FootHill Forest.
	4	648223	9521785	54	6 Mar 11, 14h45	9 Mar 11, 15h45	73.00	FootHill Forest.
	5	648246	9521760	52	6 Mar 11, 15h00	9 Mar 11, 15h45	72.75	FootHill Forest.
	6	648300	9521823	63	6 Mar 11, 15h15	9 Mar 11, 16h15	73.00	FootHill Forest.
	7	648263	9521864	67	6 Mar 11, 15h45	9 Mar 11, 16h15	72.50	FootHill Forest.
Ok Binai 1 Site	1	593014	9480601	166	11 Mar 11, 14h00	14 Mar 11, 15h00	73.00	Hill Forest.
	2	593066	9480532	166	11 Mar 11, 14h15	14 Mar 11, 15h15	73.00	Hill Forest.
	3	593078	9480515	165	11 Mar 11, 14h30	14 Mar 11, 15h30	73.00	Hill Forest.
	4	593866	9480127	156	11 Mar 11, 16h30	14 Mar 11, 12h45	68.25	Hill Forest.
	5	593869	9480090	148	11 Mar 11, 16h45	14 Mar 11, 12h30	67.75	Hill Forest.
	6	593936	9480097	154	11 Mar 11, 17h00	14 Mar 11, 13h00	68.00	Hill Forest.
	7	593991	9480135	158	11 Mar 11, 17h15	14 Mar 11, 13h15	68.00	Hill Forest.
Total							11,616.00+	

[1] Unless otherwise stated, all dates for Trips 1–3 are for the year 2010, and for Trip 4 are for 2011.

[2] Camera-traps set at Malia Site in October 2009 ran continually until batteries expired. Total hours estimated from average camera life of one month. The few images obtained from these cameras do not add any new records for the survey or the site and are excluded from all quantitative analyses of survey results.

Appendix 4.4 Miyan language group names of New Guinea bird species.

SCIENTIFIC NAME	ENGLISH NAME	WAMINTRI NAME	SIPMAP'S COMMENTS/INTERPRETAION
Casuarius casuarius	Southern Cassowary	Waniki	Most likely a reference to Northern Cassowary C. unappendiculatus
Casuarius bennetti	Dwarf Cassowary	Koborobeh	'Many here', in reference to Nena Base and surrounds, where interview took place.
Aepypodius arfakianus	Wattled Brush-turkey	Wanakwil	Present here (Nena Base and surrounds).
Talegalla jobiensis	Brown-collared Brush-turkey	Sungah (Wansin(g)ah)	Present here.
Megapodius reinwardt	Orange-footed Scrubfowl	Wenim	Present here.
Aceros plicatus	Blyth's Hornbill	Saiyun	
Eurystomus orientalis	Dollarbird	Gawak	
Alcedo azurea/Ceyx lepidus	Azure/Variable Kingfisher	Alifaviau	
Dacelo gaudichaud	Rufous-bellied Kookaburra	Ngonok	
Clytoceyx rex	Shovel-billed Kookaburra	Tofuk	'Here - digs in ground'; correct behavioural reference.
Melidora macrorrhina	Hook-billed Kingfisher	Mantap	
Syma torotoro/megarhyncha/Todirhamphus nigrocyaneus	Yellow-billed/Mountain/Blue-black Kingfisher	Timsai	Nena area: Blue-black = female; Syma spp. = male
Tanysiptera spp.	Paradise-Kingfishers	Timsai	
Merops ornatus	Rainbow Bee-eater	Imentrok Kwetrok	'Cold place on top'; questionable elevation reference for this species
Cacomantis castaneiventris	Chestnut-breasted Cuckoo	Seng-Sung/Doyemin	
Chrysococcyx spp.	Bronze-Cuckoos	Tanuan	
Microdynamis parva	Dwarf Koel	Nobo	Present here.
Scythrops novaehollandiae	Channel-billed Cuckoo	Tiam	'All place: hot, cold, this place, all got im'; lowlands, hills and highlands.
Centropus phasianinus	Pheasant Coucal	Fomanebo	All place; erroneous elevation reference for this species.
Pseudeos fuscata	Dusky Lory	Ngini	
Trichoglossus haematodus	Rainbow Lorikeet	Kera	
Lorius lory	Black-capped Lory	Kwai-Su	
Charmosyna rubronotata	Red-fronted Lorikeet	Tijin	
Charmosyna pulchella	Fairy Lorikeet	Sabuai	
Charmosyna josefinae	Josephine's Lorikeet	Shu	'Here, hot place, all places'.
Charmosyna papou	Papuan Lorikeet	Surali	'Cold place on top'; highlands above FRP area.
Psittrichas fulgidus	Pesquet's Parrot	Abau	
Cyclopsitta diophthalma	Double-eyed Fig-Parrot	Mang-Mang	
Micropsitta/Loriculus/Psittaculirostris/ Cyclopsitta	Pygmy-Parrots, Hanging-Parrot and Fig-Parrots	Neng-Neng	
Geoffroyus simplex	Blue-collared Parrot	Ngesim	

SCIENTIFIC NAME	ENGLISH NAME	WAMINTRI NAME	SIPMAP'S COMMENTS/INTERPRETAION
Eclectus roratus	Eclectus Parrot	Kakiro	
Alisterus chloropterus	Papuan King-Parrot	Tringue	
Probosciger aterrimus	Palm Cockatoo	Samdan	Present here.
Cacatua galerita	Sulphur-crested Cockatoo	Wanima	
Hemiprocene mystacea	Swifts, Treeswift	Dek-Dek	Same name applied to nightjars.
Tyto spp.	Barn-Owls	Muniyai	Referred name to Sooty and pale species.
Ninox/Uroglaux	Hawk-Owls	Sesawan	
Aegotheles spp.	Owlet-Nightjars	Koro-Koro	
Podargus spp.	Frogmouth sp(p).	Mu-Mu	Marbled Frogmouth P. ocellatus vocalisation correct.
Caprimulgus/Eurostopodus spp.	Nightjar spp.	Dek-Dek	Same name applied to swifts.
Macropygia sp(p).	Slender/Black-billed Cuckoo-Dove	Gweyn	Present here.
Reinwardtoena reinwardtsi	Great Cuckoo-Dove	Meeyun	Present here.
Chalcophaps sp(p).	Stephan's/Emerald Dove	Guingui	Present here.
Caloenas nicobarica	Nicobar Pigeon	Kubiami	'Hot place'; lowlands.
Gallicolumba rufigula	Cinnamon Ground-Dove	Bringwin	Present here.
Gallicolumba jobiensis	White-bibbed Ground-Dove	Yarwan	'Here and down below, all places'; hills and lowlands.
Otidiphaps nobilis	Pheasant Pigeon	Guan-Guan	Present here.
Ptilinopus magnificus	Wompoo Fruit-Dove	Kirwan	
Ptilinopus ornatus	Ornate Fruit-Dove	Sariya	Present here (Vocalisation correct).
Ptilinopus superbus	Superb Fruit-Dove	Afwel	Present here.
Ptilinopus coronulatus	Coroneted Fruit-Dove	Uwey	'Here and down below in hot place'; hills and lowlands.
Ptilinopus rivoli	White-bibbed Fruit-Dove	Biri	'Cold place, not here, only in high mountain'.
Ducula rufigaster/chalconota	Purple-tailed & Shining Imperial-Pigeon	Arip	
Ducula mullerii	Collared Imperial-Pigeon	Homle-Wok	
Ducula zoeae	Banded Imperial-Pigeon	Anirin	Present here (Vocalisation correct).
Gymnophaps albertisii	Papuan Mountain-Pigeon	Homere	
Goura sp. (victoria)	(Victoria) Crowned-Pigeon	Awaria	'Only in flat land'; lowlands
Ardeotis australis	Australian Bustard	Aninin (Balus)	
Rallina sp.	Forest-Rail sp.	Boom (bʊm) Se	Present here.
Numenius madagascariensis	Far Eastern Curlew	Afwet	'Cold place on top'; highlands. Erroneous elevation reference for this species.
Haliastur indus	Brahminy Kite	Wei-Wo	

SCIENTIFIC NAME	ENGLISH NAME	WAMINTRI NAME	SIPMAP'S COMMENTS/INTERPRETAION
Accipiter sp(p).	Goshawk sp(p).	Fifir (Fifir Singamin/ Drubomin)	
Harpyopsis novaeguineae	New Guinea Eagle	Tolim	
Pitta spp.	Pitta spp.	Moroko	Present here.
Cormobates placens/Daphoenositta sp(p).	Papuan Treecreeper and Sittella sp(p).	Ni-Net	Noted he had already named these birds (in reference to some petroicid robins).
Ailuroedus melanotis	Spotted Catbird	Awit	May include White-eared Catbird A. buccoides.
Sericulus sp.	Flame Bowerbird	Somyamin	Noted he had already named this bird (in reference to Golden Monarch/ Cuckooshrike). Vocalisation was incorrect for Sericulus, so probably referring to Golden Monarch/Cuckooshrike.
Chlamydera lauterbachi	Yellow-breasted Bowerbird	Bringkwin	Noted he had already named this bird (probably in reference to Cinnamon Ground-Dove).
Clytomyias insignis	Orange-crowned Fairywren	Fein-Fun	'All places'; incorrect inclusion of lower elevations for this species.
Malurus cyanocephalus	Emperor Fairywren	Iden Wek-Wek	'Cold place'; Incorrect reference to highlands for this species.
Malurus (etc.) spp.	Fairywren spp.	Tim-Sai	Same name applied to some kingfishers.
Myzomela spp.	Myzomela Honeyeaters	Ni-Net	Noted he had already named these birds (in reference to some petroicid robins, treecreepers and sittellas).
*Melilestes megarhynchu*s	Long-billed Honeyeater	Tina	
*Lichmera alboauriculari*s	Silver-eared Honeyeater	Dulam-Mais	
Meliphaga sp(p).	Meliphaga Honeyeater(s)	Dulam	
*Lichenostomus obscuru*s	Obscure Honeyeater	Durongin	Same name applied to Ptiloprora Honeyeaters.
X*anthotis flaviventer*	Tawny-breasted Honeyeater	Tablak	
Philemon meyeri	Meyer's Friarbird	Si-Oh	This species was named based on hearing its call while walking together.
Philemon novaeguineae	New Guinea Friarbird	Kwoi-Moni	
Ptiloprora sp(p).	Ptiloprora Honeyeater(s)	Dulongin	
Melidectes sp(p).	Melidectes Honeyeater(s)	Karan	
Melipotes fumigatus	Smoky Honeyeater	Gulosol	
Crateroscelis nigrorufa	Bicolored Mouse-warbler	Nemantip	Possibly Rusty Mouse-warbler C. murina or another small passerine.
*Sericornis nouhuys*i	Large Scrubwren	Iden Diyep-Mait	Cold place'; highlands.
Sericornis spilodera	Pale-billed Scrubwren	Diyep-Mait	
Gerygone palpebrosa	Fairy Gerygone	Twemvial	
Gerygone olivacea	White-throated Gerygone	Ide Nim-Nim	Potential confusion with Pachycephala whistlers.
Monachella muelleriana	Torrent Robin	Ambebel	
Microeca spp.	Flyrobin spp.	Nim-Nim	Noted he had already named these birds (in reference to Olive-yellow Robin).

SCIENTIFIC NAME	ENGLISH NAME	WAMINTRI NAME	SIPMAP'S COMMENTS/INTERPRETAION
Eugerygone rubra	Garnet Robin	Montemin	Noted he had already named this bird (in reference to Rufous-backed Fantail; Garnet Robin has fantail-like posture in field guide).
Petroica archboldi	Snow Mountain Robin	Ni-Net Kwei Balalang	
Tregellasia leucops	White-faced Robin	Alifep	
Poecilodryas placens	Olive-yellow Robin	Nim-Nim	Present here (but potential confusion with other yellow-breasted species, e.g. same name applied to White-throated Gerygone and Microeca flyrobins).
Peneothello cyanus	Blue-grey Robin	Ni-Net	
Drymodes superciliaris	Northern Scrub-Robin	Fiye	
Pomatostomus isidorei	New Guinea Babbler	Ilentutu	Noted he had already named this bird (in reference to Black-faced Cuckooshrike).
Ptilorrhoa leucosticta	Spotted Jewel-babbler	Brif-Weng	
Ptilorrhoa castanonota	Chestnut-backed Jewel-babbler	Brif-Sasawin	
Pachycare flavogrisea	Goldenface	Besong	
Pachycephala aurea	Golden-backed Whistler	Ide Nim-Nim	Noted he had already named this bird (in reference to White-throated Gerygone).
Colluricincla megarhyncha	Little Shrike-thrush	Kwa-Nim	
Pitohui kirhocephalus	Variable Pitohui	Ureyari	
Pitohui dichrous	Hooded Pitohui	Fawein	
Pitohui cristatus	Crested Pitohui	Wong-Wong	Possibly an onomatopoeic reference to the distinctive call of this species.
Melampitta gigantea	Greater Melampitta	Sorei	'All place'.
Manucodia sp(p).	Manucode sp(p).	Marifanim	
Paradigalla brevicauda	Short-tailed Paradigalla	Arem	'Mountain on top'.
Epimachus fastuosus/meyeri	Black/Brown Sicklebill	Afwet	
Lophorina superba	Superb Bird-of-paradise		Said to be female King-of-Saxony Bird.
Parotia sp(p).	Parotia(s)	Gwarivo	'Cold place on top'.
Ptiloris magnificus	Magnificent Riflebird	Awei (female: Gulosol)	'Cold place'; but also present in lower hills in FRP area.
Cicinnurus magnificus	Magnificent Bird-of-paradise	Kalom	
Cicinnurus regius	King Bird-of-paradise	Noh-Noh	
Pteridophora alberti	King-of-Saxony Bird-of-paradise	Kalan	
Seleucidis melanoleuca	Twelve-wired Bird-of-paradise	Wowom	
Paradisaea minor	Lesser Bird-of-paradise	Bemal	
Paradisaea raggiana	Raggiana Bird-of-paradise	Wau	Correct reference to highlands south of the FRP area.
Paradisaea rudolphi	Blue Bird-of-paradise	Nokolo	Flatlands; incorrect terrain/elevation reference for this species.

SCIENTIFIC NAME	ENGLISH NAME	WAMINTRI NAME	SIPMAP'S COMMENTS/INTERPRETAION
Cracticus quoyi	Black Butcherbird	Iden Sokolat	Noted he had already named these birds, though no clear earlier record, and seems unlikely to confuse this species with the dissimilar Black-winged Monarch (= 'Sokolat').
Peltops sp(p).	Peltops sp(p).	Wei-Dong	
Oriolus sp(p).	Oriole(s)	Yamlawok	
Sphecotheres viridis	Green Figbird	Yamlaneng	
Coracina novaehollandiae	Black-faced Cuckooshrike	Ilentutu	'Cold place on top'; highlands (possibly refers to Hooded Cuckooshrike)
Coracina spp.	Cuckooshrike spp.	Blankana	Includes Boyer's C. boyeri, Grey-headed C. schisticeps, Black-shouldered C, morio, Cicadabird C. tenuirostris and others.
Lalage atrovirens	Black-browed Triller	Dirikim	
Rhipidura threnothorax	Sooty Thicket-Fantail	Biri Sa-Sa	
Rhipidura hyperythra	Chestnut-bellied Fantail	Dilak	
Rhipidura rufidorsa	Rufous-backed Fantail	Montemin	
Dicrurus bracteatus/Chaetorhynchus papuensis/Aplonis sp(p).	Drongos, Starlings	Iden-Tutu	Noted he had already named these birds, though no clear earlier record, and seems unlikely to confuse these species with the dissimilar Black-faced Cuckooshrike and New Guinea Babbler (both referred to as 'Ilentutu').
Monarcha axillaris	Black Monarch	Ideng Kwekwek	Potential confusion with Black Fantail.
Monarcha frater	Black-winged Monarch	Sokolat	Also Crested Berrypecker.
Monarcha manadensis	Hooded Monarch	Fong	
Monarcha chrysomela/Campochaera sloetii	Golden Monarch/Cuckooshrike	Somyamin	
Arses insularis	Rufous-collared Monarch	Wek-Wek	
Machaerirhynchus sp(p).	Boatbill(s)	Bisal	
	Thrush spp.	Fiwei	
Mino dumontii	Yellow-faced Myna	Daikro	
Hirundo spp.	Swallows	Haral	
Zosterops sp(p).	White-eye sp(p).	Bisal	Noted he had already named this bird (in reference to Boatbill(s).
Dicaeum geelvinkianum	Red-capped Flowerpecker	Gefla-Vim	
Nectarinia aspasia	Black Sunbird	Besalwi	
Melanocharis sp(p).	Berrypecker(s)	Kakenema	Noted he had already named these birds (but no record of earlier reference).
Toxorhamphus novaeguineae	Green-crowned Longbill	Funanwi	
Toxorhamphus iliolophus	Plumed Longbill	Birit	
Motacilla sp(p).	Wagtail(s)	Titiaru	
Erythrura spp.	Parrotfinches	Diringbol	Said to be males to munia females.

SCIENTIFIC NAME	ENGLISH NAME	WAMINTRI NAME	SIPMAP’S COMMENTS/INTERPRETAION
Lonchura spp.	Munias	Diringbol	Said to be females to parrotfinch males.

Local names and notes on the distribution of species within and beyond the Study Area were provided by Yamlin Sipmap, a local resident of Sokamin (Wamintri). Information was collected while looking at pictures of birds in Beehler *et al.* (1986) during an interview conducted at Nena Base Site. Different taxa were occasionally confused with one another and given the same name. This appeared to be often due to a difficulty in interpreting the pictures in the field guide rather than to a lack of knowledge regarding the local avifauna.

Appendix 4.5 Birds recorded in the Study Area during the Project Surveys.

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Casuarius bennetti	Dwarf Cassowary	NT		h						P*				P*												
Casuarius unappendiculatus	Northern Cassowary	VU							P						P	P*	P*		P	2	P		P	P	2	2
Casuarius sp.	Cassowary sp.	LC							s2	sO				s2		SO	s2		SC	s2				sO	s2	
Aepypodius arfakianus	Wattled Brush-turkey	LC								P																
Talegalla jobiensis	Brown-collared Brush-turkey	LC		O				C	C	O				2	P		2	C	2	2			P	C		
Megapodius decollatus	New Guinea Scrubfowl	LC																	P		P	C				
Dendrocygna guttata	Spotted Whistling-Duck	LC																				O				
Anas superciliosa	Pacific Black Duck	LC																			2	C		2		
Aceros plicatus	Blyth's Hornbill	LC	P	2	P	2	2	C	2	O				2	C	C	C	P	2	O	P	2	C	C	2	2
Eurystomus orientalis	Dollarbird	LC														2	O		2	2	C	C				
Alcedo azurea	Azure Kingfisher	LC		P					P	P				P*					P		P			P*		
Ceyx lepidus	Variable Kingfisher	LC		2	P*	P2*		P*	2	2		2		P	P	2	P		P	2		P*		P		
Dacelo gaudichaud	Rufous-bellied Kookaburra	LC		2		2	O	P	2	2	O			2	P	C		P	C	C	C	2	2	C	2	
Todirhamphus nigrocyaneus	Blue-black Kingfisher	DD																	P*							
Todirhamphus sanctus	Sacred Kingfisher	LC																			P	2				
Melidora macrorrhina	Hook-billed Kingfisher	LC		2		P	O	P	O			O				2	2	C	2			2		2		P
Syma torotoro	Yellow-billed Kingfisher	LC						P	2	O				2	P	2	2		O	2		O	P	2	2	P
Syma torotoro/megarhyncha	Yellow-billed/Mountain Kingfisher	LC		2			2																			
Tanysiptera galatea	Common Paradise-Kingfisher	LC								O							O					O				

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Tanysiptera sylvia	Buff-breasted Paradise-Kingfisher	LC																	O							
Merops ornatus	Rainbow Bee-eater	LC														O			O	O	C	C				
Cuculus optatus(/saturatus)	Oriental (/Himalayan) Cuckoo	LC										O		O												
Cacomantis variolosus	Brush Cuckoo	LC		O		C					C			2	P	2			2	2	C	C	P	2	2	P
Cacomantis castaneiventris	Chestnut-breasted Cuckoo	LC		P*	P	C	P*		P*	P*	O*			2												
Rhamphomantis megarhynchus	Long-billed Cuckoo	LC																	P					P	P	
Chrysococcyx minutillus	Little (Malay) Bronze-Cuckoo	LC												O					2		P	C		2		
Chrysococcyx meyeri	White-eared Bronze-Cuckoo	LC		O																						
Caliechthrus leucolophus	White-crowned Koel	LC		O		2	2				O															
Microdynamis parva	Dwarf Koel	LC		2		O		P*	O			O		2			O							O	2	
Eudynamys scolopacea	Asian Koel	LC				O							P						C			2		2	O2*	
Scythrops novaehollandiae	Channel-billed Cuckoo	LC													2				2		P					
Centropus menbeki	Greater Black Coucal	LC		2			O		2		2	O		2	P	C		P	C	C	P	2	P	C	2	
Centropus phasianinus	Pheasant Coucal	LC																				P*				
Centropus bernsteini	Lesser Black Coucal	LC																			P	2		P		
Chalcopsitta duivenbodei	Brown Lory	LC																	C			P*				
Pseudeos fuscata	Dusky Lory	LC		O					O										O	O			P			
Chalcopsitta duivenbodei/ Pseudeos fuscata	Brown/Dusky Lory	LC																P								P
Trichoglossus haematodus	Rainbow Lorikeet	LC		O	P	C	P*	P	2	2	C		P	2	P	C	C	C	C	2	P*	C	C	C	C	
Lorius lory	Black-capped Lory	LC		2	P	C	2	2	C	2	2	O	P	C		2	2		2	C	P	C	P	2	2	P

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Charmosyna rubronotata	Red-fronted Lorikeet	LC		O		O				C							O									
Charmosyna placentis	Red-flanked Lorikeet	LC								C	O								O							
Psittrichas fulgidus	Pesquet's Parrot	VU		2	P		2	C	2	2	2	2	P	2		O	2	P					P			
Micropsitta pusio	Buff-faced Pygmy-Parrot	LC														P			P*					P	P	
Micropsitta pusio/bruijnii	Buff-faced/Red-breasted Pygmy-Parrot•	LC					O																			
Psittaculirostris edwardsii	Edwards's Fig-Parrot	LC															O		C					2		
N/A	Fig-Parrot sp.	LC							P							P									2	
Geoffroyus geoffroyi	Red-cheeked Parrot	LC				O		P	2					O		O	O		C	2	P	2	P	O	2	P
Geoffroyus simplex	Blue-collared Parrot	LC		O			C		2	O			P	O					2							
Eclectus roratus	Eclectus Parrot	LC		2	P	C		P	O		C			2	C	2	2	C	C		C	C	P	C	2	
Alisterus chloropterus	Papuan King-Parrot	LC		O																						
Loriculus aurantiifrons	Orange-fronted Hanging-Parrot	LC									P			P										P		
Probosciger aterrimus	Palm Cockatoo	LC	P					P	O	O	O			2	2	O	2	P	2			2	P	C	C	P
Cacatua galerita	Sulphur-crested Cockatoo	LC		C	P	2	O	C	C	2	C		P	C		C	C	C	C		P	2	P	C	C	
Collocalia esculenta	Glossy Swiftlet	LC		2	P	C	2	2			O	2	P	2			O									
Aerodramus hirundinaceus	Mountain Swiftlet	LC									P															
Aerodramus sp(p).	Swiftlet sp(p)	LC		C	P	P		2	2		C	O	P	C		C	C	P	2	2	C			2	2	
Mearnsia novaeguineae	Papuan Needletail	LC																P	2	2	C	2		C	O	
Hirundapus caudacutus	White-throated Needletail	LC													P											
Hemiprocne mystacea	Moustached Treeswift	LC					2						P													

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Ninox rufa	Rufous Owl	LC																		P						
Ninox theomacha	Jungle Hawk-Owl	LC		P												P								P		
Aegotheles wallacii	Wallace's Owlet-Nightjar	DD					P*																			
Podargus papuensis	Papuan Frogmouth	LC		P				P								P	P		P		P					
Podargus ocellatus	Marbled Frogmouth	LC		2			P											P	P							
Eurostopodus papuensis	Papuan Eared-Nightjar	LC																				P				
Caprimulgus macrurus	Large-tailed Nightjar	LC																			P					
Macropygia amboinensis	Slender-billed Cuckoo-Dove	LC		C	P	O	O		2		O	O2*	P	2		P*			O			P*				
Macropygia nigrirostris	Black-billed Cuckoo-Dove	LC					P*							O									P	O		
Reinwardtoena reinwardtsi	Great Cuckoo-Dove	LC		O2*			2		2		O		P	2		2	2		C					2		
Chalcophaps indica	Emerald Dove	LC																				P*				
Chalcophaps stephani	Stephan's Dove	LC													2	P	P		P					2	P	
Gallicolumba rufigula	Cinnamon Ground-Dove	LC		P										2		P		P	P					P		
Otidiphaps nobilis	Pheasant Pigeon	LC		O						O																
Ptilinopus magnificus	Wompoo Fruit-Dove	LC				C		2	2	2	O			2		O	2		C			O	P	2	2	
Ptilinopus perlatus	Pink-spotted Fruit-Dove	LC		O					O					O		2	O2*		2						O	
Ptilinopus ornatus	Ornate Fruit-Dove	LC		O																						
Ptilinopus aurantiifrons	Orange-fronted Fruit-Dove	LC																				2		O		
Ptilinopus superbus	Superb Fruit-Dove	LC		C		C	C		C	C	2		P	C		C	C		C	O		O	P	P*		
Ptilinopus coronulatus	Coroneted Fruit-Dove	LC		2		C		2	C	2	2		P	C		C	C		C	C	P	2	P	2	C	

		STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
SCIENTIFIC NAME	ENGLISH NAME	IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Ptilinopus rivoli	White-bibbed Fruit-Dove	LC										O														
Ptilinopus iozonus	Orange-bellied Fruit-Dove	LC							2					2		2	2	P	C	O	C	C	P	2	C	
Ptilinopus naina	Dwarf Fruit-Dove	LC							O					2										O		
Ducula rufigaster	Purple-tailed Imperial-Pigeon	LC		2		O	2		2	2				O		2	2		2				P	2	2	
Ducula pinon	Pinon Imperial-Pigeon	LC																P	C		P	C		2	O	P
Ducula mullerii	Collared Imperial-Pigeon	LC																			P					
Ducula zoeae	Banded Imperial-Pigeon	LC		2		2	2	2	C	2	2	O	P	2		C	2	P	C	2	P	C	P	C	C	
Gymnophaps albertisii	Papuan Mountain-Pigeon	LC		O			C		C				C	C			2	P*	2				P			
Goura victoria	Victoria Crowned-Pigeon	VU	P						2							O	P	h	2		P	P	P	P	2	2
Rallina tricolor	Red-necked Crake	LC														P			2					P		
Amaurornis moluccana	Rufous-tailed Waterhen	LC																			P	P				
Megacrex inepta	New Guinea Flightless Rail	NT																						h		
Porphyrio porphyrio	Purple Swamphen	LC																			P					
Actitis hypoleucos	Common Sandpiper	LC							P								P									
N/A	wader sp.	LC																			2					
Himantopus leucocephalus	White-headed Stilt	LC																			2	2				
Charadrius dubius	Little Ringed Plover	LC															P									
Vanellus miles	Masked Lapwing	LC																			C	2		P		
Chlidonias hybridus	Whiskered Tern	LC																			C	C				
Aviceda subcristata	Pacific Baza	LC									O					O									P	

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Henicopernis longicauda	Long-tailed Honey-buzzard	LC			P				O	O	O							P	O							
Milvus migrans	Black Kite	LC																			C	2				
Haliastur sphenurus	Whistling Kite	LC														O	2				C	C		O	P	P
Haliastur indus	Brahminy Kite	LC		O											P		2	P			C	C	P	O		
Haliaeetus leucogaster	White-bellied Fish-Eagle	LC															2	P			2	2		2	P	P
Circus spilonotus	Eastern Marsh-Harrier	LC																			P					
Accipiter hiogaster	Variable Goshawk	LC																P			P	O		O	P	
Accipiter sp.	Goshawk sp.	LC							O							O										
Megatriorchis doriae	Doria's Goshawk	NT				O																				
Harpyopsis novaeguineae	New Guinea Eagle	VU	P			P*	P*									O										
Hieraaetus weiskei	Pygmy Eagle	LC								O*					P*										P	
Anhinga novaehollandiae	Australian Darter	LC																P			2					
Phalacrocorax melanoleucos	Little Pied Cormorant	LC															O				2	O				
Phalacrocorax sulcirostris	Little Black Cormorant	LC														P	2				2					
Phalacrocorax carbo	Great Cormorant	LC															O									
Egretta garzetta	Little Egret	LC	P																			O				
Ardea modesta	Eastern Great Egret	LC	P														2				C	2		P		
Ardea sumatrana	Great-billed Heron	LC																			C	C				
Ardea picata	Pied Heron	LC																			C	O				
Mesophoyx intermedia	Intermediate Egret	LC	P																		2	C		P		

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Nycticorax caledonicus	Rufous Night-Heron	LC																			2	2				
Zonerodius heliosylus	Forest Bittern	NT							P																	
Ixobrychus sinensis (/ minutus)	Yellow(/Little) Bittern	LC																				O				
Dupetor flavicollis	Black Bittern	LC																				2				
Pitta sordida	Hooded Pitta	LC														O								O		
Pitta erythrogaster	Red-bellied Pitta	LC																							2	
Ailuroedus buccoides	White-eared Catbird	LC		O*		O			2	O				2		O	2		C			O	P	O	2	
Ailuroedus melanotis	Spotted Catbird	LC					P*						P													
Malurus grayi	Broad-billed Fairywren	LC								O	O															
Malurus alboscapulatus	White- shouldered Fairywren	LC		P								P									P	O				
Malurus cyanocephalus	Emperor Fairywren	LC																		C				O		
Myzomela eques	Red-throated Myzomela	LC								2	O2*															
Myzomela nigrita (/ cruentata)	Black(/Red) Myzomela	LC								C	O															
Melilestes megarhynchus	Long-billed Honeyeater	LC		2	P	2	P				P	2		P		2	2		2	2		2	P	P		
Glycichaera fallax	Green-backed Honeyeater	LC																	P							
Lichmera alboauricularis	Silver-eared Honeyeater	LC															P*					O				
Meliphaga montana	Forest Honeyeater	LC		P		P	P																			
Meliphaga aruensis	Puff-backed Honeyeater	LC		2					2	P	P*▪	P		P2*		P	P		P					P	P*	
Meliphaga analoga	Mimic Honeyeater	LC		P		P			P		P			P		P			P	2						
Meliphaga sp.	Meliphaga sp.▪	LC		C▪	P	P▪		2	C▪		2▪			2▪	P	C▪	2▪		C▪	C▪	P	O	P	C▪	C▪	P

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Lichenostomus obscurus	Obscure Honeyeater	LC		2		C	C	2	C	2		O		2		2	2									
Xanthotis flaviventer	Tawny-breasted Honeyeater	LC		C	P	C	O	P	C	O	2			C	P	C	2		C	2	P	2	P	C	2	
Pycnopygius ixoides	Plain Honeyeater	LC		P																						
Pycnopygius stictocephalus	Streak-headed Honeyeater	LC				2			2		2				P	2	2		C		P	O		O	O	
Philemon meyeri	Meyer's Friarbird	LC		2	P	2	C		2	P*							O									
Philemon novaeguineae	New Guinea Friarbird	LC		O	P	C		2	C	O	C			C	P	C	2	P	C	C		2	P	C	C	P
Conopophila albogularis	Rufous-banded Honeyeater	LC																				C				
Crateroscelis murina	Rusty Mouse-warbler	LC		C	P	2	C	2	C	2	2	2	P	C					C			O	P	2	2	
Sericornis beccarii	Tropical/ Beccari's Scrubwren	LC		P																						
Sericornis spilodera	Pale-billed Scrubwren	LC		P			P			2	P	P		2			P									
Gerygone chloronotus	Green-backed Gerygone	LC				P	2							2										2		
Gerygone palpebrosa	Fairy Gerygone	LC		O			2				P*			P*												
Gerygone chrysogaster	Yellow-bellied Gerygone	LC		O		C		P	C	2	2			C		2	2		O				P	C	C	P
Gerygone magnirostris	Large-billed Gerygone	LC																	P*		C	C				
Monachella muelleriana	Torrent Robin	LC			P	O		2	P			P		P												
Microeca flavovirescens	Olive Flyrobin	LC							O																	
Microeca sp.	Flyrobin sp.	LC					P																			
Tregellasia leucops	White-faced Robin	LC		2			O																			
Poecilodryas brachyura	Black-chinned Robin	LC					C						P													
Poecilodryas hypoleuca	Black-sided Robin	LC				O		P	C	C	C	O		C	P		C		C	O		P	P	2	2	

		STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
SCIENTIFIC NAME	ENGLISH NAME	IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Drymodes superciliaris	Northern Scrub-Robin	LC					2																			
Pomatostomus isidorei	New Guinea Babbler	LC														2	2			O				O		
Ptilorrhoa caerulescens	Blue Jewel-babbler	LC		P				P	2	P		P		2		2	2		O	P				P	2	
Ptilorrhoa castanonota	Chestnut- Backed Jewel-babbler	LC		P2*			P*																			
Ptilorrhoa sp.	Jewel-babbler sp.	LC				P																				
Pachycare flavogrisea	Goldenface	LC		P			C						P													
Pachycephala hyperythra	Rusty Whistler	LC		O																						
Pachycephala simplex	Brown Whistler	LC		P*																						
Pachycephala soror	Sclater's Whistler	LC		P*			P*																			
Colluricincla megarhyncha	Little Shrike-thrush	LC		C		2			2	2	O	2	P	2						C		P*		O		
Colluricincla harmonica	Grey Shrike-thrush	LC																			P*	2				
Pitohui kirhocephalus	Variable Pitohui	LC		C	P	2	C		2	2	C	C	P	2	P	2	2	P	O		P		P	2		
Pitohui ferrugineus	Rusty Pitohui	LC							O										O					O		
Pitohui cristatus	Crested Pitohui	LC		P*			2																			
Corvus tristis	Grey Crow	LC		O		O	O	2	2		2	O		2	P	O	O	P	2				P	2	P	
Manucodia chalybata/ jobiensis	Crinkle-collared /Jobi Manucode	LC	P		P					O		O								O						
Manucodia atra/jobiensis	Glossy-mantled /Jobi Manucode	LC	P																			O				
Parotia carolae	Carola's Parotia	LC	P										P													
Ptiloris magnificus	Magnificent Riflebird	LC	P			O	2		2					P												
Cicinnurus magnificus	Magnificent Bird-of-paradise	LC	P	C		C	C	P	O	2		O	P	C												

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Cicinnurus regius	King Bird-of-paradise	LC	P						C	2				O	P	O	O		2	2			P	O	P	
Seleucidis melanoleuca	Twelve-wired Bird-of-paradise	LC	P																C			O			P	
Paradisaea minor	Lesser Bird-of-paradise	LC	P	C	P	2	2	2	C	C	C			2	P	O	O		2			O				
Cracticus cassicus	Hooded Butcherbird	LC				O		P	O		2			2		2	2	P	C	2		2		2	P	P
Cracticus quoyi	Black Butcherbird	LC				2		P	2		O			2		2			2	2		2		2		
Artamus leucorynchus	White-breasted Woodswallow	LC																			P					
Peltops blainvillii	Lowland Peltops	LC		2			2			O	O	O				O			O		P	O				
Peltops montanus	Mountain Peltops	LC											P													
Oriolus szalayi	Brown Oriole	LC																			P	C				
Coracina caeruleogrisea	Stout-billed Cuckooshrike	LC					O						P													
Coracina boyeri	Boyer's Cuckooshrike	LC				O			2					2			P*		2			2	P*	2	2	
Coracina papuensis	White-bellied Cuckooshrike	LC																			2	2				
Coracina schisticeps	Grey-headed Cuckooshrike	LC		O	P*	2	2	P	C	2	2	O		C	P	2	2		C	C			P	2	C	
Coracina melas	New Guinea Cuckooshrike	LC		P*				P*																		
Coracina montana	Black-bellied Cuckooshrike	LC											P													
Campochaera sloetii	Golden Cuckooshrike	LC												2									P	2	2	
Lalage atrovirens	Black-browed Triller	LC		O			P*		2	O	2			2		2	2		2	O	P	2	P	2	C	P
Rhipidura leucophrys	Willie-wagtail	LC															2				C	C		O		
Rhipidura rufiventris	Northern Fantail	LC		O										O												
Rhipidura threnothorax	Sooty Thicket-Fantail	LC		C		2	O2*	C	O	O							O									

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Rhipidura leucothorax	White-bellied Thicket-Fantail	LC													P	C	2	P	C	C	2	C	P	O	2	
Rhipidura hyperythra	Chestnut-bellied Fantail	LC		2		O	C							O												
Rhipidura rufidorsa	Rufous-backed Fantail	LC		C		C	2	P	C	2	C			C	P	O	2									
Dicrurus bracteatus	Spangled Drongo	LC			P	2	P*		O	O	O	P*		2	P	2	O		C	2	P	2		2	2	P
Monarcha guttulus	Spot-winged Monarch	LC				P			2		2			2		P*	P							2		
Monarcha manadensis	Hooded Monarch	LC				2			2		P			2			P			C				2		
Monarcha chrysomela	Golden Monarch	LC		2					O	O	2			2		P*								2		
Arses insularis	Rufous-collared Monarch	LC		2		2			2					2					O			O		2		
Myiagra cyanoleuca	Satin Flycatcher	LC																				O				
Myiagra alecto	Shining Flycatcher	LC							O							O	2	P	2		P	2		O		
Machaerirhynchus flaviventer	Yellow-breasted Boatbill	LC		2		2	P*				2															
Grallina bruijni	Torrent-lark	LC			P																					
Aplonis cantoroides	Singing Starling	LC																			P	P				
Aplonis metallica	Metallic Starling	LC																			C	C				
Mino anais	Golden Myna	LC														2		P						O		
Mino dumontii	Yellow-faced Myna	LC		2	P	2		2	C		2			2	C	C	2	P	C	C	P	2	P	C	C	
Hirundo tahitica	Pacific Swallow	LC														P	2				P			O		
Cisticola exilis	Golden-headed Cisticola	LC																			P	C				
Zosterops minor	Black-fronted White-eye	LC		2		O			2	2	C	O	P	2												
Megalurus timoriensis	Tawny Grassbird	LC		P*																						

SCIENTIFIC NAME	ENGLISH NAME	STATUS		STUDY AREA HILL & MONTANE ZONES													STUDY AREA LOWLAND ZONE									
		IUCN	PNG	NENA BASE	NENA D2	NENA D1	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	OK ISAI	FRIEDA BEND	FRIEDA STRIP	KAUGUMI	EAST SEPIK	HAUNA (& LAKES)	INIOK	WARANGAI SOUTH	WARIO	WOGAMUSH	KUBKAIN
Dicaeum geelvinkianum	Red-capped Flowerpecker	LC		P2*			2	P	2		C	P	P	P		2			2			C	P		P	
Nectarinia aspasia	Black Sunbird	LC			P*	O	O	P	P		C	P		P	P	C	C		C		C	C		P	C	
Nectarinia jugularis	Olive-backed Sunbird	LC																			P					
Melanocharis nigra	Black Berrypecker	LC		2		2	C		C	C	2			C			2							2		
Toxorhamphus novaeguineae	Green-crowned Longbill	LC		2		2	P2*		C		2	2	P*	C		O	2		O				P	2	P2*	
Toxorhamphus iliolophus	Plumed Longbill	LC		P		2	2	P	P			P		2												
Passer montanus	Eurasian Tree-Sparrow	LC									2															
Motacilla cinerea	Grey Wagtail	LC						P			O			P												
Lonchura tristissima	Streak-headed Munia	LC																				O				
Lonchura spectabilis	Hooded Munia	LC																				O				
Totals	**220**			**87**	**27**	**64**	**62**	**43**	**80**	**55**	**60**	**34**	**29**	**81**	**31**	**73**	**76**	**33**	**84**	**40**	**72**	**93**	**44**	**90**	**57**	**19**

* = Provisional (uncertain) records.

C = Common (species found on at least two-thirds of days with significant time in suitable habitat).

2 = Fairly Common (species encountered with some regularity given significant time in suitable habitat).

O = Occasional (species encountered only once or twice despite significant time spent in suitable habitat).

P = Present but abundance not assessed.

h = species deduced present based on information from local hunters

s = species deduced present from the presence of physical signs, including faeces, footprints, feathers or skeletal material.

The total number of species recorded for each site includes provisional records.

Totals for each site and the study as a whole do not include those birds that were not identified to species level and that may be confused with species already recorded for the site or study.

** Includes records from limited time in suitable habitat, birds that are difficult to identify to species-level (e.g. Aerodramus swiftlets, Meliphaga honeyeaters) and birds only provisionally identified to species level.

IUCN status: VU – Vulnerable), Near Threatened NT, Data Deficient DD or Least Concern LC.

PNG status shows those birds listed as protected (P) under the PNG Fauna (Protection & Control)*Act 1966*.

Appendix 4.6   Birds captured

		STUDY AREA HILL & MONTANE ZONES												STUDY AREA LOWLAND ZONE						
SCIENTIFIC NAME	ENGLISH NAME	NENA BASE	NENA D1	NENA LIMESTONE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	TOTAL
Casuarius unappendiculatus	Northern Cassowary				ct1						ct1							ct1,h2	ct2	7
Aepypodius arfakianus	Wattled Brush-turkey					ct2														2
Talegalla jobiensis	Brown-collared Brush-turkey									ct2							ct2			4
Megapodius decollatus	New Guinea Scrubfowl													ct1		ct2				3
Anas superciliosa	Pacific Black Duck																	h1		1
Alcedo azurea	Azure Kingfisher	2			2	2								1						7
Ceyx lepidus	Variable Kingfisher	10	1		3	3		4		1	1	1	3	3	1		2			33
Todirhamphus sanctus	Sacred Kingfisher															1				1
Melidora macrorrhina	Hook-billed Kingfisher							1												1
Tanysiptera galatea	Common Paradise-Kingfisher															1				1
Centropus menbeki	Greater Black Coucal				ct1										ct1					2
Loriculus aurantiifrons	Orange-fronted Hanging-Parrot																3			3
Ninox theomacha	Jungle Hawk-Owl	1																		1
Chalcophaps stephani	Stephan's Dove											1		1			1			3
Gallicolumba rufigula	Cinnamon Ground-Dove	ct1								1,ct2							ct1			5
Ptilinopus ornatus	Ornate Fruit-Dove	h1																		1
Ptilinopus coronulatus	Coroneted Fruit-Dove											h1			1		1			3
Goura victoria	Victoria Crowned-Pigeon				ct2													ct4	ct2	8

SCIENTIFIC NAME	ENGLISH NAME	STUDY AREA HILL & MONTANE ZONES												STUDY AREA LOWLAND ZONE						TOTAL
		NENA BASE	NENA D1	NENA LIMESTONE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	
Rallina tricolor	Red-necked Crake												ct1	ct1						2
Zonerodius heliosylus	Forest Bittern				ct1															1
Ailuroedus buccoides	White-eared Catbird									2				1						3
Melilestes megarhynchus	Long-billed Honeyeater	1					2	4		1		3	3	3		3				20
Glycichaera fallax	Green-backed Honeyeater													1						1
Meliphaga montana	Forest Honeyeater	1	2	1																4
Meliphaga aruensis	Puff-backed Honeyeater	4			4	2		1		2		2	1	2			4			22
Meliphaga analoga	Mimic Honeyeater	1	2		3		2			1			1	1	4					15
Meliphaga sp.	Meliphaga sp.	3																	1	4
Lichenostomus obscurus	Obscure Honeyeater							1		1										2
Xanthotis flaviventer	Tawny-breasted Honeyeater									1		1		1		1	3			7
Pycnopygius ixoides	Plain Honeyeater	2																		2
Crateroscelis murina	Rusty Mouse-warbler	7	1			1		3		1				2			1			16
Sericornis spilodera	Pale-billed Scrubwren	2		2		6		2		4		1								17
Gerygone chrysogaster	Yellow-bellied Gerygone	1	h1							1		2					1			6
Gerygone magnirostris	Large-billed Gerygone															5				5
Tregellasia leucops	White-faced Robin	3																		3
Poecilodryas brachyura	Black-chinned Robin			2																2
Poecilodryas hypoleuca	Black-sided Robin				2	3	1													6

SCIENTIFIC NAME	ENGLISH NAME	STUDY AREA HILL & MONTANE ZONES												STUDY AREA LOWLAND ZONE						TOTAL
		NENA BASE	NENA D1	NENA LIMESTONE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	
Pomatostomus isidorei	New Guinea Babbler											1	1							2
Ptilorrhoa caerulescens	Blue Jewel-babbler	1						1		1										3
Ptilorrhoa castanonota	Chestnut-backed Jewel-babbler	2																		2
Pachycare flavogrisea	Goldenface	1																		1
Pachycephala hyperythra	Rusty Whistler	2																		2
Colluricincla megarhyncha	Little Shrike-thrush	4			1	2	1			1					1		1			11
Pitohui kirhocephalus	Variable Pitohui	3						1	1											5
Pitohui ferrugineus	Rusty Pitohui				ct1									2						3
Cicinnurus magnificus	Magnificent Bird-of-paradise				ct1	1		1												3
Cicinnurus regius	King Bird-of-paradise				1	1					ct1									3
Rhipidura threnothorax	Sooty Thicket-Fantail	2	2		1							1								6
Rhipidura leucothorax	White-bellied Thicket-Fantail										1	2	3			2				8
Rhipidura hyperythra	Chestnut-bellied Fantail	1																		1
Rhipidura rufidorsa	Rufous-backed Fantail		1		1	1	1													4
Monarcha guttulus	Spot-winged Monarch				3		1			5		1					2			12
Monarcha manadensis	Hooded Monarch		4		2					2		1			4		2			15
Monarcha chrysomela	Golden Monarch	1																		1
Arses insularis	Rufous-collared Monarch		h1		1															2
Myiagra alecto	Shining Flycatcher											3		2		1				6
Aplonis metallica	Metallic Starling															1				1

SCIENTIFIC NAME	ENGLISH NAME	STUDY AREA HILL & MONTANE ZONES												STUDY AREA LOWLAND ZONE						TOTAL
		NENA BASE	NENA D1	NENA LIMESTONE	MALIA	KOKI	FRIEDA BASE	HI	UBIAME	UPPER OK BINAI	OK BINAI 1	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	
Dicaeum geelvinkianum	Red-capped Flowerpecker															1				1
Nectarinia aspasia	Black Sunbird												2			6				8
Melanocharis nigra	Black Berrypecker	5			4	7				2							1			19
Toxorhamphus novaeguineae	Green-crowned Longbill	5		1	6			4		6		3					1			26
Toxorhamphus iliolophus	Plumed Longbill	1	1		2															4
Lonchura tristissima	Streak-headed Munia															1				1
Totals	**63**	**68**	**16**	**6**	**43**	**31**	**8**	**23**	**1**	**37**	**4**	**24**	**15**	**22**	**12**	**25**	**26**	**8**	**5**	**374**

Birds captured in mist-nets, by hand (h) or photographed remotely by camera-trap (ct). Figures indicate the number of individuals trapped.

Appendix 4.7 Species possibly occurring but not yet recorded in the Study Area

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Coturnix ypsilophora	Brown Quail	LC			0	2600	3600	X	X	1	BR	G
Coturnix chinensis	Blue-breasted Quail	LC			0	2200		X	X	1	BR	G
Dendrocygna arcuata	Wandering Whistling-Duck	LC			0			X		1	BR	W
Tadorna radjah	Radjah Shelduck	LC			0			X		1	BR	W
Nettapus coromandelianus	Cotton Pygmy-goose	LC			0	2255		X		1	BR	W
Salvadorina waigiuensis	Salvadori's Teal	VU	P	350	500	3700	4100		X	4	BR	RS
Anas gracilis	Grey Teal	LC			0	3000		X		1	BR+M	W
Aythya australis	Hardhead	LC			0			X		1	M(+BR)	W
Alcedo atthis	Common Kingfisher	LC			0	25		X		1	BR	RS
Alcedo pusilla	Little Kingfisher	LC			0	75	750	X		1	BR	RS
Clytoceyx rex	Shovel-billed Kookaburra	LC		0	200	1500	2400		X	4	BR	F
Todirhamphus macleayii	Forest Kingfisher	LC			0	1830		X	X	1	BR+M	O
Merops philippinus	Blue-tailed Bee-eater	LC			0	150		X		1	BR	O
Cacomantis flabelliformis	Fan-tailed Cuckoo	LC		600	1300	2900	3900		X	1	BR	F^
Chrysococcyx lucidus	Shining Bronze-Cuckoo	LC			0	1920		X	X	1	M	F/O
Chrysococcyx ruficollis	Rufous-throated Bronze-Cuckoo	LC			1130	3230			X	4	BR	F^
Psitteuteles goldiei	Goldie's Lorikeet	LC		0	650	2800			X	4	BR	F
Charmosyna wilhelminae	Pygmy Lorikeet	LC		0	750	1800			X	4	BR	F

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Charmosyna pulchella	Fairy Lorikeet	LC		25	750	2300			X	4	BR	F
Charmosyna josefinae	Josephine's Lorikeet	LC		50	760	1770			X	4	BR	F
Charmosyna papou	Papuan Lorikeet	LC		1200	1500	2800	3350		X	4	BR	F^
Neopsittacus musschenbroekii	Yellow-billed Lorikeet	LC		1100	1600	2500	3000		X	4	BR	F/O^
Cyclopsitta gulielmitertii	Orange-breasted Fig-Parrot	LC			0	1200		X	X	3	BR	F/O
Cyclopsitta diophthalma	Double-eyed Fig-Parrot	LC			0	1650	3100	X	X	1	BR	F/O
Psittacella brehmii	Brehm's Tiger-Parrot	LC		1100	1600	2800	3200		X	4	BR	F^
Psittacella picta	Painted Tiger-Parrot	LC		1370	2450	3680	4000		X	4	BR	F^
Psittacella madaraszi	Madarasz's Tiger-Parrot	LC		0	1150	2500			X	4	BR	F^
Aerodramus nuditarsus	Bare-legged Swiftlet	LC		30	900	1800			X	1	BR	A
Aerodramus papuensis	Papuan Swiftlet	DD			0	1800	2400	X	X	4	BR	A
Tyto tenebricosa	Greater Sooty-Owl	LC		400	1,000	2500	3360		X	1	BR	F^
Tyto alba	Barn Owl	LC			0	1680		X	X	1	BR	F/O
Ninox connivens	Barking Owl	LC			0	100	1040	X		1	BR	F/O
Uroglaux dimorpha	Papuan Hawk-Owl	DD			0	1500		X	X	3	BR	F
Aegotheles insignis	Feline Owlet-Nightjar	LC		80	1150	2800			X	4	BR	F^
Aegotheles bennettii	Barred Owlet-Nightjar	LC			0	900	1100	X	X	3	BR	F
Aegotheles albertisi	Mountain Owlet-Nightjar	LC			800	2900	3700		X	4	BR	F
Eurostopodus mystacalis	White-throated Eared-Nightjar	LC			0	1650		X	X	1	M	F/O

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Columba vitiensis	Metallic Pigeon	LC			0	2750		X	X	1	BR	F
Henicophaps albifrons	New Guinea Bronzewing	LC			0	2150		X	X	3	BR	F
Gallicolumba jobiensis	White-bibbed Ground-Dove	LC			0	2400		X	X	1	BR	F
Trugon terrestris	Thick-billed Ground-Pigeon	LC			0	640		X	X	3	BR	F
Gallicolumba beccarii	Bronze Ground-Dove	LC		1100	1200	2800			X	1	BR	F^
Ptilinopus pulchellus	Beautiful Fruit-Dove	LC			0	1370		X	X	3	BR	F
Ducula chalconota	Shining Imperial-Pigeon	LC			1100	2400	1,000		X	4	BR	F^
Ducula spilorrhoa	Torresian Imperial-Pigeon	LC			0	75	900	X		1	BR	F
Grus rubicunda	Brolga	LC			0	400			X	1	BR	W
Rallina forbesi	Forbes's Forest-Rail	LC			1100	3000			X	4	BR	F^
Gallirallus philippensis	Buff-banded Rail	LC			0	3600		X	X	1	BR	W
Gymnocrex plumbeiventris	Bare-eyed Rail	LC			0	150	1800	X		2	BR	W
Porzana pusilla	Baillon's Crake	LC			0	2450		X		1	BR	W
Porzana tabuensis	Spotless Crake	LC			0	3300		X		1	BR	W
Porzana cinerea	White-browed Crake	LC			0	1830		X		1	BR	W
Gallinula tenebrosa	Dusky Moorhen	LC			0	1580			X	1	BR	W
Fulica atra	Common Coot	LC			0	2320			X	1	BR	W
Gallinago hardwickii	Latham's Snipe	LC			0	3350		X		1	M	O/W
Gallinago megala	Swinhoe's Snipe	LC			0	3720		X		1	M	O/W

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Limosa limosa	Black-tailed Godwit	NT			0	10		X		1	M	W
Limosa lapponica	Bar-tailed Godwit	LC			0	10		X		1	M	W
Numenius minutus	Little Curlew	LC			0	1100	4500	X		1	M	O
Numenius phaeopus	Whimbrel	LC			0	10	1500	X		1	M	W
Tringa stagnatilis	Marsh Sandpiper	LC			0	400		X		1	M	W
Tringa nebularia	Common Greenshank	LC			0	1500		X		1	M	W
Tringa glareola	Wood Sandpiper	LC			0	1735		X		1	M	W
Heteroscelus brevipes	Grey-tailed Tattler	LC			0	1100		X		1	M	W
Calidris minuta	Little Stint	LC			0	10		X		1	M	W
Calidris ruficollis	Red-necked Stint	LC			0	1,000		X		1	M	W
Calidris subminuta	Long-toed Stint	LC			0	10		X		1	M	W
Calidris melanotos	Pectoral Sandpiper	LC			0	10		X		1	M	W
Calidris ferruginea	Curlew Sandpiper	LC			0	10		X		1	M	W
Limicola falcinellus	Broad-billed Sandpiper	LC			0	10		X		1	M	W
Irediparra gallinacea	Comb-crested Jacana	LC			0	600		X		1	BR	W
Pluvialis fulva	Pacific Golden-Plover	LC			0	2000		X	X	1	M	O/W
Charadrius veredus	Oriental Plover	LC			0	10		X		1	M	O
Gelochelidon nilotica	Gull-billed Tern	LC			0	400		X	X	1	M	S/W
Sterna hirundo	Common Tern	LC			0	10		X		1	M	S/W
Sterna albifrons	Little Tern	LC			0	10		X		1	M	S/W

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Chlidonias leucopterus	White-winged Tern	LC			0	1300		X	X	1	M	W
Elanus caeruleus	Black-winged Kite	LC			0	1830		X		1	BR	O
Accipiter fasciatus	Brown Goshawk	LC			0	1950		X	X	1	BR	F/O
Accipiter melanochlamys	Black-mantled Goshawk	LC		600	1100	3100			X	4	BR	F^
Accipiter poliocephalus	Grey-headed Goshawk	LC			0	1500		X	X	3	BR	F
Accipiter cirrocephalus	Collared Sparrowhawk	LC			0	2500		X	X	1	BR	F/O
Accipiter meyerianus	Meyer's Goshawk	LC			0	1600	2700		X	3	BR	F
Erythrotriorchis buergersi	Chestnut-shouldered Goshawk	DD			450	1580			X	4	BR	F
Aquila gurneyi	Gurney's Eagle	NT			0	1300	2970	X	X	2	BR	F
Falco berigora	Brown Falcon	LC			0	1800	3000	X	X	1	BR	F/O
Falco severus	Oriental Hobby	LC			0	1800		X	X	1	BR	F
Falco peregrinus	Peregrine Falcon	LC			0	3475		X	X	1	BR	F/O
Tachybaptus ruficollis	Little Grebe	LC			0	1520		X		1	BR	W
Tachybaptus novaehollandiae	Australasian Grebe	LC			0	3225		X		1	BR	W
Egretta novaehollandiae	White-faced Heron	LC			0	1500	1700	X		1	BR+M	W
Butorides striatus	Striated Heron	LC			0	100		X		1	BR	W
Plegadis falcinellus	Glossy Ibis	LC			0	100		X		1	M	W
Threskiornis molucca	Australian Ibis	LC			0	100		X		1	M	W
Platalea regia	Royal Spoonbill	LC			0	100		X		1	M	W

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Amblyornis macgregoriae	Macgregor's Bowerbird	LC		700	1600	2300	2800		X	4	BR	F^
Sericulus aureus	Masked Bowerbird	LC			850	1400			X	4	BR	F
Chlamydera lauterbachi	Yellow-breasted Bowerbird	LC			0	1770		X	X	4	BR	O
Cormobates placens	Papuan Treecreeper	LC			1250	2600	3000		X	4	BR	F^
Clytomyias insignis	Orange-crowned Fairywren	LC		1200	1700	2800			X	4	BR	F^
Sipodotus wallacii	Wallace's Fairywren	LC			100	800	1200		X	3	BR	F
Myzomela cruentata	Red Myzomela	LC		0	750	1450			X	2	BR	F
Myzomela adolphinae	Mountain Myzomela	LC		500	1150	1950			X	4	BR	F^
Myzomela rosenbergii	Red-collared Myzomela	LC		600	1200	3700	4000		X	3	BR	F^
Timeliopsis fulvigula	Olive Straightbill	LC		750	1400	2200	2800		X	4	BR	F^
Timeliopsis griseigula	Tawny Straightbill	LC			0	800		X	X	4	BR	F
Meliphaga orientalis	Hill-forest Honeyeater	LC			550	1750			X	3	BR	F
Meliphaga flavirictus	Yellow-gaped Honeyeater	LC			0	1400		X	X	4	BR	F
Lichenostomus subfrenatus	Black-throated Honeyeater	LC		1070	1350	3680			X	4	BR	F^
Xanthotis polygramma	Spotted Honeyeater	LC		0	100	1400			X	3	BR	F
Pycnopygius cinereus	Marbled Honeyeater	LC		500	1,000	2000			X	4	BR	F^
Ptiloprora plumbea	Leaden Honeyeater	LC			1100	1900			X	4	BR	F^
Ptiloprora meekiana	Olive-streaked Honeyeater	LC			1300	2440			X	4	BR	F^
Ptiloprora guisei	Rufous-backed Honeyeater	LC			1340	2900			X	4	BR	F^

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Melidectes belfordi	Belford's Melidectes	LC		1400	1600	3350	3800		X	4	BR	F^
Melidectes rufocrissalis	Yellow-browed Melidectes	LC		1100	1400	2400			X	4	BR	F^
Melidectes torquatus	Ornate Melidectes	LC		900	1200	1700	2200		X	4	BR	F^
Melipotes fumigatus	Smoky Honeyeater	LC			1100	2800	4200		X	4	BR	F^
Crateroscelis nigrorufa	Bicolored Mouse-warbler	LC			1220	2500			X	4	BR	F^
Crateroscelis robusta	Mountain Mouse-warbler	LC		1250	1700	3680			X	4	BR	F^
Sericornis nouhuysi	Large Scrubwren	LC		1,000	1400	3500	3750		X	4	BR	F^
Sericornis perspicillatus	Buff-faced Scrubwren	LC		850	1500	2450	2800		X	4	BR	F^
Sericornis arfakianus	Grey-green Scrubwren	LC		670	1200	1400	1700		X	4	BR	F^
Sericornis papuensis	Papuan Scrubwren	LC		850	2000	3500			X	4	BR	F^
Gerygone cinerea	Mountain Gerygone	LC		1,000	2000	2800			X	4	BR	F^
Gerygone ruficollis	Brown-breasted Gerygone	LC		900	1400	2450	3400		X	4	BR	F^
Amalocichla incerta	Lesser Ground-robin	LC		800	1200	2750			X	4	BR	F^
Microeca flavigaster	Lemon-bellied Flyrobin	LC			0	670	1460	X	X	1	BR	O
Microeca griseoceps	Yellow-legged Flyrobin	LC			550	1400	2300		X	1	BR	F
Microeca papuana	Canary Flyrobin	LC		1100	1800	2500	3500		X	4	BR	F^
Eugerygone rubra	Garnet Robin	LC		1400	1700	2500	3680		X	4	BR	F^
Eopsaltria pulverulenta	Mangrove Robin	LC			0	50		X		1	BR	Fm
Poecilodryas placens	Olive-yellow Robin	NT			100	1450			X	3	BR	F

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Poecilodryas albonotata	Black-throated Robin	LC		1150	1800	2750			X	4	BR	F^
Peneothello cyanus	Blue-grey Robin	LC		900	1500	2500	2750		X	4	BR	F^
Peneothello bimaculatus	White-rumped Robin	LC		300	700	1200	1700		X	3	BR	F
Heteromyias albispecularis	Ashy Robin	LC		850	1700	2400	2600		X	1	BR	F^
Pachycephalopsis hattamensis	Green-backed Robin	LC			760	1650	2000		X	3	BR	F
Pachycephalopsis poliosoma	White-eyed Robin	LC		400	700	1700	2200		X	4	BR	F
Orthonyx temminckii	Logrunner	LC		1200	1980	2840	3450		X	1	BR	F^
Androphobus viridis	Papuan Whipbird	DD			1400	2800			X	4	BR	F^
Ptilorrhoa leucosticta	Spotted Jewel-babbler	LC			1200	2700			X	4	BR	F^
Daphoenositta chrysoptera	Varied Sittella	LC		1075	1400	2200	2650		X	1	BR	F^
Rhagologus leucostigma	Mottled Whistler	LC		820	1500	2550	2900		X	4	BR	F^
Aleadryas rufinucha	Rufous-naped Whistler	LC		1200	1400	2600	3600		X	4	BR	F^
Pachycephala modesta	Brown-backed Whistler	LC		1130	1830	3600			X	4	BR	F^
Pachycephala schlegelii	Regent Whistler	LC		1300	1850	3650			X	4	BR	F^
Pachycephala aurea	Golden-backed Whistler	LC			0	700	1460	X	X	4	BR	F/O
Pachycephala monacha	Black-headed Whistler	LC		550	1,000	1750			X	3	BR	F/O^
Pachycephala leucogastra	White-bellied Whistler	LC			0	1200		X	X	1	BR	F/O
Colluricincla umbrina	Sooty Shrike-thrush	LC			1450	2150			X	4	BR	F
Pitohui dichrous	Hooded Pitohui	LC		0	350	1700	2000		X	4	BR	F
Pitohui nigrescens	Black Pitohui	LC		1,000	1600	2000	2600		X	3	BR	F^

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Eulacestoma nigropectus	Wattled Ploughbill	LC		1250	1950	2850			X	4	BR	F^
Corvus orru	Torresian Crow	LC			0	300	1530	X	X	1	BR	O
Melampitta lugubris	Lesser Melampitta	LC		1150	2000	2800	3500		X	4	BR	F^
Melampitta gigantea	Greater Melampitta	LC			650	1400			X	4	BR	F
Loboparadisea sericea	Yellow-breasted Bird-of-paradise	NT	P	600	1200	2000			X	4	BR	F^
Cnemophilus loriae	Loria's Bird-of-paradise	LC	P	1200	2000	2400	3000		X	4	BR	F^
Manucodia keraudrenii	Trumpet Manucode	LC	P	200	900	1800	2000		X	1	BR	F
Paradigalla brevicauda	Short-tailed Paradigalla	LC	P	1400	1570	2400	2580		X	4	BR	F^
Epimachus fastuosus	Black Sicklebill	VU	P	1280	1800	2150	2550		X	4	BR	F^
Drepanornis albertisi	Buff-tailed Sicklebill	LC	P	600	1100	1900	2250		X	4	BR	F^
Lophorina superba	Superb Bird-of-paradise	LC	P	750	1650	1900	2300		X	4	BR	F^
Pteridophora alberti	King-of-Saxony Bird-of-paradise	LC	P	1400	1800	2500	2850		X	4	BR	F^
Artamus maximus	Great Woodswallow	LC		90	600	2600	2800		X	4	BR	A
Coracina longicauda	Hooded Cuckooshrike	LC		1300	2100	2800	3700		X	4	BR	F^
Coracina incerta	Black-shouldered Cicadabird	LC		0	450	1450	1800		X	3	BR	F
Rhipidura atra	Black Fantail	LC		700	1,000	2150	3200		X	3	BR	F^
Rhipidura albolimbata	Friendly Fantail	LC		1130	1370	3600			X	4	BR	F/O^
Rhipidura brachyrhyncha	Dimorphic Fantail	LC		1160	2000	3680	3900		X	4	BR	F^
Chaetorhynchus papuensis	Pygmy Drongo	LC		200	600	1460	1600		X	4	BR	F
Monarcha axillaris	Black Monarch	LC		700	800	2350			X	3	BR	F

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Monarcha rubiensis	Rufous Monarch	LC			0	300		X	X	4	BR	F
Monarcha frater	Black-winged Monarch	LC		0	550	1550			X	1	BR	F
Machaerirhynchus nigripectus	Black-breasted Boatbill	LC		850	1130	2750			X	4	BR	F^
Zoothera heinei	Russet-tailed Thrush	LC			490	1700			X	1	BR	F
Saxicola caprata	Pied Bushchat	LC			0	2850		X	X	1	BR	O
Hirundo rustica	Barn Swallow	LC			0	1740		X	X	1	M	A
Hirundo nigricans	Tree Martin	LC			0	1830		X	X	1	M	A
Zosterops fuscicapillus	Capped White-eye	LC		750	1200	1850	2200		X	3	BR	F^
Acrocephalus stentoreus	Clamorous Reed-Warbler	LC			0	2300		X	X	1	BR	W
Phylloscopus trivirgatus	Mountain Leaf-Warbler	LC		640	1200	1800	2400		X	1	BR	F^
Mirafra javanica	Australasian Lark	LC			0	1200	1680	X		1	BR	O
Melanocharis arfakiana	Obscure Berrypecker	DD			640	1100			X	4	BR	F
Melanocharis longicauda	Lemon-breasted Berrypecker	LC			700	1900			X	4	BR	F
Melanocharis versteri	Fan-tailed Berrypecker	LC		1250	1700	3680			X	4	BR	F^
Melanocharis striativentris	Streaked Berrypecker	LC		550	1150	2300	2600		X	4	BR	F
Melanocharis crassirostris	Spotted Berrypecker	LC		850	1150	2300	2700		X	4	BR	F^
Toxorhamphus poliopterus	Grey-winged Longbill	LC		300	500	2000	2450		X	4	BR	F
Oedistoma pygmaeum	Pygmy Longbill	LC			0	800	1370	X	X	3	BR	F
Oreocharis arfaki	Tit Berrypecker	LC		850	2200	2700	3650		X	4	BR	F^
Erythrura trichroa	Blue-faced Parrotfinch	LC		750	1,000	3000			X	1	BR	F^

SCIENTIFIC NAME	COMMON NAME	STATUS		ELEVATION (M)				ZONE		ENDEMISM[3]	RESIDENCY[4]	HABITAT[5]
		IUCN[1]	PNG[2]	MIN. LOWER	AV. LOWER	AV. UPPER	MAX. UPPER	LOWLAND ZONE	HILL & MONTANE ZONES			
Erythrura papuana	Papuan Parrotfinch	LC		500	1200	2600			X	4	BR	F^
Lonchura grandis	Grand Munia	LC			0	1280		X	X	4	BR	O/W

* Data compiled from numerous sources, including: Beehler et al. (1986), Chantler and Driessens (2000), Coates (1985, 1990), Crome and Swainson (1974), Frith and Frith (2004), Geering et al. (2007), Greig-Smith (1978), Gilliard and LeCroy (1966), Jones et al. (1995), Pearson (1975), Stresemann (1923), Stringer (1977), Tolhurst (1993).

1 IUCN status indicates species listed as Globally Threatened (VU – Vulnerable), Near Threatened (NT), Data Deficient (DD) or Least Concern (LC).

2 PNG status shows those birds listed as protected (P) under the PNG *Fauna (Protection & Control)Act 1966*.

3 Endemism rankings indicate those species that: 1 – Occur more widely in the Indo-Pacific; 2 – Are endemic to New Guinea, its satellite islands, the Bismarcks and Maluku; 3 – Are endemic to New Guinea and its satellite islands (Waigeo, Misol, Yapen, Biak, Aru, d'Entrecasteaux and Louisiades); 4 – Are endemic to mainland New Guinea; 5 – Are endemic to northern mainland New Guinea, north of the Central Cordillera.

4 Residency status indicates those species that are: BR – breeding residents (New Guinea mainland); M – non-breeding migrants; BR+M – breeding residents with populations seasonally augmented by non-breeding visitors; M(+BR) – non-breeding migrants with possible resident breeding populations.

5 Habitat preferences include: F – forest species (including primary closed forest and disturbed or secondary forest); Fm – mostly mangrove forest; O – open and disturbed areas (grassland, urban, agricultural, open woodland, scrub etc.); G – grasslands; W – wetland species, including rivers, estuaries, lakes, marshes, etc.; RS – rivers and streams; S/W – predominantly seabirds that may occur along inland waterways; A – aerial foragers. Montane species marked with the suffix (^).

Chapter 5 Amphibians and Reptiles

Dr. Stephen Richards

A report prepared for Coffey Environments and

Frieda River Limited

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Tables

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EXECUTIVE SUMMARY

- A total of 58 frog and 41 reptile species were documented from 17 sites in the Study Area. The fauna is broadly consistent with that previously known from the northern foothills and lowlands of New Guinea.

- Five of the nine new treefrogs (56%), are habitat specialists requiring clear, torrential rocky streams for reproduction. Another two of these species were found only along clear, slow-flowing streams. Eight of the nine species are known only from the Study Area Hill Zone. One is known from the Study Area Hill Zone and possibly from Frieda Bend Site in the Study Area Lowland Zone, where several juveniles were tentatively assigned to this species.

- There was a significant positive relationship between elevation and frog diversity, which was highest at Nena Base Site (35 species). However elevation played no role in determining reptile diversity among sites.

- Three poorly-known frog species documented during the survey, *Litoria humboldtorum, L. purpureolata* and *Nyctimystes fluviatilis,* were previously known only from Papua Province, Indonesian New Guinea. The documentation of *L. purpureolata* and *N. fluviatilis* in the Study Area during this survey coincided with the first published records of these species in PNG, also from the Sepik River Basin.

- No frogs or reptiles listed as Vulnerable, Endangered or Critically Endangered by the IUCN were encountered during the study. None of the species documented during the survey are protected under the PNG *Fauna (Protection and Control)Act 1966.* Six species of frogs, but no reptiles, are classified as Data Deficient by IUCN.

- At least 20 and up to 25 species of frogs documented in the Study Area appear to be new to science or undescribed, and at least 16 of these are currently known only from the Study Area.

- One gecko of the genus *Lepidodactylus* appears to be new to science or undescribed and two additional species, a gecko of the genus *Cyrtodactylus* and a skink of the genus *Emoia*, may also prove to be new to science following further taxonomic studies. The species of *Emoia* identified here as *E. obscura* is probably a taxonomic complex and may constitute more than one species.

- Large populations of New Guinea Freshwater Crocodiles (*Crocodylus novaeguineae*) and Estuarine Crocodiles (*C. porosus*) were confirmed in the Iniok region, as evidenced by sightings of tracks, sighting of adult crocodiles, interviews with local informants, and the high rate of crocodiles captured by locals around Iniok during the survey period (3 crocodiles captured during the 5-day survey period). Interviews with local communities and with the Sepik Wetlands Management Initiative in Ambunti indicated that these species persist at high densities in suitable habitats throughout the Study Area Lowland Zone.

- Important habitats identified during the surveys include 1) clear streams in the Study Area Hill Zone, which harbour a diverse assemblage of torrent-dwelling frogs; 2) forests and a seepage at Nena Limestone Site which harbour an undescribed treefrog and a gecko not known from any other site and 3) oxbows and other large waterbodies isolated from the main Frieda and Sepik River channels, which appear to harbour large populations of crocodiles.

- Between them the Frieda Bend and Ok Isai sites had only three species not documented at other sites and all are common, widespread species occurring throughout northern PNG.

- The significance of the Peat Forest at East Sepik Site for herpetofauna was difficult to assess due to seasonal factors but East Sepik Site had the lowest diversity of frogs encountered at any site during this Project. Although this was probably in part because activity levels of frogs were extremely low due to the dry season, the depauperate fauna documented at this site probably also reflects the lack of aquatic habitats in this unusual habitat, which has precluded successful colonisation and persistence by most pond and swamp-breeding frogs.

1 INTRODUCTION

The herpetofauna of New Guinea is exceptionally diverse, with the total number of frog and reptile species known from the region currently exceeding 600 (Menzies 2006, Allison 2007) and expected to increase substantially. For example Gunther (2006) has predicted that the frog fauna alone probably exceeds 600 species, and this estimate is supported by recent taxonomic revisions of the fauna and exploration of remote regions that continue to reveal numerous new species, particularly in the frog families Hylidae and Microhylidae (e.g. Richards 2007) and the gecko genus *Cyrtodactylus* (e.g. Rösler et al 2007; Oliver *et al.* 2008).

Recent herpetofaunal surveys in PNG have focused predominantly on documenting the fauna of the southern slopes of the Central Cordillera in Southern Highlands and Gulf Provinces (e.g. Richards 2000; 2002a; 2002b; Kraus and Allison 2009), in high-montane regions of the central mountains (Richards 2007), and in Milne Bay Province in far-eastern PNG (Kraus and Allison 2004). Herpetofaunal diversity on the northern slopes of PNG's Central Cordillera remains poorly studied, although Mys (1988) presented an excellent summary of the distribution of scincid lizards in northern PNG and Read (1998) and Austin (2006) have summarised the herpetofauna of Kau Wildlife Management Area in Madang Province. Two recent studies have documented herpetofauna in the lowlands of the Sepik River Basin (Austin *et al.* 2008, Dahl *et al.* 2009), and a series of surveys by the Bishop Museum visited the isolated Bewani, Hunstein and Torricelli Ranges with some attention to the Sepik lowlands (Kraus and Allison 2006). However none of these expeditions ascended the Study Area Hill Zone on the northern slopes of the Central Cordillera in western PNG and the herpetofauna in this area remains poorly documented.

The herpetofauna of the Mamberamo basin and Foya Mountains in adjacent Papua Province, Indonesia, has also been the subject of recent study (e.g. Richards and Suryadi 2002) resulting in the description of several new frog taxa (Oliver *et al.* 2007; Richards *et al.* 2009). The 1938-1939 Archbold expedition undertook intensive biological surveys at sites in the lowlands of the Mamberamo basin and was one of the few expeditions to obtain herpetological material from the northern foothills of the Central Cordillera (Archbold *et al.* 1942). However that survey did not have a dedicated herpetologist and, as a result, although valuable herpetological material was collected, a synthesis of the herpetological results was never published. The Archbold material was subsequently examined by R.G. Zweifel of the American Museum of Natural History who described a number of new taxa from that expedition (e.g. Zweifel 1958, 2000). Given the continuity of habitats and lack of major biogeographic barriers along the northern face of the Central Cordillera and between the Mamberamo and Sepik River Basins, many of the taxa documented from the Mamberamo lowlands and foothills may reasonably be expected to also occur in the Sepik catchment of northern PNG.

This report presents an assessment of the overall herpetofaunal diversity in the Study Area (see Chapter 1 Figures 1 to 3) and covers a variety of terrains that support a wide range of habitats. It represents the first comprehensive survey of herpetofauna undertaken in this region.

2 OBJECTIVES

The objectives of this assessment were to:

- Conduct amphibian and reptile surveys in the Study Area
- Characterise the amphibian and reptile fauna of the Study Area.
- Identify significant amphibian and reptile communities and habitats.
- Identify IUCN listed species and species listed as protected under the PNG *Fauna (Protection and Control)Act 1966*.
- Recommend suitable mitigations to reduce impacts on amphibians and reptiles.

3 METHODS

3.1 Sites

Surveys were undertaken at survey sites in the Study Area (see Chapter 1 Table 4 and Figures 4 and 5). The habitat types and vegetation structure at these sites are described in detail in Chapters 1 and 2 so only those features specifically relevant to understanding the diversity and status of herpetofauna species are mentioned further in this report.

To aid interpretation of results in this report the Study Area has been divided into three broad regions (see Chapter 1): the Study Area Montane Zone, the Study Area Hill Zone, and the Study Area Lowland Zone, for analysis and discussion. This division is more important than vegetation structure for understanding the herpetofaunal (particularly frog) diversity and status in the Study Area, because it influences the presence and form of flowing aquatic habitats, which, in are major determinants of the structure and diversity of frog assemblages in New Guinea. The Study Area Hill Zone is defined here as all areas above the zone of alluviation of the Sepik system. Although the exact elevation at which the Study Area transitions from the Sepik plains to the Hill Zone varies across the area, about 80-100 m elevation appears to be the elevation above which alluviation ceases to occur, and above which clear, fast flowing streams become a distinctive component of the aquatic habitat diversity. All sites above 100 m elevation are therefore considered to be in the Study Area Hill Zone. Although small areas of the Frieda Bend Site extended above 100 m elevation most terrain is below 100 m and this site is considered to be in the Study Area Lowland Zone.

3.2 Survey Methods

All sampling was done by S. Richards and 2 local assistants. Water-bodies examined included seepages, small closed-canopy streams, larger streams (Table 1) and small forest pools. At each site intensive searches for frogs and reptiles were conducted along trails established for this purpose. During the day searches focused on heliothermic (basking) reptiles along trails through forest, clearings, and on stream

Table 1. Stream classification used in the herpetofauna habitat assessments

STREAM CATEGORY	CODE	MAJOR CHARACTERISTICS
Upland Torrential Stream	UTS	Small to medium (1-10 m wide), clear water creeks. Generally above 300 m elevation. Moderate-high velocity. Rocky substrate with riffle-pool morphology and sometimes with waterfalls. Transport capacity greater than supply for sand so sand and litter are minor components of substrate except in deeper pools. Water temperatures cool, high levels of dissolved oxygen. Severely influenced by spates.
Upland Low-gradient Stream	ULGS	Small to medium (1-10 m wide), clear water creeks. Generally above 300 m elevation. Low velocity, so sand is dominant substrate and litter accumulation evident. riffle/pool morphology substantially lacking. Water cool but oxygen levels lower than in UTS. Moderately influenced by spates.
Lowland Torrential Stream	LTS	As for Upland Torrential Stream but generally below 300 m elevation, moderate velocity so sand and litter more evident than in UTS although rocky substrate still dominates, riffle/pool morphology less well defined than in LTS.
Lowland Low-gradient Stream	LLGS	As for ULGS except water may be muddy or clear, generally below 300 m elevation, very low velocity so sand and litter dominate the substrate – exposed rocky substrate generally negligible, riffle/pool morphology absent and oxygen levels low
Seepage	SP	Shallow (< 10 cm), slow-flowing water-bodies seeping from the ground. Generally < 5 m wide. Velocity negligible, surface movement barely detectable. Substrate usually mud and/ or litter. Riffle/pool morphology absent. Oxygen levels low.

Notes: Riffle: shallow (normally <30 cm deep) turbulent flow with broken water surface over rocky substrate. Riffle/Pool morphology: Streams with stretches of higher-velocity, turbulent water flowing over rocks (riffles), that separate slower, deeper stretches (pools) generally containing some sand. Spate: A rapid and very large change in stream volume/velocity in response to intense rainfall events.

banks. Small lizards were collected by hand or were stunned with a large rubber band. Large lizards and snakes were collected by hand. Non-basking reptiles were sampled by searching in deeply shaded forest, during rain, or at dusk. Nocturnal reptiles, including geckos, were detected by walking along forest trails at night with a headlamp.

Frogs were sampled at night by conducting visual-encounter and aural surveys along streams, and in and around small ponds. Because a large proportion of New Guinean frogs have life cycles that are independent of free-standing water, extensive visual and aural searches along trails in forest away from water were also conducted.

Frog calls are an important diagnostic character that assists greatly with species identification. Whenever possible the advertisement calls of frogs were recorded with a Marantz PMD-661 Solid-state Recorder and Sennheiser ME66 microphone. Most species were photographed alive before preparation as voucher specimens. Specimens were euthanized by submersion in chlorotone (for amphibians and small reptiles), or with lethal injection of chlorotone for larger reptiles. Specimens were fixed in 10%-formalin solution, and then stored in 70% ethanol. Samples of liver tissue for DNE analyses were extracted from representative specimens of each species and stored in 95% ethanol. Voucher specimens will be deposited in the University of PNG's Natural Sciences Resource Centre, Port Moresby, and the South Australian Museum, Australia.

The survey effort at each site is presented in Table 2. In addition, interviews with local community representatives of Iniok, Nekei, Paru and Kubkain villages were conducted to glean information about their use and significance of crocodile and freshwater turtle species.

Special attention was directed at determining the status of regionally anticipated species with a 2011 IUCN Red List rating above Least Concern (see Table 3 for definition of IUCN Red List categories) or a listing as Protected in the PNG *Fauna (Protection and Control)Act 1966.*

Table 2. Survey search effort during 2009-2011 Study Area herpetofauna assessment

SURVEY SITE	TOTAL NIGHTS OF SAMPLING	EFFORT (MAN HOURS)
Nena Base Site	7	136
Nena D1 Site	3	95
Nena Limestone Site	3	75
Nena-Usage Site	1	26
Malia Site	8	109
Koki Site	5	75
HI Site	4	84
Upper Ok Binai Site	5	78.5
Frieda Bend Site	5	92.5
Ok Isai Site	6	104
Kaugumi Site	5	76
East Sepik Site	5	73.5
Iniok Site	5	71
Wario Site	4	63
Wogamush Site	7	71
Kubkain Site	5	73
Ok Binai 1 Site	5	84
Ubiame Site	1	5
TOTALS	83	1,391.5

Sites in Chapter 1 Table 4 not included above were not sampled due to safety issues associated with remote night working.

Table 3. Conservation classifications used by the *PNG Fauna (Protection and Control)*Act 1966 and IUCN.

PNG FAUNA (PROTECTION AND CONTROL) ACT	
Protected (P)	Taxa declared protected.
IUCN	
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.
Not Evaluated (NE)	Not yet been evaluated against the criteria.

Notes: IUCN descriptions are abridged. For a detailed explanation see IUCN. (2001). IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp. (http://www.iucnredlist.org/technical-documents/categories-and-criteria).

3.3 Taxonomic Issues Associated with Herpetofauna Assessment

The herpetofauna of New Guinea remains very poorly known. Many groups of frogs and reptiles are currently undergoing revision and new techniques including DNE and acoustic analyses are revealing widespread species to be complexes of closely related but distinct taxa. Particularly problematic groups include Forest Dragons of the genus *Hypsilurus* (Manthey and Denzer 2006), lizards of the genera *Emoia* and *Sphenomorphus*, and most microhylid frog genera but particularly *Hylophorbus* and *Oreophryne* which both contain numerous undescribed species distinguished predominantly by call structure. This report presents identifications in a way that indicates levels of certainty of identification.

- ‘**sp nov**.’ means a species new to science;
- ‘**sp**’ indicates that the information available precludes positive identification – this may occur if the species is represented by a juvenile lacking diagnostic characters, or lacks call data, or the available literature and specimens are insufficient to derive a confident identification. Further studies will be required to confirm the identifications of these taxa;
- ‘**cf**’ indicates that the species in question appears most similar to the taxon listed; and
- **‘?’** following a species name indicates that the identification to species level is only tentative but the species is probably a species new to science.

4 RESULTS & DISCUSSION

4.1 Overall

A total of 58 frog and 41 reptile species were documented during this survey, but no species were documented at Ubiame Site during five hours there due to inclement weather and inaccessibility of forest habitats so this site is not considered further. A selection of species is illustrated in Plates 1 and 2.

4.2 Frogs

4.2.1 Diversity and Abundance

The results of the frog surveys are presented in Tables 4 and 5. 58 species were recorded and a small subset of these species were documented during incidental observations at Frieda Base Site and Frieda Strip Site: *Rana sp. 1. cf grisea* at Frieda Base Site and *Platymantis papuensis* at Frieda Strip Site.

Highest frog diversity was encountered at Nena Base Site, where 35 species of frogs were identified and the calls of at least one other unidentified species were heard. However total frog diversity varied widely among sites with a maximum of 35 species at Nena Base Site, and a minimum of seven species at East Sepik Site, a variability similar to that reported from five sites on the southern slopes of New Guinea's Central Cordillera by Richards (2008) who recorded a maximum of 36 species and a minimum of 15. Although the variation observed among sites in Richards' (2008) study was due substantially to elevational effects, the influence of elevation on results obtained in the current study was less clear. There was a significant positive correlation between elevation and species diversity in the Study Area (R=0.88, p = 0.007; Figure 1) but species diversity was also positively correlated with search effort (r=0.67, P=0.006; Figure 2), which was itself positively correlated with elevation (higher elevations tended to have higher search effort; R=0.51, p=0.04). However search effort and elevation were not correlated when the high-elevation Nena Base Site, which had substantially higher sample effort than any other site, was removed from the calculation. In contrast the correlation between frog diversity and elevation remained significant with the removal of Nena Base Site (R=0.86, p = 0.001) indicating that the increase in frog diversity with increasing elevation is real.

Apart from elevational effects and search effort, seasonal effects during this study appeared to play an important role in determining the numbers of species documented. Indeed, observed variation in total diversity among sites in the Study Area was probably influenced substantially by changes in frog activity in response to weather conditions. For example, frog activity, as indicated by calling intensity and encounter rates, was substantially lower during the February 2010 survey than it had been in November-December 2009, and was exceptionally low during May-June 2010 in the Study Area Lowlands Zone even after sporadic heavy rains. This was not merely a 'site' effect because some species that were extremely abundant and vocally conspicuous during the 2009 wet-season surveys were present but observed only rarely during the 2010 dry season, when they were either not calling or called only sporadically. It is likely that many more species occur at the Frieda Bend Site (12 species), Kaugumi Site (11 species), East Sepik Site (7 species), Iniok Site (9 species), and Kubkain Site (8 species). For example Dahl *et al.* (2009) documented between 20 and 27 species at each of 5 sites in the northern lowlands of PNG and on this evidence it is likely that the frog fauna, at Frieda Bend Site and at each of the Study Area Lowland Zone sites exceeds 20 species. The exception to this may be East Sepik Site, where the Peat Forest probably has a smaller fauna due to the lack of permanent aquatic habitats.

Despite these variables, total frog diversity is broadly consistent with that known from other sites in the Sepik River Basin, and is dominated by the families Microhylidae (egg-brooding frogs) and Hylidae (treefrogs). For example Austin *et al.* (2008) reported 33 frog species from the vicinity of Utai village in the upper Sepik River Basin, and Dahl *et al.* (2009) reported a total of 44 species from 5 sites in the

Table 4. Frogs documented during Study Area herpetofauna survey 2009-2011

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE[3]	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Elevation (m)				**950**	**835**	**405**	**440**	**290**	**560**	**825**	**425**	**80**	**135**	**90**	**45**	**40**	**65**	**55**	**50**	**125**
Ceratobatrachidae	*Platymantis papuensis*	LC	T	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Hylidae	*Litoria angiana*	LC	UTS		+															
Hylidae	*Litoria eucnemis*	LC	ULGS, LLGS, SP	+		+		+					+							
Hylidae	*Litoria humboldtorum*	LC	P								+									
Hylidae	*Litoria hunti*	DD	P?	+	+															
Hylidae	*Litoria infrafrenata*	LC	LLGS, R, P, WsW/Fsw												+	+		+		
Hylidae	*Litoria leucova*	DD	UTS, ULGS		+				+	+										
Hylidae	*Litoria modica*	LC	UTS		+					+										
Hylidae	*Litoria purpureolata*	DD	P, WsW, Fsw												+		+	+		
Hylidae	*Litoria pygmaea*	LC	P					+	+		+	+	+							
Hylidae	*Litoria thesaurensis*	LC	P										+							
Hylidae	*Litoria* sp. nov. 1 cf *arfakiana*	NE	UTS		+	+	+		+											
Hylidae	*Litoria* sp. nov. 2 cf *gasconi*	NE	ULGS		+															
Hylidae	*Litoria* sp. nov. 3 cf *macki*	NE	UTS, LTS			+		+			+	+?								+
Hylidae	*Litoria* sp. nov. 4 cf *iris*	NE	ULGS	+																
Hylidae	*Litoria* sp. nov. 5 cf *nigropunctata*	NE	ULGS, LLGS, SP		+		+		+				+							+
Hylidae	*Litoria* sp. nov. 6 cf *bicolor*	NE	ULGS, LLGS, SP		+		+		+				+							
Hylidae	*Litoria* sp. nov. 7 (torrent grunter)	NE	UTS		+		+	+	+		+									

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE[3]	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Hylidae	*Litoria* sp. nov. 8 (small, torrent)	NE	UTS	+	+						+		+							
Hylidae	*Litoria* sp. nov. 9 (medium torrent)	NE	UTS		+				+											
Hylidae	*Nyctimystes pulcher*	LC	UTS			+			+											
Hylidae	*Nyctimystes fluviatilis*	DD	LTS			+		+												
Microhylidae	*Albericus* sp. 1	NE	T	+	+				+	+										
Microhylidae	*Austrochaperina* sp 1 cf *hooglandi*	NE	T	+	+					+										
Microhylidae	*Austrochaperina* sp. 2 (*aquilonia*?)	NE	T	+	+				+	+										
Microhylidae	*Austrochaperina* sp. 3 (aquatic)	NE	T, UTS								+									+
Microhylidae	*Austrochaperina* sp. 4 (Ok Isai)	NE	T										+							
Microhylidae	*Callulops* sp. 1	NE	T	+	+						+									
Microhylidae	*Callulops* sp. 2	NE	T														+	+		
Microhylidae	*Choerophryne proboscidea*	LC	T				+?							+			+	+		
Microhylidae	*Choerophryne* sp. nov. 1 cf *rostellifer*	NE	T		+															
Microhylidae	*Choerophryne* sp. nov. 2	NE	T	+	+															
Microhylidae	*Cophixalus balbus*	DD	T	+	+	+	+	+	+	+	+			+				+	+	
Microhylidae	*Cophixalus* sp. cf *bewaniensis*	NE	T				+													
Microhylidae	*Copiula pipiens*	DD	T	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	
Microhylidae	*Hylophorbus* sp. nov. 1 (tiny)	NE	T		+	+											+			
Microhylidae	*Hylophorbus* sp. nov. 2 (small)	NE	T		+											+?		+?		

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE[3]	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Microhylidae	*Hylophorbus* sp. nov. 3 (medium)	NE	T	+	+	+	+	+	+	+	+		+	+						
Microhylidae	*Hylophorbus* sp. nov. 4 (huge)	NE	T		+															
Microhylidae	*Liophryne schlaginhaufeni*	LC	T		+															
Microhylidae	*Mantophryne lateralis*	LC	T														+	+	+	
Microhylidae	*Oreophryne biroi*	LC	T			+	+					+	+	+	+	+	+	+	+	+
Microhylidae	*Oreophryne hypsiops*	LC	T			+	+	+	+		+	+	+	+	+	+	+	+	+	+
Microhylidae	*Oreophryne* sp. nov. 1 (fast peeper)	NE	T	+	+			+	+	+?	+									
Microhylidae	*Oreophryne* sp. nov. 2 (short rattler)	NE	T	+	+			+	+?	+?	+		+							
Microhylidae	*Oreophryne* sp. nov. 3 (rasper)	NE	T	+	+					+										
Microhylidae	*Oreophryne* sp. nov. 4 (chirper)	NE	T			+		+				+	+							+
Microhylidae	*Oreophryne* sp. cf *hypsiops*	NE	T												+					
Microhylidae	*Sphenophryne* sp. cf *cornuta*	NE	T	+	+	+	+	+	+	+	+		+	+						+
Microhylidae	*Xenorhina arboricola*	DD	T	+	+		+				+?									
Microhylidae	*Xenorhina oxycephala*	LC	T	+	+	+	+	+		+	+	+	+	+	+		+	+	+	+
Microhylidae	*Xenorhina* sp. 1 (slow call)	NE	T	+?	+								+				+			
Microhylidae	*Xenorhina* sp. 2 (soft fast call)	NE	T				+					+								
Ranidae	*Limnonectes grunniens*	LC	LLGS, P, WsW/ Fsw					+				+	+	+		+		+		+
Ranidae	*Rana arfaki/jimiensis*	LC	UTS, ULGS	+	+	+	+	+	+		+	+								+
Ranidae	*Rana papua*	LC	LLGS, P, WsW/ Fsw	+	+	+	+	+	+		+	+	+	+		+	+	+	+	+
Ranidae	*Rana* sp. nov. cf *daemeli*	NE	WsW/Fsw													+				

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE[3]	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Ranidae	*Rana* sp. 1cf *grisea*	NE	UTS, LTS	+	+	+	+	+	+	+	+		+				+			+
TOTAL	**Grand Total = 58**			**23**	**35**	**18**	**19**	**19**	**21**	**15**	**20**	**12**	**20**	**11**	**7**	**9**	**13**	**14**	**8**	**13**

Notes: 1'sp. nov.' designates species new to science; 'sp.' indicates that further studies are required to determine taxonomic status. 'cf ' indicates that the species is probably new to science but appears most similar to the listed form. A '?' indicates an unconfirmed observation usually without a voucher specimen.

IUCN Status: LC = Least Concern; DD = Data Deficient; VU = Vulnerable; NE = Not assessed.

Aquatic habitat type is the set of environments that the species was most frequently associated with, and presumed to be their primary breeding habitat. See Table 2 for definitions of stream types and Table 7 for ecological requirements of frogs in UTS habitats.: R = River (>5 m wide); P = Pool; WsW/Fsw = swampy forest; T = Terrestrial (no aquatic larva); F = Forest (away from water). No frogs are protected under PNG law.

north-coast lowlands. The higher total diversity documented during the current surveys reflects the greater range of elevations accessed during this study. However the proportion of frogs in the family Microhylidae is remarkably consistent among these three studies, representing 53% of the fauna in the Study Area, 58% at Utai and 52% among the 5 sites documented by Dahl *et al.* (2009) across the northern lowlands of PNG. The proportion of treefrogs in the family Hylidae is less similar among the three studies, representing 36%, 18% and, 30% of the faunas respectively. The families Ranidae (9%) and Ceratobatrachidae (2%) are minor contributors to the fauna of the Study Area, and are generally represented by common species with broad distributions beyond the Study Area. One exception is a potentially new species of *Rana* known only from a small swamp behind Iniok Site. It is probably common and widespread, and may have been misidentified as *Rana daemeli* by previous workers (Dahl *et al.* 2009).

Table 5. Numbers of frog and reptile species documented at each site.

SURVEY SITE	FROGS	REPTILES	TOTAL SPECIES/SITE
Nena Base Site	35	14	49
Nena D1 Site	18	9	27
Nena Usage Site	19	7	26
Nena Limestone Site	23	6	29
Malia Site	19	15	34
Koki Site	21	7	28
HI Site	15	3	18
Upper Ok Binai Site	20	12	32
Frieda Bend Site	12	12	24
Ok Isai Site	20	13	33
Kaugumi Site	11	13	24
East Sepik Site	7	10	17
Iniok Site	9	11	20
Wario Site	13	12	25
Wogamush Site	14	10	24
Kubkain Site	8	13	21
Ok Binai 1 Site	13	7	20

4.2.2 Frogs of the Study Area Hill and Montane Zones

The high proportion of treefrogs (Hylidae) in the Study Area relative to the other studies reflects the presence of a greater diversity of aquatic habitats in the Study Area Hill Zone, particularly fast-flowing streams, than is available in the Study Area Lowland Zone. This is reflected in the low species-similarity between treefrogs from Utai and those documented in the Study Area Hill Zone; the Utai treefrog fauna is dominated by species that breed in swamps or pools in the forest (Austin *et al.* 2008), while 10 of 19 treefrog species (53%) documented in the Study Area Hill Zone have specialised breeding habits that require clear, flowing rocky streams (UTS) for reproduction. Five of these (50%) are new species and only one of them may occur in the Study Area Lowland Zone, at Frieda Bend Site. A further two undescribed treefrogs, *Litoria* cf *nigropunctata* and *L*. cf *gasconi* (Table 4) are known only from small, slow-flowing but clear and rocky streams in the Study Area Hill Zone, and the poorly known (IUCN Data Deficient) *Litoria leucova* appears to be endemic to the Study Area Hill Zone and adjacent headwaters of the Sepik River where it is restricted to clear rocky streams with slow (ULGS) or fast (UTS) water flow regimes. Large swamps and permanent forest pools were not encountered in the Study Area Hill Zone during this survey, except at the lower margins of the Ok Isai Site, and the significance of the small forest pools at Frieda Bend Site for frog reproduction was difficult to assess due to the low frog activity at the time of the survey. However small, isolated forest pools are likely to be significant habitats for at least some treefrogs in the Study Area Hill Zone. For example the unusual spike-nosed frog *Litoria humboldtorum* was found calling from vegetation over a small (~ 3 m diametre) temporary pond formed by root upheaval during a natural treefall at Upper Ok Binai Site.

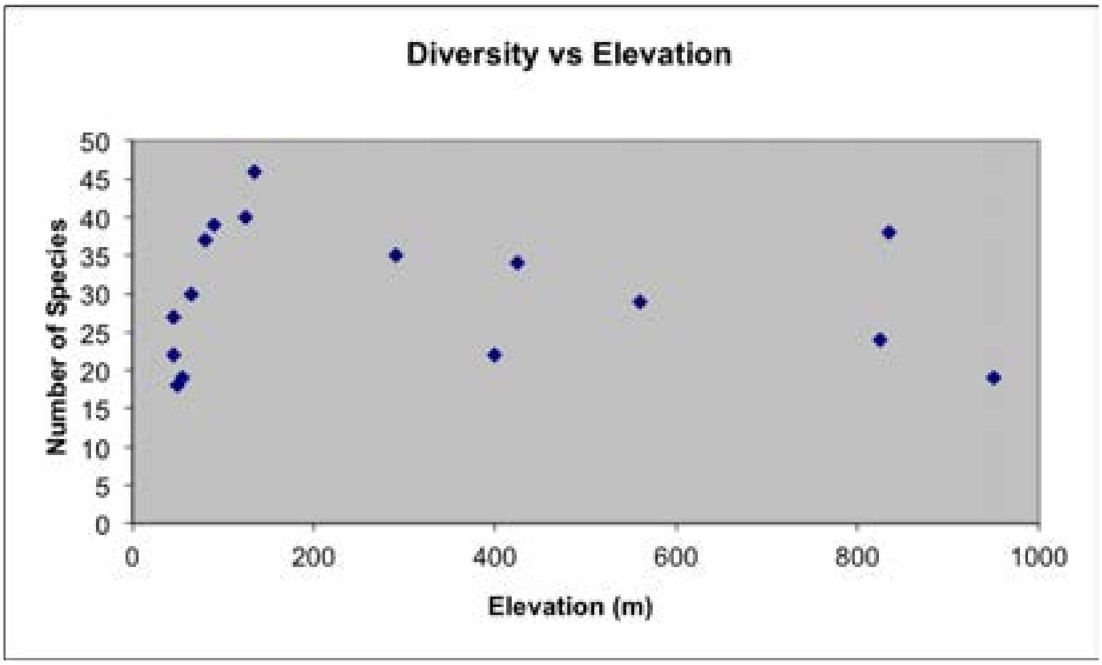

Figure 1. Frog diversity vs elevation in the Study Area

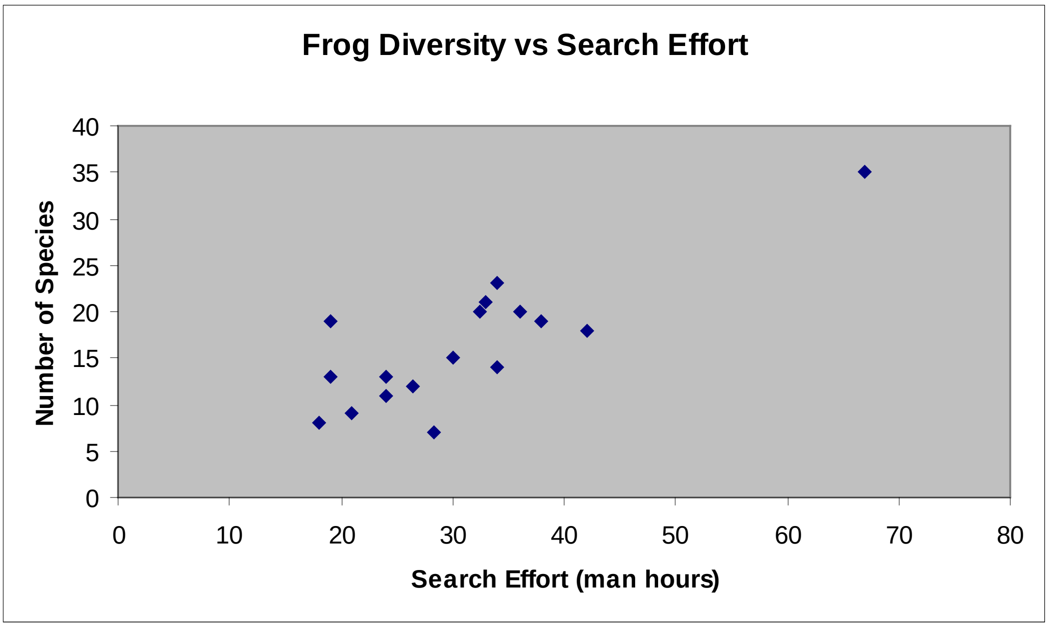

Figure 2. Frog diversity vs search effort in the Study Area

4.2.3 Frogs of the Study Area Lowland Zone

In contrast to the Study Area Hill Zone the frog fauna of the Study Area Lowland Zone was unremarkable. It was dominated by common, widespread species (Table 4) with the possible exceptions of a small microhylid frog of the genus *Oreophryne* that was found only in the Peat Forest at East Sepik Site, the poorly known but widespread treefrog *Litoria purpureolata*, and a potentially undescribed *Callulops* found at Wario and Wogamush Sites. Unfortunately the low levels of frog activity precluded collection of sufficient data to adequately determine the taxonomic status of the *Oreophryne* species at East Sepik Site. It is possible that this species is undescribed and endemic to the Peat Forest habitat but further data on its advertisement call and morphological variation are required. Three other species found in the Study Area Lowland Zone but not in the Study Area Hill Zone were *Litoria infrafrenata*, and *Mantophryne lateralis*, both exceptionally common and widespread species occurring throughout the lowlands and foothills of New Guinea (Menzies 2006), and a ranid frog that is morphologically similar to the widespread *Rana daemeli* but appears to have a different advertisement call. It was found only at Iniok Site but may occur more widely. Stream-dwelling species were entirely absent. Early wet-season surveys, particularly in the Peat Forest at East Sepik Site, may more adequately assess the diversity of frog assemblages in the Study Area Lowland Zone,

4.2.4 Do the Zones have Different Frog Assemblages?

As discussed above, the Study Area Hill Zone provides a range of lotic (flowing-water) environments for a diverse assemblage of poorly known and undescribed treefrog species. These are species that rely on cool, clear water flowing over rocky substrates (UTS, ULGS) for their survival and successful reproduction. The absence of these habitats in the Study Area Lowland Zone has precluded colonisation by these habitat specialists. That the Hill Zone provides a significant environment for this group of frogs is demonstrated by the fact that treefrogs of the family Hylidae constitute 36.5% of frogs in the Hill Zone compared to just 15% in the Study Area Lowland Zone. In contrast, microhylid frogs, which have a reproductive cycle independent of water (see below) represent a similar 53.8 and 61.5% of the frog faunas in the Study Area Hill Zone and the Study Area Lowland Zone respectively. Ranid frogs which breed in ponds and swamps represented a higher proportion of the frog fauna in the Study Area Lowland Zone than in the Study Area Hill Zone (19% vs 8%).

Only 20 species were shared between the Study Area Hill Zone and the Study Area Lowland Zone, a figure representing just 38% of the frogs of the Study Area Hill Zone. In contrast 20 of 26 species (76.9%) of the frogs found in the Study Area Lowland Zone were also found in the Study Area Hill Zone. These numbers demonstrate that the Study Area Hill Zone harbours a large assemblage of species that is restricted to this zone while the frog fauna of the Study Area Lowland Zone represents largely (though not exclusively) a subset of the much more diverse Study Area Hill Zone fauna. The importance of the Study Area Hill Zone as a habitat for stream-dwelling frogs is reinforced by the observation that six of the seven new species of hylid frogs restricted to UTS and ULGS habitats were found only in the Study Area Hill Zone. Indeed 17 of 19 treefrogs (89%) recorded from the Study Area Hill Zone during this study were not found in the Study Area Lowland Zone.

4.2.5 Comments on Frogs of the Family Microhylidae

Frogs of the family Microhylidae have a reproductive strategy that is independent of free-standing water. They deposit large, yolk-filled eggs in moist terrestrial, arboreal or subterranean nests where males guard them until they hatch directly into small frogs, avoiding an aquatic tadpole stage. This group dominates the frog fauna at most sites in New Guinea, particularly where free-standing or flowing water is absent, and their high diversity (>50% of the fauna) in the Study Area reflects the constantly wet environment of the region, where their terrestrial embryos do not face desiccation. The distribution of these species within the Study Area is independent of the distribution of waterbodies, and retention of forest habitats will be required to maintain this diversity. All 10 of the new microhylid species discovered during this study were found in the Study Area Hill Zone and six of these (60%) were not found in the Study Area Lowland Zone. This reinforces the significance of the forests of the Study Area Hill Zone for a unique and poorly known frog fauna. One species of *Callulops* from Wario and Wogamush may also be confirmed as new to science following further studies. It was not detected at any site in the Study Area Hill Zone.

The Microhylidae remains taxonomically the least well understood group of New Guinean frogs, and at least 10 (32%) of the species documented during the current surveys appear to be undescribed.

4.3 Reptiles

4.3.1 Diversity and Abundance

The results of the reptile surveys are presented in Tables 6 and summarised in Table 5. Forty one species were recorded and a small subset of these species were documented during incidental observations at Frieda Base Site and Frieda Strip Site: the gecko *Hemidactylus frenatus* and the skinks *Lamprolepis smaragdina, Emoia caeruleocauda , E. kordoana and E. obscura* were recorded at both and *Emoia pallidiceps* at Frieda Base Site.

The reptile fauna documented during these surveys is relatively depauperate and diversity ranged from 6-15 species at all sites except HI Site where only 3 species were documented.

The low diversity at HI Site was not surprising because the weather was cold and raining during most of the survey period, conditions that greatly reduce reptile activity. There was no correlation between reptile diversity and survey effort, or between reptile diversity and elevation (Rank Correlations, $p > 0.5$). Overall the reptile fauna is very similar to and largely a subset of, the fauna reported from the vicinity of Utai Village at the base of the Bewani Mountains by Austin *et al.* (2008). Numerically the fauna was dominated by the widespread and abundant skinks *Emoia obscura* and *E. pallidiceps*, the agamid (dragon) lizard *Hypsilurus modestus* (although there is some indication that in the Study Area this species may comprise two morphologically cryptic species), the gecko *Cyrtodactylus sermowaiensis* and the Brown Tree Snake *Boiga irregularis*. With the exceptions of an undescribed gecko of the genus *Lepidodactylus*, and a possibly new species in each of the gecko genus *Cyrtodactylus*, and the skink genus *Emoia*, the reptile fauna was dominated by common, widespread species known from other sites outside the Study Area.

Although snake diversity was generally rather low, we encountered three notable species, the Green Tree Python (*Morelia viridis*) at Malia and Wario Sites, the Amethistine Python (*Morelia amethistina*) at Malia Site, Ok Isai Site and East Sepik Site, and a D'Albertis Python (*Leiopython albertisii*) at Kaugumi Site. Surprisingly, no dangerously venomous snakes were documented during these surveys, although Death Adders (*Acanthophis* sp) and Small-eyed Snakes (*Micropechis ikaheka*) are highly likely to occur in the lower elevations of the Study Area Hill Zone and throughout the Study Area Lowland Zone.

Two freshwater turtles, *Elseya novaeguinea*, were found in a small tributary of the Frieda River at Frieda Bend Site, and both freshwater and saltwater crocodiles were documented in the vicinity of Iniok. These species are commonly harvested by communities living along lowland waterways in northern New Guinea.

The most surprising result from the reptile surveys was that, although species diversity in the Study Area Lowland Zone sites was moderately high compared to most Study Area Hill Zone sites (Tables 6 and 5), 23 of 33 species (69%) of reptiles documented in the Study Area Lowland Zone were also present in the Study Area Hill Zone. The 23 shared species represented a similar 74% of reptiles found in the Study Area Hill Zone that were found also in the Study Area Lowland Zone. Furthermore, unlike the frogs for which the Study Area Hill Zone provides specific habitats for an assemblage of species so far not known from elsewhere on the Sepik Plain, most of the reptile species documented in the Study Area Hill Zone are known to occur not only in the Study Area Lowland Zone but also elsewhere in the lowland forests of New Guinea (e.g. Austin 2006, Austin *et al.* 2008, Kraus and Allison 2006).

Table 6. Reptiles documented during Study Area herpetofauna assessment 2009-2011

FAMILY	SCIENTIFIC NAME	IUCN STATUS	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Elevation (m)			950	835	405	440	290	560	825	425	80	135	90	45	40	65	55	50	125
Family	Species																		
Agamidae	*Hypsilurus modestus*	NE	+	+	+	+	+	+		+	+		+			+		+	+
Agamidae	*Hypsilurus* sp. 1 (semi-aquatic)	NE								+									
Agamidae	*Hypsilurus* sp. 2 (cf *dilophus*)	NE			+											+	+	+	
Gekkonidae	*Cyrtodactylus novaeguineae*	NE								+			+				+		
Gekkonidae	*Cyrtodactylus sermowaiensis*	NE		+	+	+	+	+			+	+	+	+		+	+	+	+
Gekkonidae	*Cyrtodactylus* sp. 1 (may be *serratus*)	NE	+																
Gekkonidae	*Gehyra* sp.	NE															+		
Gekkonidae	*Gekko vittatus*	NE											+						
Gekkonidae	*Hemidactylus frenatus*	lc		+							+				+				+
Gekkonidae	*Lepidodactylus* sp. nov.	NE																+	
Gekkonidae	*Nactus cf. pelagicus*	NE								+	+	+		+			+		
Scincidae	*Emoia caeruleocauda*	NE					+			+	+	+	+	+	+	+	+	+	+
Scincidae	*Emoia kordoana*	NE		+	+	+	+								+	+	+		+
Scincidae	*Emoia longicauda*	NE									+	+	+			+	+	+	
Scincidae	*Emoia obscura*	NE	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+
Scincidae	*Emoia pallidiceps*	NE	+	+	+	+	+					+	+		+			+	

FAMILY	SCIENTIFIC NAME	IUCN STATUS	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Scincidae	*Emoia* sp. 1	NE										+		+	+?			+	
Scincidae	*Eugongylus rufescens*	NE					+			+									
Scincidae	*Lamprolepis smaragdina*	NE		+														+	
Scincidae	*Lipinia noctua*	NE																+	
Scincidae	*Sphenomorphus simus*	NE	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
Scincidae	*Sphenomorphus solomonis*	NE		+															
Scincidae	*Sphenomorphus* sp. (tiny)	NE		+				+?								+			
Scincidae	*Sphenomorphus jobiensis*-group	NE												+		+			
Scincidae	*Tribolonotus gracilis*	NE					+	+				+							
Varanidae	*Varanus* probably *indicus*	LC		+															
Boidae	*Candoia aspera*	NE								+		+							
Boidae	*Candoia carinata*	NE															+		
Elapidae	*Aspidomorphus lineaticollis*	NE		+												+			
Colubridae	*Boiga irregularis*	NE	+	+	+	+	+	+	+	+	+		+		+			+	
Colubridae	*Dendrelaphis* sp.	NE		+								+	+	+	+				
Colubridae	*Stegonotus cucullatus*	NE		+			+				+								
Colubridae	*Stegonotus* cf *diehli*	NE								+		+	+	+					
Colubridae	*Tropidonophis doriae*	NE					+	+		+									
Colubridae	*Tropidonophis* sp. (prob *multiscutellatus*)	NE									+								

FAMILY	SCIENTIFIC NAME	IUCN STATUS	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Pythonidae	*Leiopython albertisii*	NE											+						
Pythonidae	*Morelia amethistina*	NE					+					+		+					
Pythonidae	*Morelia viridis*	LC					+									+			
Chelidae	*Elseya novaeguineae*	LC									+								
Crocodylidae	*Crocodylus novaeguineae*	LC													+				
Crocodylidae	*Crocodylus porosus*	LC													+				
TOTALS	Grand Total = 41		6	14	9	7	15	7	3	12	12	13	13	10	11	12	10	13	7

Notes: UCN Status: LC = Least Concern; DD = Data Deficient; VU = Vulnerable; NE = Not assessed.

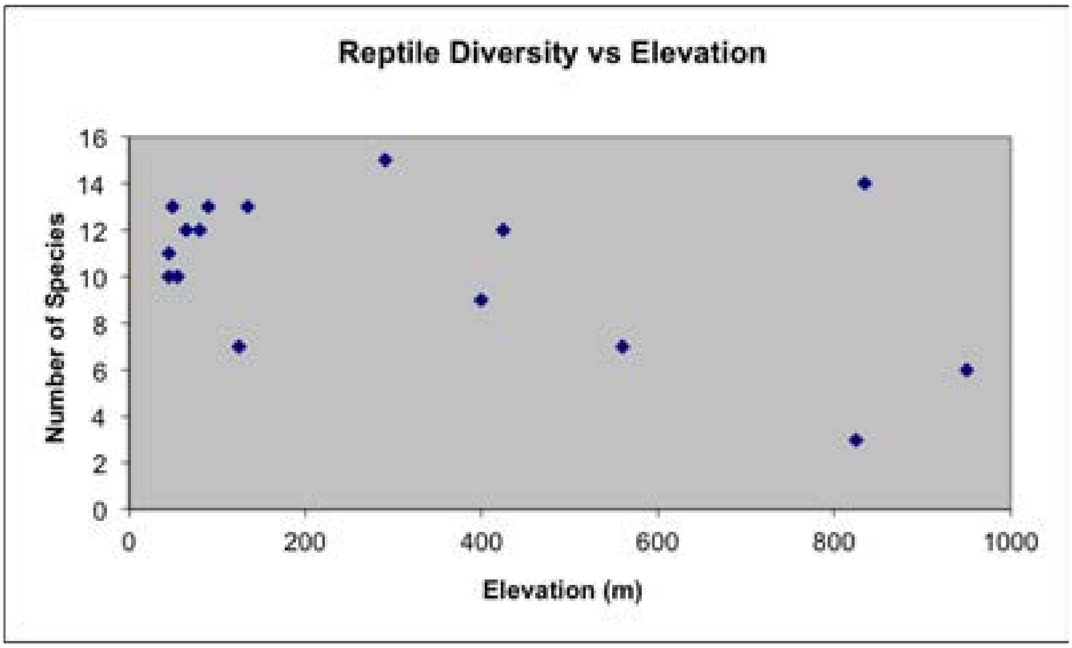

Figure 3. Reptile diversity vs elevation in the Study Area

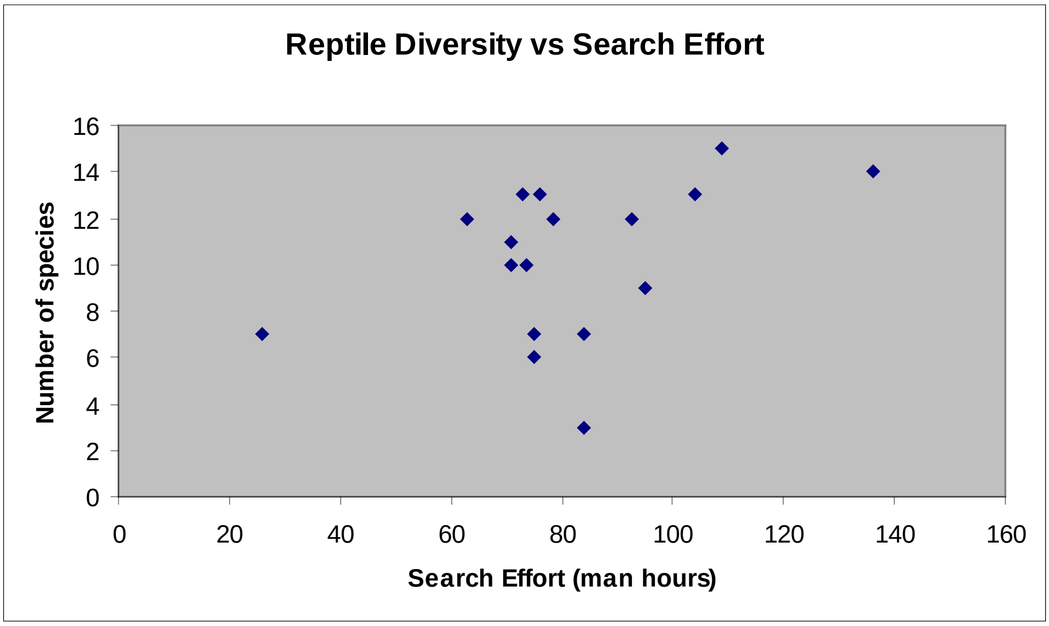

Figure 4. Reptile diversity vs search effort in the Study Area

It is clear that for reptiles, unlike frogs, there is little distinction between the faunas of the Study Area Hill Zone and those of the Study Area Lowland Zone, and that most species occurring in the Study Area are common, widespread species with broad habitat tolerances.

4.4 Species of Conservation Significance

No frog species is classified as Critically Endangered, Endangered, Vulnerable or Near Threatened by IUCN. Six of the described frog species documented during this survey are listed as 'Data Deficient' by the IUCN (Table 7) due to their small known geographic ranges and poorly understood population status. (www.iucnredlist.org. Downloaded on 04 October 2011).

Only three species of the reptiles that were documented during this study have been assessed by the IUCN and all are listed as 'Least Concern'. None of the species documented during this survey are protected under the PNG *Fauna (Protection and Control)Act 1966*.

Unlike mammals and birds (Chapters 3 and 4) whose ecologies and ranges are much better known, it is not possible to use published distributions to predict the possible occurrence of other listed herpetofauna in the Study Area. The only exception may be Boelen's Python (*Morelia boeleni*) (Protected under the PNG *Fauna (Protection and Control)Act 1966*). It is well known to the author and has a distribution restricted predominantly to montane New Guinea (O'Shea 1996) at elevations as low as 1,000 m. It is known to occur at higher elevations on Mt Stolle to the south of the Study Area and so may occur in the upper portions of the Study Area.

Table 7. Herpetofauna species documented in the Study Area that are listed by IUCN as Data Deficient

SPECIES	IUCN CATEGORY
Litoria hunti	Data Deficient ver 3.1
Litoria leucova	Data Deficient ver 3.1
Litoria purpureolata	Data Deficient ver 3.1
Nyctimystes fluviatilis	Data Deficient ver 3.1
Copiula pipiens	Data Deficient ver 3.1
Xenorhina arboricola	Data Deficient ver 3.1

Notes: IUCN data taken from: IUCN Red List of Threatened Species. Version 2010.2. <www.iucnredlist.org>. Downloaded on 04 October 2011.

4.5 Species New to Science

Up to 25 species of frogs (43% of total) and perhaps three reptiles documented in the Study Area appear to be new to science or undescribed. At least 16 of these (64%) are currently known only from the Study Area. They are listed in Table 8. An unusually high proportion of these new species are from the family Hylidae (Treefrogs), with nine new. Five of these nine undescribed treefrogs (56%) are habitat specialists requiring clear, torrential rocky streams (UTS) for reproduction, and a small undescribed species of the microhylid genus *Austrochaperina* that is known only from streams at Upper Ok Binai and Ok Binai 1 sites also appears to UTS habitats.

The discovery of new species at any site in PNG is not unexpected (e.g. Richards 2002c) but the large number of new species discovered in the Study Area that are unknown from other localities is somewhat unusual. However this reflects the fact that few studies have been conducted anywhere on the northern slopes of the Central Cordillera in north-central New Guinea, and it is extremely likely, given the extensive areas of apparently suitable habitat available that most of the species reported here have broad distributions in the foothills of the Central Cordillera. The exception is *Litoria* sp. nov. 4 cf *iris* which may have a limited distribution on limestone ridge habitats (see below).

A riparian frog, *Austrochaperina* species, is known only from Upper Ok Binai and Ok Binai 1 Sites; one

Table 8. Species potentially new to science or undescribed.

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE[3]	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Elevation (m)				**950**	**835**	**405**	**440**	**290**	**560**	**825**	**425**	**80**	**135**	**90**	**45**	**40**	**65**	**55**	**50**	**125**
Hylidae	*Litoria* sp. nov. 1 cf *arfakiana*	NE	UTS		+	+	+		+											
Hylidae	*Litoria* sp. nov. 2 cf *gasconi*	NE	ULGS		+															
Hylidae	*Litoria* sp. nov. 3 cf *macki*	NE	UTS, LTS			+		+			+	+?								+
Hylidae	*Litoria* sp. nov. 4 cf *iris*	NE	ULGS	+																
Hylidae	*Litoria* sp. nov. 5 cf *nigropunctata*	NE	ULGS, LLGS, SP		+		+		+				+							+
Hylidae	*Litoria* sp. nov. 6 cf *bicolor*	NE	ULGS, LLGS, SP		+		+		+				+							
Hylidae	*Litoria* sp. nov. 7 (torrent grunter)	NE	UTS		+		+	+	+		+									
Hylidae	*Litoria* sp. nov. 8 (small, torrent)	NE	UTS	+	+						+		+							
Hylidae	*Litoria* sp. nov. 9 (medium torrent)	NE	UTS		+				+											
Microhylidae	*Albericus* sp. 1	NE	T	+	+				+	+										
Microhylidae	*Austrochaperina* sp 1 cf *hooglandi*	NE	T	+	+					+										
Microhylidae	*Austrochaperina* sp. 2 (*aquilonia*?)	NE	T	+	+				+	+										
Microhylidae	*Austrochaperina* sp. 3 (aquatic)	NE	T, UTS								+									+
Microhylidae	*Austrochaperina* sp. 4 (Ok Isai)	NE	T										+							
Microhylidae	*Choerophryne* sp. nov. 1 cf *rostellifer*	NE	T		+															
Microhylidae	*Choerophryne* sp. nov. 2	NE	T	+	+															

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE[3]	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1
Microhylidae	*Hylophorbus* sp. nov. 1 (tiny)	NE	T		+	+											+			
Microhylidae	*Hylophorbus* sp. nov. 2 (small)	NE	T		+											+?		+?		
Microhylidae	*Hylophorbus* sp. nov. 3 (medium)	NE	T	+	+	+	+	+	+	+	+		+	+						
Microhylidae	*Hylophorbus* sp. nov. 4 (huge)	NE	T		+															
Microhylidae	*Oreophryne* sp. nov. 1 (fast peeper)	NE	T	+	+			+	+	+?	+									
Microhylidae	*Oreophryne* sp. nov. 2 (short rattler)	NE	T	+	+			+	+?	+?	+		+							
Microhylidae	*Oreophryne* sp. nov. 3 (rasper)	NE	T	+	+					+										
Microhylidae	*Oreophryne* sp. nov. 4 (chirper)	NE	T			+		+				+	+							+
Ranidae	*Rana* sp. nov. cf *daemeli*	NE	WsW/Fsw													+				
Agamidae	*Hypsilurus* sp. 1 (semi-aquatic)	NE								+										
Gekkonidae	*Cyrtodactylus* sp. 1 (may be *serratus*)	NE		+																
Scincidae	*Emoia* sp. 1	NE										+		+	+			+		

species of *Oreophryne* was found only at East Sepik Site, a *Callulops* was found only at Wario and Wogamush Sites and a *Rana* was only found at Iniok Site. Among the reptiles one species of large brown skink in the taxonomically difficult genus *Emoia* that may turn out to be new to science was found at Ok Isai Site, at East Sepik Site, Iniok Site and Kubkain Site in the Study Area Lowland Zone. It probably has a broad distribution in the Study Area Lowland Zone.

4.5.1 Frogs

Litoria sp. nov. 1 cf *arfakiana*

A moderately large, stream-dwelling treefrog (males ~ 45 mm) that was found at four sites in the Study Area Hill Zone. It was found only in UTS habitats (Table 1). This long-legged species has highly variable colouration but consistently has a sharp snout and a small spike on each heel. It is related to the widespread species *Litoria arfakiana* but has a different call.

Litoria sp. nov. 2 cf *gasconi*

A beautiful, bright green treefrog known only from a single male specimen collected at Nena Base Site where it was calling at night from a tree overhanging a small, clear stream (ULGS) below camp. It appears to be most closely related to but is distinct from *Litoria gasconi*, a species recently described from the Foja Mountains in Indonesian New Guinea (Richards et al 2009).

Litoria sp. nov. 3 cf *macki*

A moderately small, UTS-dwelling treefrog (males ~ 38 mm) that was found at 3-4 sites in the Study Area Hill Zone. Several juveniles resembling this species were found near a rocky stream (LTS) at Frieda Bend Site. It has a mottled pattern on the back and the call is a single rasping note, unlike the bell-like calls of *L. macki*. It was most commonly seen and heard calling from high in trees adjacent to streams.

Litoria sp. nov. 4 cf *iris*

It is a beautiful treefrog (males to 36 mm) with bright colours on the hidden surfaces of the legs that was found only along a single seepage at Nena Limestone Site. Its absence from all other sites in the Study Area was surprising and there is a possibility that it is associated closely with limestone habitats with small seepages. Males of this attractive frog were calling from trees overhanging shallow isolated pools in a gully in steep and rugged terrain. It was not observed at a fast-flowing stream nearby over several nights, and was not documented at apparently suitable seepages at other sites. The limestone ridge at Nena Limestone Site may be a habitat critical for the survival of this species.

Litoria sp. nov. 5 cf *nigropunctata*

A small (males ~ 32 mm) brown treefrog found only along narrow, rocky streams and clear seepages (ULGS, LLGS, SP) in the Study Area Hill Zone. It is similar to *Litoria* sp. nov. 4 (above) but is more slender, lacks the bright colours on the legs, and has a different advertisement call.

Litoria sp. nov. 6 cf *bicolor*

A small (males ~ 30 mm) bright green treefrog that was found only at several sites with slow-flowing water in the Study Area Hill Zone. Males called from low perches on vegetation in shallow seepages (SP), with slow but distinct water flow.

Litoria sp. nov. 7 (torrent grunter)

This small (males to ~ 30 mm) brown treefrog occurred in large numbers along UTS habitats in the Study Area Hill Zone where males called from foliage adjacent to and overhanging the streams.

Litoria sp. nov. 8 (small, torrent)

The smallest treefrog documented during the survey, this tiny frog (males < 25 mm) was found along UTS habitats in the Study Area Hill Zone. It was not common, and males were heard calling infrequently, including from large boulders on a steep waterfall below Nena Base Site.

Litoria sp. nov. 9 (medium torrent)

A moderately small, stream-dwelling treefrog (males ~ 34 mm) that was found only in UTS habitats at Nena Base Site and Koki Site in the Study Area Hill Zone. This species has a mottled pattern on the back and the call consists of a buzz followed by a sharp click.

Albericus sp.

This small nondescript terrestrial frog was found at four sites in the Hill Zone.

Austrochaperina sp.

In the Study Area *Austrochaperina* consists of a group of small (males < 35 mm), plump frogs with few distinguishing features. Though secretive and rarely seen, most species have loud and conspicuous calls consisting of a very long sequence of rapidly repeated, harsh yaps that may last for more than one minute. Two of the potentially four new species were closely associated with small streams or seepages (sp 3 and sp 4; Table 4)

Choerophryne spp

A group of tiny, short-legged frogs (males < 25 mm) that all have an elongated and prominent nose. Males call from between a few centimetres to two metres above the ground predominantly at dusk in the forest understorey, with a soft scratching call. Two species documented in the Study Area Hill Zone appear to be new to science.

Hylophorbus spp

This genus is one of the taxonomically most difficult groups of frogs in New Guinea. It includes a large number of ground-dwelling rainforest species that are almost impossible to distinguish morphologically, and careful analysis of calls and genetic data will be required to resolve the status of populations in the Study Area. It appears likely that all four of the species documented during this survey are new to science.

Oreophryne spp

Like *Hylophorbus,* this genus is a taxonomically difficult group. All species of this predominantly arboreal group are small and relatively nondescript so call structure and genetic data are important characters for distinguishing among species. However preliminary studies of the Study Area material indicate that at least four species are undescribed. They all live in and call from forest understorey vegetation.

4.5.2 Reptiles

Hypsilurus spp

Three species in this genus of forest-dwelling dragon-lizards were documented during this biodiversity survey. These species are most easily distinguished from all other lizards in the area by having a crest on the neck. The most common species, *H. modestus*, is a small green lizard with a low crest that was commonly found sleeping on branches and leaves in the forest throughout the Study Area at night. Although it is a widespread species, subtle differences among specimens found in the Study Area indicate that an undescribed, 'cryptic' species may occur in the area. However genetic studies are required to confirm this. The species is similar to *H. dilophus* but its status also requires further studies, including genetic comparisons. The third species, a long-tailed stream-dwelling lizard found only at Nena D1 Site remains unidentified and may be undescribed. Further studies on its status are required.

Cyrtodactylus sp.

One species of large, ring-tailed gecko documented at Nena Limestone Site is similar to the recently described *Cyrtodactylus serratus*. It was high in a forest tree that was cut down to make the camp at this site. Studies are currently under way to confirm its taxonomic status but it appears that this large and spectacular species may be new to science.

Emoia **sp.**

The lizard genus *Emoia* contains many species in New Guinea, and is one of the most taxonomically difficult genera of reptiles in the country. Most species are small, brown, and forage for food in sunny patches on the forest floor but several species are large or extremely colourful, and forage up and down tree-trunks and into the trees. Most species in the Study Area are common, widespread forms but one large (70 mm body length) brown species that was found at Ok Isai Site, Iniok Site and Kubkain Site appears to be undescribed. Further taxonomic studies on this species will be undertaken to confirm its status.

4.6 Previously Undescribed Species

Rana sp. nov. cf. *daemeli*

A potentially new species of *Rana* was found in a small swamp behind Iniok Site. It is probably common and widespread, and may be already have been collected but misidentified as *Rana daemeli* by previous workers (Dahl *et al.* 2009).

Lepidodactylus sp. nov.

A single small, slender gecko of the genus *Lepidodactylus* was collected in forest regrowth on the ridge at Kubkain Site and appears to represent an undescribed species. Although currently un-named, it was previously known from a single specimen collected at the base of the Foja Mountains in Papua Province, Indonesia by S. Richards.

4.7 Species New to PNG

Two poorly known species, *Nyctimystes fluviatilis* (IUCN: DD) and *Litoria humboldtorum*, that were previously known only from sites far to the west in Indonesian New Guinea were found during the current surveys. *Nyctimystes fluviatilis* is now known from three sites in Indonesia's Papua Province (Richards 2000), from one site in the lower foothills of the Study Area (Richards, this study). Kraus (2010) reported *N. fluviatilis* from the Torricelli Mountains in Sandaun Province. The known sites for this species now span a distance of over 400 km of lowland and foothill rainforest habitats with small, clear streams known to be suitable for this species. The documentation of *N. fluviatilis* in PNG is not surprising and discovery of the Study Area and Torricelli populations suggests that its conservation status is likely to be secure.

The documentation of *Litoria humboldtorum* in the Study Area is more surprising because it was previously known only from Yapen Island and the foothills of the Foya Mountains in Indonesia's Papua Province. This species is listed as Least Concern by IUCN because the two previously known localities are widely separated, with large areas of suitable intervening habitat. The documentation of this species in the Study Area extends its known distribution by about 300 km.

4.8 Restricted-distribution Species

Litoria hunti (IUCN: DD) is a recently described large, green treefrog (Richards *et al.* 2006) previously known with certainly only from one other site in the Sepik River Basin. It was common at Nena Limestone Site and Nena Base Site during these surveys and almost certainly occurs widely across the Study Area Hill Zone, the Study Area Lowland Zone, and into neighbouring Indonesian Papua Province (Richards *et al.* 2006).

Litoria leucova (IUCN: DD) is a small green treefrog described from Busilmin near the May River and subsequently re-discovered at an elevation of 1600 m on Mt Stolle to the south of the Study Area (Johnston and Richards 1994). The Study Area Hill Zone population reported here is only the third known location for this species, which is possibly endemic to the upper Sepik region. It occurs along small, clear streams and larger, more open rocky streams (UTS).

Litoria purpureolata (IUCN: DD) is a moderately large, green treefrog that was described as recently as 2007 (Oliver *et al.* 2007) from the Mamberamo basin of Papua Province, Indonesia. The species was subsequently recorded from several sites in the Sepik River Basin by Kraus (2010) and during these surveys was found at East Sepik Site, Wogamush Site and Kubkain Site. These new records extend the known distribution across nearly 500 km of suitable habitat.

Cophixalus balbus (IUCN: DD) is a small brown microhylid frog that was originally described from northern Papua Province, Indonesia. It has subsequently been documented from several localities in the Sepik River Basin (Dahl *et al.* 2009) and probably has a wide distribution across the northern lowlands of western PNG.

Xenorhina arboricola (IUCN: DD), previously known only from the Bewani and Hunstein Ranges, was recently documented from the Foya Mountains in Papua Province, Indonesia (Richards, unpubl). Its documentation in the Study Area is the first record of this species from the slopes of the Central Cordillera and the species likely occurs between these sites.

4.9 Species Significant to Local Communities

With the exception of crocodiles, herpetofauna species generally have limited cultural or dietary significance for local communities. Our local assistants reported that the Giant River Frog (*Rana arfaki/ jimiensis*) and reptiles including the semi-aquatic Forest Dragon (*Hypsilurus* sp.), monitor lizards (*Varanus* spp), large pythons (*Leiopython albertisii*, *Morelia amethistina* and *M. viridis*), and the New Guinea freshwater turtles *Elseya novaeguinea* and *Pelochelys signifera*, are consumed when encountered but are not specifically targeted by hunting. Consumption of frogs is unlikely to have a major impact on any populations in the Study Area due to their high abundance, and the local people's decreasing interest in eating frogs. However large reptiles including monitor lizards, crocodiles, freshwater turtles and pythons are still consumed when encountered and are likely to be impacted by an increasing local population.

4.9.1 Crocodiles and Turtles

Available information about the distribution, status and ecology of the two freshwater turtles (*Elseya novaeguineae* and *Pelochelys signifera*) and the two crocodiles (*Crocodylus novaeguineaea* and *C. porosus*) in the Study Area are presented briefly by Hydrobiology (2011).

The following brief notes on turtles are provided to supplement the Hydrobiology (2011) summary, based on observations and interviews undertaken at Iniok, Nekei, Paru and Kubkain in the Study Area Lowland Zone.

Elseya novaeguineae New Guinea Snapping Turtle

This small side-necked turtle species is abundant throughout the Sepik system and other rivers in New Guinea. Although it occurs in the main river channel, and in swamps, lakes and other off-river waterbodies throughout the region, it is also commonly found and collected in small tributary streams. Two specimens were found in a small, clear stream at Frieda Bend Site during this Project surveys. The species is harvested whenever found, particularly during the nesting season, which locals report is from around May-June and occurs in both the main river channel and off-river waterbodies. Although locals reported that they do not specifically hunt for this species they do look for signs of nesting, and harvest adults and clutches at this time. Adults are also collected and consumed whenever they are encountered, throughout the year. At Kubkain local villagers kept several live turtles in a pit in the ground awaiting consumption.

Pelochelys signifera Giant Softshelled Turtle

This is a very large, soft-shelled turtle found only in northern PNG. The populations there have a complicated taxonomic history, the result of which is that the Sepik River population is currently considered to be a species distinct from the population in southern PNG and also distinct from the species in SE Asia. As a result the Sepik population is not covered by previous IUCN Red List assessments and urgently requires a new assessment. This species is less abundant than *Elseya*. At Nekei and Paru informants reported that the species also breeds in May-June, and that it is abundant and harvested whenever encountered. However at Kubkain informants reported that this species is much rarer than *Elseya*, and that they are unaware of its breeding sites and season. This is an interesting contradiction because the species appears to have cultural significance for the Kubkain community, who report that as well as being a food source the shells of this species are used for making ‘bilas’ (ceremonial decorations).

5 IMPORTANT HABITATS

These surveys identified a number of habitats that are important for the maintenance of herpetofaunal diversity or species of conservation significance in the Study Area.

5.1 Rocky Mountain Streams

Clear, fast-flowing mountain streams (UTS) occur throughout the Study Area Hill Zone and were identified as important habitats at all sites in this zone during the survey. These streams and the dense riparian vegetation along their banks provide habitat for distinct assemblages of frogs that rely on cool, clear streams for successful reproduction. Within these assemblages are five new species of treefrogs (genus *Litoria*) and one possibly new species of microhylid frog (*Austrochaperina*) that were discovered during these surveys.

The structure and density of riparian vegetation associated with these streams is a crucial factor determining the species of frogs that are able to persist along them. For example, frog assemblages were different in stretches of stream retaining dense overhanging riparian vegetation from those in more open sections of the same stream, and some species such as *Litoria* sp nov 8 and *Austrochaperina* sp nov preferred smaller streams with complex understorey riparian vegetation (while others preferred streams with open understoreys and large trees to provide elevated perch sites (e.g. *Nyctimystes fluviatilis*)) (Table 9).

These streams are characterised by rapid changes in volume following intense rainfall events, and sediment loads increase and then decrease rapidly during these events (Table 1 for summary of stream characteristics).

Many of these species are likely to occur in streams of similar morphology throughout the Study Area and along the northern slopes of the Central Cordillera outside the Study Area.

5.2 Wet Forests Of The Nena Limestone Area

The wet forests of Nena Limestone Site consist of Hill Forest (Hm) and Lower Montane Forest (L ± c) with conifers on the ridge-tops (Chapters 1 and 2). This site had a moderately diverse herpetofauna (Tables 4, 5 and 6) and contained a distinctive species of frog that appears to be new to science. It is a small, brightly coloured treefrog of the genus *Litoria* that was found only along a small seepage that drained the ridge at Nena Limestone Site. It was not found at any other site in the Study Area. A very large gecko of the genus *Cyrtodactylus*, which is known only from a single specimen collected from a tree felled to make the camp at Nena Limestone Site may also be new to science. The frog and possibly the gecko species are not currently known from any other sites in New Guinea, either within or outside the Study Area. This limestone ridge has relatively limited flowing water compared to the other sites. Despite this, the forest retains the second-most diverse frog assemblage documented during the 2009-2011 surveys.

5.3 Off-River Waterbodies In The Study Area Lowland Zone

Off-river waterbodies along the Sepik River provide important nesting and refuge sites for two crocodile species, two freshwater turtles, and for the common frogs *Litoria infrafrenata* and *Rana papua*. The structure of aquatic vegetation in these waterbodies, and particularly of floating mats of vegetation, is critical for the nesting success of crocodiles.

Table 9. Habitat characteristics of stream-dwelling frog assemblages in the Study Area Hill Zone

SPECIES	1. LARGE STREAMS (> 2 M WIDE) WITH DENSE OVERHANGING RIPARIAN VEGETATION	2. MORE OPEN SECTIONS OF LARGE STREAMS	3. SMALLER STREAMS (< 2 M WIDE) WITH COMPLEX UNDERSTOREY RIPARIAN VEGETATION	4. STREAMS WITH OPEN UNDERSTOREYS AND LARGE TREES TO PROVIDE ELEVATED PERCH SITES
Litoria angiana	X	X	X	X
Litoria leucova	X		X	
Litoria modica	X	X?	X	
Litoria sp. nov. 1 cf *arfakiana*	X	X		X
Litoria sp. nov. 2 cf *gasconi*			X	
Litoria sp. nov. 3 cf *macki*	X			
Litoria sp. nov. 5 cf *nigropunctata*			X	
Litoria sp. nov. 7 (torrent grunter)	X	X	X	
Litoria sp. nov. 8 (small, torrent)			X	
Litoria sp. nov. 9 (medium torrent)	X			
Nyctimystes pulcher	X			
Nyctimystes fluviatilis	X			X
Austrochaperina sp. 3 (aquatic)			X	
Rana cf *grisea*	X	X	X	

Notes: indicative of most common habitat use only. Does not preclude species being found occasionally in other habitats.

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7 PLATES

Family Ceratobatrachidae: *Platymantis papuensis*

Family Hylidae: *Litoria leucova*

Family Hylidae: Nyctimystes fluviatilis

Family Microhylidae: *Cophixalus balbus*

Family Microhylidae: *Liophryne schlaginhaufeni*

Family Microhylidae: *Oreophryne biroi*

Family Ranidae: Limnonectes grunniens

Family Ranidae: *Rana cf grisea*

Plate 1. Some Frogs of the Study Area

Family Agamidae: *Hypsilurus cf dilophus*

Family Gekkonidae: *Cyrtodactylus novaeguineae*

Family Scincidae: *Emoia obscura*

Family Elapidae: *Aspidomorphus lineaticollis*

Family Pythonidae: *Morelia viridis*

Family Chelidae: *Elseya novaeguineae*

Family Trionychidae: *Pelochelys signifera*

Family Crocodylidae: *Crocodylus novaeguineae*

Plate 2. Some Reptiles of the Study Area

Chapter 6 Odonata

Dr. Stephen Richards

A report prepared for Coffey Environments and

Frieda River Limited.

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PLATES

EXECUTIVE SUMMARY

A total of 107 odonate species (58 damselflies and 49 dragonflies) were documented at 20 sites in the Study Area. The fauna of the Study Area Hill Zone was dominated by species inhabiting small forest streams, while that of the Study Area Lowland Zone was dominated by species breeding in ponds and other large water-bodies.

Odonate diversity was highest at Ok Isai Site (46 species) and Ok Binai 1 Site (40 species) and was also high at Kaugumi Site (39 species), Nena Base Site (38 species) and Frieda Bend Site (37 species). Diversity appeared to be influenced by aquatic habitat heterogeneity. The Ok Isai Site, Ok Binai 1 Site and Frieda Bend Site included microhabitats typical of both Study Area Hill Zone and Study Area Lowland Zone forests, and this diversity of local microhabitats contributed to the high species diversity documented at these sites.

The dragonfly *Bironides teuchestes* from Malia Site in the Study Area Lowland Zone is listed by IUCN as Vulnerable. It was previously known only from three sites in the vicinity of Jayapura and the Cyclops Mountains in north-eastern Papua Province, Indonesia. Its discovery at Frieda Bend Site represents a major range extension.

Four poorly known damselfly species documented during the survey, *Cyanocnemis aureofrons, Palaiargia halcyon, Papuargia stueberi* and *Thaumatagrion funereum*, are listed as Data Deficient by the IUCN. All are species described from eastern Papua Province, Indonesia and their occurrence in the Study Area extends their known distributions significantly to the east.

At least 12 species are new to science and nine of these occur only along clear flowing streams.

The most important habitat identified during the surveys was clear mountain streams in primary forest in the Study Area Hill Zone, which harbour a diverse assemblage of stream-dwelling odonates including new and Data Deficient species.

The Peat Forest at East Sepik Site had a depauperate odonate fauna that was dominated by common, widespread species. This low species diversity reflects a lack of free-standing water. No new species or IUCN-listed species were found that were unique to this habitat.

1 INTRODUCTION

With more than 400 described species, the dragonflies and damselflies (Odonata) of New Guinea are a diverse and colourful component of the region's biodiversity. Although the fauna shares many components with Australia (Theischinger and Hawking 2006) there are also striking differences between the faunas, and several groups that are species-rich in New Guinea, such as Platycnemidid and Platystictid damselflies, are absent from Australia. Given their moderately large size, relative ease of identification, and a complex life cycle that includes an aquatic larva and terrestrial, flying adult stage, odonates are considered to be potentially useful indicators of environmental change (e.g. Clark and Samways 1996). However despite this ease of identification, the odonate fauna of New Guinea remains incompletely documented and numerous new species have been described from the region in the last 5 years (e.g. Theischinger and Richards 2005, 2006a, b, c, 2007; Englund and Polhemus 2007; Gassmann and Richards 2008).

The northern lowlands of New Guinea between the Central Cordillera and the north coast are known to have an exceptionally diverse odonate fauna, with more than 200 described species occurring in the region. However much of our knowledge about this fauna is based on material collected in Indonesian (then Dutch) Papua Province, mainly by the 1938-1939 Archbold Expedition (Archbold *et al.* 1942) and private collectors including W. Stueber and E. Cheesman. That material was examined and published by M.A. Lieftinck in a series of seminal papers (e.g. Lieftinck 1949) that continue to provide the foundation for current taxonomic and biogeographical work on New Guinean odonates. In contrast, the fauna of northern Papua New Guinea remains poorly documented, with recent odonate surveys in the country focused on the southern and far-eastern regions of the country (e.g. Richards et. al. 1998).

The disparity in survey effort between the Central Cordillera's Hill Zone of northern Papua Province, Indonesia, and the adjacent northern hills of Papua New Guinea is exemplified by the observation of Polhemus *et al.* (2004) that the foothills of the central mountains between 50 and 1200 m elevation in the Mamberamo basin contain 15 odonate species apparently endemic to that region (due largely to collections made by the Third Archbold Expedition in 1939), while no endemic species are known from similar elevations in the Sepik-Ramu Hill Zone of Papua New Guinea. Polhemus *et al.* (2004) concluded that this latter area, which includes the Study Area considered in this report, has been 'surprisingly poorly surveyed for aquatic biota'.

In their overview and assessment of New Guinea freshwater biotas, Polhemus et al (2004) used damselflies as one of the indicator taxa to delineate areas of freshwater endemism in the region. They included the Mamberamo and Sepik Hill Zones within the large 'Central Mountain Ranges' region of freshwater endemism but separated the Hill Zones of these two major catchments into the Mamberamo Foreland and the Sepik-Ramu Foreland, adjacent areas of freshwater endemism delineated only by the Sepik-Mamberamo Divide. Given the continuity of habitats and lack of major biogeographic barriers along the northern face of the Central Cordillera and between the Mamberamo and Sepik River Basins, many of the taxa documented from the Mamberamo foothills may reasonably be expected to also occur in the Sepik River headwaters. Similarly, the odonate fauna of the Sepik lowlands is likely to closely resemble the better-known faunas of the Jayapura area and the Mamberamo basin in northern Papua Province, Indonesia.

This report presents a comprehensive assessment of odonate diversity at 20 sites in the Study Area in north-west mainland Papua New Guinea and covers a variety of terrains that support a wide range of habitats. It represents the first comprehensive survey of odonates undertaken in this region.

2 OBJECTIVES

The objectives of this assessment were to:

- Conduct surveys of odonates in the Study Area
- Characterise the odonate fauna of the Study Area.
- Identify significant odonate communities and habitats.
- Identify IUCN listed species and species listed as protected under the PNG *Fauna (Protection and Control)Act 1966*.
- Recommend suitable mitigations to reduce impacts on odonates.

3 METHODS

3.1 Sites

The location of each survey site is shown in Figures 4 and 5 in Chapter 1, and survey trails are shown in Figures 4 and 5 of Chapter 1. The habitat types and vegetation structure at these sites are described in detail in Chapters 1 and 2 so only those features specifically relevant to understanding the diversity and status of herpetofauna species are mentioned further in this report.

The Study Area covers two major terrain features that are biogeographically distinct from one another - the north-central slopes of the Central Range and the upper Sepik River Basin (Beehler 2007; Mack and Dumbacher 2007).

These two broad regions form the basis for the subdivision of the Study Area into its three Zones (Chapter 1). Each is considered separately in the following analysis and discussion because their influence on the presence and form of flowing aquatic habitats is more important than vegetation structure for understanding odonate diversity and status in the Study Area.

The Study Area Lowland Zone consists of depositional landforms resulting from past or present overbank flooding of the Sepik River and its major tributaries. Its upper elevational limit varies between 0 and 100 m and is here defined as all lands below 100 m. This zone is one of flat lands forming river floodplains and excludes isolated hills such as Frieda Mountain that jut out of the plains even where these hills do not reach 100 m elevation. These hills are rightly part of the Study Area Hill Zone as their vegetation is not subject to the effects of over-bank river flooding due to the abrupt gradient change at their bases.

The Study Area Hill Zone consists of primary erosional and colluvial (i.e. slope deposit) landforms comprising the northern foothills of the Central Cordillera between 100 and 1,000 m elevation. It includes both continuous hills and ranges, and isolated hills surrounded by areas of active alluviation of the Study Area Lowland Zone.

Only five hours in total were spent sampling in the Study Area Montane Zone, consisting of primary erosional and colluvial landforms above 1,000 m elevation at Ubiame in the northern foothills of the Central Cordillera (Table 1) so discussion of the fauna in this zone is limited.

3.2 Survey Methods

At each site intensive searches were conducted for adult dragonflies and damselflies along and around all available water-bodies, during the morning, on sunny afternoons, and in the evenings. Activity patterns of odonates vary among species, with some taxa preferring to perch in early-morning sun patches in the forest, others defending territories along streams, and others flying in forest gaps predominantly at dusk, and rarely perching. Water zbodies examined included seepages, small closed-canopy streams, larger streams (Table 1) and small forest pools. Additional surveys were conducted along forest trails and in clearings, especially helipads, where large dragonflies often hunt for small flying insect prey. Samples were conducted by 1-4 (usually 3) persons. Specimens were captured with large insect nets, fixed in acetone and stored in glassine envelopes in boxes containing naphthalene and silica gel to prevent mould and deterioration. Search effort (man-hours) for odonate sampling at each site is summarised in Table 2.

Larval odonates were not targeted during this study because the larvae of most New Guinean taxa remain unknown. Larvae are predaceous and providing sufficient prey to rear individuals to metamorphosis for identification in the field would have been labour intensive and, based on studies of other tropical species, development rates of most species encountered would have been too slow to permit successful rearing in the field. As a result, identifications based on larval collections would be problematic at best.

Table 1. Stream classification used in habitat assessments

STREAM CATEGORY	CODE	MAJOR CHARACTERISTICS
Upland Torrential Stream	UTS	Small to medium (1-10 m wide), clear water creeks. Generally above 300 m elevation. Moderate-high velocity. Rocky substrate with riffle-pool morphology and sometimes with waterfalls. Transport capacity greater than supply for sand so sand and litter are minor components of substrate except in deeper pools. Water temperatures cool, high levels of dissolved oxygen. Severely influenced by spates.
Upland Low-gradient Stream	ULGS	Small to medium (1-10 m wide), clear water creeks. Generally above 300 m elevation. Low velocity, so sand is dominant substrate and litter accumulation evident. riffle/pool morphology substantially lacking. Water cool but oxygen levels lower than in UTS. Moderately influenced by spates.
Lowland Torrential Stream	LTS	As for Upland Torrential Stream but generally below 300 m elevation, moderate velocity so sand and litter more evident than in UTS although rocky substrate still dominates, riffle/pool morphology less well defined than in LTS.
Lowland Low-gradient Stream	LLGS	As for ULGS except water may be muddy or clear, generally below 300 m elevation, very low velocity so sand and litter dominate the substrate – exposed rocky substrate generally negligible, riffle/pool morphology absent and oxygen levels low
Seepage	SP	Shallow (< 10 cm), slow-flowing water-bodies seeping from the ground. Generally < 5 m wide. Velocity negligible, surface movement barely detectable. Substrate usually mud and/or litter. Riffle/pool morphology absent. Oxygen levels low.

Notes: Riffle: shallow (normally <30 cm deep) turbulent water flow with broken water surface over rocky substrate.
Riffle/Pool morphology: Streams characterized by stretches of higher-velocity, turbulent water flowing over rocks (riffles), that separate slower, deeper stretches (pools) generally containing some sand.
Spate: A rapid and very large change in stream volume/velocity in response to intense rainfall events.

Special attention was directed at determining the status of regionally anticipated species with a 2011 IUCN Red List rating above Least Concern (see Table 3 for definition of IUCN Red List categories) or a listing as Protected in the PNG *Fauna (Protection and Control)Act 1966.*

3.3 Taxonomic Issues Associated with Odonate Assessment.

The odonate fauna of New Guinea remains poorly known. Several groups are currently being revised (e.g. Kalkman *et al.* 2010) and the identities of some species reported here, including members of the taxonomically difficult genera *Argiolestes*, *Diplacina*, *Macromia* and *Teinobasis*, remain uncertain. However examination of voucher material obtained during these surveys confirmed that some species are undescribed, and others appear to represent species so poorly known that comparison with type material in European museums will be required to confirm their identities. To account for these issues, identifications in this report are presented in a way that indicates levels of certainty of identification.

- **'sp nov.'** means a species new to science;
- **'sp'** indicates that the information available precludes positive identification – this has occurred if the available literature and/or specimens are insufficient to derive a confident identification;
- **'cf'** indicates that the species in question appears most similar to, but is probably different from, the taxon listed – and it may be undescribed;

- **'?'** following a species name indicates that the identification to species level is only tentative but the species is probably a species new to science.

Further studies will be required to confirm the identifications of such taxa.

Several recent studies have proposed changes to some family and genus names for Australian and New Guinean odonates. To avoid confusion, in this report I follow the terminology adopted by Theischinger and Hawking (2006). The term 'dragonfly' is commonly used in two different ways in the literature: either to denote the entire order Odonata (including both dragonflies and damselflies), or to denote only the sub-order Anisoptera, or 'True Dragonflies', excluding the subfamily Zygoptera or 'Damselflies'. To avoid confusion the term 'odonate' is used throughout this report to indicate the entire order, including both dragonflies and damselflies. The term 'dragonfly' and 'damselfly' are used in the specific sense to indicate these respective subfamilies.

Table 2. Survey effort for the 2009-2011 odonate survey

SURVEY SITE	TRANSECT SURVEYS (MAN HOURS)
Nena Base Site	69
Nena D1 Site	53
Nena Limestone Site	41
Nena-Usage Site	7
Malia Site	71
Koki Site	42
Frieda Base Site	6
HI Site	54
Ubiame Site	5
Upper Ok Binai Site	46
Frieda Bend Site	66
Ok Isai Site	68
Kaugumi Site	52
East Sepik Site	45
Iniok Site	50
Frieda Strip Site	4
Wario Site	44
Wogamush Site	37
Kubkain Site	55
Ok Binai 1 Site	60
TOTALS	**875**

Table 3. Conservation classifications used by the PNG *Fauna (Protection and Control)Act 1966* **and IUCN**

PNG FAUNA (PROTECTION AND CONTROL) ACT	
Protected (P)	Taxa declared protected.
IUCN	
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.
Not Evaluated (NE)	Not yet been evaluated against the criteria.

Notes: IUCN descriptions are abridged. For a detailed explanation see IUCN. (2001). IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp. (http://www.iucnredlist.org/technical-documents/categories-and-criteria).

4 RESULTS AND DISCUSSION

4.1 Species Diversity

A total of 107 odonate species were documented from 20 sites during this survey (Tables 4 and 5; Plates 1-2). However only incidental observations over 4-6 hours were made at three of these sites (Frieda Strip Site, Frieda Base Site and Ubiame Site) and only 7 hours sampling was available at Nena-Usage Site. The discussion about patterns of diversity presented below are therefore restricted to those 16 sites where more than 35 hours of sampling effort was achieved (Table 1), unless stated otherwise.

Table 4. Numbers of damselflies (Zygoptera) and Dragonflies (Anisoptera) documented at each site where at least 35 hours of sampling was achieved

SURVEY SITE	DAMSELFLIES	DRAGONFLIES	TOTAL SPECIES/ SITE
Nena Base Site	24	14	38
Nena D1 Site	14	8	22
Nena Limestone Site	11	8	19
Malia Site	19	16	35
Koki Site	17	12	29
HI Site	14	10	24
Upper Ok Binai Site	19	15	34
Frieda Bend Site	22	15	37
Ok Isai Site	22	24	46
Kaugumi Site	16	23	39
East Sepik Site	7	15	22
Iniok Site	9	18	27
Wario Site	12	18	30
Wogamush Site	6	13	19
Kubkain Site	5	13	18
Ok Binai 1 Site	23	17	40

Odonate diversity was highest at Ok Isai Site (46 species) and Ok Binai 1 Site (40 species) and was also extremely high at Kaugumi Site (39 species), Nena Base Site (38 species) and Frieda Bend Site (37 species). Numbers of species per site are presented in Table 4. There was no trend of either increasing or decreasing diversity with elevation (Figure 1; R=0.16, p=0.51) but this result is difficult to interpret because there was a significant correlation between sample effort and species diversity irrespective of elevation (Figure 2; R=0.76, p=0.001). The overwhelming impression from field observations was that habitat heterogeneity, and in particular diversity of available aquatic habitat types, was the most important driver of species diversity at any site. For example the Ok Isai Site, Ok Binai 1 Site and Frieda Bend Site were among the most diverse sites surveyed and they all had a diversity of aquatic habitats typical of both the Study Area Hill Zone and Study Area Lowland Zone forests; this diversity of local microhabitats probably contributed to the high species diversity documented at these sites. In contrast the relatively low diversities documented at East Sepik Site, Wogamush Site and Kubkain Site probably reflect the uniformity of swampy aquatic habitats in those lowland areas.

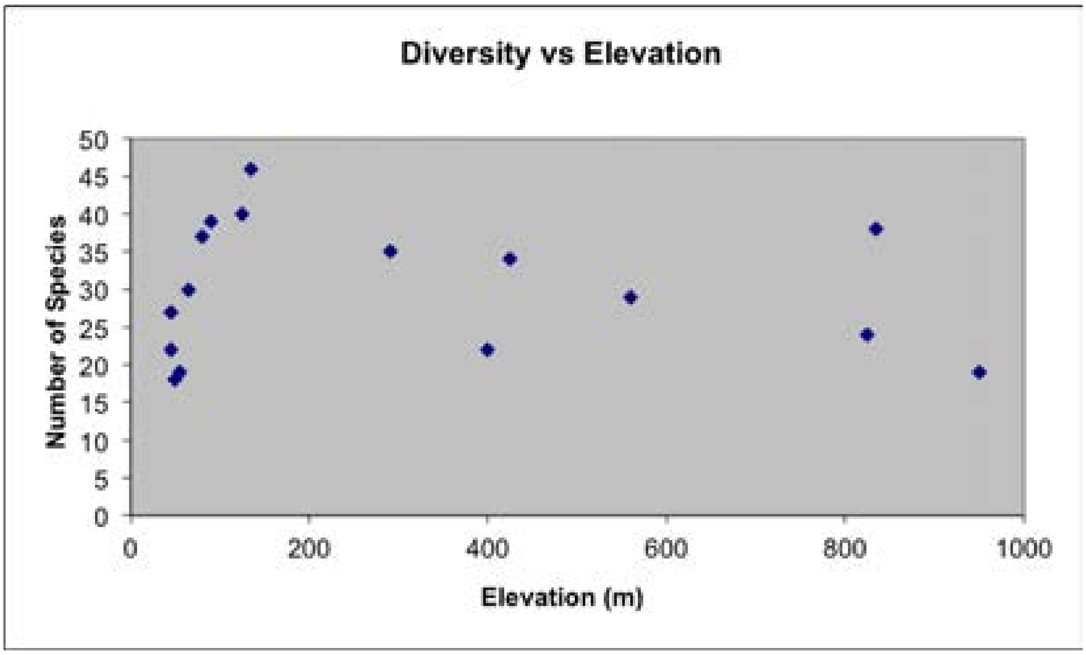

Figure 1. Odonate species diversity vs elevation at sites where at least 35 man-hours of sampling had been accomplished.

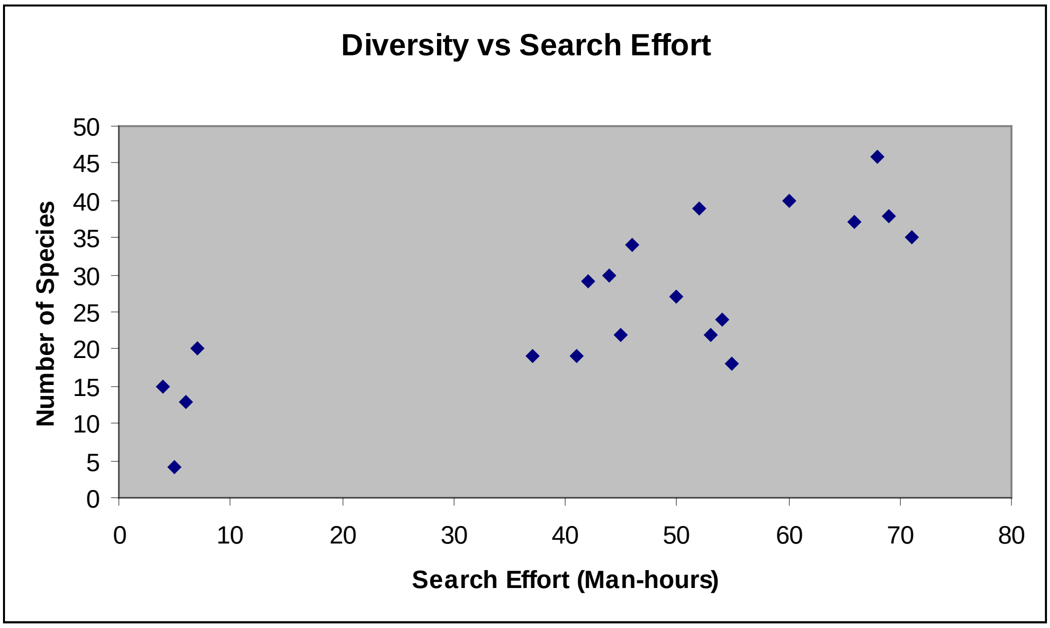

Figure 2. Odonate diversity vs search effort at all sites surveyed.

4.1.1 The Study Area Lowland Zone

Odonate diversity in the Study Area Lowland Zone was moderately high, with a total of 74 species comprising 37 damselflies and 37 dragonflies, documented at eight sites. In contrast a 1-month survey in the Lake Kamu Basin of Papua New Guinea's southern lowlands documented just 35 species (Richards *et al.* 1998). However the lowland fauna documented in the Study Area Lowland Zone is generally of less conservation significance than the assemblage documented in the Study Area Hill Zone because it is dominated by common and widespread species. At the broadest scale this is demonstrated by the proportions of damselflies and dragonflies in the Hill Zone vs the Lowland Zone with damselflies comprising 57% of the fauna in the Hill Zone, and 50% of the fauna in the Study Area Lowland Zone. More significant is the proportion of damselflies restricted to just one of these zones; nearly 40% (20 species) of the damselfly species found in the Study Area Hill Zone were not found in the Study Area Lowland Zone. In contrast only 16% of damselfly species found in the Study Area Lowland Zone were restricted to this zone. Dragonflies showed a less distinct pattern, with 31% of species in the Study Area Hill Zone and 27% of species in the Study Area Lowland Zone not shared with the other zone. Dragonflies are known to dominate the fauna in more disturbed or open environments, particularly those characterised by larger, open waterbodies. Damselflies requiring clear streams for reproduction were largely absent from the Study Area Lowland Zone, and the fauna at these latter sites was dominated by common widespread species of both odonate groups.

However a number of significant species were documented in the Study Area Lowland Zone. A tiny black damselfly, *Thaumatagrion funereum*, was rediscovered at Kaugumi Site. It was previously known only from the vicinity of Jayapura in Papua Province, Indonesia, where it was last collected in 1931. One new species of *Nososticta* was first discovered in the Peat Forest at East Sepik Site but was subsequently detected at Wogamush Site and Kubkain Site. The taxonomic status of several other species is currently being examined and it is possible that at least two additional species from the lowland swamps of the Study Area are new to science.

4.1.2 The Study Area Hill Zone

Ninety-one species of odonates were documented from the Study Area Hill Zone. Although few studies of New Guinean odonata are available for comparison the fauna documented in this study is broadly consistent with that known from an undisturbed lower-montane site (850-1,300 m elevation) in the Crater Mountain Wildlife Management Area (CMWMA) on the southern slopes of the Central Cordillera (Oppel 2005). That study documented a smaller fauna (61 vs 91 species) and damselflies contributed a higher proportion to the overall fauna than they did in the Study Area Hill Zone (62% vs 54%). However the faunal composition at the family and genus level was remarkably similar indicating that the odonate fauna in the Study Area Hill Zone is probably typical of hill-lower montane faunas in New Guinea. For example the two studies documented 14 (CMWMA) and 15 (this study) families of odonates, of which only the Gomphidae, represented by the widespread species *Ictinogomphus australis*, was not shared. It was found in the Study Area but not in the CMWMA.

The fauna of both studies was dominated by damselflies of the family Coenagrionidae (Study Area Hill Zone 16% fauna, CMWMA 21% of total) and dragonflies of the family Libellulidae (Study Area Hill Zone 21.8%, CMWMA 19.7%). Only one other family contributed more than 15% of the hill-zone fauna in either study. That was the family Platystictidae (genus *Drepanosticta*), a poorly known group represented by 11 unidentified species (18% of total) at CMWMA, but by only five species in the Study Area. The other major difference between the two studies was the remarkably high diversity of the family Protoneuridae (genus *Nososticta*) documented during this survey. *Nososticta* is a genus of small, colourful damselflies occurring predominantly in the lowlands across New Guinea. Eleven species, including at least three new to science, were documented in the Study Area and 10 of these occurred in both the Study Area Hill Zone and Study Area Lowland Zone. Remarkably, while only three species were found at elevations above 800 m eight species occurred in sympatry at Frieda Bend Site, and the difference between *Nososticta* diversity at CMWMA and the Study Area probably reflects the generally lower elevations accessed during this study. For example at Lakekamu, a lowland site in southern Papua New Guinea, the genus *Nososticta* represented more than 15% of the total odonate fauna (Richards *et al.* 1998).

Ecologically, the Study Area Hill Zone fauna was dominated by species using permanent streams and small rivers in forest for reproduction. This included 40 of 52 damselflies (77%) and 19 of 39 dragonflies (48.7%). Most of these species, including a number of new and rare damselflies, appeared to be restricted exclusively to the vicinity of these streams and were rarely found more than ~ 10 m from the water's edge (e.g. *Drepanosticta* spp, *Argiolestes* spp, *Paramecocnemis* spp, *Hylaeargia* sp. nov.) although they may move into the canopy to rest and sleep. Other species that breed in streams, particularly members of the genera *Idiocnemis* and *Nososticta*, were often found perching long distances from the water in sun patches in the forest when not breeding.

A small assemblage of species appears to be independent of water bodies on the forest floor. These include the damselflies *Podopteryx selysi*, which breeds in tree-holes, and *Papuagrion occipitale* and several species of *Teinobasis* which probably breed in trapped water in *Pandanus* leaves and/or other arboreal sites such as tree holes. These species were generally encountered randomly in the forest and were not associated with streams or ponds.

Only five species of damselflies in the Study Area Hill Zone (9.6%) were closely associated with temporary or permanent ponds. In contrast, 16 species of dragonflies (41%) in this zone were closely associated with stationary water-bodies and most of these are common, widespread species occurring across most of New Guinea.

Despite having a broadly similar composition, the Study Area Hill Zone fauna appears to be ecologically somewhat different from that at CMWMA. Habitat characteristics were defined and measured differently in the CMWMA study (Oppel 2005) precluding robust comparison, but a striking difference between the sites is the apparent significance of temporary streams as breeding sites for odonates at CMWMA compared to the Study Area. Oppel (2005) reported that more than one quarter of the odonate fauna at CMWMA (26%) utilises temporary streams for reproduction. In contrast during this study none of the streams examined ceased flowing for any period and most odonates occupied streams that appeared to be permanent.

In summary, the odonate fauna of the Study Area Hill Zone is exceptionally diverse, and probably represents the most species-rich assemblage documented on New Guinea to date. It is dominated by species requiring clear, flowing stream environments for reproduction. These habitats were present at all sites in this zone, and the extremely high odonate diversities recorded at Ok Isai Site and Ok Binai 1 Site reflected the presence of these habitats in addition to small forest pools and swampy habitats more typical of lowland forests, a combination of habitats providing maximum breeding sites for odonate species. Many of the Study Area Hill Zone species closely associated with forest stream habitats are damselflies that are new to science, or have poorly documented and sometimes limited known distributions. For example 13 of the damselflies associated closely with stream environments are either new species or so poorly known as to require further studies to permit confident identification.

4.1.3 The Study Area Montane Zone

Too few data were collected to characterise this zone.

4.1.4 Importance of Odonates to Local Communities

Interviews with local assistants indicated that odonates have no cultural or dietary significance for local communities. Despite their abundance, bright colours and conspicuous behaviour, many species that were documented during this survey were unfamiliar to the locals.

Table 5. Odonates documented during Study Area odonata surveys 2009-20111

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Calopterygidae	*Neurobasis ianthinipennis*	NE	UTS, LTS, R	+	+	+	+	+	+	+	+	+	+	+						+			
Chlorocyphidae	*Rhinocypha tincta*	NE	UTS, LTS, R	+	+	+	+	+	+	+	+	+	+	+			+			+			
Coenagrionidae	*Agriocnemis ?aderces*	NE	P,H, Wsw, FsW											+		+							
Coenagrionidae	*Agriocnemis femina*	NE	P,H, Wsw, FsW							+		+	+									+	
Coenagrionidae	*Archibasis crucigera*	LC	P,H, Wsw, FsW										+	+	+	+							
Coenagrionidae	*Archibasis mimetes*	NE	P,H, Wsw, FsW										+	+	+			+					
Coenagrionidae	*Argiocnemis ensifera*	NE	P,H, Wsw, FsW										+	+		+	+		+			+	
Coenagrionidae	*Austroagrion*? sp	NE	P,H, Wsw, FsW													+							
Coenagrionidae	*Hylaeargia* sp. nov.	NE	UTS		+																		O
Coenagrionidae	*Palaiargia ceyx*	NE	UTS		+						+									+			
Coenagrionidae	*Palaiargia charmosyna*	NE	LTS					+					+										
Coenagrionidae	*Palaiargia halcyon*	DD	UTS		+																		
Coenagrionidae	*Papuargia stueberi*	DD	UTS, LTS	+	+															+			+
Coenagrionidae	*Papuagrion occipitale*	NE	F		+	+		+		+	+	+	+	+		+	+	+	+	+			
Coenagrionidae	*Pseudagrion civicum*	NE	LTS, R									+	+							+			
Coenagrionidae	*Teinobasis dominula*	NE	F		O									+	+	+	+	+	+				
Coenagrionidae	*Teinobasis olthofi*	NE	F										+	+	+	+				+			
Coenagrionidae	*Teinobasis scintillans*	NE	F, UTS, LTS	+	+	+	+	+	+	+	+	+	+	+	+	+		+		+	+		
Coenagrionidae	*Teinobasis* sp. 1 cf *aurea*	NE	F			+		+					+										
Coenagrionidae	*Teinobasis* sp. 2	NE	F					+															
Coenagrionidae	*Teinobasis* sp 3. (tiny)	NE	F			+																	
Coenagrionidae	*Thaumatagrion funereum*	DD	Fsw											+									
Coenagrionidae	*Xiphiagrion truncatum*	NE	P							O		+											

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Isostictidae	*Selysioneura capreola*	NE	UTS, LTS		+			+	+		+		+										
Isostictidae	*Selysioneura drymobia*	NE	UTS, LTS			+			+			O											
Isostictidae	*Selysioneura umbratilis*	NE	UTS, LTS	+	+												?						
Isostictidae	*Tanymecosticta* sp.	NE	UTS								+												
Lestidae	*Indolestes luxatus*	NE	WsW, Fsw											+				+	+				
Lestidae	*Indolestes lygistocercus*	NE	WsW, Fsw												+								
Megapodagrionidae	*Argiolestes* sp 1. (*ornatus* group)	NE	UTS	+	+				+	+	+	O											
Megapodagrionidae	*Argiolestes* sp. 2 (*ornatus* group - B&W)	NE	UTS		+	+	+	+	+		+	+	+				+			+	+		
Megapodagrionidae	*Argiolestes* sp. 3 (*australis* group)	NE	UTS						+	+	+									+			+
Megapodagrionidae	*Argiolestes* sp. nov. 1(cf *kula*)	NE	UTS								+												
Megapodagrionidae	*Podopteryx selysi*	NE	F	+				+															
Platycnemididae	*Arrhenocnemis* sp.	NE	LTS																	+			
Platycnemididae	*Cyanocnemis aureofrons*	DD	UTS, LTS			+	+	+	+		+									+			
Platycnemididae	*Idiocnemis chloropleura*	NE	UTS	+	+	+		+	+	+	+	+	+							+	+		
Platycnemididae	*Idiocnemis inaequidens*	LC	UTS		+	+					+									+			
Platycnemididae	*Idiocnemis obliterata*	NE	UTS	+	+	+	+	+	+			+	+	+			+			+	+		
Platycnemididae	*Lochmaeocnemis malacodora*	NE	UTS		+																		
Platycnemididae	*Paramecocnemis* sp. nov. 1	NE	UTS		+																		
Platycnemididae	*Paramecocnemis* sp. nov. 2	NE	UTS				+				+												
Platystictidae	*Drepanosticta clavata*	NE	UTS		+	+	+	+	+	+	+	+											
Platystictidae	*Drepanosticta dendrolagina*	NE	UTS							+							+						
Platystictidae	*Drepanosticta* sp. nov. 1 (black apps)	NE	UTS		+			+	+	+	+	+											
Platystictidae	*Drepanosticta* sp. nov. 2 (Blue-tail)	NE	UTS						+		+									+			

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Platystictidae	*Drepanosticta* sp. nov. 3 (Ok Isai Blue-tail)	NE	UTS										+										
Protoneuridae	*Nososticta beatrix*	NE	LLGS, P									+								+			
Protoneuridae	*Nososticta callisphaena*	NE	LTS, LLGS, R									+								+			
Protoneuridae	*Nososticta chalybeostoma?*	NE	UTS, ULGS, LLGS, LTS		+		+	+				+	+	+			+			+			
Protoneuridae	*Nososticta erythrura*	LC	UTS, ULGS, LLGS, LTS		+			+	+	+		+	+										
Protoneuridae	*Nososticta fonticola*?	NE	UTS	+	+	+	+	+	+	+	+	+	+							+			
Protoneuridae	*Nososticta lorentzi*	NE	LLGS, R									+					+			+			
Protoneuridae	*Nososticta melanoxantha*	NE	LLGS										+	+									
Protoneuridae	*Nososticta nigrofasciata*	NE	LLGS, R										+	+			+						
Protoneuridae	*Nososticta* sp. nov. 1 (orange)	NE	UTS, LLGS, LTS, R	+	+							+				+	+			+			
Protoneuridae	*Nososticta* sp. nov. 2 (small blue)	NE	LLGS					+	+			+								+			
Protoneuridae	*Nososticta* sp. nov. 3 (small blue # 2)	NE	WsW, Fsw												+			+	+				
Aeshnidae	*Agyrtacantha dirupta*	NE	UTS, LTS, LLGS, R, Fsw/ WsW									+	+	+	+	+	+	+		+		+	
Aeshnidae	*Agyrtacantha microstigma*	NE	UTS, LTS, LLGS, R, Fsw/ WsW					+	+		+		+	+			+	+	+		+		
Aeshnidae	*Agyrtacantha tumidula*	NE	F											+	+	+							
Aeshnidae	*Gynacantha kirbyi*	NE	F										+		+	+							
Aeshnidae	*Gynacantha* sp. nov.	NE											+										
Aeshnidae	*Plattycantha venatrix*	NE	F	+	+						+					+							
Corduliidae	*Hemicordulia silvarum*	NE	UTS, ULGS, LLGS, LTS, F,R	+	+	+	+	+	+	+	+	+	+				+	+	+	+	+	+	

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Corduliidae	*Metaphya tillyardi*	LC	F						+											+			
Corduliidae	*Procordulia leopoldi*	NE	UTS							+													
Gomphidae	*Ictinogomphus australis*	NE	UTS, LTS, LLGS					+					+	+		+				+	+	+	
Libellulidae	*Agrionoptera longitudinalis*	LC	P, Fsw, WsW		+	+	+	+	+	+	+	+	+	+			+	+		+			
Libellulidae	*Agrionoptera insignis*	NE	P, Fsw, WsW										+	+	+	+	+		+				
Libellulidae	*Bironides teuchestes*	Vu	LTS					+															
Libellulidae	*Brachydiplax duivenbodei*	LC	WsW																+				
Libellulidae	*Diplacina phoebe anthaxia*	NE	LLGS, R											+						+			
Libellulidae	*Diplacina smaragdina*	NE	UTS, LTS	+	+	+	+	+	+	+	+									+	+		
Libellulidae	*Diplacina* sp. 1 (white spot)	NE	UTS	O		+	+	+				+	+				+						
Libellulidae	*Diplacodes bipunctata*	NE	P						+		+												
Libellulidae	*Huonia epinephele*	NE	UTS, LTS	+	+			+		+	+	+	+							+			
Libellulidae	*Huonia thalassophila* or *arborophila*	NE	UTS, LTS	+	+	+	+	+			+		+							+			
Libellulidae	*Lyriothemis meyeri*	LC	P, F				+	+				+	+	+		+	+	+	+	+			
Libellulidae	*Microtrigonia marsupialis*	NE	UTS		+																		
Libellulidae	*Nannophlebia adonira*	NE	R														+						
Libellulidae	*Nannophlebia amphicyllis*	NE	UTS, LTS, R		+			+			+	+	O										
Libellulidae	*Nannophlebia axiagasta*	NE	R													+							
Libellulidae	*Nannophya pygmaea*	NE	P, F, LLGS											+					+	+			
Libellulidae	*Nesoxenia mysis*	NE	WsW/Fsw					+	+		+	+	+	+	+	+	+	+	+	+			
Libellulidae	*Neurothemis decora*	NE	P, F										+	+	+	+	+		+			+	
Libellulidae	*Neurothemis stigmatizans*	NE	P, WsW/Fsw									+	+	+	+	+	+		+	+		+	
Libellulidae	*Orthetrum glaucum*	LC	P		+		+		+	+	+	+								+	+	+	
Libellulidae	*Orthetrum serapia*	LC	P, LLGS									+			+		+	+	+		+	+	

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Libellulidae	*Orthetrum villosovittatum*	NE	P, WsW/Fsw		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Libellulidae	*Pantala flavescens*	LC	P		+							+	+	+		+	+	+	+	+	+	+	
Libellulidae	*Protorthemis coronata*	NE	P				+	+	+	+	+	+	+	+	+		+	+			+		
Libellulidae	*Rhyothemis phyllis*	NE	P										+									+	
Libellulidae	*Rhyothemis princeps irene*	LC	P, WsW/Fsw		+							+		+	+	+		+	+			+	
Libellulidae	*Rhyothemis resplendens*	NE	P, WsW/Fsw											+	+			+					
Libellulidae	*Risiophlebia risi?*	DD	P, F											+									
Libellulidae	*Tetrathemis irregularis*	NE	WsW/Fsw											+		+							
Libellulidae	*Tholymis tillarga*	LC	P													+							
Libellulidae	*Tramea aquila*	NE	P											+	+		+					+	
Libellulidae	*Zyxomma petiolatum*	LC	P,F,R			+			+				+	+	+	+	+	+				+	
Libellulidae	*Zyxomma elgneri*	NE	P,F,R												+	+							
Macromiidae	*Macromia melpomene*	NE	UTS, LTS, LLGS	+	+		+	+	+	+	+		+	+									
Macromiidae	*Macromia terpsichore*	NE	UTS, LTS, LLGS										+	+			+			+			
Synthemistidae	*Palaeosynthemis cyrene*	NE	UTS, F							+	+												+
Synthemistidae	*Palaeosynthemis feronia*	NE	UTS, F										+										
Synthemistidae	*Palaeosynthemis primigenia*	LC	UTS, F	+	+	+																	
Synthemistidae	*Palaeosynthemis* sp. nov.	NE	UTS, F					1															
TOTAL 107				19	38	22	20	35	29	24	34	37	46	39	22	27	30	19	18	40	13	15	4

Notes: ‘sp. nov.’ designates species new to science; ‘sp.’ indicates that further studies are required to determine taxonomic status. ‘cf ’ indicates that the species is probably new to science but appears most similar to the listed species; ‘?’ indicates identification not certain; + - confirmed present and voucher specimen obtained; O - an unconfirmed observation usually without a voucher specimen.

IUCN Status: LC = Least Concern; DD = Data Deficient; VU = Vulnerable; NE = Not evaluated.

Aquatic habitat type is the set of environments that the species was most frequently associated with, and presumed to be their primary breeding habitat. See Table 1 for definitions of stream types. Other abbreviations: R = River (>5 m wide); P = Pool; WsW/Fsw = swampy forest; F = Forest (away from water); H = encountered most frequently in open, including heavily disturbed, habitats.

4.2 Species of Conservation Significance

4.2.1 Species Listed in PNG under the Fauna (Protection and Control)*Act 1966*

No odonate species are listed under the PNG *Fauna (Protection and Control)Act 1966.*

4.2.2 Species Listed by IUCN

Assessment of the world's odonate fauna has been sporadic and uneven. For example a recent project for IUCN assessed the red-list status of 1,500 randomly selected odonate species representing just over a quarter of the world's fauna (Clausnitzer *et al.* 2009). Significantly, a number of species selected for assessment were from New Guinea which, as a large tropical land-mass has a particularly diverse odonate fauna (Kalkman *et al.* 2008). Six species documented during these surveys were assessed by IUCN to be in categories other than Least Concern and are presented in Table 6.

Table 6. Odonate species documented in the Study Area that are listed by IUCN in a category other than Least Concern.

SPECIES	IUCN CATEGORY
Bironides teuchestes	VU
Cyanocnemis aureofrons	DD
Palaiargia halcyon	DD
Papuargia stueberi	DD
Thaumatagrion funereum	DD
Risrophlebia risi	DD

Notes: IUCN data taken from: IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 29 September 2011. VU = Vulnerable, DD = Data Defficient.

4.3 Species New to Science

The discovery of new odonate species at any site in Papua New Guinea is not unexpected (e.g. Oppel 2005) and at least 12 new species were documented during the 2009-2011 Project surveys (Table 7). Ten of these are damselflies, nine of which are closely associated with small streams in forested environments. It is likely that as many as half of the species that are currently listed as 'sp.' in Table 5 will also be confirmed as new species following further detailed studies of voucher material.

Species that are new to science and ecologically or biogeographically significant include:

Argiolestes spp.

At least one, and possibly all four of the *Argiolestes* species documented during this Project are new to science. This genus contains a number of species with small known distributions, making them a biogeographically significant component of the fauna. The confirmed new species, found at Upper Ok Binai Site, is a beautiful red damselfly belonging to a group within *Argiolestes* that was previously known only from eastern Papua New Guinea. All species rely on small streams for reproduction.

***Drepanosticta* spp**

At least three of the species in this genus are undescribed. They have a very close association with forest streams, although both sexes sometimes move deep into the forest where they perch in shady or dappled sunny positions.

Table 7. Species potentially new to science.

FAMILY	SCIENTIFIC NAME	IUCN STATUS	AQUATIC HABITAT TYPE	NENA LIMESTONE	NENA BASE	NENA D1	NENA-USAGE	MALIA	KOKI	HI	UPPER OK BINAI	FRIEDA BEND	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Coenagrionidae	*Hylaeargia* sp. nov.	NE	UTS		+																		+
Platycnemididae	*Paramecocnemis* sp. nov. 1	NE	UTS		+																		
Platycnemididae	*Paramecocnemis* sp. nov. 2	NE	UTS				+				+												
Platystictidae	*Drepanosticta* sp. nov. 1 (black apps)	NE	UTS		+			+	+	+	+	+											
Platystictidae	*Drepanosticta* sp. nov. 2 (Blue-tail)	NE	UTS						+		+									+			
Platystictidae	*Drepanosticta* sp. nov. 3 (Ok Isai Blue-tail)	NE	UTS										+										
Protoneuridae	*Nososticta* sp. nov. 1 (orange)	NE	UTS, LLGS, LTS, R	+	+							+				+	+			+			
Protoneuridae	*Nososticta* sp. nov. 2 (small blue)	NE	LLGS					+	+			+								+			
Protoneuridae	*Nososticta* sp. nov. 3 (small blue # 2)	NE	WsW, Fsw												+			+	+				
Aeshnidae	*Gynacantha* sp. nov.	NE											+										
Aeshnidae	*Plattycantha venatrix*	NE	F	+	+						+					+							
Synthemistidae	*Palaeosynthemis* sp. nov.	NE	UTS, F					1															

Notes: + - confirmed present and voucher specimen obtained.IUCN Status: NE = Not evaluated.

Aquatic habitat type is the set of environments that the species was most frequently associated with, and presumed to be their primary breeding habitat. See Table 1 for definitions of stream types. Other abbreviations: R = River (>5 m wide); P = Pool; WsW/Fsw = swampy forest; F = Forest (away from water); H = encountered most frequently in open, including heavily disturbed, habitats.

***Hylaeargia* sp. nov.**

A stream-dwelling damselfly, this species is only the third known member of the genus and is currently known from a single stream at Nena Base Site and from Ubiame Site.

***Paramecocnemis* spp.**

Two beautiful, slender damselflies with blue tail-tips. These species were found only along or near small forest streams, and are only the third and fourth known members of the genus. One species is known only from Nena Base Site, while the other was found at Upper Ok Binai Site and possibly at Nena-Usage Site.

***Nososticta* spp.**

A genus of small, black damselflies often having colourful markings on the thorax and abdomen. At least three species in this genus are undescribed. Two are small, blue-and black species; one was found along small clear streams at Malia Site, Frieda Bend Bend Site and Ok Binai 1 Site. The other appears to be restricted to swampy habitats and was found at East Sepik Site, Wogamush Site and Kubkain Site where males and females perched in sun patches on vegetation approximately 1-2 m above the ground.

All of these new species are, to date, known only from the Study Area, and all except one (from East East Sepik, Wogamush and Kubkain) require small forest streams for successful reproduction.

***Gynacantha* sp. nov.**

A very large, crepuscular (dusk-flying) dragonfly known only from a single specimen collected at Ok Isai Site. Taxonomic studies are continuing but this species appears to be new to science, and if this is confirmed it will represent the largest known member of the genus in New Guinea.

As mentioned above, although identifications of most species documented during these surveys is complete, the status of several species in taxonomically difficult genera remains unclear, requiring substantial specialist revision of the genera in question. Given the extensive areas of forest present in the Sepik Basin, and the documentation during this study of a number of species previously known only from Papua Province in Indonesia, it is likely that most if not all of the new species discovered during these surveys have broader distributions that extend outside of the Study Area

4.4 Range Extensions and New Records for PNG

Bironides teuchestes (Vulnerable) is a small libellulid dragonfly previously known only from the vicinity of Jayapura and the slopes of the Cyclops Mountains. Given its previously-known restricted distribution, and habitat disturbance in that area, it was listed as Vulnerable by the IUCN (Kalkman 2007a). This is a taxonomically difficult genus but the Study Area material appears to represent this poorly known species, and thus represents a substantial range extension.

Cyanocnemis aureofrons (Data Deficient), a moderately large blue damselfly with a yellow face, was previously known only from a single location on the Idenberg River in West Papua (Kalkman 2007b). During the 2009-2011 surveys this species was common at most of the mid- and lower-elevation sites (150-550 m elevation) with Upland Torrential Streams. These new records represent a major extension of the species' known range and the first records from Papua New Guinea. It probably occurs throughout the foothills and lowlands of central-northern New Guinea.

Palaiargia halcyon (Data Deficient) is a robust, stream-dwelling damselfly that was previously known only from a single site in the southern Bewani Mountains where it was collected in 1937. Rediscovery of this species in the Study Area represents a major range extension. It was found only along a single steep, rocky stream below Nena Base Site at about 750 m elevation, where males descended from the canopy to perch on rocks adjacent to waterfalls and turbulent torrents in mid-morning sunshine. According to the IUCN assessment the only previously known locality for this species was at about 250 m elevation (Kalkman 2007c) but extensive searches throughout the Hill Zone of the current Study Area failed to detect *P. halcyon* at any additional sites.

Papuargia stueberi (Data Deficient), a large and beautiful green and blue damselfly, is the only member of its genus and was previously known only from two sites near the PNG-West Papua border in the foothills of the Bewani Mountains (Kalkman 2007d). During the current surveys this species was documented at Nena Limestone Site, Nena Base Site and Ok Binai 1 Site. Material of this species collected at Ubiame Site appears to be slightly different from the Nena material but studies undertaken in the laboratory suggest that the differences are not sufficient to warrant recognition of two taxa at this stage. Observations in the field indicate that this species may have a specialised reproductive strategy involving egg deposition on rocks in steep waterfall habitats. The Study Area population represents a major range extension for this species.

Thaumatagrion funereum **(**Data Deficient) is a tiny black damselfly with broad, dark wings that was previously known from Pandanus swamps in the vicinity of Jayapura where the only known specimens were collected in 1930-1931. There the specimens were found ‘flying low to the ground or sitting a few cm above the ground on roots and leafs making them hard to find’ (Kalkman 2007e), a behaviour similar to that observed for the population at Kaugumi Site. The IUCN assessment of this species noted that it ‘is likely that the species is far more widespread than currently known’ (Kalkman 2007e) and the discovery of only the second known population of this species at Kaugumi Site confirms this prediction. This species represents a monotypic genus of uncertain relationships and bizarre appearance, and its documentation at Kaugumi is a significant discovery.

At Kaugumi Site this species was found at only one locality, described in Chapter 2 as a spatially discrete community of mixed swamp forest (Fsw) west of Kaugumi Site. ‘The forest there has an even canopy composed of Clusiaceae (*Calophyllum* and *Garcinia*, seen only as sterile trees), with *Gynotroches axillaris*, *Myristica* cf. *lancifolia*, *Podocarpus neriifolius*, *Terminalia* sp. (‘*canaliculata-complanata* morphotype”), and *Vatica rassak* at lesser frequencies. *Metroxylon sagu* forms a distinct, second tier beneath the depauperated overstorey. Most of the ground surface is covered by pools of standing water with hydrophytic *Hanguana malayana* and *Hydrostemma motleyi*. The numerous masses of ascending pneumatophores at this site are indicative of a fluctuating water table, the latter probably keyed to periodic overflows from adjacent rivers’ (Chapter 2).

Whether this unusual species occurs more widely in the Sepik River Basin Lowlands, or has a patchy distribution limited by specific hydrological and vegetative features of the landscape is not known.

Risiophlebia risi (Data Deficient) is known only from a single specimen collected 100 years ago on the southern slopes of New Guinea’s Central Cordillera in Papua Province, Indonesia. Two specimens from the Study Area have been tentatively identified as this species. However based on examination of overall morphology and wing venation, there is a high likelihood that the Study Area populations are distinct and may represent an undescribed species. Given this uncertainty the species in question requires further study and comparison with museum material. It is not considered further here.

5 IMPORTANT HABITATS

Odonate species exhibit variable life history characteristics that will determine their responses to habitat disturbance and water quality changes. Although in reality an ecological continuum, in the context of the tropical Frieda/Sepik catchment there are broadly two groups of species with contrasting ecologies and life histories. One group consists of species that breed in pools and swamps, and the other is a large group of species that breeds in clear forest streams. In the Hill Zone of the Study Area the latter group dominates (Table 4).

Although few data are available regarding the life spans of larvae in cool tropical streams, available studies indicate that development of odonate larvae in these streams is very long, lasting around 8-9 months (Corbet 1999). In the only available Melanesian example, Marchant and Yule (1996) found that damselfly larvae in an aseasonal stream at 750 m elevation on Bougainville Island had a larval span of around 250 days. Water quality is very important for odonate development in Hill-Zone streams.

5.1 Clear Mountain Streams

Clear, fast-flowing mountain streams (UTS; see Table 1) occur throughout the Study Area Hill Zone and were identified as important habitats at all 12 sites in this zone during the surveys. These streams and the dense riparian vegetation along their banks provide habitat for distinct assemblages of damselflies that rely on cool, clear streams for successful reproduction. Within these assemblages are nine new species of damselflies that were discovered during these surveys.

The structure and density of riparian vegetation associated with these streams is a crucial factor determining the species of odonates that are able to persist along them. For example, assemblages were often completely different in stretches of stream retaining dense overhanging riparian vegetation from those in more open sections of the same stream, and some genera, e.g. *Drepanosticta*, *Selysioneura*, preferred smaller shaded streams with complex understorey riparian vegetation while other species, e.g. *Cyanocnemis aureofrons and Huonia* spp, preferred streams with open understoreys and canopy gaps that allowed large sun patches to penetrate to the creek bed.

Although many of these species are likely to occur in Upland Torrential Streams of similar morphology (see Table 1) throughout the Study Area Hill Zone, these fast-flowing streams are an important habitat for an assemblage of odonates not known to date from any other area and they are identified as a noteworthy habitat requiring careful management during construction activities. It should also be noted that the streams and their immediately adjacent riparian vegetation cannot be considered in isolation. It was clear during this survey that many species move into the forest, onto nearby ridges or into nearby moist gullies, and protection of suitable buffer zones along streams deserves careful consideration.

6 CONCLUSIONS

This study is the first attempt to comprehensively document the odonate fauna within the Sepik River catchment, and the first study of an odonate assemblage across an entire upper catchment anywhere in New Guinea. It has substantially increased our knowledge of the odonate fauna of the Upper Sepik River Basin, documenting numerous new species and providing range extensions and new country records for a number of poorly known species.

The Study Area Hill Zone contained assemblages exhibiting the highest levels of habitat specificity, and hence susceptibility to habitat degradation. In particular, damselflies restricted to clear streams in closed forest may be most susceptible to habitat alteration. Although the Peat Forest at East Sepik Site is unique floristically (Chapter 2) it was unremarkable odonatologically. No species were documented only at that site, and all species found there are likely to have broad distributions in the lowlands of the Sepik River Basin.

Given the extensive areas of forest present in the Sepik River Basin, and the documentation during this study of a number of species previously known only from Papua Province in Indonesia, it is likely that most if not all of the new species discovered during these surveys have distributions that extend outside of the Study Area. Nonetheless it remains important to maintain these species in the Study Area.

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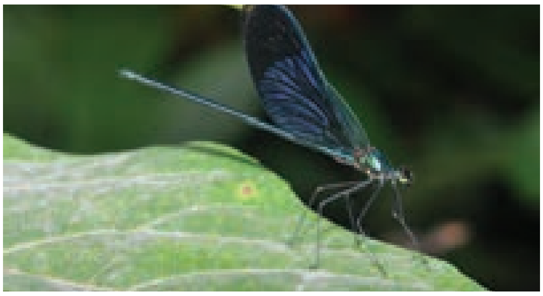
8 PLATES



Family Calopterygidae: *Neurobasis ianthinipennis*

Family Chlorocyphidae: *Rhinocypha tincta*

Family Coenagrionidae: *Archibasis crucigera*

Family Isostictidae: *Selysioneura capreola*

Family Megapodagrionidae: *Argiolestes* sp.

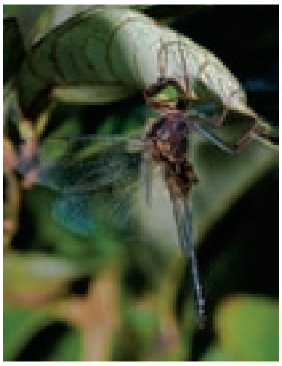
Family Platycnemididae: *Idiocnemis obliterata*

Family Platystictidae: *Drepanosticta clavata*

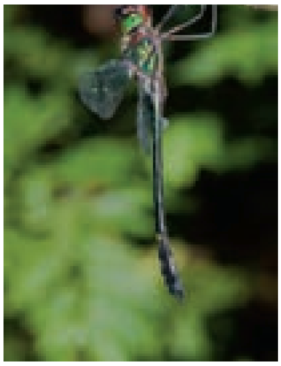
Family Protoneuridae: *Nososticta fonticola*

Plate 1. Damselflies

Family Aeshnidae:
Agyrtacantha microstigma



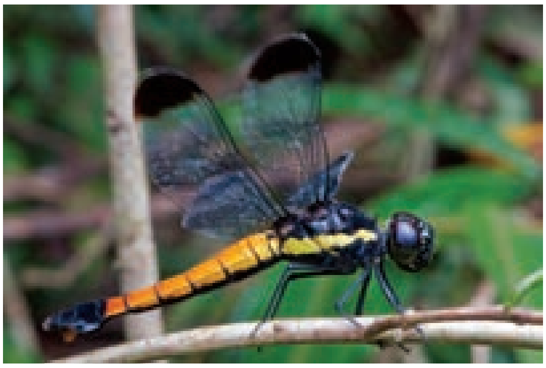
Family Corduliidae:
Metaphya tilyardi



Family Macromiidae:
Macromia melpomene

Family Gomphidae: *Ictinogomphus australis*

Family Libellulidae: *Huonia epinephele*



Family Libellulidae: *Protorthemis coronata*

Family Libellulidae: *Rhyothemis resplendens*

Plate 2. Dragonflies

CHAPTER 7 BUTTERFLIES (LEPIDOPTERA: RHOPALOCERA)

Chris J. Müller

A report prepared for Coffey Environments and
Frieda River Limited
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GLOSSARY

Androconial – hairs and/or scales on an insect's wings or body which are distinctly related to sexual reproduction, e.g., the production of pheremones.

Apical – the pointed end of a tapering structure in an insect, e.g., an insect's forewing tips.

Arboreal - living in, or restricted to, trees.

Cilia – hair-like scales, usually fringing the margin of an insects' wings.

Costal – the anterior (forward-facing) part of the wing in an insect (costa).

Crepuscular – active at dawn and/or dusk.

Instar – a stage in the development of a larva which is terminated by shedding of the skin. At the end of the final instar a larva will pupate.

Lepidoptera – Order (systematic large group) of insects comprising all the Butterflies and Moths.

Life histories – pertaining to the early (immature) stages, i.e., egg, larva and pupa.

Macro-species - large butterflies, generally belonging to the families Papilionidae and Nymphalidae, with wingspans greater than approximately 80mm.

Monophagous – feeding on only one type/species [of plant].

Monotypic – unique, comprising only one species.

Müllerian mimicry – describes a situation where two or more species have very similar warning or aposematic signals and both share genuine anti-predation attributes (e.g., being unpalatable).

Myrmecophagous – associated with and/or feeding upon ants.

Ocelli – eye-spots on a butterfly's wings. These are particularly pronounced in the subfamily Satyrinae.

Oviposit – to lay eggs.

Puparium – a shelter made from natural materials by a larva prior to pupation.

Rhopalocera – the suborder constituting all Butterflies (i.e., Lepidoptera, not including moths).

Setae – fine hairs on the external surface of a butterfly larva/pupa. Functions are various but apparently assist respiration.

Sex brand – specialised scent-dispersing scales grouped together on the male butterfly's wings. The arrangement commonly form intricate patterns which are highly diagnostic in several butterfly families, particularly Hesperiidae.

Sexually dimorphic – both male and female are morphologically very different in appearance, sometimes resembling separate species.

Thecline lycaenids – group of butterflies in family Lycaenidae, subfamily Theclinae.

Taxa – plural of taxon; a systematic division (e.g., a genus, species and a subspecies are separate taxa).

EXECUTIVE SUMMARY

1. Three hundred and fifty nine butterfly species were recorded during the terrestrial biodiversity assessment of the Study Area, two of which were also recorded in the literature from Frieda Strip. Such a compilation surpasses the total number of butterflies recorded from any other survey in New Guinea and is the first major butterfly survey of this biologically poorly known region. The species/effort curve for all sites approaches an asymptote, implying that the majority of species occurring in the Study Area were documented.

2. Sampling at Nena Base Site yielded the most species, with the least number recorded at HI Site/Ubiame Site and East Sepik Site. Conversely, HI Site/Ubiame Site boasted the highest endemicity ranking. A cluster analysis of the sites revealed that HI Site, together with Ubiame Site, is anomalous relative to other sites and that the grouping of sites reflects similarities in elevation, clearly defining the Study Area Lowland Zone, Study Area Hill Zone and Study Area Montane Zone.

3. Nine species appear to be new to science: *Chaetocneme* sp. 1, *Sabera* sp. 1, *Sabera* sp. 2, *Kobrona* sp. 1, *Philiris* sp. 1, *Candalides* sp. 1, *Mycalesis* sp. 1, *Mycalesis* sp. 2, *Taenaris* sp. 1. Additionally, one species of *Delias* (Pieridae) from Nena Base Site, three species of *Philiris* (Lycaenidae), one species of *Candalides* and a species of *Mycalesis* (Nymphalidae) are yet to be identified and may represent undescribed taxa. Comparison with type material of related species and possible mitochondrial gene sequencing is required before their status can be confirmed.

4. Four species, *Delias pulla* (Pieridae), *Hypochrysops calliphon*, *Philiris* cf. *elegans* (Lycaenidae) and *Mycalesis* cf. *arabella* (Nymphalidae) were recorded in PNG for the first time and a number of taxa recorded within the Study Area were previously only known from the type series. Numerous species were recorded from the Sepik River Basin for the first time. The hitherto unknown life histories of several butterfly species were discovered during the survey of the Study Area.

5. Three Birdwing Butterflies listed by both the IUCN Red data list and or the PNG *Fauna (Protection and Control)Act 1966* were recorded in the Study Area. *Ornithoptera goliath*, was present at Malia Site, Ok Isai Site and Wario Site and *O. paradisea* was observed at several sites in the northern part of the Study Area, including Kaugumi Site where the endangered *O. meridionalis* was also tentatively recorded. The latter species was previously recorded from Frieda Strip Site (Parsons, 1998). A fourth species *O. chimaera* may also occur. Together with the other two birdwing species occurring within the Study Area, *O. priamus* and *Troides oblongomaculatus*, all of these represent potentially economically viable species, which are ‘ranched’ by local communities elsewhere in PNG.

6. Nearly all survey sites support populations of species listed as other than Least Concern or protected under the PNG *Fauna (Protection and Control)Act 1966*.

1 INTRODUCTION

1.1 Butterflies in New Guinea

New Guinea boasts nearly 1,000 described butterfly species, of which approximately 840 are recorded from Papua New Guinea (PNG) (Tennent, 2006). High endemicity characterises the New Guinea butterfly fauna, including some spectacular radiations of closely related species (e.g., the genera *Delias* Hübner and *Philiris* Röber, which, combined, comprise nearly 25% of the total fauna). Several of these are cryptic, typical of tropical radiations (see Hajibabaei *et al*., 2006). New Guinea is home to the world's largest butterflies, the Birdwings (*Ornithoptera* Boisduval).

Such high diversity results from a complex interplay of equatorial landmass, dynamic geological evolution and climatic processes, leading to localised isolation for extended periods and resultant speciation. A range of interpretations for the geological evolution of mainland New Guinea have been proposed by various authors (e.g., Audley-Charles, 1981; Coleman & Packham, 1976; Davies, 1990, 2009; Davies *et al*., 1997; Pigram & Davies, 1987) but it is generally circumscribed to comprise a series of stacked volcanic terrains that have been successively accreted onto the northern margin of the Australian Plate, forming the New Guinea orogen (mountain range). The southern, relatively low-lying portion of the New Guinea mainland consists of uplifted basin strata that formed in the gulf between northern Australia and New Guinea following the initial orogenesis. Since there is great variation in topographic relief on the island of New Guinea, with high mountain ranges and peaks separated by deep extensive valleys, climatic fluctuations significantly affected the distribution of the island's fauna. Populations endured expansion and contraction of their ranges, promoted by glacial cycles which led to repeated isolation and in turn explosive speciation, whereby one species would give rise to a number of daughter species over a relatively short time frame. The Pleistocene period is believed to have been the primary time period for speciation but Müller & Beheregaray (unpublished) demonstrated that diversification within *Delias* was mostly of Pliocene age.

Distinct faunistic zones, marked by pronounced endemicity, are apparent for the many archipelagos within the New Guinea region (see Simpson, 1977) but are not so obvious on the mainland. However, both Eliot (1969) and Brooks (1950) noted that the New Guinea fauna could be grouped into four zones based on their independent studies of the butterfly tribe Neptini and genus *Taenaris*, respectively. They considered the northern zone to span an area from the southern part of Geelvink Bay eastwards to Madang, including the Sepik River Basin. More locally, a zone constituting the low-moderate elevations from the West Sepik through to Humboldt Bay, Papua Province, Indonesia, appears to be particularly important in the distribution of butterflies and is one which is relatively poorly known. The Study Area is of particular interest since it hosts a combination of intact Hill Forest (Hm) and Lowland Open Forest (Po) and Alluvial Wooded Swamp Complexes (Wsw/FsW).

Collections of butterflies in the region have been scant and have focused on the coastal plains and ranges which are now much deforested and disturbed from logging and plantation development. The earliest collection records appear to be those of Bernard Hagen, who collected butterflies in the vicinity of Aitape in 1893–95 during German administration. During 1938, Lucy Evelyn Cheesman collected around Aitape, the Torricellis and adjacent plains as well as near Wewak to the east (specimens at British Museum of Natural History and the South Australian Museum). Frank Henry Taylor collected arthropods of medical interest, along with some butterflies, from around Wewak while serving with the Australian army in WWII, and Trevor Hawkeswood collected butterflies near Wewak in 1989. William W. Brandt collected from the Torricelli Mountains and lowland sites near Aitape in the late 1950s. Further afield, Lucy Cheesman collected near Vanimo, Krisa and Mount Sowa (Asowa) to the west near the Dutch border, William Brandt collected from Angoram and Maprik in the lower Sepik River Basin in 1950, and Harrold Borch collected butterflies around Maprik, where he was based between 1969 and 1976. The Dutch entomologist Ramón Straatman travelled extensively throughout mainland PNG. In the 1960s, while employed by the Bishop Museum, he journeyed several hundred kilometres up the Sepik River, collecting at various localities along the way, to beyond the Study Area and along the Green River. To the west, L. J. Toxopeus and J. Olthof collected butterflies from around Jayapura and the Cyclops Mountains during the 1938–39 Archbold Expedition (Roepke 1955). Ornithologist Ernst Mayr had collected butterflies in the Cyclops Mountains in 1928. Frederick Dodd also collected at Wewak, Maprik and Lumi during 1962. Within the Central Cordillera, in the proximity of the Study Area, several collections have been made at/near Telefomin and Elliptamin by R. Straatman and Michael Parsons. David Beebe observed specimens of two *Ornithoptera* species at Frieda Strip (Parsons, 1998; M. J. Parsons *pers. comm.*, 2010). However, the details of such observations are not currently known.

1.2 The Study Area

The Frieda River Copper-Gold Project is located in north-west mainland PNG and covers a variety of terrains that support a wide range of habitats. Project infrastructure will traverse the Sandaun and East Sepik Provinces, fromthe location of copper and gold deposits in the northern hills of the Central Range north-east to the Sepik River.

The Study Area within which the butterfly surveys took place is defined in Chapter 1 and covers two major terrain features that are biogeographically distinct from one another (Beehler 2007; Mack and Dumbacher 2007): the north-central slopes of the Central Range and the upper Sepik River Basin.

The Study Area is divided into three Zones (see chapter 1 Figures 1 to 5) for the purposes of discussion: Lowland Zone, Hill Zone and Montane Zone. See Chapters 1 and 4 for further descriptions.

2 OBJECTIVES

The butterfly survey of the Study Area had multiple objectives, namely:

1. Collate and assess existing information relevant to butterfly (Lepidoptera: Rhopalocera) communities in the vicinity of the Study Area.

2. Survey butterfly communities present across the Study Area and provide expert advice on their status and conservation value with particular attention to:

    - new and rare and/or threatened species as listed on the IUCN Red data list or by the PNG *Fauna (Protection and Control)Act 1966,*

    - exotic pest species,

    - migratory species and

    - species of community/cultural significance (value).

3. Identify significant butterfly communities and habitats (e.g., microhabitats).

4. Report on the status of conservationally significant butterfly species recorded or potentially present within the Study Area, and on their habitat requirements and the viability and importance of existing populations in a local, regional and global context.

5. Discuss the susceptibility of the butterfly fauna and conservationally significant species to future developments of the Project.

6. Assist in the development of recommendations relevant to the protection of vulnerable taxa and/or communities.

This report details and discusses the results of surveys in relation to objectives 1 to 4 outlined above.

3 SURVEY SITES AND TIMING

The Project surveys were undertaken in four phases:

- Trip 1 – Nena Surveys: 29 November to 15 December 2009. The 2009 Nena Surveys were conducted from five locations in the headwaters of the Nena (Frieda River catchment) and Usake (May River catchment) rivers. The author was not involved with the Trip 1 surveys but surveyed Nena Base Site during Trip 2.

- Trip 2 – The mine and Frieda River areas: 1 February to 3 March 2010. The 2010 Trip 2 surveys were conducted from seven sites centred on the mine and Frieda River drainage in the Study Area Hill Zone. Surveys focused on the proposed open pit area and Koki, and other sites earmarked for development of associated logistics and infrastructure centres during the early stages of Project design. One site was surveyed in the Frieda River drainage. All of the Trip 2 survey sites were located within the Frieda River catchment.

- Trip 3 – Study Area Lowland Zone and Frieda River areas: 26 May to 20 June 2010. The 2010 Trip 3 surveys were conducted from one site in the Frieda River drainage and five sites in the Study Area Lowland Zone. Most sites were situated in the Frieda River catchment. Surveys of the Hauna area were conducted in the April River catchment.

- Trip 4 – Study Area Lowland Zone: 23 February to 16 March 2011. The 2011 Trip 4 surveys were conducted from three sites in the Study Area Lowland Zone in the Wario and Wogamush River catchments. Limited observations were also made from Frieda Airstrip (Frieda Strip Site).

Table 4 in Chapter 1 lists the survey dates, base co-ordinates and elevations covered at each of the survey sites during each of the survey periods. The location of each survey site is shown in Figures 4 and 5 in Chapter 1.

All biotic communities undergo marked changes in species composition with change in elevation and habitat. Survey sites were positioned to cover a representative sample of the elevations and the habitats present throughout the Study Area.

A complete tabulated outline of the Study Area sites is provided in Table 1. A brief description of each is provided below and Chapter 2 provides detailed habitat descriptions of all sites. Chapter 1 provides an overview of the vegetation nomenclature used subsequently in this butterfly report.

Nena Base Site (750 – 1,030 m)

Hill Forest (Hm) dominates at this site, which is the most species diverse habitat of all sites assessed. The uneven canopy representing a vast number of tree species attests to this (Chapter 2). Butterfly food plants of many plant families are abundant at Nena Base Site, e.g., Lauraceae, Rutaceae and Euphorbiaceae.

Steep gorges, with narrow, Upland Torrential Streams were ideal locations for butterfly flight paths. Many species were solely found in such situations. Some of the forest had been degraded between Trips 1 and 3, owing to the land clearing by locals in the vicinity of Nena Base Site.

Malia Site (225 – 400 m)

This site is situated next to an Upland Torrential Stream that exposed the contact between the Horse-Ivaal Granodiorite and adjacent volcanic. While surrounded by hills of significant elevation, the valley area in which the majority of the survey was carried out constituted the larger part of the survey (Plate 127). The entire valley is dissected by relatively fast flowing waterways.

The forest type is essentially Hill Forest (Hm) and at this site Laurels (*Litsea* sp. and *Cryptocarya* sp.), the food plants for the larvae of many butterflies, abound. Forest at this site is quite open on the floor and in several areas the canopy is only approximately 60% total coverage, allowing much sunlight to reach the ground. Many butterfly species were recorded in small clearings and observed feeding on rotten native fruits.

Koki Site (510 – 660 m)

The Koki Site is on a granodiorite outcrop cut by numerous fast-flowing streams and is characterised by Hill Forest (Hm), where epiphytes and mosses are very common, and vines are much less frequent. Ferns dominate at this site.

There are a series of old drill pads which had been variably obliterated by the regenerating forest. These clearings offered an ideal place to survey the butterfly fauna, as did the heli pad close to Koki Site camp itself, which was next to an Upland Torrential Stream. A significant number of species were observed in riparian vegetation tracts along the margins of Upland Torrential Streams and nowhere else.

HI Site (610 – 1,305 m)

Possibly the most variable in terms of forest types, this site is Hill Forest (Hm), broken by large tracts of secondary growth on very steep gradients. This includes largely impenetrable bamboo thickets. This latter forest type is exceptionally interesting in its uniqueness and appears to be natural, forming its own micro-habitat. It is more typical of the Lower Montane Forest (L ± c) described in Chapter 2.

Survey traverses were completed to the top of the proposed open pit, where cliffs in marbilised limestone and associated caves outcrop (Plate 129). One knoll at 1300m was surveyed and is dominated by Heath (Plate 130), including *Cypress* sp. (Cupressaceae). This vegetation type, although characterised by stunted trees with hardened trunks and branches, is included under Lower Montane Forest (L ± c).

Frieda Bend Site (65 – 150 m)

Flooded Lowland Open Forest (Po) and Alluvial Wooded Swamp Complexes (Wsw/FsW) dominates this site for the most part and the understorey is characteristically very open and dominated by palms (Arecaceae). The forest changes facies dramatically over short transects, with Lowland Open Forest (Po) meeting the flooded Riverine Mixed Successions (Fri/Wri) then finally the river banks, bordered by tussock grass. The Frieda River runs through this site and was a means to access proximal areas (Plate 132).

Upper Ok Binai Site (325 – 575 m)

This site is positioned in an area of moderate gradient and is dominated by Hill Forest (Hm). The number of suitable localities for surveying butterflies was rather limited, as there were relatively few clearings. Additionally, poor weather prevailed at this site when it was assessed during Trip 2. Much of the survey work was conducted along both Upland Torrential and Upland Low-gradient Streams, where butterflies followed regular pathways. Sandy banks of these stream types were an opportune environment to observe adults of various species drinking.

Ok Isai Site (100 – 145 m)

Dominated by Lowland Open Forest (Po) and Hill Forest (Hm), this locality is characterised by vast areas of standing water. In the lower parts it is represented by Lowland Open Forest (Po) with a very wet floor, which meets with the Frieda River. The latter vegetation type, in particular, is canopy-species poor

(Chapter 2). Conversely, the understory growth is quite diverse and extensive and is characterised by many grass species (food plants for many species of Hesperiidae and Nymphalidae). This extensive undergrowth is possibly prolific due to the open canopy and increased sunlight.

Kaugumi Site (60 – 90 m)

This site is characterised by Alluvial Wooded Swamp Complexes (Wsw/FsW), being essentially a mosaic of the different forest types (Chapter 2). Some areas are dominated by sago palm, with only few understory plants. Large tracts of secondary forest abound at this site, as do areas largely devoid of vegetation and floored with thick mud. Such areas were sun glades where butterflies commonly congregated.

At Kaugumi Site, many *Aristolochia* (Aristolochiaceae) vines were located, especially close to the camp site. These are the food plants for the *Ornithoptera* species. Butterfly food plants recorded commonly at Kaugumi Site included *Pometia*, *Macaranga* and many species of vines, e.g., *Derris* and *Mucuna*.

East Sepik Site (35 – 55 m)

Probably the most anomalous habitat encountered during the survey of the Study Area, the drill pad/ camp area and surrounds are situated within a Peat Forest, which is remarkably depauperate. The very few canopy plant species present are dominated by *Tetramerista*, *Calophyllum* and *Garcinia* sp. While a dense understory of *Freycinetia* (Pandanaceae) is ubiquitous, the mid/shrub layers are virtually empty and epiphytes are non-existant.

Bore hole 317XC09G drilled by revealed a peat depth of more than 28 m, which overlies a thick sequence of alluvials. There are no waterways at the surface, since there is no drainage. The water table is stilted (elevated relative to surrounding areas). At this site there is very little in the way of open spaces and sunlit clearings. Therefore, there was little chance for butterflies to congregate in specific areas.

Iniok Site (35 – 50 m)

The vegetation at Iniok Site are dominated by Riverine Mixed Successions (Fri/Wri) which are more susceptible to seasonal flooding and changes in the watercourse. Hence the forest at and proximal to this site is essentially secondary. Convoluted meandering sequences and scrolls are apparent at Iniok, with sharp contrast between various vegetation facies. Indeed, narrow tracts of Gallery Forest with tall trees are interspersed by grassy areas.

For the most part, trees are of limited height and dominated by *Ficus*, *Trichospermum* and *Glochidion* sp. The understorey is essentially of monocot composition, with palms, gingers and sedges (e.g., *Rhyncospora* sp.) most abundant. High diversity of vines (butterfly larval food plants) (e.g., *Derris*, *Mucuna*, *Zanonia* sp.) was also noted at Iniok Site.

Frieda Base Site (390 – 515 m)

Hill Forest (Hm) is most prevalent at Frieda Base Site, which is in relatively hilly granodioritic terrain. One of the dominant tree species is *Euodia* sp. (Rutaceae), the flowers of which are very attractive to butterflies. At times, more than a dozen species could be observed in the crown of a single tree. Most of the survey work conducted at this site focused around the camp with several outings upstream along the main river.

As a result of localised clearing for the camp, as well as proximal historic drill sites, regrowth vegetation at Frieda Base Site is ubiquitous and supports high densities of butterflies. Of particular interest from a sampling perspective were open areas above narrow, fast-flowing Upland Torrential Streams. These provided vantage points for adult males within their territories, which they vigorously defended from elevated perches.

Frieda Strip Site (60 m)

Riverine Mixed Successions (Fri/Wri) and Lowland Open Forest (Po) dominate this low-lying site, which essentially overlies alluvial fan sediments. The habitats are typical alluvial, characterised by low growing vegetation owing to the continual change in river geomorphology and repeated flooding. Tall tussock grasses are prevalent along the margins of the forest and the river banks. Within the forest the understorey is dominated by monocotyledons, especially gingers (Zingiberaceae) and lawyer palms (Arecaceae), many of which are climbers. Many different invasive plant species occur at this site and these have exploited the cleared areas, in particular close to the airstrip facilities.

Very limited time was spent at this transit locality. All observations were made within 300 m of the airstrip structures, in open/semi-open areas.

Ubiame Site (1,360 – 1,385 m)

The steep spine ridges at Ubiame Site are characterised by heath typical of much higher elevations (W. Takeuchi, *pers. comm.*, 2010). This locality was not assessed in Chapter 2 but is similar to the knoll at ~1,300 m above HI Site, characterised as Lower Montane Forest (L ± c). The maximum height of trees on the uppermost part of the ridgeline is about 8 metres. Thick moss blankets are water saturated. A rudimentary camp was established for a brief survey of the repeater station and surrounds. The ridges are rather open but the valleys are dark and densely forested. Mt. Stolle (Western Province) can be seen to the south from the Ubiame Site summit (Plate 131).

Wario Site (40 - 335 m)

Wario Site is situated within a diversity of vegetation types. Along the banks of the Wario River, where Nekiei Village is located, a combination of both Riverine Mixed Successions (Fri/Wri) and Lowland Open Forest (Po) predominates and there are localised embayments of Mixed Swamp Forest (Fsw). A network of tracks from Nekiei Village allowed easy access to these low-lying habitats. These vegetation types rapidly give way to Hill Forest (Hm) with elevation. To the south-east of the Wario Site Camp a rather isolated volcanic ridge reaches c. 450 m and several butterfly species were recorded in small clearings along the top of the ridge where gaps in the canopy had been created by falling trees.

Wogamush Site (45 - 120 m)

This site represented an isolated low elevation ridge, dominated by Hill Forest (Hm) amid a great expanse of Alluvial Wooded Swamp Complexes (Wsw/FsW), representing combinations of variably sago dominated swamp, which was for the most part inundated. A large lake to the south-east of the survey site is evidently broadly rimmed by permanently flooded Herbaceous Swamp (Hsw), dominated by tall sedges and water lilies. Owing to the risk of crocodile presence, inaccessibility and the very low butterfly diversity of such habitats, this vegetation type was not surveyed.

Although wide ranging transects were conducted throughout the site area, in a variety of habitats, the majority of time was spent along the main ridge at Wogamush Site. Abundant open clearings along the ridge and steep ravines allowed detailed observations of many butterfly species. In the latter case, adult butterflies could be observed in the canopy from vantage points along the ridge top.

Kubkain Site (30 - 135 m)

Kubkain Site is a low isolated hill that supports mostly regrowth Hill Forest (Hm) and is surrounded by Alluvial Wooded Swamp Complexes (Wsw/FsW), as well as Riverine Mixed Successions (Fri/Wri) manifested as scrolls close to the Sepik River. At the interface of the Hill Forest (Hm) and the Alluvial Wooded Swamp Complexes (Wsw/FsW) there is a narrow band of monocot dominant vegetation, particularly rich in *Calamus* palms and Cordylines, notable foodplant genera for many butterflies in the families Hesperiidae and Nymphalidae.

The main hill at Kubkain Site is ideal for hill-topping butterflies, being steep, isolated and fairly open at its summit. Numerous adult male butterfly species were present in this environment, often flying and settling only at the tops of the tallest trees. For the most part, each species appeared, sometimes in numbers, for only fairly short periods. Some species, especially of the subfamily Riodinidae, persisted until dark.

Ok Binai 1 Site (115 - 330 m)

This site is dominated by Hill Forest (Hm) with intergrades to Lowland Open Forest (Po). The former is similar compositionally to Ok Isai Site. Riverine habitat, specifically Riparian Forest, is common along the Ok Binai and its tributaries and extensive build up of sediment along the river bank provided ideal places for butterflies to drink. A well established track which evidently connects Ok Isai Village with Telefomin and another with Frieda Strip enabled surveying through each of the habitats. The camp area used at Ok Binai 1 Site is cleared and supports a grassy habitat.

Several short, steep hills surrounding the site appeared to be potential sites for hill-topping butterflies but the majority of trees along the ridge summits were felled, apparently during high winds in October, 2010 (J. Jones, *pers. comm.*, 2011). Many other ridge tops in the area had been degraded similarly. The hill tops examined were rather devoid of butterflies, since there was no suitable perches or shelter, although surveying was impeded with the difficulty of accessing the damaged, log-ridden landscape.

Table 1. Conservation classifications used by the PNG Fauna (Protection and Control)*Act 1966* and IUCN.

PNG FAUNA (PROTECTION AND CONTROL) ACT 1966	
Protected (P)	Taxa declared protected.
IUCN*	
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.
Least Concern (LC)	Does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Abridged. For a detailed explanation see IUCN. (2001). IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp. (http://www.iucnredlist.org/technical-documents/categories-and-criteria).

4 METHODS

4.1 Transects

Surveying was carried out along transects, some of which were pre-cut, while others were constructed ad-hoc. Other transects were designed to follow natural features, e.g., along streams and ridges. In particular, males of many butterfly species will congregate at the tops of hills or in open areas above fast-flowing streams, so such habitats were of much focus during the survey.

Some minor clearing of more open glades in the forest was sometimes necessary to optimise the area exploited by sun-loving insects. However, effort was made so as not to bias-sample either closed or more open forest. Additionally, surveying of as many micro-habitats as possible was conducted.

Butterflies were searched for along the transects and either identified visually or collected by long handled nets for identification later. A significant proportion of butterflies, especially the larger species, are readily identified visually, often with the assistance of image stabiliser binoculars. Where identification was not certain in the field, e.g., for cryptic, less easily discernible species, or for taxa of scientific value, voucher specimens were collected for identification. One or two local assistants, aided with butterfly nets, assisted at most sites and collected samples randomly. In nearly all cases the specimens were released following identification. At all survey sites, the maximum amount of daylight time was used for field surveying. Adult butterflies are mostly reliant on strong sunshine and are most active between 1100 and 1500 hours. However, many species, especially thecline lycaenids, are most prevalent during the late afternoon, often flying as late as 1800 hours. Other species, particularly those of the genera *Chaetocneme* C. Felder (Hesperiidae), *Melanitis* Fabricius (Nymphalidae) and *Liphyra* Westwood (Lycaenidae) are crepuscular. Very few butterfly species are active before 0900 hours in closed-canopy tropical forests. Considering the above, surveying was conducted daily from 0800 hours or earlier, usually returning to base camp at 1800 hours. The adults of nearly all butterfly species will fly only during periods of full sunshine, therefore sampling was impeded significantly by persistent poor weather conditions at many sites, particularly during Trip 2. During periods of heavy rain when butterfly activity was negligible, a greater focus was paid to searching for the early stages (eggs, larvae and pupae) of resident butterflies and recording their ecologies and larval food plants.

Long-handled nets were also employed to collect specimens of the more elusive arboreal, canopy-dwelling species (see Plate 128). Searching for the early stages of butterflies was done so with an existing knowledge of larval food plants or with correlation to those used by related species occurring in tropical Australia, Indonesia and the Solomon Islands. Where possible, or worthy of record, both adults and early stages were photographed live. Most photographs were taken by the author, although many, particularly those of close-up early stages were photographed by S. J. Richards. W. Takeuchi kindly assisted with larval food plant identifications.

Selected samples were stored in glassine envelopes with the preservatives paradichlorobenzene and chloro-m-chresol. Two legs were stored separately as tissue samples for potential DNA sequence analysis.

4.2 Bait Traps

4.2.1 Urine Bait

Freshly emerged adult males of many butterfly species will imbibe mammal urine that has soaked into sand and congregations representing numerous species are common in the Indo-Pacific tropics. The reasons are not fully understood but it is possible that the male genitalia require maturing/hardening and salt may facilitate this. Another theory is that the sodium uptake improves reproductive success, as males transfer the sodium and amino acids to the females together with the spermatophere during mating

(Khew, 2010).

A number of species, representing all families, were attracted to urine baits placed at irregular intervals along the banks of streams during the survey of the Study Area (see Plates 28, 29, 41 - 43, 45, 46, 59, 76, 79, 80, 106, 106, 108, 116, 125). This was most obvious at lower elevation sites. In such situations, adults can generally be approached closely allowing reliable identification. Table 2 outlines the total number of urine baits for each surveyed site.

4.2.2 Fruit Baits

Fermented pineapple, banana and pawpaw are ideal for attracting nymphaline butterflies, particularly in the subfamilies Amathusiinae and Satyrinae (see Plate 92, 98, 102, 114). Fruit baits were stored for three days in air-tight plastic bags and, once rotten, placed at various intervals above the forest floor, from the ground up to 10 m. At Wogamush Site, certain species (e.g., *Taenaris dina*) were exclusively attracted to the baits and not observed elsewhere during the survey of the Study Area. Table 2 outlines the total number of fruit baits for each surveyed site.

4.2.3 Paper Lures

Many hesperiid (Skipper Butterflies) adults, and some butterflies of the families Lycaenidae and Nymphalidae, imbibe moisture and presumably nutrients from bird droppings. Therefore, paper cut roughly circular to imitate excrement, was placed at regular intervals on the uppersides of leaves in various micro-habitats (see Plates 10, 15, 23, 25). Once attracted the adults would generally 'feed' for long periods, such that twice daily checks were adequate. Several poorly known hesperiids recorded during Trips 2, 3 and 4 surveys were taken only at paper lures. Table 2 outlines the total number of paper lure baits for each surveyed site. Note that each individual bait contained approximately 10 pieces of paper.

4.3 Analysis

The global conservation status of all species was taken from the 2011 International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (IUCN 2011). IUCN conservation categories rank the relative risk of individual taxa becoming extinct in the wild based on a set of standardised criteria. These categories and the conservation classifications under the PNG *Fauna (Protection & Control)Act 1966* are shown in Table 1.

Nomenclature in this report follows that of Hancock (1983), Sands (1986), Yagashita *et al*. (1993), Parsons (1998), Vane-Wright and de Jong (2003), Wahlberg *et al*. (2009) and Müller & Beheregaray (unpubl.). Voucher specimens will be deposited in the National Insect Collection (Port Moresby), the Australian National Insect Collection (Canberra), the Natural History Museum (London) and the Macquarie University Entomological Collection (Sydney).

Note that only a few butterflies in New Guinea have common names and therefore this report generally uses standard scientific names.

Statistical methods follow those described in Kattan *et al.* (2006). Survey sites were clustered according to similarity in species composition by means of a hierarchical (agglomerative) cluster analysis generated from the presence/absence data using the centroid method and Jaccard's similarity index using the SPSS (Statistical Package for the Social Sciences) version 12.0 statistical package.

4.4 Important Note: Hill-Topping

In the following discussion it is important to understand the phenomenon of butterflies “hill-topping”. Hill-topping behaviour is still relatively poorly understood, although it presumably assists in the reproduction of certain butterflies which otherwise occur in low density throughout the forest.

Male butterflies will spend much of their adult lives establishing and guarding territories atop mountains/hills awaiting females. When the females emerge, they ascend the spurs and ridges and upon reaching the summit, they are quickly found by males of the same species and mated. Once fertilised, they then return down the slopes where they search for oviposition sites. Without the concentration of both sexes in small, specific areas, the chances of male and female butterflies coming into contact would be much more remote. This concentration of adults appears to be compounded temporally as well. Where there are more than one closely related species utilising a particular hilltop, each species will appear for short, non-overlapping periods of less than one hour, before being replaced by another. This behaviour is presumed to maintain isolation between species (Müller *et al*., 2010).

5 RESULTS

The sample effort over all surveys is given in Table 2. All butterfly species recorded are listed in Appendix 7.1. Elevation ranges and endemicity ranking and habitat preferences are presented in Appendices 7.2 and 7.3 respectively.

Table 2. Study Area survey sites and total sampling effort.

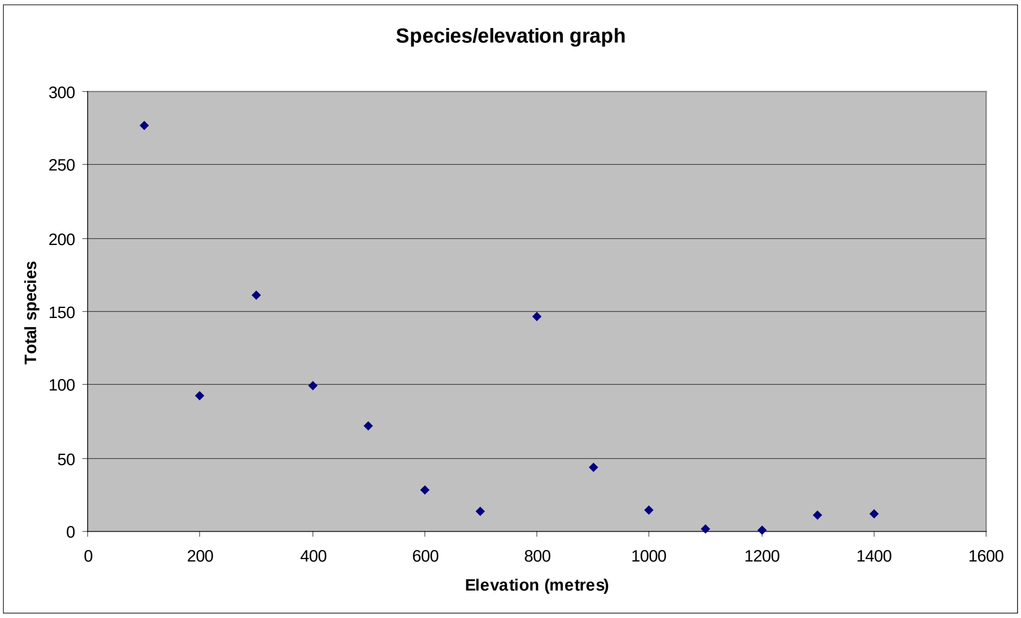
LOCATION	BAIT TRAPS (TOTAL NUMBER)			TOTAL EFFORT (MAN HOURS)
	URINE	FRUIT	PAPER LURES	
Nena Base Site	9	7	51	25
Malia Site	31	15	65	114
Koki Site	5	6	41	80
Frieda Base Site	5	-	23	13
HI Site	12	20	55	102
Ubiame Site	2	-	3	6
Upper Ok Binai Site	18	13	34	100
Frieda Bend Site	25	19	47	98
Ok Isai Site	22	16	68	108
Kaugumi Site	20	16	55	100
East Sepik Site	12	6	20	44
Iniok Site	17	11	41	92
Wario Site	18	-	43	68
Wogamush Site	4	15	58	90
Kubkain Site	13	15	74	92
Ok Binai 1 Site	28	12	45	60
Frieda Strip Site	4	-	7	11
Totals	245	171	730	1203

5.1 Species Inventory

A total of 359 butterfly species were recorded during the survey. This diversity greatly exceeds that documented for surveys in recent times of Rhopalocera in the region. An indepth study of the butterflies of the Lake Hargy Caldera and Hargy Oil Palm sites, West New Britain, revealed a total of 74 species (D. Miller, *pers. comm.*, 2010) and another in the Waria Valley, Morobe Province yielded 102 species (Dawson *et al*., 2009).

Nena Base Site yielded the most species (145), followed by Kubkain Site (140) and Malia Site (135). The fewest species were recorded at Ubiame Site (14), which was sampled only briefly (Section 5.2), as well as HI Site and East Sepik Site (36 and 38 species, respectively) (Table 3). The best represented butterfly families were Lycaenidae, with 138 (38.4%) and Nymphalidae with 98 (27.3%) species. This is close to the proportions of each family across New Guinea as a whole, with 39% Lycaenidae and 23% Nymphalidae (Parsons 1998). Representatives of all butterfly subfamilies known from PNG were recorded during this survey. A significant number of species, particularly in the subfamily Lycaeninae, were recorded only from single sites (Table 3 and Table 4). 50.0% of all butterfly species recorded at Ubiame Site and 16.7% at HI Site were located nowhere else during this survey.

Figure 1 (species/elevation graph) and Appendix 7.2 (elevation records) show that species number drops markedly above 400 m elevation. An exception is the Nena Base Site anomaly at 700 – 800 m, where



Note that elevation records are rounded up in 100 m increments. For example, all records between 0 and 100m are plotted at 100 m.

Figure 1. Total number of butterfly species versus elevation.

145 species were recorded, which is at odds with the trend showing species diversity decreasing with elevation (Figure 1). Although more exaggerated in the Study Area, a similar trend exists for butterflies overall in New Guinea (Parsons, 1998). Several species more typical of higher elevations (e.g., *P. laglazei*, *P. melusine*) were recorded at lower elevations, corresponding with observations made by other members of the team (e.g., for frogs and plants).

It appears that mountains below approximately 900 m can act as sites for hill-topping species, whereas above this elevation, the mountain and ridge tops are sites for flight pathways only. Conversely, those species (for the most part) recorded at both upper elevation sites at HI Site and at Ubiame Site are typical of taxa of mid-high montane areas that are fairly widespread within the Central Cordillera and are undoubtedly residents.

Three species were not identified with certainty, namely *Hypochrysops* sp. (probably *cleonides*) (specimen extensively worn), *Telicota* sp. (not collected) and *Philiris* sp. (probably *innotata*) (single female; females of several Philiris species are difficult to separate). Nine species appear to be new to science. A further six species (*Delias* cf. *eudiabolas, Philiris* cf. *elegans*, *P. cf. argentea, P. cf. putih, Candalides* cf. *margarita* and *Mycalesis cf. arabella*) appear to represent geographical variation and are here recorded from generally well outside their known range. It is possible, though considered unlikely, that they represent species new to science.

Table 3. Numbers of butterfly species in each survey site of the Study Area.

(SUB) FAMILY	NENA BASE SITE	MALIA SITE	KOKI SITE	HI SITE	FRIEDA BEND SITE	UPPER OK BINAI SITE	OK ISAI SITE	KAUGUMI SITE	EAST SEPIK SITE	INIOK SITE	WARIO SITE	WOGAMUSH SITE	KUBKAIN SITE	OK BINAI 1 SITE	FRIEDA BASE SITE	FRIEDA STRIP SITE	UBIAME SITE
Pyrginae	3	4	1	1	2	0	3	4	1	2	3	3	4	4	2	2	0
Coeliadinae	2	4	1	0	1	0	5	3	3	1	2	1	5	3	2	0	0
Trapezitinae	1	0	1	0	1	0	0	1	0	1	1	1	2	1	1	0	1
Hesperiinae	13	15	5	4	13	2	11	6	3	15	5	6	29	12	8	6	0
Papilioninae	9	14	5	5	10	6	12	14	6	2	14	12	10	11	11	11	1
Coliadinae	2	4	1	1	3	3	4	3	0	0	4	0	2	4	3	3	0
Pierinae	7	8	6	3	2	1	2	3	1	3	4	5	3	4	2	2	3
Riodininae	2	3	2	1	1	0	0	2	1	3	0	2	3	1	1	0	0
Curetinae	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Lycaeninae	53	34	26	10	33	14	26	25	8	24	37	28	37	27	23	6	4
Libytheinae	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0
Ithomiinae	1	1	0	1	1	0	1	0	0	0	1	0	0	1	1	0	0
Danainae	3	3	0	1	5	2	4	4	1	6	6	7	9	5	2	7	0
Morphinae	6	5	1	4	6	4	7	8	4	2	4	7	5	6	2	1	1
Satyrinae	15	14	6	2	13	9	9	8	3	7	10	8	14	12	9	5	3
Charaxinae	3	3	0	0	3	2	2	2	0	0	1	2	1	2	2	0	0
Apaturinae	2	3	1	0	1	1	1	0	0	1	2	1	1	1	3	2	0
Nymphalinae	21	19	9	3	16	15	16	18	5	4	18	13	14	18	13	11	0
Acraeini	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Total Species	**145**	**135**	**65**	**36**	**111**	**59**	**105**	**101**	**38**	**72**	**113**	**97**	**140**	**112**	**85**	**57**	**14**

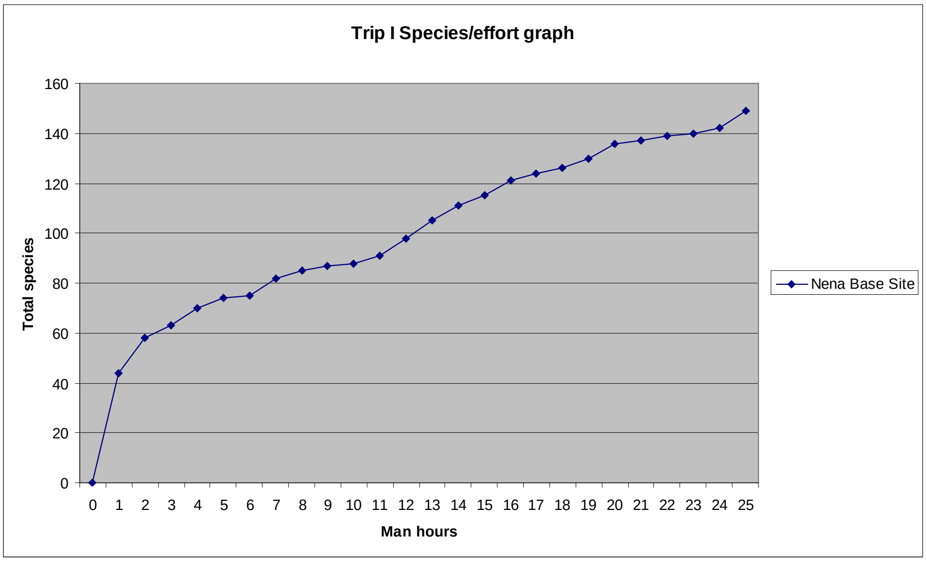
Notes: Entries are numbers of species.

Table 4. Numbers of butterfly species recorded from only one survey site within the Study Area.

(SUB) FAMILY	NENA BASE SITE	MALIA SITE	KOKI SITE	HI SITE	FRIEDA BEND SITE	UPPER OK BINAI SITE	OK ISAI SITE	KAUGUMI SITE	EAST SEPIK SITE	INIOK SITE	WARIO SITE	WOGAMUSH SITE	KUBKAIN SITE	OK BINAI 1 SITE	FRIEDA BASE SITE	FRIEDA STRIP SITE	UBIAME SITE
Pyrginae	-	1	1	-	-	-	-	1	-	-					-	-	-
Coeliadinae	-	-	-	-	-	-	-	-	-	-					-	-	-
Trapezitinae	-	-	-	-	-	-	-	-	-	-					-	-	1
Hesperiinae	3	6	-	1	1	-	1	1	-	2	1	-	9	1	-	1	-
Papilioninae	-	1	-	1	-	-	-	1	-	-					-	-	-
Coliadinae	-	-	-	-	-	1	-	-	-	-					-	-	-
Pierinae	1	2	-	-	-	-	-	-	-	-					-	-	2
Riodininae	-	-	-	-	-	-	-	-	-	-					-	-	-
Curetinae	-	-	-	-	-	-	-	-	-	-					-	-	-
Lycaeninae	8	6	4	3	3	-	1	1	-	1	2	1	6	-	3	1	2
Libytheinae	-	-	-	-	-	-	-	-	-	-					-	-	-
Ithomiinae	-	-	-	1	-	-	-	-	-	-					-	-	-
Danainae	-	-	-	-	-	-	-	-	-	-					-	3	-
Morphinae	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-
Satyrinae	1	-	-	-	-	-	-	-	1	1					-	-	2
Charaxinae	-	-	-	-	-	-	-	-	-	-					-	-	-
Apaturinae	-	-	-	-	-	-	-	-	-	-					1	-	-
Nymphalinae	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-
Acraeini	-	-	-	-	-	-	-	-	-	-					-	-	-
Totals	**13**	**17**	**5**	**6**	**4**	**1**	**2**	**4**	**1**	**4**	**4**	**2**	**17**	**1**	**5**	**6**	**7**
Total Sp. (Site)	**145**	**135**	**65**	**36**	**111**	**59**	**105**	**101**	**38**	**72**	**113**	**97**	**140**	**112**	**85**	**57**	**14**
% of total species	**8.7**	**12.6**	**7.7**	**16.7**	**3.6**	**1.7**	**1.9**	**4.0**	**2.6**	**5.6**	**3.5**	**2.1**	**12.1**	**0.9**	**5.9**	**10.5**	**50.0**

5.2 Species Effort Curves

Species inventories from each of the sites were compiled cumulatively on an approximately hourly basis and plotted against time (Figures 2 to 4). While survey durations were similar at most sites, Frieda Strip Site and Frieda Base Site were sampled for less time, since they were assessed primarily during transit periods. Only a total of six daylight hours were spent at Ubiame. Also, the poor weather at HI Site and Koki Site hindered survey efforts so the totals were reduced at these sites.



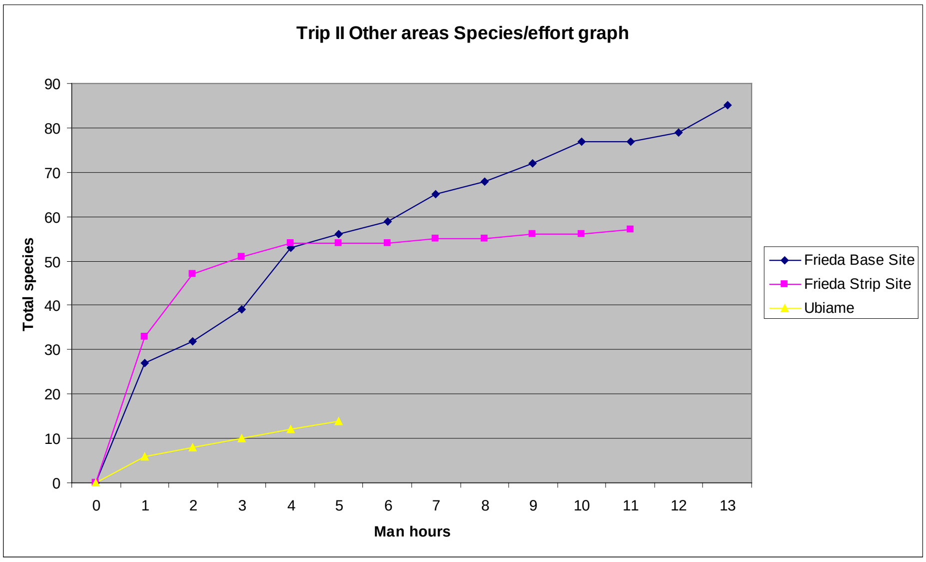
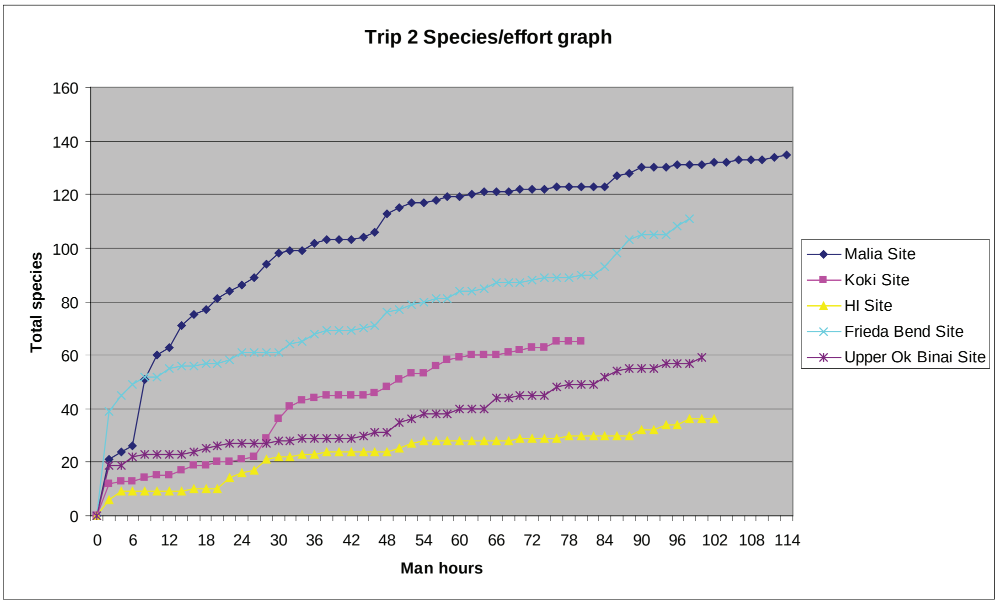


Figure 2. Species effort curves I

An asymptote was nearly achieved in the species/effort curve for Malia Site, Koki Site, HI Site, Frieda Strip Site, Wario Site and Ok Binai 1 Site, suggesting that the inventory was approaching completion. Noteworthy examples of where the inverse applied include Nena Base Site, Frieda Bend Site, Frieda Base Site and Kubkain Site. Overall, when all survey sites were plotted as a cumulative total, the species/ effort curve appears to be approaching an asymptote, suggesting that by far the majority of species occurring in the Study Area were documented.



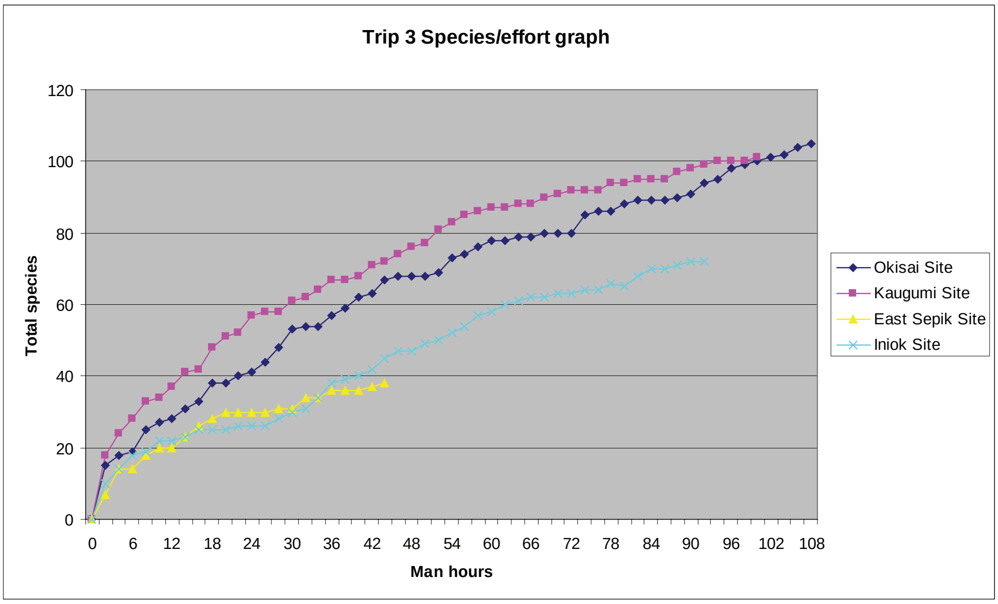
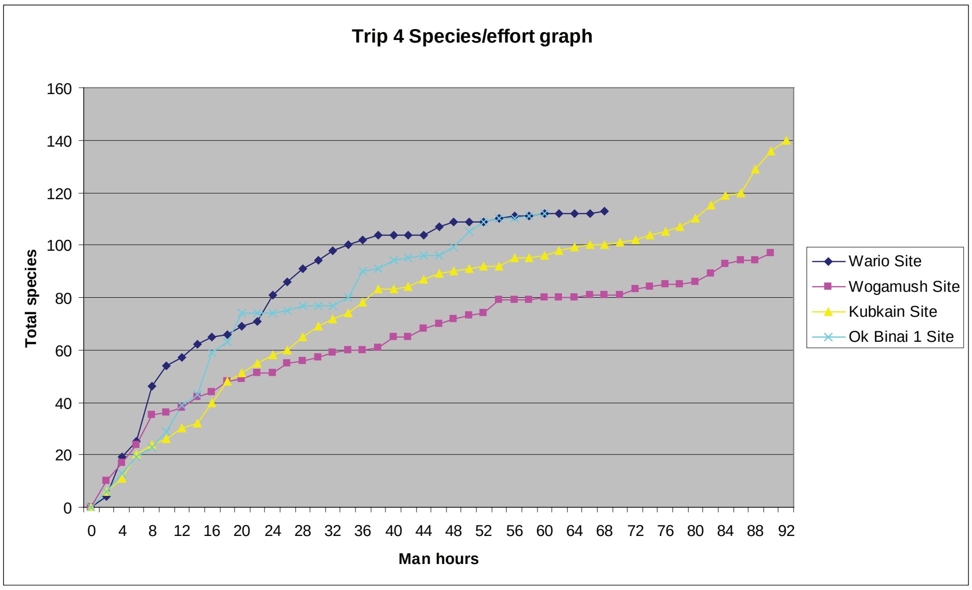


Figure 3. Species effort curves II.



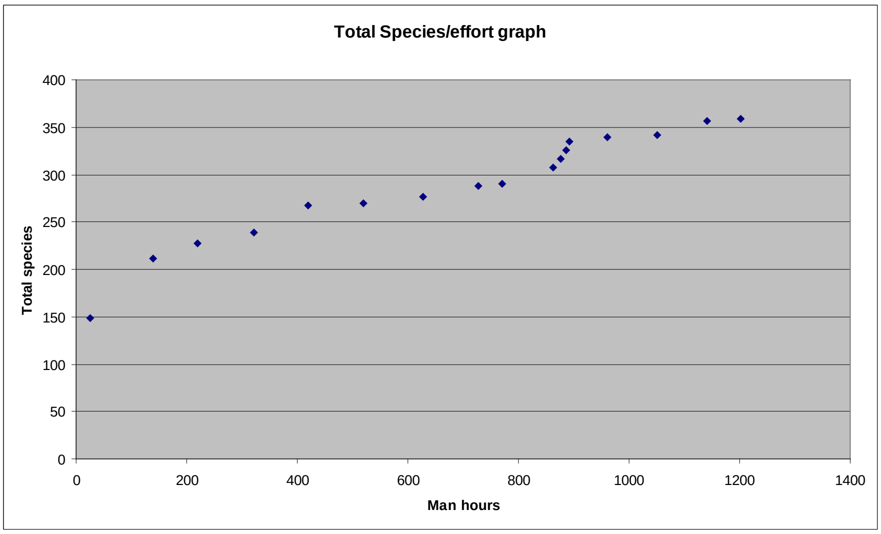


Figure 4. Species effort curves III.

5.3 Species Abundance

Species abundance was estimated at each survey site by recording the mean duration between sightings of individuals of each species (Appendix 7.1) on the basis that the more common the species the more frequently it would be encountered.

Abundance was graded as follows:

- Grade 5 - very high density with sighting less than two hours apart.
- Grade 4 - high density with sightings two to six hours apart.
- Grade 3 - medium density with sightings six to 12 hours apart.
- Grade 2 - Low density with sightings 15 to 32 hours apart and
- Grade 1 - Very low density with sightings > 32 hours apart

The abundance of each species was relatively consistent where they were recorded and species that were reported as high density were generally widespread between the sites.

5.4 Species Endemism

Each site was accorded an endemicity score based on the percentage of species with scores of either four or five at each site.

6 Narrow endemic to the Telefomin region

5 Endemic to northern mainland New Guinea, north of the Central Cordillera

4 Endemic to mainland New Guinea

3 Endemic to New Guinea and its satellite islands (Waigeo, Misol, Yapen, Biak, Aru, d'Entrecasteaux and Louisiades islands)

2 Endemic to New Guinea, its satellite islands, the Bismarcks and Maluku islands

1 Occurs more widely in the Indo-Pacific

Levels of endemicity at each site were calculated and are summarised in Table 5 (site endemicity) and Appendix 7.2 (endemicity ranking).

Table 5. Butterfly endemicity levels at each site

ENDEMICITY	NENA BASE SITE	MALIA SITE	KOKI SITE	HI SITE	FRIEDA BEND SITE	UPPER OK BINAI SITE	OK ISAI SITE	KAUGUMI SITE	EAST SEPIK SITE	INIOK SITE	WARIO SITE	WOGAMUSH SITE	KUBKAIN SITE	OK BINAI 1 SITE	FRIEDA BASE SITE	FRIEDA STRIP SITE	UBIAME SITE
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	5	4	3	3	0	2	3	0	1	3	2	2	2	3	2	0	1
4	24	14	9	18	10	4	7	9	2	7	10	6	17	12	2	2	8
3	26	27	14	4	23	13	17	21	4	20	21	26	30	19	11	4	2
2	28	23	9	8	19	15	21	19	7	10	16	12	25	24	16	9	1
1	66	67	30	13	59	25	57	52	22	32	65	51	66	54	54	40	2
Total species	**149**	**135**	**65**	**36**	**111**	**59**	**105**	**101**	**38**	**72**	**113**	**97**	**140**	**112**	**85**	**57**	**14**
Endemicity score*	**19.5**	**13.3**	**18.5**	**58.3**	**9.0**	**10.2**	**9.5**	**8.9**	**8.3**	**13.9**	**10.6**	**8.2**	**13.6**	**13.4**	**4.7**	**3.6**	**64.3**

Notes: Entries are numbers of species. Endemicity rating: see text. Species of butterflies new to science scored as "5".

* percent of species scoring 4 or more.

Endemism at each site was scored as the % of species scoring 4 or more on the above scale. It was most pronounced at Ubiame Site (64.3%) and HI Site (58.3%). The low elevation sites Frieda Strip Site, Frieda Base Site and Wogamush Site scored 3.6%, 4.7% and 8.2% respectively. However, there does not appear to be any direct overall correlation between endemism and elevation, since both Iniok Site and Kubkain Site (both in the Study Area Lowland Zone) scored at intermediate levels(13.9% and 13.6%, respectively).

Many described species recorded during the survey of the Study Area are known only from the northern low-moderate elevation region of New Guinea, including the Cyclops Mountains, Humboldt Bay. These include *Mimene verda*, *Delias pulla*, *Hypochrysops hermogenes, H. calliphon, Philiris pagwi*, *Mycalesis giamana* and *M. comes*.

5.5 Threatened and Protected Species

Table 6 lists butterfly species recorded in the Study Area that appear on the 2011 IUCN Red List of Threatened Species as other than Least Concern and/or are listed as Protected under the PNG *Fauna* (Prote*ction and Control)Act 1966* ('Fauna Act'). The meanings of the classification codes are presented

Table 6. Butterfly fauna listed as of conservation concern in the Study Area

COMMON NAME	SCIENTIFIC NAME	IUCN	PNG FAUNA ACT
Goliath Birdwing	*Ornithoptera goliath* Oberthür, 1888		P
Butterfly of Paradise	*Ornithoptera paradisea* (Staudinger, 1893)		P
Ornithoptère Méridional	*Ornithoptera meridionalis* Rothschild, 1897	EN	P
*Chimaera Birdwing	**Ornithoptera chimaera* Rothschild, 1904	NT	P

* Species likely to occur but not yet recorded.
Checked on 29 September 2011 (http://www.redlist.org/)

in Table 1.

With the exception of five Birdwing Butterfly species, there are no mainland New Guinea butterflies currently on the IUCN Red List. Müller & Tennent, Tennent & Müller (in press) assessed c. 150 randomly selected Indo-Pacific butterflies for the IUCN 2011 Red List. Although a significant proportion of these species were known from or restricted to PNG, none were classified as threatened or above. Indeed, they recommended one species, *Ornithoptera chimaera* be down-graded from near threatened (NT) to Least Concern (LC) based on a re-assessment of its status and more information.

All the spectacular large butterflies of PNG are protected under the PNG *Fauna* (Prote*ction and Control) Act 1966* ('Fauna Act').

5.6 Species possibly New to Science

Nine distinct unidentified taxa (Table 7) were recorded during the survey of the Study Area. They may represent species new to science.

***Chaetocneme* sp. nov. (Hesperiidae)**

A single male specimen was collected at fluorescent light during the evening at Koki Site in Hill Forest (Hm). The genus *Chaetocneme* is represented by approximately a dozen species in mainland New Guinea and since they are largely crepuscular in nature, several have been taken at artificial lights. The males of all mainland New Guinea *Chaetocneme* species bear a costal ancroconial flap, while that of the undescribed species is without this secondary sexual character and is otherwise distinctive in its ferruginous ground colour, relatively rounded hindwings and pale brown cilia (Plate 8).

No *Chaetocneme* species are commonly encountered in New Guinea, with the exception of *C. tenuis* (van

Table 7. Possible species new to science

SCIENTIFIC NAME	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Chaetocneme sp. nov.							1														
Sabera sp. nov. 1	1																				
Sabera sp. nov. 2														2							
Kobrona sp. nov.														1			1				
Philiris sp. nov.	1						1												2		
Candalides sp. nov.	3									2											
Taenaris sp. nov.						3		1		2	3							1	2		
Mycalesis sp. nov. 1													1								
Mycalesis sp. nov. 2	5							3													

Notes: Entries are number of specimens collected.

Eecke), and several are known from all but a few specimens. Additionally, the life histories are unrecorded in nearly all cases, except that of *C. antipodes* documented here-in. In Australia, the larvae of two tropical species, *C. porphyropis* and *C. sphinterifera*, feed on plants belonging to Lauraceae and Annonaceae, respectively. Early instar larvae are readily located in characteristic shelters, while adults are only rarely seen and their secretive habits are probably misleading as to their overall abundance. At Koki Site, several *Chaetocneme* larvae were encountered on plants of both these families and some of these may have represented those of the undescribed taxon. Based on the paucity of records of other *Chaetocneme* and their elusive nature, it can be assumed that the above-mentioned species is not restricted to the area around Koki Site. Most *Chaetocneme* have fairly wide elevational ranges and this can probably also be assumed for this taxon.

Sabera sp. sp. nov. 1 (Hesperiidae)

A distinctive species of *Sabera*, a genus of small, fast flying, inconspicuous orange and/or brown skipper butterflies, was taken at Nena Base Site, at c. 1,050 m in Hill Forest (Hm). Members of the genus are distinguished largely by the configuration of the male fore-wing sex brand as well as the wing size, shape and pattern. The undescribed species from Nena Base Site has a continuous sex-brand, which is relatively narrow and oblique and the underside is very dark with a purple suffusion, the hind wing being almost completely unmarked.

The life histories of *Sabera* are poorly known, although in north Queensland the larvae feed on various palms and cordylines (Muller & Wood, 1999). Several *Sabera* taxa are known from only very few specimens and, since the Hill Forest (Hm) habitat at Nena Base Site is apparently rather widespread in adjacent areas, it is unlikely the undescribed species is likely more widely distributed.

Sabera sp. nov. 2 (Hesperiidae)

A further distinctive species of *Sabera* was recorded at Iniok Site in a flooded environment of Riverine Mixed Successions (Fri/Wri) close to a major channel. The species is small for the genus, with long, pointed forewings and a unique sex brand. Two male specimens were attracted to paper lures very early in the morning. Although an extensive search of the locality and surrounds revealed no additional adults, the swampy habitat was evidently widespread, indeed, many species of *Sabera* are elusive and difficult to detect giving a false impression of rarity.

Kobrona sp. nov. (Hesperiidae)

The genus *Kobrona* is represented by about 15 species, all of which are endemic to mainland New Guinea. Similar to the fore-mentioned *Sabera* taxa, *Kobrona* species are invariably small, with orange and brown wings. A single male of an apparently undescribed species was taken in Gallery Forest several kilometres from Iniok Site and another was recorded at Kubkain Site, at the interface of Hill Forest (Hm) forest with surrounding Lowland Open Forest (Po). It is unusually large, has a distinctive hind wing central band that is disjunct towards the inner margin and has a dark border to the bands on the under surface of both wings.

Many *Kobrona* species are known only from their holotypes or type series and the life histories are unrecorded. The life history of one species, *K. wama* (Plotz) was discovered at Iniok Site, feeding on *Rhyncophora* sp. (Cyperaceae). The structure of the larva and pupa resembled *Telicota* sp., while the detachable puparium shows a similarity to *Sabera* and *Mimene* species. *Kobrona* are poorly known and often only from widely disjunct localities.

***Philiris* sp. nov. (Lycaenidae)**

Philiris is the second largest genus of butterflies in New Guinea and is currently under revision (Sands & Muller, in prep.). Males of an undescribed taxon in the *fulgens* or *agatha* species group was taken at Nena Base Site, Koki Site and was also observed at Frieda Base Site. In the latter two localities they were defending territories from perches approximately ten metres above the ground overhanging rapid-flowing Upland Torrential Streams, in the company of several other *Philiris* species. The undescribed species has a relatively pronounced hind-wing tornus, an unusual violet colouration with a very broad dark border to the fore-wing upperside but with a hairline-narrow margin to the hing-wing upperside. The underside is distinctly buff with a yellowish tinge and is unmarked.

Where known, the larvae of *Philiris* in the *fulgens* and *agatha* complexes feed upon plants belonging to Lauraceae and Euphorbiaceae. Larvae of several *Philiris* species were collected on such plants but only those of *P. violetta* and *P. sp.* nr. *fulgens* were reared to adult. It is possible that some larvae may have represented those of the undescribed species.

Since this relatively inconspicuous species was observed at two sites, several kilometres apart and differing in elevation, it can be assumed that it occurs more widely in the area and is probably not at risk, following proposed development within the Study Area. Typical of many *Philiris*, the males establish territories in the afternoon and will generally be on the wing for only one or two hours. For these reasons, *Philiris* tend to go unnoticed and are often more abundant than initial surveys suggest.

***Candalides* sp. nov. (Lycaenidae)**

A highly distinctive member of this genus, unlike any described taxon, was taken at Nena Base Site and at Upper Ok Binai Site. The male is characterised by very broad dark brown borders to the blue upperside, a small but prominent turquoise dusted trident sex brand, extensive whitish hind-wing apical area and a pure white underside, weakly marked with brown. The female is fairly similar to a number of other *Candalides* species.

Males were observed at Nena Base Site flying around the tops of tall saplings, or occasionally drinking from damp places on the ground. Females were usually inconspicuous and kept close to elevated foliage. At Upper Ok Binai Site males were encountered at only a single site, where they guarded established territories from perches from four to 25m above the ground.

Preliminary investigation suggests this species represents a relatively isolated lineage within the genus *Candalides* and is of much conservation importance. Detailed examination of foodplants in the vicinity used by other tropical members of the group in other parts of New Guinea and north Queensland, essentially new growth foliage of several plant families, revealed no early stages and adults were not encountered anywhere else. However, they are not particularly conspicuous, flying high and infrequently. The species likely occurs at similar elevations in the area and possibly more widely. Its occurrence at both Nena Base Site and Upper Ok Binai Site over an elevation range of some 500 metres suggests that it is more widely distributed. Various *Candalides* are known from few specimens from widely disjunct localities in New Guinea (e.g., *C. limbata*).

***Taenaris* sp. nov. (Nymphalidae)**

Taenaris (Owl) butterflies are conspicuous and well known in New Guinea for their large eye-spots and characteristic flight. Several species were collected during the survey of the Study Area including one which resembles *T. chionides*, endemic to eastern PNG. The species is similarly large, with falcate fore-wings but its wings are more stout than those of *T. chionides* and the apical eye spot on the hind-wing underside is very large and almost always in duplicate, while in *T. chionides* there is only usually one pair of ocelli.

Compared to most other *Taenaris*, adults of the undescribed species were exceptionally wary and very difficult to approach. They would immediately fly when persued and always keep several metres between the observer. Occasionally they were encouraged to fruit bait traps (Plates 98, 102). The life history of this species was not recorded. Its presence in Hill Forest (Hm) at Nena Base Site, Frieda Base Site, Malia Site, HI Site, Ok Isai Site and Ok Binai 1 Site implies a significant spatial and elevation range within the Study Area.

***Mycalesis* sp. nov. 1 (Nymphalidae)**

Many species of *Mycalesis* were recorded during the survey, several of which form clades of similar species. An undescribed species, which shows no close relationship to any described species, was recorded at the East Sepik Site by a single, worn male specimen. The taxon is matt black above, with a purple sheen and an extensive cream costa on the hind wing, while the underside is boldly spotted in the terminal half of the wings but unmarked basally. The species is large for the genus and exhibits much longer, more pointed fore wings than any described species.

Sampling at East Sepik Site revealed it had the lowest butterfly diversity and endemism of any site. This is undoubtedly due to its remarkably depauperate flora (potential larval food plants) typical of a Peat Forest environment. The unusual habitat possibly governs the distribution of the undescribed *Mycalesis* and it is therefore of great ecological importance, since, if it is not widley distributed, disruption to its habitat could render it endangered. Brief surveying at East Sepik Site, which included bait trapping at the original site, revealed no additional specimens.

Mycalesis sp. nov. 2 (Nymphalidae)

A further undescribed species, which clearly falls within a group representing *M. barbara*, *M. valeria* and *M. pernotata*, was recorded at Nena Base Site and HI Site, within a very small elevation range. Males are characterised by diffuse, pale orange bands above and large orange subterminal spots in the tornal area of the hind-wing, which are not ringed by black, as in related species. Females show characters of all three related species. Both sexes were fairly conspicuous and common within confined areas. While a small series of females were collected, males were very flighty and were never seen to alight, thereby differing from those of related species which tend to settle often, within small territories.

A female of this species was observed to oviposit on a common jungle grass at HI Site, growing among debris. The same grass was observed at many other sites and therefore does not appear to be a controlling factor on the distribution of this species. Conversely, this species appears to be peculiar to Mossy Forest around HI Site and Nena Base Site. Such vegetation appears to be naturally degraded and secondary, possibly owing to the regular landslips which would be common in such steep slopes.

5.7 Unidentifed Species

Six other species (cf) are very close to described species and slight differences are likely attributed to geographical variation. A further three species were not identified with certainty due to specimens being in exceedingly poor condition, not captured or within complexes of very closely related species. The locations at which they were recorded is shown in Table 8.

***Delias* cf. *eudiabolas* Rothschild, 1915 (Pieridae)**

To date this species is only known from about five specimens from the Aroa River area (Central Province) and a small series from near Tabubil (Western Province), this species is superficially very close to the common, widespread *D. ladas*, which was encountered at a number of sites during the survey. A single specimen taken at Nena Base Site is much smaller than those of *D. ladas* and the pale marking beneath are more obscure. The specimen is tentatively assigned to *D. eudiabolas* until DNA sequencing can reveal its true identity.

***Philiris* cf. *elegans* Tite, 1963 (Lycaenidae)**

The beautiful *P. elegans* is currently only known from its type locality at Mt. Siwi, in the Arfak Mountains of West Papua Province, Indonesia. Specimens of both sexes were recorded at Nena Base Site and most closely resemble *P. elegans*, although detailed comparison is difficult, since the only existing specimens of *P. elegans*, in the Natural History Museum (London) are in very poor condition.

Table 8. Unidentified species

SCIENTIFIC NAME	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME
Delias cf. *eudiabolas* Rothschild, 1915	2																				
Philiris cf. *elegans* Tite, 1963	3																				
Philiris cf. argentea (Rothschild, 1916)																	1				
Philiris cf. putih Wind & Clench, 1947								2	1												
Candalides cf. *margarita* (Semper, 1879)							2		2												
Philiris ?innotata (Miskin, 1874)									1												
Telicota sp.						1															
Hypochrysops ?cleonides Grose-Smith, 1900						1															
Mycalesis cf. *arabella* Fruhstorfer, 1906									1									3			

Notes: Entries are number of specimens collected.

***Philiris cf. argentea* Rothschild, 1916) (Lycaenidae)**

P. argentea belongs to a small group of very closely related species, all of which are lustrous blue on the uppersides, with very broad dark brown borders and silky white undersides. All species bear a small white central patch on the fore wing upperside, yet a single male taken on the main hill at Kubkain Site is devoid of this patch. It is otherwise very similar to *P. argentea* and is tentatively assigned to that species. In northern Queensland, this patch may be absent in dry season forms of a similar species, *P. nitens* (Grose-Smith), suggesting that seasonal variation may also occur in other members of the group. According to Parsons (1998) *P. argentea* is only known from the types from the Snow Mountains, Papua Province, Indonesia, a small series from two montane localities in Central Province and also from a single specimen from Telefomin, Sandaun Province. It is likely to occur even more widely in mainland New Guinea.

Philiris cf. putih **Wind & Clench, 1947 (Lycaenidae)**

Males of a species most closely related to and possibly belonging to *P. putih* were recorded at HI Site (~850 m) and upstream of Frieda Bend Site (~100 m). The dark border at the apex of the hind-wing in the male is much broader than that of *P. putih* specimens examined. *P. putih* is relatively widespread in mainland New Guinea, including records from Maprik and Angoram, East Sepik Province.

Candalides **cf.** ***margarita*** **Semper, 1879 (Lycaenidae)**

C. margarita is a common species in coastal tropical Australia and is also known from a number of localities in New Guinea. As with most others in the genus, the adult male is lustrous blue above with a narrow brown border and a prominent sex mark, while the female is predominantly black and white. Beneath, the wings of both sexes are silky white with linear brown markings. In several specimens from both Koki Site and Frieda Bend Site these markings are absent and, in the male, the sex brand appears to be more prominent than other specimens of *C. margarita* examined. This is possibly attributed to variation within the species and only gene sequencing will establish their true identity. Since these unusual specimens were collected over a wide elevational range, it is likely they are widespread in the Study Area and elsewhere.

Mycalesis cf. arabella **Fruhstorfer, 1906 (Nymphalidae)**

A single male specimen that resembles specimens of *M. arabella*, endemic to Waigeo, West Papua Province, Indonesia, was taken upstream of Frieda Bend Site. Additional males were taken at Ok Binai 1 Site (Plate 91). The identification was based on an examination of the series, including types, of *M. arabella* in the Natural History Museum, London, for a separate study (Kodandaramaiah *et al*., 2010). These are significant records and suggests that this taxon is likely widespread across much of lowland northern New Guinea. Like many *Mycalesis* species, it is inconspicuous and seemingly extremely localised and has likely remained unnoticed in several localities. Specimens at Ok Binai 1 Site were all recorded within a very small opening in the forest, less than 40m^2.

Telicota **sp. (Hesperiidae)**

At Malia Site a male of a *Telicota* species was photographed, but not captured, feeding at a paper lure bait (Plate 23). Of the approximately 25 representative species of *Telicota* known from PNG, at least half are extremely similar in external morphology, being small, orange and brown, and may only be distinguished by comparing slight differences in the male sex brand and genitalia. The undersides of these species are not generally diagnostic and the upperside of the above mentioned specimen was not examined. It is possible this species belonged to the related genus *Cephrenes*, three species of which were recorded in the Study Area.

Hypochrysops ?cleonides **Grose-Smith, 1900 (probable) (Lycaenidae)**

H. cleonides belongs to a group of very closely related species which exhibit subtle differences. A single, very worn male of a specimen closest to *H. cleonides*, but possibly the widespread *H. thesauras* Grose-Smith was found dead on river rocks at Malia Site by the site senior Project geologist. This species is otherwise only known from southern mainland New Guinea where it has a rather extensive, if not sporadic, distribution.

Philiris ?innotata **(Miskin, 1874) (probable)**

Philiris innotata belongs to the *moira* complex of very closely related *Philiris* in which the males are invariably purplish blue with narrow brown borders on the upperside and the females brown with varying degrees of blue basally. Both sexes are silky white on the undersides with a single black spot on the inner margin of the hind wing. The females of most species are indecipherable from one another and reliable identity depends on association with the males (e.g., pairs taken in copula). A single female, most closely resembling *P. innotata*, was taken in a shaded Lowland Low-gradient Stream at Frieda Bend Site. The only other *Philiris* species of the *moira* complex recorded during the survey of the Study Area was *P. moira*, which is much smaller than *P. innotata*. Both species are widespread in PNG, *P. innotata* also occurring in eastern Australia as far south as Port Macquarie (Braby, 2000).

5.8 Poorly Known Species

This section treats rare or localised butterfly taxa recorded in the Study Area whose discovery in the Study Area, the author considers important biogeographically. These include species known previously from only the original type series or from exceedingly few specimens and/or species not previously recorded from PNG or at least not from the Sepik Provinces.

***Chaetocneme antipodes* Guérin-Méneville, 1831 (Hesperiidae)**

This is a rare, highly distinctive species endemic to mainland New Guinea. It was recorded at Malia Site and Wario Site, where a male displayed behaviour typical of the genus, within a territory which it defended from the underside of a leaf within low-growing vegetation. Unusual for the genus, which are otherwise crepuscular, it was active around midday. Additionally, a female specimen, only the second known, was reared from a larva found on *Neolitsea* sp. (Lauraceae) at approximately 320m at Wario Site. This life history record (see Plates 13, 14) is significant as no other New Guinean *Chaetocneme* have been reared to adult. Several other *Chaetocneme* larvae were located on Lauraceous plants at many sites in the Study Area, some of which may have been of this species. Time limitations did not allow them to be reared to adult.

In PNG, *C. antipodes* was only known from three specimens taken in the Western Highlands and Western Provinces. Although very poorly known, this species is assumed to have a wide distribution based on widely disjunct known historic collection localities in both PNG and West Papua, Indonesia.

***Chaetocneme critomedia* Guérin-Méneville, 1831 (Hesperiidae)**

Previously only three specimens were known from PNG, from East Sepik and Madang Provinces. Parsons (1998) recognised that the related taxa *C. caristus* and *C. sphinterifera* were not conspecific with *C. critomedia*. Many larvae of *Chaetocneme* were found on plants belonging to the family Annonaceae in the Study Area (Plate 9), probably representing this species. Annonaceae has been recorded for *C. sphinterifera* on Cape York, Australia. Male specimens of this crepuscular species were attracted to paper lures just before dark at HI Site and at Kubkain Site (Plate 7). When disturbed and in flight, the adult resembled a species of *Milionea* moth (Noctuidae). This is the same as for *C. porphyropis* in northern Queensland which resembles *M. queenslandica* (*pers. obs*.). The abundance of larvae located at Frieda Base Site, Malia Site, HI Site and Ok Binai 1 Site on Annonaceous plants suggests that this species is not rare, the paucity of records likely being attributable to the secretive habits of the adults.

***Rachelia extrusa* C. & R. Felder, 1867 (Hesperiidae)**

Known from only six specimens from widely disjunct localities in PNG, this taxon was not previously known north of the Central Cordillera, except for one specimen from Humboldt Bay in north-eastern Papua Province, Indonesia. A single male was observed resting in deep shade on a palm frond approximately one metre above the ground at Frieda Bend Site and another was taken at a paper lure at Nena Base Site.

It is widely distributed in mainland New Guinea.

***Rachelia icosia* Fruhstorfer, 1911 (Hesperiidae)**

This is a striking species, currently known only from about ten specimens from PNG but it is otherwise known from Waigeo, Biak, Japen and Papua Province, Indonesia. It had not been previously recorded from Sandaun Province. Two females were recorded at Kaugumi Site, where they appeared to be seeking oviposition sites on blades of a low-growing *Pandanus* sp. (Pandanaceae). Additionally, several males were recorded at Kubkain Site, at the boundary of Hill Forest (Hm) and Alluvial Wooded Swamp Complexes (Wsw/FsW) (Plate 16). The relatively wide distribution of this species both on mainland New Guinea and various satellite islands suggests that the species is not under any significant threat as a whole.

***Tiacellia tiacellia* Hewitson, 1868 (Hesperiidae)**

T. tiacellia is a unique, colourful taxon known from very few specimens. A single male was taken at a paper lure near dusk at Kaugumi Site and is the first record of the species from the Sepik River Basin. Most specimens originate from east PNG but it is also known from the Aru Islands, so a moderately wide range is inferred.

***Sabera kumpia* Evans, 1949 (Hesperiidae)**

Only three specimens of this small, dark and inconspicuous species were known previously. The nominate subspecies (one pair) is recorded from the Weyland Mountains, West Papua Province, Indonesia, while ssp. *baxta* Evans is known only from the holotype from near Kokoda. A small number of males were recorded at Malia Site, including one which was attracted to a paper lure. Based on the widely disjunct localities for this taxon over a wide area, this taxon is presumed to have a wide distribution.

***Sabera misola* Evans, 1949 (Hesperiidae)**

This species is very closely related to *S. kumpia* and is essentially identical in appearance but has a distinctive sex brand on the upperside of the forewing which is considerably reduced. The taxon was previously known from just four localities in PNG; Nengian (Sandaun Province), Kiunga (Western Province) and Loloipa and Upper Aroa rivers (Central Province) (Parsons, 1998). A single male was recorded at Kubkain Site, at the summit of the main hill. The butterfly is also known from Indonesian Papua Province, including some satellite islands and it likely occurs widely in mainland New Guinea (Parsons, 1998).

***Mimene celia* Evans, 1935 (Hesperiidae)**

In PNG, *M. celia* was known only from a small series taken by W. Brandt at Kiunga, Western Province. Elsewhere the species is known from less than ten specimens from Yapen Island (type locality) and near Jayapura, Indonesian Papua Province. A single male was recorded at Kubkain Site, where swamp forest meets the main hill, an environment particularly rich for other unusual species of the family Hesperiidae. Although this species is currently known only from central New Guinea, sufficient suitable habitat remains such that it not threatened.

***Mimene celiaba* Parsons, 1986 (Hesperiidae)**

Previously only known from the very small type series comprising specimens from two locations in Papua Province, Indonesia and from Kiunga, Western Province, this species was recorded at HI Site, Frieda Bend Site, Ok Isai Site, Kaugumi Site and at Wogamush Site. The specimen taken at the former locality is much larger than that those at other localities and of the types examined from Kiunga, held in the Australian National Insect Collection. A wide inferred distribution, here extended north of the Central Cordillera, coupled with a wide elevational range imply that the species is not threatened.

***Mimene biakensis* Joicey & Talbot, 1917 (Hesperiidae)**

This species was previously only known from three specimens from the type locality in Biak and an additional three specimens from near Madang representing the subspecies *gunta* Evans. A male at Malia Site was observed resting on the upperside of a leaf in dappled sunlight overhanging a Seepage beside an Upland Torrential Stream at about 350 m. Others were recorded at Ok Isai Site and Wogamush Site in similar situations. While the nominate subspecies is possibly vulnerable on the island of Biak, the species is otherwise probably fairly widely distributed in the lowlands of northern New Guinea.

***Mimene caesar* Evans, 1935 (Hesperiidae)**

Although known from only a handful of specimens, this species distribution extends from the Bomberai Peninsula in West Papua Province to Morobe Province in PNG. Several hesperiid larvae (Plate 17) were collected from juvenile *Calamus* palms at Frieda Bend Site. One of these pupated (Plate 18) and emerged as a male specimen of *M. caesar*. Adult males were also recorded at Ok Isai Site, Kaugumi Site, Wogamush Site and Ok Binai 1 Site. This record of the life history is of utmost interest as it is only the second time that a member of this genus has been reared. As with larvae of the related *Sabera*, which can withstand temporary flooding of their habitats, upon reaching maturity they cut out a section of leaf of the foodplant and drop, enclosed within a silk-padded puparium which is able to float. Peculiar to these two genera is the ability to expand the wings while the adult stands upright and fly within minutes of eclosure. This is likely an adaptation to minimise the time spent on the forest floor where potential predators abound (Muller & Wood, 1999).

***Mimene sariba* Evans, 1935 (Hesperiidae)**

Previously only recorded from a small number of specimens from Kiunga (Western Province) and Sariba Island (Milne Bay Province), this was observed with *M. biakensis* at Malia Site where it was observed resting on low foliage in deep shade and was very inconspicuous. This record implies a relatively wide distribution in PNG.

***Mimene verda* Parsons, 1986 (Hesperiidae)**

M. verda is a distinctive skipper butterfly that is small and dark brown, with very obscure pale brown markings above and a shiny green head and thorax. Known previously only from the unique holotype taken by W. Brandt at Maprik, several specimens observed at Ok Isai Site and Ok Binai 1 Site imply a wider distribution for the species.

***Mimene cyanea* (Evans, 1928) (Hesperiidae)**

The most colourful member of the genus, *M. cyanea* was previously only recorded from Kiunga (Western Province) and Deria (Central Province) in PNG and from a few localities in Papua Province, Indonesia. Together with several other fore-mentioned *Mimene* species, *M. cyanea* was recorded only at Malia Site, where a male was observed resting on foliage in a well shaded gully. Despite its rarity and the widely disjunct known localities, a wide distribution is inferred for this species.

***Mimene milnea* Evans, 1935 (Hesperiidae)**

Besides the holotype from Milne Bay, the distinctive, purple-suffused *M. milnea* is known from a small number of specimens from islands in the D'Entrecasteaux Archipelago, Northern Province and two localities in Papua Province, Indonesia. During the survey the species was recorded at Frieda Bend Site, Iniok Site and at Wogamush Site. As with many *Mimene* species, *M. milnea* is known from a small number of localities over a wide range, suggesting that it has a wide distribution.

***Cephrenes augiana* Evans, 1934 (Hesperiidae)**

A taxon hitherto recorded only from Aru Islands and one specimen from "German New Guinea", a number of specimens taken at East Sepik Site and Iniok Site show that it is not rare and is much more widely distributed. Indeed, at the later locality the taxon was abundant, occasionally dominant. Numerous palm species, the foodplant of the related *Cephrenes augiades* were present and are likely the foodplant of *C. augiana*.

***Delias pulla* Talbot, 1937 (Pieridae)**

This remarkable species, belonging to the group of Pierids known as Jezabels, has remained an enigma since its discovery in the Cyclops Mountains, Papua Province, Indonesia, more than 70 years ago. Only two specimens were known previously. A number of specimens were recorded on the summit of Ubiame Site, above the designated HI Site. They were in the company of other *Delias* species and evaded capture by flying very rapidly at some height. This is the first record of the species from PNG and is a few hundred kilometres of the type locality and that of a second specimen known from Mt. Borme, in the Star Mountains, Papua Province, Indonesia. It is likely that this taxon has a fairly limited range in the northern part of the Central Cordillera, since it is relatively conspicuous and belongs to a genus which is much studied (Braby & Pierce, 2007). Although of some conservational concern, all specimens are known from relatively high elevations (> 1,300m) suggesting a montane distribution.

***Hypochrysops argyriorufus* van Eecke, 1924 (Lycaenidae)**

A small number of males were recorded at Iniok Site in a very localised situation, where they imbibed fluids from the extra-floral nectaries of *Flagellaria indica* vines. Males were also observed in secondary vegetation at Wario Site and hill-topping at Kubkain Site. This species was previously known only from about a dozen specimens from mainland New Guinea and Tagula Island and it has a relatively wide distribution.

***Hypochrysops castaneus* Sands, 1986 (Lycaenidae)**

This intriguing species differs from all other known members of the genus *Hypochrysops* by the absence of any metallic scales on the upper surface of both wings. It was previously known only from the type series, originating from both Papua Province, Indonesia and PNG. Localities in PNG include Kiunga, Maprik, Stephansort and Hydrographer Mountains. As for *H. argyriorufus*, this species was recorded from a small number of adults of both sexes feeding on secretions from *Flagellaria* vines. A single female was also observed flying around and possibly ovipositing upon a tree identified as *Aporosa* sp. (Euphorbiaceae) at Wario Site. A search revealed batches of *Hypochrysops* eggs but none hatched. The species has a wide, yet disjunct, range.

***Hypochrysops hermogenes* Grose-Smith, 1894 (Lycaenidae)**

This intriguing butterfly was known from a single pair, the holotype from near Jayapura and another from Maprik, East Sepik Province (Sands, 1986; Parsons, 1998). The new record from Koki Site considerably extends the known range of the species south from the northern coastal range (Cyclops Mountains, Prince Alexander Range). Its presence at localities in a section of northern Guinea, spanning suitable undisturbed habitat over a significant area suggestsa wide range.

***Hypochrysops calliphon* Grose-Smith, 1894 (Lycaenidae)**

More than 120 years have passed since the three type specimens were collected in Humboldt Bay, Papua Province, Indonesia and it has not been seen since. The record of this fascinating species at Malia Site is hence particularly exciting. A single female was flying in the vicinity of a *Syzigium* sp. tree approximately six metres above the ground. It was perhaps preparing to oviposit. The tree was covered by small black 'Coconut' ants possibly belonging to the genus *Iridomyrmex*, which attend the larvae of several *Hypochrysops* species in symbiotic relationships. An intensive search of the tree and those in the vicinity revealed no signs of the early stages. It is likely that the species occurs throughout much of northern New Guinea, close to the border with Papua Province. The Study area records suggests it has a wide distribution in New Guinea.

Philiris vicina **(Grose-Smith, 1898) (Lycaenidae)**

This bold, purple-suffused species is endemic to mainland New Guinea where it is recorded from Mailu, Alotau, Wafi and the Hydrographer Mountains. A single male was recorded at Nena Base Site where it flew next to an Upland Torrential Stream and another in secondary vegetation beside the Wario River at Wario Site. Although known localities are widely disjunct, it apparently has a wide overall distribution.

Philiris tapini **Sands, 1979 (Lycaenidae)**

Belonging to a small group of species with prominent, dark upperside wing margins, *P. tapini* is only known from a small number of localities in mainland PNG, including Maprik (East Sepik Province). Its occurrence at Nena Base Site shows that it is more widely ranging in the Sepik River Basin.

Philiris praeclara **Tite, 1963 (Lycaenidae)**

The species is known from Northern, Central and Morobe Provinces in PNG and from Papua Province, Indonesia. The taxon was recorded at Nena Base Site (900m), Malia Site (~350m), Koki Site (~550 m) and Frieda Bend Site (95 m) (Plate 51). Both sexes were taken from foliage several metres above rapidly flowing Upland Torrential Streams. The life history was recorded by Parsons (1998), with larvae feeding on *Litsea guppyi* (Lauraceae). Several *Philiris* larvae were located on this plant at various sites but only the related *P. violetta* was reared to adult, owing to time constraints. While rare, *P. praeclara* is clearly widespread.

Philiris harterti **(Grose-Smith, 1894) (Lycaenidae)**

Not previously known north of the Central Cordillera in New Guinea, a male of this species was recorded above the HI Site at approximately 1,300 m displaying typical territorial behaviour. This species was also recorded at Nena Base Site (~850 m), Kaugumi Site (~40 m) and Wario Site (~45 m). A wide distribution at low to moderate elevations across mainland New Guinea implies that the species is not threatened. Related species occur in Biak (*P. albiplaga*) and New Britain (*Philiris* sp. undescribed).

Philiris hemileuca **(Jordan, 1930) (Lycaenidae)**

Very few specimens of this distinctive taxon are known and all records are from mid to high elevations in Morobe, Enga and Sandaun Province. At HI Site a male was observed in a steep gully at about 1,000 m where it settled at the top of a tree about 8 m above the ground. *P. hemileuca* is likley a higher elevation species.

Philiris sibatanii **Sands, 1979 (Lycaenidae)**

This species is known from the type locality and Wau in Morobe Province, and the Musgrave River in Central Province. Specimens recorded from Koki Site significantly extend the range of this taxon. Males were observed around mid morning on an old drill site atop a ridge at approximately 650 m. They displayed typical territorial behaviour, pursuing any passing butterflies and returning to prominent perches some metres above the ground. While only known from a handful of specimens, the wide, albeit sporadic, distribution of this taxon suggests a wide distribution.

***Philiris pagwi* Sands, 1979 (Lycaenidae)**

P. pagwi is a highly distinctive taxon in which only half of the upperside hind wing is covered by iridescence. In nearly all known species, the majority or all of the wings are iridescent. The species was previously known only from the type series taken at Pagwi, near Ambunti (East Sepik Province). Both sexes were recorded at Ok Isai Site and at Iniok Site (Plate 52) and imply a wider distribution along the Sepik River. However, the species appears to predominate in secondary forest that is relatively disturbed by frequent flooding. No information on the life history of the species was revealed, although this would undoubtedly aid in predicting the species range in the Sepik River Basin.

***Titea caerulea* (Tite, 1963) (Lycaenidae)**

A male of this spectacular species was taken from the top of a tall tree overhanging an Upland Torrential Stream near the Koki Site, at least 12 m above the ground. It flew late in the afternoon, in the company of several *Hypochrysops* and *Philiris* species. A further male specimen was observed at Nena Base Site. Only a few specimens of *T. caerulea* were previously known, from both PNG and Papua Province, Indonesia, making the record highly significant. This species was assessed by Tennent & Muller (in press) as part of an IUCN survey for the new Red List and graded as Least Concern, based on a fairly wide distribution.

***Arhopala auxesia* (Hewitson, 1863) (Lycaenidae)**

Previously known only from three specimens in eastern PNG and from a couple of localities in Papua and West Papua Provinces, including Salawati Island, a number of specimens were seen at Koki Site, significantly extending the known range of this intriguing species. Males were observed for about an hour around mid morning on consecutive days on a ridge top at ~650 m elevation, exposed by prior drilling. They followed the same flight paths along the tops of tall saplings several metres above the ground. Although poorly known, this species appears to have a wide distribution.

***Arhopala antharita* Grose-Smith, 1894 (Lycaenidae)**

There are few known specimens of this large, boldly patterned species which occupies a narrow range in north-eastern and central Papua Province, Indonesia and north-western PNG. The species has been recorded from near Green River Station (Parsons, 1998) near the Study Area. Adult males were observed at several sites in proximity to Malia Site, where they flew exceptionally rapidly along regular flight paths. Another male was observed at Kubkain Site. A female was observed at close range at Malia Site flying around a shrub with nests of *Oceophylla* green tree ants, presumably in search of oviposition sites. *Oceophylla* ants are commonly associated with the early stages of other *Arhopala* species in the Indo-Pacific. A search of the foliage did not reveal any early stages. There is significant suitable habitat in the insects' range.

***Deudorix parsonsi* Tennent, 2000 (Lycaenidae)**

This recently described species was previously confused with the more widespread, common *D. epijarbus* (Moore). However, *D. parsonsi* differs quite markedly in its wing shape, pattern and colouration from that species. Parsons (1998), who first outlined the species as *Deudorix* Species b, recognised only two known specimens, from Kiunga (Western Province) and near Fak Fak, West Papua Province, Indonesia. Additional specimens in various collections are now known from Sorong and Timika, Indonesian New Guinea and the female was described by Gotts & Pangemanan (2001). A single male was observed hill-topping late in the afternoon on a low ridge behind the camp at Wario Site. Although known from few specimens, the widely disjunct localities recorded for this species imply that it is relatively widespread in mainland New Guinea.

***Bindahara meeki* (Rothschild & Jordan, 1905) (Lycaenidae)**

Considered by Müller and Sands (1999) to be one of the rarer species in New Guinea, on the mainland it is known from few specimens from widely disjunct localities. The species is also known from the Moluccas (Okubo, 2007) and the Bismarck Archipelago (Müller and Sands, 1999). The life history was recorded by Muller and Sands (1999) from New Ireland, the larvae feeding on the fruits of *Salacia disepala*. Males were observed on two occasions within a few hundred metres of each other at Malia Site, although potential *Salacia* foodplants were not located. This spectacular species is known from several, widely disjunct localities in New Guinea and appears to have a wide range.

***Nacaduba nerine* (Grose-Smith & Kirby, 1899) (Lycaenidae)**

This is a very unusual, poorly known species which forms part of a Müllerian mimicry complex comprising several species of often distantly related butterflies within the family Lycaenidae. Only ten specimens of *N. nerine* were previously known (Parsons, 1998), some of which originate from East Sepik Province (Maprik) and Sandaun Province (Green River). In PNG the species is otherwise known only from Central Provice but four specimens are recorded from Papua Province, Indonesia, including Roon Island. Two male specimens were recorded during the survey of the Study Area, hill-topping at the summit of the main hill at Kubkain Site around midday on the same day. Despite extensive searching, no others were observed. Its occurrence at several widely disjunct localities in New Guinea suggests a wide range.

***Danis regalis* (Grose-Smith & Kirby, 1895) (Lycaenidae)**

Another member of the Müllerian mimicry complex mentioned under *N. nerine*, this species was recorded at both Wario Site and at Ok Binai 1 Site. Adult females were frequently encountered at the latter site, where they flew close to the ground in dense understorey, seemingly in search of oviposition sites. This species, known from few specimens, is known from Papua Province, Indonesia but in PNG is only recorded from Nengian (Sandaun Province), Angoram and Ambunti (East Sepik Province). Owing to its known occurrence in both Indonesian Papua Province and the Sepik, the distribution of this species is inferred to extend across the gap and be potentially fairly widespread.

***Sahulana scintillata* (Lucas, 1889) (Lycaenidae)**

Essentially an eastern Australian butterfly, this species is known from a few localities in Papua Province, Indonesia and from near Wau in PNG. Records of males imbibing moisture along water couses at both Upper Ok Binai Site (~350 m) and Frieda Bend Site (~90 m) imply that the species occupies a much wider range.

***Parantica kirbyi (Grose-Smith, 1894)* (Nymphalidae)**

Apparently restricted to northern central New Guinea between Humboldt Bay (Papua Province, Indonesia) and Astrolabe Bay (Madang Province) (Ackery and Vane-Wright, 1984; Parsons, 1998), specimens were seen at several sites (Wario Site, Wogamush Site and Kubkain Site) in the Study Area Lowland Zone. At Kubkain Site, adults were observed in heavily disturbed secondary habitat.

***Taenaris dina Staudinger, 1894* (Nymphalidae)**

A single pair of this rare, beautiful species were recorded at Wario Site, the female of which was taken in a bait trap at dusk. In PNG the taxon was known only from Astrolabe Bay and Madang (Madang Province). Elsewhere the butterfly is only known from three main areas in Papua and West Papua Provinces, Indonesia, including Salawati Island (Parsons, 1998). Although likely restricted to northern New Guinea, it has a wide range from the far western extremity of the island to Madang Province.

Morphopsis biakensis **Joicey & Talbot, 1916 (Nymphalidae)**

This rare, striking species was only known in PNG from five East Sepik Province specimens and others from outlying islands in Papua Provinces, Indonesia. A fresh male was recorded at HI Site at 1,050 m where it flew between tree trunks, each time settling in an upright position several metres above the ground (Plate 81). A further male was observed at the same elevation, exhibiting similar behaviour above Nena Base Site. This is another species with widely separated records suggesting a broad range.

Mycalesis giamana **Parsons, 1986 (Nymphalidae)**

Known only from five type specimens from Papua Province, Indonesia and another from Maprik, this intriguing species was recorded from males at Malia Site (~350 m) and at Ok Isai Site (~140 m) (Plate 87). A female, only the second known, was recorded at Ok Binai 1 Site (~100 m). It was observed in company of the common, closely related *M. cocadaemon*, where it rested on foliage in deep shade. Although very poorly known, this species has a relatively wide distribution in the western half of the New Guinea mainland.

Mycalesis comes **Grose-Smith, 1894 (Nymphalidae)**

Known previously only from the area around Jayapura (Cyclops Mountains) in Papua Province, Indonesia and from near Madang, the collection of this species at Nena Base Site, Malia Site, Upper Ok Binai Site and Wario Site represent significant records. It is likely distributed fairly widely in the northern part of mainland New Guinea since it is relatively secretive and has probably avoided detection in many localities.

Altiapa pandora **(Joicey & Talbot, 1916) (Nymphalidae)**

Outside of Papua Province, Indonesia, this species was known only from a single specimen from Kundiawa, Eastern Highlands Province. Males were noted on a knoll at 1300m above the HI Site where they flew rapidly among low-growing Heath. They disappeared after flying for an hour during the mid morning. The genus *Altiapa* comprises species which are all high elevation and *A. pandora* is no exception. Therefore, while the species was recorded during the Study Area survey it is unlikely to occur at lower elevations.

Elymnias papua **Wallace, 1869 (Nymphalidae)**

Very few specimens of this obscure species are known from museum collections, such that records of *E. papua* from Malia Site and Kubkain Site are highly significant. At the former site, this species was attracted to fermented pineapples, together with *E. cybele*. A female at Kubkain Site laid approximately 20 eggs when confined to a plastic bag containing sprigs of various palm species (known foodplants for other *Elymnias* species). However the first instar larvae (see Plate 94) refused to eat any of those provided and subsequently died. Although rare, this taxon is widely distributed in mainland New Guinea.

5.9 Life History Records

The early stages (egg, larva and pupa) of the great majority of butterflies in PNG are as yet unknown. Information on life histories is very important in any ecological impact assessment, since, where known, most species are monophagous, feeding as larvae only on single plant species (food plant specific).

During the Study Area survey, the life histories of 64 butterfly species were recorded in the field and their food plants noted (see Table 9). Several of these had not previously been recorded and are hence noteworthy (e.g., Chaetocneme antipodes, Hasora celaenus, Mimene caesar and Kobrona wama, Hesperiidae; Terinos tethys and Parthenos aspila, Nymphalidae; Arhopala thamyras and Upolampes evena, Lycaenidae). Some of these are illustrated in this report. The early stages of additional butterfly species were identified to genus only as they were parasitised by various flies (Diptera) and not reared to adult for positive identification. Others, e.g., Elymnias papua, were enticed to oviposit in confined conditions but the larvae would not accept the foliage provided.

Life histories of two of the species identified as new to science (Section 5.6.) were partially documented. A currently unidentified species of fleshy grass, growing low in shaded areas was recognised as a foodplant for the undescribed *Mycalesis* sp. 2. Larvae of at least two unidentified *Chaetocneme* and *Philiris* species were located on Lauraceous plants (laurels) during the survey and it is possible each of the undescribed species discussed in Section 5.6. were represented. Certainly related members in both *Chaetocneme* and *Philiris* are known to feed on laurels. No evidence for the early stages of any of the undescribed *Sabera*, *Kobrona*, *Taenaris* or *Candalides* were located.

5.10 Migratory Species

There are very few truly migratory butterfly species occurring in New Guinea. The only exceptions are *Libythea geoffroyi* (Beak), *Badamia exclamationis* (Migratory Awl), *Catopsilia pomona* (Lemon Migrant) and *Danaus plexippus* (Monarch Butterfly, Wanderer). The latter species is known worldwide for its vast migrations, particularly in North America. More localised migration is fairly apparent in butterflies of New Guinea, whereby numerous individuals of a species will fly from one valley to another over a ridge etc. However, for the most part, species composition within an area rarely changes and butterflies in tropical areas are notably sedentary.

5.11 Species of Cultural Value

Largely due to their conspicuous nature and beauty, butterflies play an iconic role in society. Birdwing butterflies, being enormous and spectacular, are popular with naturalists, artists, researchers and collectors worldwide. In New Guinea, the stronghold for the Birdwing butterflies, male birdwings are sometimes used in tribal displays. The wings may be rubbed onto the faces, leaving a film of iridescent green scales and wings, or entire specimens, may be pinned to head dresses. In many PNG towns and villages Birdwings are encouraged to proliferate, through planting of their vine larval foodplants, to portray health and serenity in gardens. This is a particularly common practice in Ambunti, Esat Sepik Province (A. Gambia, local resident, *pers. comm.*, 2010).

For many years the trade in Birdwings has thrived in PNG. It was at a peak during the period when the Insect Farming and Trading Agency, Bulolo (1978 – 2009) was in operation. The organisation, run by UniTech in Lae, purchased pupae and adults of Birdwings and other butterflies from villagers which were then sold on the international market. In the case of the Birdwings, villagers were trained how to ‘ranch’ the pupae, thereby increasing the output of Birdwings for sale. Gardens are constructed with flowers that are attractive to the butterflies, e.g., those of *Hibiscus*, together with the larval foodplant, primarily *Aristolochia tagala* (Aristolochiaceae) all which are enclosed within an area fenced off, or hedged, to prohibit pigs entering and destroying the area. The percentage of pupae produced is much higher than that in the wild, due to decreased mortality rates. This practice hence does not harm the species natural populations, as they are protected against predators, through the use of increased suitable habitat for adults, food plants, hedges to keep pigs out, i.e., it is a non invasive means of farming.

Despite the closure of Insect Farming and Trading Agency and the Wau Ecology Institute, where Birdwing butterflies were also reared, there are evidently numerous villagers who possess export permits to trade in the insects. A viable option for residents within the Study Area is to obtain a licence so that they may be farmed and sold. Several Birdwing species, with a record of being ranched elsewhere in PNG, are recorded from the Study Area, as follows:

***Troides oblongomaculatus* (Goeze, 1779). Troides Birdwing.**

This Birdwing is common, sometimes abundant, throughout most of lowland mainland New Guinea. It

Table 9. Foodplants recorded for butterfly fauna in the Study Area.

TAXON	FOODPLANT SPECIES	FOODPLANT FAMILY
Chaetocneme antipodes (Guérin-Méneville, 1831)	*Neolitse sp.*	Lauraceae
Chaetocneme critomedia (Guérin-Méneville, 1831)	*unidentified*	Annonaceae
Chaetocneme callixenus Hewitson, 1867	*Neolitsea* sp.	Lauraceae
Chaetocneme tenuis (van Eecke, 1924)	*Litsea* sp.	Lauracea
Chaetocneme sp. undescribed	*Litsea* sp.	Lauraceae
Tagiades japetus (Stoll, 1781)	*Dioscorea* sp.	Dioscoraceae
Tagiades nestus (C. Felder, 1860)	*Dioscorea* sp.	Dioscoraceae
Allora dolleschalli (C. Felder, 1860)	*Rhysopteris timorensis*	Malpighiaceae
Hasora discolor (C. & R. Felder, 1859)	*Mucuna* sp.	Fabaceae
Hasora celaenus (Stoll, 1782)	*Derris cuneifolia*	Leguminaceae
Hasora subcaelestis Rothschild, 1916	*Derris elegans*	Leguminaceae
Toxidia inornata (Butler, 1883)	Wire grass species	Poaceae
Rachelia icosia (Fruhstorfer, 1911)	*?Pandanus sp.*	Pandanaceae
Notocrypta waiguensis (Plötz, 1882)	*Alpinia* sp.	Zingiberaceae
Notocrypta renardi (Oberthür, 1878)	*Alpinia* sp.	Zingiberaceae
Sabera dobboe (Plötz, 1885)	*Cordyline* sp.	Agavaceae
Mimene caesar Evans, 1935	*Calamus* sp.	Arecaceae
Kobrona wama (Plötz, 1885)	*Rhyncospora* sp.	Cyperaceae
Cephrenes augiades (C. Felder, 1868)	*Alexandria* sp.	Arecaceae
Telicota eurotas (C. Felder, 1860)	*Rhyncospora* sp.	Cyperaceae
Arrhenes marnas (C. Felder, 1860)	Grass species	Poaceae
Suniana sunias (C. Felder, 1860)	Grass species	Poaceae
Borbo cinnara (Wallace, 1866)	Grass species	Poaceae
Pelopidas agna (Moore, 1866)	Grass species	Poaceae
Atrophaneura polydorus (Linnaeus, 1763)	*Aristolochia* sp.	Aristolochiaceae
Troides oblongomaculatus (Goeze, 1779)	*Aristolochia schlechteri*	Aristolochiaceae
Graphium agamemnon (Linnaeus, 1758)	*Melodorum* sp.	Annonaceae
Papilio aegeus Donovan, 1805	*Tetractomia tetrandrum*	Rutaceae
Papilio ambrax Boisduval, 1832	*Micromelium* sp.	Rutaceae
Papilio ulysses Linnaeus, 1758	*Euodia* sp.	Rutaceae
Papilio euchenor (Guérin-Méneville, 1831)	*Euodia* sp.	Rutaceae
Catopsilia pomona (Fabricius, 1775)	*Cassia* sp.	Fabaceae
Eurema hecabe (Linnaeus, 1758)	*Cassia* sp.	Fabaceae
Praetaxila statira (Hewitson, 1861)	*unidentified*	Fabaceae
Hypochrysops apelles (Fabricius, 1775)	*Allophylus* sp.	Sapindaceae
Hypochrysops pythias C. & R. Felder, 1865	*Commersonia* sp.	Sterculiaceae
Hypochrysops polycletus (Linnaeus, 1758)	*Rhysopteris morensis*	Malpighiaceae
Philiris violetta (Röber, 1926)	*Litsea guppyi*	Lauraceae
Philiris sp. nr. *fulgens* (Grose-Smith & kirby, 1897)	*Litsea ?leefeana*	Lauraceae
Philiris intensa (Butler, 1876)	*Pipturus* sp.	Urticaceae
Philiris moira (Grose-Smith, 1899)	*Ficus sp.*	Moraceae
Arhopala philander C. & R. Felder, 1865	*Pometia pinnata*	Sapindaceae
Arhopala thamyras (Linnaeus, 1758)	*Syzigium* sp.	Myrtaceae
Hypolycaena phorbas (Fabricius, 1793)	*Smilax* sp.	Smilacaceae
Hypolycaena danis (C. & R. Felder, 1865)	*Dendrobium* sp.	Orchidaceae

TAXON	FOODPLANT SPECIES	FOODPLANT FAMILY
Nacaduba cyanea (Cramer, 1775)	*Entanda* sp.	Fabaceae
Psychonotis caelius (C. & R. Felder, 1860)	*Alphitonia petriei*	Rhamnaceae
Catopyrops ancyra (C. Felder, 1860)	*Pipturus argenteus*	Urticaceae
Upolampes evena (Hewitson, 1876)	*Alphitonia petriei*	Rhamnaceae
Euchrysops cnejus (Fabricius, 1798)	*Pueraria* sp.	Fabaceae
Euploea wallacei C. & R. Felder, 1860	*Ficus* sp.	Moraceae
Mycalesis sp. 2 undescribed	Grass species	Poaceae
Harsiesis hygea (Hewitson, 1863)	*Bambusa* sp.	Poaceae
Melanitis leda (Linnaeus, 1758)	Grass species	Poaceae
Polyura (Charaxes) jupiter (Butler, 1869)	*Albizzia* sp.	Fabaceae
Cyrestis acilia (Godart, 1819)	*Ficus* sp.	Moraceae
Parthenos aspila Honrath, 1888	*Zanonia indica*	Cucurbitaceae
Pantoporia consimilis (Boisduval, 1832)	*Dalbergia* sp.	Fabaceae
Cethosia cydippe (Linnaeus, 1763)	*Hollrungia* sp.	Passifloraceae
Vindula arsinoe (Cramer, 1777)	*Adenia heterophylla*	Passifloraceae
Terinos tethys Hewitson, 1862	*Rhinorea sp.?.*	Violaceae
Cirrochroa regina C. & R. Felder, 1865	*Flacourtia* sp.	Flacourtiaceae
Phalanta alcippe (Cramer, 1782)	*Flacourtia* sp.	Flacourtiaceae
Cupha prosope (Fabricius, 1775)	*Flacourtia* sp.	Flacourtiaceae

was only recorded once, at the Frieda Base Site, during this survey but the species is also relatively seasonal in other parts of New Guinea and is in low numbers during the peak of the wet season (*pers. obs.*). Discussion with the site Project geologist revealed that this distinctive, conspicuous species is often common at Frieda Base Site.

Ornithoptera priamus **(Linnaeus, 1758). Common Birdwing.**

The most common of all *Ornithoptera* in New Guinea, this species was common to abundant at all sites surveyed, over a wide elevational range. Hatched pupae were located on vegetation entangled with foliage of *Aristolochia tagala*, the known larval foodplant.

Ornithoptera goliath **Oberthür, 1888. Goliath Birdwing.**

This impressive species, the second largest butterfly in the world and that with arguably the greatest wing area, was observed at Malia Site on three occasions and also at Ok Isai Site and Wario Site. On the current market, specimens fetch more than 30K per pupa (Wau Ecology Institute personnel *pers. comm*., 2009).

Ornithoptera paradisea **(Staudinger, 1893). Butterfly of Paradise.**

This beautiful, tailed birdwing species is highly sought after and fetches sometimes several tens of Kina per pupae/adult. It has been reared from *Paristolochia* sp., and occurs fairly commonly within the Study Area and at Ambunti, East Sepik Province. The species could be readily ranched.

Ornithoptera meridionalis **Rothschild, 1897. Onithoptère Méridional**

This species, another tailed taxon, similar to *O. paradisea* is much prized by collectors and adults or pupae fetch large sums. There is little record of the species being ranched in PNG, although it is feasible. Certainly the alleged presence of the species at Frieda Strip Site suggests that this predominantly lowland species could be ranched on the flats in the Study Area.

Ornithoptera chimaera **Rothschild, 1904. Chimaera Birdwing**

Although not recorded during the survey, it is likely present in the upper reaches of the Study Area, above approximately 1,200 m. It is ranched on Mt. Kaindi, Morobe Province and at various villages in Chimbu Province. According to the Wau Ecology Institute (*pers. comm.*, 2009), pupae of the insect are purchased from local villagers for 20K each at the former locality, making them a viable resource.

5.12 Habitat Selection

Despite their apparent mobility, the majority of butterflies are generally localised in occurrence and peculiar to specialised environments. All species recorded during the Study Area survey were assessed in terms of their habitat requirements, based on observations made during this survey, as well as experience with the same taxa attained throughout the region over two decades and information from the literature.

Butterfly composition and diversity is constrained less by FIMS forest types than the successional status of the vegetation which is directly related to the presence/absence of their particular foodplants and the particularly microclimates that prevail. Habitat conditions are divided into six categories, as outlined in Table 10.

The degree of restriction to these different categories is outlined in Appendix 7.3. Mature forest (A) and lightly disturbed forest (C), the two most prevalent in the Study Area, support the highest number of butterfly species. Two hundred fourty-six species (68.5%) and 249 species (69.4%) were found in mature forest and lightly disturbed forest, respectively and 76 species (21.2%) were considered to be restricted to closed canopy forest. Only 33 species (9.2%) of the total 359 were potential inhabitants of grasslands.

No species appeared restricted to riparian forest but this habitat is commonly used by males of many species for territories and for flight paths. If this forest type was eliminated it may substantially interfere with the butterflies’ reproductive cycles.

The tops of steep, jungle-clad hills are commonly used by males of many butterfly species to establish territories in which to seek females to copulate with. These sites are not necessarily the areas in which the butterflies breed but are extremely important in the conservation of species which are rare or in such low densities within the forest that such meeting points facilitate pairing.

5.13 Similarity Between Survey Sites

Figure 5 presents the dendrogram from cluster analysis. The obvious patterns indicate that there are two groups of lowland sites forming clusters, (i) Kaugumi Site, Wario Site, Wogamush Site, Kubkain Site, Frieda Bend Site, Ok Binai 1 Site, Malia Site and Ok Isai Site, (ii) East Sepik Site, Frieda Strip Site and Iniok Site. Upland sites also form two groups, namely (i) Nena Base Site, Frieda Base Site, Koki Site and Upper Ok Binai Site, (ii) HI Site and Ubiame Site. Strong correlation of butterfly faunas between survey sites is evident, with notable relationships between the various vegetation types and elevation (see under section 4).

One pairing that forms relatively early in the analysis (sister to all other sites) is that of HI Site with Ubiame Site, both of which were the highest elevation sites sampled during the survey of the Study Area. At Ubiame Site and the uppermost reaches of HI Site there is a unique vegetation type, amalgamated with the Lower Montane Forest (L ± c) forest described in Chapter 2. The accompanying butterfly fauna recorded is also unique, with several high elevation species not found elsewhere during the survey. In light of the peculiar fauna, boasting high endemicity, this Study Area Montane Zone is considered to be of particular value.

The second grouping of upland (moderate elevation) survey sites occurs within the Study Area Hill Zone, comprising Nena Base Site, Frieda Base Site, Koki Site and Upper Ok Binai Site. These sites range in elevation from 390 – 1,030 m and show affinities in the type of Hill Forest (Hm) vegetation at each site. Plants in the families Lauraceae and Euphorbiaceae, prominent foodplants for the most species diverse butterfly family, Lycaenidae, abound at all of these sites and several unusual lycaenid species (e.g., *Philiris* sp. undescribed, *Candalides* sp. undescribed) were shared between these sites but nowhere else. The Hill Forest (Hm) shared at the above mentioned sites appears to be extensive within and beyond the Study Area.

The remaining clusters emanating from the dendrogram all comprise sites that fall within the Study Area Lowland Zone or at the lowest margins of the Study Area Hill Zone (Kaugumi Site, Wario Site, Wogamush Site, Kubkain Site, Frieda Bend Site, Ok Binai 1 Site, Malia Site, Ok Isai Site, East Sepik Site, Frieda Strip Site and Iniok Site) and are characterised by Lowland Open Forest (Po), interspersed with Alluvial Wooded Swamp Complexes (Wsw/FsW) and grading into Hill Forest (Hm) where the sites abut hills. Where Lowland Open Forest (Po), interspersed with Alluvial Wooded Swamp Complexes (Wsw/FsW) meet appears to be particularly rich in monocotyledons (palms, sedges and grasses), which are the foodplants for the species diverse butterfly subfamilies Hesperiinae, Morphinae and Satyrinae (101 species combined recorded in the Study Area). Many of the butterfly taxa from these subfamilies were shared between the sites in the Study Area Lowland Zone but not found elsewhere.

On a finer scale, some explanation is required for the lack of similarity of some survey sites within the Study Area Lowland Zone. Iniok Site and Kubkain Site, for example, did not cluster, yet are very close spatially, similarly situated proximal to the Sepik River. However, the vegetation types at each of these sites differs considerably, with the former site dominated by Riverine Mixed Successions (Fri/Wri), physically manifested as scrolls, with intermittent Gallery Forest along drainages in more open areas while Kubkain Site has Hill Forest (Hm) amid Alluvial Wooded Swamp Complexes (Wsw/FsW). Several butterfly species were recorded only at one site or the other during the survey of the Study Area. Although seasonality is not particularly pronounced in New Guinea butterflies, the inverse timing of sampling at each site, late June (dry season) for Iniok Site and early March (wet season) for Kubkain Site, together with the vegetation type differences, may have contributed to the disparity between the sites.

Other sites in the Study Area Lowland Zone cluster depending on their vegetation types and resultant butterfly faunas. One cluster of four sites, namely Kaugumi Site, Wario Site, Wogamush Site and Kubkain Site may group because each site is a mosaic of Hill Forest (Hm) and Alluvial Wooded Swamp Complexes (Wsw/FsW). Conversely, although a proportion of the resident butterfly species are shared, there are few obvious similarities between the vegetation types at East Sepik Site, Frieda Strip Site and Iniok Site, hence the rather divergent, rather than tight clustering.

Table 10. Habitat condition types in the Study Area.

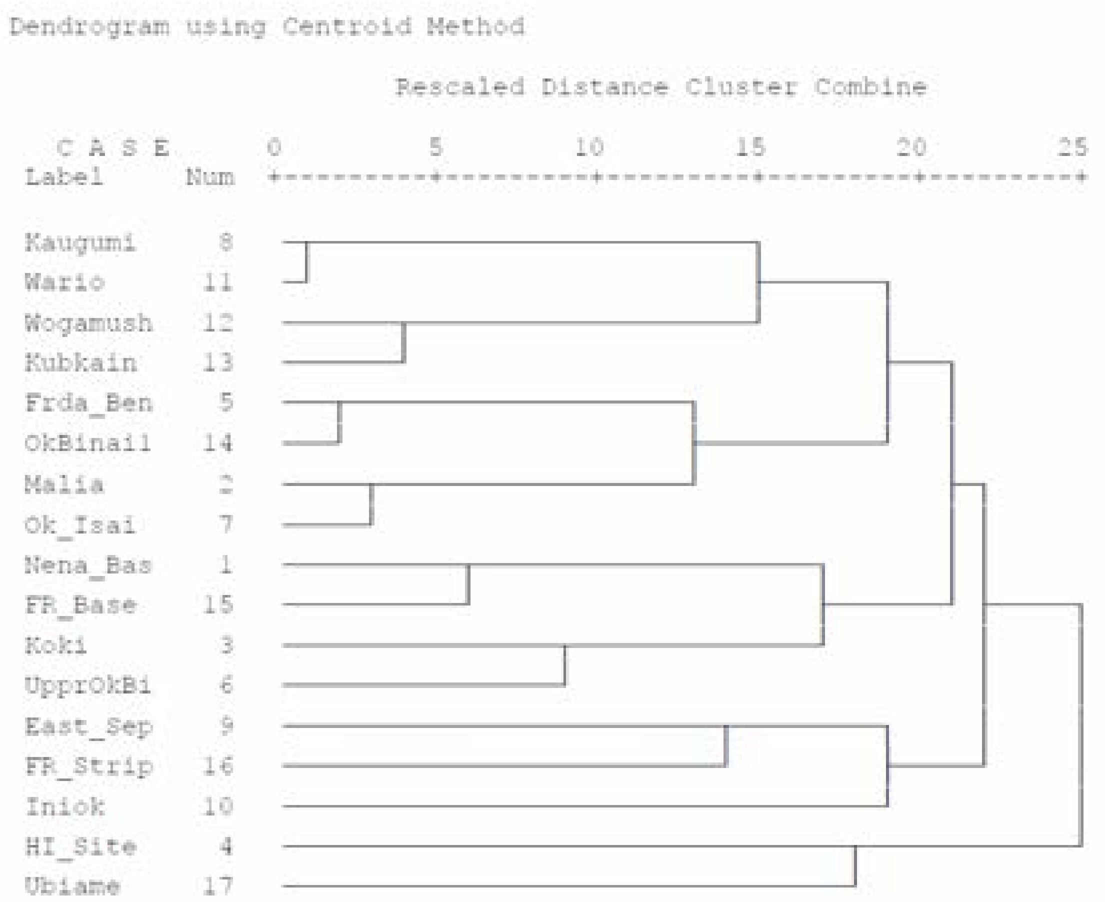
HABITAT CONDITION	LOWLAND OPEN FOREST (PO) AND ALLUVIAL WOODED SWAMP COMPLEXES (WSW/ FSW)	ALL OTHER FOREST TYPES
Mature forest (A)	Advanced stages of succession with continuous cover averaging at least 60% of medium to large crowned trees and a very uneven canopy but can have numerous gaps but few > 0.2 ha. Little evidence of human activity.	Old growth or primary habitat with natural levels of small gap disturbance (approx. 1%) and, if present, infrequent scattered larger gaps up to 0.2 ha each caused by large wind throws, small landslips or possibly human activity far from settlements.
Lightly disturbed forest (C)	Lightly disturbed and/or advanced successional open forests. They may be (1) advanced stages of succession but with a more even canopy produced by dominance of early secondary species and/or (2) well developed but not mature open forest with numerous large gaps likely to have resulted from gardening activity. Gaps generally greater than 0.2 ha, and areas of canopy damage or thinning. Generally occurs adjoining settlements, garden areas, or successional areas.	Forest with small areas of clearance or disturbance caused by isolated garden plots, or larger landslips. Gaps generally greater than 0.2 ha, and areas of canopy damage or thinning. Generally occurs adjoining settlements, garden areas, or areas of heavily disturbed forest (Type D)
Heavily disturbed, cleared or early successional forest (D)	Complexes of areas of pioneer, early secondary and other regenerating forest with areas of degraded but intact mature or lightly disturbed forest. These are either early to mid stage successions after flooding Riverine Mixed Successions (Fri/Wri) or have been heavily disturbed by man.	Forest that has been heavily disturbed by man or large-scale natural disturbance such as extensive landslides or flooding. Consisting of complexes of areas of pioneer, early secondary and other regenerating forests with areas of Mature or Lightly disturbed forest.
Riparian Forest	Lowland Open forest (Po), Hill Forest (Hm) or Lower Montane Forest (L ± c) immediately adjacent to waterways (> ca. 4m wide at least flow) within continously forested areas. Variously developed from mature forest with understory of often specilaised stream side trees and shrubs to areas dominated by tall grass or vines and scraggly regrowth.	
Heath		Areas of small crowned lower montane forest and small crowned lower montane forest with conifers with stunted vegetation, usually less than 8 metres tall. Few fleshy species, nearly all with hardened trunks and branches. Essentially restricted to moderate and high elevations.

6 CONCLUSION

This study has substantially increased our knowledge of the butterflies of the Upper Sepik River basin. Several new and/or poorly known species were recorded during the survey, and five of the seven Birdwing species known to occur in mainland PNG are reported.

Survey sites in the Study Area Montane Zone exhibited the highest degrees of endemism. However, overall there was no direct correlation between endemism and elevation and endemics were recorded in mature forest (A) and lightly disturbed forest (C) in a range of vegetation types at varying elevations. The Peat Forest at East Sepik Site is unique.

With very few exceptions, even the rarest and undescribed butterfly species encountered during the survey have, or are expected to have, wider distributions outside of the Study Area.



Sites are labelled Nena Base Site (Nena_Bas); Malia Site (Malia); Koki Site (Koki); HI Site (HI_Site); Frieda Bend Site (Frda_Ben); Upper Ok Binai Site (UpperOkBi); Ok Isai Site (Ok_Isai); Kaugumi Site (Kaugumi); East Sepik Site (East_Sep); Iniok Site (Iniok); Frieda Base Site (FR_Base); Frieda Strip Site (FR_Strip); Ubiame Site (Ubiame); Wario Site (Wario); Wogamush Site (Wogamush); Kubkain Site (Kubkain) and Ok Binai 1 Site (OkBinai1)

Figure 5. Dendrogram for all Study Area sites using Centroid Method.

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PLATES

1. Adult male *Hasora subcaelestis*, freshly emerged.

2. Adult male *Hasora celaenus*, freshly emerged.

3. Anterior view of *H. subcaelestis* mature larva.

4. Anterior view of *H. celaenus* mature larva.

5. Dorsal view of *H. subcaelestis* pupa.

6. Dorsal view of *H. celaenus* pupa.

7. As with other members of the subfamily, the Banded Red-Eye, *Chaetocneme critomedia*, typically rests on the undersides of leaves.

8. An undescribed *Chaetocneme* species from Koki WE Site, distinctive in the absence of a forewing costal fold, its wing shape, ferruginous ground colour and orange cilia.

9. *Chaetocneme* larval shelters, likely those of *C. critomedia* on an unidentified Annonaceous foodplant.

10. *Chaetocneme tenuis*, typical of the genus with its fore wing costal (anterior) flap.

11. The ubiquitous *Tagiades japetus* at rest under foliage.

12. The beautiful, moth-like, *Allora doleschalli*.

13. The early stages of *Chaetocneme* were hitherto unknown from outside of Australia. Illustrated is a mature larva of *C. antipodes*.

14. The pupa of *C. antipodes*, exposed within its shelter.

15. Fairly common at most sites in the Study Area Lowland Zone is *Hewitsoniella migonitis*, shown here feeding from a paper lure.

16. The unusual, moth like *Kachella icosa*.

17. The hitherto unknown larva of *Mimene* cf. *caesar* on its foodplant, *Calamus* sp. (Arecaceae).

18. The pupa of *M.* cf. *caesar* exposed within its puparium.

19. Almost exclusively Australian, the subfamily Trapezitinae is represented by only a few in NG. This species is *Toxidia inornata*.

20. Ginger Darter, *Notocrypta waigensis*, feeding on discarded sugar cane.

21. *Telicota paceka* at rest.

22. Mature larva of a *Sabera* species, unidentified due to parasitism by a Tachinid fly, i.e., The adult butterfly did not emerge.

23. Several species of skipper butterfly (Hesperiidae) were attracted to paper lures, imitating bird droppings. Shown here is an unidentified species of *Telicota*, not captured.

24. Many *Mimene* species were recorded during the Study Area surveys. Shown is *M. basalis*.

25. The rare *Caltoris philippina* attracted to paper lures.

26. The Green-Spotted Triangle, *Graphium agamemnon*, a common butterfly throughout the Indo-Pacific tropics.

27. The Five Bar Swordtail, *G. aristeus*, is one of several tailed Graphiums occurring in the Indo-Pacific.

28. A Green Triangle, *G. macfarlanei*, imbibing from urine-stained pebbles.

29. An aggregation of three *Graphium* species: *G. aristeus*, *G. eurypylus* (Pale Green Triangle) and *G. sarpedon* (Blue Triangle).

30. Birdwing Butterflies are universally known. Shown here is a female of the 'Butterfly of Paradise', *Ornithoptera paradisea*, ready to be released.

31. Males of *O. paradisea* often defended territories from high canopy perches. They rest with wings outstretched, showing their magnificent colouration.

32. Adult male *O. paradisea* flew very high, their hind wing tails being particularly evident.

33. Figured is a male of *Ornithoptera priamus*, common at nearly all surveyed sites in the Study Area.

34. The females, in particular, of Birdwings can attain appreciable wingspans. All *Ornithoptera* species are sexually dimorphic, the females always brown and cream/yellow.

35. The Red Bodied Swallowtail, *Atrophaneura polydorus*, was recorded at nearly all sites in the Study Area Lowland Zone.

36. The larva of *A. polydorus* on its foodplant, *Aristolochia* sp. (Aristolochiaceae).

37. A large species, ubiquitous in primary forest, *Papilio euchenor*, always rests with outspread wings.

38. The Orchard Butterfly, *Papilio aegeus*, is very common in forests and gardens throughout the region.

39. *Delias* butterflies (Jezebels) constitute a significant proportion of the PNG butterfly fauna, *D. aruna*, figured, is one of the largest.

40. *Delias ornytion* was infrequently encountered at Upper Ok Binai Site and Koki Site in the Study Area.

41. The Broad Margined Yellow, *Eurema puella*, was abundant at most sites in the Study Area.

42. The Tree Yellow, *Gandaca butyrosa*.

43. A group of the Rare Albatross, *Appias ada*, drinking from a damp spot. At right is the lycaenid, *Catopyrops ancyra*.

44. 17 species of *Hypochrysops* were recorded in the Study Area. The highly elusive *H. heros* was recorded singly at several sites.

45. The spectacular *Hypochrysops polycletus* was abundant at several sites in the Study Area.

46. *Hypochrysops chrysargyrus*, one of the most distinctive in its genus, is remarkably camouflaged, considering its beauty.

47. The Copper Jewel, *Hypochrysops apelles*.

48. The Peacock Jewel, *Hypochrysops pythias*.

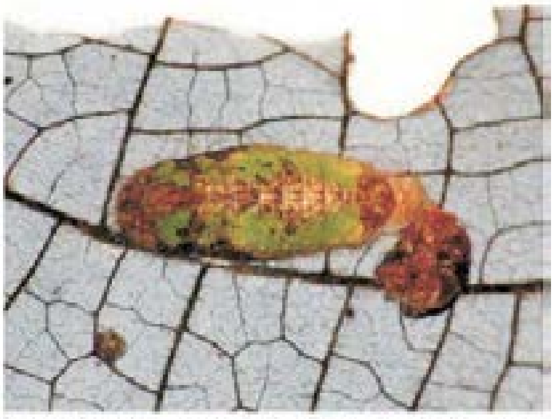
49. *H. apelles*, parasitised larva.

50. *H. apelles*, pupa in rolled dead leaf.

51. Several *Philiris* species were recorded in the Study Area. That figured is *P. praeclara*, known from only a few localities in PNG.

52. Previously only known from the type series taken at Pagwi (East Sepik Prov.), here shown is a male *Philiris pagwi* defending its territory.

53. The larva of *Philiris violetta* on its foodplant, *Litsea guppyi* [Lauraceae].



54. Pupa of *P. violetta*. Note the shed larval skin at the right of the pupa.

55. The ubiquitous, yet beautiful, Common Tit, *Hypolycaena phorbas*.

56. *Hypochlorosis ancharia* was common at several sites in the Study Area Lowland Zone.

57. The mature larva of *Philiris fulgens*, feeding on *Litsea irwiniana*.

58. The well disguised pupa of *P. fulgens*.

59. The Small Green-Banded Blue, *Psychonotis caelius*, is common in both NG and eastern Australia and certainly throughout the Study Area. It is part of a mimicry ring of similarly patterned Lycaenid butterflies.

60. The Large Green-Banded Blue, *Danis danis*, was ubiquitous in primary forest at nearly all Study Area sites.

61. *Perpheres perpheres* is yet another species within a complex Muellerian mimicry ring, comprising species with metallic green bands.

62. Photographed on take off, this glorious *Arhopala herculina* male shows its true colours.

63. Oakblues, *Arhopala* species, were diverse within the Study Area. Figured is *A. alkisthenes*.

64. *Arhopala thamyras* was dominant at many Study Area survey sites.

65. Where known, the larvae of all *Arhopala* species are attended by ants. Here, *Crematogaster* ants 'milk' a larva of *A. thamyras*, in exchange for protection from predators.

66. Pupa of *A. thamyras*, exposed from opened shelter on *Syzygium* (Myrtaceae) foodplant.

67. Several species of Riodininae were recorded in the Study Area. Figured is *Dicallaneura ribbei*.

68. A female of *Dicallaneura kirschi*.

69. The intricately patterned *Praetaxila statira*.

70. The egg of *P. statira*. No life history information is known about NG members of this subfamily.

71. Adult males of *Praetaxila segecia* were commonly encountered on various hilltops at dusk, sometimes flying until dark.

72. Denizens of deep, dark jungle, *Praetaxila huntei* typically flits among low foliage about a metre from the ground.

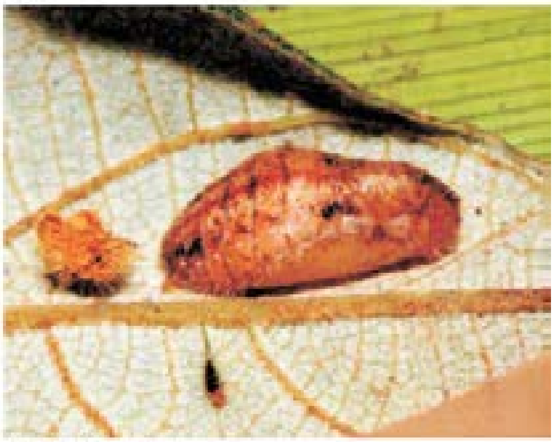
73. The Dusky Blue, *Erysichton lineata*, was dominant at several Study Area sites.

74. *Nacaduba subperusia* is one of only two NG species in the genus lacking a fore wing cell bar on the underside.

75. A pair of mating *Nacaduba tristis*.

76. *Upolampes evena* was common at most sites in the Study Area Hill Zone.

77. The mature larva of *U. evena* ejecting frass.



78. The pupa of *U. evena*.

79. The iridescent male *Epimastidia inops*, together with unrelated lycaenids *Ionolyce helicon* and *Prosotas dubiosa*.

80. Agglomeration of *Ionolyce helicon* at urine stained sand, where they are particularly well camouflaged.

81. The large, beautiful and poorly known *Morphopsis biakensis* was encountered at higher altitudes at HQ site.

82. Abundant but very localised is the unusual *Lamprolenis nitida*.

83. The striking *Mycalesis duponcheli*.

84. The rather elusive *M. fulvianetta*.

85. Bushbrowns, *Mycalesis* species, were well represented in the Study Area. Shown is *M. sirius*.

86. A male *M. durga*.

87. Known previously only from the type series, figured is a male of *M. pomaria*.

88. The boldly marked *M. mehadeva*.

89. A male *M. cacodaemon* defends its territory from a low perch.

90. One of the largest *Mycalesis* is *M. mucia*, recorded at several sites in both the Study Area Lowland and Hill Zones.

91. *Mycalesis anabella* was hitherto known only from Waigeo Island, Papua Province, Indonesia.

92. A male of *Euthaliopsis aetion*, entering a bait trap.

93. An egg of the poorly known *Elymnias papua* .

94. A freshly emerged larva of *E. papua*, having consumed its egg shell.

95. Several species of Crow, *Euploea* species, were recorded during the Study Area surveys. Probably the most common was *E. alcathoe*, shown here.

96. The Black and White Tiger, *Danaus affinis*, is a pioneer species in disturbed habitats.

97. Several species of Owl Butterflies (*Taenaris*), so named for their eye spots, were recorded during the Study Area. This is *T. catops*.

98. Fermented fruit baits worked particularly well for *Taenaris* species. At left is *T. dimona*, while the species to the right is undescribed.

99. The rather localised *Taenaris honrathi*.

100. *Taenaris myops* at rest at night.

101. Similar to *Taenaris* is the monotypic genus *Hyantis*. *H. hodeva* has a peculiar habit of resting with its hindwings partially open.

102. Bait traps were a very successful means of sampling *Taenaris*. At least three species can be seen within the trap in this photograph.

103. The satyrid *Hypocysta isis* is an inconspicuous insect that keeps close to the forest floor.

104. Butterflies of the genus *Elymnias* are secretive by nature. Here figured is *E. cybele*.

105. The powerful Orange Rajah, *Charaxes latona*, feeding from urine stained sand.

106. The Tailed Emperor, *Polyura* (*Charaxes*) *jupiter*, feeding in a creek bed.

107. Common at nearly all lowland sites but difficult to observe at close range is *Prothoe australis*.

108. Urine baits worked particularly well at Malia Site and at Frieda Bend Site. Photographed here is an agglomeration of some 15 species.

109. The ova of the Clipper, *Parthenos aspila*, effectively disguised among seeds of the sedge, *Rhynchospora* sp.

110. The mature larva of *P. aspila*, feeding on its vine food plant, *Zanonia indica*.

111. The pupa of *P. aspila*.

112. A freshly emerged male *P. aspila*, drying its wings.

113. *P. aspila* female in typical rest mode, with wings outstretched.

114. *P. aspila* and *Elymnias cybele* attracted to rotten *Ficus* fruits.

115. One of the most common nymphalid in NG is the Cape York Aeroplane, *Pantoporia venilia*.

116. The striking *Dichorragia ninus* at a seepage within a creek bed.

117. An inhabitant of deep jungles, a female of *Lexias aeropa*.

118. The hitherto unknown larva of *Terinos tethys*.

119. The hitherto unknown pupa of *T. tethys*.

120. Freshly emerged male of *Terinos tethys*, drying its wings.

121. *Cirrochroa regina* was particularly common at all Study Area Lowland Zones sites. A male is shown here resting on foliage.

122. *C. regina*, wings outspread.

123. The larva of *C. regina*, feeding on an unidentified species of *Flacourtia* (Flacourtiaceae).

124. Pupae of the subfamily Heliconiinae are highly ornate. Those of *C. regina* are no exception.

125. The Cruiser, *Vindula arsinoe*, is a widespread, powerful insect, shown here feeding at a river bank.

126. One of the most conspicuous butterflies in NG is the Red Lacewing, *Cethosia cydippe*.

127. Main Site, viewed from the air towards the south-west.

128. Long handled nets were required to collect certain high flying arboreal species, particularly Lycaenidae.

129. Secondary vegetation at Hi Site below Urabe. Type habitat for *Mycalesis* sp. undescribed.

130. Panorama of Frieda Base Site and Hi Site towards the north-east from a knoll above Hi Site.

131. Mt. Stolle viewed from the summit of Urabe.

132. Frieda River, north of Wabia, following heavy rain.

APPENDICES

Appendix 7.1. Species recorded and their abundance at each site.

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Hesperiidae	Pyrginae	*Chaetocneme antipodes* (Guérin-Méneville, 1831)									1									1							
Hesperiidae	Pyrginae	*Chaetocneme callixenus* Hewitson, 1867															2										
Hesperiidae	Pyrginae	*Chaetocneme critomedia* (Guérin-Méneville, 1831)	Banded Red-Eye										1									3	1				
Hesperiidae	Pyrginae	*Chaetocneme tenuis* (van Eecke, 1924)				4								1		3	3			1		1	1				
Hesperiidae	Pyrginae	*Chaetocneme* sp. nov.										1															
Hesperiidae	Pyrginae	*Netrocoryne thaddeus* (Hewitson, 1876)																	1		1						
Hesperiidae	Pyrginae	*Tagiades japetus* (Stoll, 1781)	Black and White Flat			3					5			3		3	3		4	3	2	4	3	4	5		
Hesperiidae	Pyrginae	*Tagiades trebellius* (Höpffer, 1874)									3																
Hesperiidae	Pyrginae	*Tagiades nestus* (C. Felder, 1860)				5					5					5	5	5		2	3	4	5	4	5		
Hesperiidae	Coeliadinae	*Badamia exclamationis* (Fabricius, 1775)	Migratory Awl											1		1		1				1					
Hesperiidae	Coeliadinae	*Allora dolleschalli* (C. Felder, 1860)	Peacock Awl								1					1	1							2			
Hesperiidae	Coeliadinae	*Hasora discolor* (C. & R. Felder, 1859)	Green Awl			1												1				1	1	2			
Hesperiidae	Coeliadinae	*Hasora hurama* (Butler, 1870)	Broad-Banded Awl														1					1	2				
Hesperiidae	Coeliadinae	*Hasora khoda* (Mabille, 1876)	Narrow banded Awl								1	1				1							2				
Hesperiidae	Coeliadinae	*Hasora celaenus* (Stoll, 1782)									1					1			1	1	1	1					
Hesperiidae	Coeliadinae	*Hasora subcaelestis* Rothschild, 1916				1					2					1	1	2		3		3					
Hesperiidae	Trapezitinae	*Hewitsoniella migonitis* (Hewitson, 1876)																	2		2	5					
Hesperiidae	Trapezitinae	*Felicena dirpha* (Boisduval, 1832)																								2	
Hesperiidae	Trapezitinae	*Toxidia inornata* (Butler, 1883)	Spotless Grass Skipper									2								2			2	3			
Hesperiidae	Trapezitinae	*Rachelia extrusa* (C. & R. Felder, 1867)	Blue-Flash Skipper			1								1													
Hesperiidae	Trapezitinae	*Rachelia icosia* (Fruhstorfer, 1911)															2					3					
Hesperiidae	Hesperiinae	*Tiacellia tiacellia* (Hewitson, 1868)															1										
Hesperiidae	Hesperiinae	*Erionota thrax* (Linnaeus, 1767)	Banana Skipper																						4		
Hesperiidae	Hesperiinae	*Notocrypta waiguensis* (Plötz, 1882)	Banded Demon			5					5	5		5		5	4	5		4	1	3		4	5		
Hesperiidae	Hesperiinae	*Notocrypta renardi* (Oberthür, 1878)									4	4	5	2	4		2					4		4			
Hesperiidae	Hesperiinae	*Notocrypta flavipes* (Janson, 1886)																		1							

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Hesperiidae	Hesperiinae	*Sabera caesina* (Hewitson, 1886)	White-clubbed Swift																			3	1				
Hesperiidae	Hesperiinae	*Sabera kumpia* Evans, 1949									2																
Hesperiidae	Hesperiinae	*Sabera biaga* Evans, 1949																				1					
Hesperiidae	Hesperiinae	*Sabera misola* Evans, 1949																				1					
Hesperiidae	Hesperiinae	*Sabera fuliginosa* (Miskin, 1889)	White-fringed Swift																				1				
Hesperiidae	Hesperiinae	*Sabera dobboe* (Plötz, 1885)	Yellow-streaked Swift			1																1		2			
Hesperiidae	Hesperiinae	*Sabera tabla* (Swinhoe, 1905)												1	1												
Hesperiidae	Hesperiinae	*Sabera sp. nov. 1*				1																					
Hesperiidae	Hesperiinae	*Sabera sp. nov. 2*																	2								
Hesperiidae	Hesperiinae	*Mimene kolbei* (Ribbe, 1899)																				1					
Hesperiidae	Hesperiinae	*Mimene celiaba* Parsons, 1986											1	1		2	2				1						
Hesperiidae	Hesperiinae	*Mimene biakensis* Joicey & Talbot, 1917									1					1					1						
Hesperiidae	Hesperiinae	*Mimene caesar* Evans, 1935												1		3	2				1		2				
Hesperiidae	Hesperiinae	*Mimene sariba* Evans, 1935									1																
Hesperiidae	Hesperiinae	*Mimene basalis* (Rothschild, 1916)												2		3											
Hesperiidae	Hesperiinae	*Mimene verda* Parsons, 1986														2							2				
Hesperiidae	Hesperiinae	*Mimene atropatene* (Fruhstorfer, 1911)	Purple Swift											1		1			1			3					
Hesperiidae	Hesperiinae	*Mimene cyanea* (Evans, 1928)									1																
Hesperiidae	Hesperiinae	*Mimene lysima* (Swinhoe, 1905)																				2					
Hesperiidae	Hesperiinae	*Mimene celia* Evans, 1935																				1					
Hesperiidae	Hesperiinae	*Mimene miltias* (Kirsch, 1877)																				1					
Hesperiidae	Hesperiinae	*Mimene melie* (de Nicéville)																				1					
Hesperiidae	Hesperiinae	*Mimene milnea* Evans, 1935												1					2		1	1					
Hesperiidae	Hesperiinae	*Kobrona wama* (Plötz, 1885)				1													1								
Hesperiidae	Hesperiinae	*Kobrona rasta* Evans, 1935				1																					
Hesperiidae	Hesperiinae	*Kobrona infralutea* (Rothschild, 1916)											1														
Hesperiidae	Hesperiinae	*Kobrona* sp. nov.																	1			1					

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Hesperiidae	Hesperiinae	*Cephrenes augiades* (C. Felder, 1868)	Palm Dart								2	5										1					
Hesperiidae	Hesperiinae	*Cephrenes moseleyi* (Butler, 1884)									1																
Hesperiidae	Hesperiinae	*Cephrenes augiana* Evans, 1934																1	5								
Hesperiidae	Hesperiinae	*Telicota augias* (Linnaeus, 1763)	Bright Orange Darter													2											
Hesperiidae	Hesperiinae	*Telicota melanion* (Mabille, 1878)															2		2			2	1				
Hesperiidae	Hesperiinae	*Telicota ternatensis* Swinhoe, 1907												1								2					
Hesperiidae	Hesperiinae	*Telicota paceka* Fruhstorfer, 1911												1					3			1	1				
Hesperiidae	Hesperiinae	*Telicota bulwa* Parsons, 1986				1													2			4					
Hesperiidae	Hesperiinae	*Telicota kezia* Evans, 1949				2													2				1				
Hesperiidae	Hesperiinae	*Telicota gervasa* Evans, 1949				1																					
Hesperiidae	Hesperiinae	*Telicota vinta* Evans, 1949																	3			2	1				
Hesperiidae	Hesperiinae	*Telicota eurotas* (C. Felder, 1860)	Northern Sedge Darter																			2			4		
Hesperiidae	Hesperiinae	*Telicota sp.*									1																
Hesperiidae	Hesperiinae	*Arrhenes marnas* (C. Felder, 1860)	Swamp Darter			5					5	5	5	5		5			5	5	2	1	4	5			
Hesperiidae	Hesperiinae	*Arrhenes dschilus* (Plötz, 1885)	Scrub Darter																	3				2	4		
Hesperiidae	Hesperiinae	*Suniana sunias* (C. Felder, 1860)	Wide-Brand Grass Dart			5					5			5		5				5		2	5	5	5		
Hesperiidae	Hesperiinae	*Ocybadistes ardea* Bethune-Baker, 1906	Orange Grass Dart			1																1		2			
Hesperiidae	Hesperiinae	*Ocybadistes papua* Evans, 1934												2													
Hesperiidae	Hesperiinae	*Parnara amalia* (Semper, 1879)	Orange Swift																1								
Hesperiidae	Hesperiinae	*Borbo impar* (Mabille, 1883)	Yellow Swift								4												2				
Hesperiidae	Hesperiinae	*Borbo cinnara* (Wallace, 1866)	Rice Swift								4																
Hesperiidae	Hesperiinae	*Pelopidas agna* (Moore, 1866)	Dingy Swift			3					2							2				2		3	5		
Hesperiidae	Hesperiinae	*Pelopidas lyelli* Rothschild, 1915	Lyell's Swift			3					1					2			3			2	2				
Hesperiidae	Hesperiinae	*Pelopidas mathias* (Fabricius, 1789)																				1					
Hesperiidae	Hesperiinae	*Caltoris boisduvali* (C. & R. Felder, 1867)										1							2			2					
Hesperiidae	Hesperiinae	*Caltoris philippina* (Herrich-Schäffer, 1869)																				2					
Papilionidae	Papilioninae	*Atrophaneura polydorus* (Linnaeus, 1763)	Red-Bodied Swallowtail								4			5	4	4	2			2	2		3	5	4		

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Papilionidae	Papilioninae	*Troides oblongomaculatus* (Goeze, 1779)	Troides Birdwing																					2			
Papilionidae	Papilioninae	*Ornithoptera priamus* (Linnaeus, 1758)	Common Birdwing			3					4	3		4	5	4	4			3	1			4	5		
Papilionidae	Papilioninae	*Ornithoptera goliath* Oberthür, 1888	Goliath Birdwing		P						3					1				1							
Papilionidae	Papilioninae	*Ornithoptera paradisea (Staudinger, 1893)*	Butterfly of Paradise		P												4			3	4	1	1		1		X
Papilionidae	Papilioninae	**Ornithoptera meridionalis* Rothschild, 1897	Ornithoptère Méridional	EN	P												1										X
Papilionidae	Papilioninae	*Graphium agamemnon* (Linnaeus, 1758)	Green-Spotted Triangle			5					4	2	4	4	5	5	5	5		4	4	3	4	4	4		
Papilionidae	Papilioninae	*Graphium macfarlanei* (Butler, 1877)	Green Triangle			3					4					4									4		
Papilionidae	Papilioninae	*Graphium wallacei* (Hewitson, 1858)				2					2					2	2	1		2	2	4	1				
Papilionidae	Papilioninae	*Graphium weiskei* (Ribbe, 1900)	Weiske's Swallowtail																							2	
Papilionidae	Papilioninae	*Graphium codrus* (Cramer, 1777)				3										3	2	1		1	3	3		2			
Papilionidae	Papilioninae	*Graphium sarpedon* (Linnaeus, 1758)	Blue Triangle			4					4			3		5	4	2		3	3	4	5	4	5		
Papilionidae	Papilioninae	*Graphium euryplus* (Linnaeus, 1758)	Pale-Green Triangle			4					5			5		5	5			5	4	5	5	5	5		
Papilionidae	Papilioninae	*Graphium aristeus* (Stoll, 1781)	Five-Bar Swordtail								3			5			4	3		1	1		4	5	5		
Papilionidae	Papilioninae	*Chilasa laglazei* (Depuiset, 1877)									1																
Papilionidae	Papilioninae	*Papilio aegeus* Donovan, 1805	Orchard Swallowtail								5	5	4	5	5	3	4			5	4	5	3	5	5		
Papilionidae	Papilioninae	*Papilio ambrax* Boisduval, 1832	Ambrax Swallowtail								5			1			2			4	4	4	5				
Papilionidae	Papilioninae	*Papilio albinus* Wallace, 1865											1														
Papilionidae	Papilioninae	*Papilio ulysses* Linnaeus, 1758	Ulysses			3					5	5	3	4	5	4	5			2	2	3	4	5	5		
Papilionidae	Papilioninae	*Papilio euchenor* (Guérin-Méneville, 1831)				5					5	5	3	5	5	5	5	3	1	3		3	3	5	5		
Pieridae	Coliadinae	*Catopsilia pomona* (Fabricius, 1775)	Lemon Migrant								3			5		3	4			5			5	5	5		
Pieridae	Coliadinae	*Eurema hecabe* (Linnaeus, 1758)	Large Grass Yellow			5					3			5	2	4	4			4		4	3	5	5		
Pieridae	Coliadinae	*Eurema blanda* (Boisduval, 1836)													1												
Pieridae	Coliadinae	*Eurema puella* (Boisduval, 1832)	Broad-Margined Yellow			5					5	3	4	5	4	4	4			5		5	5	4	5		
Pieridae	Coliadinae	*Gandaca butyrosa* (Butler, 1875)									1					2				2			1				
Pieridae	Pierinae	*Leuciacria acuta* Rothschild & Jordan, 1905																								2	
Pieridae	Pierinae	*Elodina andropis* Butler, 1876				2						1															
Pieridae	Pierinae	*Elodina hypatia* C. & R. Felder, 1865										1							4	2	3						

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Pieridae	Pierinae	*Saletara cycinna* (Hewitson, 1868)									1												4				
Pieridae	Pierinae	*Appias paulina* (Cramer, 1777)	Common Albatross								2																
Pieridae	Pierinae	*Appias celestina* (Boisduval, 1832)	Blue Albatross			4					2			5		4	3	1		5	3		4	5	5		
Pieridae	Pierinae	*Appias ada* (Stoll, 1781)	Rare Albatross								1						2		5		2	2					
Pieridae	Pierinae	*Cepora abnormis* (Wallace, 1867)										2								2							
Pieridae	Pierinae	*Cepora perimale* (Donovan, 1805)	Common Gull																				1		4		
Pieridae	Pierinae	*Delias enniana* (Oberthür, 1880)									1																
Pieridae	Pierinae	*Delias pulla* Talbot, 1937																								2	
Pieridae	Pierinae	*Delias ennia* (Wallace, 1867)	Yellow-Banded Jezebel			1															1	1		2			
Pieridae	Pierinae	*Delias gabia* (Boisduval, 1832)				2					3	5		1		2				2							
Pieridae	Pierinae	*Delias ladas* Grose-Smith, 1894				4							4													3	
Pieridae	Pierinae	*Delias* cf. *eudiabolas* Rothschild, 1915				2																					
Pieridae	Pierinae	*Delias mysis* (Fabricius, 1775)	Union Jack								2						2		2		3	3					
Pieridae	Pierinae	*Delias aruna* (Boisduval, 1832)	Orange Jezebel								3		1										1				
Pieridae	Pierinae	*Delias discus* Honrath, 1886				2						3	2														
Pieridae	Pierinae	*Delias ornytion* (Godman & Salvin, 1880)										2			2												
Lycaenidae	Riodininae	*Dicallaneura decorata* (Hewitson, 1862)											2									1		3			
Lycaenidae	Riodininae	*Dicallaneura kirschi* Röber, 1886				2					2	3		2				1	2		1						
Lycaenidae	Riodininae	*Dicallaneura ribbei* Röber, 1886																	1			3					
Lycaenidae	Riodininae	*Praetaxila huntei* (Sharpe, 1903)									2	2					1										
Lycaenidae	Riodininae	*Praetaxila satraps* (Grose-Smith, 1894)				1															1	5					
Lycaenidae	Riodininae	*Praetaxila statira* (Hewitson, 1861)									2						2						1				
Lycaenidae	Curetinae	*Curetis barsine* C. Felder, 1860				3					5					2				2							
Lycaenidae	Lycaeninae	*Liphyra brassolis* Westwood, 1864	Moth Butterfly									2				1											
Lycaenidae	Lycaeninae	*Pseudodipsas eone* (C. & R. Felder, 1860)	Dark Forest Blue								4	4	4							1							
Lycaenidae	Lycaeninae	*Hypochrysops apollo* Miskin, 1891	Apollo Jewel																			2					

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Lycaenidae	Lycaeninae	*Hypochrysops chrysargyrus* Grose-Smith & Kirby, 1895									1								2								
Lycaenidae	Lycaeninae	*Hypochrysops arronica* (C. & R. Felder, 1859)				3						2	1									2					
Lycaenidae	Lycaeninae	*Hypochrysops plotinus* Grose-Smith, 1894				2														1	1			2			
Lycaenidae	Lycaeninae	*Hypochrysops narcissus* (Fabricius, 1775)	Narcissus Jewel																		2	3		2			
Lycaenidae	Lycaeninae	*Hypochrysops argyriorufus* van Eecke, 1924																	4	1		3					
Lycaenidae	Lycaeninae	*Hypochrysops castaneus* Sands, 1986																	3	1							
Lycaenidae	Lycaeninae	*Hypochrysops hermogenes* Grose-Smith, 1894										1															
Lycaenidae	Lycaeninae	*Hypochrysops ?cleonides* Grose-Smith, 1900 (probable)									1																
Lycaenidae	Lycaeninae	*Hypochrysops apelles* (Fabricius, 1775)	Copper Jewel									1				2			5	3			2				
Lycaenidae	Lycaeninae	*Hypochrysops dicomas* Hewitson, 1874										3															
Lycaenidae	Lycaeninae	*Hypochrysops geminatus* Sands, 1986																							5		
Lycaenidae	Lycaeninae	*Hypochrysops pythias* C. & R. Felder, 1865	Peacock Jewel													5			5		2				4		
Lycaenidae	Lycaeninae	*Hypochrysops polycletus* (Linnaeus, 1758)	Royal Jewel			4					5			4	5		4			4			4	5			
Lycaenidae	Lycaeninae	*Hypochrysops calliphon* Grose-Smith, 1894									1																
Lycaenidae	Lycaeninae	*Hypochrysops heros* Grose-Smith, 1894				1															2	2					
Lycaenidae	Lycaeninae	*Hypochrysops theon* C. & R. Felder, 1865	Green-banded Jewel																			1					
Lycaenidae	Lycaeninae	*Philiris diana* Waterhouse & Lyell, 1914	Diana Moonbeam			1						4		1													
Lycaenidae	Lycaeninae	*Philiris praeclara* Tite, 1963				1					2	4		1													
Lycaenidae	Lycaeninae	*Philiris violetta* (Röber, 1926)				1						3			2								1				
Lycaenidae	Lycaeninae	*Philiris harterti* (Grose-Smith, 1894)				1							1				1			1							
Lycaenidae	Lycaeninae	*Philiris hemileuca* (Jordan, 1930)											1														
Lycaenidae	Lycaeninae	*Philiris vicina* (Grose-Smith, 1898)				1														1							
Lycaenidae	Lycaeninae	*Philiris fulgens* (Grose-Smith & Kirby, 1897)	Bicolour Moonbeam			1						1															
Lycaenidae	Lycaeninae	*Philiris* sp. nr. *fulgens* (Grose-Smith & kirby, 1897)				1																					
Lycaenidae	Lycaeninae	*Philiris* cf. *elegans* Tite, 1963				3																					
Lycaenidae	Lycaeninae	*Philiris helena* (Snellen, 1887)				3								2			3			4		3	2	4			

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Lycaenidae	Lycaeninae	*Philiris agatha* (Grose-Smith, 1899)				3																					
Lycaenidae	Lycaeninae	*Philiris tapini* Sands, 1979				1																					
Lycaenidae	Lycaeninae	*Philiris ziska* (Grose-Smith, 1898)				3								1							1						
Lycaenidae	Lycaeninae	*Philiris cf. argentea* (Rothschild, 1916)																				1					
Lycaenidae	Lycaeninae	*Philiris cf. putih* Wind & Clench, 1947											2	1													
Lycaenidae	Lycaeninae	*Philiris sibatanii* Sands, 1979										2															
Lycaenidae	Lycaeninae	*Philiris intensa* (Butler, 1876)									3			1					3								
Lycaenidae	Lycaeninae	*Philiris ?innotata* (Miskin, 1874) (probable)	Common Moonbeam											1													
Lycaenidae	Lycaeninae	*Philiris moira* (Grose-Smith, 1899)										2							5	2			2				
Lycaenidae	Lycaeninae	*Philiris* sp. nov.				1						1												2			
Lycaenidae	Lycaeninae	*Philiris pagwi* Sands, 1979														1			4								
Lycaenidae	Lycaeninae	*Titea caerulea* (Tite, 1963)				1						1															
Lycaenidae	Lycaeninae	*Arhopala auxesia* (Hewitson, 1863)										4															
Lycaenidae	Lycaeninae	*Arhopala antharita* Grose-Smith, 1894									3											1					
Lycaenidae	Lycaeninae	*Arhopala herculina* Staudinger, 1888	Large Oakblue			2					5			5	4	2	2	1		2	5	5	4	4			
Lycaenidae	Lycaeninae	*Arhopala nobilis* C. Felder, 1860									1																
Lycaenidae	Lycaeninae	*Arhopala chamaeleona* Bethune-Baker, 1903																						2			
Lycaenidae	Lycaeninae	*Arhopala adherbal* Grose-Smith, 1902												2					3			3					
Lycaenidae	Lycaeninae	*Arhopala madytus* Fruhstorfer, 1914	Bright Oak Blue			2																					
Lycaenidae	Lycaeninae	*Arhopala meander* Boisduval, 1832				1					1					1						5					
Lycaenidae	Lycaeninae	*Arhopala philander* C. & R. Felder, 1865				2					3											2	2		1		
Lycaenidae	Lycaeninae	*Arhopala leander* Evans, 1957															1										
Lycaenidae	Lycaeninae	*Arhopala ander* Evans, 1957									1																
Lycaenidae	Lycaeninae	*Arhopala micale* Boisduval, 1853	Shining Oakblue											4							3	4					
Lycaenidae	Lycaeninae	*Arhopala alkisthenes* Fruhstorfer, 1914												1					3			1					
Lycaenidae	Lycaeninae	*Arhopala aexone* (Hewitson, 1863)																				2					
Lycaenidae	Lycaeninae	*Arhopala azenia* (Hewitson, 1863)									1																

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Lycaenidae	Lycaeninae	*Arhopala admete* Hewitson, 1863				1								3					2				1				
Lycaenidae	Lycaeninae	*Arhopala thamyras* (Linnaeus, 1758)												2	2	5	5	5	5	1	3	5	2				
Lycaenidae	Lycaeninae	*Amblypodia annetta* Staudinger, 1887										2		4	4	3		3						5			
Lycaenidae	Lycaeninae	*Hypochlorosis ancharia* (Hewitson, 1869)												2		2				4			4				
Lycaenidae	Lycaeninae	*Hypochlorosis antipha* (Hewitson, 1869)																		1							
Lycaenidae	Lycaeninae	*Hypolycaena phorbas* (Fabricius, 1793)	Common Tit			3					1			2	2	5	3			5	3	4	4				
Lycaenidae	Lycaeninae	*Hypolycaena danis* (C. & R. Felder, 1865)	Black and White Tit			2					2												2				
Lycaenidae	Lycaeninae	*Deudorix epijarbus* (Moore, 1858)	Dull Cornelian																			5					
Lycaenidae	Lycaeninae	*Deudorix littoralis* Joicey & Talbot, 1916										1										2					
Lycaenidae	Lycaeninae	*Deudorix parsonsi* Tennent, 2000																		1							
Lycaenidae	Lycaeninae	*Deudorix epirus* (C. Felder, 1860)	Blue Cornelian											1			1				1						
Lycaenidae	Lycaeninae	*Rapala varuna* (Horsfield, 1829)	Indigo Flash																		3						
Lycaenidae	Lycaeninae	*Bindahara meeki* (Rothschild & Jordan, 1905)									2																
Lycaenidae	Lycaeninae	*Bindahara phocides* (Fabricius, 1793)	Australian Plane											1								3					
Lycaenidae	Lycaeninae	*Anthene lycaenoides* (C. Felder, 1860)	Pale Cilated-blue								4	3		1		5	5	4		4	4	4		5	5		
Lycaenidae	Lycaeninae	*Anthene seltuttus* (Röber, 1886)	Dark Ciliated-bue			2											3	1				2					
Lycaenidae	Lycaeninae	*Candalides tringa* (Grose-Smith, 1894)									1											1					
Lycaenidae	Lycaeninae	*Candalides helenita* (Semper, 1879)	Helenita Blue								3			2						2	2	4	2	4			
Lycaenidae	Lycaeninae	*Candalides ardosiacea* (Tite, 1963)									2						2						3				
Lycaenidae	Lycaeninae	*Candalides margarita* (Semper, 1879)	Margarita Blue														2				2						
Lycaenidae	Lycaeninae	*Candalides* cf. *margarita* (Semper, 1879)	Margarita Blue									2		2													
Lycaenidae	Lycaeninae	*Candalides* sp. nov.				3									2												
Lycaenidae	Lycaeninae	*Petrelaea tombugiensis* (Röber, 1886)	Mauve Line Blue																2								
Lycaenidae	Lycaeninae	*Nacaduba subperusia* (Snellen, 1896)														3	2		2			1					
Lycaenidae	Lycaeninae	*Nacaduba hermus* (C. Felder, 1860)									1					1				3	3	4					
Lycaenidae	Lycaeninae	*Nacaduba berenice* (Herrich-Schäffer, 1869)	Large Purple Line Blue													1			1								
Lycaenidae	Lycaeninae	*Nacaduba pactolus* (C. Felder, 1860)				2																		2			

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Lycaenidae	Lycaeninae	*Nacaduba kurava* (Moore, 1857)	White Line Blue			4					3			3		3					4	3	2				
Lycaenidae	Lycaeninae	*Nacaduba cyanea* (Cramer, 1775)	Tailed Green-Banded Blue			2					3	2							2	1	3		2				
Lycaenidae	Lycaeninae	*Nacaduba mioswara* Tite, 1963												2			3	5			4	4	5				
Lycaenidae	Lycaeninae	*Nacaduba ruficirca* Tite, 1963				3																					
Lycaenidae	Lycaeninae	*Nacaduba tristis* Rothschild, 1916				5					4					5					2	2	1				
Lycaenidae	Lycaeninae	*Nacaduba nerine* (Grose-Smith & Kirby, 1899)																				1					
Lycaenidae	Lycaeninae	*Erysichton lineata* (Murray, 1874)	Dusky Blue			5					1	5		5	5	5	5	4		1	2		4	3			
Lycaenidae	Lycaeninae	*Erysichton palmyra* (C. Felder, 1860)	Marbled Line Blue																					2			
Lycaenidae	Lycaeninae	*Danis danis* (Cramer, 1775)	Large Green-Banded Blue								5	5	3	5	5	4	4		3	4	5		5	5		1	
Lycaenidae	Lycaeninae	*Danis glaucopis* (Grose-Smith, 1894)				1									1												
Lycaenidae	Lycaeninae	*Danis melimnos* (Druce & Bethune-Baker, 1893)														1											
Lycaenidae	Lycaeninae	*Danis regalis* (Grose-Smith & Kirby, 1895)																			1		3				
Lycaenidae	Lycaeninae	*Perpheres perpheres* (Druce & Bethune-Baker, 1893)									1										5	3	1				
Lycaenidae	Lycaeninae	*Psychonotis caelius* (C. & R. Felder, 1860)	Small Green-Banded Blue			4					5	4		4	2		3		3	3			2				
Lycaenidae	Lycaeninae	*Prosotas nora* (C. Felder, 1860)	Long-Tailed Line Blue			2											2			2				2			
Lycaenidae	Lycaeninae	*Prosotas papuana* Tite, 1963				3																		2			
Lycaenidae	Lycaeninae	*Prosotas dubiosa* (Semper, 1879)	Dubiosa Line Blue											2								2					
Lycaenidae	Lycaeninae	*Catopyrops ancyra* (C. Felder, 1860)	Speckled Blue			3											3			5	4	2	3	2			
Lycaenidae	Lycaeninae	*Ionolyce helicon* (C. Felder, 1860)				2					2						2			1	1	1					
Lycaenidae	Lycaeninae	*Paraduba metriodes* (Bethune-Baker, 1911)				1															5				1		
Lycaenidae	Lycaeninae	*Sahulana scintillata* (Lucas, 1889)	Variegated Blue											1	1												
Lycaenidae	Lycaeninae	*Upolampes evena* (Hewitson, 1876)				5					1					4								5			
Lycaenidae	Lycaeninae	*Caleta mindarus* (C. & R. Felder, 1865)				1																	2				
Lycaenidae	Lycaeninae	*Pistoria nigropunctata* (Bethune-Baker, 1908)																								2	
Lycaenidae	Lycaeninae	*Jamides amarauge* Druce, 1891	Shining Cerulean											1				2	2	3							
Lycaenidae	Lycaeninae	*Jamides nitens* (Joicey & Talbot, 1916) probable				1																					

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Lycaenidae	Lycaeninae	*Jamides cytus* (Boisduval, 1832)	Pale Cerulean			3						4				3	4	1		2				3			
Lycaenidae	Lycaeninae	*Jamides celeno* (Cramer, 1775)																	5	5							
Lycaenidae	Lycaeninae	*Jamides aetherialis* (Butler, 1884)																	4	3	2						
Lycaenidae	Lycaeninae	*Jamides allectus* (Grose-Smith, 1894)				2							1			3	2		4	2		1					
Lycaenidae	Lycaeninae	*Jamides reverdini* (Fruhstorfer, 1915)				2					5	3				2				3							
Lycaenidae	Lycaeninae	*Jamides coritus* (Guérin-Méneville, 1831)				4					4	3		2	4		5		5	5	3	4	5				
Lycaenidae	Lycaeninae	*Epimastidia inops* (C. & R. Felder, 1860)				2					1					1				1							
Lycaenidae	Lycaeninae	*Catochrysops amasea* Waterhouse & Lyell, 1914	Cobalt Pea Blue																2	1							
Lycaenidae	Lycaeninae	*Catochrysops panormus* (C. Felder, 1860)	Pale Pea Blue			4										2				1				3			
Lycaenidae	Lycaeninae	*Lampides boeticus* (Linnaeus, 1767)	Pea Blue										1														
Lycaenidae	Lycaeninae	*Callictita lara* Parsons, 1986				1																					
Lycaenidae	Lycaeninae	*Pithecops dionisius* (Boisduval, 1832)	Pied Blue			4										3									4		
Lycaenidae	Lycaeninae	*Zizina labradus* (Godart, 1824)	Common Blue			5																		5			
Lycaenidae	Lycaeninae	*Zizula hylax* (Fabricius, 1775)	Tiny Blue																					2			
Lycaenidae	Lycaeninae	*Everes lacturnus* (Godart, 1824)	Orange-tipped Pea Blue											2													
Lycaenidae	Lycaeninae	*Megisba strongyle* (C. Felder, 1860)	Malayan												1									2			
Lycaenidae	Lycaeninae	*Udara dilecta* (Moore, 1879)												1													
Lycaenidae	Lycaeninae	*Udara cardia* (C. Felder, 1860)				2							2			2	1										
Lycaenidae	Lycaeninae	*Udara drucei* (Bethune-Baker, 1906)											1														
Lycaenidae	Lycaeninae	*Udara owgarra* (Bethune-Baker, 1906)																								2	
Lycaenidae	Lycaeninae	*Monodontoides argioloides* (Rothschild, 1916)																					2			1	
Lycaenidae	Lycaeninae	*Euchrysops cnejus* (Fabricius, 1798)																		5					5		
Nymphalidae	Libytheinae	*Libythea geoffroy* Godart, 1820	Beak			2										4			4		1				4		
Nymphalidae	Ithomiinae	*Tellervo nedusia* (Geyer, 1832)				3					5			4		3				3			2	4			
Nymphalidae	Ithomiinae	*Tellervo zoilus* (Fabricius, 1775)	Hamadryad										5														
Nymphalidae	Danainae	*Parantica kirbyi* (Grose-Smith, 1894)																		1	1	2					
Nymphalidae	Danainae	*Parantica melusine* (Grose-Smith, 1894)				1					1		1														

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Nymphalidae	Danainae	*Ideopsis juventa* (Cramer, 1777)															2		5	3	1	4					
Nymphalidae	Danainae	*Tirumala hamata* (Macleay, 1827)	Blue Tiger																						4		
Nymphalidae	Danainae	*Danaus affinis* (Fabricius, 1775)	Black and White Tiger																5	3		2		2	4		
Nymphalidae	Danainae	*Danaus plexippus* (Linnaeus, 1758)	Wanderer, Monarch																						4		
Nymphalidae	Danainae	*Euploea phaenareta* (Schaller, 1785)									1						1		2			3	2				
Nymphalidae	Danainae	*Euploea leucostictos* (Gmelin, 1790)									4			2							2	2	3				
Nymphalidae	Danainae	*Euploea tulliolus* (Fabricius, 1793)	Purple Crow																2		2	1					
Nymphalidae	Danainae	*Euploea stephensii* C. & R. Felder, 1865																							4		
Nymphalidae	Danainae	*Euploea algea* (Godart, 1819)	Northern Crow											4		1				1							
Nymphalidae	Danainae	*Euploea netscheri* Snellen, 1889				2								4	2	2			1		4	3	3		5		
Nymphalidae	Danainae	*Euploea alcathoe* (Godart, 1819)	No-brand Crow											5		5	5	5	5	5	4	5	5		5		
Nymphalidae	Danainae	*Euploea wallacei* C. & R. Felder, 1860	Wallace's Crow			5								3	2	5	5			3	3	3	2	3	5		
Nymphalidae	Morphinae	*Morphopsis biakensis* Joicey & Talbot, 1916				1							1														
Nymphalidae	Morphinae	*Morphopsis albertisi* Oberthür, 1880																					1				
Nymphalidae	Morphinae	*Hyantis hodeva* Hewitson, 1862											5	5	2	4	5	2		2	1	3	2				
Nymphalidae	Morphinae	*Taenaris catops* (Westwood, 1851)	Catops Owl			5					5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	1	
Nymphalidae	Morphinae	*Taenaris bioculatus* (Guérin-Méneville, 1831)				1					2			1			1										
Nymphalidae	Morphinae	*Taenaris dina* Staudinger, 1894																			2						
Nymphalidae	Morphinae	*Taenaris dioptrica* (S.C. Snellen van Vollenhoven, 1860)																				1					
Nymphalidae	Morphinae	*Taenaris honrathi* Staudinger, 1886															2				3						
Nymphalidae	Morphinae	*Taenaris myops* (C. & R. Felder, 1860)				2										4	3	2		2	4						
Nymphalidae	Morphinae	*Taenaris cyclops* Staudinger, 1893				2					3			1	2	2	2						2				
Nymphalidae	Morphinae	*Taenaris dimona* (Hewitson, 1862)									5			3	2	3	2				3	3	2				
Nymphalidae	Morphinae	*Taenaris artemis* (S. C. Snellen van Vollenhoven, 1860)				3								1		4	4	3	4	3	2	4					
Nymphalidae	Morphinae	*Taenaris* sp. nov.									3		1			3							1	2			
Nymphalidae	Satyrinae	*Mycalesis perseus* (Fabricius, 1775)	Common Bush Brown											1											4		

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Nymphalidae	Satyrinae	*Mycalesis duponchelii* (Guérin-Méneville, 1831)				4					4			3	3	4		2		3	3	3	3	3			
Nymphalidae	Satyrinae	*Mycalesis mucia* Hewitson, 1862												2		4	2			2	2	4		3			
Nymphalidae	Satyrinae	*Mycalesis phidon* Hewitson, 1862				5					5			5	3	5	5			5		3	5	5	5		
Nymphalidae	Satyrinae	*Mycalesis terminus* (Fabricius, 1775)	Orange Bush Brown								1									1							
Nymphalidae	Satyrinae	*Mycalesis elia* Grose-Smith, 1894				5						3		4			3			5		3	5	5			
Nymphalidae	Satyrinae	*Mycalesis cacodaemon* Kirsch, 1877				4					5	1		4	5	4	4				2		4	3			
Nymphalidae	Satyrinae	*Mycalesis giamana* Parsons, 1986									1					1							1				
Nymphalidae	Satyrinae	*Mycalesis comes* Grose-Smith, 1894				3					2				1					1							
Nymphalidae	Satyrinae	*Mycalesis mehadeva* (Boisduval, 1832)				2					3			2	1	2					2	4	1				
Nymphalidae	Satyrinae	*Mycalesis fulvianetta* Rothschild, 1916				2					3			2	1	2							1				
Nymphalidae	Satyrinae	*Mycalesis aethiops* Butler, 1868																	4								
Nymphalidae	Satyrinae	*Mycalesis shiva* (Boisduval, 1832)																	5						4		
Nymphalidae	Satyrinae	*Mycalesis* cf. *arabella* Fruhstorfer, 1906												1									3				
Nymphalidae	Satyrinae	*Mycalesis* sp. nov. 1																1									
Nymphalidae	Satyrinae	*Mycalesis* sp. nov. 2				5							3														
Nymphalidae	Satyrinae	*Mycalesis durga* Grose-Smith & Kirby, 1894				3											3		4	4	5	4					
Nymphalidae	Satyrinae	*Orsotriaena medus* (Fabricius, 1775)																	5	2					4		
Nymphalidae	Satyrinae	*Lamprolensis nitida* Godman & Salvin, 1880										1							5			3					
Nymphalidae	Satyrinae	*Hypocysta isis* Grose-Smith, 1894	Black and White Ringlet			3					3	2					2			4	3	4	3				
Nymphalidae	Satyrinae	*Harsiesis hygea* (Hewitson, 1863)									5	4	5	3	3	5			5		4	5		3		5	
Nymphalidae	Satyrinae	*Altiapa pandora* (Joicey & Talbot, 1916)																								2	
Nymphalidae	Satyrinae	*Erycinidia gracilis* Rothschild & Jordan, 1905																								2	
Nymphalidae	Satyrinae	*Ypthima arctoa* (Fabricius, 1775)	Dusky Ring								2									1			4	5	5		
Nymphalidae	Satyrinae	*Melanitis leda* (Linnaeus, 1758)	Evening Brown			3					4			2	1							3		4			
Nymphalidae	Satyrinae	*Melanitis amabilis* (Boisduval, 1832)				4						3			2							2	1	2			
Nymphalidae	Satyrinae	*Melanitis constantia* (Cramer, 1777)				2								2			2					2					
Nymphalidae	Satyrinae	*Elymnias papua* Wallace, 1869									1											1					

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Nymphalidae	Satyrinae	*Elymnias cybele* (C. Felder, 1860)	Palm Fly			4					3			1		5	4	1	5		5	4	3				
Nymphalidae	Satyrinae	*Elymnias agondas* (Boisduval, 1932)				2																					
Nymphalidae	Charaxinae	*Charaxes latona* Butler, 1865	Orange Rajah			2					2			3		1					1	2		2			
Nymphalidae	Charaxinae	*Polyura (Charaxes) jupiter* (Butler, 1869)	Tailed Emperor			2					3			3	2		2			2			2				
Nymphalidae	Charaxinae	*Prothoe australis* (Guérin-Méneville, 1831)				5					5			4	2	5	5				2		3	3			
Nymphalidae	Apaturinae	*Apaturina erminea* (Cramer, 1779)	Turquoise Emperor								1									1							
Nymphalidae	Apaturinae	*Helcyra chionippe* C. Felder, 1860																						2			
Nymphalidae	Apaturinae	*Dichorragia ninus* (C. & R. Felder, 1859)				1					1																
Nymphalidae	Apaturinae	*Cyrestis acilia* (Godart, 1819)				5					5	3		4	5	5			5	5	3	3	5	5	5		
Nymphalidae	Apaturinae	*Cyrestis achates* Butler, 1865	Mapwing																					2	4		
Nymphalidae	Nymphalinae	*Lexias aeropa* (Linnaeus, 1758)	Orange-Banded Plane			2					5			4	2	3	3	4		2		4	1	3			
Nymphalidae	Nymphalinae	*Euthaliopsis aetion* (Hewitson, 1862)									2				2	3	3	3		2	4	4	3				
Nymphalidae	Nymphalinae	*Parthenos aspila* Honrath, 1888				5					5			1	2	5	5		5	5	5	5	5	5	5		
Nymphalidae	Nymphalinae	*Pantoporia consimilis* (Boisduval, 1832)	Orange Aeroplane			4					5	4		4	2	5	5			5	2	4	4	5			
Nymphalidae	Nymphalinae	*Pantoporia venilia* (Linnaeus, 1758)	Cape York Aeroplane			5					5	5		5	5	5	5	5		3	2		3	5			
Nymphalidae	Nymphalinae	*Neptis praslini* (Boisduval, 1832)	Yellow-eyed Aeroplane			1					1					1	2		2	4	4	2	2				
Nymphalidae	Nymphalinae	*Neptis satina* Grose-Smith, 1894				1									1						1						
Nymphalidae	Nymphalinae	*Phaedyma shepherdi* (Moore, 1858)	Common Aeroplane			2					3			3						2	1	2					
Nymphalidae	Nymphalinae	*Mynes geoffroyi* (Guérin-Méneville, 1831)	White Nymph			2					2	2			1												
Nymphalidae	Nymphalinae	*Symbrenthia hippoclus* (Cramer, 1779)				1																		2			
Nymphalidae	Nymphalinae	*Dolleschallia noorna* Grose-Smith & Kirby, 1893	Leafwing								4	2		3						2	2	1	2				
Nymphalidae	Nymphalinae	*Dolleschallia hexopthalmos* (Gmelin, 1790)																						2			
Nymphalidae	Nymphalinae	*Dolleschallia nacar* (Boisduval, 1832)									1																
Nymphalidae	Nymphalinae	*Hypolimnas bolina* (Linnaeus, 1764)	Common Eggfly			2								1		1									4		
Nymphalidae	Nymphalinae	*Hypolimnas alimena* (Linnaeus, 1758)	Blue-Banded Eggfly			4					1			2			3			4			2	4	4		
Nymphalidae	Nymphalinae	*Hypolimnas antilope* (Cramer, 1777)									1					2	2		3								
Nymphalidae	Nymphalinae	*Hypolimnas deois* (Hewitson, 1858)				4					4	3	2		2		2			3		3	3				

FAMILY	SUBFAMILY	SCIENTIFIC NAME	ENGLISH NAME	IUCN[1]	PNG[2]	NENA BASE	NENA D1	NENA D2	NENA LIMESTONE	NENA-USAGE	MALIA	KOKI	HI	FRIEDA BEND	UPPER OK BINAI	OK ISAI	KAUGUMI	EAST SEPIK	INIOK	WARIO	WOGAMUSH	KUBKAIN	OK BINAI 1	FRIEDA BASE	FRIEDA STRIP	UBIAME	LITERATURE RECORD
Nymphalidae	Nymphalinae	*Yoma algina* (Boisduval, 1832)	Lurcher			3					4			3	2	3	2			3		4	3				
Nymphalidae	Nymphalinae	*Junonia hedonia* (Linnaeus, 1764)	Chocolate Soldier			5										4	4		5	4			2	4	5		
Nymphalidae	Nymphalinae	*Junonia erigone* (Cramer, 1775)	Northern Argus																			4					
Nymphalidae	Nymphalinae	*Junonia villida* (Fabricius, 1787)	Meadow Argus																						2		
Nymphalidae	Nymphalinae	*Cethosia cydippe* (Linnaeus, 1763)	Red Lacewing			5					5	5	4	4	4	5	5	5		3	4	5	5	5	5		
Nymphalidae	Nymphalinae	*Vindula arsinoe* (Cramer, 1777)	Cruiser			5					5	5	3	5	3	5	5	5		3	2	3	3	5	5		
Nymphalidae	Nymphalinae	*Terinos tethys* Hewitson, 1862												5			1			5	5		4		1		
Nymphalidae	Nymphalinae	*Cirrochroa regina* C. & R. Felder, 1865				4					5			5	5	5	5	3		5	5	5	5	5	5		
Nymphalidae	Nymphalinae	*Algia felderi* (Kirsch, 1877)				5									2												
Nymphalidae	Nymphalinae	*Vagrans egista* (Stoll, 1780)	Vagrans			5					4	3		4	3	4	4			4			1	5			
Nymphalidae	Nymphalinae	*Phalanta alcippe* (Cramer, 1782)	Leopard			3								2		2	2						4				
Nymphalidae	Nymphalinae	*Cupha prosope* (Fabricius, 1775)	Rustic			4					5	4		5	4	4	3			4	3	3	5	5	5		
Nymphalidae	Acraeini	*Acraea meyeri* Kirsch, 1877	Glasswing																			1				1	

Note: 5 - very high density with sighting less than two hours apart.

4 - high density with sightings two to six hours apart.

3 - medium density with sightings six to 12 hours apart.

2 - Low density with sightings 15 to 32 hours apart and

1 - Very low density with sightings > 32 hours apart

Appendix 7.2. Endemicity and occurrence in 100 m elevation zones.

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Pyrginae	Chaetocneme antipodes (Guérin-Méneville, 1831)	3				X										
Pyrginae	Chaetocneme callixenus Hewitson, 1867	3	X													
Pyrginae	Chaetocneme critomedia (Guérin-Méneville, 1831)	4	X							X						
Pyrginae	Chaetocneme tenuis (van Eecke, 1924)	4	X	X						X						
Pyrginae	Chaetocneme sp. nov.	5						X								
Pyrginae	Netrocoryne thaddeus (Hewitson, 1876)	3	X													
Pyrginae	Tagiades japetus (Stoll, 1781)	1	X	X	X	X				X						
Pyrginae	Tagiades trebellius (Höpffer, 1874)	1			X											
Pyrginae	Tagiades nestus (C. Felder, 1860)	2	X	X	X	X				X	X					
Coeliadinae	Badamia exclamationis (Fabricius, 1775)	1	X	X												
Coeliadinae	Allora dolleschalli (C. Felder, 1860)	1	X	X	X											
Coeliadinae	Hasora discolor (C. & R. Felder, 1859)	1	X		X					X						
Coeliadinae	Hasora hurama (Butler, 1870)	1	X													
Coeliadinae	Hasora khoda (Mabille, 1876)	1	X	X	X		X			X						
Coeliadinae	Hasora celaenus (Stoll, 1782)	1	X	X	X											
Coeliadinae	Hasora subcaelestis Rothschild, 1916	4	X	X	X	X					X					
Trapezitinae	Hewitsoniella migonitis (Hewitson, 1876)	3	X													
Trapezitinae	Felicena dirpha (Boisduval, 1832)	4													X	X
Trapezitinae	Toxidia inornata (Butler, 1883)	1	X		X	X	X									
Trapezitinae	Rachelia extrusa (C. & R. Felder, 1867)	1	X							X						
Trapezitinae	Rachelia icosia (Fruhstorfer, 1911)	3	X													
Hesperiinae	Tiacellia tiacellia (Hewitson, 1868)	3	X													
Hesperiinae	Erionota thrax (Linnaeus, 1767)	1	X													
Hesperiinae	Notocrypta waiguensis (Plötz, 1882)	1	X	X	X	X	X			X	X					
Hesperiinae	Notocrypta renardi (Oberthür, 1878)	2	X		X	X	X	X	X	X						
Hesperiinae	Notocrypta flavipes (Janson, 1886)	3	X													
Hesperiinae	Sabera caesina (Hewitson, 1886)	1	X													
Hesperiinae	Sabera kumpia Evans, 1949	4			X											
Hesperiinae	Sabera biaga Evans, 1949	4	X													
Hesperiinae	Sabera misola Evans, 1949	3	X													
Hesperiinae	Sabera fuliginosa (Miskin, 1889)	1	X													
Hesperiinae	Sabera dobboe (Plötz, 1885)	1	X		X					X						
Hesperiinae	Sabera tabla (Swinhoe, 1905)	4	X			X										
Hesperiinae	Sabera sp. nov. 1	5											X			
Hesperiinae	Sabera sp. nov. 2	5	X													
Hesperiinae	Mimene kolbei (Ribbe, 1899)	2	X													

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Hesperiinae	Mimene celiaba Parsons, 1986	4	X	X								X				
Hesperiinae	Mimene biakensis Joicey & Talbot, 1917	3	X	X	X											
Hesperiinae	Mimene caesar Evans, 1935	3	X	X												
Hesperiinae	Mimene sariba Evans, 1935	3			X											
Hesperiinae	Mimene basalis (Rothschild, 1916)	4	X	X												
Hesperiinae	Mimene verda Parsons, 1986	5		X												
Hesperiinae	Mimene atropatene (Fruhstorfer, 1911)	1	X													
Hesperiinae	Mimene cyanea (Evans, 1928)	4			X											
Hesperiinae	Mimene lysima (Swinhoe, 1905)	4	X													
Hesperiinae	Mimene celia Evans, 1935	4	X													
Hesperiinae	Mimene miltias (Kirsch, 1877)	3	X													
Hesperiinae	Mimene melie (de Nicéville)	3	X													
Hesperiinae	Mimene milnea Evans, 1935	3	X													
Hesperiinae	Kobrona wama (Plötz, 1885)	3	X							X						
Hesperiinae	Kobrona rasta Evans, 1935	4								X						
Hesperiinae	Kobrona infralutea (Rothschild, 1916)	4									X					
Hesperiinae	Kobrona sp. nov.	5	X													
Hesperiinae	Cephrenes augiades (C. Felder, 1868)	1	X		X											
Hesperiinae	Cephrenes moseleyi (Butler, 1884)	1			X											
Hesperiinae	Cephrenes augiana Evans, 1934	3	X													
Hesperiinae	Telicota augias (Linnaeus, 1763)	1	X													
Hesperiinae	Telicota melanion (Mabille, 1878)	3	X													
Hesperiinae	Telicota ternatensis Swinhoe, 1907	2	X													
Hesperiinae	Telicota paceka Fruhstorfer, 1911	4	X													
Hesperiinae	Telicota bulwa Parsons, 1986	4	X							X						
Hesperiinae	Telicota kezia Evans, 1949	2	X							X						
Hesperiinae	Telicota gervasa Evans, 1949	3								X						
Hesperiinae	Telicota vinta Evans, 1949	4	X													
Hesperiinae	Telicota eurotas (C. Felder, 1860)	1	X													
Hesperiinae	Telicota sp.	5			X											
Hesperiinae	Arrhenes marnas (C. Felder, 1860)	1	X	X	X	X	X	X	X	X	X					
Hesperiinae	Arrhenes dschilus (Plötz, 1885)	1	X		X											
Hesperiinae	Suniana sunias (C. Felder, 1860)	1	X	X	X	X				X	X					
Hesperiinae	Ocybadistes ardea Bethune-Baker, 1906	1	X		X											
Hesperiinae	Ocybadistes papua Evans, 1934	3	X													
Hesperiinae	Parnara amalia (Semper, 1879)	1	X													
Hesperiinae	Borbo impar (Mabille, 1883)	1	X		X											

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Hesperiinae	Borbo cinnara (Wallace, 1866)	1			X											
Hesperiinae	Pelopidas agna (Moore, 1866)	1	X		X	X				X						
Hesperiinae	Pelopidas lyelli Rothschild, 1915	1	X	X	X					X						
Hesperiinae	Pelopidas mathias (Fabricius, 1789)	1	X													
Hesperiinae	Caltoris boisduvali (C. & R. Felder, 1867)	2	X				X									
Hesperiinae	Caltoris philippina (Herrich-Schäffer, 1869)	1	X													
Papilioninae	Atrophaneura polydorus (Linnaeus, 1763)	1	X	X	X	X										
Papilioninae	Troides oblongomaculatus (Goeze, 1779)	2			X											
Papilioninae	Ornithoptera priamus (Linnaeus, 1758)	1	X	X	X	X	X			X	X					
Papilioninae	Ornithoptera goliath Oberthür, 1888	2	X	X	X											
Papilioninae	Ornithoptera paradisea (Staudinger, 1893)	4	X													
Papilioninae	*Ornithoptera meridionalis Rothschild, 1897	4	X													
Papilioninae	Graphium agamemnon (Linnaeus, 1758)	1	X	X	X	X	X	X	X	X						
Papilioninae	Graphium macfarlanei (Butler, 1877)	1	X	X	X					X						
Papilioninae	Graphium wallacei (Hewitson, 1858)	2	X	X	X	X				X	X					
Papilioninae	Graphium weiskei (Ribbe, 1900)	4													X	X
Papilioninae	Graphium codrus (Cramer, 1777)	1	X	X	X					X						
Papilioninae	Graphium sarpedon (Linnaeus, 1758)	1	X	X	X	X				X	X					
Papilioninae	Graphium euryplus (Linnaeus, 1758)	1	X	X	X	X				X	X					
Papilioninae	Graphium aristeus (Stoll, 1781)	1	X	X	X											
Papilioninae	Chilasa laglazei (Depuiset, 1877)	3			X											
Papilioninae	Papilio aegeus Donovan, 1805	1	X	X	X	X	X	X	X	X	X					
Papilioninae	Papilio ambrax Boisduval, 1832	1	X		X					X						
Papilioninae	Papilio albinus Wallace, 1865	4							X							
Papilioninae	Papilio ulysses Linnaeus, 1758	1	X	X	X	X	X	X	X	X	X	X				
Papilioninae	Papilio euchenor (Guérin-Méneville, 1831)	2	X	X	X	X	X	X	X	X	X	X				
Coliadinae	Catopsilia pomona (Fabricius, 1775)	1	X	X	X	X										
Coliadinae	Eurema hecabe (Linnaeus, 1758)	1	X	X	X	X	X			X						
Coliadinae	Eurema blanda (Boisduval, 1836)	1			X											
Coliadinae	Eurema puella (Boisduval, 1832)	1	X	X	X	X	X	X	X	X	X	X				
Coliadinae	Gandaca butyrosa (Butler, 1875)	1	X	X	X											
Pierinae	Leuciacria acuta Rothschild & Jordan, 1905	4														X
Pierinae	Elodina andropis Butler, 1876	3					X			X						
Pierinae	Elodina hypatia C. & R. Felder, 1865	3	X				X									
Pierinae	Saletara cycinna (Hewitson, 1868)	3	X		X											
Pierinae	Appias paulina (Cramer, 1777)	1			X											
Pierinae	Appias celestina (Boisduval, 1832)	1	X	X	X	X				X						

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Pierinae	Appias ada (Stoll, 1781)	1	X		X											
Pierinae	Cepora abnormis (Wallace, 1867)	4	X				X									
Pierinae	Cepora perimale (Donovan, 1805)	1	X													
Pierinae	Delias enniana (Oberthür, 1880)	3				X										
Pierinae	Delias pulla Talbot, 1937	5													X	X
Pierinae	Delias ennia (Wallace, 1867)	1	X		X					X						
Pierinae	Delias gabia (Boisduval, 1832)	3	X	X	X		X			X						
Pierinae	Delias ladas Grose-Smith, 1894	4								X	X				X	X
Pierinae	Delias cf. eudiabolas Rothschild, 1915	4								X						
Pierinae	Delias mysis (Fabricius, 1775)	1	X		X											
Pierinae	Delias aruna (Boisduval, 1832)	1		X	X	X					X					
Pierinae	Delias discus Honrath, 1886	4							X	X	X					
Pierinae	Delias ornytion (Godman & Salvin, 1880)	3				X	X	X								
Riodininae	Dicallaneura decorata (Hewitson, 1862)	4	X		X						X					
Riodininae	Dicallaneura kirschi Röber, 1886	4	X		X	X	X									
Riodininae	Dicallaneura ribbei Röber, 1886	3	X													
Riodininae	Praetaxila huntei (Sharpe, 1903)	4	X		X		X									
Riodininae	Praetaxila satraps (Grose-Smith, 1894)	4	X							X						
Riodininae	Praetaxila statira (Hewitson, 1861)	4	X		X	X										
Curetinae	Curetis barsine C. Felder, 1860	1	X	X	X					X	X					
Lycaeninae	Liphyra brassolis Westwood, 1864	1		X			X									
Lycaeninae	Pseudodipsas eone (C. & R. Felder, 1860)	1	X		X	X	X			X	X					
Lycaeninae	Hypochrysops apollo Miskin, 1891	1	X													
Lycaeninae	Hypochrysops chrysargyrus Grose-Smith & Kirby, 1895	3	X		X											
Lycaeninae	Hypochrysops arronica (C. & R. Felder, 1859)	2	X				X			X	X					
Lycaeninae	Hypochrysops plotinus Grose-Smith, 1894	4	X			X				X						
Lycaeninae	Hypochrysops narcissus (Fabricius, 1775)	1	X		X											
Lycaeninae	Hypochrysops argyriorufus van Eecke, 1924	3	X													
Lycaeninae	Hypochrysops castaneus Sands, 1986	4	X													
Lycaeninae	Hypochrysops hermogenes Grose-Smith, 1894	5						X								
Lycaeninae	Hypochrysops ?cleonides Grose-Smith, 1900 (probable)	4			X											
Lycaeninae	Hypochrysops apelles (Fabricius, 1775)	1	X	X			X									
Lycaeninae	Hypochrysops dicomas Hewitson, 1874	3					X									
Lycaeninae	Hypochrysops geminatus Sands, 1986	4	X													
Lycaeninae	Hypochrysops pythias C. & R. Felder, 1865	1	X													
Lycaeninae	Hypochrysops polycletus (Linnaeus, 1758)	1	X		X	X				X						

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Lycaeninae	Hypochrysops calliphon Grose-Smith, 1894	5			X											
Lycaeninae	Hypochrysops heros Grose-Smith, 1894	3	X							X						
Lycaeninae	Hypochrysops theon C. & R. Felder, 1865	1	X													
Lycaeninae	Philiris diana Waterhouse & Lyell, 1914	1	X				X			X						
Lycaeninae	Philiris praeclara Tite, 1963	4	X		X		X			X						
Lycaeninae	Philiris violetta (Röber, 1926)	4	X			X	X			X						
Lycaeninae	Philiris harterti (Grose-Smith, 1894)	4	X							X					X	
Lycaeninae	Philiris hemileuca (Jordan, 1930)	4										X				
Lycaeninae	Philiris vicina (Grose-Smith, 1898)	4	X							X						
Lycaeninae	Philiris fulgens (Grose-Smith & Kirby, 1897)	1					X			X						
Lycaeninae	Philiris sp. nr. fulgens (Grose-Smith & kirby, 1897)	3								X						
Lycaeninae	Philiris cf. elegans Tite, 1963	4								X						
Lycaeninae	Philiris helena (Snellen, 1887)	2	X		X	X				X						
Lycaeninae	Philiris agatha (Grose-Smith, 1899)	4								X						
Lycaeninae	Philiris tapini Sands, 1979	4								X						
Lycaeninae	Philiris ziska (Grose-Smith, 1898)	1	X							X						
Lycaeninae	Philiris cf. argentea (Rothschild, 1916)	4	X													
Lycaeninae	Philiris cf. putih Wind & Clench, 1947	4	X							X						
Lycaeninae	Philiris sibatanii Sands, 1979	4						X								
Lycaeninae	Philiris intensa (Butler, 1876)	2	X		X											
Lycaeninae	Philiris ?innotata (Miskin, 1874) (probable)	1	X													
Lycaeninae	Philiris moira (Grose-Smith, 1899)	3	X				X									
Lycaeninae	Philiris sp. nov.	5				X	X									
Lycaeninae	Philiris pagwi Sands, 1979	5	X													
Lycaeninae	Titea caerulea (Tite, 1963)	4					X			X						
Lycaeninae	Arhopala auxesia (Hewitson, 1863)	3						X								
Lycaeninae	Arhopala antharita Grose-Smith, 1894	4	X		X	X										
Lycaeninae	Arhopala herculina Staudinger, 1888	3	X	X	X	X				X						
Lycaeninae	Arhopala nobilis C. Felder, 1860	3				X										
Lycaeninae	Arhopala chamaeleona Bethune-Baker, 1903	3				X										
Lycaeninae	Arhopala adherbal Grose-Smith, 1902	3	X													
Lycaeninae	Arhopala madytus Fruhstorfer, 1914	1								X						
Lycaeninae	Arhopala meander Boisduval, 1832	2	X		X					X						
Lycaeninae	Arhopala philander C. & R. Felder, 1865	2	X		X					X						
Lycaeninae	Arhopala leander Evans, 1957	3	X													
Lycaeninae	Arhopala ander Evans, 1957	3			X											
Lycaeninae	Arhopala micale Boisduval, 1853	1	X													

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Lycaeninae	Arhopala alkisthenes Fruhstorfer, 1914	3	X													
Lycaeninae	Arhopala aexone (Hewitson, 1863)	1	X													
Lycaeninae	Arhopala azenia (Hewitson, 1863)	2			X											
Lycaeninae	Arhopala admete Hewitson, 1863	3	X							X						
Lycaeninae	Arhopala thamyras (Linnaeus, 1758)	2	X	X												
Lycaeninae	Amblypodia annetta Staudinger, 1887	2	X	X	X	X	X									
Lycaeninae	Hypochlorosis ancharia (Hewitson, 1869)	4	X													
Lycaeninae	Hypochlorosis antipha (Hewitson, 1869)	3	X													
Lycaeninae	Hypolycaena phorbas (Fabricius, 1793)	1	X	X	X					X						
Lycaeninae	Hypolycaena danis (C. & R. Felder, 1865)	1	X		X					X						
Lycaeninae	Deudorix epijarbus (Moore, 1858)	1	X													
Lycaeninae	Deudorix littoralis Joicey & Talbot, 1916	3	X				X									
Lycaeninae	Deudorix parsonsi Tennent, 2000	4	X													
Lycaeninae	Deudorix epirus (C. Felder, 1860)	2	X													
Lycaeninae	Rapala varuna (Horsfield, 1829)	1	X													
Lycaeninae	Bindahara meeki (Rothschild & Jordan, 1905)	2			X	X										
Lycaeninae	Bindahara phocides (Fabricius, 1793)	1	X													
Lycaeninae	Anthene lycaenoides (C. Felder, 1860)	1	X	X	X	X	X			X	X					
Lycaeninae	Anthene seltuttus (Röber, 1886)	1	X	X						X						
Lycaeninae	Candalides tringa (Grose-Smith, 1894)	4	X		X											
Lycaeninae	Candalides helenita (Semper, 1879)	1	X		X											
Lycaeninae	Candalides ardosiacea (Tite, 1963)	4	X		X					X						
Lycaeninae	Candalides margarita (Semper, 1879)	1	X													
Lycaeninae	Candalides cf. margarita (Semper, 1879)	1	X					X								
Lycaeninae	Candalides sp. nov.	5					X			X	X					
Lycaeninae	Petrelaea tombugiensis (Röber, 1886)	1	X													
Lycaeninae	Nacaduba subperusia (Snellen, 1896)	1	X													
Lycaeninae	Nacaduba hermus (C. Felder, 1860)	1	X		X											
Lycaeninae	Nacaduba berenice (Herrich-Schäffer, 1869)	1	X													
Lycaeninae	Nacaduba pactolus (C. Felder, 1860)	1			X					X						
Lycaeninae	Nacaduba kurava (Moore, 1857)	1	X	X	X					X	X	X				
Lycaeninae	Nacaduba cyanea (Cramer, 1775)	1	X		X	X	X			X						
Lycaeninae	Nacaduba mioswara Tite, 1963	1	X													
Lycaeninae	Nacaduba ruficirca Tite, 1963	4								X	X					
Lycaeninae	Nacaduba tristis Rothschild, 1916	2	X	X	X					X	X					
Lycaeninae	Nacaduba nerine (Grose-Smith & Kirby, 1899)	3	X													
Lycaeninae	Erysichton lineata (Murray, 1874)	1	X	X	X	X	X				X					

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Lycaeninae	Erysichton palmyra (C. Felder, 1860)	1			X											
Lycaeninae	Danis danis (Cramer, 1775)	1	X	X	X	X	X	X	X	X						
Lycaeninae	Danis glaucopis (Grose-Smith, 1894)	4				X				X						
Lycaeninae	Danis melimnos (Druce & Bethune-Baker, 1893)	3		X												
Lycaeninae	Danis regalis (Grose-Smith & Kirby, 1895)	5	X													
Lycaeninae	Perpheres perpheres (Druce & Bethune-Baker, 1893)	4	X		X											
Lycaeninae	Psychonotis caelius (C. & R. Felder, 1860)	1	X		X	X	X			X						
Lycaeninae	Prosotas nora (C. Felder, 1860)	1	X			X										
Lycaeninae	Prosotas papuana Tite, 1963	2			X					X						
Lycaeninae	Prosotas dubiosa (Semper, 1879)	1	X													
Lycaeninae	Catopyrops ancyra (C. Felder, 1860)	1	X		X	X				X						
Lycaeninae	Ionolyce helicon (C. Felder, 1860)	1	X	X	X					X						
Lycaeninae	Paraduba metriodes (Bethune-Baker, 1911)	3	X							X						
Lycaeninae	Sahulana scintillata (Lucas, 1889)	1	X		X											
Lycaeninae	Upolampes evena (Hewitson, 1876)	3		X	X	X				X	X					
Lycaeninae	Caleta mindarus (C. & R. Felder, 1865)	2	X							X						
Lycaeninae	Pistoria nigropunctata (Bethune-Baker, 1908)	4													X	X
Lycaeninae	Jamides amarauge Druce, 1891	1	X													
Lycaeninae	Jamides nitens (Joicey & Talbot, 1916) probable	5								X						
Lycaeninae	Jamides cytus (Boisduval, 1832)	1	X	X	X	X	X			X						
Lycaeninae	Jamides celeno (Cramer, 1775)	1	X													
Lycaeninae	Jamides aetherialis (Butler, 1884)	1	X													
Lycaeninae	Jamides allectus (Grose-Smith, 1894)	2	X	X						X						
Lycaeninae	Jamides reverdini (Fruhstorfer, 1915)	2		X	X	X	X			X						
Lycaeninae	Jamides coritus (Guérin-Méneville, 1831)	3	X		X	X	X			X	X					
Lycaeninae	Epimastidia inops (C. & R. Felder, 1860)	3	X	X	X					X						
Lycaeninae	Catochrysops amasea Waterhouse & Lyell, 1914	1	X													
Lycaeninae	Catochrysops panormus (C. Felder, 1860)	1	X		X											
Lycaeninae	Lampides boeticus (Linnaeus, 1767)	1									X					
Lycaeninae	Callictita lara Parsons, 1986	4								X						
Lycaeninae	Pithecops dionisius (Boisduval, 1832)	1	X							X						
Lycaeninae	Zizina labradus (Godart, 1824)	1	X		X					X	X					
Lycaeninae	Zizula hylax (Fabricius, 1775)	1			X											
Lycaeninae	Everes lacturnus (Godart, 1824)	1	X													
Lycaeninae	Megisba strongyle (C. Felder, 1860)	1	X		X	X										
Lycaeninae	Udara dilecta (Moore, 1879)	1	X													

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Lycaeninae	Udara cardia (C. Felder, 1860)	2	X	X						X					X	X
Lycaeninae	Udara drucei (Bethune-Baker, 1906)	2														X
Lycaeninae	Udara owgarra (Bethune-Baker, 1906)	4														X
Lycaeninae	Monodontoides argioloides (Rothschild, 1916)	2	X													X
Lycaeninae	Euchrysops cnejus (Fabricius, 1798)	1	X													
Libytheinae	Libythea geoffroy Godart, 1820	1	X	X						X						
Ithomiinae	Tellervo nedusia (Geyer, 1832)	2	X		X	X										
Ithomiinae	Tellervo zoilus (Fabricius, 1775)	1								X	X	X				
Danainae	Parantica kirbyi (Grose-Smith, 1894)	5	X													
Danainae	Parantica melusine (Grose-Smith, 1894)	3			X					X		X				
Danainae	Ideopsis juventa (Cramer, 1777)	1	X													
Danainae	Tirumala hamata (Macleay, 1827)	1	X													
Danainae	Danaus affinis (Fabricius, 1775)	1	X		X											
Danainae	Danaus plexippus (Linnaeus, 1758)	1	X													
Danainae	Euploea phaenareta (Schaller, 1785)	1	X		X											
Danainae	Euploea leucostictos (Gmelin, 1790)	1	X		X											
Danainae	Euploea tulliolus (Fabricius, 1793)	1	X													
Danainae	Euploea stephensii C. & R. Felder, 1865	2	X													
Danainae	Euploea algea (Godart, 1819)	1	X	X												
Danainae	Euploea netscheri Snellen, 1889	2	X	X	X					X						
Danainae	Euploea alcathoe (Godart, 1819)	1	X	X												
Danainae	Euploea wallacei C. & R. Felder, 1860	2	X	X	X	X				X						
Morphinae	Morphopsis biakensis Joicey & Talbot, 1916	4										X				
Morphinae	Morphopsis albertisi Oberthür, 1880	3	X													
Morphinae	Hyantis hodeva Hewitson, 1862	3	X	X	X	X	X	X								
Morphinae	Taenaris catops (Westwood, 1851)	1	X	X	X	X	X	X	X	X	X	X			X	
Morphinae	Taenaris bioculatus (Guérin-Méneville, 1831)	3	X		X	X				X						
Morphinae	Taenaris dina Staudinger, 1894	3	X													
Morphinae	Taenaris dioptrica (S.C. Snellen van Vollenhoven, 1860)	3	X													
Morphinae	Taenaris honrathi Staudinger, 1886	3	X													
Morphinae	Taenaris myops (C. & R. Felder, 1860)	3	X	X						X						
Morphinae	Taenaris cyclops Staudinger, 1893	3	X	X	X	X	X			X	X					
Morphinae	Taenaris dimona (Hewitson, 1862)	2	X	X	X	X	X									
Morphinae	Taenaris artemis (S. C. Snellen van Vollenhoven, 1860)	1	X	X						X						
Morphinae	Taenaris sp. nov.	5		X	X					X						
Satyrinae	Mycalesis perseus (Fabricius, 1775)	1	X													

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Satyrinae	Mycalesis duponchelii (Guérin-Méneville, 1831)	3	X	X	X	X	X			X						
Satyrinae	Mycalesis mucia Hewitson, 1862	3	X	X	X											
Satyrinae	Mycalesis phidon Hewitson, 1862	2	X	X	X	X	X			X						
Satyrinae	Mycalesis terminus (Fabricius, 1775)	1	X		X											
Satyrinae	Mycalesis elia Grose-Smith, 1894	3	X		X	X	X	X		X						
Satyrinae	Mycalesis cacodaemon Kirsch, 1877	3	X	X	X	X	X			X						
Satyrinae	Mycalesis giamana Parsons, 1986	4	X			X										
Satyrinae	Mycalesis comes Grose-Smith, 1894	5	X		X	X	X			X						
Satyrinae	Mycalesis mehadeva (Boisduval, 1832)	3	X		X	X				X						
Satyrinae	Mycalesis fulvianetta Rothschild, 1916	4	X	X	X					X						
Satyrinae	Mycalesis aethiops Butler, 1868	3	X													
Satyrinae	Mycalesis shiva (Boisduval, 1832)	2	X													
Satyrinae	Mycalesis cf. arabella Fruhstorfer, 1906	3	X													
Satyrinae	Mycalesis sp. nov. 1	5	X													
Satyrinae	Mycalesis sp. nov. 2	5								X	X	X				
Satyrinae	Mycalesis durga Grose-Smith & Kirby, 1894	3	X							X						
Satyrinae	Orsotriaena medus (Fabricius, 1775)	1	X													
Satyrinae	Lamprolensis nitida Godman & Salvin, 1880	4	X				X									
Satyrinae	Hypocysta isis Grose-Smith, 1894	3	X		X	X	X			X						
Satyrinae	Harsiesis hygea (Hewitson, 1863)	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Satyrinae	Altiapa pandora (Joicey & Talbot, 1916)	4													X	
Satyrinae	Erycinidia gracilis Rothschild & Jordan, 1905	4													X	
Satyrinae	Ypthima arctoa (Fabricius, 1775)	1	X		X	X										
Satyrinae	Melanitis leda (Linnaeus, 1758)	1	X		X	X	X			X						
Satyrinae	Melanitis amabilis (Boisduval, 1832)	2	X		X		X			X						
Satyrinae	Melanitis constantia (Cramer, 1777)	2	X							X						
Satyrinae	Elymnias papua Wallace, 1869	3	X			X										
Satyrinae	Elymnias cybele (C. Felder, 1860)	2	X	X	X	X				X						
Satyrinae	Elymnias agondas (Boisduval, 1932)	1								X						
Charaxinae	Charaxes latona Butler, 1865	1	X	X	X	X				X						
Charaxinae	Polyura (Charaxes) jupiter (Butler, 1869)	2	X		X	X	X			X						
Charaxinae	Prothoe australis (Guérin-Méneville, 1831)	2	X	X	X	X	X			X						
Apaturinae	Apaturina erminea (Cramer, 1779)	1	X			X										
Apaturinae	Helcyra chionippe C. Felder, 1860	2			X											
Apaturinae	Dichorragia ninus (C. & R. Felder, 1859)	2			X					X						
Apaturinae	Cyrestis acilia (Godart, 1819)	2	X	X	X	X	X	X		X						
Apaturinae	Cyrestis achates Butler, 1865	3	X		X											

SUBFAMILY	SPECIES	ENDEMICITY	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Nymphalinae	Lexias aeropa (Linnaeus, 1758)	1	X	X	X	X	X			X						
Nymphalinae	Euthaliopsis aetion (Hewitson, 1862)	2	X	X	X											
Nymphalinae	Parthenos aspila Honrath, 1888	3	X	X	X	X				X						
Nymphalinae	Pantoporia consimilis (Boisduval, 1832)	1	X	X	X	X	X	X		X	X					
Nymphalinae	Pantoporia venilia (Linnaeus, 1758)	1	X	X	X	X	X	X		X	X					
Nymphalinae	Neptis praslini (Boisduval, 1832)	1	X			X				X						
Nymphalinae	Neptis satina Grose-Smith, 1894	3	X		X					X						
Nymphalinae	Phaedyma shepherdi (Moore, 1858)	1	X		X	X				X						
Nymphalinae	Mynes geoffroyi (Guérin-Méneville, 1831)	1			X	X	X	X		X						
Nymphalinae	Symbrenthia hippoclus (Cramer, 1779)	2				X					X					
Nymphalinae	Dolleschallia noorna Grose-Smith & Kirby, 1893	3	X		X	X	X	X								
Nymphalinae	Dolleschallia hexopthalmos (Gmelin, 1790)	2				X										
Nymphalinae	Dolleschallia nacar (Boisduval, 1832)	3				X										
Nymphalinae	Hypolimnas bolina (Linnaeus, 1764)	1	X							X						
Nymphalinae	Hypolimnas alimena (Linnaeus, 1758)	1	X		X	X				X						
Nymphalinae	Hypolimnas antilope (Cramer, 1777)	1	X	X	X											
Nymphalinae	Hypolimnas deois (Hewitson, 1858)	2	X		X	X	X	X		X	X					
Nymphalinae	Yoma algina (Boisduval, 1832)	2	X	X	X	X	X			X						
Nymphalinae	Junonia hedonia (Linnaeus, 1764)	1	X		X					X						
Nymphalinae	Junonia erigone (Cramer, 1775)	1	X													
Nymphalinae	Junonia villida (Fabricius, 1787)	1	X													
Nymphalinae	Cethosia cydippe (Linnaeus, 1763)	1	X	X	X	X	X	X	X	X	X	X				
Nymphalinae	Vindula arsinoe (Cramer, 1777)	1	X	X	X	X	X	X	X	X	X	X				
Nymphalinae	Terinos tethys Hewitson, 1862	3	X													
Nymphalinae	Cirrochroa regina C. & R. Felder, 1865	3	X	X	X	X	X			X						
Nymphalinae	Algia felderi (Kirsch, 1877)	3				X				X	X	X				
Nymphalinae	Vagrans egista (Stoll, 1780)	1	X	X	X	X	X	X		X						
Nymphalinae	Phalanta alcippe (Cramer, 1782)	1	X	X						X						
Nymphalinae	Cupha prosope (Fabricius, 1775)	1	X	X	X	X	X	X		X	X					
Acraeini	Acraea meyeri Kirsch, 1877	3	X													X

Notes: Elevation classes in metres.

Endemism scores

6 Narrow endemic to the Telefomin region

5 Endemic to northern mainland New Guinea, north of the Central Cordillera

4 Endemic to mainland New Guinea

3 Endemic to New Guinea and its satellite islands (Waigeo, Misol, Yapen, Biak, Aru, d'Entrecasteaux and Louisiades islands)

2 Endemic to New Guinea, its satellite islands, the Bismarcks and Maluku islands

1 Occurs more widely in the Indo-Pacific

Appendix 7.3. Habitat Preferences of Butterflies

SUBFAMILY	SCIENTIFIC NAME	MATURE FOREST (A)	LIGHTLY DISTURBED FOREST (C)	HEAVILY DISTURBED, CLEARED OR EARLY SUCCESSIONAL FOREST (D)	RIPARIAN FOREST	HEATH	GRASSLAND
Pyrginae	*Chaetocneme antipodes* (Guérin-Méneville, 1831)	X					
Pyrginae	*Chaetocneme callixenus* Hewitson, 1867	X	X				
Pyrginae	*Chaetocneme critomedia* (Guérin-Méneville, 1831)	X	X				
Pyrginae	*Chaetocneme tenuis* (van Eecke, 1924)	X					
Pyrginae	*Chaetocneme* sp. nov.	X					
Pyrginae	*Netrocoryne thaddeus* (Hewitson, 1876)	X	X				
Pyrginae	*Tagiades japetus* (Stoll, 1781)	X	X	X	X		
Pyrginae	*Tagiades trebellius* (Höpffer, 1874)	X	X	X	X		
Pyrginae	*Tagiades nestus* (C. Felder, 1860)	X	X	X	X		
Coeliadinae	*Badamia exclamationis* (Fabricius, 1775)		X	X	X		X
Coeliadinae	*Allora dolleschalli* (C. Felder, 1860)	X	X	X	X		
Coeliadinae	*Hasora discolor* (C. & R. Felder, 1859)	X	X	X	X		
Coeliadinae	*Hasora hurama* (Butler, 1870)		X	X	X		
Coeliadinae	*Hasora khoda* (Mabille, 1876)	X	X	X	X		
Coeliadinae	*Hasora celaenus* (Stoll, 1782)	X	X	X	X		
Coeliadinae	*Hasora subcaelestis* Rothschild, 1916	X	X	X	X		
Trapezitinae	*Hewitsoniella migonitis* (Hewitson, 1876)	X					
Trapezitinae	*Felicena dirpha* (Boisduval, 1832)			X		X	
Trapezitinae	*Toxidia inornata* (Butler, 1883)		X	X	X		
Trapezitinae	*Rachelia extrusa* (C. & R. Felder, 1867)	X	X				
Trapezitinae	*Rachelia icosia* (Fruhstorfer, 1911)	X	X				
Hesperiinae	*Tiacellia tiacellia* (Hewitson, 1868)	X					
Hesperiinae	*Erionota thrax* (Linnaeus, 1767)		X	X	X		X
Hesperiinae	*Notocrypta waiguensis* (Plötz, 1882)	X	X		X		
Hesperiinae	*Notocrypta renardi* (Oberthür, 1878)	X	X		X		
Hesperiinae	*Notocrypta flavipes* (Janson, 1886)	X	X				
Hesperiinae	*Sabera caesina* (Hewitson, 1886)	X	X				
Hesperiinae	*Sabera kumpia* Evans, 1949	X					
Hesperiinae	*Sabera biaga* Evans, 1949	X	X				
Hesperiinae	*Sabera misola* Evans, 1949	X	X				
Hesperiinae	*Sabera fuliginosa* (Miskin, 1889)	X	X				
Hesperiinae	*Sabera dobboe* (Plötz, 1885)	X	X	X	X		
Hesperiinae	*Sabera tabla* (Swinhoe, 1905)	X					
Hesperiinae	*Sabera sp. nov. 1*	X					
Hesperiinae	*Sabera sp. nov. 2*	X					

SUBFAMILY	SCIENTIFIC NAME	MATURE FOREST (A)	LIGHTLY DISTURBED FOREST (C)	HEAVILY DISTURBED, CLEARED OR EARLY SUCCESSIONAL FOREST (D)	RIPARIAN FOREST	HEATH	GRASSLAND
Hesperiinae	*Mimene kolbei* (Ribbe, 1899)	X	X				
Hesperiinae	*Mimene celiaba* Parsons, 1986	X					
Hesperiinae	*Mimene biakensis* Joicey & Talbot, 1917	X					
Hesperiinae	*Mimene caesar* Evans, 1935	X					
Hesperiinae	*Mimene sariba* Evans, 1935	X					
Hesperiinae	*Mimene basalis* (Rothschild, 1916)	X	X				
Hesperiinae	*Mimene verda* Parsons, 1986	X					
Hesperiinae	*Mimene atropatene* (Fruhstorfer, 1911)	X					
Hesperiinae	*Mimene cyanea* (Evans, 1928)	X	X				
Hesperiinae	*Mimene lysima* (Swinhoe, 1905)	X					
Hesperiinae	*Mimene celia* Evans, 1935	X					
Hesperiinae	*Mimene miltias* (Kirsch, 1877)	X					
Hesperiinae	*Mimene melie* (de Nicéville)	X					
Hesperiinae	*Mimene milnea* Evans, 1935	X					
Hesperiinae	*Kobrona wama* (Plötz, 1885)	X	X				
Hesperiinae	*Kobrona rasta* Evans, 1935	X	X				
Hesperiinae	*Kobrona infralutea* (Rothschild, 1916)	X	X				
Hesperiinae	*Kobrona* sp. nov.	X					
Hesperiinae	*Cephrenes augiades* (C. Felder, 1868)	X	X	X	X		
Hesperiinae	*Cephrenes moseleyi* (Butler, 1884)	X	X	X	X		
Hesperiinae	*Cephrenes augiana* Evans, 1934	X	X	X			
Hesperiinae	*Telicota augias* (Linnaeus, 1763)	X	X	X			
Hesperiinae	*Telicota melanion* (Mabille, 1878)	X	X				
Hesperiinae	*Telicota ternatensis* Swinhoe, 1907	X	X				
Hesperiinae	*Telicota paceka* Fruhstorfer, 1911	X	X				
Hesperiinae	*Telicota bulwa* Parsons, 1986	X	X				
Hesperiinae	*Telicota kezia* Evans, 1949	X	X				
Hesperiinae	*Telicota gervasa* Evans, 1949	X					
Hesperiinae	*Telicota vinta* Evans, 1949	X	X				
Hesperiinae	*Telicota eurotas* (C. Felder, 1860)			X			X
Hesperiinae	*Telicota sp.*	X					
Hesperiinae	*Arrhenes marnas* (C. Felder, 1860)			X			X
Hesperiinae	*Arrhenes dschilus* (Plötz, 1885)		X	X			X
Hesperiinae	*Suniana sunias* (C. Felder, 1860)			X	X		X
Hesperiinae	*Ocybadistes ardea* Bethune-Baker, 1906		X	X			X
Hesperiinae	*Ocybadistes papua* Evans, 1934		X				

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Hesperiinae	*Parnara amalia* (Semper, 1879)		X	X			
Hesperiinae	*Borbo impar* (Mabille, 1883)			X			X
Hesperiinae	*Borbo cinnara* (Wallace, 1866)			X			X
Hesperiinae	*Pelopidas agna* (Moore, 1866)			X			X
Hesperiinae	*Pelopidas lyelli* Rothschild, 1915			X			X
Hesperiinae	*Pelopidas mathias* (Fabricius, 1789)		X	X			
Hesperiinae	*Caltoris boisduvali* (C. & R. Felder, 1867)	X	X	X			X
Hesperiinae	*Caltoris philippina* (Herrich-Schäffer, 1869)		X				
Papilioninae	*Atrophaneura polydorus* (Linnaeus, 1763)	X	X	X	X		
Papilioninae	*Troides oblongomaculatus* (Goeze, 1779)			X			
Papilioninae	*Ornithoptera priamus* (Linnaeus, 1758)	X	X	X			
Papilioninae	*Ornithoptera goliath* Oberthür, 1888	X	X				
Papilioninae	*Ornithoptera paradisea (Staudinger, 1893)*	X	X				
Papilioninae	*Ornithoptera meridionalis* Rothschild, 1897	X	X				
Papilioninae	*Graphium agamemnon* (Linnaeus, 1758)	X	X	X			
Papilioninae	*Graphium macfarlanei* (Butler, 1877)	X	X	X			
Papilioninae	*Graphium wallacei* (Hewitson, 1858)	X	X	X			
Papilioninae	*Graphium weiskei* (Ribbe, 1900)	X	X				
Papilioninae	*Graphium codrus* (Cramer, 1777)		X	X			
Papilioninae	*Graphium sarpedon* (Linnaeus, 1758)		X	X			
Papilioninae	*Graphium euryplus* (Linnaeus, 1758)		X	X			
Papilioninae	*Graphium aristeus* (Stoll, 1781)	X	X	X			
Papilioninae	*Chilasa laglazei* (Depuiset, 1877)	X	X				
Papilioninae	*Papilio aegeus* Donovan, 1805	X	X	X	X		
Papilioninae	*Papilio ambrax* Boisduval, 1832	X	X				
Papilioninae	*Papilio albinus* Wallace, 1865	X	X				
Papilioninae	*Papilio ulysses* Linnaeus, 1758	X	X	X			
Papilioninae	*Papilio euchenor* (Guérin-Méneville, 1831)	X	X				
Coliadinae	*Catopsilia pomona* (Fabricius, 1775)			X	X		X
Coliadinae	*Eurema hecabe* (Linnaeus, 1758)		X	X	X		X
Coliadinae	*Eurema blanda* (Boisduval, 1836)		X	X			
Coliadinae	*Eurema puella* (Boisduval, 1832)	X	X				
Coliadinae	*Gandaca butyrosa* (Butler, 1875)	X	X				
Pierinae	*Leuciacria acuta* Rothschild & Jordan, 1905	X				X	
Pierinae	*Elodina andropis* Butler, 1876		X				
Pierinae	*Elodina hypatia* C. & R. Felder, 1865		X				

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Pierinae	*Saletara cycinna* (Hewitson, 1868)		X				
Pierinae	*Appias paulina* (Cramer, 1777)	X	X	X			
Pierinae	*Appias celestina* (Boisduval, 1832)	X	X	X			
Pierinae	*Appias ada* (Stoll, 1781)	X	X	X			
Pierinae	*Cepora abnormis* (Wallace, 1867)	X	X	X			
Pierinae	*Cepora perimale* (Donovan, 1805)		X	X			
Pierinae	*Delias enniana* (Oberthür, 1880)	X	X				
Pierinae	*Delias pulla* Talbot, 1937					X	
Pierinae	*Delias ennia* (Wallace, 1867)	X	X				
Pierinae	*Delias gabia* (Boisduval, 1832)	X					
Pierinae	*Delias ladas* Grose-Smith, 1894	X					
Pierinae	*Delias* cf. *eudiabolas* Rothschild, 1915	X					
Pierinae	*Delias mysis* (Fabricius, 1775)	X	X	X	X		
Pierinae	*Delias aruna* (Boisduval, 1832)	X	X				
Pierinae	*Delias discus* Honrath, 1886	X	X				
Pierinae	*Delias ornytion* (Godman & Salvin, 1880)	X	X				
Riodininae	*Dicallaneura decorata* (Hewitson, 1862)	X					
Riodininae	*Dicallaneura kirschi* Röber, 1886	X					
Riodininae	*Dicallaneura ribbei* Röber, 1886	X	X				
Riodininae	*Praetaxila huntei* (Sharpe, 1903)	X					
Riodininae	*Praetaxila satraps* (Grose-Smith, 1894)	X					
Riodininae	*Praetaxila statira* (Hewitson, 1861)	X					
Curetinae	*Curetis barsine* C. Felder, 1860	X	X				
Lycaeninae	*Liphyra brassolis* Westwood, 1864		X	X			
Lycaeninae	*Pseudodipsas eone* (C. & R. Felder, 1860)	X	X				
Lycaeninae	*Hypochrysops apollo* Miskin, 1891		X				
Lycaeninae	*Hypochrysops chrysargyrus* Grose-Smith & Kirby, 1895	X	X				
Lycaeninae	*Hypochrysops arronica* (C. & R. Felder, 1859)	X	X				
Lycaeninae	*Hypochrysops plotinus* Grose-Smith, 1894	X					
Lycaeninae	*Hypochrysops narcissus* (Fabricius, 1775)		X				
Lycaeninae	*Hypochrysops argyriorufus* van Eecke, 1924		X	X			
Lycaeninae	*Hypochrysops castaneus* Sands, 1986		X	X			
Lycaeninae	*Hypochrysops hermogenes* Grose-Smith, 1894		X				
Lycaeninae	*Hypochrysops ?cleonides* Grose-Smith, 1900 (probable)	X					
Lycaeninae	*Hypochrysops apelles* (Fabricius, 1775)			X	X		
Lycaeninae	*Hypochrysops dicomas* Hewitson, 1874	X	X				

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Lycaeninae	*Hypochrysops geminatus* Sands, 1986		X	X			
Lycaeninae	*Hypochrysops pythias* C. & R. Felder, 1865		X	X			
Lycaeninae	*Hypochrysops polycletus* (Linnaeus, 1758)		X	X	X		
Lycaeninae	*Hypochrysops calliphon* Grose-Smith, 1894	X					
Lycaeninae	*Hypochrysops heros* Grose-Smith, 1894	X	X				
Lycaeninae	*Hypochrysops theon* C. & R. Felder, 1865		X				
Lycaeninae	*Philiris diana* Waterhouse & Lyell, 1914	X	X				
Lycaeninae	*Philiris praeclara* Tite, 1963	X					
Lycaeninae	*Philiris violetta* (Röber, 1926)	X					
Lycaeninae	*Philiris harterti* (Grose-Smith, 1894)	X					
Lycaeninae	*Philiris hemileuca* (Jordan, 1930)	X					
Lycaeninae	*Philiris vicina* (Grose-Smith, 1898)	X					
Lycaeninae	*Philiris fulgens* (Grose-Smith & Kirby, 1897)	X	X				
Lycaeninae	*Philiris* sp. nr. *fulgens* (Grose-Smith & kirby, 1897)	X	X				
Lycaeninae	*Philiris* cf. *elegans* Tite, 1963	X					
Lycaeninae	*Philiris helena* (Snellen, 1887)	X	X	X			
Lycaeninae	*Philiris agatha* (Grose-Smith, 1899)	X	X				
Lycaeninae	*Philiris tapini* Sands, 1979	X					
Lycaeninae	*Philiris ziska* (Grose-Smith, 1898)		X	X			
Lycaeninae	*Philiris cf. argentea* (Rothschild, 1916)		X				
Lycaeninae	*Philiris cf. putih* Wind & Clench, 1947		X				
Lycaeninae	*Philiris sibatanii* Sands, 1979		X				
Lycaeninae	*Philiris intensa* (Butler, 1876)		X	X	X		
Lycaeninae	*Philiris ?innotata* (Miskin, 1874) (probable)		X	X			
Lycaeninae	*Philiris moira* (Grose-Smith, 1899)		X	X			
Lycaeninae	*Philiris* sp. nov.	X			X		
Lycaeninae	*Philiris pagwi* Sands, 1979		X	X	X		
Lycaeninae	*Titea caerulea* (Tite, 1963)	X			X		
Lycaeninae	*Arhopala auxesia* (Hewitson, 1863)		X				
Lycaeninae	*Arhopala antharita* Grose-Smith, 1894		X	X			
Lycaeninae	*Arhopala herculina* Staudinger, 1888	X	X	X			
Lycaeninae	*Arhopala nobilis* C. Felder, 1860	X	X				
Lycaeninae	*Arhopala chamaeleona* Bethune-Baker, 1903	X	X	X			
Lycaeninae	*Arhopala adherbal* Grose-Smith, 1902		X	X			
Lycaeninae	*Arhopala madytus* Fruhstorfer, 1914		X	X			
Lycaeninae	*Arhopala meander* Boisduval, 1832	X	X				

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Lycaeninae	*Arhopala philander* C. & R. Felder, 1865	X	X	X			
Lycaeninae	*Arhopala leander* Evans, 1957	X	X				
Lycaeninae	*Arhopala ander* Evans, 1957	X					
Lycaeninae	*Arhopala micale* Boisduval, 1853	X	X	X			
Lycaeninae	*Arhopala alkisthenes* Fruhstorfer, 1914	X	X				
Lycaeninae	*Arhopala aexone* (Hewitson, 1863)	X	X				
Lycaeninae	*Arhopala azenia* (Hewitson, 1863)	X	X	X			
Lycaeninae	*Arhopala admete* Hewitson, 1863	X					
Lycaeninae	*Arhopala thamyras* (Linnaeus, 1758)	X	X				
Lycaeninae	*Amblypodia annetta* Staudinger, 1887	X	X				
Lycaeninae	*Hypochlorosis ancharia* (Hewitson, 1869)	X	X				
Lycaeninae	*Hypochlorosis antipha* (Hewitson, 1869)	X					
Lycaeninae	*Hypolycaena phorbas* (Fabricius, 1793)	X	X	X	X		
Lycaeninae	*Hypolycaena danis* (C. & R. Felder, 1865)		X	X	X		
Lycaeninae	*Deudorix epijarbus* (Moore, 1858)		X				
Lycaeninae	*Deudorix littoralis* Joicey & Talbot, 1916	X	X	X			
Lycaeninae	*Deudorix parsonsi* Tennent, 2000	X	X				
Lycaeninae	*Deudorix epirus* (C. Felder, 1860)	X	X				
Lycaeninae	*Rapala varuna* (Horsfield, 1829)		X	X			
Lycaeninae	*Bindahara meeki* (Rothschild & Jordan, 1905)	X	X				
Lycaeninae	*Bindahara phocides* (Fabricius, 1793)	X	X	X			
Lycaeninae	*Anthene lycaenoides* (C. Felder, 1860)		X	X			
Lycaeninae	*Anthene seltuttus* (Röber, 1886)		X	X	X		
Lycaeninae	*Candalides tringa* (Grose-Smith, 1894)	X	X				
Lycaeninae	*Candalides helenita* (Semper, 1879)	X	X	X			
Lycaeninae	*Candalides ardosiacea* (Tite, 1963)	X	X				
Lycaeninae	*Candalides margarita* (Semper, 1879)		X	X			
Lycaeninae	*Candalides* cf. *margarita* (Semper, 1879)	X	X	X			
Lycaeninae	*Candalides* sp. nov.	X					
Lycaeninae	*Petrelaea tombugiensis* (Röber, 1886)		X				
Lycaeninae	*Nacaduba subperusia* (Snellen, 1896)		X				
Lycaeninae	*Nacaduba hermus* (C. Felder, 1860)		X				
Lycaeninae	*Nacaduba berenice* (Herrich-Schäffer, 1869)		X	X			
Lycaeninae	*Nacaduba pactolus* (C. Felder, 1860)		X	X			
Lycaeninae	*Nacaduba kurava* (Moore, 1857)		X	X			
Lycaeninae	*Nacaduba cyanea* (Cramer, 1775)	X	X				

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Lycaeninae	*Nacaduba mioswara* Tite, 1963	X					
Lycaeninae	*Nacaduba ruficirca* Tite, 1963	X	X				
Lycaeninae	*Nacaduba tristis* Rothschild, 1916	X	X				
Lycaeninae	*Nacaduba nerine* (Grose-Smith & Kirby, 1899)		X				
Lycaeninae	*Erysichton lineata* (Murray, 1874)	X	X				
Lycaeninae	*Erysichton palmyra* (C. Felder, 1860)	X	X				
Lycaeninae	*Danis danis* (Cramer, 1775)	X					
Lycaeninae	*Danis glaucopis* (Grose-Smith, 1894)	X					
Lycaeninae	*Danis melimnos* (Druce & Bethune-Baker, 1893)	X					
Lycaeninae	*Danis regalis* (Grose-Smith & Kirby, 1895)	X					
Lycaeninae	*Perpheres perpheres* (Druce & Bethune-Baker, 1893)	X					
Lycaeninae	*Psychonotis caelius* (C. & R. Felder, 1860)	X	X	X	X		
Lycaeninae	*Prosotas nora* (C. Felder, 1860)	X	X	X	X		
Lycaeninae	*Prosotas papuana* Tite, 1963	X	X				
Lycaeninae	*Prosotas dubiosa* (Semper, 1879)	X	X	X			
Lycaeninae	*Catopyrops ancyra* (C. Felder, 1860)		X	X	X		
Lycaeninae	*Ionolyce helicon* (C. Felder, 1860)	X	X	X	X		
Lycaeninae	*Paraduba metriodes* (Bethune-Baker, 1911)		X	X			
Lycaeninae	*Sahulana scintillata* (Lucas, 1889)		X	X	X		
Lycaeninae	*Upolampes evena* (Hewitson, 1876)		X	X			
Lycaeninae	*Caleta mindarus* (C. & R. Felder, 1865)		X	X			
Lycaeninae	*Pistoria nigropunctata* (Bethune-Baker, 1908)	X				X	
Lycaeninae	*Jamides amarauge* Druce, 1891	X	X				
Lycaeninae	*Jamides nitens* (Joicey & Talbot, 1916) probable	X					
Lycaeninae	*Jamides cytus* (Boisduval, 1832)	X	X				
Lycaeninae	*Jamides celeno* (Cramer, 1775)		X	X	X		
Lycaeninae	*Jamides aetherialis* (Butler, 1884)		X	X			
Lycaeninae	*Jamides allectus* (Grose-Smith, 1894)	X	X				
Lycaeninae	*Jamides reverdini* (Fruhstorfer, 1915)	X	X				
Lycaeninae	*Jamides coritus* (Guérin-Méneville, 1831)	X	X				
Lycaeninae	*Epimastidia inops* (C. & R. Felder, 1860)	X					
Lycaeninae	*Catochrysops amasea* Waterhouse & Lyell, 1914		X	X			
Lycaeninae	*Catochrysops panormus* (C. Felder, 1860)		X	X	X		
Lycaeninae	*Lampides boeticus* (Linnaeus, 1767)			X			X
Lycaeninae	*Callictita lara* Parsons, 1986	X	X				
Lycaeninae	*Pithecops dionisius* (Boisduval, 1832)	X	X				

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Lycaeninae	*Zizina labradus* (Godart, 1824)			X		X	X
Lycaeninae	*Zizula hylax* (Fabricius, 1775)			X			X
Lycaeninae	*Everes lacturnus* (Godart, 1824)			X	X		X
Lycaeninae	*Megisba strongyle* (C. Felder, 1860)	X	X				
Lycaeninae	*Udara dilecta* (Moore, 1879)	X	X			X	
Lycaeninae	*Udara cardia* (C. Felder, 1860)	X	X			X	
Lycaeninae	*Udara drucei* (Bethune-Baker, 1906)	X	X			X	
Lycaeninae	*Udara owgarra* (Bethune-Baker, 1906)	X				X	
Lycaeninae	*Monodontoides argioloides* (Rothschild, 1916)	X				X	
Lycaeninae	*Euchrysops cnejus* (Fabricius, 1798)			X	X		X
Libytheinae	*Libythea geoffroy* Godart, 1820			X			
Ithomiinae	*Tellervo nedusia* (Geyer, 1832)	X					
Ithomiinae	*Tellervo zoilus* (Fabricius, 1775)	X					
Danainae	*Parantica kirbyi* (Grose-Smith, 1894)		X	X			
Danainae	*Parantica melusine* (Grose-Smith, 1894)	X					
Danainae	*Ideopsis juventa* (Cramer, 1777)		X	X	X		
Danainae	*Tirumala hamata* (Macleay, 1827)			X			X
Danainae	*Danaus affinis* (Fabricius, 1775)			X			X
Danainae	*Danaus plexippus* (Linnaeus, 1758)			X			X
Danainae	*Euploea phaenareta* (Schaller, 1785)		X	X			
Danainae	*Euploea leucostictos* (Gmelin, 1790)	X	X	X			
Danainae	*Euploea tulliolus* (Fabricius, 1793)		X	X			
Danainae	*Euploea stephensii* C. & R. Felder, 1865		X	X			
Danainae	*Euploea algea* (Godart, 1819)		X	X			
Danainae	*Euploea netscheri* Snellen, 1889		X	X			
Danainae	*Euploea alcathoe* (Godart, 1819)		X	X			
Danainae	*Euploea wallacei* C. & R. Felder, 1860	X	X	X			
Morphinae	*Morphopsis biakensis* Joicey & Talbot, 1916	X					
Morphinae	*Morphopsis albertisi* Oberthür, 1880	X					
Morphinae	*Hyantis hodeva* Hewitson, 1862	X					
Morphinae	*Taenaris catops* (Westwood, 1851)	X	X	X	X		
Morphinae	*Taenaris bioculatus* (Guérin-Méneville, 1831)	X	X	X			
Morphinae	*Taenaris dina* Staudinger, 1894	X					
Morphinae	*Taenaris dioptrica* (S.C. Snellen van Vollenhoven, 1860)	X					
Morphinae	*Taenaris honrathi* Staudinger, 1886	X	X				
Morphinae	*Taenaris myops* (C. & R. Felder, 1860)	X	X				

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Morphinae	*Taenaris cyclops* Staudinger, 1893	X	X				
Morphinae	*Taenaris dimona* (Hewitson, 1862)	X	X				
Morphinae	*Taenaris artemis* (S. C. Snellen van Vollenhoven, 1860)	X	X	X			
Morphinae	*Taenaris* sp. nov.	X					
Satyrinae	*Mycalesis perseus* (Fabricius, 1775)			X			X
Satyrinae	*Mycalesis duponchelii* (Guérin-Méneville, 1831)	X					
Satyrinae	*Mycalesis mucia* Hewitson, 1862	X					
Satyrinae	*Mycalesis phidon* Hewitson, 1862		X	X			X
Satyrinae	*Mycalesis terminus* (Fabricius, 1775)		X	X	X		X
Satyrinae	*Mycalesis elia* Grose-Smith, 1894		X	X			X
Satyrinae	*Mycalesis cacodaemon* Kirsch, 1877	X	X				
Satyrinae	*Mycalesis giamana* Parsons, 1986	X					
Satyrinae	*Mycalesis comes* Grose-Smith, 1894	X					
Satyrinae	*Mycalesis mehadeva* (Boisduval, 1832)	X					
Satyrinae	*Mycalesis fulvianetta* Rothschild, 1916	X					
Satyrinae	*Mycalesis aethiops* Butler, 1868		X	X	X		
Satyrinae	*Mycalesis shiva* (Boisduval, 1832)	X	X				
Satyrinae	*Mycalesis* cf. *arabella* Fruhstorfer, 1906	X					
Satyrinae	*Mycalesis* sp. nov. 1	X					
Satyrinae	*Mycalesis* sp. nov. 2		X				
Satyrinae	*Mycalesis durga* Grose-Smith & Kirby, 1894	X	X				
Satyrinae	*Orsotriaena medus* (Fabricius, 1775)			X			X
Satyrinae	*Lamprolensis nitida* Godman & Salvin, 1880	X	X	X			
Satyrinae	*Hypocysta isis* Grose-Smith, 1894	X	X				
Satyrinae	*Harsiesis hygea* (Hewitson, 1863)	X	X			X	
Satyrinae	*Altiapa pandora* (Joicey & Talbot, 1916)					X	
Satyrinae	*Erycinidia gracilis* Rothschild & Jordan, 1905					X	
Satyrinae	*Ypthima arctoa* (Fabricius, 1775)			X			X
Satyrinae	*Melanitis leda* (Linnaeus, 1758)		X	X	X		X
Satyrinae	*Melanitis amabilis* (Boisduval, 1832)	X	X				
Satyrinae	*Melanitis constantia* (Cramer, 1777)	X	X				
Satyrinae	*Elymnias papua* Wallace, 1869	X					
Satyrinae	*Elymnias cybele* (C. Felder, 1860)	X					
Satyrinae	*Elymnias agondas* (Boisduval, 1932)	X	X				
Charaxinae	*Charaxes latona* Butler, 1865	X	X	X			
Charaxinae	*Polyura (Charaxes) jupiter* (Butler, 1869)	X	X				

SUBFAMILY	SCIENTIFIC NAME	MATURE FOREST (A)	LIGHTLY DISTURBED FOREST (C)	HEAVILY DISTURBED, CLEARED OR EARLY SUCCESSIONAL FOREST (D)	RIPARIAN FOREST	HEATH	GRASSLAND
Charaxinae	*Prothoe australis* (Guérin-Méneville, 1831)	X					
Apaturinae	*Apaturina erminea* (Cramer, 1779)	X	X	X			
Apaturinae	*Helcyra chionippe* C. Felder, 1860	X	X				
Apaturinae	*Dichorragia ninus* (C. & R. Felder, 1859)	X	X				
Apaturinae	*Cyrestis acilia* (Godart, 1819)	X	X	X			
Apaturinae	*Cyrestis achates* Butler, 1865	X	X				
Nymphalinae	*Lexias aeropa* (Linnaeus, 1758)	X					
Nymphalinae	*Euthaliopsis aetion* (Hewitson, 1862)	X	X				
Nymphalinae	*Parthenos aspila* Honrath, 1888		X	X	X		
Nymphalinae	*Pantoporia consimilis* (Boisduval, 1832)	X	X	X	X		
Nymphalinae	*Pantoporia venilia* (Linnaeus, 1758)	X	X				
Nymphalinae	*Neptis praslini* (Boisduval, 1832)	X					
Nymphalinae	*Neptis satina* Grose-Smith, 1894	X					
Nymphalinae	*Phaedyma shepherdi* (Moore, 1858)	X	X				
Nymphalinae	*Mynes geoffroyi* (Guérin-Méneville, 1831)	X	X				
Nymphalinae	*Symbrenthia hippoclus* (Cramer, 1779)		X	X			
Nymphalinae	*Dolleschallia noorna* Grose-Smith & Kirby, 1893	X	X	X			
Nymphalinae	*Dolleschallia hexopthalmos* (Gmelin, 1790)	X	X				
Nymphalinae	*Dolleschallia nacar* (Boisduval, 1832)	X	X				
Nymphalinae	*Hypolimnas bolina* (Linnaeus, 1764)		X	X	X		X
Nymphalinae	*Hypolimnas alimena* (Linnaeus, 1758)		X	X	X		
Nymphalinae	*Hypolimnas antilope* (Cramer, 1777)		X	X			
Nymphalinae	*Hypolimnas deois* (Hewitson, 1858)	X	X				
Nymphalinae	*Yoma algina* (Boisduval, 1832)		X	X			
Nymphalinae	*Junonia hedonia* (Linnaeus, 1764)			X			X
Nymphalinae	*Junonia erigone* (Cramer, 1775)		X	X			
Nymphalinae	*Junonia villida* (Fabricius, 1787)						X
Nymphalinae	*Cethosia cydippe* (Linnaeus, 1763)	X	X	X			
Nymphalinae	*Vindula arsinoe* (Cramer, 1777)	X	X				
Nymphalinae	*Terinos tethys* Hewitson, 1862	X	X				
Nymphalinae	*Cirrochroa regina* C. & R. Felder, 1865	X	X	X			
Nymphalinae	*Algia felderi* (Kirsch, 1877)	X	X				
Nymphalinae	*Vagrans egista* (Stoll, 1780)	X	X	X			
Nymphalinae	*Phalanta alcippe* (Cramer, 1782)	X	X	X			
Nymphalinae	*Cupha prosope* (Fabricius, 1775)	X	X				
Acraeini	*Acraea meyeri* Kirsch, 1877		X	X		X	X