A Rapid Biodiversity Assessment of Papua New Guinea's Hindenburg Wall Region

edited by
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Front cover Image: Rocky Roe (waterfall on approach to Minni Camp)
Rear cover Image: Stephen J. Richards (*Nyctimystes oktediensis*)

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Partner Organisation Profiles

PNG Sustainable Development Program (PNGSDP)

www.pngsdp.com

PNGSDP was established in 2002 with the mission of promoting development that meets the needs of the present generation and establishes the foundation for continuing progress for future generations of Papua New Guineans. This was achieved by using funds generated from its share in Ok Tedi Mining Limited to support development in PNG, in particular for the people of the Western Province. PNGSDP's objective is to support selected sustainable development programs through projects and initiatives in keeping with the aims and aspirations outlined in the UN Millennium Development Goals.

Papua New Guinea Department of Environment and Conservation (DEC)

www.dec.gov.pg

DEC is vested with powers to protect environmental values and for the sustainable use of natural resources as mandated by the Fourth Goal of the PNG National Constitution. Its mission is to ensure PNG's natural resources are managed to sustain environmental quality, human wellbeing and support improved standards of living. The Directive Principles of DEC include the wise use of natural resources and the environment in the interest of development and in trust for future generations, the conservation and replenishment of the environment and its sacred, scenic and historical qualities, and giving adequate protection to PNG's unique plants and animals.

Wildlife Conservation Society (WCS)

www.wcs.org

The Wildlife Conservation Society, founded in 1895 as the New York Zoological Society, has the clear mission to save wildlife and wild places across the globe. WCS does so through science, global conservation, education and the management of the world's largest system of urban wildlife parks, led by the flagship Bronx Zoo. With a commitment to protect 25 percent of the world's biodiversity, WCS addresses four of the biggest issues facing wildlife and wild places: climate change, natural resource exploitation, the connection between wildlife health and human health, and the sustainable development

of human livelihoods. While taking on these issues, WCS manages more than 80 million hectares of protected lands around the world, with more than 200 scientists on staff. The goals of the WCS programme in PNG are to promote the sustainable use and rehabilitation of terrestrial and coastal marine ecosystems and to identify and implement measures to address the effects of climate change. This approach aims to safeguard biodiversity, livelihoods, cultural heritage, and user rights of Papua New Guineans.

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Executive Summary

Aim

The Hindenburg Wall, along with the Muller Range and Nakanai Mountains, is a part of a proposed UNESCO World Heritage Site called The Sublime Karst of Papua New Guinea (Hamilton-Smith 2006). This survey document reports on a biodiversity assessment undertaken by the Wildlife Conservation Society Papua New Guinea (WCS), financed by the Papua New Guinea Sustainable Development Program Ltd (PNGSDP), and undertaken in partnership with the Papua New Guinea Department of Environment and Conservation (DEC). The aim of this project was to conduct a series of biological surveys in the region by a WCS-led team of international and national taxonomic experts in order to investigate the biodiversity values in light of the area being a proposed UNESCO World Heritage Area.

Location of the Hindenburg Wall survey

The survey was conducted in the upper Ok Tedi catchment on the southern slopes of the Hindenburg Range (two survey locations) and the Star Mountains (one survey location). Initially three sites corresponding to low, mid and high elevations in the Olsobip region were targeted by WCS for survey, and permissions were granted from local representatives and the villages visited. Unfortunately, unforeseen community issues forced the withdrawal of the WCS preparatory team and new locations had to be scouted. The locations and altitudes of each site sampled during the 2013 WCS Hindenburg Wall biodiversity survey are shown in the map while survey details are given in Table 1. Two locations, the Tabubil area and Bilbilokabip hamlet at Tupnonbil, are located on the southern slopes of the Hindenburg Range whereas Mt Minni is on the eastern fringe of the Star Mountains. Not all participants sampled each site: due to logistical constraints only the Mammal and Vegetation teams sampled at Mt Minni.

Sampling areas of the 2013 WCS Hindenburg Wall biodiversity survey. Camps are shown as dark green, other sampling locations are shown in red. Inset: Papua New Guinea – area of interest shown in red.

Table 1. Locations and altitudes of each site sampled during the 2013 WCS Hindenburg Wall biodiversity survey

Site*	Latitude	Longitude	Elevation (m)	Comments
Bilbilokabip	5.1203	141.2512	1770	Hamlet at Tupnonbil, base for Camp
Dablin Creek *at waterfall*	5.2151	141.2318	909	Second major stream above Tabubil Town on Tabubil-to-Mine road
Dablin Creek *below waterfall*	5.2156	141.2309	859	
Kawarobip				Local name for Mt Minni area
Kumarang Wok	5.3047	141.2485	380	First stream below Tabubil with large swimming hole
Minni Camp	5.0775	141.1505	2383	The high-montane camp on the slopes of Mt Minnie in the Kawarobip area
Ok Tupnon				The main stream flowing past Bilbilokabip
Tabubil Area				General area around township
Tabubil Quarry	5.297	141.2415	407	Water-filled quarry below Tabubil southern entrance security gate
Tabubil Town	5.2657	141.22	546	Tabubil town
Tulenbeng Wok	5.3082	141.2528	433	Second major stream below Tabubil
Tupnonbil				The general area surrounding Bilbilokabip hamlet
Umansim Stream *(road)*	5.334	141.2775	360	
Umansim Stream *(lower)*	5.3369	141.2764	336	
Umansim Stream *(upper)*	5.3328	141.278	365	Third major stream below Tabubil
Yakulgabip	5.1202	141.2582	1817	Hamlet and associated clearing above Bilbilokabip
Yemun Wok	5.3871	141.2972	285	Fourth major stream below Tabubil at Sawmill
Yukfon Creek	5.2333	141.2221	734	First major stream above Tabubil town on Tabubil-to-Mine road

*names were obtained from local informants

Expedition dates

Tabubil environs (low elevation)	6–10 Feb 2013 and 25 Feb–1 Mar 2013
Tupnonbil (mid elevation)	11–24 Feb 2013
Kawarobip (high elevation)	24–28 Feb 2013

Major results

A total of 1108 animal and plant species were documented during the survey. This included 89 species known or suspected to be new to science and 17 species listed in a category higher than Least Concern by the IUCN. A summary of the major results is presented below and total numbers of species documented is presented in Table 2.

Table 2. Number of species documented (including invasives), number estimated to be new to science, and the number of indigenous species holding an IUCN threat classification above Least Concern during the 2013 Hindenburg Wall Survey.

	Plants	Ants	Bats	Beetles	Birds	Butterflies	Fishes	Herpeto-fauna	Non-volant mammals	Odonates	TOTALS
Total Species	452	172	11	15	157	165	13	37	33	53	**1108**
New Species	23	26	1	7	0	5	0	10	1	16	**89**
IUCN Species	2	0	1	0	4	1	1	4	4	0	**17**

Traditional and local ecological knowledge

Despite changes associated with proximity to industrialised mining and the influx of modern hunting technologies, village life around the Hindenburg Wall still revolves to a large extent around subsistence gardening and hunting. Wild plants and animals are still culturally and nutritionally important. Much of the hunting around the Hindenburg Wall is cyclic and seasonal, following the traditional gardening calendar and the fruiting of certain species of trees. Of all the species recounted to us from the testimony of hunters the tree kangaroos (Dubol: *Dendrolagus stellarum / notatus*) are by far the most important; having high nutritional, cultural, and exchange value. Other species of high importance are the Coppery Ringtail (*Pseudochirops cupreus*), Dwarf Cassowary (*Casuarius bennetti*), Papuan Eagle (*Harpyopsis novaeguinae*), Black and Brown Sicklebills (*Epimachus fastosus/meyeri*), Raggiana Bird of Paradise (*Paradisaea raggiana*), and the Vulturine Parrot (*Psittrichas fulgidus*). Much of the traditional knowledge of wildlife is sacred and only revealed during times of initiation.

Vascular plant biodiversity

Ten vegetation formations are described from three survey sites at altitudes between 980 m above sea level (asl) near Tabubil and 2,400 m at Kawarobip. This area is floristically rich and a rapid taxonomic inventory documented 60 species of ferns and lycophytes, two species of gymnosperms, 132 species of monocotyledons and 258 species of dicotyledons for a total of 452 species in 105 families. Of these, 23 species are new to science and a further 65 records represent extensions of known distributions and new records for Western Province.

Ant and scolytine beetle biodiversity

Seven sites were sampled ranging from 350 m (asl) to approximately 1,770 m asl. Overall ant species diversity was high, with 172 species belonging to 54 genera encountered. Of these, more than 26 species appear to be new to science. Nine species are introduced in Papua New Guinea, and six of these are recognized as globally invasive species. All of the invasive species were confined to human-disturbed areas near Tabubil; not a single known introduced species was encountered in intact forest farther from human disturbance. Scolytine beetles were also sampled at these sites and 15 species were found, seven of which are likely new to science.

Butterfly biodiversity

165 butterfly species were recorded during the survey of the Hindenburg Wall area. Four of these appear to be new to science and a further species is undescribed. Two conservation listed Birdwing species (*Ornithoptera*) were noted during the surveys. Three butterfly species are recorded from Papua New Guinea for the first time and a number of others are newly recorded from Western Province. The highest butterfly diversity was recorded in the vicinity of Tabubil, with 141 species, while 28 species were recorded at Bilbilokabip camp at the base of the Hindenburg Wall.

Odonates (dragonfly and damselfly) biodiversity

Fifty-three species of odonates were encountered, including 28 species of damselflies (Zygoptera) and 25 species of dragonflies (Anisoptera). Between 13 and 16 of these species (up to 30%) appear to be new to science. Diversity at the lower, foothill sites was much higher (40 species) than at the montane location, which totalled just 14 species despite higher search effort. However the fauna at the montane site was remarkable for the high proportion of species that are new to science (six of 14 species or 43%).

Fish biodiversity

Ten sites were sampled in the Tabubil and Tupnonbil areas. No fish were recorded at Tupnonbil, a result that was predicted for this higher elevation area where water temperatures are cool and streams frequently flash-flood. Twelve native fishes and one introduced species (Tilapia, *Oreochromis mossambicus*) were recorded from the Tabubil area. Although no species new to science were confirmed one very large gudgeon (Eleotridae: *Bostrychus*) is morphologically atypical in comparison to the known species in the region. Other important results included the documentation of apparently large populations of the threatened narrow-range endemic Ok Tedi Rainbowfish (*Melanotaenia oktediensis;* ranked as Vulnerable on the IUCN Red List), and the first records of Southern Tandan (*Neosilurus equinus*) from the region in recent times.

Herpetofauna (reptile and amphibian) biodiversity

A total of 37 species (24 frogs and 13 reptiles) were documented across a 2,000 m altitudinal gradient. At least 10 species of frogs are undescribed, and six of these appear to be entirely new to science (discovered for the first time during this survey). One species of lizard, a member of the montane genus *Papuascincus*, also appears to be undescribed. Of the 12 described frog species assessed by the IUCN four are classified as Data Deficient due to their poorly-known distributions and ecological requirements. None of the reptiles encountered has been assessed by the IUCN.

Bird biodiversity

Birds were surveyed during 6–28 February 2013 from two locations: (1) Bilbilokabip, in the western sector of the Hindenburg Range near the base of the northern Hindenburg Wall (main survey focus; 1,700–1,990 m asl); (2) areas around Tabubil (opportunistic birding; 350–1,075 m asl). Additional records were obtained while mist netting for bats in the Kawarobip area (2,400–2,490 m asl). One hundred and fifty-seven species were recorded. Two hundred and one birds from 36 species were mist netted, photographed by camera trap or otherwise captured. Nine conservation listed species were recorded, including four birds listed by the IUCN as Vulnerable (Papuan Eagle *Harpyopsis novaeguineae*, Pesquet's Parrot *Psittrichas fulgidus*, [Black] Sicklebill *Epimachus fastosus*) or Near Threatened (Dwarf Cassowary *Casuarius bennetti*) and eight species that are protected under PNG law. Rufous-banded Honeyeater *Conopophila albogularis* and Eurasian Tree Sparrow *Passer montanus* are newly reported for the Tabubil area. Four species from Bilbilokabip are previously unrecorded from the Hindenburg Range and upper Ok Tedi catchment: New Guinea Scrubfowl *Megapodius decollatus*, Bronze Ground Dove *Gallicolumba beccarii*, Rufous-throated Bronze Cuckoo *Chrysococcyx ruficollis* and Lesser Ground Robin *Amalocichla incerta*.

Non-volant (non-flying) mammal biodiversity

We surveyed mammals around two sites at elevations of c. 1,800 m asl (Bilbilokabip) in the southern foothills of the Hindenburg Range and c. 2,500 m asl (Kawarobip) at the eastern end of the Star Mountains. The combined survey methods produced direct evidence of 33 species of non-volant mammals: one monotreme, 17 marsupials and 15 rodents. The survey produced new regional records of 14 species of non-volant (non-flying) mammals, including six marsupials and eight rodents. At least two of the rodents are undescribed species but in each case these are known from prior collections. Our records of the Great-tailed Triok (*Dactylopsila megalura*), the Mountain Mammelomys (*Mammelomys lanosus*) and Louise's Mirzamys (*Mirzamys lousieae*) represent the first occurrence of these taxa on the southern side of the Hindenburg Range; and the occurrence of Brass's Mouse (*Brassomys* cf. *albidens*) in the Mt Minni bone deposit represents only the second known locality for this species and the first record from Papua New Guinea.

Bat biodiversity

Bat fauna was surveyed around two sites at elevations of 1,750–1,900 m asl (Bilbilokabip) in the southern foothills of the Hindenburg Range, and at 2,208–2,529 m asl (Kawarobip) at the eastern end of the Star Mountains. The survey produced records of three species of pteropodid bats and eight insectivorous bats. Only one of the insectivorous bats was captured, the remainder being detected acoustically. Notable results of the survey include the capture of three species of the blossom bat genus *Syconycteris* in strict syntopy at 1,820 m asl, including multiple examples of the IUCN Vulnerable Montane Blossom Bat, *Syconycteris hobbit*; and the potential acoustic detection of the IUCN Data Deficient Fly River Leaf-nosed Bat, *Hipposideros muscinus*, at an elevation 1,000 m higher than any previous record. Although we did not obtain any direct evidence of the IUCN Critically Endangered Bulmer's Fruit Bat, *Aproteles bulmerae*, our Wopkaimin informants reported that large flying foxes are currently using Luplupwintem Cave where the species was rediscovered in the late 1970s and monitored through to the early 1990s.

Key conservation recommendations

This survey demonstrates that the Hindenburg Wall area holds exceptional biodiversity values and harbors many of PNG's elusive threatened species including echidnas (*Zaglossus* spp), tree kangaroos (*Dendrolagus* spp), Papuan Eagles (*Harpyopsis novaeguineae*), Pesquet's Parrots *Psittrichas fulgidus*, Black Sicklebills (*Epimachus fastosus*) and Bulmer's Fruit Bat (*Aproteles bulmerae*). The aforementioned animals are all conservation priorities and many are of the highest cultural importance. The presence of such creatures and the biodiversity recorded during the 2013 WCS survey attests to the outstanding universal value of the Hindenburg Wall area under UNESCO operational guidelines (*x*) as "an important and significant natural

habitat for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation". The safeguarding and maintenance of the Hindenburg Wall ecosystem under such circumstances is both an international and domestic priority.

The possibility of UNESCO World Heritage status should be advanced in partnership with the Department of Environment and Conservation by undertaking the development of a nomination file which is a prerequisite for consideration. The production of such a nomination file requires substantial community consultation and the development of critical infrastructure. This will likely necessitate the development of a conservation area which in turn would help the government of Papua New Guinea achieve its Convention on Biodiversity targets. Local communities in the area have little idea that their area has already been put on the UNESCO tentative list – bridging this information gap must be a priority. Community engagement, land-use planning and land tenure mapping exercises as part of a Participatory Rural Appraisal programme could serve as a means of liaising with local communities, understanding their land use perspectives and developing a basic foundation for conservation project development. A land use planning exercise would also need to be undertaken with other stakeholders such as local level government, Ok Tedi Mining Limited, and the Western Province provincial government to fully understand the perspectives of the different stakeholders and mitigate potential land-use divergence. Culturally acceptable income generation associated with a protected area or World Heritage status would need to be investigated and quantified in order to assess project viability.

Due to operational factors the karstic environments representative of much of the Hindenburg Wall were not well represented in the 2013 survey. Any further biodiversity surveys of the region should focus on such karstic areas as a priority.

Compared to many other areas of PNG the threats to the Hindenburg Wall area are ostensibly fewer with an absence of logging activity and a low and often decreasing human population. The migration of people towards services has seen people forgoing traditional village areas, which in some cases, have transformed to secondary forest. However, fires have caused notable vegetation changes in the Hindenburg Wall area and these have been exacerbated by droughts over the last 20 years, in particular that associated with the 1997–1998 El Niño event. Community education about mitigating fire risk will be vital to control this threat in the future.

Mining exploration is currently ongoing in the Hindenburg Wall vicinity and the discovery of large deposits and associated transport initiatives may result in industrial scale developments. By developing negotiated land use plans it would be hoped that the footprint of such developments could be contained and adverse environmental effects mitigated or offset.

View from Bilbilokabip helicopter pad *(Photo N.Whitmore)*

Introduction

The Hindenburg Wall is a series of large limestone escarpments situated in the centre of the island of New Guinea near the border between Papua New Guinea (PNG) and Indonesia. The escarpments were named after the Prussian-German field marshal and statesman Paul von Hindenburg by members of the Kaiserin-Augusta-Fluss expedition of 1912–13 who were the first Europeans to view the landscape. The Hindenburg Wall is situated in the North Fly District of Western Province, the largest province by land area in PNG. The area is bordered by Sandaun Province to the north, Southern Highlands Province to the east, and the Indonesian Province of Papua to the west.

Along with the Muller Range and Nakanai Mountains, the Hindenburg Wall is part of a proposed series of UNESCO World Heritage Sites called *The Sublime Karst of Papua New Guinea* (Hamilton-Smith 2006). The submission to UNESCO described the Hindenburg Wall as an exceptional testimony to a cultural tradition as a consequence of the many caves and overhangs that contain artefacts, paintings and stone carvings; a superlative natural phenomenon of exceptional natural beauty and aesthetic importance; an outstanding example of a major stage of earth's history; an outstanding example of ecological processes; and among the most important natural habitats for in-situ conservation of biological diversity (Hamilton-Smith 2006).

The escarpments that make up the Hindenburg Wall span 50 km within the Hindenburg Range and are located in a zone characterized by extremely heavy rainfall (over 7m per year), persistent cloud cover and steep topography. The area is also geologically dynamic and encapsulates conditions known to promote diversity and endemism. The area has long been considered an area of biological importance and has been highlighted in the Conservation Needs Assessment (Beehler 1993) and Convention on Biodiversity Program of Work on Protected Areas (Lipsett-Moore et al. 2010) as a biodiversity hotspot. In addition to its biodiversity significance it is of importance for peoples' livelihoods in much of Western Province because it forms the catchment for the Fly and the Strickland rivers which, in turn, are used by the local communities for water, fisheries and transport. Much of the area along and around the Hindenburg Wall is uninhabited by humans, making it less disturbed than virtually any other part of the country, further enhancing its value and the opportunity for a significant conservation outcome

This survey report was the second phase of a project undertaken by the Wildlife Conservation Society Papua New Guinea (WCS) financed by the Papua New Guinea Sustainable Development Program (PNGSDP), and undertaken in partnership with the Papua New Guinea Department of Environment and Conservation (DEC). The first phase was a review of the literature on the biological knowledge of the area, which was published as *The Hindenburg Wall: a review of existing knowledge* (Zeriga-Alone et al. 2012). This second

stage reports on the outcome of a series of biological surveys conducted in the region by a WCS team of international and national experts in February and March 2013. These surveys were conducted to investigate the biodiversity values in light of the area being a proposed UNESCO World Heritage Area.

What is World Heritage status?

The member states of UNESCO adopted the World Heritage Convention in 1972, which recognises that cultural and natural heritage is a priceless and irreplaceable asset, not only of each nation, but of humanity as a whole. The Convention states that the loss, through deterioration or disappearance, of such prized assets constitutes an impoverishment of the heritage of all the peoples of the world. Parts of that heritage, because of their exceptional qualities, can be considered to be of "Outstanding Universal Value" and as such worthy of special protection against the dangers which increasingly threaten them. To ensure, as far as possible, the proper identification, protection, conservation and presentation of the world's heritage, the Member States of UNESCO adopted the World Heritage Convention. The Convention aims at the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage of Outstanding Universal Value. The criteria and conditions for the inscription of properties on the World Heritage List have been developed to evaluate the Outstanding Universal Value of properties and to guide States Parties in the protection and management of properties with World Heritage status.

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Chapter 1

Traditional & Local Ecological Knowledge

John Par Kagl, Nathan Whitmore and Ken P. Aplin

Summary

Despite changes associated with proximity to industrialised mining and the influx of modern hunting technologies (guns, and new materials: rubber, wire and nylon) village life around the Hindenburg Wall still revolves to a large extent around subsistence gardening and hunting. Wild plants and animals are still culturally and nutritionally important. Much of the hunting around the Hindenburg Wall is cyclic and seasonal, following the traditional gardening calendar and the fruiting of certain species of trees. Of all the species recounted to us from the testimony of hunters the tree kangaroos (Dubol: *Dendrolagus stellarum /notatus*) are by far the most important: having high nutritional, cultural, and exchange value. Other species of importance are the Coppery Ringtail (*Pseudochirops cupreus*), Dwarf Cassowary (*Casuarius bennetti*), Harpy/Papuan Eagle (*Harpyopsis novaeguineae*), Black and Brown Sicklebills (*Epimachus fastosus/meyeri*), Raggiana Bird of Paradise (*Paradisaea raggiana*), and the Vulturine Parrot (*Psittrichas fulgidus*). Much of the traditional knowledge of wildlife is sacred and only revealed during times of initiation. Knowledge of the traditional ways and values associated with these culturally important species should allow future conservation projects to be better integrated within the existing cultural landscape.

Introduction

Traditional ecological knowledge is the accumulated body of knowledge, practice and belief built up during the interactions of people with each other and with their environment (Rasalato et al. 2010). Researchers now make a distinction between traditional ecological knowledge which involves cultural transmission and local ecological knowledge which is the accumulation of the personal observations and experiences of an individual (Cano & Telleria 2013). Traditional ecological knowledge is helpful for understanding the relationship of communities with nature and the values imbued to certain species while local ecological knowledge has an element of independence and has been suggested as a useful method for studying the status of wild animal populations where scientific data is lacking (Cano & Telleria 2013). The records presented here represent a combination of both forms of ecological knowledge but veer heavily to traditional ecological knowledge.

Methods

The traditional and local ecological knowledge recorded here comes from oral interviews, often conducted in communal settings, during the 2013 Hindenburg Wall survey. Local experts were identified by informal enquiry with the villagers present at the survey camps. Three men from Bultem, five men from Kawarobip, and one fisherman from Migalsim were subsequently interviewed. The interviewees were prompted to comment on groups of plants or animals in the vicinity of their customary land and aspects of the taxon's natural history and customary use. Information from those interviews was collated and paraphrased here as testimony. No effort was made to corroborate or reinterpret the information, it remains idiosyncratic. From observation it is clear that one animal or plant name may refer to a number of different species, and that differentiation by name is usually based on general morphology. There was no way to attest to the authenticity or expertise of the interviewee on the quality of this cultural information other than by their prior identification by their peers. Local language names were recorded from the hunters (coded by village: B = Bultem, F= Finalbin, K = Kawarobip, M = Migalsim, T = Telefomin). The taxon category of the annotated species list reflects the quality of the information; generally only broad English common names were used unless there was substantial evidence to conclude that a scientific classification was warranted. In some cases, usage of names was confirmed against captured individuals; these instances are noted in the text (see also Aplin and Lamaris, this volume). Where even a broad identity could not be established a tag of "NE" (not established) was used. On occasions when there was a cultural prohibition against the disclosure of certain information that information was omitted from the text. Information on mammals, birds, herpetofauna, fish and plants is presented. General hunting strategies were compiled from the testimony of the interviewees. Not all species mentioned by the hunters were sufficiently described to allow an annotated testimonial to be developed. Fishing strategies were not recorded.

Results and discussion

General hunting strategies

According to the testimonial of hunters the supply of wildlife in the region is plentiful. Some hunters suggested that the abundance of game animals is increasing and surplus to their requirements. Hunters report that the introduction of mining to the area has indirectly brought changes in hunting patterns: hunting activity is not as frequent as it was before mining began and they more often use guns to catch the animals. With the introduction and use of guns hunting success has improved, with typically two game animals being caught in any single hunting trip. Guns are frequently used alongside dogs. Traps are still used to catch cassowary and wild pigs but the use of this method is less frequent. Sling-shots, and bow and arrows are frequently used for hunting smaller mammals. In a single hunting trip one hunter reported he would catch between four and six cuscus but his aim was to catch a tree kangaroo because of its meat and the status it brought to him. Hunters recognized a dependency between the number of tree kangaroos caught and the number of well-trained hunting dogs. At least one hunter suggested that there has been a decline in the number of good hunting dogs as it is hard to train them now with men generally spending less time in the bush.

Despite the advent of industrial scale mining in the region village life is still very much a subsistence lifestyle revolving around gardening and hunting. Much of the hunting, particularly for the tree kangaroos known as Dubol (*Dendrolagus stellarum /notatus*) occurs during the gardening period. The gardening period is spread out over three phases: 1) clearing the bush and planting, 2) weeding, and 3) harvesting. It is during these three periods that villagers set up camps and hunt with the help of the dogs. When starting the cycle the garden would be cleared during the first week and during the following week three days, at most, would be spent hunting. During the garden harvesting period hunting intensifies and substantially more people are involved. This results in more tree kangaroos being caught than at other times. The meat or carcass is then distributed with the taro to other members of the family. Hunting is also intensified during the pandanus fruiting season.

In addition to Dubol, smaller mammals and Dwarf Cassowary are targeted in hunting for meat. Game is typically shared with other families, or used to repay customary obligations such as a bride price contribution. Birds are targeted where they are easy to catch: drinking holes on boughs of three special

trees (locally named: Deink, Bapnik, Murmul), at courtship display areas, fruiting trees, and resting point for doves and pigeons. The latter are considered particularly good eating: Yawok (Papuan mountain pigeon: *Gymnophaps albertisii*) and Kik (ornate fruit dove: *Ptilinopus ornatus*). At these locations hunters build shelters made of twigs and leaves in which they hide while they await the bird's arrival. Snares are also sometimes used for birds targeting water holes and ripe pandanus. Some species of bird which are targeted for their decorative and cultural value include the Dwarf Cassowary (*Casuarius bennetti*), Vulturine Parrot (*Psittrichas fulgidus*), and Black and Brown sicklebill *(Epimachus meyeri*). Hunters also identified some birds which were particularly trappable by snares: Kakolok (Belford's melidectes: *Melidectes belfordi*), Sikan (Papuan lorikeet: *Charmosyna papou*), Fariak (Magnificent bird of paradise: *Diphyllodes magnificus*), Kubatok (Black and Brown Sicklebill: *Epimachus fastosus/meyeri*), as well as many parrot species.

Other species which feature highly in their culture include: the Harpy/Papuan Eagle and the Coppery Ringtail Possum. Both species feature in initiation and rites of passage. A number of bat species are imbued with supernatural powers that can be unleashed for charms, witchcraft and appear as harbingers of death.

Annotated Traditional Ecological Knowledge

Mammals

Local language name: Yakil (K & B), Yakil mawil (K)
Taxon: *Zaglossus* sp. (Long-beaked Echidna) and possibly *Tachyglossus aculeatus* (Short-beaked Echidna).
Testimony: Forages only at night time. When it meets people it makes itself smaller by curling up. Only has one young per year. Feeds on worms. It forages up to 1 km away from its young. The mother expresses its milk via the roots of trees and the young drink its milk through these roots. It is very hard to locate and hunters require dogs in order to stand a chance of success. There are two species: a large one, and a smaller one. The female is short and sturdy and the male is slimmer and longer.

Local language name: Aboimp (B)
Taxon: *Dasyurus albopunctatus* (Quoll)
Testimony: Hunts other animals and forages on worms. Hunts on its own and scavenges dead animals and calls for back up to attack other animals or cuscus.

Local language name: Bibiyanim (B), Bibiyanium (K)
Taxon: Possibly *Cercartetus* cf. *caudatus* (Dasyurid); based on captured animal (B).
Testimony: Has a pointy nose and big testicles. It nests in moss and cavities in fern stems. Feeds on ants, worms, sweet potato, and tree grubs. Forages both day and night. Has two litters of up to 5–6 offspring, raises them in the nest. If two birds are seen in the company of this animal it is a sign of danger.

Local language name: Dubolok (K), Dubol (B), Dibal (T)
Taxon: *Dendrolagus stellarum*? (Seri's Tree Kangaroo)
Testimony: Two tree kangaroo species are recognised by villagers. This one has a yellow tail and forages during daylight. It forages on the ground and in the trees. Found in Kawarobip, Bultem, and Olsobip. Sleeps on tree trunks. Only one young per year. When the young becomes an adult a new one is born to the mother. Considered plentiful. Lives far away from human activity in large forests. Feeds on shoots of young pandanus, ferns, and a special salty soil (known in Bultem as Geofagi). One offspring per year. It calls in times of danger and for mating purposes. It has a scat similar to pig. The Dubol is considered the highest status quarry because of its cultural importance. It is used for bride price payment, compensation and strengthening social relationships. It is also associated with status of an individual in the community. The status of Dubol is equivalent is that of pigs in the PNG Highlands. The animal has a sacred name (not recorded here) which is only revealed to those who have been initiated through a spirit house. If the name is revealed to women, children or the uninitiated, death will come to the family. The tail is cut off to be used as part of ceremonial decoration and the fur is singed off during cooking.

Local language name: Dubolok (K), Dubol (B)
Taxon: *Dendrolagus notatus*? (Central Ranges Tree Kangaroo)
Testimony: As above. Two species are recognised by villagers; this one has a black tail and forages at night. There are cultural restrictions regarding this animal and a prohibition for parents against eating it before a baby is one year old. If parents eat it during this time the baby will die.

Local language name: Watom (K & B), Suwei (B)
Taxon: *Dorcopsulus* cf. *vanheurni* (Forest Wallaby); confirmed with captured animal (B).
Testimony: Forages at both night and day. It has one offspring. Usually black or brown in colour. Does not call. It is very fast and can out-run a dog. Carries young in a pouch. It eats all green leaves, sweet potato, fruit and grass. Lives on the ground only. Nests in tree stumps and rotten logs. Has a scat that resembles a dog's. Animals three years and older have molars worn down to the gum and brown pouch hair, once skinned old animals appear wrinkly.

Local language name: Kaiyang (B & T)
Taxon: *Pseudochirops cupreus* (Coppery Ringtail); confirmed with captured animal (B).
Testimony: Nests in stumps and caves, moss, branches and in cavities in trees. Feeds on fruit, leaves, and sugar trees. Nocturnal. Brown all over, black stripes from back of the neck right down to tail. One offspring. Old animals have stained teeth and when cooked have tough skin. Hunters need dogs to catch it. The best time to hunt is at the start of the pandanus and fruit season. The animal has a sacred name which is silently prayed by the hunter at the distribution of the meat to ward off the spirit of the dead. The name can also be used to summon good health. Girls up to puberty can still eat the meat of the Kaiyang. After first menstruation only the father of the girl can give her the meat which is used for good health and success.

Local language name: Kitam (K &B)
Taxon: *Phalanger carmelitae* & *Phalanger sericeus* (Mountain & Silky cuscus); confirmed with captures of both species (B).
Testimony: Nocturnal. Black with white on the belly. Smooth coat. Nests in the moss, fallen logs, roots and hollows of trees. Feeds on leaves, sap, fruits and grubs. One offspring, 1–3 litters per year. Always travels with its young. Plenty at Kawarobip. The tails differ between individuals. Lifespan 15–20 years. Skin and bones are used as a charm for planting taro and sweet potato. This animal can be eaten by most people except mothers who are forbidden to eat it until two weeks after the child's birth.

Local language name: Takip (K)
Taxon: Cuscus
Testimony: Forages mostly at night and sometimes during the day. Feeds on leaves, fruit and sap from trees. Only has one offspring per year. When shot with an arrow it will retaliate so the hunter must keep his distance.

Local Language Name: Arik (K)
Taxon: Almost certainly *Phalanger mimicus* (cuscus); the only sexually dimorphic cuscus in this area).
Testimony: Forages at night, feeds on leaves, fruit and sap from the flowers and trees. Sleeps and lives in moss or occasionally lives in a cluster of leaves on the ground. Always bears two young. Separate names are given to male and female juveniles.

Local language name: Kwimnok (K) – see below for Kuiyam, recorded Kwemnok as an alternative name for *Phalanger gymnotis* for Faiwol speakers at Setaman (Whitehead 1995)
Taxon: *Phalanger gymnotis* (Ground cuscus)
Testimony: Plentiful along Hindenburg Wall, forges at night only. Lives in hollows in trees or fallen logs, destroys food gardens. One offspring per year. Forbidden to be eaten by Aimblaimkaimin clan. Death will usually follow once eaten. If a hunter eats it he must not go near his family. It will affect the growth of the children and they will become stunted while the wife will experience haemorrhaging.

Local language name: Kuiyam (B)
Taxon: This name is widely used among Faiwol speakers for *Phalanger gymnotis* (Ground Cuscus).
Testimony: Nests in cavities and beneath stone piles. White on the belly and sometimes greyish. Black stripe from back of neck all the way down to the tail. One offspring per year. Eats virtually any plant matter.

Forages at night time, alone or with a partner. Carries young in pouch and when they get bigger on their back. Lives in the valley only. Climbs trees and walks on the ground. Hard to catch when it is on a tree. In cleared areas it is easy to catch.

Local language name: Morim (K)
Taxon: Cuscus
Testimony: Forages at night. Sprint/jumps from tree to tree (similar to silky cuscus).

Local language name: Botok (B)
Taxon: Possibly *Pseudochirulus larvatus* (Ringtail).
Testimony: Nests in cavities in trees where there is moss. Nocturnal. Brown all over and white spots on the face. Has two offspring that they carry in the pouch until they are big enough to forage on their own. It feeds on the sap of trees, fruits and leaches. It is easy to catch when feeding on the sap of the tree. Can be caught by hand. Lives at the bottom of the mountains and valleys. Regarded as the keeper of the "garden of the mammals".

Local language name: Kabong (K)
Taxon: Ringtail
Testimony: Forages at night only. Eats only leaves, sap and juice from flowers. Nests beneath the moss of trees. One offspring per year.

Local language name: Galnemyap (F & B)
Taxon: *Dactylopsila megalura* (Great-tailed Triok); confirmed with captured animal (B).
Testimony: It feeds on larvae, ants, and the sap of trees. It has 3–4 offspring and raises them in a pouch and in the nest within a tree. It has a coat with black and white stripes. The tail is bushy. It has two long fingers and very strong jaws. Nocturnal. Considered a mundane animal.

Local language name: Gelwem (F?)
Taxon: Triok
Testimony: It has a coat with black and white stripes that runs from head to buttock. Nests in cavities in trees. It lives on the ground. It has some grey in its dorsal coat with a white belly. It feeds on larvae beetles and ants. Older animals have tougher skin and bones.

Local language name: Silakim (K) (Hyndman recorded Slakim for *Petaurus breviceps* Sugar Glider)
Taxon: *Petaurus breviceps* (Sugar Glider)
Testimony: Roams at night. It forages on fruits and insects and lives colonially. Believed to change its form from flying fox to cuscus and back to flying fox.

Local language name: Boiim (B)
Taxon: Rat (applied to various small rats from disturbed habitat).
Testimony: Brown dorsal fur. Nests in houses. 6–8 offspring. Feeds on taro, sweet potato, ants and worms. Nocturnal. Lives less than 5 years. Found in the lowlands and at high elevations. Eaten by children, midwives and those people without special status.

Local language name: Boiyam (B)
Taxon: Rat
Testimony: Feeds on sweet potato. Nests in shallow roots or logs. 2–3 offspring per year. Abundant in the forest. Eaten.

Local language name: Abilkan (K & B)
Taxon: At least 4 species of rat (applied to various small rats from forest habitat; B).
Testimony: Lives only at high elevation. Eats pandanus nuts, insects, leaves, sweet potato and taro. Young born in the womb. One offspring per litter. Up to 5 months between litters. Litters born year round. Commonly eaten.

Local language name: Suminok (K), Siminok (B)
Taxon: *Syconycteris* spp. (Blossom Bats); confirmed with captured animal (B).
Testimony: Very small. Lives anywhere, cliffs and caves, under leaves, moss, trees. Feeds only on nectar and ripe bananas. Forages only at night. Has only one offspring raised in a pouch. Emits a scream. Harbinger of death. When one of these enters the house or cries or approaches a person that is a sign that one of your relatives will die.

Local language name: Kinming (K)
Taxon: Bat
Testimony: Roosts virtually anywhere including rock outcrops, trees, and flowers. Has only one young per year and carries the young around with it. Feeds on ripe pawpaw, bananas, sucks banana plant sap. Considered plentiful. Considered a mundane animal.

Local language name: Yawom (K)
Taxon: Bat – tube nosed bat *Nyctimene* sp.
Testimony: Only lives in warm areas. They appear only during flowering season. Only gets new young as soon as last young leaves. The male and female live separately. One offspring per year. It is forbidden for women to eat it. Men use the bones of the bat to charm and lure girls into marriage. Umil is the name of the mountain where the men find the charms.

Local language name: Lukonok (K), Bululam (K)
Taxon: Flying fox
Testimony: Very elusive. Found at Selminamtem (Old Bultem). Nocturnal. King of all the flying foxes. Solitary. Those with witchcraft get their powers from the bat to do the supernatural.

Local language name: Bilbilok (B), Aninimp (B)
Taxon: Recorded by Pernetta and Hyndman for *Parahydromys asper* (Waterside Rat).
Testimony: An aquatic creature, hunts tadpoles. Lives around the riverside. Has straight hair like a pig.

Local language name: Sirakim (B)
Taxon: NE
Testimony: Black with white chest and white tail. Feeds on the nectar of flowers and bananas. Has 4–6 offspring. Nests in tree cavities. Used in ceremonial dress.

Birds

Local language name: Kumsop (B)
Taxon: *Casuarius bennetti* (Dwarf cassowary)
Testimony: Only found around Bilbilokabip and Old Bultem, Adults identified by the blackness of the coat. Mainly feeds on fallen fruit including bush pandanus. Lays 3–4 eggs. The Kumsop is a very sensitive bird and very observant. In order to catch it the hunter needs very special skills and it demands a lot of patience. Today hunters use traps or sometimes a gun to shoot it. In setting the trap the rope must be very strong, which is often improvised from wire or nylon. When a cassowary is caught in a trap, it struggles and will take up to three days until it is weakened by exhaustion. During this struggle if it sees the hunter approaching it will attempt to kill the hunter by targeting its claw to the hunter's heart. Its kicking is precise and can be fatal. When snared the hunters approach it from its blind spot and club it to death. Sometimes the cassowary will fake death, so hunters have to be extra careful. If a cassowary is killed by shotgun the hunters will cautiously observe it for a time before moving in. In Kawarobip the cassowary is still considered to be plentiful.

Local language name: Misi (B)
Taxon: *Harpyopsis novaeguineae* (Papuan Eagle /New Guinea Harpy Eagle)
Testimony: Feeds on large cuscus. It will disembowel the animal, discard the brain and skin then eat the rest of the carcass including the eyeballs. At initiation the meat of the bird is given to the boys at the spirit house. During the process the bird's sacred name is revealed. Misi is believed to be a man in bird's feathers. There is an important legend about Misi which is only disclosed during the initiation.

Local language name: Gawar (B)
Taxon: *Psittrichas fulgidus* (Pesquet's / Vulturine parrot)
Testimony: Found at low elevations and warmer climates. Lays one egg. Nests inside tree cavities. Both parents assist in feeding young. Abundant. Used in ceremonial decoration.

Local language name: Kulap (K), Wakom (K & B)
Taxon: *Paradisaea raggiana* (Raggiana Bird of Paradise)
Testimony: Live at lower elevations, lays one egg. Plentiful around mining area. Age can be estimated from feather colours as they fade during old age, and the cooked meat is stronger in taste. Used for bride price exchange. Caught from hunting towers and shelters, and snaring at drinking pools. Used in ceremonial dress, typically 3–5 birds in each outfit will cost a total of 100 kina. Eaten.

Local language name: Wawap (K)
Taxon: *Astrapia splendidissima* (Splendid Astrapia)
Testimony: Lives at high elevations. Feeds on fruit, wild taro and wild marita. Lays only one egg about three times a year. Number of young per year depends on the growth rate of the previous offspring. Feathers used in initiation and is present at feasts. It is compulsory to give initiates a bag decorated with the feathers of this bird.

Local language name: Mungam (B), Mukamkan (B)
Taxon: *Paradigalla brevicauda* (Short-tailed Paradigalla)
Testimony: Feeds on umbrella tree fruit and wild taro flowers. Lays one egg. Found at high elevations only. Lives 10–20 years. Hunted occasionally for food. A myth exists that the bird is lamenting his brother's death each afternoon.

Local language name: Kasupnok (K), Kasup (B)
Taxon: *Melipotes fumigates* (Common Smoky Honeyeater)
Testimony: Lays only one egg per nest, both male and female share parenting. Male sits on egg during day and female sits at night. Yellow and gold around eye. Lives on fruit, insects and spiders. Lives at high elevations and becomes a trickster when threatened.

Local language name: Kubatok (B)
Taxon: *Epimachus fastosus/meyeri* (Black/Brown sicklebill)
Testimony: Found from mid to high elevations. Feeds on wild pandanus and umbrella tree fruits. Raises one egg. Lives 10–20 years. Hunted for feathers for ceremonial dress, and sold as part of bride price. Eaten.

Local language name: Sukululomkan (K)
Taxon: *Peneothello cyanus* (Slaty Robin)
Testimony: Feeds on insects and worms. Lays one egg four times a year. Likes both cold and warm climates. Female is the first to sing in the morning or gives the wakeup call. Regarded as a traditional alarm clock.

Local language name: Daru (B)
Taxon: Bird
Testimony: Found at high elevations. Lays only one egg about four times per year. Eaten.

Local language name: Dimanok (K)
Taxon: Bird
Testimony: Honey eater, but also feeds on insects ants and worms. Constructs a small nest. Lays one egg per nest about four times a year. Builds nest at landslides or sometimes in the dry leaves of pandanus or in hanging moss. Makes a variety of calls and is good at mimicry. Believed to carry messages of happenings and arrivals "mep talane" = man arriving. Known to be a trickster and capable of telling lies and swearing.

Local language name: Diokin (K)
Taxon: Bird
Testimony: Black edges and grey underbelly. Lays one egg. Both male and female take turns parenting. Lives on insects and small fruits. Lives at low and high elevations but prefers warmer areas. Eaten.

Local language name: Muamkaing (B)
Taxon: Bird
Testimony: Found at high elevations. Lays one egg. Both male and female raise the chick.

Local language name: Oksirakan (B)
Taxon: Bird
Testimony: Feeds on ants and insects. Nests in cavities in houses. Lays two eggs. Eaten.

Local language name: Olstraupen (B)
Taxon: Bird
Testimony: Lives at both high and low elevations. Feeds on only ants, insects and worms. Nests in tree cavities and lays three eggs. Female incubates young but both parents assist in feeding young.

Local language name: Sarenimnim (K)
Taxon: Bird
Testimony: Doesn't make nest but burrows into dry trees. Lays only one egg. Feeds on ants, nectar and small fruit. Has young four times a year. Lives in both warm and cold climates.

Local language name: Switok (K)
Taxon: Bird
Testimony: Yellow on the belly and under the tail. Feeds on ants, other insects and fruit. Lives in high elevations. Builds a nest and lays an egg once a year.

Local language name: Wilipkan (K)
Taxon: Bird
Testimony: Black on outer coat, brownish underbelly. Drinks nectar. Lays only one egg about four times a year. Population can increase rapidly. Lives at high elevations. Gives a warning call "peng-peng-peng". Has a mournful song.

Herpetofauna

Local language name: Gumpeimkan (B)
Taxon: Snake
Testimony: Dorsal surface brown, white belly, ~30 cm long. Preys on frogs, rodents, rats, and insects. Lives in valley and lives amongst ground level vegetation. Climbs trees and swims in water. Has up to 20 eggs. Forages both day and night.

Local language name: Worom (K)
Taxon: Frog
Testimony: Lays millions of eggs. Calls only at night. Green. Male is smaller than the female. Eaten. Hunting season is at beginning of every month.

Plants

Local language name: Bunung (K & B)
Taxon: *Myrmecodia horrida* (Ant Plant)
Testimony: Attaches to branches of trees. Ants live within the plant. Birds are attracted to the plant to eat the ants. Has wind dispersed seed. Generally avoided due to its spiny and stinging nature, considered poisonous. Often mistaken for cuscus by hunters at a distance.

Local language name: Dimanim Kameg (K), Dimanok Kamen (B)
Taxon: *Nepenthes* spp. (Pitcher plants)
Testimony: Flowers all year round. Birds and bees drink its nectar. Grows virtually anywhere. Traps water. Used as a roping material to build shelters and houses. Sometimes used for as a penis sheath in the absence of gourds.

Local language name: Wilwil (K)
Taxon: Epiphyte
Testimony: Lives in trees but can be found free living. All fruit eating birds are attracted to its fruit. Flowers once a year. During the fruiting season hunters build huts next to the tree to catch birds.

Local language name: Gor (B)
Taxon: Vine-like
Testimony: Flowers all once a year. Birds feed on the nectar. Produces a white fruit which is eaten by cassowaries. Edible fruit.

Local language name: Dakaufal (K)
Taxon: Tree
Testimony: Grows only at high elevations. Nectar feeding birds and insects such as bees and butterflies are attracted to this tree. It flowers every three months. The flowers only last about a week and the plant bears fruit for about three months. Considered beautiful but of no utility.

Local language name: Ganukes (K)
Taxon: Tree
Testimony: Parrots usually frequent this tree to suck its nectar. Name comes from *Gan* = parrot and *Kes* = tree. Hunters cut the tree to build huts while they lay in wait to catch its birds.

Local language name: Dakil (K)
Taxon: NE
Testimony: Grows both at high and low elevations. Used medicinally for all sicknesses. It has a sour/chilli like taste. The leaves are boiled and the liquid is drunk warm.

Local language name: Bulgiem (K)
Taxon: NE
Testimony: Birds, cuscus and tree kangaroo feed off its fruits. It is a perennial plant and flowers once a year. Fruit is used to paint kundu drums. It is considered sacred and associated with ritual.

Fish

Local language name: Gulim (M), Bom akun (M: "mother of the big fish")
Taxon: *Neoarius latirostri* (Broad Nosed Catfish)
Testimony: Is the biggest fish in the Ok Tedi river. Populations are fast disappearing now. Eggs are laid around edges of rocks and stones. Does a courtship dance. Feeds on smaller fish, worms and insects. The village people catch this catfish for marriage ceremonies, and in exchange for sago.

Local language name: Sabam (M)
Taxon: *Mogurnda cingulata* (Banded Purple-spotted Gudgeon)
Testimony: It lives in swamp, pools and creeks. It lays eggs on the edges of swamps, pools and creeks around roots of trees and old leaves. Feeds on worms and insects.

Local language name: Kinfom (M)
Taxon: *Hephaestus habbemai* (Mountain Grunter)
Testimony: It used to live in the Ok Tedi river. It is found in long pools, fast flowing creeks and rivers. The fry are found along shallow, dark coloured pools. Feeds on worms and insects.

Local language name: Kulo (M)
Taxon: *Glossogobius concavifrons* (Concave Gobi)
Testimony: The one of the smallest fish in Tabubil. It lays eggs along the sides of riverbanks. Live around small rocks and stones near the river edge. Feeds on worms and insects.

Local language name: Warami (M)
Taxon: *Glossogobius robertsi* (Robert's Goby)
Testimony: The one of the smallest fish. It lives along the sides of the river banks. Feeds on worms and small insects. It lays eggs near the riverbank.

Local language name: Dol (M)
Taxon: *Neolsilurus equines* (Southern Tandan)
Testimony: A catfish that lives in the big river. Its laying season coincides with the As Kas (Walap tree in Faiwaol Language). It has a courtship dance. Feeds on worms and insects. Served at feasts, particularly appropriate food for in-laws and chiefs.

Local language name: Kiwal (M)
Taxon: *Anguilla bicolor* (Indian Short-finned Eel)
Testimony: This eel is one of the biggest fish in the Faiwol area. It has a courtship dance. Feeds on worms, insects, small fish and crabs and dol fish. When people go diving and see a lot of dol it is an indication an eel is nearby and so they will use spear to catch dol fish first and then spear the eel. Villages customarily eat the eel at feasts.

Local language name: Bom (M)
Taxon: *Oxyeleotris fimbriata* (Fimbriate Gudgeon)
Testimony: Lives up at Wangbin lake. People believe if you catch this fish and eat it there are certain rules you must follow: you must not add salt because the lake will flood your house, if you fry this fish you won't catch any more, as a result it must be cooked in an earth oven (mumu).

Local language name: Dumsiri (M)
Taxon: *Craterocephalus nouhuysi* (Mountain Hardyhead)
Testimony: This fish has a small mouth and lives in streams which are fast flowing. It is a schooling fish. Feeds on worms and insects.

Local language name: Ganim (M), Baiang (A)
Taxon: *Neosilurus ater* (Black Catfish)
Testimony: A catfish with whiskers. Lays eggs near riverbank in the season when they do a courtship dance. Feeds on worms and insects. The catch of this fish is celebrated with feasting.

Local language name: Wigan (M)
Taxon: *Glossamia trifasciata* (Threebar Mouth Almighty)
Testimony: This fish has a big mouth. It lays eggs along the banks of the river. Feeds on worms and insects.

Local language name: Nayngim (M)
Taxon: *Bostrychus strigogenys?* (Stripe-cheeked Gudgeon)
Testimony: It produces a strong odour when caught which repels other fish. It lives in shallow pools and feeds on worms, insects. Only occasionally caught in rivers. When caught it is eaten by elders. If children eat this fish their stomach will swell up and they will get sick.

The spawning time for fish in the vicinity of the Ok Tedi river was reported by the Migalsim fisher as between October and December.

Discussion

Certain animals feature prominently in the culture of the villages around the survey area. The animal conferred with the highest status was the Dubol tree kangaroo (*Dendrolagus stellarum/notatus*) which has high customary value and is used for bride price, compensation payments and social exchanges. Two species which feature highly in the culture are the Harpy/Papuan Eagle (*Harpyopsis novaeguinae*) and the Coppery Ringtail (*Pseudochirops cupreus*). Both species feature in Faiwol creation stories and clan origin stories, and are important during initiation and rites of passage. Species of high nutritional value are the cuscuses and the Dwarf Cassowary (*Casuarius bennetti*). High cultural importance is also attached to Black

and Brown Sicklebill (*Epimachus fastosus/meyeri*), Raggiana Bird of Paradise (*Paradisaea raggiana*), and the Vulturine Parrot (*Psittrichas fulgidus*), for use in ceremonial dress and adornment. A number of bat species and the Sugar Glider (*Petaurus breviceps*) are imbued with supernatural powers that can be unleashed for charms, witchcraft and appear as harbingers of death. Possible future conservation work in the area would do well to focus on the species held in high cultural esteem and in need of conservation intervention.

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Hunting lodge Bilbilokabip camp. *(Photo N.Whitmore)*

Chapter 2

Vascular Plants

Fanie Venter and Arison Arihafa

Summary

Ten vegetation formations are described from three survey sites at altitudes between 980 m asl near Tabubil and 2,400 m at Kawarobip. This area is floristically rich and a rapid taxonomic inventory documented 60 species of ferns and lycophytes, two species of gymnosperms, 132 species of monocots and 258 species of dicots for a total of 452 species in 105 families. Of these, 23 species are new to science and a further 65 records represent extensions of known distributions and new records for Western Province. Additional surveys of the Tupnonbil and Kawarobip areas will no doubt double the number of plant species known from this area.

Introduction

New Guinea is home to one of the world's richest floras with an estimated vascular plant diversity of more than 25,000 species (Davis et al. 1995). The highest peaks in Malesia are situated on the Central Cordillera of New Guinea, and they contain the richest assortment of montane plant life in the Indo-Malayan region (Paijmans 1976, Takeuchi 2007). Compared to other areas in the Malesian region knowledge of Papua New Guinea's (PNG) floristic wealth is based on very few collections and the discovery of many new plant species in PNG every year is evidence that most of the country remains floristically undersampled (Frodin 1990, Takeuchi 2011).

Large tracts of rainforest in PNG are still intact but in the vicinity of Tabubil, a large mining town in the foothills of the Star Mountains, there are large areas dominated by secondary forest in different stages of succession (Hyndman and Menzies 1990). This report presents the results of a rapid floristic inventory of Foothill Rain Forest north of Tabubil town, and of two more isolated sites at about 1,800 m and 2,400 m asl in the vicinity of the Hindenburg Wall.

Methods

The Hindenburg Wall botanical survey was centred on the area immediately north of Tabubil, Western Province, PNG and at two field camps to the northeast in the upper Ok Tedi catchment (see below).

The vegetation of PNG has been mapped and the PNG Forest Inventory Mapping System (FIMS) recognises 63 major vegetation types for the country (Hammermaster and Saunders 1995). Unfortunately, the scale of the FIMS maps, a system generally available only in 1:250,000 scale maps did not permit easy recognition of a number of distinct vegetation communities encountered during this survey as they represent formations below the spatial resolution capability of the FIMS. Plant communities at the three sampling localities were therefore ground-truthed against the FIMS classification and a more detailed description is given for these areas.

The flora team surveyed a total of three locations during the period 6–28 February 2013; one around Tabubil, one at Bilbilokabip in the Tupnonbil area and one at Mt. Minni.

Study sites

The survey was conducted from the following individual sites:

Site 1: Dablin Creek near Tabubil
5.21508°S, 141.2318°E, 982 m

Site 2: Bilbilokabip
5.12033°S, 141.25121°E, 1,770 m

Site 3: Minni Camp
5.0775°S, 141.1505°E, 2,383 m

Methods

The same sampling procedures were employed as used in other rapid biodiversity assessments in New Guinea (Takeuchi 1998, Ridsdale 2000, Beehler and Alonso 2001, Takeuchi 2007, Takeuchi 2011).

Transects were established at each site to maximise the number of different plant communities traversed. The botanical survey focused on ferns, gymnosperms and angiosperms. Fertile specimens of all taxa not known to the authors or those not well represented in the Papua New Guinea National Herbarium (Lae) in Lae, were collected and dried. Collections were field-packed in large strong plastic bags in 75% ethanol and sent for further drying and processing at Lae. Five duplicate sets were made for all new or possibly new taxa. Photographs were taken of all taxa in flower and/or fruit. The Herbarium specimens were identified at Lae by the authors.

Family and generic assignments follow Kramer and Green (1990) and Brummit (1992) for ferns and lycophytes, Laubenfels (1988) for gymnosperms and the Angiosperm Phylogeny Group (2003, 2009) for the angiosperms.

Results and discussion

Vegetation typing: Tabubil area

Secondary foothill rain forest (Hyndman & Menzies 1990).
This is the Hmd – Medium crowned depauperate/damaged forest according to the PNG Forest Inventory Mapping System (FIMS). In its undisturbed state, this forest is the most extensive and species rich vegetation type in PNG (Louman and Nicholls 1995).

This forest type is present in most areas around Tabubil but is particularly evident along the road to Ok Tedi Mine and along other roads and in areas of construction or human habitation (e.g. Tabubil Intake at Dablin Creek). It consists of a mosaic of secondary growth of various ages, most of them 20 years and younger. The vegetation is characterized by dense to very dense growth dominated by species of fern, vine, and shrub, and by early pioneer tree species from the genera *Trema, Glochidion* and *Homalanthus* to mid pioneer tree species from the genera *Glochidion, Macaranga, Saurauia* and *Ficus*. Epiphytes consist mainly of a few orchid, fern, liverwort and moss species. The canopy ranges from fairly open to very dense and the ground stratum is well developed.

The lower slopes adjacent to Tabubil are denuded of vegetation as a result of the high influx of settlers that turn this area into 'gardens'.

Primary foothill rain forest (Hyndman & Menzies 1990).
This vegetation forms part of Hm – Medium crowned forest according to the PNG Forest Inventory Mapping System (FIMS). It occurs mainly along streams and on the undisturbed mountain slopes at the top of the Dablin creek. A moderately open forest floor covered in aroid species of the genera *Alocasia* and *Cyrtosperma*, ginger species of the genera *Alpinia, Riedelia* and *Hornstedtia*, small shrub species from the genera *Ixora, Psychotria*, and *Symplocos* and tree species from the genera *Ficus, Goniothalamus, Garcinia, Melicope* and *Myristica* characterize this forest. The overall structure is dense, with less dense areas in which emergents occur in numbers. *Carpodetes arboreus, Chloranthus elatior, Piper* spp., *Procris* spp. and *Garcinia* spp. are common along the stream margins and *Chisocheton, Ficus, Syzygium* and *Elaeocarpus* species are common in the taller section of the forest.

Secondary alluvial forest
Forms a narrow zone along the banks of the Ok Tedi River and is in its early stages of development consisting mostly of pioneer species. The canopy is low, maximum 15 m with an open to fairly dense understory. This forest is about 30 years old and induced by the siltation of the river by the Ok Tedi mine.

Vegetation typing: Tupnonbil area

Secondary lower montane rain forest (Hyndman & Menzies 1990).
This vegetation is an anthropogenic early-successional forest present in areas near habitation (Bilbilokabip and the three huts a small distance towards the northeast) and is made-up of a mosaic of secondary growth of various ages; some date back at least 50 years. This vegetation is characterized by a few open grass-covered areas colonised by various fern, forb and grass species and the first stage of plant colonization; dense (older vegetation) to very dense (younger vegetation) growth of primarily fern, vine, shrub and early (*Trema, Glochidion, Homalanthus*) to mid (*Glochidion, Saurauia, Ficus*), pioneer woody species. Whilst the pioneer species are much the same as for the Secondary Foothill Rain Forest, the structure, ground and mid strata differs markedly in species and composition. There are a few areas covered in late pioneer species (*Aglaia, Dysoxylum, Elaeocarpus, Myristica*) but these are quite some distance away from the Bilbilokabip hamlet indicating earlier habitation with its associated subsistence gardens. Orchids and ferns represent the epiphytic vascular plants.

Nothofagus forest
A 30 m tall undisturbed forest type within Lower Montane Rain Forest. *Nothofagus, Castanopsis* and *Engelhardtia* are the dominant emergent species. At this altitude the *Nothofagus* forest occurs as isolated areas, to the east and north of Bilbilokabip. The forest floor is open with a well-developed layer of leaf litter. The ground stratum is sparse and represented by a few *Riedelia, Alpinia* and *Alocasia* species together with

scattered tree ferns (*Cyathea* spp.). Ferns are mostly restricted along the small drainage lines cutting through the forest. Dominant epiphyte species are from the Urticaceae, Melastomataceae, Orchidaceae and Ericaceae families with various *Rhododendron* species in the upper canopy.

Primary lower montane rain forest (Hyndman & Menzies 1990)
This type of forest forms part of the L – Small crowned forest of the Lower Montane Forest – above 1000m Group according to the PNG Forest Inventory Mapping System (FIMS). It occured a short distance away from the camp and covers most of the valley slopes. This forest is characterised by a canopy composed of *Syzygium* species with *Syzygium versteegii* and *S. effusum* the most common species followed by *Buchanania macrocarpa*, *Campnosperma brevipetiolatum*, *Caldcluvia nymannii*, *Pimeleodendron amboinicum*, *Planchonella* and *Calophyllum* species. Another feature of this forest is the scattered individuals of *Pandanus*. The most abundant genera in the understory are *Cyathea* and *Cyrtandra* (especially on the banks and along the drainage lines), *Garcinia*, *Medinilla* (as vines and epiphytes) with *Psychotria* and *Myrsine* as scattered individuals. *Dianella ensifolia*, *Medinilla* and various fern species commonly occupy the banks of streams. Dominant epiphyte genera are *Medinilla*, *Freycinetia*, various orchids and *Dimorphanthera* species.

Ericoid scrub
A specialized vegetation type not discussed by Hyndman & Menzies (1990) and similar to the *Rhododendron – Vaccinium* scrub on Mt. Kerinci, Sumatra (Ohsawa et al. 1985). The Ericoid Scrub occurs as a few scattered isolated areas on the valley floor. The closest of these is situated between the camp and the Helipad. The vegetation is characteristically low (0.5–3m) and very dense. The trees and shrubs branch profusely and have small leaves and dense crowns. These areas are usually species rich. Dominant tree and shrub genera are *Olearia, Decaspermum, Pandanus, Vaccinium, Dimorphanthera, Rhododendron, Breynia* and *Xanthomyrtus*. Most dominant species of vines are from the *Hoya, Dimorphanthera, Nepenthes, and Dioscorea* and *Marsdenia* genera. Various genera of the Cyperaceae and Poaceae are present as well on the outer margin of the area. This area is exceptionally rich in orchid species.

Vegetation typing: Minni Camp, Kawarobip

Midmontane rain forest (Hyndman & Menzies 1990)
This type of forest forms part of the LN – Small crowned forest with *Nothofagus* according to the PNG Forest Inventory Mapping System (FIMS). The Midmontane Rain Forest here can be divided into two distinct forest types and Ericoid Scrub.

***Nothofagus* – bamboo forest**
This is proper *Nothofagus* forest and covers most of the slopes in the survey area especially on Mt. Minni. The forest floor is characteristically covered in a dense growth of bamboo (*Nastus productus*) that gives way to other plant species along drainage lines. Other plant genera present in the canopy are *Caldcluvia, Cryptocarya,* and *Lithocarpus. Saurauia, Pandanus, Myrsine* and *Schefflera* represent the understory tree genera. Along the drainage lines there are some herbaceous genera (*Begonia, Ophiorrhiza, Cyrtandra*) tolerating low light and very moist conditions.

Cloud forest
Covers the lower slopes of Mt. Minni. The low open canopy and the dense moss cover on the trunks and branches, even on the ground, characterize this forest. Most of the tree and shrub species are either microphyllous or nanophyllous and are represented by the genera *Eurya, Symplocos, Vaccinium, Syzygium* and *Xanthomyrtus.* This forest type is not as species-rich as the *Nothofagus* Forest. Epiphytes are common representing the families Orchidaceae, Ericaceae and Melastomataceae.

Ericoid scrub
A specialized vegetation type not discussed by Hyndman & Menzies (1990) and similar to the *Rhododendron – Vaccinium* scrub on Mt. Kerinci, Sumatra (Ohsawa et al. 1985). An extensive open area covered in scrub growing so thick that movement through it was only possible by walking on the branches, sometimes a few meters above the ground. Nearly all of the woody species in this scrub are characterized by a very dense branching architecture and small leaves, and the branches are covered in a dense growth of moss and liverworts. The most dominant woody plant genera are *Dimorphanthera, Vaccinium,*

Rhododendron, Schefflera and *Ternstroemia. Hoya* and *Nepenthes* species represent the climbers. This Ericoid Scrub is exceptionally rich in orchid species.

Botanical inventory

The Hindenburg Wall survey documented a total of 436 species despite few plants being in flower during the survey period. At least 117 plant families were recorded (Table 1).

Table 1. Taxonomic counts by plant category for the survey.

Group	Ferns & Lycophytes	Gymnosperms	Monocots	Dicots	TOTAL
Families	18	2	15	70	105
Genera	36	2	54	154	246
Species	60	2	131	258	451

A total of 348 leaf samples were collected for DNA sequencing and 105 live orchid specimens were retained to grow for later identification (these unidentified species are not included in Table 1 and Table 2). A total of 23 species that are new to science were collected, and range extensions for a further 65 species were documented. Nine species were recorded in PNG for the first time.

Bulbophyllum scaphosepalum – rediscovered after 100 years at Tupnonbil. (*Photo F.Venter*)

Table 2. List of plant species recorded during the Hindenburg Wall Survey. An asterisk (*) behind a species name indicates an exotic species. Scientific name is followed by the abbreviations of the author specific epithet.

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Ferns & Lycophytes					
Aspleniaceae	*Asplenium acrobryum* Christ			×	
Aspleniaceae	*Asplenium cromwellianum* Rosenst.			×	×
Aspleniaceae	*Asplenium normale* D. Don var. *normale*			×	
Aspleniaceae	*Asplenium nudus* L.		×		×
Aspleniaceae	*Asplenium pellucidum* Lam				
Cyatheaceae	*Cyathea perpelvigera* Alderw.			×	×
Cyatheaceae	*Cyathea rigens* Rosenst.			×	
Davalliaceae	*Humata alpina* T. Moore				×
Davalliaceae	*Humata deltoidea* Copel.			×	
Davalliaceae	*Nephrolepis lauterbachii* Christ		×	×	×
Dennstaedtiaceae	*Lindsaea pulchella* (J. Sm.) Mett. ex Kuhn var. *blanda* (Kuhn) K.U. Kramer			×	
Dennstaedtiaceae	*Lindsaea pulchella* (J. Sm.) Mett. ex Kuhn var. *pulchella*			×	
Dennstaedtiaceae	*Pteridium qauilinum* (L.) Kuhn		×		
Dryopteridaceae	*Leucostegia pallida* Copel.			×	×
Dryopteridaceae	*Didymochlaena truncatula* (Sw.) J. Sm.	LC	×		
Equisetaceae	*Equisetum ramosissimum* Kunth subsp. *debile* (Roxb. ex Vaucher) Hauke		×		
Gleicheniaceae	*Dicranopteris linearis* (Burm. F.) Underw. var. *linearis*			×	×
Grammitidaceae	*Calymmodon mnioides* Copel.			×	
Grammitidaceae	*Calymmodon pergracillimus* Copel.				×
Grammitidaceae	*Grammitis intromissa* (H. Christ) Parris			×	×
Grammitidaceae	*Grammitis knutsfordiana* (Baker) Copel.			×	×
Grammitidaceae	*Scleroglossum juncifolium* Copel.			×	×
Hymenophyllaceae	*Crepidomanes pallidum* (Blume) K. Iwats.			×	
Hymenophyllaceae	*Hymenophyllum geluense* Rosenst.			×	×
Hymenophyllaceae	*Hymenophyllum imbricatum* Col.			×	
Hymenophyllaceae	*Hymenophyllum melanosorum* (Copel.) C.V. Morton			×	×
Hymenophyllaceae	*Hymenophyllum pallidum* Ebihara & K. Iwats.			×	×
Hymenophyllaceae	*Hymenophyllum reinwardtii* Bosch			×	
Hymenophyllaceae	*Hymenophyllum rubellum* Rosenst.			×	
Lycopodiaceae	*Huperzia phlegmaria* (L.) Rothm. var. *phlegmaria*			×	×
Lycopodiaceae	*Huperzia squarrosa* (G. Forst.) Trevis.			×	×
Lycopodiaceae	*Lycopodiella cernua* (L.) Pic. Serm.		×	×	×
Lycopodiaceae	*Lycopodium clavatum* L. var. *clavatum*			×	×

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Lycopodiaceae	*Pseudodiphasium volubile* (G. Forst.) Holub		×	×	×
Marattiaceae	*Angiopteris evecta* (G. Forst.) Hoffm.			×	
Oleandraceae	*Oleandra gracilis* Copel.			×	
Ophioglossaceae	*Ophioglossum pendulum* L.		×	×	
Plagiogyriaceae	*Plagiogyria glauca* (Blume) Mett.			×	
Polypodiaceae	*Belvisia mucronata* (FÈe) Copel.			×	
Polypodiaceae	*Belvisia novoguineensis* (Rosenst.) Copel.			×	
Polypodiaceae	*Ctenopteris geluensis* Copel.			×	×
Polypodiaceae	*Ctenopteris yoderi* Copel.			×	
Polypodiaceae	*Crypsinus albidosquamatus* (Blume) Copel.			×	
Polypodiaceae	*Crypsinus enervis* Copel.				×
Polypodiaceae	*Crypsinus lamprophyllus* Copel.			×	
Polypodiaceae	*Crypsinus senescens* Copel.			×	
Polypodiaceae	*Crypsinus subundulatus* Copel.			×	×
Polypodiaceae	*Microsorum papuanum* Parris			×	×
Polypodiaceae	*Ctenopteris geluensis* Copel.			×	×
Polypodiaceae	*Ctenopteris micropaleata* Copel.				×
Polypodiaceae	*Schellolepis subauriculata* (Blume) J. Sm.			×	
Polypodiaceae	*Microsorum papuanum* Parris		×	×	
Polypodiaceae	*Phymatosorus membranifolium* (R. Br.) S.G. Lu		×		
Polypodiaceae	*Selliguea caudiformis* (Blume) J. Sm.			×	×
Selaginellaceae	*Selaginella braunii* Baker			×	
Selaginellaceae	*Selaginella opaca* Warb.			×	
Thelypteridaceae	*Coryphopteris fasciculata* (E. Fourn.) Holttum			×	×
Thelypteridaceae	*Coryphopteris subnigra* (Brause) Holttum			×	
Thelypteridaceae	*Pronephrium womersleyi* Holttum			×	
Thelypteridaceae	*Sphaerostephanos archboldii* Holttum			×	
Woodsiaceae	*Diplazium cordifolium* Blume		×	×	
Gymnosperms					
Gnetaceae	*Gnetum gnemon* L.	LC	×	×	
Podocarpaceae	*Podocarpus neriifolius* D. Don	LC	×	×	×
Monocots					
Araceae	*Alocasia brancifolia* (Schott) A. Hay		×		
Araceae	*Alocasia hollrungii* Engl.				×
Araceae	*Alocasia macrorrhizos* (L.) G. Don				×
Araceae	*Alocasia nicholsonii* A. Hay		×		
Araceae	*Colocasia esculenta* (L.) Schott	LC	×		
Araceae	*Cyrtosperma cuspidispathum* Alderw.		×		

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Araceae	*Cyrtospermum macrotum* Becc. ex Engl.		×		
Araceae	*Holochlamys beccarii* (Engl.) Engl.		×		
Araceae	*Homalomena aromatic* (Spreng.) Schott		×		
Araceae	*Raphidiphora geniculata* Engl.		×	×	
Araceae	*Spathiphyllum schlechteri* (Engl. & K.Krause) Nicolson			×	
Arecaceae	*Caryota rumphiana* Mart.		×		
Arecaceae	*Heterospathe elegans* (Becc.) Becc.		×		
Arecaceae	*Hydriastele costata* F.M. Bailey			×	
Asparagaceae	*Cordyline fruticosa* (L.) A. Chev.		×	×	
Costaceae	*Cheilocostus speciosus* (J.König) C.Specht		×		
Costaceae	*Tapeinochilos ananassae* (Hassk.) K.Schum.		×		
Cyperaceae	*Carex brunnea* Thunb.				×
Cyperaceae	*Cyperus pilosus* Vahl		×		
Cyperaceae	*Gahnia javanica* Moritzi				×
Eriocaulaceae	*Eriocaulon montanum* P.Royen			×	×
Flagellariaceae	*Flagellaria indica* L.		×	×	×
Marantaceae	*Donax canniformis* (G. Forst.) K. Schum.		×	×	
Orchidaceae	*Aglossorrhyncha biflora* J.J.Sm.			×	
Orchidaceae	*Anoectochilus papuanus* (Schltr.) W.Kittr.			×	×
Orchidaceae	*Appendicula aberrans* Schltr.				×
Orchidaceae	*Appendicula polystachya* (Schltr.) Schltr.		×	×	
Orchidaceae	*Appendicula reflexa* Blume			×	
Orchidaceae	*Appendicula* sp.			×	
Orchidaceae	*Arundina graminifolia* (D. Don) Hochr.*		×		
Orchidaceae	*Bulbophyllum acanthoglossum* Schltr.		×		
Orchidaceae	*Bulbophyllum andreeae* A.D.Hawkes			×	
Orchidaceae	*Bulbophyllum cf. B. antennatum* Schltr.				×
Orchidaceae	*Bulbophyllum apodum* Hook. f.			×	
Orchidaceae	*Bulbophyllum aristilabre* J.J.Sm.			×	
Orchidaceae	*Bulbophyllum callichroma* Schltr.		×		
Orchidaceae	*Bulbophyllum cylindrobulbum* Schltr.			×	
Orchidaceae	*Bulbophyllum discolor* Schltr.			×	
Orchidaceae	*Bulbophyllum erinaceum* Schltr.			×	
Orchidaceae	*Bulbophyllum graciliscapum* Schltr.			×	×
Orchidaceae	*Bulbophyllum guttulatum* (Hook.f.) N.P.Balakr.			×	
Orchidaceae	*Bulbophyllum pachytelos* Schltr.			×	
Orchidaceae	*Bulbophyllum aff. B. pemae* Schltr.			×	
Orchidaceae	*Bulbophyllum quadrangulare* J.J.Sm.		×		

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Orchidaceae	*Bulbophyllum quadrichaete* Schltr.			×	
Orchidaceae	*Bulbophyllum aff. B. quasimodo* J.J.Verm.		×		
Orchidaceae	*Bulbophyllum aff. B. renipetalum* Schltr.		×		
Orchidaceae	*Bulbophyllum cf. B. rivulare* Schltr.			×	
Orchidaceae	*Bulbophyllum scaphosepalum* Ridl.			×	
Orchidaceae	*Bulbophyllum sp.nov.*(Venter 14684)			×	
Orchidaceae	*Bulbophyllum sp.nov.*(Venter14755)			×	
Orchidaceae	*Bulbophyllum sp.nov.*((Venter 14759)			×	
Orchidaceae	*Bulbophyllum sp.nov.4 'aff.B. attenuatum*				×
Orchidaceae	*Bulbophyllum sp.nov.* (Venter 14835)			×	
Orchidaceae	*Bulbophyllum staetophyton* J.J.Verm.			×	
Orchidaceae	*Bulbophyllum unicaudatum* Schltr.			×	
Orchidaceae	*Cadetia aprina* (J.J.Sm.) Schltr.			×	
Orchidaceae	*Cadetia aprinoides* (J.J.Sm.) A.D.Hawkes				×
Orchidaceae	*Cadetia chionantha* (Schltr.) Schltr.			×	
Orchidaceae	*Calanthe aquamarina* Schuit. & de Vogel			×	×
Orchidaceae	*Calanthe caulescens* J.J.Sm.			×	
Orchidaceae	*Calanthe hololeuca* Reichb. f.			×	×
Orchidaceae	*Calanthe micrantha* Schltr.			×	
Orchidaceae	*Calanthe rhodochila* Schltr. var. *rhodochila*			×	×
Orchidaceae	*Calanthe triplicata* (Willemet) Ames		×	×	×
Orchidaceae	*Calanthe ventilabrum* Rchb.f.			×	
Orchidaceae	*Ceratostylis platychila* Schltr.		×	×	
Orchidaceae	*Ceratostylis scirpoides* Schltr.				×
Orchidaceae	*Coelogyne beccarii* Rchb.f.		×		
Orchidaceae	*Coelogyne fragrans* Schltr.			×	
Orchidaceae	*Corybas sexalatus* J.J.Sm.			×	×
Orchidaceae	*Dendrobium agrostophylloides* Schltr.			×	
Orchidaceae	*Dendrobium apertum* Schltr.			×	
Orchidaceae	*Dendrobium caliculimentum* R.S. Rogers			×	
Orchidaceae	*Dendrobium cuthbertsonii* F. Muell.			×	×
Orchidaceae	*Dendrobium debile* Schltr.		×		
Orchidaceae	*Dendrobium igneum* J.J.Sm.		×		
Orchidaceae	*Dendrobium habbamense* van Royen				×
Orchidaceae	*Dendrobium hamadryas* Schltr.		×		
Orchidaceae	*Dendrobium hellwigianum* Kraenzl. ex Warb.			×	
Orchidaceae	*Dendrobium hippocrepiferum* Schltr.			×	
Orchidaceae	*Dendrobium laceratum* Schltr.			×	
Orchidaceae	*Dendrobium masarangense* Schltr .subsp.			×	

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
	masarangense				
Orchidaceae	*Dendrobium masarangense* Schltr. subsp. *theionanthum* (Schltr.) T.M.Reeve & P.Woods			×	
Orchidaceae	*Dendrobium nardoides* Schltr.				×
Orchidaceae	*Dendrobium pentapterum* Schltr.				×
Orchidaceae	*Dendrobium prostheciglossum* Schltr.			×	
Orchidaceae	*Dendrobium rupestre* J.J.Sm.			×	
Orchidaceae	*Dendrobium sp.nov.'white green lip'*				×
Orchidaceae	*Dendrobium subclausum* Rolfe var. *speciosum* J.J.Wood			×	×
Orchidaceae	*Dendrobium subclausum* Rolfe var. *subclausum*			×	
Orchidaceae	*Dendrochilum longifolium* Rchb. f.		×		
Orchidaceae	*Dendrobium vexillarius* J.J. Sm.			×	
Orchidaceae	*Diplocaulobium cadetioides* (Schltr.) A.D.Hawkes			×	
Orchidaceae	*Diplocaulobium centrale* (J.J.Sm.) P.F.Hunt & Summerh.			×	
Orchidaceae	*Diplocaulobium guttulatum* (Schltr.) A.D.Hawkes			×	
Orchidaceae	*Diplocaulobium longicolle* (Lindl.) Kraenzl.			×	
Orchidaceae	*Diplocaulobium regale* (Schltr.) A.D.Hawkes			×	
Orchidaceae	*Epiblastus chimbuensis* P.Royen			×	
Orchidaceae	*Glomera aurea* Schltr.			×	
Orchidaceae	*Glomera bambusiformis* Schltr.			×	
Orchidaceae	*Glomera compressa* J.J.Sm.			×	×
Orchidaceae	*Glomera leucomela* (Schltr.) J.J.Sm.			×	×
Orchidaceae	*Glomera sp.nov* (Venter 14890)				×
Orchidaceae	*Glomera sp.nov.* (Venter 14955)				×
Orchidaceae	*Glomera verruculosa* (Schltr.) J.J.Sm.				×
Orchidaceae	*Glomera viridis* (Schltr.) J.J.Sm.			×	
Orchidaceae	*Glossorhyncha ambricaulis* P.Royen			×	
Orchidaceae	*Goodyera sp.*			×	
Orchidaceae	*Liparis calcarea* Schltr.			×	
Orchidaceae	*Liparis pedicellaris* Schltr.			×	
Orchidaceae	*Liparis werneri* Schltr.			×	
Orchidaceae	*Macodes obscura* Schltr.			×	
Orchidaceae	*Microtatorchis sp.nov.'micro'*			×	
Orchidaceae	*Oberonia pectinata* Schltr.			×	
Orchidaceae	*Peristylus tradescantifolius* (Rchb.f.) Kores		×		
Orchidaceae	*Pholidia imbricata* Benth.		×		
Orchidaceae	*Phreatia elata* Schltr.			×	
Orchidaceae	*Phreatia ganggapensis* van Royen				×

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Orchidaceae	*Phreatia longicaulis* Schltr.			×	
Orchidaceae	*Spiranthes sinensis* (Pers.) Ames			×	
Orchidaceae	*Stichorkis condylobulbon* (Rchb.f.) Marg., Szlach. & Kulak		×		
Orchidaceae	*Taeniophyllum latipetalum* Schltr.			×	
Orchidaceae	*Taeniophyllum sp.nov.* (Venter 14731)			×	
Poaceae	*Coix lacryma-jobi* L.*		×	×	
Poaceae	*Nastus productus* (Pilg.) Holttum				×
Poaceae	*Racemobambos schultzei* (Pilg.) Holttum				×
Pandanaceae	*Pandanus conoideus* Lam.			×	×
Pandanaceae	*Pandanus iwen* B.C.Stone			×	
Pandanaceae	*Pandanus julianettii* Martelli			×	
Philesiaceae	*Geitonoplesium cymosum* (R.Br.) A.Cunn. ex R.Br.			×	
Poaceae	*Imperata cylindrica* (L.) Raeusch.		×		
Triuridaceae	*Sciaphylla sp.nov.*			×	
Xanthorrhoeaceae	*Dianella ensifolia* (L.) DC.		×	×	
Xanthorrhoeaceae	*Dianella sp.nov.* (Venter 14623)			×	×
Zingiberaceae	*Alpinia sp.nov.* (Venter 14615)		×		
Zingiberaceae	*Hornstedtia scottiana* (F. Muell.) K. Schum.		×		
Zingiberaceae	*Riedelia corallina* (K. Schum.) Valeton			×	
Zingiberaceae	*Riedelia subalpina* van Royen			×	×
Dicots					
Actinidiaceae	*Saurauia conferta* Warb.			×	
Actinidiaceae	*Saurauia naumanii* Diels			×	
Actinidiaceae	*Saurauia occulta* A.C.Sm.			×	
Actinidiaceae	*Saurauia sp.nov.* (Venter 14926)				×
Actinidiaceae	*Saurauia sp.nov.*(Venter 14917)				×
Actinidiaceae	*Saurauia sp.nov.* (Venter 14700)			×	×
Anacardiaceae	*Buchanania macrocarpa* Lauterb.			×	
Anacardiaceae	*Rhus taitensis* Guill.			×	
Annonaceae	*Goniothalamus imbricatus* Scheff.		×		
Annonaceae	*Haplostichanthus longirostris* (Scheffer) Heusden		×	×	
Apocynaceae	*Cerbera floribunda* K.Schum.			×	
Apocynaceae	*Hoya solaniflora* Schltr.			×	
Apocynaceae	*Hoya subalpina* P.I. Forster & Liddle				×
Apocynaceae	*Hoya subglabra* Schltr.		×		
Apocynaceae	*Hoya venusta* Schltr.				×
Apocynaceae	*Marsdenia cremea* P.I.Forst.			×	
Apocynaceae	*Tabernaemontana cf. T. pandacaqui* Lam.		×		

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Apocynaceae	*Wrightia laevis* Hook.f.	LC		×	
Aquifoliaceae	*Ilex arnhemensis* Loes.			×	
Aquifoliaceae	*Ilex malaccensis* Loes.			×	
Araliaceae	*Arthrophyllum macranthum* Philipson			×	
Araliaceae	*Mackinlaya schlechteri* (Harms) Philipson			×	
Araliaceae	*Osmoxylon novoguineense* (Scheff.) Becc.			×	
Araliaceae	*Schefflera oligodon* Harms				×
Araliaceae	*Schefflera setulosa* Harms			×	
Asteraceae	*Olearia platyphylla* Mattf. var. *cinerea* (Mattf.) J.Kost.			×	
Balsaminaceae	*Impatiens hawkeri* W. Bull			×	
Begoniaceae	*Begonia sp.nov.* (Venter 14672)			×	×
Begoniaceae	*Begonia tafaensis* Merr. & L.M. Perry			×	
Bignoniaceae	*Tecomanthe dendrophila* (Blume) K. Schum.		×		
Bignoniaceae	*Tecomanthe volubilis* Gibbs			×	×
Brassicaceae	**Cardamine africana* L.		×	×	
Burseraceae	*Canarium acutifolium* (DC.) Merr.			×	
Burseraceae	*Canarium vitiense* A. Gray		×	×	
Calophyllaceae	*Calophyllum soulattri* Burm.f.	LC	×	×	
Calophyllaceae	*Calophyllum vexans* P.F.Stevens	LC		×	
Campanulaceae	*Lobelia zeylanica* L.			×	
Cannabaceae	*Celtis hildebrandii* Soepadmo		×		
Cannabaceae	*Trema orientalis* (L.) Blume		×	×	
Chloranthaceae	*Ascarina philippinensis* C.B.Rob.			×	×
Chloranthaceae	*Chloranthus elatior* Link		×	×	
Clusiaceae	*Garcinia hunsteinii* Lauterb.		×	×	
Clusiaceae	*Garcinia ledermannii* Lauterb.		×	×	
Cornaceae	*Alangium villosum* (Blume) Wangerin subsp. *ferrugineum* (C.T.White) Bloemb.			×	
Cornaceae	*Mastixia kaniensis* Melch. subsp.kaniensis			×	
Cucurbitaceae	*Trichosanthes lobata* Roxb.			×	
Cunoniaceae	*Acsmithia reticulata* (Schltr.) Hoogland			×	×
Cunoniaceae	*Caldcluvia nymanii* (K.Schum.) Hoogland			×	
Cunoniaceae	*Pullea glabra* Schltr.			×	
Datiscaceae	*Octomeles sumatrana* Miq.	LC	×	×	
Dilleniaceae	*Dillenia montana* Diels			×	
Elaeocarpaceae	*Aceratium oppositifolium* DC.		×	×	
Elaeocarpaceae	*Elaeocarpus angustifolius* Blume			×	
Elaeocarpaceae	*Elaeocarpus culminicola* Warb.			×	
Ericaceae	*Dimorphanthera alba* J.J.Sm.			×	

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Ericaceae	*Dimorphanthera anchorifera* J.J.Sm.			×	
Ericaceae	*Dimorphanthera dekockii* J.J.Sm.				×
Ericaceae	*Dimorphanthera tedentii* P.F.Stevens				×
Ericaceae	*Dimorphanthera viridiflora* P.F. Stevens			×	×
Ericaceae	*Diplycosia pendens* Sleumer			×	
Ericaceae	*Rhododendron beyerinckianum* Koord.			×	×
Ericaceae	*Rhododendron dielsianum* Schltr.			×	×
Ericaceae	*Rhododendron commonae* F. Foerster				×
Ericaceae	*Rhododendron gardenia* Schltr.				×
Ericaceae	*Rhododendron gaultheriifolium* J.J.Sm.				×
Ericaceae	*Rhododendron incommodum* Sleumer			×	×
Ericaceae	*Rhododendron konori* Becc.				×
Ericaceae	*Rhododendron latoucheae* Franch.			×	
Ericaceae	*Rhododendron lindaueanum* Koord.			×	×
Ericaceae	*Rhododendron macgregoriae* F. Muell.			×	×
Ericaceae	*Rhododendron rubrobracteum* Sleumer			×	
Ericaceae	*Rhododendron sp.nov.*(Venter 14949)			×	×
Ericaceae	*Rhododendron* (Venter 14942)			×	×
Ericaceae	*Rhododendron wentianum* Koord.			×	
Ericaceae	*Rhododendron wrightianum* Koord.				×
Ericaceae	*Vaccinium cf. V. sororium* J.J.Sm.			×	
Ericaceae	*Vaccinium crassistylum* Sleumer			×	
Ericaceae	Vaccinium globosum J.J.Sm.			×	
Ericaceae	*Vaccinium gracile* J.J.Sm.			×	
Ericaceae	Vaccinium sororium J.J.Sm.				×
Ericaceae	*Vaccinium sp.nov.* (Venter 14961)			×	
Ericaceae	*Vaccinium striicaule* Sleumer				×
Escalloniaceae	*Polyosma sp.*			×	
Euphorbiaceae	*Claoxylon microcarpum* Airy Shaw		×	×	
Euphorbiaceae	*Endospermum medullosum* L.S.Sm.			×	
Euphorbiaceae	*Macaranga aleuritoides* F. Muell.		×	×	
Euphorbiaceae	*Macaranga clemensiae* L.M. Perry			×	×
Euphorbiaceae	*Macaranga hispida* (Blume) Muell. Arg.			×	
Euphorbiaceae	*Macaranga tanarius* (L.) Muell. Arg.		×	×	
Euphorbiaceae	*Manihot esculenta* Crantz*		×	×	
Euphorbiaceae	*Homalanthus nervosus* J.J.Sm.			×	
Euphorbiaceae	*Homalanthus novoguineÎnsis* (Warb.) K.Schum.		×		
Euphorbiaceae	*Homalanthus nutans* (G.Forst.) Guill.			×	
Euphorbiaceae	*Pimelodendron amboinicum* Hassk.		×	×	

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Euphorbiaceae	*Spathiostemon javensis* Blume			×	
Fagaceae	*Castanopsis acuminatissima* (Blume) A.DC.			×	×
Fagaceae	*Lithocarpus rufovillosus* (Markgr) Rehder			×	×
Gesneriaceae	*Aeschynanthus leptocladus* C.B. Clarke			×	
Gesneriaceae	*Aeschynanthus pachyanthus* Schltr.			×	×
Gesneriaceae	*Aeschynanthus pullei* Schltr.				×
Gesneriaceae	*Cyrtandra erectiloba* G.W. Gillett			×	
Gesneriaceae	*Cyrtandra pulleana* Lauterb.			×	
Gesneriaceae	*Cyrtandra schumanniana* Schltr.			×	
Gesneriaceae	*Cyrtandra sp.nov.* (Venter 14649)			×	
Goodeniaceae	*Scaevola oppositifolia* Roxb.			×	
Juglandaceae	*Engelhardtia rigida* Blume	LC		×	×
Lamiaceae	*Callicarpa longifolia* Lam.			×	
Lamiaceae	*Clerodendrum buruanum* Miq.		×		
Lamiaceae	*Faradaya sp.nov.* (Venter 14828)			×	
Lamiaceae	*Plectranthus scutellarioides* L.		×		
Lamiaceae	*Plectranthus sp.nov.* (Venter 14764)		×		
Lamiaceae	*Premna herbacea* Roxb.		×		
Lamiaceae	*Scutellaria javanica* Jungh. var. *luzonica* (Rolfe) H.Keng			×	
Lauraceae	*Cryptocarya laevigata* Blume			×	
Leguminosae	*Entada phaseoloides* (L.) Merr.			×	
Leguminosae	*Mucuna schlechteri* Harms		×	×	
Loganiaceae	*Geniostoma rupestre* J.R. & G.Forst.		×		
Loganiaceae	*Neuburgia corynocarpa* (A. Gray) Leenh.		×	×	
Loranthaceae	*Amyema strongylophylla* (Lauterb.) Danser			×	
Loranthaceae	*Amyema wichmannii* (K.Krause) Danser			×	
Loranthaceae	*Papuanthes albertisii* (Tiegh.) Danser			×	
Malvaceae	*Commersonia bartramia* (L.) Merr.		×	×	
Melastomataceae	*Astronidium anomalum* Merr. & L.M. Perry				×
Melastomataceae	*Medinilla forbesii* Bak.f.				×
Melastomataceae	*Medinilla maluensis* Mansf.			×	
Melastomataceae	*Medinilla cauliflora* Hemsl.			×	
Melastomataceae	*Medinilla triochiton* Bodegom			×	
Melastomataceae	*Melastoma malabathricum* L.			×	
Meliaceae	*Chisocheton ceramicus* (Miq.) C.DC.			×	
Meliaceae	*Chisocheton lasiocarpus* (Miq.) Valeton			×	
Menispermaceae	*Stephania japonica* (Thunb.) Miers		×	×	
Monimiaceae	*Kibara coriacea* (Blume) Hook.f. & A. Thomps.			×	

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Monimiaceae	*Kibara karengana* Philipson			×	
Monimiaceae	*Steganthera hospitans* (Becc.) Kaneh. & Hatus.			×	
Moraceae	*Ficus adenosperma* Miq.		×		
Moraceae	*Ficus dammaropsis* Diels		×		
Moraceae	*Ficus fistulosa* Reinw. ex Blume		×	×	
Moraceae	*Ficus itoana* Diels		×		
Moraceae	*Ficus subulata* Blume		×		
Moraceae	*Ficus trachypison* K.Schum. & Lauterb.		×	×	
Moraceae	*Ficus wassa* Roxb.			×	
Myristicaceae	*Gymnacranthera farquhariana* (Hook.f. & Thomson) Warb.		×	×	×
Myristicaceae	*Myristica globosa* Warb.	NT		×	
Myristicaceae	*Myristica hollrungii* Warb.	LC	×	×	
Myristicaceae	*Myristica subalulata* Miq.		×	×	
Myrtaceae	*Decaspermum fruticosum* J.R.Forst. & G.Forst.			×	
Myrtaceae	*Octamyrtus behrmannii* Diels		×	×	
Myrtaceae	*Rhodomyrtus trineura* (F. Muell.) Benth. var. *novoguineensis* (Diels) A.J.Scott			×	
Myrtaceae	*Syzygium acuminatissimum* (Blume) DC.			×	×
Myrtaceae	*Syzygium effusum* (A.Gray) M¸ ll.Stuttg.			×	
Myrtaceae	*Syzygium hylophilum* (K.Schum. & Lauterb.) Merr. & L.M.Perry			×	
Myrtaceae	*Syzygium pergamaceum* (Greves) Merr. & L.M.Perry		×	×	
Myrtaceae	*Syzygium versteegii* (Lauterb.) Merr. & L.M.Perry			×	
Myrtaceae	*Xanthomyrtus polyclada* Diels			×	×
Myrtaceae	*Xanthomyrtus scolopacina* (Ridl.) Diels			×	
Nepenthaceae	*Nepenthes maxima* Reinw.	LC		×	×
Nothofagaceae	*Nothofagus carrii* Steenis				×
Nothofagaceae	*Nothofagus grandis* Steenis			×	×
Nyctaginaceae	*Pisonia longirostris* Teijsm. & Binn.			×	
Ochnaceae	*Schuurmansia elegans* Blume			×	
Paracryphiaceae	*Quintinia sp.*				×
Pentaphyllaceae	*Adinandra forbesii* Baker f.	NT	×	×	
Pentaphyllaceae	*Eurya osimensis* Masam.		×	×	
Pentaphyllaceae	*Eurya tigang* K.Schum. & Lauterb.			×	
Pentaphyllaceae	*Ternstroemia britteniana* F.Muell.			×	×
Phyllanthaceae	*Aporosa papuana* Pax & K. Hoffm.			×	
Phyllanthaceae	*Breynia cernua* (Poir.) Muell. Arg.		×	×	
Phyllanthaceae	*Glochidion macrocarpum* Blume			×	
Phyllanthaceae	*Glochidion pomiferum* Airy Shaw			×	

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Phyllanthaceae	*Glochidion sp.nov.* (14790)			×	
Piperaceae	*Peperomia tenuipila* C.DC.				×
Piperaceae	*Piper aduncum* L.*		×		
Piperaceae	*Piper caninum* Blume		×	×	
Piperaceae	*Piper gibbilimbum* C.DC.			×	
Piperaceae	*Piper macropiper* Pennant		×	×	×
Piperaceae	*Piper subcaniramum* C.DC.			×	
Piperaceae	*Piper versteegii* C. DC.			×	
Pittosporaceae	*Pittosporum ramiflorum* Zoll. ex Miq.			×	
Pittosporaceae	*Pittosporum sinuatum* Blume		×	×	×
Polygalaceae	*Polygala paniculata* L.*		×		
Polygalaceae	*Xanthophyllum papuanum* Whitmore ex Meijden			×	
Primulaceae	*Ardisia dasyneura* Mez			×	×
Primulaceae	*Ardisia elliptica* Thunb.			×	
Primulaceae	*Ardisia forbesii* S. Moore			×	×
Primulaceae	*Discocalyx latepetiolata* (Mez) Sleumer			×	
Primulaceae	*Maesa papuana* Warb.			×	
Primulaceae	*Rapanea brassii* P.Royen		×	×	
Primulaceae	*Rapanea cacuminum* Mez			×	
Primulaceae	*Eriocaulon montanum* P.Royen			×	×
Rhamnaceae	*Alphitonia incana* (Roxb.) Teijsm. & Binn. ex Kurz		×	×	
Rhizophoraceae	*Gynotroches axillaris* Blume			×	
Rosaceae	*Rubus fraxinifolius* Poir.			×	
Rosaceae	*Rubus moluccanus* L.		×	×	
Rousseaceae	*Carpodetus arboreus* (Lauterb. & K.Schum.) Schltr.		×	×	
Rubiaceae	*Amaracarpus grandifolius* Valeton var. *humilis* (Valeton) A.P. Davis			×	
Rubiaceae	*Argostemma bryophilum* K. Schum.			×	
Rubiaceae	*Atractocarpus decorus* (Valeton) Puttock		×	×	
Rubiaceae	*Bikkia tetrandra* (L.f.) A. Rich.		×		
Rubiaceae	*Dolicholobium acuminatum* Burkill			×	
Rubiaceae	*Hydnophytum sp.*			×	
Rubiaceae	*Ixora minor* (Valeton) Mouly & B. Bremer		×		
Rubiaceae	*Ixora cf. I. solomonensium* Bremek.		×		
Rubiaceae	*Lasianthus stipularis* Blume		×	×	
Rubiaceae	*Dolicholobium acuminatum* Burkill			×	
Rubiaceae	*Gardenia lamingtonii* F.M.Bailey		×	×	
Rubiaceae	*Mussaenda cylindrocarpa* Burck		×	×	
Rubiaceae	*Mussaenda ferruginea* K.Schum.		×		

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Rubiaceae	*Myrmecodia horrida* Huxley & Jebb			×	
Rubiaceae	*Nauclea orientalis* (L.) L.		×		
Rubiaceae	*Nertera granadensis* (Mutis ex L.f.) Druce			×	
Rubiaceae	*Ophiorrhiza debruynii* Valeton			×	
Rubiaceae	*Ophiorrhiza valetonii* Merr. & L.M.Perry.			×	
Rubiaceae	*Psychotria asekiensis* Sohmer			×	
Rubiaceae	*Psychotria multicostata* Valeton			×	
Rubiaceae	*Psychotria sp.nov.* (Venter 14654)			×	
Rubiaceae	*Timonius belensis* Merr. & L.M.Perry				×
Rubiaceae	*Timonius scabriflorus* (Valeton) Merr. & L.M.Perry			×	
Rubiaceae	*Timonius timon* (Spreng.) Merr. var. *whiteanus* (S.Moore) S.P.Darwin			×	
Rubiaceae	*Uncaria orientalis* Guillaumin			×	
Rutaceae	*Acronychia rugosa* T.G.Hartley				×
Rutaceae	*Evodiella muelleri* (Engl.) B.L.Linden f. *dinggi* Veldkamp & Rouw.				×
Rutaceae	*Halfordia kendack* Guillaumin		×	×	
Rutaceae	*Melicope elleryana* (F. Muell.) T.G. Hartley		×	×	
Rutaceae	*Melicope robbinsii* T.G.Hartley			×	
Sapindaceae	*Guioa comesperma* Radlk.			×	
Sapindaceae	*Pometia pinnata* J.R. Forst. & G. Forst.		×	×	
Sapotaceae	*Planchonella thyrsoidea* C.T.White		×	×	
Solanaceae	*Nicotiana tabacum* L.*			×	
Sphenostemonaceae	*Sphenostemon papuanum* (Lauterb.) Steenis & Erdtman			×	
Symplocaceae	*Symplocos cochinchinensis* (Lour.) S. Moore		×	×	
Thymelaeaceae	*Gonystylus macrophyllus* (Miq.) Airy Shaw			×	
Thymelaeaceae	*Phaleria macrocarpa* (Scheff.) Boerl.		×	×	
Thymelaeaceae	*Wikstroemia androsaemifolia* Decne.			×	
Urticaceae	*Cypholophus kerewensis* P.Royen				×
Urticaceae	*Cypholophus nummularis* H.J.P.Winkl.		×	×	
Urticaceae	*Cypholophus rotundifolius* H.J.P.Winkl.			×	
Urticaceae	*Cypholophus sp.nov.*(Venter 14679)			×	
Urticaceae	*Elatostema morobense* L.M.Perry			×	
Urticaceae	*Elatostema novoguineense* Warb.			×	
Urticaceae	*Elatostema sp.nov.* (Venter 14610)		×		
Urticaceae	*Leucosyke capitellata* Wedd.		×		
Urticaceae	*Nothocnide repanda* (Blume) Blume			×	
Urticaceae	*Pilea melastomoides* (Poir.) Wedd.				×
Urticaceae	*Pilea papuana* H.J.P.Winkl.			×	
Urticaceae	*Pipturus argenteus* (G. Forst.) Wedd.			×	

Family	Scientific name	IUCN status	Tabubil	Tupnonbil (Bilbilokabip)	Minni camp
Urticaceae	*Procris frutescens* Blume		×	×	×
Urticaceae	*Procris grueningii* (H.J.P.Winkl.) R.J.Johns			×	
Urticaceae	*Procris pedunculata* (J.R. Forst. & G. Forst.) Wedd.		×	×	
Vitaceae	*Tetrastigma pullei* Lauterb.				×
Vitaceae	*Leea indica* L.		×		
Vitaceae	*Leea zippeliana* Miq.			×	
Winteraceae	*Drimys piperita* Hook.f.			×	
Winteraceae	*Zygogynum cf. Z. oligocarpum* (Schltdl.) Vink		×		

New distribution records

Orchidaceae

Anoectochilus papuanus (Schltr.) W.Kittr. (Ormerod 1996).
One of the Jewel Orchids. A small population of 15 plants was found growing in leaf litter in the *Nothofagus* Forest above Bilbilokabip at Tupnonbil. Previously known in PNG from the eastern Provinces and from Indonesia's Papua Province in the west, this record fills a major gap in the species' range and is the first record for Western Province.

Appendicula aberrans Schltr. (Schlechter 1912).
An epiphyte of the Mid Montane Rain Forest both on and north of the cordillera including the north-coast ranges. Occurs as scattered individuals in the Secondary Montane Forest at Tupnonbil. This is the first record on the southern side of the cordillera and the first record for Western Province.

Appendicula polystachya (Schltr.) Schltr.
An epiphytic orchid that normally grows in Lowland Rainforest altitudes between ~100 and 400 m. The plants documented above the Tabubil Intake (953 m) are at more than double that altitude showing the adaptability of this taxon to climatic conditions. Previously known from the eastern part of PNG, this is the first record of this species for Western Province.

Appendicula reflexa Blume
A common Malesian epiphytic orchid previously known from Madang, Morobe and Milne Bay Provinces in eastern PNG. This species was found at Tupnonbil, and the new record extends its known distribution considerably to the west; it is also the first record for Western Province.

Bulbophyllum scaphosepalum Ridl. (Schlechter 1916)
This orchid was only known from the type specimen collected by Kloss on the lower slopes of Mt. Carstenz in 1913. A single specimen (S. Venter [1]14762) found about 150 m southeast of Bilbilokabip at Tupnonbil represents the only other collection of this species, and the photos taken are the first for the taxon. This record extends the distribution considerably and it is also the first record for PNG (see photograph page 18).

[1] Collection moniker of Stephanus "Fanie" Venter

Cadetia aprina (J.J.Sm.) Schltr.
An epiphytic orchid that is widely distributed in Papua Province, Indonesian New Guinea. The specimens (S.Venter 14819) collected at the Ok Tupnon at Tupnonbil represent the first record of this taxon for PNG.

Cadetia aprinoides (J.J.Sm.) A.D. Hawkes
An epiphytic orchid of low *Vaccinium*–dominated montane ridge forest in the Paniai Regency of Papua Province, Indonesian New Guinea. The specimen (S. Venter 14889) found at Minni Camp represents the first record for PNG and also extends the altitudinal range upwards by more than 1000 m.

Cadetia chionantha (Schltr.) Schltr.
A common epiphytic orchid from the highlands of New Guinea. The plants from Tupnonbil represent the first record for Western Province.

Calanthe aquamarina Schuit. & de Vogel
Only recently (2009) described, and previously known only from Papua Province, Indonesian New Guinea. The specimens from Tupnonbil were growing as epiphytes on moss-covered tree trunks at the foot of the Hindenburg Wall and they represent the first record of this taxon for PNG.

Calanthe hololeuca Rchb.f.
A terrestrial orchid growing in thick leaf litter and previously known only from New Britain, Bougainville, Karkar Island off Madang, and Normanby Island. The plants recorded during this survey represent the first record for Mainland PNG

Calanthe micrantha Schltr.
A terrestrial orchid of forests above 1,800 m altitude. A common species around Bilbilokabip at Tupnonbil, this is the first record of this species for Western Province.

Calanthe ventilabrum Rchb.f.
A taxon widely distributed on the northern side of the Central Cordillera in PNG. A single specimen of this species was photographed at Tubnonbil during the survey and is the first record for Western Province.

Ceratostylis platychila Schltr.
A small tussock-like epiphytic orchid known from Foothill Rain Forests up to 1,000 m altitude in Central and Madang Provinces. The specimens from Minni Camp extend the altitudinal range up to 2,384 m and the distribution far to the west; they represent the first record of this species from Western Province.

Ceratostylis scirpoides Schltr.
An epiphytic orchid previously known only from a small area below 1,000 m asl in East Sepik Province. The current specimens are the first record for Western Province and also the first specimens of this taxon south of the Central Cordillera.

Corybas sexalatus J.J.Sm.
A small terrestrial orchid previously known from two widely separated areas at altitudes above 3,000 m; the upper montane forests of Morobe Province and a small area in Papua Province, Indonesian New Guinea The specimens collected at Minni Camp during this survey (S. Venter 14932) are from a somewhat lower altitude (2,380 m asl) and they are the first record of this taxon for Western Province.

Dendrobium agrostophylloides Schltr.
This epiphytic orchid is known from the Kani Mountains in Madang Province. The collection (S. Venter 14628) from near Bilbilokabip at Tupnonbil is a large range extension and also the first record for Western Province. It is also an extension of the known altitudinal range from 1,000 m to 2,380 m asl.

Dendrobium apertum Schltr.
An epiphytic orchid with pinkish-red flowers that was previously known only from eastern PNG; the specimens from c. 1 km north of Bilbilokabip Camp are the first record for Western Province.
Dendrobium debile Schltr.

An epiphytic orchid that grows in the forest canopy, on tall trees in Low altitude Midmontane Rain Forest. It is known only from two old collections made by Rudolph Schlechter in a small area of Madang Province. The material from Bilbilokabip growing as a high level epiphyte represents a large range extension, the only recent collection, and the first record for Western Province.

Dendrobium habbamense van Royen
This epiphytic orchid is widely distributed in the eastern part of PNG with the survey collection S. Venter 14896 from Minni Camp being the first record for Western Province.

Dendrobium hamadryas Schltr.
This epiphytic orchid was known only from a small area along the Djamu River in Madang Province. The Tupnonbil material (S. Venter 14662) was recorded at the river near Bilbilokabip. This is an altitudinal extension upwards of nearly 900 m. It is also the first record of this species from south of the Central Cordillera and the first record for Western Province.

Dendrobium hippocrepiferum Schltr.
This is an epiphytic (and sometimes terrestrial on moss-covered ground) orchid with erect stems that was known only from Eastern Highlands Province. The plants recorded from Ericoid Scrub at Minni Camp represent a large range extension and the first record for Western Province.

Dendrobium igneum J.J.Sm.
A most beautiful epiphytic orchid with large, deep-yellow flowers. Previously known from lowland forests in Papua Province, Indonesian New Guinea, and also from material possibly collected in Central Province, the plants growing on trees near Tabubil are the first confirmed record for PNG. This species is a popular item with orchid growers and there is a possibility that these plants originated from introduced stock by orchid growers in town.

Dendrobium laceratum Schltr.
An epiphytic orchid of montane forest that is sparsely distributed in the eastern parts of PNG. The Tupnonbil collection (S. Venter 14821) represents a large range extension and is the first record of this species for Western Province. The flower of the Tupnonbil material is purplish brown instead of yellowish white but colour is quite variable in the genus and this is probably a regional colour variant.

Dendrobium pentapterum Schltr.
An epiphytic orchid from montane forest up to an altitude of 2,000 m. The collection S. Venter 14937 from Moss Forest on the lower slopes of Mt. Minni at 2,400 m asl is therefore an altitudinal extension of 400 m. These specimens are also the first record of this taxon for Western Province.

Dendrobium prostheciglossum Schltr.
A common epiphytic orchid of open montane forest and grassland with the collection S. Venter 14788 representing the first record for Western Province.

Diplocaulobium cadetioides (Schltr.) A.D.Hawkes
An epiphytic orchid of the lowlands, foothills, and lower montane forests at altitudes up to 1,300 m in Southern Highlands, Morobe and Oro Provinces. The collection S. Venter 14686 from the area around Bilbilokabip is 400 m higher than previously recorded and is also the first record for Western Province.

Diplocaulobium centrale (J.J.Sm.) P.F.Hunt & Summerh.
An epiphytic orchid of montane forests in Enga and Morobe Provinces. The collection S. Venter 14824 from Moss Forest at the foot of the Hindenburg Wall north of Bilbilokabip is a range extension and the first record for Western Province.

Diplocaulobium guttulatum (Schltr.) A.D.Hawkes
A glossy, dark-green orchid growing as a low level epiphyte in lower montane forest in Madang and Morobe Provinces. The collection S. Venter 14763 from around Tupnonbil represents an increase in altitude of 800 m and it is also the first record for Western Province.

Diplocaulobium regale (Schltr.) A.D.Hawkes
This is a most attractive epiphytic orchid with large pink flowers that was previously known from montane forests in eastern PNG. The plants found growing as a low level epiphyte on the foot of the Hindenburg Wall at Tupnonbiol during this survey are the first record for Western Province.

Epiblastus chimbuensis P.Royen
Previously known from several localities between 2,600–3,350 m asl in upper montane forests in eastern PNG. The Hindenburg material (S. Venter 14743) was found in the forest margin at Tupnonbil which is more than 800 m below the lowest previous altitudinal record. It is also a substantial range extension to the west and a first record for Western Province.

Glomera aurea Schltr.
An epiphytic orchid species from montane forests in Enga, Eastern Highlands and Morobe Provinces. The specimens from Bilbilokabip at Tapnonbil represent a range extension to the west and a first record for Western Province.

Glomera bambusiformis Schltr.
An epiphytic orchid from montane forests in Morobe Province and New Ireland. The collection S. Venter 14823 from the base of the Hindenburg Wall represents a huge range extension towards the west and the first record for Western Province. The flower is deep yellow instead of the typical white and is probably a local colour variant.

Glomera leucomela (Schltr.) J.J.Sm.
A rare epiphytic orchid only known from the type material collected in 1912 in upper montane forests in Madang Province. The material from the Ericoid Scrub at Minni Camp represents a massive range extension to the south-west, and the first record for Western Province. It is also the first time *G. leucomela* has been photographed.

Glomera verruculosa (Schltr.) J.J.Sm.
An epiphytic orchid previously known from montane forests in a small area of Madang Province and a single locality on New Ireland. The specimen S. Venter 14931 from the Ericoid Scrub near Minni Camp represents a substantial range extension to the west and south of the Central Cordillera, and an altitudinal extension upwards of more than 1,200 m. The lip of the flower in this population is greener than that of the type material. The flowers of this rare species were photographed for the first time.

Glomera viridis (Schltr.) J.J.Sm.
Previously known only from the type specimen collected on Mt. Kama in Madang Province in 1912. The collection at Minni Camp is the first re-collection of the species, a large range extension and the first record for Western Province. The flowers of this species were photographed for the first time.

Liparis calcarea Schltr.
A terrestrial orchid known from limestone cliff faces at 1,100–1,645 m asl in Madang, Oro and Morobe Provinces. The material from Tupnonbil represents a large range extension and the first record for Western Province.

Liparis pedicellaris Schltr.
A terrestrial orchid known from foothill forest at altitudes of 450–760 m asl in Morobe Province and on Karkar Island in Madang Province. The collection S. Venter 14677 from the foot of the Hindenburg Wall at Bilbilokabip appears to be the first collection of this taxon in 40 years. This collection is also an upward altitudinal extension of more than 1000 m and is the first record for Western Province.

Macodes obscura Schltr.
Previously known from montane forests in the eastern part of PNG. The collection S. Venter 14704 from the Ericoid Scrub next to Bilbilokabip Camp at Tupnonbil is the first record of this taxon for Western Province.

Oberonia pectinata Schltr.
An epiphytic orchid known from lower montane forest at 1,100 m asl in Madang Province. The survey collection S. Venter 14818 is from *Nothofagus* forest at Tupnonbil where the species appeared to be quite rare. This record is a large range and upward altitudinal extension. It is also the first record for Western Province.

Phreatia elata Schltr.
Known from a few localities in Papua Province, Indonesian New Guinea. The survey record S. Venter 14630 from the area southeast of Bilbilokabip Camp at Tupnonbil is the first record for PNG.

Phreatia ganggapensis van Royen
An epiphytic orchid growing on lower branches in Cloud Forest previously known only from the eastern part of PNG and a record from Papua Province, Indonesian New Guinea. The survey record S. Venter 14948 collected at 2383 m alt., on the lower slopes of Mt. Minni extends the species' range to Western Province.

Taeniophyllum latipetalum Schltr.
A leafless epiphytic orchid growing on tree trunks, this species was previously known only from Lower Montane Rain Forests in Morobe Province. A few scattered specimens were recorded at an altitude of 1820 m in the moss forest above Bilbilokabip. The collection S. Venter 14735 represents a large range extension and the first record for Western Province.

Apocynaceae
Wrightia laevis Hook.f.
A small to large tree growing up to 25 m tall. This species is never common and occurs as scattered individuals so it is only a minor timber species. Specimens in the forest near the river at Bilbilokabip represent the first record of this species for Western Province.

Aquifoliaceae
Ilex malaccensis Loes.
A species common in Indonesia but generally rare in PNG. The specimen S. Venter 14733 represents a new distribution record and a first for Western Province. A few scattered specimens were recorded along the main creek near Bilbilokabip.

Araliaceae
Mackinlaya schlechteri (Harms) Philipson
Widely distributed in the eastern provinces of PNG. This species occurs as scattered plants in forest margins and in scrub forest near Bilbilokabip. The survey collection S. Venter 14655 represents the first record for Western Province.

Begoniaceae
Begonia tafaensis Merr. & L.M. Perry
A fairly widely distributed species in the eastern provinces of PNG. The survey record S. Venter 14873 is however the first time this species has been recorded in Western Province.

Cannabaceae
Celtis hildebrandii Soepadmo
This species is common in the Solomon Islands but there are just two previous collections from PNG, one from Morobe Province and the other from West Sepik Province. The record at Tabubil is a significant range extension and the first record for Western Province.

Chloranthaceae
Chloranthus elatior Link
A rare plant species in PNG with the only previous records from the Garaina area in Morobe Province. The survey records from Tabubil and Tupnonbil represent the first records of this species for Western Province. Occurs as small populations near creeks.

Clusiaceae
Garcinia ledermannii Lauterb.
Known from a number of localities in Morobe and Milne Bay Provinces. A common species growing on mountain slopes at Tabubil and Tupnonbil. The specimen S. Venter 14779 represents the first record of this species for Western Province.

Dilleniaceae
Dillenia montana Diels
A large canopy tree recorded from East Sepik and Eastern Highlands Provinces. This species occurs sporadically in the forest around Bilbilokabip. This is the first record of *D. montana* for Western Province.

Ericaceae
Dimorphanthera viridiflora P.F. Stevens
All known localities are from Southern Highlands Province. The records from Ericoid Scrub at Tupnonbil and Kawarobip are a significant range extension and the first record of this species for Western Province.

Diplycosia pendens Sleumer
A species previously only known from the Vogelkop Peninsula in West Papua Province, Indonesian New Guinea. The survey record S. Venter 14730 from the Ericoid Scrub close to Bilbilokabip Camp at Tupnonbil is a significant range extension and the first record for PNG.

Rhododendron commonae F. Foerster
A fairly common species in the eastern provinces of PNG. The plants growing in the Ericoid Scrub at Kawarobip represent a new record for Western Province.

Gesneriaceae
Aeschynanthus pullei Schltr.
This species was only known from Puncak Jaya in Papua Province, Indonesian New Guinea. The survey specimen S. Venter 14934 represents the first record for PNG.

Cyrtandra pulleana Lauterb.
Previously only known from Cyclops Mountains in Papua Province, Indonesian New Guinea. A few scattered populations of this species were recorded along the creeks in forest near Bilbilokabip. The specimen S. Venter 14746 represents the first record of this species for PNG.

Melastomataceae
Astronidium anomalum Merr. & L.M. Perry
Previously known from Western Highlands Province and the Solomon Islands. The specimen S. Venter 14915 from the slopes of Mt. Minni at Kawarobip represents a significant range extension and the first record for Western Province.

Medinilla forbesii Bak.f.
Known from Central Province in PNG and from the Snow Mountains in Papua Province, Indonesian New Guinea. Specimens of this species occur as scattered individuals in the *Nothofagus*-bamboo forest at Kawarobip. The specimen S. Venter 14959 thus fills a major gap in its known distribution and is a first record for Western Province.

Medinilla maluensis Mansf.
Previously known from forests along rivers and creeks in Morobe and Central Provinces, this species was last recorded in 1963. The survey specimen S. Venter 14737 is the first record for Western Province.

Medinilla cauliflora Hemsl.
A species previously known only from Bougainville and the Solomon Islands. A few scattered specimens were recorded during the survey at Tupnonbil and the specimen S. Venter 14722 is the first record for PNG.

Medinilla triochiton Bodegom
Previously known only from Ialibu Station at Pegaigu Village in Southern Highlands Province, this species was moderately common at Bilbilokabip where plants were found climbing on tree trunks. The specimen S. Venter 14752 represents a significant range extension and the first record for Western Province.

Primulaceae
Rapanea cacuminum Mez
Known from Eastern Highlands and West Sepik Provinces of PNG, and also from Papua Province, Indonesian New Guinea. This species occurs as a scattered undershrub in the forest along creeks on the slopes of Mt. Minni at Kawarobip. The survey specimen S. Venter 14905 fills a major gap in the known distribution of this species and is the first record for Western Province.

Rubiaceae
Bikkia tetrandra (L.f.) A. Rich.
A most attractive shrub with large, white, highly scented flowers that was previously known from Morobe and Milne Bay Provinces and their offshore islands. A large population grows next to the road between Tabubil and the Ok Tedi Mine and the survey record S. Venter 14609 is a substantial range extension and the first record for Western Province.

Ophiorrhiza debruynii Valeton
Previously known from a single collection from Hamata in Morobe Province. The collection S. Venter 14634 from the creek below Bilbilokabip Camp at Tupnonbil represents only the second record for PNG and an extension of the species range towards the south of the Central Cordillera as well as the first record for the Western Province.

Psychotria asekiensis Sohmer
Known from Mt. Bosavi area. The specimen S. Venter 14748 from along the Ok Tupnon at Bilbilokabip is a range extension for the species, and the first record for Western Province.

Urticaceae
Elatostema morobense L.M. Perry
A species from Madang and Eastern Highlands Provinces in PNG. It was common in Cloud Forest above Bilbilokabip at Tupnonbil and the survey specimen S. Venter 14785 represents the first specimen south of the Central Cordillera and the first record for Western Province.

Species new to science

Actinidiaceae
Saurauia sp. nov.; Tupnonbil: Venter 14880.
A tree growing to 8 m tall with open branching. The bark is smooth and light brown. Leaves are leathery and light green with a pinkish petiole and a curved lamina. The flowers are pendulous with a whitish calyx that is speckled with red. The corolla is white with upcurved margins. No scent. Scattered individuals along the Ok Tupnon.

Saurauia sp. nov.; Kawarobip: Venter 14917.
A tree growing to 6 m tall with a spreading crown. Stems reddish brown Leaves leathery, light green, spreading horizontal with reddish petioles. Flowers drooping, white. Known from eight populations in *Nothofagus* – bamboo Forest.

Saurauia sp. nov.; Kawarobip: Venter 14926.
A tree growing to 10 m tall with an open crown. Bark smooth and brown. The leaves are hard and leathery and dark green; they are domed and the petiole has light green glands. Flowers are drooping, white, with a reddish calyx. Known from five populations in *Nothofagus* – bamboo Forest.

Begoniaceae
Begonia sp. nov.; Tupnonbil: Venter 14672, Venter 14760.
A climber that is sometimes epiphytic. The stems are succulent and reddish and the leaves are succulent and light green, with reddish venation underneath. Young leaves have silver markings. The leaves are held flat against the tree trunk. The fruits are nearly twice the size of any other climbing *Begonia*. Known from three populations in Lower Montane Rain Forest at the foot of the Hindenburg Wall.

Ericaceae
Vaccinium sp. nov.; Kawarobip: Venter 14962.
A 3 m tall shrub with flaky bark. The light green leaves are recurved, hard and leathery. The flowers and fruit are white. Known from more than 50 individuals in the Ericoid Scrub.

Rhododendron sp. nov.; Kawarobip: Venter 14949.
A small shrublet growing to 30 cm tall in the Ericoid Scrub. The stems are erect and the glossy green leaves are erect-spreading. The flower is solitary, pendulous and purplish pink. Rarely encountered. Only in the Ericoid Scrub.

Gesneriaceae
Cyrtandra sp. nov.; Tupnonbil: Venter 14649.
A very fleshy shrublet with prostrate stems growing up to 50 cm tall. The leaves are dark glossy green and the fruit is fleshy and white. More fleshy than any known *Cyrtandra* species. Known from three populations each no larger than 30 individual specimens. These populations grow on the banks of a drainage line in Lower Montane Rain Forest about 1 km north of Bilbilokabip.

Lamiaceae
Faradaya sp. nov.; Tupnonbil: Venter 14828.
A robust climber in Secondary Lower Montane Rain Forest. The bark is rough and grey brown. The leaves are hard, leathery, and recurved with sunken venation on the upper surface. The large white flowers are scentless and the fruit is pendulous, whitish-green and semi-fleshy. Known from two small populations about 1 km northeast Bilbilokabip.

Orchidaceae
Bulbophyllum sp. nov.; Tupnonbil: Venter 14684.
A mid-level epiphyte. The branches are flaccid with erect apices. The leaves are tinged purple and the flowers are maroon with a maroon lip having cream lines. The flower resembles that of *B. microrhombos* but the plant is quite different.

Bulbophyllum sp. nov.; Tupnonbil: Venter 14755.
A low-level epiphyte that hangs down from the trunk. The plant is flaccid and the flower is cream-coloured speckled with maroon. The flower is different from any known species. Known from only four specimens.

Bulbophyllum sp. nov.; Tupnonbil: Venter 14759.
A low-level epiphyte that is very fleshy and light green. The flowers are erect with the dorsal sepal streaked with purple, and the petals are yellow speckled with purple and with cream-coloured apices. Plants grow scattered throughout the Ericoid Scrub next to Bilbilokabip.

Bulbophyllum sp. nov.; Tupnonbil: Venter 14835.
A high-level epiphyte. The pseudobulbs are light green and the petiole is purple. The flowers are pendant and the sepals are purple on the outside, and purple at the top and white in the bottom half on the inside. The lip is boat-shaped and white with dense purple spots. Only two specimens found.

Glomera sp. nov.; Kawarobip: Venter 14890.
A low-level epiphyte with pendulous branches up to 30 cm long. The leaves are grass-like. The flower is white and sweetly scented. Known from a single population numbering five individuals.

Glomera sp. nov.; Kawarobip: Venter 14955.
A small epiphyte in the Ericoid Scrub. The erect-spreading leaves are light green tinged with purple. The flowers are transparent white with a black lip apex. Only a single population of 14 plants are known.

Taeniophyllum sp. nov.; Tupnonbil: Venter 14731.
A minute epiphytic orchid growing on thin branches of shrubs in Ericoid Scrub. It is light green with lime yellow flowers. Rare, found only in the Ericoid Scrub. Differs markedly from other *Taeniophyllum* species in the well-developed leaves and possibly belongs to a different genus.

Phyllanthaceae
Glochidion sp. nov.; Tupnonbil: Venter 14790.
A tree growing to 10 m tall with a closed crown. The leaves are hard and brittle and glaucous below. Flowers are greenish yellow. The fruit is fleshy, large and round, pink outside and deep pink inside. Found occasionally along creeks. Resembles *G. beehleri* but differs in the glaucous brittle leaves, the shape of the fruit and the inside colour of the fruit. It is also not cauliflorous.

Rubiaceae
Psychotria sp. nov.; Tupnonbil: Venter 14645.
A 1 m tall shrub with spreading branches and very leathery leaves. The flowers are white and slightly scented and the fruit is fleshy and white. No less than 14 populations numbering 30+ individuals each, recorded during this survey.

Psychotria sp. nov.; Tupnonbil: Venter 14654.
A 3 m tall shrub with spreading branches and glossy dark green leaves. The flowers are white but with no scent and the fruit is fleshy and white. Known from eight large populations.

Triuridaceae
Sciaphylla sp.
A common taxon growing only on termite mounds on the forest floor (S. Venter 14979, S. Venter 15064). The dark purple colour of the plants is unique. It does not key out to any species in the revision of the genus (van Meerendonk et al. 1984) and possibly represents an undescribed taxon.

Urticaceae
Cypholophus sp. nov.; Tupnonbil: Venter 14679.
A small tree growing to 3 m tall with most branches spreading horizontally. The fleshy leaves are small for the genus and held in the same plane. Known from three populations in mossy Lower Montane Rain Forest .

Elatostema sp. nov.; Tabubil Intake at the top of Dablin Creek: Venter 14610.
A common, low-level fleshy epiphyte with drooping branches and purple tinged stems. The mature leaves are dull dark green above with a purple midrib below. The single known population is from undisturbed Foothill Rain Forest.

Xanthorrhoeaceae
Dianella sp. nov.; Tupnonbil: Venter 14623, Venter 14897, Venter 14952.
A tufted epiphytic herb with light green leaves and prominent trailing stems. The flower is deep blue and the fruit a fleshy blue berry. Common especially in the Lower Montane Rain Forest. The rhizomatous stems are very unusual for this genus.

Zingiberaceae
Alpinia sp. nov.; Tabubil Intake at Dablin Creek: Venter 14615.
An erect-stemmed ginger with stems up to 1 m tall. The stems are covered in dense coarse brown hairs. The leaves are dull light green and much lighter below. The drooping fruit is fleshy and bright red. The population here consists of 15 individuals scattered over a 100 m^2 area. The dense coarse hairs are unique to this taxon.

IUCN listed species
Adinandra forbesii Baker f. (Pentaphyllaceae) Near Threatened
Eight widely scattered specimens (five adult and three young) were recorded in the Lower Montane Rain Forest near Bilbilokabip especially along drainage lines. No threat present at the moment. In other parts of PNG, especially the Oriomo River area, Western Province, it is regarded as an occasional timber species and most known populations in this area have suffered from logging activities over recent years (Oldfield et al. 1998). Traded under the name 'Oriomo Redwood'.

Myristica globosa Warb. subsp. *globosa* (Myristicaceae) Near Threatened
A widely distributed taxon in PNG and the Solomon Islands but never common. Eighteen widely scattered specimens were recorded along creeks in the Lower Montane Rain Forest near Bilbilokabip. Eight of these specimens were adult plants, three were young plants and seven were seedlings. No threat present at the moment. In other parts of PNG it is sometimes logged for its timber and traded under the name 'Penarahan' (Oldfield et al. 1998).

Comments on phenology
Fewer plants were flowering and fruiting at Minni Camp than at Tupnonbil. This pattern is in keeping with the view of other authors (Paijmans 1976, Grubb and Stevens 1985, Takeuchi 2007) who described a similar pattern of phenological variation at other localities. However without doing a more detailed survey of plant species of the areas around Bilbilokabip and Minni Camp at different seasons it is impossible to state that plant diversity is lower at the higher elevation camp.

Most tropical plants, especially woody plants, produce new leaves and flowers in bursts rather than continuously and also show seasonal variation in phenology (van Schaik et al. 1993, Reich 1995). The view that plant species can reduce predation by synchronizing their phenological activity has been recorded in many tropical rain forests (Reich 1995). This may account for the many *Syzygium* and *Garcinia* fruit that were found on the forest floor during this survey. Irradiance also plays an important role in plant phenology in rain forests with peaks in irradiance usually accompanied by peaks in leaf flush and flowering (van Schaik et al. 1993). Overall, flowering and fruiting were very poor during the survey period impacting on the recording of taxa and for collecting fertile material for identification purposes.

Conservation recommendations

The rainforest vegetation around Tabubil is under severe pressure by the local people, for subsistence farming and for construction timber. Large areas around Tabubil that were relatively intact rainforest a mere 15 years ago are now devoid of vegetation. A possible response to this problem is to develop a management plan wherein a restriction is placed on removal of vegetation above a certain elevation around Tabubil. This will not only help in protecting the catchment area for the smaller creeks and other drainage lines that provide water to local communities, but it will also protect the general habitat in the broad sense.

The Ericoid Scrub habitats in the Hindenburg Wall area, and throughout the mountains of PNG, are frequently targeted by exploration and telephone companies for the building of survey and construction camps because they provide scarce natural open areas. The old exploration camp at Kawarobip was constructed in the Ericoid Scrub there. The biodiverse Ericoid Scrub is an ecologically sensitive area containing a high number of rare and undescribed taxa and contractors should be made aware of its sensitivity and uniqueness in an effort to reduce impacts as much as possible in an effort to protect this unique plant community.

The forests of the Hindenburg Wall have an exceptionally rich orchid and ericoid (e.g. *Rhododendron, Vaccinium*) flora. Based on this recent survey, the possibility of finding many more new distribution records, rediscoveries and species new to science is a very real possibility.

To assess in greater detail the biodiversity of the Hindenburg Wall area, basic biodiversity surveys should continue. Additional sites need to be surveyed to establish the status of ecologically sensitive areas, especially in the midmontane (1,500–2,800 m) and karst areas that were not surveyed during this expedition. There is little doubt that investigation of the karst areas will drastically increase the number of species known from this region. Many species are endemic to karst environments, which in the Malesian palaeotropics are synonymous with floristic rarity and endemism (Whitmore 1984, Clements et al. 2006, Takeuchi 2011).

Efforts to declare the Hindenburg Wall region as a World Heritage Area are a crucial step towards protecting the high biodiversity of this area, one that is unique in so many ways.

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Preparing botanical specimens at Bilbilokabip camp. *(Photo F.Venter)*

Rhododendron sp. nov. discovered on the slopes of Mt Minni. *(Photo F.Venter)*

CHAPTER 3

ANTS & SCOLYTINE BEETLES

Andrea Lucky, Leeanne E. Alonso, Eli Sarnat and Jiri Hulcr

Summary

We surveyed ants in the Hindenburg Wall area of Western Province, Papua New Guinea to assess their diversity and endemism in disturbed and intact forested sites. We sampled at seven sites ranging from 350 m above sea level (asl) to approximately 1,770 m asl. Overall diversity was high, with 172 species belonging to 54 genera in eight subfamilies encountered. Of these, more than 15% (26 species) appear to be new to science. Nine species (7%) are introduced in Papua New Guinea, and six of these are recognized as globally invasive species. All of the invasive species were confined to human-disturbed areas near Tabubil; not a single known introduced species was encountered in intact forest farther from human disturbance. Given the utility of ants as indicators of ecosystem disturbance, the general lack of introduced species in the forested areas away from Tabubil town suggests that these habitats remain substantially intact and efforts should be made to retain the integrity of forest adjacent to the highly impacted Tabubil area. In addition to ants, we also sampled scolytine beetles at these sites and found 15 species, seven of which are likely new to science. Based on these findings, and in light of the threats this area faces in terms of human disturbance and expansion, natural resource extraction and introduced species, we recommend that conservation measures, including progress towards declaration of the Hindenburg Wall as a World Heritage Area, be taken in this unique and diverse forested area.

Introduction

Ants

With over 15,000 described species of ants in the world and a social lifestyle consisting of colonies ranging in size from just a few to millions of workers, ants are a dominant force in all terrestrial ecosystems, especially tropical rainforests (Holldobler and Wilson, 1990). They are important members of the ecosystem, with high biomass and population size, and they provide key ecological functions such as aerating and turning soil, dispersing plant seeds, consuming dead animals, and controlling pest insects.

Features of ants that are especially useful for conservation planning include: 1) their ubiquity in most terrestrial environments, 2) they are easily sampled in sufficiently high numbers for statistical analysis in short periods of time (Agosti et al. 2000), 3) they are sensitive to environmental change (Kaspari and Majer

2000), and 4) they are indicators of ecosystem health and of the presence of other organisms, due to their numerous symbioses with plants and other animals (Alonso 2000).

In Papua New Guinea (PNG) and surrounding archipelagos alone, more than 800 species of ants belonging to 88 genera are known, and estimates of new species suggest that the true number of species in this region is 20–30% higher (AntWeb). The highest ant diversity in PNG has been reported from tropical moist forests at low and mid-elevations. Diverse and commonly encountered ants include the genera *Camponotus, Crematogaster, Polyrhachis, Pheidole, Strumigenys* and *Tetramorium.* Other characteristic Melanesian ant genera that are often locally abundant are *Anonychomyrma, Leptomyrmex, Lordomyrma, Philidris, Podomyrma* and *Rhytidoponera.*

Scolytine beetles
Scolytine beetles, generally known as bark and ambrosia beetles, are often found in the same habitats, and can be collected using similar methods. Since these beetles are ecologically and economically important, we include them as part of this chapter.

Scolytine beetles are one of the most diverse, and at the same time most ecologically and economically important, groups of beetles. There are an estimated 7,500 species, but the undescribed diversity may be substantially higher. There are invasive species that occur in nearly every patch of forest and backyard around the word, yet there are also several thousand rare rainforest species that have been seen only once.

Scolytine beetles are excellent bioindicators for several reasons: 1) since the group contains many economically important pests, its taxonomy has been relatively well studied, 2) scolytine beetles are relatively easy to catch with traps, 3) it is well known which species are invasive around the world, and which are not, 4) they have fascinating biology, captivating for both academics as well as the public. Bark beetles include some of the most destructive pests of forests in the world, and some of the most widespread invasives. But they also include species with bizarre life strategies. There are fungal farmers, which have been cultivating fungal gardens in miniature caves in wood for 60 million years. There are unusual reproduction strategies: in many species, females produces many daughters and only one son, and these all mate among themselves. Many species are no bigger than a pin head, but when magnified, they look like beetle-teddy-bears: being 'furry', with large eyes and ear-shaped antennae.

Bark and ambrosia beetles of Papua New Guinea are unusually diverse (the total species count is unknown, but certainly over 700). Beetles from the lowland rainforests have been well studied and there are probably few undiscovered species there. In contrast beetle communities at high altitudes in PNG remain essentially unknown. As the island of New Guinea is increasingly deforested and also increasingly inundated by invasive beetle species, it is critical to document the native species that occur in intact upland rainforest habitats.

Methods

Survey sites
Ants and beetles were sampled at two locations near the Hindenburg Wall:

Bilbilokabip (February 14–21, 2013)
Bilbilokabip (5.12033° S, 141.2512° E; 1,770 m asl) is a small hamlet located in the Tupnonbil area near the base of the Hindenburg Wall in the Hindenburg Range. The hamlet is used by its owners from Bultem when they visit the area to hunt and tend their taro gardens. The forest was mostly undisturbed moist, mossy Lower Montane Rain Forest with many *Pandanus* trees and epiphytes (see Chapter 2 for more details). Several characteristics of this site are likely to have influenced the composition of the ant and beetle fauna, as well as our ability to sample the communities thoroughly. The weather was overcast and rainy most of the time, and temperatures at this elevation remain cool year-round. The forest floor was constantly saturated with moisture and most surfaces were covered with moss. Dead vegetation rotted very quickly, thus leaf litter was less common than at lower elevation sites, and nesting sites such as sticks or logs were more ephemeral. Our primary sampling method (leaf litter sifting), was therefore less productive than at other sites, and we instead relied heavily on actively searching for ant nests.

Tabubil and vicinity
Ants and beetles were collected at six sites ranging from 280–900 m asl in and around Tabubil town. Most of the sites sampled were regrowth of old gardens and secondary forest but some intact patches of riparian forest adjacent to streams were sampled.

See Table 1 for descriptions, locations, and sampling dates for each of the seven sampling sites near Tabubil.

Table 1. Ant collection localities in the Hindenburg Wall area in Western Province, Papua New Guinea.

Site	Dates collected (2013)	Habitat type	Latitude	Longitude	Elevation (m)
Bilbilokabip	February 14-21*	wet pre-montane forest	5.12033	141.2512	1,770
Dablin Creek	February 14, March 2	secondary forest	5.21508	141.2318	909
Upper Umansim Stream	February 15, February 27	regrown taro gardens, secondary forest on hill	5.3328	141.278	350–450
Lower Umansim Stream	February 24,	disturbed riparian forest	5.33395	141.2775	350
Tabubil town	February 22–March 3	disturbed riparian, urban gardens	5.26569	141.2199	546
Yemun Wok	February 26,	secondary riparian forest	5.3871	141.2972	<500
Tulenbeng Wok	February 28,	secondary forest	5.3082	141.2528	<450

**Ants were sampled by Wallace Takendu February 14–15, by Leeanne Alonso February 16–21.*

Ants
Bilbilokabip
Sampling at Bilbilokabip was conducted by Leeanne Alonso with assistance from Maltex Erisam, Kops Namabon and Wallace Takendu. Ant activity was extremely low, reflecting the cool temperatures and prevalent rain at this site. Sampling techniques therefore focused on detecting nesting sites inside rotting logs and *Pandanus* stumps, and under moss that covered the trunks and branches of trees. Most specimens were obtained by using a bush knife (machete) to open rotting logs to extract the ant colonies inside. Ant foragers and colonies were collected primarily in soil, under moss or in stumps. Carton tunnels, made of fragments of organic material to protect foraging trails on tree trunks, were also useful cues for finding ant species, principally in the genus *Philidris*. Additional ants were found nesting under stones, foraging on ground, litter, tree trunks and understory plants, as well as in ant-plants (*Myrmecodia* spp.), epiphytic plants with a modified swollen stem that may house colonies of many different genera of ants. Collections were made in the forest along three principal trails within 1 km to the north, south and east of the hamlet.

We had planned to use the Ants of the Leaf Litter (ALL) protocol (Agosti et al. 2000) at Bilbilokabip since it is the best method for collecting very small ants that live in the leaf litter or in the soil and are otherwise difficult to detect in the forest. However we did not have access to a proper leaf-litter sifter, and had only 6 maxi-Winklers and no mini-Winklers. We improvised a sifter using a plastic shopping basket with 2 cm x 1 cm square holes in all sides and in the bottom (see photograph). This worked fairly well but was not as efficient at cutting up leaf litter and sifting out small insects, a problem compounded by the fact that leaf

litter at Bilbilokabip was extremely wet and heavy, which made sifting using the basket difficult because ants and other insects tended to stick to the leaves.

Despite these problems we implemented a highly modified leaf litter/Winkler sifting protocol. We established four forest transects perpendicular to the three trails and collected samples of leaf litter at approximately 10 m intervals (20 X 1 m^2 collections per transect). These 20 leaf litter samples per transect were combined and carried in plastic bags back to camp, where we sifted sample using the basket with a white tray positioned beneath the basket. This sifting method broke up large leaves and allowed debris and invertebrates including ants to fall through the holes into the tray. The (very wet) sifted leaf litter was then placed into two small mesh sacks which were placed into a maxi (full sized) Winkler extractor (cotton bag; see photograph). Ants then would run out of the litter and the mesh sack and fall to the bottom of the extractor bag into a collecting cup of 95% ethanol. The Winkler extractors were hung in the field lab for 48 hours. After 48 hours the ethanol sample was removed from the Winkler extractor and leaf litter was discarded into the forest.

Tabubil area
Sampling in the secondary forests around Tabubil was conducted by Leeanne Alonso with help from local field assistants: Noah Tameng, Michael Borok and Joshaia Betkon. Ants were much more active than at Bilbilokabip and were collected predominantly by searching actively for nests in rotting logs, under bark on trees, and from the soil, as well as for foraging workers on the ground and on vegetation, as well as from nests. Ants were also collected using the modified leaf litter/Winkler sifting protocol described above. At these six sites 10–20 x 1 m^2 leaf litter samples were collected randomly (not along a transect). A total of ten samples were collected, and ten Winkler extractors were hung for 48 hours at the team house in Tabubil. At the Upper Umansim site ants were also collected from a *Macaranga* sp., a small tree with a hollow trunk that houses ants. See Table 2 for details of the Winkler/leaf litter samples collected from all ant sampling sites.

Identifications were made to the species level wherever possible based on comparisons with museum material from the Los Angeles County Museum (LACM) and Philip S. Ward (PSWC) collections, and through consultation with taxonomists and published literature. New species designations were assigned conservatively, and we assessed species as new to science only if they belonged to groups for which the taxonomy is well resolved in New Guinea. Many additional new species are expected among less well-resolved groups (e.g. *Hypoponera, Pheidole, Vollenhovia, Carebara, Myrmecina, Polyrhachis*). Special consideration was given to determining whether species were native or introduced in order to assess the potential impact of invasive species on this area. See Table 3 for a summary of introduced and invasive species encountered at all sampling sites.

Beetles
Scolytine beetles (bark and ambrosia beetles) were collected by several of the same methods used for surveying ants: leaf litter (Winkler) sampling and hand collecting in soil, leaf litter and rotten logs. Additionally, we hung ethanol-lure baited traps in trees. These traps were constructed from 2 litre soda bottles with one large window cut from one side. The capped bottles were hung upside-down and the base filled with ethanol, which acts as both an attractant and a preservative for the beetles.

Table 2. Winkler leaf litter samples collected during the Hindenburg Wall survey.

Leaf litter sample	Site	Habitat description	Date litter collected	Date sample removed
1	Dablin Creek	Steep forest slope along creek	14 Feb	16 Feb
2	Upper Umansim Stream	Secondary forest	15 Feb	17 Feb
3	Bilbilokabip	Cool, wet, mossy forest. East Trail	16 Feb	18 Feb
4	Bilbilokabip	Cool, wet, mossy forest. East Trail	17 Feb	19 Feb
5	Bilbilokabip	Cool, wet, mossy forest. South Trail	18 Feb	20 Feb
6	Bilbilokabip	Cool, wet, mossy forest. North Trail	19 Feb	21 Feb
7	Lower Umansim Stream	Disturbed riparian forest along river	24 Feb	26 Feb
8	Lower Umansim Stream	Disturbed riparian forest across river	24 Feb	26 Feb
9	Tabubil Town	Disturbed riparian forest	26 Feb	28 Feb
10	Yemon Wok	Secondary forest	26 Feb	28 Feb
11	Yemon Wok	Secondary forest	26 Feb	28 Feb
12	Upper Umansim Stream	Secondary forest	27 Feb	29 Feb
13	Tulenbeng Wok	Disturbed secondary forest	28 Feb	30 Feb
14	Dablin Creek	Steep riparian forest slope along creek	2 March	4 March

Table 3. Introduced ant species in the Hindenburg Range and around Tabubil in Western Province, Papua New Guinea. Asterisks indicate globally invasive ant species.

Locality name	Ants collected
Dablin Creek	*****_Monomorium pharaonis_
Upper Umansim Stream	*****_Cardiocondyla minutior_ _Technomyrmex vitiensis_
Lower Umansim Stream	*****_Tapinoma melanocephalum_
Tabubil Town	*****_Monomorium floricola_ *****_Anoplolepis gracilipes_ *****_Tapinoma melanocephalum_ *****_Tetramorium bicarinatum_ _Technomyrmex cf. albipes_ _Iridomyrmex anceps_
Yemun Wok	*****_Tapinoma melanocephalum_ *****_Monomorium floricola_
Tulenbeng Wok	*****_Tapinoma melanocephalum_ _Iridomyrmex anceps_

An ant, *Anonychomyrma* cf. *scrutator*, emerges from a *Macaranga tanarius* tree. *(Photo S.J.Richards)*

Winkler traps set up under cover at Bilbilokabip. *(Photo L.E .Alonso)*

Results

Ants

A total of 172 ant species belonging to 54 genera in eight subfamilies were documented. Of these, 26 species (15%) are new to science. The greatest diversity was found in the subfamily Myrmicinae (23 genera and 90 species), and in particular within the genus *Pheidole*. Among the 26 species of *Pheidole,* 15 are likely new to science.

Common components of the ant fauna collected on this survey include dolichoderine ants in the genera *Anonychomyrma* and *Philidris,* which were often present in high numbers, as well as the formicine species *Nylanderia vaga* and *Camponotus aureopilus.*

Ants considered rare based on previous PNG surveys included the amblyoponine *Mystrium camillae,* the myrmicines *Vombisidris bilongrudi, Dacetinops ignotus* and an undescribed species of *Lordomyrma*.

See Table 4 for a list of ant species collected on this survey of the Hindenburg Wall area.

Bilbilokabip

A total of 64 ant species were collected at this site, 13 (20%) of which are likely new to science. This diversity of species new to science was driven in large part by the genus *Pheidole,* to which 11 of these new species belong. No introduced ant species were encountered at this site. Several ant species were common in rotting logs and under moss, including *Amblyopone australis, Camponotus aureopilus, Strumigenys spp.*, *Pheidole* spp. and *Hypoponera* spp. Commonly encountered forest floor foragers included the ectatommine species *Rhytidoponera* cf. *rotundiceps*, as well as the ponerine species *Odontomachus simillimus* and *Pachycondyla croecicornis.* Notable finds include an undescribed species of the rarely collected, cryptic ant genus *Lordomyrma,* as well as a remarkable diversity of *Pheidole* composed of 14 species, 11 of which are likely new to science.

Twenty-seven ant species were collected at both Bilbilokabip and Tabubil area sites, including four species of *Hypoponera,* several arboreal species in the Dolichoderinae (*Anonychomyrma* cf. *scrutator*. and *Philidris* spp.), and soil / leaf litter dwelling species in the genus *Carebara.*

Tabubil Area

A total of 135 ant species were collected around Tabubil, 12 (9%) of which are likely new to science. Nine introduced species were encountered in collections around Tabubil, and in many cases multiple introduced species were found at a single site. Six of these introduced species are known global invasives. Dolichoderine ants were particularly prominent around Tabubil. An abundant ant making trails on the ground at the Tabubil site and also at the Lower Umansim Stream site was *Leptomyrmex flavitarsus*. Species of *Anonychomyrma* and *Philidris* were very common on tree trunks and vegetation. Common forest floor foragers included the ponerine species *Odontomachus simillimus* and *Pachycondyla croecicornis,* which were also common at the higher elevation site.

Beetles

In total, we collected 15 species of scolytine beetles, seven of which are likely new to science. Many of the species here are identified to genus only as no identification keys exist for these organisms. While these are likely to be new to science (especially the tiny *Coccotrypes spp.*), their status as new species awaits confirmation by comparison with major reference collections. See Table 5 for a complete list of scolytine species collected on this survey.

Seven species were collected at Bilbilokabip and 11 from the Tabubil area. There was very little species overlap between the sites, with only 2 species encountered in both places: *Arixyleborus puberulus* and *Coccotrypes cyperi*. Generic diversity encountered at each site did not differ (six genera at each site), but in the Tabubil area there was one genus with unusually high species-level diversity: the seed-feeding genus *Coccotrypes*. There were several minute *Coccotrypes* spp. that the author has not seen before. These are likely to be new species, and potentially a new genus.

Table 4. Ant species collected in the Hindenburg Wall area and the Tabubil area in Western Province, Papua New Guinea.

Subfamily	Species (I=introduced, *=new to science)	Bilbilokabip	Tabubil area
Amblyoponinae	*Amblyopone australis*	X	
Amblyoponinae	*Mystrium camillae*		X
Amblyoponinae	*Prionopelta* cf. *kraepelin*		X
Amblyoponinae	*Prionopelta majuscula*		X
Cerapachyinae	*Cerapachys* cf. *flavaclavatus*		X
Dolichoderinae	*Anonchomyrma* cf. *scrutator*	X	X
Dolichoderinae	*Anonchomyrma* ems06**		X
Dolichoderinae	*Dolichoderus* ems01		X
Dolichoderinae	*Iridomyrmex anceps (I)*		X
Dolichoderinae	*Leptomyrmex flavitarsus*		X
Dolichoderinae	*Leptomyrmex fragilis*		X
Dolichoderinae	*Ochetellus* ems01, nr. *glabrior*	X	
Dolichoderinae	*Philidris brunnea*	X	
Dolichoderinae	*Philidris* cf. *cordata*	X	X
Dolichoderinae	*Philidris* ems06	X	X
Dolichoderinae	*Philidris* ems10	X	X
Dolichoderinae	*Philidris* ems11	X	X
Dolichoderinae	*Tapinoma melanocephalum (I)*		X
Dolichoderinae	*Technomyrmex albicoxis*		X
Dolichoderinae	*Technomyrmex* cf. *albipes (I)*		X
Dolichoderinae	*Technomyrmex vitiensis (I)*		X
Ectatomminae	*Rhytidoponera* cf. *araneoides*		X
Ectatomminae	*Rhytidoponera* cf. *rotundiceps*	X	
Ectatomminae	*Rhytidoponera* cf. *strigosa*		X
Ectatomminae	*Rhytidoponera nexa*		X
Formicinae	*Acropyga acutiventris*		X
Formicinae	*Acropyga ambigua*		X
Formicinae	*Acropyga pallida*		X
Formicinae	*Anoplolepis gracilipes (I)*		X
Formicinae	*Camponotus aureopilus*	X	X
Formicinae	*Camponotus* ems07		X
Formicinae	*Camponotus quadriceps*		X
Formicinae	*Camponotus vitreus*		X
Formicinae	*Nylanderia* cf. *bourbonica*		X
Formicinae	*Nylanderia* cf. *glabrior*	X	X
Formicinae	*Nylanderia* ems01		X
Formicinae	*Nylanderia* ems01, nr. *vaga*	X	
Formicinae	*Nylanderia* ems02		X
Formicinae	*Nylanderia nuggeti*		X
Formicinae	*Paraparatrechina parapara,* cf. *lecamopteridis*	X	X

Subfamily	Species (I=introduced, *=new to science)	Bilbilokabip	Tabubil area
Formicinae	*Polyrachis bellicosa*	X	X
Formicinae	*Polyrachis* cf. *nitidiventris*		X
Formicinae	*Polyrachis* ems18, nr. *arcuata*		X
Formicinae	*Polyrachis* ems19		X
Formicinae	*Polyrachis* ems21		X
Formicinae	*Polyrachis* nr. *rastellata*	X	X
Formicinae	*Polyrachis undet. 1*	X	
Formicinae	*Pseudolasius* cf. *breviceps*		X
Formicinae	*Pseudolasius* cf. *waigeuensis*		X
Myrmicinae	*Adelomyrmex biroi*		X
Myrmicinae	*Aphaenogaster quadrispina*		X
Myrmicinae	*Cardiocondyla minutior (I)*		X
Myrmicinae	*Cardiocondyla nuda*		X
Myrmicinae	*Cardiocondyla thoracia*		X
Myrmicinae	*Cardiocondyla wheeleri*	X	X
Myrmicinae	*Carebara armata*		X
Myrmicinae	*Carebara atoma*	X	X
Myrmicinae	*Carebara* ems01	X	X
Myrmicinae	*Carebara* ems05		X
Myrmicinae	*Carebara* ems06	X	
Myrmicinae	*Carebara* ems07	X	
Myrmicinae	*Carebara* ems08		X
Myrmicinae	*Carebara minima*		X
Myrmicinae	*Carebara subreptor*		X
Myrmicinae	*Crematogaster dahlii*		X
Myrmicinae	*Crematogaster elegans*	X	X
Myrmicinae	*Crematogaster flavitarsus*	X	X
Myrmicinae	*Crematogaster paradoxa*		X
Myrmicinae	*Dacetinops ignotus*		X
Myrmicinae	*Eurhopalothrix* ems01*		X
Myrmicinae	*Eurhopalothrix punctata*		X
Myrmicinae	*Lordomyrma* ems02*, cf. *cryptocera*		X
Myrmicinae	*Lordomyrma* ems08*	X	
Myrmicinae	*Mayriella sharpi*		X
Myrmicinae	*Meranoplus armatus*		X
Myrmicinae	*Monomorium australicum*		X
Myrmicinae	*Monomorium* cf. *subtilis*	X	
Myrmicinae	*Monomorium floricola (I)*		X
Myrmicinae	*Monomorium pharaonis (I)*		X
Myrmicinae	*Myrmecina* ems08*		X
Myrmicinae	*Myrmecina* ems09*		X
Myrmicinae	*Myrmecina* ems10*	X	
Myrmicinae	*Myrmecina* ems11*		X

Subfamily	Species (I=introduced, *=new to science)	Bilbilokabip	Tabubil area
Myrmicinae	*Odontomachus* cf. *animosus*		X
Myrmicinae	*Pheidole* cf. *distincta*	X	X
Myrmicinae	*Pheidole elegans*		X
Myrmicinae	*Pheidole* emsm125	X	
Myrmicinae	*Pheidole* emsm137		X
Myrmicinae	*Pheidole* emsm140*	X	
Myrmicinae	*Pheidole* emsm142*	X	
Myrmicinae	*Pheidole* emsm143*	X	
Myrmicinae	*Pheidole* emsm144*	X	
Myrmicinae	*Pheidole* emsm145*	X	
Myrmicinae	*Pheidole* emsm146*		X
Myrmicinae	*Pheidole* emsm147*	X	
Myrmicinae	*Pheidole* emsm148*	X	X
Myrmicinae	*Pheidole* emsm149*	X	
Myrmicinae	*Pheidole* emsm150*, nr. *sexdentata*		X
Myrmicinae	*Pheidole* emsm151*	X	
Myrmicinae	*Pheidole* emsm152*	X	
Myrmicinae	*Pheidole* epem033*		X
Myrmicinae	*Pheidole* epem060		X
Myrmicinae	*Pheidole* epem069, cf. *distincta*	X	X
Myrmicinae	*Pheidole* epem085		X
Myrmicinae	*Pheidole* epem109*, nr. *barumtuan*		X
Myrmicinae	*Pheidole* epem118*	X	
Myrmicinae	*Pheidole fuscula*		X
Myrmicinae	*Pheidole gambogia*		X
Myrmicinae	*Pheidole melanogaster*		X
Myrmicinae	*Pheidole sexdentata*		X
Myrmicinae	*Pheidologeton* cf. *affinis minor*		X
Myrmicinae	*Podomyrma alae*		X
Myrmicinae	*Podomyrma gastralis*		X
Myrmicinae	*Podomyrma laevissima*		X
Myrmicinae	*Pristomyrmex minusculus*		X
Myrmicinae	*Rhoptromyrmex melleus*		X
Myrmicinae	*Rhoptromyrmex wroughtonii*		X
Myrmicinae	*Solenopsis papuana*		X
Myrmicinae	*Strumigenys chyzeri*		X
Myrmicinae	*Strumigenys disarmata*	X	X
Myrmicinae	*Strumigenys* ems21	X	
Myrmicinae	*Strumigenys* ems26*		X
Myrmicinae	*Strumigenys* ems27*	X	X
Myrmicinae	*Strumigenys* ems28*, nr. *yasumatsui*	X	
Myrmicinae	*Strumigenys ferocior*		X
Myrmicinae	*Strumigenys kyroma*	X	X

Subfamily	Species (I=introduced, *=new to science)	Bilbilokabip	Tabubil area
Myrmicinae	*Strumigenys mayri*		X
Myrmicinae	*Strumigenys wallacei*		X
Myrmicinae	*Tetramorium bicarinatum (I)*		X
Myrmicinae	*Tetramorium fulviceps*		X
Myrmicinae	*Tetramorium politum*	X	
Myrmicinae	*Tetramorium pulchellum*		X
Myrmicinae	*Tetramorium sculptatum*	X	
Myrmicinae	*Vollenhovia* ems03		X
Myrmicinae	*Vollenhovia* ems05	X	
Myrmicinae	*Vollenhovia* ems18	X	
Myrmicinae	*Vollenhovia nitida*		X
Myrmicinae	*Vollenhovia oblonga*		X
Myrmicinae	*Vombisidris bilongrudi*	X	
Ponerinae	*Anochetus graeffei*		X
Ponerinae	*Cryptopone butteli*		X
Ponerinae	*Cryptopone* cf. *testacea*		X
Ponerinae	*Cryptopone fusciceps*		X
Ponerinae	*Diacamma rugosum*		X
Ponerinae	*Hypoponera* cf. *biroi*		X
Ponerinae	*Hypoponera* ems30	X	X
Ponerinae	*Hypoponera* ems31	X	
Ponerinae	*Hypoponera* ems32	X	X
Ponerinae	*Hypoponera* ems33		X
Ponerinae	*Hypoponera* ems34		X
Ponerinae	*Hypoponera* ems35	X	X
Ponerinae	*Hypoponera* ems36	X	X
Ponerinae	*Hypoponera pruinosa*		X
Ponerinae	*Leptogenys* ems03*	X	
Ponerinae	*Myopias* cf. *laevigata*		X
Ponerinae	*Myopias* cf. *tenuis*		X
Ponerinae	*Myopias* ems10	X	
Ponerinae	*Myopias* ems11	X	
Ponerinae	*Odontomachus simillimus*	X	X
Ponerinae	*Odontomachus tetaceous*		X
Ponerinae	*Odontomachus tyrannicus*		X
Ponerinae	*Orectognathus longispinosus*	X	
Ponerinae	*Pachycondyla* cf. *aequalis*		X
Ponerinae	*Pachycondyla* cf. *australis*		X
Ponerinae	*Pachycondyla croececornis*	X	X
Ponerinae	*Pachycondyla exarata*		X
Ponerinae	*Pachycondyla* nr. *australis*	X	
Ponerinae	*Pachycondyla simillima*		X
Ponerinae	*Ponera alpha*		X

Subfamily	Species (I=introduced, *=new to science)	Bilbilokabip	Tabubil area
Ponerinae	*Ponera* ems07		X
Ponerinae	*Ponera* ems12	X	
Proceratiinae	*Proceratium* cf. *papuanum*	X	
TOTALS			
8	**172**	**64**	**135**
# New Species	**26 (15.1%)**	**13 (20.0%)**	**12 (8.9%)**
# Introduced Species	**9**	**0**	**9**

**EMS= Eli M. Sarnat catalogue number; EMSM= Eli M. Sarnat morphospecies name; EPEM=Evan P. Economo morphospecies name

Beetles continued

Our different collection methods collected entirely different assemblages of scolytine beetles. Using leaf litter sampling we collected seven species in two genera (dominated by six species in the genus *Coccotrypes).* In contrast, the combination of hand collecting and ethanol traps resulted in eight species in seven different genera. The difference in diversity between these methods suggests that leaf litter sampling selects for specialized scolytines (seed feeding or dead twig nesting), whereas ethanol trapping is broadly effective across different groups.

Table 5. Scolytine (bark and ambrosia) beetle species collected at Bilbilokabip and in the Tabubil area from leaf litter (Winkler) samples (L), ethanol-lure traps (T) and hand collections (H). Asterisks indicate species that are likely new to science.

Species	Bilbilokabip	Near Tabubil	Collection method
Ambrosiophilus mogia	X		T
Arixyleborus puberulus	X	X	T, H
Coccotrypes cyperi	X	X	L
Coccotrypes JH01*		X	L
Coccotrypes JH02*		X	L
Coccotrypes JH03*		X	L
Coccotrypes JH04*		X	L
Coccotrypes JH05*		X	L
Cyclorhipidion apicipenne	X	X	T, H
Cyclorhipidion spurlinum	X		T
Diuncus adossuarius	X		T
Microperus perparva		X	H
Ozopemon JH01*		X	H
Platypus JH02*	X		T
Xyleborinus exiguus		X	L
TOTAL SPECIES 15	**7**	**11**	

Discussion

Ants

The ant species richness documented during this survey can be compared cautiously to that observed during two RAP biodiversity surveys of the Muller Range and Nakanai Mountains (Lucky et al. 2011a, 2011b). Although the collecting methods and time spent collecting are not equivalent, and the absence of a proper sifter and fewer Winkler extractors required us to modify techniques used in previous surveys, the time spent collecting at Bilbilokabip was comparable to that spent at each site during previous RAP surveys (6–8 days), and the elevations at Bilbilokabip (1,770 m) and Sawetau (Muller Range; 1,300–1,600 m) are not dissimilar.

Generic diversity in the Hindenburg wall area (54 genera) was comparable to that of the Muller Range (57 genera), but species-level diversity encountered was much higher in the latter (237 species vs. 172). This difference is likely a result of differences in sampling techniques. Despite the lower species diversity in the Hindenburg Wall area, the number of ant species new to science is comparable (26, compared to 29 in the Muller Range. There is an overall higher proportion of new species found in the Hindenburg Wall area (15% vs. 12% in the Muller Range). No introduced species of ants were collected at either of these forested sites, indicating the intact state of these habitats.

Comparison of ants new to science from collections at Bilbilokabip in the Hindenburg Wall area to those encountered at Sawetau in the Muller Range reveals some differences: of the 64 ant species collected at Bilbilokabip, a very high 20% (13 spp.) is likely new to science. At Sawetau, in contrast, only 15% (12 of 70 spp.) are likely new. The diversity of new species from this survey of the Hindenburg Wall is comparable to that encountered during a recent survey of the Ants of the Nakanai Mountains in New Britain (Lucky et al. 2011b), where 140 species were encountered, 44 of which were undescribed (31%). We expect that more complete surveys of the Hindenburg wall area, using standard equipment and techniques, would reveal the true diversity of ants to be more similar to that of the Muller Range, where a recent survey encountered 237 species of ants, 31 (13%) of which were new to science (Lucky et al. 2011a).

Beetles

The scolytine beetles collected at during this survey Bilbilokabip and in the Tabubil area indicate a unique community of beetles unlike other areas sampled in PNG (i.e. Hulcr et al. 2007, Hulcr and Cognato 2013). Some of these species are known from collections elsewhere in PNG, but from only a handful of specimens. In contrast, our results indicate they are common at our sampling sites. As far as we were able to identify, all but four species appear to be endemic to the island.

In summary, scolytine beetles collected from these surveys represent unusual communities. Notably, these species are very different from those in scolytine communities in PNG lowlands, where most species are well known to science, and which are increasingly homogenised by globally invasive generalists.

Diversity and new species

The ant species diversity encountered during the Hindenburg survey was 172 species, 26 of which are likely to be new to science. Fifteen species of scolytine beetles were collected, seven of which are likely to be new. Compared to other sites sampled for ants and scolytine beetles in Papua New Guinea (i.e. Lucky 2011a, 2011b, Hulcr et al. 2007, Hulcr and Cognato 2013), new ant and beetle species make up a considerable proportion of the ant fauna collected during this survey (15%). This high proportion likely reflects a combination of this area's high plant diversity in forested ecosystems, wet climate and relatively high elevation.

Invasive species

No non-native ant species were encountered at Bilbilokabip, a relatively intact forest site. This is quite different from the number of introduced ant species encountered around Tabubil (nine species), which is more heavily impacted by humans. Of these nine introduced species, six are known global invasives; the remaining three are not known to be invasives, but are not native to PNG.

In and around Tabubil town itself, six introduced ant species were collected, including four globally invasive ant species and two introduced species. Known global invasives include *Anoplolepis gracilipes* (Yellow

Crazy Ant), *Tapinoma melanocephalum* (Ghost Ant), *Tetramorium bicarinatum* (Pavement Ant) and *Monomorium floricola* (Bicolored Trailing Ant). These ants were abundant throughout the house used as a base in suburban Tabubil, especially in the kitchen and bathroom where they quickly made trails to any food left out or to water. Two species found at the house in Tabubil that are introduced into PNG but not known to be invasive are *Technomyrmex* cf. *albipes* and *Iridomyrmex anceps.*

Four species of globally invasive ants and two species of non-invasive introduced species were encountered away from houses near Tabubil, including in gardens, along creeks and in disturbed forest: *Monomorium pharaonis* (Pharoh ant), *Cardiocondyla minutior* (no common name), *Tapinoma melanocephalum* (Ghost ant) and *Monomorium floricola* (Bicolored Trailing Ant) are global invasives while *Technomyrmex vitiensis* and *Iridomyrmex anceps* are not invasive but introduced to PNG.

Reproductives
A high percentage (~25%) of the ant colonies (49 of 192 hand-collections) sampled at Bilbilokabip had either female or male alates (sexuals) in the nest. However, alates of only a few species were collected at blacklights at night. This suggests that ant colonies at this site prepare their male and female sexuals for mating flights by February, possibly waiting for warmer temperatures or clearer skies in March for their mating flights.

Conservation recommendations

The results of this survey demonstrate that the ant faunas of Bilbilokabip and sites around Tabubil were very different, and this is mainly due to differences in elevation (1,770 m vs. 350–900 m) and associated habitat types and climate. Further, these sites differ dramatically in level of disturbance. Forests sampled around Tabubil were mostly secondary forests that are regrowing on old garden sites. Highly disturbed riparian forests were also sampled along several rivers and creeks. These forests bordered on gardens and homes and thus were exposed to frequent disturbance from people passing through.

One indication of the lack of disturbance in Bilbilokabip is the lack of introduced ants, whereas introduced and invasive ants (three and six species, respectively) appear to be well established in and around Tabubil. Care should be taken to avoid spreading invasive species into the Tupnonbil area and conservation measures should take into account the importance of preventing introduction of especially damaging invasive species such as those classified as global invasives. Invasive ants, including several of the species encountered here, have been shown to have great negative impacts on native ants and other native species (e.g. Berman et al. 2013, O'Dowd et al. 2003, Pacific Invasive Ants Key 2013 http://itp.lucidcentral.org/id/ant/pia/index.html) . One species, *Anoplolepis gracilipes,* is listed among the World's 100 Worst Invasive Alien Species (Global Invasive Species Database: http://www.issg.org/database/species/search.asp?st=100ss). Several introduced and invasive ants appear to be well established around Tabubil, and are likely to have a negative effect on the diversity of native ants as well as on other flora and fauna.

The information collected by the team will be used to fill in gaps in scientific knowledge of the Hindenburg Wall area and to guide conservation efforts in the region. Despite being within approximately 30 km of the Ok Tedi mine, large tracts of forest remain in the Hindenburg Wall area and many new species were discovered during this survey suggesting that the fauna of the region remains under-documented. In contrast the town of Tabubil has grown considerably in the last 30 years and the forests in the immediate vicinity of town have been cleared for gardens. There are many trails and scattered villages throughout the Hindenburg Range and Star Mountains and these provide avenues for the unwitting introduction of invasive ants as people's mobility through the region increases. The movement of invasive ants to the forested areas remote from Tabubil is therefore a significant risk. Similarly migration to Tabubil from outside Western Province and increasing development pose increasing risks for the introduction of invasive species to the Tabubil area.

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Searching for ants in litter. (*Photo L.E .Alonso*)

Using the modified sifter. (*Photo L.E .Alonso*)

CHAPTER 4

BUTTERFLIES

Chris J. Müller

Summary

The Hindenburg Wall and surrounds in Western Province, Papua New Guinea remain poorly known from a biological perspective. A terrestrial ecological study was undertaken by Wildlife Conservation Society (WCS) to document the diversity of various faunistic groups and to examine the potential impacts on terrestrial ecology. This technical report presents the methods and results of the butterfly research component which was undertaken during February 6–25, 2013. 165 butterfly species were recorded during the survey of the study area. Four of these appear to be new to science and a further species is undescribed. Two conservation listed Birdwing species (*Ornithoptera*) were noted during the surveys. Three butterfly species are recorded from Papua New Guinea for the first time and a number of others are newly recorded from Western Province. The highest butterfly diversity was recorded in the vicinity of Tabubil, with 141 species, while only 28 species were recorded at Tupnonbil at the base of the Hindenburg Wall itself. Potential threats to the Hindenburg Wall include habitat loss, waterway contamination and displacement due to invasive species. Mitigations are proposed to reduce the severity of impacts on butterflies, including re-vegetation, and promoting the area for eco-tourism.

Introduction

Butterflies are the most well studied of all invertebrates (Kerr 2001, Dincă et al. 2011) and the majority of species are probably already described (Kitching et al. 2001). New Guinea boasts nearly 1,000 described butterfly species, of which approximately 840 are recorded from Papua New Guinea (PNG) (Tennent 2006). High endemism 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 and Packham 1976, Davies 1990, Davies 2009, Davies et al. 1997, Pigram and Davies 1987) but it is generally circumscribed to comprise a series of stacked volcanic terranes 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 et al. (2013) demonstrated that diversification within *Delias* was mostly of late Miocene/Pliocene age.

Phylogenetic studies of the origins of New Guinea butterflies point to both Australian and Asian ancestries. The geographical distributions of certain genera (e.g., *Tellervo*, *Cressida*) suggest a Gondwanan component to the New Guinea fauna, with closest relatives in South America. The generation of the eastern Indonesian archipelago, particularly the opening/spreading of Wallacea likely allowed faunal interchange between the Oriental and Australian regions. Since Wallacea itself fragmented in a south-easterly direction from the Sundaland margin, much of the butterfly composition in this transition zone is dominated by older Asian taxa, overprinted by more recent invasions from New Guinea (Australian Plate) (Müller and Beheregaray 2010, Müller et al. 2010). 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 the genus *Taenaris*, respectively. They considered the southern zone to span an area from the southern part of the Snow Mountains to the Gulf of Papua. The Star Mountains fall at the junction of this and the Central Cordillera Hill Zone, which can be further subdivided into faunistic zones along its axis.

Collections of Lepidoptera in the region have been scant. It was only after 1870 that penetration of the forbidding New Guinea interior was begun in earnest (Parsons 1998). The naturalist L. M. d'Albertis collected in the Fly River region in 1875. Previously, within mainland New Guinea, the only documented exploits of butterfly collectors in the interior of New Guinea were those of Alfred Wallace (collectors sent by him into the mountains in 1858) and those of d'Albertis and the botanist Odoardo Beccari during 1872–73 into the Arfak Mountains, West Papua. Australian Walter Wilson Froggatt was appointed Assistant Entomologist to the 1885 Australian Geographical Society NG Expedition to the Fly and Strickland Rivers led by explorer H. O. Forbes (Parsons 1998).

In Europe, an ever-increasing interest in New Guinea butterflies lead to sponsorship of various collectors in New Guinea by the wealthy British collector Lord Walter Rothschild in the early 1900's (Parsons 1998). Most of the collections by Alfred Stanley Meek, who was engaged by Rothschild, were in the eastern part of the country and also in the Snow Mountains of Papua Province and were made during the early 1900's (until 1925). The Pratts (Antwerp Pratt and his sons) collected widely in both eastern Papua New Guinea and in both (cuurent) Papua and West Papua Province, Indonesia, periodically from 1901 to 1920. Several other collectors and expeditions visited the central ranges of the New Guinea mainland during this time. In particular, the Dutch Military Expeditions of Netherlands New Guinea (Indonesia) saw numerous trips during the period 1907–1915 (Parsons 1998). That of A. F. R. Wollaston attempted to reach the summit of Mount Carstenz, the highest mountain between the Himalaya and the Andes. Together with C. B. Kloss he reached a little over 3000 m above sea level (asl), collecting 40 butterfly species that were new to science. During the 1930's, four major biological field surveys were carried out in New Guinea by the Archbold Expeditions, financed by American oil millionaire Richard Archbold. These targeted mountainous parts of Dutch New Guinea.

The first documented expeditions to collect Lepidoptera in the remote highlands of the Central Cordillera in western Papua New Guinea were undertaken by W. W. Brandt. Brandt collected extensively in Papua New Guinea between 1949 and 1963. Localities visited proximal to the Star Mountains include Kiunga near sea level and Eliptamin and Feramin in the Telefomin area (both Western Province). During 1970, O. K. McCaw collected some butterflies and other insects near Ok Tedi (Western Province). Some of these are held in the Australian Museum, Sydney. M. J. Parsons visited Telefomin during the 1980's, as did R. Straatman. H. van Mastrigt who compiled a significant collection on butterflies from Indonesian New Guinea, including the Star Mountains (van Mastrigt 1990, van Mastrigt 2000, Morinaka et al.1993). Within the Star Mountains and Hindenburg Range, R. Lachlan collected in the area surrounding Tabubil during the

1990's, his efforts resulting in the discovery of several new species in remote high-altitude areas (Lachlan 1999a, Lachlan 1999b, Lachlan 2000). During 2008, C. Muller briefly visited Kiunga and the Tabubil area seeking new butterfly records. Elsewhere north of the Trans-Fly, Don Sands collected butterflies at Lake Murray in 1973.

Butterflies are increasingly being recognised as valuable environmental indicators, both for their rapid and sensitive responses to subtle habitat or climatic changes and as representatives for the diversity and responses of other wildlife (Duelli and Obrist 2003, Brereton et al. 2011). For example, Kerr et al. (2000) found that butterflies, including Skippers (Hesperiidae), could be used to predict richness among Hymenoptera at a range of study sites in the USA. A greater taxonomic understanding of a particular group increases the chances of plausible correlations with respect to the environmental condition of an area (Thomas 2005), as is the case with butterflies.

While much work has been carried out to determine the conservation status of butterflies globally (Lewis and Senior 2011), for mainland PNG only a proportion of the fauna have been assessed using IUCN criteria (Muller and Tennent in press, Tennent and Muller in press). The main objective of the butterfly survey of the study area was to characterise and document butterfly diversity, distribution and abundance and to identify significant butterfly communities and habitats (e.g. microhabitats) that may be vulnerable.

Methods

Two sites (Tabubil area and Bilbilokabip) were surveyed for approximately six and ten days, respectively. Bilbilokabip was situated at approximately 1,780 m in the Tupnonbil area and transects ranged over a wide area from c. 1,600–2,100 m asl. A network of foot trails connecting widely spaced villages made surveying of the terrain at the base of the Hindenburg Wall possible. The vegetation at this site was dominated by Lower Montane Rain Forest, interspersed with swampy habitats and large clearings dominated by *Pandanus* sp. and various grasses (Poaceae). Abundant swift-flowing creeks dissected the landscape and proved to be the most suitable sites for observing the butterfly fauna, since these places were used as flight paths as well as sources for drinking.

A number of creeks were surveyed in the vicinity of Tabubil, with most time spent at Dablin Creek, where a gravelled road and foot track enabled access along the pipeline supplying water to Ok Tedi Mine, to an altitude of 1,100 m. Lower Montane Rain Forest predominated at the highest point of this site, whereas typical Hill Forest was present at lower altitudes (minimum of 350 m). Creeks were followed upstream from their intersection with the Ok Tedi Mine-Tabubil-Kiunga Road to survey the butterfly fauna. It was necessary to travel for several hundred metres in some instances, to reach pristine vegetation, since much of the forest near the road has been obliterated by settlement activities and mine infrastructure. The abundance of various butterfly foodplants in the families Lauraceae, Euporbiaceae, Myrtaceae, Moraceae and Rutaceae undoubtedly explains the high diversity of butterfly species in the Tabubil area.

Transects

Surveying was carried out along transects, often pre-existing trails and/or following natural features, e.g. along streams and ridges. Some minor clearing of more open glades in the forest was sometimes necessary to optimise the area exploited by sun-loving butterflies. 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 transects and either identified visually on the spot or collected by long handled nets for identification later. A significant proportion of butterflies, especially the larger species, are readily identified visually, often assisted by 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, were employed at most sites and collected samples randomly. In nearly all cases such specimens were released following identification.

At all survey sites, the maximum amount of daylight time was used for field surveying. Allowing for crepuscular species active only during dawn and dusk, surveying was conducted daily from 0900 hrs or earlier, usually returning to base camp at 1800 hrs (but sometimes as late as 1930 hrs). The adults of nearly all butterfly species will fly only during periods of full sunshine; therefore sampling was impeded at times by poor weather conditions. 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. Occasional night forays were conducted in order to locate roosting adult butterflies and early stages.

Flowering plants were always sought, as these are nectar sources for adults of a number of butterfly species. Additionally, mature stems of the vine *Flagellaria indica* (Flagellariaceae) and lawyer palm (*Calamus* sp., Arecaceae) are attractive to adult butterflies of several families and were actively searched for. Many species of butterflies of butterfly are only known to feed as adults from particular canopy trees.

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. Fanie Venter kindly assisted with larval food plant identifications. Since many butterflies in the family Lycaenidae have an association with ants during their early stages (i.e., are myrmecophagous), ant nests and ant congregations were sought in order to better locate the butterfly early stages.

Selected samples were stored in glassine envelopes with the preservatives paradichlorobenzene and chloro-m-chresol. Two legs of each individual sample were stored separately as tissue samples for potential DNA sequence analysis.

Urine baits
Freshly emerged adult males of many butterfly species will imbibe mammal urine that has soaked 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). One proposed explanation is that nitrogen, contained in urine, promote butterfly fitness (Jervis and Boggs 2005). A number of species, representing all families, were attracted to urine baits placed at irregular intervals in open areas during the survey of the study area. In such situations, adults can generally be approached closely allowing reliable identification .

Fruit baits
Fermented pineapple, banana and pawpaw are ideal for attracting nymphaline butterflies, particularly in the subfamilies Amathusiinae and Satyrinae. 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 4m. In some cases, fermented native fruits were found in the field and stored in bags for subsequent bait trapping. For example, certain *Taenaris* species (Nymphalidae), were attracted to the fruits of *Eleocarpus* sp. lying on the ground.

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 upper sides of leaves in various micro-habitats. Once attracted the adults generally 'feed' for long periods, such that hourly checks are adequate.

Additionally, certain butterflies of the family Pieridae (e.g., *Delias* species) were attracted to white paper lures attached by string to sticks and waved vigorously, high in the air, sometimes luring them from as high as the canopy.

Yellow pans
Together with other groups of flying insects, certain butterfly species are attracted to yellow and small species may occasionally be trapped in dishes containing water and detergent. This technique is ineffective for large species, as they are too powerful to break the surface tension of the water and therefore will not succumb to this trapping method.

Taxonomy and nomenclature
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 et al. (2013). Note that only a few butterflies in New Guinea have common names and therefore this report uses standard scientific names.

GIS
All coordinates were recorded WGS84 UTM and correlated with geo-referenced 1:100,000 topographic maps using the software Mapinfo Discover v. 12.

RESULTS

All butterfly species recorded during the Field Surveys are listed in Table 1. Several species were only recorded at one site and others only by single specimens.

Species diversity
A total of 165 butterfly species were recorded during the survey of the study area (Tables 1, 2). The Tabubil area yielded the most species (141), while much fewer species were recorded at Bilbilokabip (28), reflecting a change in diversity with altitude, as noted by Parsons (1998) for butterflies in New Guinea as a whole. The best represented butterfly families were Lycaenidae, with 53 (32.1%) species and Nymphalidae with 50 (30.3%) species. Representatives of all butterfly subfamilies known from PNG were recorded during this survey, with the exception of the subfamily Curetinae, which comprises just one species in the Australian Region, including New Guinea.

Philiris sp. B (Lycaenidae) at rest on foliage. This taxon is known from both Madang Province and West Papua, Indonesia but is as yet undescribed. (*Photo C.J.Müller*)

Table 1. Butterfly species recorded in each survey site of the study area.

Family	Subfamily	Taxon	Authority, Date	Tabubil area (350–1100 m)	Bilbilokabip (~1800 m)
Hesperiiidae	Pyrginae	*Tagiades japetus*	Stoll 1781	X	-
Hesperiiidae	Pyrginae	*Tagiades nestus*	C. Felder 1860	X	-
Hesperiiidae	Coeliadinae	*Allora dolleschalii*	C. Felder 1860	X	-
Hesperiiidae	Coeliadinae	*Hasora discolor*	C. & R. Felder 1859	X	-
Hesperiiidae	Coeliadinae	*Hasora hurama*	Butler 1870	X	-
Hesperiiidae	Trapezitinae	*Toxidia inornata*	Butler 1883	X	X
Hesperiiidae	Hesperiinae	*Notocrypta waiguensis*	Plötz 1882	X	-
Hesperiiidae	Hesperiinae	*Notocrypta renardi*	Oberthür 1878	X	-
Hesperiiidae	Hesperiinae	*Sabera caesina*	Hewitson 1886	X	-
Hesperiiidae	Hesperiinae	*Sabera dobboe*	Plötz 1885	X	-
Hesperiiidae	Hesperiinae	*Sabera expansa*	Evans 1935	X	-
Hesperiiidae	Hesperiinae	*Sabera sp. A (U)*	-	X	-
Hesperiiidae	Hesperiinae	*Mimene miltias*	Kirsch 1877	X	-
Hesperiiidae	Hesperiinae	*Mimene sp. A (U)*	-	X	-
Hesperiiidae	Hesperiinae	*Cephrenes augiades*	C. Felder 1868	X	-
Hesperiiidae	Hesperiinae	*Telicota augias*	Linnaeus 1763	X	-
Hesperiiidae	Hesperiinae	*Arhennes germana*	Rothschild 1916	X	X
Hesperiiidae	Hesperiinae	*Suniana sunias*	C. Felder 1860	X	-
Hesperiiidae	Hesperiinae	*Ocybadistes papua*	Evans 1934	X	-
Hesperiiidae	Hesperiinae	*Borbo cinnara*	Wallace 1866	X	-
Hesperiiidae	Hesperiinae	*Pelopidas agna*	Moore 1866	X	-
Papilionidae	Papilioninae	*Atrophaneura polydorus*	Linnaeus 1763	X	-
Papilionidae	Papilioninae	*Ornithoptera priamus*	Linnaeus 1758	X	-
Papilionidae	Papilioninae	*Ornithoptera goliath*	Oberthür 1888	X	-
Papilionidae	Papilioninae	*Ornithoptera chimaera*	Rothschild 1904	-	X
Papilionidae	Papilioninae	*Graphium agamemnon*	Linnaeus 1758	X	-
Papilionidae	Papilioninae	*Graphium weiskei*	Ribbe 1900	-	X
Papilionidae	Papilioninae	*Graphium codrus*	Cramer 1777	X	-
Papilionidae	Papilioninae	*Papilio laglazei*	Depuiset 1877	X	-
Papilionidae	Papilioninae	*Papilio aegeus*	Donovan 1805	X	-
Papilionidae	Papilioninae	*Papilio ambrax*	Boisduval 1832	X	-
Papilionidae	Papilioninae	*Papilio albinus*	Wallace 1865	X	-
Papilionidae	Papilioninae	*Papilio ulysses*	Linnaeus 1758	X	-
Papilionidae	Papilioninae	*Papilio euchenor*	Guérin-Méneville 1831	X	-
Pieridae	Coliadinae	*Catopsilia pomona*	Fabricius 1775	X	-
Pieridae	Coliadinae	*Eurema hecabe*	Linnaeus 1758	X	-
Pieridae	Coliadinae	*Eurema blanda*	Boisduval 1836	X	-
Pieridae	Coliadinae	*Eurema puella*	Boisduval 1832	X	-
Pieridae	Coliadinae	*Gandaca butryosa*	Butler 1875	X	-
Pieridae	Pierinae	*Leuciacria acuta*	Rothschild & Jordan 1905	-	X
Pieridae	Pierinae	*Elodina hypatia*	C. & R. Felder 1865	X	-
Pieridae	Pierinae	*Elodina definita*	Joicey & Talbot 1916	X	-
Pieridae	Pierinae	*Appias celestina*	Boisduval 1832	X	-
Pieridae	Pierinae	*Appias ada*	Stoll 1781	X	-
Pieridae	Pierinae	*Delias aruna*	Boisduval 1832	X	-
Pieridae	Pierinae	*Delias lara*	Boisduval 1836	X	-
Pieridae	Pierinae	*Delias mavroneria*	Fruhstorfer 1914	X	-
Pieridae	Pierinae	*Delias ennia*	Wallace 1867	X	-

Family	Subfamily	Taxon	Authority, Date	Tabubil area (350–1100 m)	Bilbilokabip (~1800 m)
Pieridae	Pierinae	*Delias aroae*	Ribbe 1900	-	X
Pieridae	Pierinae	*Delias kummeri*	Ribbe 1900	-	X
Pieridae	Pierinae	*Delias akrikensis*	Lachlan 1999	-	X
Pieridae	Pierinae	*Delias iltis*	Ribbe 1900	-	X
Pieridae	Pierinae	*Delias hapalina*	Jordan 1911	-	X
Pieridae	Pierinae	*Delias leucias*	Jordan 1911	-	X
Pieridae	Pierinae	*Delias campbelli*	Joicey & Talbot 1922	-	X
Pieridae	Pierinae	*Delias catisa*	Jordan 1912	X	-
Pieridae	Pierinae	*Delias meeki*	Rothschild & Jordan 1904	-	X
Pieridae	Pierinae	*Delias ladas*	Grose-Smith 1894	X	-
Pieridae	Pierinae	*Delias eudiabolus*	Rothschild 1915	X	-
Pieridae	Pierinae	*Delias nais*	Jordan 1911	-	X
Pieridae	Pierinae	*Delias hypomelas*	Rothschild & Jordan 1907	-	X
Pieridae	Pierinae	*Delias autumnalis*	Roepke 1955	-	X
Lycaenidae	Riodininae	*Dicallaneura decorata*	Hewitson 1862	X	-
Lycaenidae	Riodininae	*Dicallaneura kirschi*	Röber 1886	X	-
Lycaenidae	Riodininae	*Dicallaneura ribbei*	Röber 1886	X	-
Lycaenidae	Riodininae	*Dicallaneura leucomelas*	Rothschild & Jordan 1905	X	-
Lycaenidae	Riodininae	*Praetaxila huntei*	Sharpe 1903	X	-
Lycaenidae	Riodininae	*Praetaxila heterisa*	Jordan 1912	-	X
Lycaenidae	Riodininae	*Praetaxila statira*	Hewitson 1861	X	-
Lycaenidae	Lycaeninae	*Pseudodipas eone*	C. & R. Felder 1860	X	-
Lycaenidae	Lycaeninae	*Hypochrysops plotinus*	Grose-Smith 1894	X	-
Lycaenidae	Lycaeninae	*Hypochrysops narcissus*	Fabricius 1775	X	-
Lycaenidae	Lycaeninae	*Hypochrysops pythias*	C. & R. Felder 1865	X	-
Lycaenidae	Lycaeninae	*Hypochrysops polycletus*	Linnaeus 1758	X	-
Lycaenidae	Lycaeninae	*Hypochrysops antiphon*	Grose-Smith 1897	X	-
Lycaenidae	Lycaeninae	*Hypochrysops herdonius*	Hewitson 1874	X	-
Lycaenidae	Lycaeninae	*Philiris elegans*	Tite 1963	X	-
Lycaenidae	Lycaeninae	*Philiris montigena*	Tite 1963	-	X
Lycaenidae	Lycaeninae	*Philiris hypoxantha*	Röber 1926	X	-
Lycaenidae	Lycaeninae	*Philiris sp. A (U)*	-	X	-
Lycaenidae	Lycaeninae	*Philiris sp. B (U)*	-	X	-
Lycaenidae	Lycaeninae	*Philiris sp. C (U)*	-	-	X
Lycaenidae	Lycaeninae	*Philiris ignobilis*	Joicey & Talbot 1916	X	-
Lycaenidae	Lycaeninae	*Philiris albicostalis*	Tite 1963	X	-
Lycaenidae	Lycaeninae	*Philiris moira*	Grose-Smith 1899	X	-
Lycaenidae	Lycaeninae	*Philiris biplaga*	Sands 1981	-	X
Lycaenidae	Lycaeninae	*Philiris unipunctata*	Bethune-Baker 1908	X	-
Lycaenidae	Lycaeninae	*Arhopala aexone*	Hewitson 1863	X	-
Lycaenidae	Lycaeninae	*Arhopala chamaeleona*	Bethune-Baker 1903	X	-
Lycaenidae	Lycaeninae	*Arhopala thamyras*	Linnaeus 1758	X	-
Lycaenidae	Lycaeninae	*Hypochlorosis antipha*	Hewitson 1869	X	-
Lycaenidae	Lycaeninae	*Hypolycaena phorbas*	Fabricius 1793	X	-
Lycaenidae	Lycaeninae	*Hypolycaena danis*	C. & R. Felder 1865	X	-
Lycaenidae	Lycaeninae	*Deudorix littoralis*	Joicey & Talbot 1916	X	-
Lycaenidae	Lycaeninae	*Artipe grandis*	Rothschild & Jordan 1905	X	-
Lycaenidae	Lycaeninae	*Anthene seltuttus*	Röber 1886	X	-
Lycaenidae	Lycaeninae	*Candalides limbata*	Tite 1963	X	-
Lycaenidae	Lycaeninae	*Candalides neurapacuna*	Bethune-Baker 1908	-	X
Lycaenidae	Lycaeninae	*Erysichton lineata*	Murray 1874	X	-

Family	Subfamily	Taxon	Authority, Date	Tabubil area (350–1100 m)	Bilbilokabip (~1800 m)
Lycaenidae	Lycaeninae	*Erysichton palmyra*	C. Felder 1860	X	-
Lycaenidae	Lycaeninae	*Danis danis*	Cramer 1775	X	-
Lycaenidae	Lycaeninae	*Psychonotis caelius*	C. & R. Felder 1860	X	-
Lycaenidae	Lycaeninae	*Catopyrops ancyra*	C. Felder 1860	X	-
Lycaenidae	Lycaeninae	*Discolampa albula*	Grose-Smith 1897	X	-
Lycaenidae	Lycaeninae	*Jamides cyta*	Boisduval 1832	X	-
Lycaenidae	Lycaeninae	*Jamides reverdini*	Fruhstorfer 1915	X	-
Lycaenidae	Lycaeninae	*Jamides celeno*	Cramer 1775	X	-
Lycaenidae	Lycaeninae	*Jamides aetherialus*	Butler 1884	X	-
Lycaenidae	Lycaeninae	*Jamides coritus*	Guérin-Méneville 1831	X	-
Lycaenidae	Lycaeninae	*Epimastidia inops*	C. & R. Felder 1860	X	-
Lycaenidae	Lycaeninae	*Callictita lara*	Parsons 1986	X	X
Lycaenidae	Lycaeninae	*Pithecops dionisius*	Boisduval 1832	X	-
Lycaenidae	Lycaeninae	*Zizina labradus*	Godart 1824	X	-
Lycaenidae	Lycaeninae	*Monodontoides argiolus*	Rothschild 1916	X	X
Lycaenidae	Lycaeninae	*Udara drucei*	Bethune-Baker 1906	-	X
Lycaenidae	Lycaeninae	*Udara manokwariensis*	Joicey & Noakes 1916	-	X
Nymphalidae	Libytheinae	*Libythea geoffroy*	Godart 1820	X	-
Nymphalidae	Ithomiinae	*Tellervo zoilus*	Fabricius 1775	X	-
Nymphalidae	Danainae	*Parantica melusine*	Grose-Smith 1894	X	-
Nymphalidae	Danainae	*Euploea leucostictos*	Gmelin 1790	X	-
Nymphalidae	Danainae	*Euploea wallacei*	C. & R. Felder 1860	X	-
Nymphalidae	Morphinae	*Morphopsis albertisi*	Oberthür 1880	X	-
Nymphalidae	Morphinae	*Hyantis hodeva*	Hewitson 1862	X	-
Nymphalidae	Morphinae	*Taenaris catops*	Westwood 1851	X	-
Nymphalidae	Morphinae	*Taenaris dioptrica*	S.C. Snellen van Vollenhoven 1860	X	-
Nymphalidae	Morphinae	*Taenaris cyclops*	Staudinger 1893	X	-
Nymphalidae	Morphinae	*Taenaris schoenbergi*	Fruhstorfer 1893	-	X
Nymphalidae	Satyrinae	*Mycalesis duponchelii*	Guérin-Méneville 1831	X	-
Nymphalidae	Satyrinae	*Mycalesis discobolus*	Fruhstorfer 1906	-	X
Nymphalidae	Satyrinae	*Mycalesis phidon*	Hewitson 1862	X	-
Nymphalidae	Satyrinae	*Mycalesis terminus*	Fabricius 1775	X	-
Nymphalidae	Satyrinae	*Mycalesis barbara*	Grose-Smith 1894	X	-
Nymphalidae	Satyrinae	*Mycalesis giamana*	Parsons 1986	X	-
Nymphalidae	Satyrinae	*Mycalesis biformis*	Rothschild & Durrant 1915	X	-
Nymphalidae	Satyrinae	*Mycalesis mehadeva*	Boisduval 1832	X	-
Nymphalidae	Satyrinae	*Mycalesis fulvianetta*	Rothschild 1916	X	-
Nymphalidae	Satyrinae	*Platypthima homochroa*	Rothschild & Jordan 1907	-	X
Nymphalidae	Satyrinae	*Melanitis leda*	Linnaeus 1758	X	-
Nymphalidae	Satyrinae	*Melanitis amabilis*	Boisduval 1832	X	-
Nymphalidae	Satyrinae	*Elymnias papua*	Wallace 1869	X	-
Nymphalidae	Satyrinae	*Elymnias agondas*	Boisduval 1932	X	-
Nymphalidae	Charaxinae	*Charaxes latona*	Butler 1865	X	-
Nymphalidae	Charaxinae	*Charaxes jupiter*	Butler 1869	X	-
Nymphalidae	Charaxinae	*Prothoe australis*	Guérin-Méneville 1831	X	-
Nymphalidae	Apaturinae	*Dichorragia ninus*	C. & R. Felder 1859	X	-
Nymphalidae	Apaturinae	*Cyrestis acilia*	Godart 1819	X	-
Nymphalidae	Nymphalinae	*Euthaliopsis aetion*	Hewitson 1862	X	-
Nymphalidae	Nymphalinae	*Parthenos tigrina*	M. Snellen van Vollenhoven 1886	X	-

Family	Subfamily	Taxon	Authority, Date	Tabubil area (350–1100 m)	Bilbilokabip (~1800 m)
Nymphalidae	Nymphalinae	*Pantoporia consimilis*	Boisduval 1832	X	-
Nymphalidae	Nymphalinae	*Pantoporia venilia*	Linnaeus 1758	X	-
Nymphalidae	Nymphalinae	*Phaedyma shepperdi*	Moore 1858	X	-
Nymphalidae	Nymphalinae	*Mynes geoffroyi*	Guérin-Méneville 1831	X	-
Nymphalidae	Nymphalinae	*Mynes websteri*	Grose-Smith 1894	X	-
Nymphalidae	Nymphalinae	*Mynes aroensis*	Ribbe 1900	-	X
Nymphalidae	Nymphalinae	*Dolleschallia hexopthalmus*	Gmelin 1790	X	-
Nymphalidae	Nymphalinae	*Hypolimnas bolina*	Linnaeus 1764	X	-
Nymphalidae	Nymphalinae	*Hypolimnas alimena*	Linnaeus 1758	X	-
Nymphalidae	Nymphalinae	*Hypolimnas deois*	Hewitson 1858	X	-
Nymphalidae	Nymphalinae	*Yoma algina*	Boisduval 1832	X	-
Nymphalidae	Nymphalinae	*Junonia hedonia*	Linnaeus 1764	X	-
Nymphalidae	Heliconiinae	*Cethosia cydippe*	Linnaeus 1763	X	-
Nymphalidae	Heliconiinae	*Vindula arsinoe*	Cramer 1777	X	-
Nymphalidae	Heliconiinae	*Cirrochroa regina*	C. & R. Felder 1865	X	-
Nymphalidae	Heliconiinae	*Vagrans egista*	Stoll 1780	X	-
Nymphalidae	Heliconiinae	*Cupha prosope*	Fabricius 1775	X	-
Nymphalidae	Heliconiinae	*Acraea meyeri*	Kirsch 1877	X	-

Table 2. Numbers of butterfly species in each survey site of the study area.

(Sub) Family	Tabubil (350–1100 m)	Bilbilokabip (~1800 m)	TOTAL
Pyrginae	2	-	**2**
Coeliadinae	3	-	**3**
Trapezitinae	1	1	**1**
Hesperiinae	15	1	**15**
Papilioninae	11	2	**13**
Coliadinae	5	-	**5**
Pierinae	11	12	**23**
Riodininae	6	1	**7**
Curetinae	-	-	**-**
Lycaeninae	41	7	**46**
Libytheinae	1	-	**1**
Ithomiinae	1	-	**1**
Danainae	3	-	**3**
Morphinae	5	1	**6**
Satyrinae	12	2	**14**
Charaxinae	3	-	**3**
Apaturinae	2	-	**2**
Nymphalinae	13	1	**14**
Heliconiinae	6	-	**6**
TOTAL SPECIES	**141**	**28**	**165**

Conservation significant species
One Near Threatened IUCN listed Birdwing Butterfly species (*Ornithoptera chimaera*) and one additional Protected Birdwing (*Ornithoptera goliath*) were recorded. With the exception of five Birdwings, there are no mainland New Guinea butterflies currently on the IUCN Red List. Tennent and Muller (in press) assessed c. 150 randomly selected Indo-Pacific butterfly species 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, *Ornithoptera chimaera* was down-graded from Near Threatened (NT) to Least Concern (LC) based on a re-assessment of its status and more information, although this is yet to be reflected on the IUCN Red List website.Table 3 lists the two butterfly species recorded in the study area that appear on the 2010 IUCN Red List of threatened species, checked on September 10, 2013 (http://www.redlist.org/), and/or are recorded under the PNG *Fauna (Protection and Control) Act 1966, 1978* ('Fauna Act').

Table 3. Butterfly fauna listed as of conservation concern in the study area.

Common Name	Scientific Name	IUCN [1]	PNG Fauna Act [2]
Goliath Birdwing	*Ornithoptera goliath* Oberthür, 1888		P
Chimaera Birdwing	*Ornithoptera chimaera* Rothschild, 1904	NT	P

[1] IUCN status NT = Near Threatened, Least concerns species are not included.
[2] Status under the PNG Fauna (Protection and Control) Act. P = Protected

New and undescribed species
Four butterfly species recorded in the study area appears to be new to science and a further one is undescribed. Their occurrence, habitat and ecology is outlined below. Interestingly, four (80%) of these were recorded at the mid-range elevations in the study area, within the vicinity of Tabubil.

Species apparently new to science
**Sabera* sp. A (U) (Hesperiidae), Lower Hindenburg Range, north of Tabubil, 950 m.
The undescribed *Sabera* is intriguing as it completely lacks a sex brand on its unmarked dark brown wings. All other known Sabera possess sex scales and/or androconia on the uppersides of the forewing. An adult male of this taxon was taken feeding from the flowers of an unidentified tree, some metres above the ground.

**Mimene* sp. A (U) (Hesperiidae), Lower Hindenburg Range, north of Tabubil, 950 m.
Some workers (e.g., Parsons 1998) consider that *Mimene* and *Sabera* are congeneric. Males of both species invariably bear forewing upperside sex brands that are useful diagnostic characters. The new *Mimene* bears a sex brand that is reminiscent of *M. wandammensis* but has more elongated wings than that species. Additionally, the undescribed species bears obscure orange bands on the upperside of both wings, whereas that of *M. wandammensis* is uniformly dull brown. Two males were taken around midday while they defended territories from the tops of bushes some five metres above the ground, along a fast-flowing creek.

**Philiris* sp. A (U) (Lycaenidae), Lower Hindenburg Range, north of Tabubil, 950–1,050 m.
The genus *Philiris* (Lycaenidae) is the second largest genus of butterflies in New Guinea, after *Delias* (Pieridae). All are small butterflies, with wingspans less than 25 mm. *Philiris* sp. A (U) is a distinct species with a dark border to the underside of both wings and a male which has a greenish upperside, quite unlike any known *Philiris* species. Both sexes were taken within two small areas, where they flew at the tops of trees about 8–10 metres above the ground.

**Philiris* sp. C (U) (Lycaenidae), Bilbilokabip, Hindenburg Wall, 1,800 m.
This is a very dark species, in which all margins of the wings are broadly black and the underside is a dull glossy white, with a very obscure black spot on the inner margin of the hindwing underside. A single male was taken together with the high altitude *P. montigena* and *P. biplaga* along a fast-flowing creek.

Undescribed Species
**Philiris* sp. B (U) (Lycaenidae), Lower Hindenburg Range, north of Tabubil, 950 m.
Philiris sp. B (U) is predominantly brown and cream on the upperside, with a yellow-cream underside (Photograph 15). It is closely related to *P. hypoxantha*, also recorded in the same locality and was previously confused with that species (Tite 1963, d'Abrera 1971, d'Abrera 1977, d'Abrera 1990). *Philiris* sp. B was previously known from southern Papua Province (specimens in Natural History Museum, London) and from Madang Province, Papua New Guinea.

Other Significant Records
Three butterfly species are recorded from Papua New Guinea for the first time, namely *Hypochrysops herdonius*, *Philiris elegans* (both Lycaenidae), and *Mycalesis biformis* (Nymphalidae). New country records from PNG could be nationally significant, as the species may only occur in a small area, despite being more widespread in Indonesia.

Discussion

The butterfly fauna within the study area changes markedly with altitude, with species diversity decreasing with increasing elevation. The Bilbilokabip site was relatively depauperate, while the Tabubil area had a very rich species inventory.

Despite their mobility, the majority of butterflies are generally localised in occurrence and peculiar to specialised environments. The habitats and micro-habitats of all species recorded during the field survey were noted in an attempt to recognise those most sensitive to any impact.

Anomalous micro-habitats, even those that are restricted in area, often support a diversity of butterflies. Even more important are mosaics where several forest types may be present in a single area. Such micro-habitats are often difficult to detect from aerial surveys. Ecological micro-habitats were observed at all four surveyed sites and their specific butterfly fauna was documented. These were often as subtle as large clearings in the multi-storied hill forest, resulting from tree falls or land slips. Those which are most in need of preservation in the study area are those which are restricted in overall extent and are generally stable biomes, as opposed to successional phases of a forest undergoing maturation.

The Hindenburg Wall study area is overall remarkably intact, representing a vast tract of largely undisturbed primary forest, with little or no human activity. Unsurprisingly, therefore, the butterfly diversity in the study area is high, with several new, conservation-listed and/or restricted range species present.

A desktop assessment of available literature and personal records/observations suggest that as many as 487 known butterfly species may occur within the study area (Table 4), representing nearly half of the known butterflies in Papua New Guinea and as many as two-thirds of those occurring on the mainland. Such diversity would grant the area 'hotspot' status and be comparable to the species diversity at Mount Kinabalu, Malaysia, one of the world hotspots for butterflies (Häuser et al. 1997). The study area is situated near the border of the Southern Zone (comprising lowland New Guinea south of the Central Cordillera), the 'Western Sub Province' (incorporating the Star Mountains of far western Papua New Guinea and eastern Papua Province, Indonesia) and the 'Central Divide' (Hagen Range east of Wabag). Undoubtedly the potential biodiversity richness of this area may be attributed to some overlap of these faunistic zones.

As indicated by the discovery of new species in the Hindenburg Wall study area, the semi-isolated Hindenburg Range and Star Mountains likely bear additional new species that are endemic to this small area. As Vane-Wright (1991) emphasised, endemic butterfly species and the general endemicity of an area are indicative of its biogeographical relationships to other areas. The percentages of endemic species in the New Guinea butterfly fauna are high and suggest that speciation was very rapid in certain genera with an apparent recent history in New Guinea. Those butterflies which are endemic to mainland New Guinea can be considered as very useful indicators of areas of endemism within the main landmass. They imply that

such areas have been geologically distinct for relatively long periods of time. It follows that these areas of endemism may well indicate regions of probable geological and/or geographical significance (Parsons 1998). For example, they may, at one time or another been separated by significant stretches of water. This is possible for New Guinea where parts of the now fused composite mainland may have been largely archipelagic (i.e. corroborates data from geological studies e.g. Kikkawa et al. 1981).

Conservation recommendations

The fact that several butterfly species were only recorded from single specimens, with additional records to the end of the survey, suggests that a significant proportion of species present in the study area remain to be recorded. Ideally, there is a need to continue surveys of butterfly diversity in the study area. Wider surveys in the Hindenburg Wall area and surrounding low-lying areas would be advantageous, to determine the existence of sensitive/new species. In particular, delineating the presence of the endangered *Ornithoptera meriodionalis* in the study area could be confirmed with additional survey effort.

Since habitat loss and degradation is potentially the most significant threat to the well-being of the butterfly fauna within the study area, it is important that clearing of forest be kept to a minimum and re-vegetation of affected areas should be a priority counter measure. Vast tracts of forest have been destroyed in the vicinity of Tabubil and also around Bultem Village.

Minimising clearing practices would reduce the opportunity for invasive plant species to take a hold in the Hindenburg Wall area. Since the Hindenburg Wall and surrounds is one of the World's natural wonders, there is potential to develop this area for eco-tourism. If structured carefully, this would provide a valuable offset, encouraging the community to care for their environment for generations to come. Recognition of the region as a World Heritage Area would be a first step in this direction.

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Mynes aroensis (Nymphalidae), a truly montane taxon, was encountered fairly commonly at Tupnonbil. (*Photo C.J.Müller*)

Chapter 5

Odonata (Dragonflies & Damselflies)

Stephen J. Richards and Günther Theischinger

Summary

We report the results of a survey of dragonflies and damselflies at two broad elevations (~285–910 m asl and 1,770–1,850 m asl) on the southern slopes of the Hindenburg Range in western Papua New Guinea (PNG). Fifty-three species were encountered, including 28 species of damselflies (Zygoptera) and 25 species of dragonflies (Anisoptera). Between 13 and 16 of these species (up to 30%) appear to be new to science. Diversity at the lower, foothill sites was much higher (40 species) than at the montane location, which totalled just 14 species despite higher search effort. However the fauna at the montane site was remarkable for the high proportion of species that are new to science (six of 14 species or 43%).
Most of the new species documented during this survey are associated with clear, flowing streams in forest. We present the first comprehensive list of odonate species from the upper Ok Tedi area but note that this is based on just 3 weeks of sampling and that the total diversity of this important indicator group is certainly much higher in this topographically diverse part of Papua New Guinea.

Introduction

With more than 600 species of dragonflies and damselflies currently known from New Guinea and adjacent Melanesian islands (Michalski 2012), this region is host to about ten percent of the world's total number of species. Furthermore, half of the odonate species and more than a quarter of the genera reported from New Guinea are endemic to the region. This impressive documented diversity and endemism is increasing rapidly with an increase in fieldwork, and subsequently in the number of species described, from the region (e.g. Englund & Polhemus 2007, Kalkman 2008a, 2013, Michalski and Oppel 2010, Michalski et al. 2012, Orr et al. 2012, Theischinger and Richards 2012a,b, 2013).

Although small numbers of odonates have been collected from numerous sites in the central mountains of New Guinea (see Figure 12.1 in Kalkman et al. 2011), there are few published studies that are based on sufficient sampling to give an impression of local odonate diversity. A notable exception is the important study by Oppel (2005, 2006) which was conducted in the Crater Mountain Wildlife Management Area (CMBRS) far to the east of the Hindenburg Range. That study, at about 500 m asl documented 61 species over a 10 month period.

An important study in the context of this Hindenburg Wall survey was a survey of odonates conducted by V. Kalkman and colleagues at Borme in the northern catchments of the Star Mountains on the Indonesian side of the border (Kalkman 2008b). That study documented a total of 37 species, but predicted that a total of 70 species are likely to be present in the area. A small collection of odonates from the Star Mountains and Hindenburg Range was reported briefly by Richards (1993) but those collections were made only opportunistically and are insufficient to provide an impression of the odonate fauna of this region.

Here we report the results of a short (3 weeks) but intensive survey of odonates in the southern catchments of the Hindenburg Range near the Hindenburg Wall in Western Province, Papua New Guinea.

Methods

Adult odonates were collected with a hand net during daylight from around all available freshwater habitats at the sites visited. Larvae were not sampled intensively but several larvae collected from streams at Bilbilokabip were retained as vouchers for future identification. Identifications were based mainly on the series of seminal papers by M. A. Lieftinck (e.g Lieftinck 1949), with reference also to Michalski (2012).

Table 1. Sampling sites at two locations near the Hindenburg Wall; Tupnonbil and Tabubil

Site	Latitude (S)	Longitude (E)	Elevation (m)
Tupnonbil Area			
Bilbilokabip	5.1203	141.2512	1,770
Yakulgabip	5.1202	141.2582	1,817
Tabubil Area			
Dablin Creek at waterfall	5.2151	141.2318	909
Dablin Creek below waterfall	5.2156	141.2309	859
Yukfon Creek	5.2333	141.2221	734
Tabubil Town	5.2657	141.2200	546
Tabubil Quarry	5.2970	141.2415	407
Kumarang Wok	5.3047	141.2485	380
Tulenbeng Wok	5.3082	141.2528	433
Umansim Stream (Upper, at hut)	5.3328	141.2780	365
Umansim Stream (Lower, below road, adjacent Ok Tedi)	5.3369	141.2764	336
Umansim Stream (at road)	5.3340	141.2775	360
Yemun Wok (Sawmill Flats)	5.3871	141.2972	285

Sites

Tabubil Area: 6–10 & 25–28 February 2013

A number of streams along the Kiunga-Ok Tedi Mine road were sampled. All of these streams are clear with rocky substrates, and drain the southern slopes of the Hindenburg Range into the Ok Tedi; their locations and altitudes are presented in Table 1. Without exception the forest along these streams was severely degraded, and only at the highest point accessed on Dablin Creek (> 900 m asl; Table 1) was forest resembling undisturbed, foothill rainforest encountered. The weather during surveys at this location was mostly sunny in the mornings, but on most days clouds had formed by mid-day and rain fell during the afternoon.

Tupnonbil Area: Bilbilokabip: 11–24 February 2013

Sampling in this area was based out of the small hamlet of Bilbilokabip, a group of huts in a small clearing in Primary Lower Montane Rainforest used by their owners from Bultem when hunting and gardening in the Tupnonbil area. Habitats for odonates included the Ok Tupnon, a large, clear stream running through primary forest adjacent to camp, and a number of its smaller tributaries. A small stream passing through gardens and remnant forest patches at Yakulgabip hamlet several hundred metres from Bilbilokabip (Table 1) also harboured a number of very interesting species. A small, shallow seepage in the ericoid scrub (see Chapter 2) at the edge of Bilbilokabip hamlet attracted several dragonfly species, as did a number of small temporary pools that formed along trails through the forest after heavy rain. Standing (non-flowing) water was absent and most of the streams were shaded for large parts of the day due to both the surrounding forest and the extremely inclement weather, with rain falling for part (or most) of each day at this site. Sunny periods were extremely brief, and on many days were non-existent, so windows of opportunity for collecting odonates were limited.

Results and discussion

A total of 53 species were documented during this survey, 28 damselflies and 25 dragonflies (Table 2). The fauna was much more diverse in the foothill forests around Tabubil (40 species) than at Bilbilokabip (14 species) and there was minimal overlap, with just one of the 53 species (1.9%) shared between the locations. This high turnover of species probably reflects a combination of the higher altitude at Tupnonbil, which was constantly much colder and wetter than the foothills around Tabubil, and to a lesser extent the more dense vegetation along the streams at Tupnonbil which created a dim, cool environment that was probably unsuitable for most odonate species occurring at the warmer, lower elevations.

New and significant species

Although the odonate fauna was relatively depauperate at Tupnonbil (14 species), it included a remarkable number of species that are new to science (six species or 43% of the fauna). The figures are even more remarkable when considering only the damselflies; six of the 7 species (86%) encountered appear to be new to science. Three of the new species are stream specialists, and were found only along fast-flowing, clear rocky streams. The remaining three species are all members of the genus *Papuagrion*, a group suspected to breed in *Pandanus* trees.

The number of new species documented around Tabubil was also surprisingly high, with between seven and 10 species (eight damselflies and two dragonflies) new to science. All of these were collected along clear, flowing streams in remnant forest. Although this is a somewhat lower proportion than at Tupnonbil (up to 25% vs 43%) it was an unexpected result because 1) the area around Tabubil has been accessible to biologists for more than 40 years, and 2) most of the streams were running through severely degraded forest. It is clear that the remnant riparian vegetation along the streams near Tabubil continues to harbor a diverse and very interesting stream-dwelling odonate assemblage. Brief comments on the new and significant species are presented below.

IUCN listed species
Ten of the species documented during this survey have been evaluated by the IUCN as part of a partial assessment of the global odonate fauna (e.g. Clausnitzer et al. 2009). Nine of these are listed as Least Concern and one, *Nososticta nigrifrons*, is listed as Data Deficient.

Nososticta nigrifrons is a small, blue and black damselfly that was found to be common along the stream banks at Sawmill. It is listed as Data Deficient due to the fact that it is 'Only known from the male holotype. No further information on distribution and habitat known' (IUCN 2013: www.iucnredlist.org, downloaded on 25 October 2013). The holotype was collected in the Lorentz Drainage of southern (current) Papua Province in 1910 but, contrary to the account on the Red List web site, *N. nigrifrons* is also known from the Lakekamu Basin (Richards et al. 1998) and given this new record from the foothills below Tabubil it certainly has a wide distribution in the lowlands south of New Guinea's central cordillera.

New species
Sixteen species collected during this survey are new to science. These include 14 damselflies and two dragonflies. Brief accounts are given here.

Family Argiolestidae: *Argiolestes* sp. nov. (See photograph).
A moderately large damselfly that is unusual in sitting with the wings spread flat. The thorax and abdomen are dark, and in two specimens there is a conspicuous blue patch on each side of the dorsum of the thorax. It is possible that the specimens without this blue patch belong to yet another unrecognised species but further studies are required to determine this and we take the conservative approach of recognising only one species at this time. Currently known from forest patches along small tributaries of the Ok Menga near the main Kiunga-Mine road

Family Argiolestidae: *Metagrion* sp. nov.
This species is similar in overall appearance to the new species discussed above. It also sits with its wings spread flat and has a predominantly dark thorax and abdomen. In this species the labrum is blue and the thorax is always marked with a distinct but variable pale pattern. It is a common species along small streams between Sawmill (< 300 m asl) and Dablin Creek (>900 m asl).

Family Coenagrionidae: *Papuagrion* spp.
Four species of the coenagrionid genus *Papuagrion* appear to be new to science; three from Tupnonbil and one from Dablin Creek near Tabubil. All are moderately large, robust species and three of them are rather mutely coloured. The fourth species is dramatically coloured in yellow and black, and was found only at a garden clearing near a stream in remnant forest at Yakulgabip, a small hamlet above the main camp at Bilbilokabip.

Family Coenagrionidae: *Teinobasis*? spp nov.
Two species of the coenagrionid genus *Teinobasis* that were found in remnant forest patches along the Kiunga road south of Tabubil may be new to science. Studies are underway to confirm this. One is distinctive in being predominantly bright yellow in colour; and the other has conspicuous green eyes.

Family Platycnemididae: *Hylaeargia* sp. nov.
An attractive, moderately large and robust stream-dwelling damselfly with small but vivid blue patches on the thorax. It was found only along a small stream running through remnant rainforest near the base of the Hindenburg Wall at Yakulgabip. This new species represents only the fourth known species in the genus. This species has now been described as *Hylaeargia lisae* by Theischinger and Richards (2013)

Family Platycnemididae: *Palaiargia* spp.
Three new species of this spectacular genus were discovered during the 2013 survey. Considered the 'Birds of Paradise' of the damselfly world in New Guinea, this genus contains some of the most brightly-coloured odonates in the region. All are forest-stream specialists, descending from the canopy to perch in the sun on boulders and low foliage along fast-flowing streams. One species was found along streams between Tabubil and Sawmill, one at Dablin Creek, and one at Yakulgabip, Tupnonbil area. The latter is a most spectacular species with a bright orange-red head and blue markings on the abdomen (see photograph). These three species have now been described by Orr et al. (2014).

Family Platycnemididae: Gen. nov., sp. nov.
A large, green and black damselfly found only along streams adjacent to Bilbilokabip. It appears to warrant recognition as a new genus. The same species, or a similar species belonging in the same genus, is known to occur in the central highlands east of the Hindenburg Range. Studies are underway to determine whether these species are conspecific, and to formally describe the Bilbilokabip species.

Family Platystictidae: *Drepanosticta* sp. nov.
A moderately small, dark damselfly with blue colouration on the terminal abdominal segments giving the impression of a 'blue paddle' on the end of the abdomen. A single specimen of this secretive genus was found perched next to a small waterfall at Dablin Creek and it is currently being described.

Family Libellulidae: *Microtrigonia* sp. nov.
A medium-sized, rather nondescript stream-dwelling dragonfly that was found at Yukfon Creek near Tabubil. All specimens were perched in sunny patches on low foliage next to small, steep and clear streams in riparian forest. It is currently being described.

Family Synthemistidae: *Palaeosynthemis*? sp. nov.
An extremely slender dragonfly that may be new to science. A single male specimen was captured as it hawked over the stream at Yukfon Creek. No other specimens were seen during the survey.

General comments
The documentation of 53 species including 16 that are new to science within just 3 weeks sampling suggests that the odonate diversity in the Hindenburg Wall area is exceptionally diverse. For example at Crater Mountain Biological Research Station Oppel (2005) reported a very slow accumulation curve of species. Sixty-one species were found during 112 days of fieldwork there and it took 45 days to find the first 75% of species. It is therefore likely that the Hindenburg survey has documented less than half of the species present in the area, and that a large number of additional species new to science await discovery.

The species found during this survey belong to 11 families, a result similar to that obtained for an odonate assemblage at ~500 m asl in the Muller Range by Kalkman et al. (2011). The two assemblages are also similar in the high proportion of species dependent on forest streams. Twenty five of the 31 species (80%) at the Muller Range site are probably dependent on streams or seepages while a lower proportion (51%) of the fauna documented in the Hindenburg range are dependent on streams. However this result is biased by the predominance at Tabubil of widespread, pond-dwelling libellulid species that have successfully invaded the newly created open spaces and associated temporary and permanent ponds around the town.

It is interesting to note the extremely low similarity between the species encountered on the southern slopes of the Hindenburg Range during this survey and those reported by Kalkman (2008b) from Borme on the northern slopes of the Star Mountains. Only 12–13 of the 31 species documented in that study were also found during this study, and most (nine of the 12) are common, widespread species – predominantly libellulid dragonflies – that occupy ponds and other standing water for reproduction. Despite the relatively close proximity of these sites none of the small, forest-stream specialist damselflies were found at both sites. This reflect the important role that New Guinea's central cordillera plays as a barrier in determining the distributions of small, poorly-dispersing damselflies that also require humid, and often partly shaded, stream-habitats.

Table 2. List of odonates from the Hindenburg Wall area, Papua New Guinea

Family	Species	Tabubil area (285–910 m)	Tupnonbil area (1770–1850 m)	IUCN status
Zygoptera				
Argiolestidae	*Argiolestes* sp. *nov.*	X		NE
Argiolestidae	*Metagrion sp. nov.*	X		NE
Calopterygidae	*Neurobasis australis*	X		NE
Chlorocyphidae	*Rhinocypha tincta*	X		NE
Coenagrionidae	*Agriocnemis femina*	X		LC
Coenagrionidae	*Papuagrion* sp. *nov.* 1 (nr magnanimum)	X		NE
Coenagrionidae	*Papuagrion* sp. *nov.* 2 (nr digitiferum)		X	NE
Coenagrionidae	*Papuagrion* sp. *nov.* 3 (yellow-legs)		X	NE
Coenagrionidae	*Papuagrion* sp. *nov.* 4 (black-and-yellow)		X	NE
Coenagrionidae	*Pseudagrion farinicolle*	X		NE
Coenagrionidae	*Teinobasis scintillans*		X	NE
Coenagrionidae	*Teinobasis ?*sp. nov. 1 (green eyes)	X		NE
Coenagrionidae	*Teinobasis ?*sp. nov. 2 (yellow)	X		NE
Coenagrionidae	*Xiphiagrion truncatum*	X		NE
Isostictidae	*Selysioneura cervicornu*	X		NE
Platycnemididae	*Hylaeargia* sp. *nov.*		X	NE
Platycnemididae	*Idiocnemis australis*	X		NE
Platycnemididae	*Idiocnemis* sp. *nov.?*	X		NE
Platycnemididae	*Palaiargia ceyx*	X		NE
Platycnemididae	*Palaiargia* sp. *nov.* 1		X	NE
Platycnemididae	*Palaiargia* sp. *nov.* 2	X		NE
Platycnemididae	*Palaiargia* sp. *nov.* 3	X		NE
Platycnemididae	*Gen. nov., sp. nov.*		X	NE
Platycnemididae	*Nososticta nigrifrons*	X		DD
Platycnemididae	*Nososticta ?marina*	X		NE
Platycnemididae	*Nososticta ?rosea*	X		NE
Platycnemididae	*Nososticta* cf *finisterrae*	X		NE
Platystictidae	*Drepanosticta* sp. *nov.*	X		NE
N = 28 species of Zygoptera		21	7	
Anisoptera				
Aeshnidae	*Anax selysi*		X	NE
Aeshnidae	*Plattycantha ?cornuta*		X	NE
Corduliidae	*Hemicordulia ericetorum*		X	NE
Corduliidae	*Hemicordulia silvarum*	X		NE
Corduliidae	*Procordulia astridae/sylvia*		X	NE
Libellulidae	*Agrionoptera insignis*	X		LC
Libellulidae	*Agrionoptera longitudinalis*	X		LC
Libellulidae	*Diplacina hippolyte*		X	NE
Libellulidae	*Diplacina smaragdina*	X		NE
Libellulidae	*Huonia arborophila*	X	X	LC
Libellulidae	*Lanthanusa richardi*		X	NE
Libellulidae	*Lyriothemis hirundo*	X		NE
Libellulidae	*Microtrigonia* sp. *nov.*	X		NE

Family	Species	Tabubil area (285–910 m)	Tupnonbil area (1770–1850 m)	IUCN status
Libellulidae	*Nannophlebia amphicyllis*	X		NE
Libellulidae	*Nannophya pygmaea*	X		LC
Libellulidae	*Neurothemis oligoneura*	X		NE
Libellulidae	*Neurothemis ramburi*	X		LC
Libellulidae	*Neurothemis stigmatizans*	X		NE
Libellulidae	*Orthetrum glaucum*	X		LC
Libellulidae	*Orthetrum serapia*	X		LC
Libellulidae	*Orthetrum villosovittatum*	X		NE
Libellulidae	*Pantala flavescens*	X		LC
Libellulidae	*Protorthemis coronata*	X		NE
Libellulidae	*Tramea sp.*	X		NE
Synthemistidae	*Palaeosynthemis ?*sp. *nov.*	X		NE
N = 25 species of Anisoptera		**19**	**7**	

Conservation issues and recommendations

Results of the 2013 Hindenburg Wall survey indicate that the forests around the Wall support an extremely rich but poorly-known odonate fauna. Although we documented only one damselfly species listed as Data Deficient by the IUCN, the number of new species discovered was unexpectedly high. Many of these new species are known or expected to occur only along small forested streams, and damselfly species with these habitat requirements in New Guinea appear to have more restricted distributions, due to requirements for high humidity and relatively stable microclimates, than strongly-flying, migratory dragonflies. Limiting damage to riparian vegetation along small, clear streams in forest is the most practical way to ensure the long-term survival of these species.

This is a particular problem around Tabubil where clearing for gardens, and harvesting of wood for fires and construction, has severely damaged the vegetation on the hill slopes. These impacts are most evident in the near-complete removal of vegetation from the ridges on the north-eastern edge of Tabubil Town. We recommend that the local community be encouraged to actively protect the freshwater habitats and riparian corridors on their land, as a way of not only ensuring survival of the many species reliant on these habitats, but also of ensuring the continued ecosystem services (including clean water) provided by these streams.

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New species of damselfly *Argiolestes* sp. nov. from the Tabubil area. (*Photo S.J.Richards*)

New species of damselfly *Palaiargia quandti* from Tupnonbil (Orr et al. 2014). (*Photo S.J.Richards*)

Chapter 6

Freshwater Fishes

Michael Hammer

Summary

The Fly River system of southern Papua New Guinea is an expansive and diverse drainage, with a significant freshwater fish fauna. The Hindenburg Wall biodiversity expedition in February 2013 to the headwaters region of the Fly River provided access to torrential tributary streams flowing into the upper Ok Tedi. Ten sites were sampled in the Tabubil and Tupnonbil areas using a combination of net types. No fish were recorded at Tupnonbil, a result that was predicted for this higher elevation area where water temperatures are cool and streams frequently flash-flood. Twelve native fishes and one introduced species (Tilapia, *Oreochromis mossambicus*) were recorded from the Tabubil area. Although no species new to science were confirmed one very large gudgeon (Eleotridae: *Bostrychus*) is morphologically atypical in comparison to the known species in the region, and ongoing taxonomic reviews of material obtained may see additional species described from the area (e.g. Gobiidae: *Glossogobius* species). Other important results included the documentation of apparently large populations of the narrow-range endemic Ok Tedi Rainbowfish (*Melanotaenia oktediensis*), and the first records of Southern Tandan (*Neosilurus equinus*) from the region in recent times. Local people greatly aided sampling, and passed on their personal and family knowledge of Faiwol names for the local fishes. There remains much potential for species discovery in the Hindenburg Wall region and future exploration should target remote areas of the Fly River system at moderate elevations (~50–500 m asl). Progressive introduction of invasive fishes is of concern, and public education about the impacts of such introductions on aquatic ecosystems is urgently required.

Introduction

Freshwater fishes are a key component of natural resource management due to their diversity in number and form, intriguing life histories and adaptations, role in human culture and use, links within food-chains, value as bio-indicators, and as icons for aquatic conservation and environmental awareness (Berra 2001, Bunn and Arthington 2002, Kennard et al. 2006, Hammer et al. 2009). The tropical regions of northern Australia and New Guinea have extensive and diverse aquatic habitats, and support a substantially unique fish fauna with two endemic families (rainbowfishes and blue-eyes) and prominent radiations of local genera and species of marine or otherwise Euro-Asian groups (e.g. high endemism in forktail and eeltail catfishes, hardyheads, glassfishes, grunters, gobies and gudgeons (Allen 1991, Unmack 2001, Unmack et al. 2013).

The Fly River system is a hotspot for freshwater fish diversity in the Australia-New Guinea region. It is an expansive freshwater catchment of some 76,000 km^2 with a river distance from its source in the Hindenburg Wall area to the sea of around 1,200 km. There is a natural transition of habitats from torrential mountain streams in the headwaters, larger upland rivers, a foothill zone, though to the middle and lower Fly River sections that have significant lateral connections with a vast area of floodplain habitat. So far some 108 species are known across these habitats, which represents over one quarter of the species known in New Guinea and is the highest for any river system in the region (Allen et al. 2008). The tally includes a staggering 12 endemic species, including the blue-eye genus *Kiunga* represented by two species. Endemic species are found from the headwaters (e.g. colourful Ok Tedi Rainbowfish, *Melanotaenia oktediensis*) to freshwater-estuarine habitats (e.g. the bizarre Fly River Blind Goby, *Gymnoamblyopus novaeguineae*).

The Fly River system has been relatively well sampled for fishes, at least for sites located along the more readily accessible areas of main rivers (Fly, Ok Tedi, Strickland) and areas with road access (e.g. Roberts 1978). Allen et al. (2008) have chronicled European collection of fishes in the system stretching from early exploration in the 1880s to comprehensive monitoring in recent times associated with the Ok Tedi Mine (Storey and Smith 2007). The biology and distribution of fishes known from the Fly River was also reviewed by Allen et al. (2008) and this allows ready interpretation of the significance of records obtained on new surveys. With specific reference to the current study, only a small selection of the overall fauna is known from streams above 400 m above sea level (asl), and no fish have been recorded at elevations of approximately 1,500 m asl. Key survey gaps, and potential sites for discovery of new species, include tributaries in the foothill zone that are remote from roads as these appear to support localised species with specialised ecological requirements (Allen et al. 2008).

This report details a fish survey in the Hindenburg Wall area that was conducted during the WCS Hindenburg Wall biodiversity expedition in February 2013, and includes recommendations for regional conservation and further research.

Methods

Study region and sites

Aquatic habitats of the Hindenburg Wall region include a combination of small mountainous tributary streams and larger upland rivers (e.g. Ok Tedi, Ok Menga, Strickland River). These streams and rivers are characterised by linear rocky habitats with medium to high flow; base-flow is clear, but these habitats are prone to flashy flow events following periods of heavy rain as witnessed during the survey (see photographs).

The survey locations encompassed tributary habitats of the Ok Tedi above elevations of ~300 m asl. Sampling was undertaken at 10 sites in two localities, namely the Tupnonbil area and around Tabubil (north of Tabubil to just south of Ok Menga). Location details and habitat features are detailed in Tables 1 and 2.

Fish sampling

Fish sampling involved a combination of methods, each designed for specific habitat types and target species, to collectively provide the best chance of maximising the number of species documented at each site (Table 3). Gear types included:

- Seine net: 6 m, 4 mm stretch mesh for tragetting fish in open areas.
- Cast net: 2.7 m drop, 19 mm monofilament mesh for secretive species in deeper water.
- Dip net: 0.4 m D hoop, 3 mm stretch mesh. Ideal for sampling crytobenthic fishes from shallows and dense habitat (e.g. plant roots).
- Bait trap: 0.6 x 0.25 x 0.25 m rectangular collapsible, 60 mm entrance hole and 1 mm mesh. A passive technique for areas of dense structural habitat (e.g. rocky boulders in side pools).
- Night observation: waterproof torch light to observe nocturnal species and resting diurnal species, used in combination with dip net. Ideal for shallow, clear streams with high structural integrity.
- Angling: monofilament handlines with small baited hooks. A supplementary technique for carnivorous fish (gobies to grunters).

Table 1. Sampling sites for freshwater fishes.

Site	Site code	Date	Waterway	Location	Lat. (s)	Long. (E)
Tupnonbil area	MH13-09	15–17/2/13	Trib. Ok Tupnon	Gardens	5.1194	141.2585
Tupnonbil area	MH13-10	13–17/2/13	Ok Tupnon	Track crossing	5.1195	141.2533
Tabubil area	MH13-04	7/2/13	Yukfon	Waterfall north of Tabubil	5.2337	141.2212
Tabubil area	MH13-05	7/2/13	Small spring pond	Near Yukfon	5.2287	141.2181
Tabubil area	MH13-06	8/2/13	Trib. Ok Tedi	Five Mile (quarry)	5.2970	141.2415
Tabubil area	MH13-07	9/2/13	Tulenbeng Wok	Kiunga Road	5.3082	141.2528
Tabubil area	MH13-08	9&24/2/13	Umansim Wok	Kiunga Road	5.3340	141.2775
Tabubil area	MH13-11	26/2/13	Yemun Wok	Sawmill	5.3871	141.2972
Tabubil area	MH13-12	26–27/2/13	Ok Menga	Kiunga Road bridge	5.3702	141.2947
Tabubil area	MH13-13	1/3/13	Kumarang Wok	Swimming hole	5.3047	141.2485

Table 2. Habitat features of freshwater fish sampling sites.

Site code	Waterway	Habitat type	Size	Flow	Substrate	°C	Cond µS/cm	pH
MH13-09	Trib. Ok Tupnon	Karst stream	Small	Low	Cobble	15.9	255	6.5
MH13-10	Ok Tupnon	Montane stream	Medium	High	Limestone	14.4	201	
MH13-04	Yukfon	Forest stream	Small	Moderate	Limestone	21.8	237	
MH13-05	Small spring pond	Instream dam on soak	Small	Low	Mud			
MH13-06	Trib. Ok Tedi	Large dam on small stream	Large	Low	Clay	26.5	260	7.0
MH13-07	Tulenbeng Wok	Montane stream	Small	Moderate	Rock			
MH13-08	Umansim Wok	Montane stream	Medium	Moderate	Tock	23.6	239	
MH13-11	Yemun Wok	Open shallow stream	Medium	Low	Rock, cobble	25.8	74	6.5
MH13-12	Ok Menga	Upland river	Large	High	Rock	21.4	260	7.0
MH13-13	Kumarang Wok	Montane stream	Medium	Moderate	Cobble			

Site selection, access and fish sampling was greatly aided by local assistants, who were also able to pass on their personal and family knowledge to document Faiwol takam (fish) names for local species (Table 4). Fishes were initially identified in the field using the keys of Allen et al. (2008), and representative voucher specimens were taken from each site to facilitate laboratory confirmation of identification, quality assurance, and as routine tissue vouchers for broader taxonomic reviews.

Table 3. Fish sampling methods and collectors.

Site code	Waterway	Method	Collectors
MH13-09	Trib Ok Tupnon	Dip, night obs., trap	M Hammer, J Mark
MH13-10	Ok Tupnon	Dip, night obs.	M Hammer, J Mark
MH13-04	Yukfon	Dip net, night obs.	M Hammer, M Borok
MH13-05	Small spring pond	Angle	M Hammer, M Borok
MH13-06	Trib. Ok Tedi	Seine, trap, dip, cast	M Hammer, M Borok, J Bekton
MH13-07	Tulenbeng Wok	Dip, angle, trap	M Hammer, M Borok, J Bekton
MH13-08	Umansim Wok	Seine, dip, trap, angle, cast	M Hammer, M Borok, J Bekton, S Richards
MH13-11	Yemun Wok	Seine, cast	M Hammer, M Borok, J Lieng
MH13-12	Ok Menga	Cast, angle, night obs.	M Hammer, M Borok, J Lieng, S Richards
MH13-13	Kumarang Wok	Cast and night obs.	M Hammer, M Borok, J Bekton, S Richards

Results and discussion

Survey data, review of literature, and anecdotal Faiwol knowledge of local fishes indicates that at least 19 species occur in the region surveyed (Table 4). The fauna at the two survey locations is discussed along with taxonomic and conservation issues for different species groups.

Regional fish data

No fish were recorded at Tupnonbil (Table 5) as may be expected for a higher elevation area where small streams have cool water (for a tropical region) and unstable habitat, being very flashy in response to frequent heavy rain (Allen et al. 2008). Nevertheless the streams at this location were relatively pristine, and may support localised populations of upland species like Fimbriate Gudgeon (*Oxyeleotris fimbriata*); and they represent a significant aquatic habitat for tadpoles and invertebrates, including larval stages of a unique odonate fauna (see Chapter 5).

Twelve native and one introduced fishes were sampled from the Tabubil region (Table 5). Several species were found only in the Ok Menga proper, and this large-river habitat likely houses further species including additional grunters and catfishes. Species richness is known to increase steadily with decreasing elevation in the mountainous sections of the Fly River (Roberts 1978, Storey and Smith 2007, Allen et al. 2008), so this list should be considered to apply to the Tabubil region only, with a southern boundary at the Ok Menga. Anecdotal information indicates the presence of Indian Long-finned Eel (*Anguilla bicolor*) and additional catfish species that were not seen but are caught by locals in the study area south of Tabubil (Table 4).

Collectively the fish fauna of the Tabubil region is highly significant because it includes a number of Fly River endemics including the Ok Tedi Rainbowfish which is restricted to the upper Ok-Tedi, other narrow range New Guinea endemics, and a range of species with specialised upland habitat requirements (Table 4). The Ok Tedi Rainbowfish is listed by the IUCN as Vulnerable A2ce (IUCN 2006).

All of the species recorded had Faiwol names (Table 4) and hence were species known to and likely to be utilised by local communities (Maunsell and Partners 1982), especially dol (eeltailed catfishes), kinfoom (grunter) and bom and nayugim (larger gudgeons). Nayugim had special significance as a rare and prestigious fish, that one is "famous in the village" for catching.

None of the species collected were obviously new to science, but taxonomic investigations of poorly-known groups in the Australia and New Guinea region will use samples collected during this survey to study several difficult species complexes and additional Fly River endemic species may be revealed (see below).

Table 4. Takam (fish) of the Tabubil region, including tributaries of the Ok Tedi. Compiled from Allen et al. (2008), Storey and Smith (2007), Roberts (1978) and sampling data and anecdotal Faiwol information from this study. Faiwol names in brackets are alternate spelling or regional takam names sourced from Maunsell and Partners (1982); † kinfoom is the name given to the Sooty Grunter *Hephaestus* sp. in this publication. * Introduced species.

Family	Species	Faiwol name	Common name	Distribution	This survey
Anguillidae	Anguilla bicolor	kiwal - eel fish	Indian Short-finned Eel	Indo-west Pacific	Anecdotal, matches previous data
Clupeidae	Clupeoides venulosus	kulakan - silver flat fish	River Sprat	Narrow range New Guinea endemic	Not found, locally extinct?
Ariidae	Neoarius latirostris	gulim	Broad Snouted Catfish	Southern New Guinea	Anecdotal, matches previous data
Plotosidae	Neosilurus equinus	dol - yellow	Southern Tandan	Mountainous southern New Guinea	First records in recent years
Plotosidae	Oloplotosus luteus	dol - brown thick skin	Pale-yellow Tandan	Upper Fly River endemic	Anecdotal, not recorded in recent years
Plotosidae	Plotosus papuensis	dol - black & white stripes	Papuan Tandan	Central southern New Guinea	Anecdotal, would be a range extension
Plotosidae	Neosilurus ater	ganim (baiang)	Black Catfish	Northern Australia and New Guinea	Anecdotal, matches previous data
Atherinidae	Craterocephalus nouhuysi	dumisiri	Mountain Hardyhead	Mountainous southern New Guinea	Matches previous data
Melanotaeniidae	Melanotaenia cf. goldiei	gus (gas)	Goldie River Rainbowfish	Southern New Guinea	Matches previous data
Melanotaeniidae	Melanotaenia oktediensis	gus (gas)	Ok Tedi Rainbowfish	Upper Fly River endemic	Good populations recorded
Melanotaeniidae	Melanotaenia rubrostriata	gus - with pink stripes	Red-striped Rainbowfish	Central southern New Guinea	Matches previous data
Terapontidae	Hephaestus habbemai	kinfoom† (uikan)	Mountain Grunter	Mountainous southern New Guinea	Matches previous data
Apogonidae	Glossamia trifasciata	wigan	Threebar Mouth Almighty	Central southern New Guinea	Extended elevation limit
Eleotridae	Bostrychus strigogenys?	nayugim	Stripe-cheeked Gudgeon	Central southern New Guinea	Extended elevation limit
Eleotridae	Mogurnda cingulata	sabam (sabbom)	Banded Purple-spotted Gudgeon	Central southern New Guinea	Matches previous data
Eleotridae	Oxyeleotris fimbriata	bom	Fimbriate Gudgeon	Northern Australia and New Guinea	Matches previous data
Gobiidae	Glossogobius concavifrons	kulok (kuulim)	Concave Goby	Northern Australia and New Guinea	Matches previous data
Gobiidae	Glossogobius robertsi	warami	Roberts' Goby	Narrow range New Guinea endemic	Matches previous data
Cichlidae	Oreochromis mossambicus	makow	Tilapia*	Expanding across New Guinea	New records from Tabubil

Table 5. Freshwater fish data for sampled sites. * Introduced species. † These fish were sampled several kilometres further upstream.

Site code	Waterway	No fish	*Neosilurus equinus*	*Craterocephalus nouhuysi*	*Melanotaenia* cf. *goldiei*	*Melanotaenia oktediensis*	*Melanotaenia rubrostriata*	*Hephaestus habbemai*	*Glossamia trifasciata*	*Bostrychus strigogenys*?	*Mogurnda cingulata*	*Oxyeleotris fimbriata*	*Glossogobius concavifrons*	*Glossogobius robertsi*	*Oreochromis mossambicus**
MH13-09	Trib Ok Tupnon	x													
MH13-10	Ok Tupnon	x													
MH13-04	Yukfon											15			
MH13-05	Small spring pond														30
MH13-06	Trib. Ok Tedi					35					20				350
MH13-07	Tulenbeng Wok											5	5	10	
MH13-08	Umansim Wok		1	30		75	5	2			20	4	12	5	
MH13-11	Yemun Wok			20	20		3				10	1	10	5	
MH13-12a	Ok Menga - main river		2			1				1	2		1	5	5†
MH13-12b	Ok Menga - side stream					15			1		10	5			
MH13-13	Kumarang Wok					30							10	10	

Herrings

Herrings (Clupeidae) are a group of thin silvery fishes, with three endemic species occurring in southern central New Guinea. One of these, the West Irian River Sprat (*Clupeoides venulosus*), is the only herring in the world known to inhabit mountainous rivers (50–500 m asl), and was formerly common in the upper Ok Tedi region (Allen et al. 2008). There have been no recent records of the species and concern is held for its status in the Fly River system; specific targeted surveys should be undertaken to inform conservation (Storey and Smith 2007).

Catfishes

Catfishes are distinctive in having barbells around the mouth which help them locate prey; three pairs for fork-tail catfishes (Ariidae) and four pairs for eel-tail catfishes (Plotosidae). The taxonomy of catfishes appears relatively stable and currently described species are morphologically distinct, but the presence of cryptic species in different New Guinea catchments cannot be ruled out, especially for upland specialist species like the Mountain Catfish (*Neosilurus equinus*). Furthermore, additional unknown forms could still occur in remote areas given the apparent rarity of several of the currently known species (Roberts 1978). Catfishes were not well represented in catches from the current study, nor in recent sampling projects in the area, and serious populations declines are thought to have occurred in eel-tail catfishes in the Ok Tedi

Example of extreme variation of flow in streams in the Hindenburg Range. The Ok Tupnon at Bilbilokabip, Tupnonbil area. (*Photos S.J. Richards*)

catchment (Allen et al. 2008). Catfishes were well known to locals, especially at Ok Menga, but knowledge of their occurrence in smaller streams seemed to be more in living memory than from recent experience, and this may also be indicative of broader declines in the region. A targeted study of catfishes in the upper Fly River area, including the Tabubil area, would help to inform the status and management of this group which has important conservation and cultural values.

Rainbowfishes

Rainbowfishes (family Melanotaeniidae), as the name implies, are a spectacular group of small native fishes, and they are very popular in the aquarium hobby around the world. The taxonomy of rainbowfishes has been advanced considerably in the last 30 or so years, with a steady stream of new forms discovered and many species formally described (e.g. Allen and Hadiaty 2013). Evidence from molecular genetic data now suggests that many widespread 'single' species in fact constitute two or more cryptic forms and a new wave of species descriptions is likely to follow (Unmack et al. 2013). Three species of rainbowfish were found during the current study, and this is consistent with results from previous surveys. The Ok Tedi Rainbowfish is of special importance given its small and now fragmented distribution. This species is known to occur only in a narrow strip of habitat in the Tabubil region where streams flatten out slightly before entering the Ok Tedi, a water body now unsuitable for the persistence of this species. High gradient, very fast flowing stream sections in this area do not seem to be occupied by the species. Larvae of this species were observed in small slow-flowing areas of suitable streams behind boulders (e.g. Kumarang Wok).

Detailed mapping and long-term monitoring of this species would help to inform the basis for conservation options, especially in light of the threat posed by Tilapia (see below). Similar research would be valuable for the Strickland Rainbowfish (*Melanotaenia iris*), a parallel example of a narrow range endemic species in the upper Strickland River. Finally taxonomic research is in progress for the Goldie River Rainbowfish (*Melanotaenia goldiei*), which becomes more common with decreasing elevation (Upper and Mid Fly distribution), as this species appears to be a complex of several species and the Fly River population possibly represents another narrow-range endemic species (Allen et al. 2008, Unmack et al. 2013).

Gobies and gudgeons

Gobies and gudgeons are small, typically non-descript species that live on the benthos. Despite the generally smaller size of gobies and gudgeons, being the only fish inhabitants of some upland high velocity streams they are often well known by local communities. As in the case of nayugim (see Table 4) they can be highly regarded as part of stream ecosystems and perhaps have ongoing value as food. The group is very diverse globally, and in New Guinea there are many unique species some of which have special adaptations for living in upland areas. For example Roberts' Goby (*Glossogobius robertsi*) has a small modified pelvic disk, which helps it to cling to rocks in fast flowing habitats. The Fimbriate Gudgeon (*Oxyeleotris fimbriata*) appears to have special behavioural adaptations for penetrating well upstream, having one of the widest distributions across diverse habitat types of any fish in New Guinea (assuming it is a single species) (Allen 1991). The taxonomy of gobies and gudgeons is far from settled, and there are likely to be taxonomic revisions recognising regional populations as distinct species, in groups such as purple-spotted gudgeons (Genus *Mogurnda*) and the highland adapted Roberts' Goby. Identification of *Glossogobius* material in the Tabubil region using current keys is challenging due to wide variation in characters and appearance, and leading taxonomists suggest that there are possibly two additional species present in the area (D. Hoese pers. comm. 2013). Future genetic characterisation of samples from the current study will aid the separation of candidate species. A single nayugim was sampled that was provisionally identified as Striped Cheeked Gudgeon (*Bostrychus strigogenys*) based on overall morphology. However, this species is otherwise reported as a lowland fish of slow flowing streams and swamps and the large (215 mm SL, 258 mm TL) individual from Ok Menga is beyond the maximum size reported (180 mm SL) and was dark in colour lacking the typical colouration of *B. strigogenys*, including cheek stripes and tail ocellus (Allen et al. 2008); genetic comparison with fish from the Middle Fly would shed light on this atypical fish.

Tilapia and other introduced species

Prior to the mid-1980s there were very few records of introduced fish in the Fly River system and in south-central New Guinea in general (Allen et al. 2008). However, there has since been a proliferation in the number of introduced species (at least five species) and an expansion of their ranges in the Fly River (now

widespread across the lower and mid Fly regions). This study provides the first records of Tilapia in the Tabubil region, and discussion with local communities tracked several recent independent introductions. Releases into the wild have apparently occurred within the last two years, originating from live fish purchased at the Kiunga markets. Tilapia have now rapidly populated at least two artificial off-stream habitats in the area, and were also recorded in lower densities in stream and river environments around and including the Ok Menga. Tilapia are a prolific species and known to be a significant threat to native fishes through competitive displacement, predation and habitat alteration (Russell et al. 2012). Once established they are difficult to remove, with prevention of spread and localised control often the only options (Russell et al. 2012). Tilapia do tend to be most prolific in disturbed environments (as witnessed in this study), and hence maintaining streams of the Tabubil area in a natural state could provide some buffer to impacts (Linde et al. 2008), but will be challenging considering the large and growing human population. The advantages of the ready source of food offered by Tilapia needs to be assessed against the loss of species of conservation and cultural significance. Education programs highlighting the consequences of introducing Tilapia, and other species, to wild habitats are recommended as an urgent management priority.

Conservation recommendations

A series of recommendations are made toward conservation of fishes and aquatic habitats in the study area and in the broader Hindenburg Wall region:

Address species introductions
Establishing education programs and localised control actions could help to minimise the impacts of Tilapia and other potential invasive species in the region.

Survey remote habitats
There remains great potential for discovery of new fish species in the Hindenburg Wall region due to the large areas of forest and associated waterways that remain unexplored. Exploration that targets areas at moderate elevation (50–500 m asl) away from roads are most likely to locate unique forms.

Undertake targeted surveys assessing species' status
The very localised distribution of the endemic Ok Tedi Rainbowfish, the rarity of catfish species in the study area, and the apparent absence of River Sprat call for further targeted studies to determine these species' distributions and population status and to support their conservation and management.

Support ongoing taxonomic studies
Combined morphological and genetic investigation of widespread species across New Guinea and Australia is likely to reveal localised endemic species in the Fly River, especially for upland habitat specialists. There are particular issues in the Fly River that need investigation (e.g. *Glossogobius*).

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Fimbriate Gudgeon, *Oxyeleotris fimbriata.* (Photo M.Hammer)

Ok Tedi Rainbowfish, *Melanotaenia oktediensis.* (Photo M.Hammer)

Chapter 7

Herpetofauna

Stephen J. Richards

Summary

This chapter summarises a survey of herpetofaunal diversity in forests around the Hindenburg Wall and Tabubil in Western Province, Papua New Guinea. A total of 37 native species (24 frogs and 13 reptiles) were documented across a 2,000 m altitudinal gradient. At least 10 species of frogs are undescribed, and six of these appear to be entirely new to science (discovered for the first time during this survey). One species of lizard, a member of the montane genus *Papuascincus*, also appears to be undescribed. Of the 12 described frog species assessed by the IUCN four (33.3%) are classified as Data Deficient due to their poorly-known distributions and ecological requirements. None of the reptiles encountered has been assessed by the IUCN. The exotic Cane Toad, *Rhinella marina*, is abundant in Tabubil's suburbs but its impacts on native species there are unknown. The extremely wet, forest-covered mountains of the Hindenburg Range and adjacent Star Mountains provide habitat for a large number of new and poorly known frog species, and recognition of the Hindenburg Range as part of the proposed 'Sublime Karst of Papua New Guinea' World Heritage Area would be a critical first step in ensuring the long-term survival of this diverse herpetofaunal assemblage.

Introduction

Although the Dutch conducted a major expedition to the Star Mountains in eastern Dutch New Guinea (now Indonesian Papua Province) in 1959 (Brongersma and Venema 1962) and made collections of herpetofauna there, it was not until the 1960s that documentation of herpetofauna in the southern catchments of the Star Mountains and Hindenburg Range in (current) Papua New Guinea began. The first significant collections of both frogs and reptiles in the upper Ok Tedi were made by Fred Parker, who travelled through the area as a Kiap in the late 1960s. His material was sent to museums in Australia and the USA, where it was used in several taxonomic studies of lizards and frogs (e.g. Greer and Parker 1974, Zweifel 1972). Meanwhile Barry Craig at the South Australian Museum made collections to the north in the Telefomin region during the 1965 Australian Star Mountains Expedition and some of his material was also examined by Zweifel (1972) and by Michael Tyler at the South Australian Museum (e.g. Tyler 1968). More recently Harold Cogger collected a number of new frog and lizard species from the Ok Tedi headwaters in 1987 during the joint Australian Museum and PNG Division of Wildlife expedition to the Star Mountains, which ascended to ~3,200 m above sea level (asl). That material was included in papers describing new montane frogs (Zweifel et al. 2005) and lizards (Greer et al. 2005) from across New Guinea. Perhaps the

most significant contribution to herpetological studies of this region was by Hyndman and Menzies (1990). These authors summarised the biological collections and data compiled by David Hyndman between 1973 and 1985 as part of his ethnobiological studies of the Wopkaimin, and by James Menzies as part of his zoological studies in the region beginning in 1972. They provided one of the few comprehensive lists of herpetofauna species for any region in New Guinea and attempted to place the fauna in a biogeographical context. Although a number of their identifications require correction, this paper remains a seminal work on the herpetofauna of the Hindenburg Range and Star Mountains.

Since publication of this work, Menzies (1993, 1999) has described several new frogs from the Ok Tedi headwaters and, based on a series of expeditions between 1991 and 1995, Stephen Richards from the South Australian Museum and colleagues also described several frog species from this region (Richards et al. 1992, 1994, Richards and Johnston 1993, Johnston and Richards 1994, Richards et al. 1995).

Despite these studies the frog fauna (in particular) of the Ok Tedi headwaters remains inadequately documented. This is evident from the fact that each expedition to the region has documented a very high proportion of species new to science (S. Richards pers. obs.). The 2013 Wildlife Conservation Society expedition to the Hindenburg Wall area in the Ok Tedi headwaters provided the opportunity to undertake an intensive, targeted survey for frogs and reptiles. Results of that survey are presented here.

Methods

Study sites
See Table 1 for list of site coordinates and sampling dates, and Chapter 2 for vegetation characteristics of sample localities.

Tabubil area (~285–910 m asl),
Sampling in the Tabubil area was restricted to sites accessible by car along the Kiunga-Ok Tedi Mine road. Sampling was further constrained by limited availability of vehicles, and was possible only for 3–5 hours on each of six days. Sampling took place between Dablin Creek in the north and Yemun Wok at 'Sawmill Flats' in the south (Table 1). Forest along the road has been severely degraded, being converted to gardens or heavily disturbed by timber extraction. Forest on the western side of the Ok Tedi was not accessed due to structural damage to the access bridge, and the vegetation on the north-eastern slopes of the Ok Tedi valley adjacent to Tabubil has been entirely removed in the past 18 years (S. Richards, pers. obs).

Remnant riparian forest occurs along a number of streams in the area, and primary forest persists at the top of the Dablin Creek access track/pipeline.

Tupnonbil area (~1,700–1,850 m asl)
Sampling in this area was based out of the small hamlet of Bilbilokabip, a group of three huts used by their owners from Bultem when hunting and gardening in the Tupnonbil area. Primary Lower Montane Rainforest (sensu Hyndman and Menzies 1990; see also Chapter 2) surrounded the hamlet, but to the north-east extensive areas of gardens and secondary forest dominated. I sampled in all available terrestrial habitats. Aquatic habitats sampled for frogs included the Ok Tupnon, a large, clear stream running adjacent to camp, and a number of its smaller tributaries. A small seepage in the Ericoid Scrub (see Chapter 2) at the edge of Bilbilokabip hamlet provided habitat for at least one species of hylid frog and the small temporary pools formed along trails through the forest after heavy rain were also sampled.

Minni camp (~2,300–2,500 m asl)
Sampling at this site was extremely limited (Table 1) and was conducted by the mammal and plant teams because the remainder of the biodiversity team did not access this site. The vegetation at this montane site is described in Chapter 2.

Table 1. Sample sites and schedule for herpetofauna survey, Hindenburg Wall area.
Surveys at Minni Camp and Bilbilokabip were conducted by day and night

Site	Latitude	Longitude	Elevation (m)	Dates (2013)
Kawarobip				
Minni Camp	5.0775	141.1505	2,383	24–28 February (Aplin, Venter collectors)
Tupnonbil				
Bilbilokabip	5.1203	141.2512	1,770	11–24 February
Tabubil Area	~5.2–5.4	~141.2–141.3	~280–910	8–10 & 26–28 February
Remnant forest and regrowth along Kiunga-Ok Tedi Mine road including following sites:				**D=Day, N=Night**
Dablin Creek	5.2151	141.2318	909	D
Yukfon Creek	5.2333	141.2221	734	D+N
Tabubil Town	5.2657	141.2200	546	D+N
Quarry S. Tabubil	5.2970	141.2415	407	D
Kumarang Wok	5.3047	141.2485	380	D+N
Tulenbeng Wok	5.3082	141.2528	433	D
Umansim Stream	5.3340	141.2775	360	D+N
Yemun Wok	5.3871	141.2972	285	D

Field methods

All sampling was undertaken by myself and 1–2 local assistants (except at Minni Camp, see above). At each site we conducted intensive searches for frogs and reptiles along trails established for this purpose. During the day we searched for heliothermic (basking) reptiles along trails through forest, in clearings, and on stream 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. We searched for nocturnal reptiles, including geckos, by walking along forest trails at night with a headlamp.

We searched for frogs at night by conducting visual-encounter and aural surveys along streams, and in and around small ponds. Because a large proportion of New Guinea's frogs have life cycles that are independent of freestanding water, we also conducted extensive visual and aural searches along trails in forest away from water. Frog calls are an important diagnostic character that assist greatly with species identification so whenever possible

I recorded the advertisement calls of frogs with a Marantz PMD-661 Solid-state Recorder and a Sennheiser ME66 microphone. Representatives of 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 forlarger reptiles. Specimens were fixed in 10% formalin solution, and then stored in 70% ethanol. Samples of liver tissue for DNA analyses were extracted from representative specimensof each species and stored in 95% ethanol. Voucher specimens will be deposited in the Papua New Guinea National Museum and Art Gallery, Port Moresby, and in the South Australian Museum, Australia.

Results and discussion

A total of 37 native species (24 frogs and 13 reptiles) were documented during this survey (Table 2). At least 10 species of frogs are undescribed and six of these appear to be entirely new to science, being discovered for the first time during this survey; one lizard also appears to be undescribed. Although the total diversity of frogs and reptiles documented during this survey is less than that half of that reported by Hyndman and Menzies for the upper Ok Tedi region (57 frogs and 40 reptiles), their list was based on more than 10 years of accumulated knowledge over a much larger area than was accessed during this survey.

Although the total diversity of herpetofauna documented around Tabubil and at Tupnonbil was similar (18 vs 16 species respectively; Table 2) the proportions of frogs and reptiles at each site are strikingly different. In the foothills around Tabubil reptiles and frogs each comprised 50% of the herpetofauna while at Tupnonbil frogs represented 75% of the fauna and reptiles just 25%. The higher proportion of frogs found in wet, Lower Montane Rainforest is typical of most sites in New Guinea. For example Richards and Dahl (2011) found that at ~1,600 m asl in the Muller Range reptiles accounted for just 13% of the total herpetofauna.

Further comparisons with the Muller Range survey are difficult because sampling in the foothills around Tabubil during this survey was so limited, and the accessible habitat was so severely degraded; both frog and reptile diversity at these elevations in the Ok Tedi headwaters are known to be much higher (Hyndman and Menzies 1990), and S. Richards and colleagues documented more than 30 frog species between ~300 and ~900 m asl around Tabubil during 1991–1995 in forests that have now been almost entirely cleared (S. Richards, personal observation).

Despite these limitations, it is clear that the frog fauna of the southern catchments of the Star Mountains and Hindenburg Range is exceptionally diverse. This conclusion is supported by the observation that at least six of the frog species encountered during this survey appear not to have been documented previously. Their documentation brings the total number of frog species known from the upper Ok Tedi area to more than 60.

Significant species

Reptiles

Cyrtodactylus capreoloides (see photograph)
This is a small member of the gecko genus *Cyrtodactylus* that was described only recently (Rösler et al. 2007) from the Kikori Basin in Southern Highlands Province. It has subsequently been documented from two additional sites in Southern Highlands Province and at one site in the upper Strickland River catchment (Oliver et al. 2012). The record from Yukfon Creek near Tabubil is the most westerly locality for this poorly-known species.

Papuascincus sp. nov.
Lizards of the endemic New Guinean genus *Papuascincus* are generally confined to high altitudes and they are often abundant in forest clearings or open meadows. The genus is taxonomically difficult, but it appears that the taxon encountered at Minni Camp is an undescribed species that was previously known only from two specimens collected on Mt Akrik near Tabubil (Richards unpublished data). A *Papuascincus* species was also documented at Bilbilokabip and studies will be conducted to determine whether it is conspecific with the Minni Camp form.

Table 2. List of frog and reptile species documented from three locations during the Hindenburg Wall survey, February 2013.

Family	Species	Tabubil	Bilbilokabip	Minni Camp	IUCN Status
Frogs					
Dicroglossidae	*Limnonectes grunniens*	X			LC
Hylidae	*Litoria angiana*		X		LC
Hylidae	*Litoria bulmeri*			X	DD
Hylidae	*Litoria infrafrenata*	X			LC
Hylidae	*Litoria iris*		X		LC
Hylidae	*Litoria modica*		X		LC
Hylidae	*Litoria sp. nov. 1 cf arfakiana*	X			NE
Hylidae	*Litoria sp. nov. 2 cf micromembrana*		X		NE
Hylidae	*Litoria sp. nov. 3 cf pratti*	X			NE
Hylidae	*Nyctimystes oktediensis*		X		DD
Hylidae	*Nyctimystes zweifeli*			X	DD
Microhylidae	*Asterophrys turpicola*	X			LC
Microhylidae	*Callulops sagittatus*			X	DD
Microhylidae	*Cophixalus? sp. nov. (aquatic)*		X		NE
Microhylidae	*Hylophorbus sp. nov.*		X		NE
Microhylidae	*Oreophryne sp. (probably ampelos)*	X			NE
Microhylidae	*Oreophryne sp. nov. 1*		X		NE
Microhylidae	*Oreophryne sp. nov. 2 (tiny rattler)*		X		NE
Microhylidae	*Oreophryne sp. nov. 3*		X		NE
Microhylidae	*Oreophryne sp. nov. 4 (Minni Buzzer)*			X	NE
Microhylidae	*Xenorhina sp.*			X	NE
Ranidae	*Hylarana daemeli*	X			LC
Ranidae	*Hylarana cf grisea*	X	X		NE
Ranidae	*Hylarana sp. nov.*	X	X		NE
Totals (Frogs)		**9**	**12**	**5**	
Reptiles					
Lizards					
Gekkonidae	*Cyrtodactylus capreoloides*	X			NE
Gekkonidae	*Cyrtodactylus serratus*	X			NE
Gekkonidae	*Hemidactylus sp.*	X			NE
Gekkonidae	*Lepidodactylus lugubris*	X			NE
Scincidae	*Emoia longicauda*	X			NE
Scincidae	*Eugongylus rufescens*	X			NE
Scincidae	*Papuascincus sp. nov.*		X(?)	X	NE
Scincidae	*Sphenomorphus cinereus*		X		NE
Scincidae	*Sphenomorphus nigriventris*		X		NE
Scincidae	*Sphenomorphus schultzei*	X	X		NE
Snakes					NE
Elapidae	*Toxicocalamus sp.*	X			NE
Colubridae	*Stegonotus cucullatus*	X			NE
Colubridae	*Tropidonophis sp.*		X		NE
Totals		9	5	1	
GRAND TOTALS		**18**	**16**	**6**	

Frogs

New and undescribed species

Litoria sp. nov. 1 cf *arfakiana*

This moderate-sized treefrog has extremely variable colour patterns and a sharp snout, and appeared to be quite common at Yukfon Creek above Tabubil where males called from perches high in the trees over a small waterfall. This frog is related to *Litoria arfakiana* (to which it was referred by Hyndman and Menzies 1990) but it has a slightly different advertisement call and genetic studies are required to confirm its status.

Litoria sp. nov. 2 cf *micromembrana*

A moderately small, often strikingly marked frog with large eyes and a rather blunt snout that was found on low vegetation next to torrential stretches of the Ok Tupnon in forest adjacent to Bilbilokabip. This species was referred to *L. micromembrana* by Hyndman and Menzies (1990) but it is different from other populations of that species from central and eastern PNG, and it remains undescribed.

Litoria sp. nov. 3 cf *pratti*

A moderately small, rather nondescript brown treefrog that lives along torrents and waterfalls at Yukfon Creek above Tabubil, where males called from leaves hanging over the stream. The species is morphologically similar to *Litoria pratti*, a species known only from far western Papua Province, Indonesian New Guinea. It was referred to *L.* cf *pratti* by Hyndman and Menzies (1990), and remains undescribed.

Cophixalus? sp. nov. (aquatic)

A moderately small, brown, semi-aquatic frog that was found only along a waterfall draining into the Ok Tupnon at Bilbilokabip. Frogs were active in shallow water or among rocks adjacent to a series of small torrents. Few Melanesian microhylid frogs are aquatic, and this species appears to be completely new to science. This species' generic relationships are currently ambiguous and require further study.

Hylophorbus sp. nov.

A small, brown, rather long-legged terrestrial frog that was found in mossy forest at Bilbilokabip. This is probably the same species recorded by Hyndman and Menzies (1990) from the Ok Tedi headwaters, and it remains undescribed.

Oreophryne spp nov.

The microhylid frog genus *Oreophryne* is both speciose and taxonomically difficult. Most species are small, morphologically conservative, and distinguishing characters are often based on osteological and/or myological features. However five species were documented during this survey, and at least four of them appear to be new to science. Although it is possible that one or more of these species was included in Hyndman and Menzies' (1990) list of seven unidentified *Oreophryne* taxa from the region, it will not be possible to confirm this until their material is re-examined.

Hylarana sp. nov.

A very large, long-legged frog that lives along mountain torrents. It does not appear to belong to any of the species of this genus reported (as *Rana*) from the region by Hyndman and Menzies (1990). It was, however, documented from Mt Akrik in the 1990s by S. Richards and G. Johnston.

IUCN listed species

Four species of frogs documented during this survey are currently listed by the IUCN as Data Deficient.

Litoria bulmeri

This attractive, bright green treefrog with a black lateral stripe was listed as Data Deficient 'in view of continuing uncertainties as to its extent of occurrence, status and ecological requirements' (Richards and Parker 2004a). It is known only from two widely separated localities in Papua New Guinea, the Schrader Mountains and the southern flanks of the Star Mountains, between 1,600 and 2,200 m asl. The documentation of this species at Minni Camp does not represent a significant range extension, but it does confirm that at least one population of this poorly-known species persists in the Ok Tedi headwaters region. No calls that could be attributed to this species were heard.

Nyctimystes oktediensis (Rear cover photograph)
This large brown treefrog, with extremely large eyes, is listed by the IUCN (as *Litoria oktediensis*) as Data Deficient 'in view of continuing uncertainties as to its extent of occurrence, status and ecological requirements' (Richards and Price 2004). *Nyctimystes oktediensis* was described by Richards and Johnston (1993) from the upper Ok Tedi drainage system and it remains known only from the Star Mountains (on both sides of the PNG/Indonesia border) at altitudes between 1,600–2,000 m asl. Two animals were seen in forest near streams at Bilbilokabip.

Nyctimystes zweifeli
A large and spectacular treefrog that is listed as Data Deficient 'in view of the absence of recent information on its extent of occurrence, status and ecological requirements'. (Richards and Parker 2004b). It is known only from the Hindenburg Range and Star Mountains. A single specimen was found in a small tree beside an open rocky stream at Minni Camp.

Callulops sagittatus
This is a robust, ground-dwelling frog, often with orange markings on the head, and a call that sounds like a series of deep barking notes. The species is listed as Data Deficient by the IUCN on the basis that 'it has only recently been described, and there is still very little information on its Extent of Occurrence, population status and ecological requirements.' (Richards and Bickford 2004). Prior to its rediscovery at Minni Camp during this survey it was known only from the type locality on the summit of Mt Binnie adjacent to the Ok Tedi mine. The Minni specimens were found during clearing of dense ground cover on arrival at the campsite.

Exotic species
The Cane Toad, *Rhinella marina* has colonised the Tabubil area since the mid-1990's, when it was not present in the area (S. Richards, pers. obs.). This highly invasive species has had serious impacts on a number of native predators in Australia, but its impacts on native wildlife around Tabubil are currently unknown.

Conservation recommendations

The results of this survey reinforce the importance of the Hindenburg Wall area as a major centre of frog diversity in New Guinea. They highlight the importance of careful management of the forest that remains in the region in order to retain this exceptional diversity; for example broad-scale loss of forest in the lower Ok Tedi valley close to Tabubil town has dramatically reduced the herpetofaunal (particularly frog) diversity there (S. Richards, pers. obs.). By helping the local community at Bultem to develop management plans for the region around Bilbilokabip that consider the impacts of broadscale clearing and, in particular, promotes awareness about the impact of fire, impacts on local forest-dwelling species may be reduced.

The major issue identified by the IUCN assessments of the four frog species listed as Data Deficient was a lack of information about these species' distributions, ecological requirements and status. This survey has provided new distributional information about populations of these species within the Hindenburg Range and Star Mountains, but done little to assess the status of these populations. A major recommendation by the IUCN for these species is to instigate monitoring programs to assess their population status. Repeated sampling at a site(s) known to harbour these species (i.e., Minni Camp where three of the four Data Deficient species, *Litoria bulmeri*, *Nyctimystes zweifeli* and *Callulops sagittatus*, were found) would provide valuable information about the status of these regionally endemic or near-endemic species.

The current distribution of Cane Toads in the Tabubil area should be documented, and a management plan to reduce the probability of its spread to other remote areas in Western Province should be developed. Recognition of the Hindenburg Range as a globally significant environment through World Heritage listing will be an important step towards protection for a suite of forest-dependent frog and reptile species found no-where else on earth. Efforts should be continued, in close collaboration with local communities, towards declaring the Hindenburg Range as a World Heritage Area.

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The poorly-known gecko *Cyrtodactylus capreoloides* from near Tabubil. (Photo S.J.Richards)

Nyctimystes oktediensis, a species endemic to the Star Mountains and Hindenburg Range, and listed as Data Deficient by the IUCN. It was found at Tupnonbil. (*Photo S.J.Richards*)

Chapter 8

Birds

Iain Woxvold, Bensolo Ken and Ken P. Aplin

Summary

Birds were surveyed during 6–28 February 2013 from two locations in the Ok Tedi headwaters area of Western Province, Papua New Guinea: 1) Bilbilokabip, in the western sector of the Hindenburg Range near the base of the northern Hindenburg Wall (main survey focus; 1,700–1,990 m); 2) areas around Tabubil (opportunistic birding; 350–1,075 m). Additional samples were collected while mist netting for bats in the Kauwol River headwaters in the eastern Star Mountains (2,400–2,490 m). One hundred and fifty-seven species were recorded. Two hundred and one birds from 36 species were mist netted, photographed by camera trap or otherwise captured. Nine conservation listed species were recorded, including four birds listed by the IUCN as Vulnerable (Papuan Eagle *Harpyopsis novaeguineae*, Pesquet's Parrot *Psittrichas fulgidus*, [Black] Sicklebill *Epimachus fastosus*) or Near Threatened (Dwarf Cassowary *Casuarius bennetti*) and eight species that are protected under PNG law. Rufous-banded Honeyeater *Conopophila albogularis* and Eurasian Tree Sparrow *Passer montanus*are newly reported for the Tabubil area. Four species from Bilbilokabip are previously unrecorded from the Hindenburg Range and upper Ok Tedi catchment – New Guinea Scrubfowl *Megapodius decollatus*, Bronze Ground Dove *Gallicolumba beccarii*, Rufous-throated Bronze Cuckoo *Chrysococcyx ruficollis* and Lesser Ground Robin *Amalocichla incerta*. The conservation value of the Hindenburg Wall area is discussed.

Introduction

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 2007, Shearman et al. 2009). New Guinea and its satellite islands support the world's highest concentration of endemic birds (Gregory 2013)[2]. The region is exclusively home to most species of bird-of-paradise (Paradisaeidae), bowerbirds (Ptilonorhynchidae), Australasian robins (Petroicidae), cassowaries (Casuariidae) and owlet-nightjars (Aegothelidae), and is the only place in which berrypeckers and longbills (Melanocharitidae, Paramythiidae), satinbirds (Cnemophilidae), melampittas (*Melampitta* spp., Incertae sedis) and pitohuis (*Pitohui* spp. Pachycephalidae) are found (del Hoyo et al. 1999, 2007, 2008, Mack & Dumbacher 2007).

[2] Gregory's most recent checklist (2013) puts the figure at 47% (362/770).

Endemism on mainland New Guinea is highest along the Central Cordillera[3], a rugged complex of mountain ranges and high elevation valleys that stretch unbroken (not below 1,000 m above sea level (asl)) for ca. 1,600 km along almost the entire length of the island. Most montane bird species occur throughout the Central Cordillera. Others, however, exhibit discontinuous or incomplete distributions of various forms. For example, speciation in some groups has resulted in two or more sister species occupying separate ranges along an east-west axis (e.g. *Astrapia* birds-of paradise, 'bearded' *Melidectes* honeyeaters), while a number of distinct forms that occupy eastern (e.g. Blue Bird-of-paradise *Paradisaea rudolphi*) or western (e.g. Papuan Whipbird *Androphobus viridis*, Sooty Shrikethrush *Colluricincla tenebrosa*, Orange-cheeked Honeyeater *Oreornis chrysogenys*) sectors have no apparent replacement elsewhere; some species exhibit highly disjunct distributions, with one or more populations separated by long distances (e.g. Papuan Logrunner *Orthonyx novaeguineae*, Papuan Treecreeper *Cormobates placens*, Greater Ground Robin *Amalocichla sclateriana*), while a few are limited range endemics restricted (or nearly so) to small areas of montane habitat on one or a few isolated peaks (e.g. Snow Mountains Quail *Anurophasis monorthonyx*, Snow Mountains Robin *Petroica archboldi*). Avian community composition thus shifts among zoogeographic zones along the cordillera (Gilliard and LeCroy 1961, Diamond 1972, Beehler et al. 1986).

Situated approximately midway along the Central Cordillera, the Hindenburg Range lies between the Star Mountains and the Victor Emanuel Range. At its western end is the Hindenburg Wall, a series of three spectacular limestone escarpments that trend southeast above the eastern headwaters of the Ok Tedi. In places these rise nearly 1,000 m from their base, atop of which the range attains a height of more than 3,300 m (at Mt Aiyang) before descending north to the headwaters of the Sepik River. The base of the Hindenburg Wall varies in elevation from ca. 1,000 m in the south to 2,200 m at its northern end. From here the Ok Tedi flows south through rugged terrain before debouching onto the vast dissected alluvial plains of the Fly Platform.

As part of a broader multi-disciplinary biodiversity study, this report outlines the results of a bird survey undertaken in the Hindenburg Wall area of the upper Ok Tedi catchment.

Existing Data

The Ok Tedi headwaters around Tabubil and the Ok Tedi mine have been the subject of extensive survey effort. Bell (1969) first surveyed birds in the Ok Tedi drainage in 1966. Coates and Lindgren (1978) surveyed the area in 1978 as part of an environmental impact study prior to mining. Hyndman and Menzies (Hyndman 1984, Hyndman and Menzies 1990) reported on birds in the Ok Tedi headwaters as part of their broader 1973–85 ethnobiological studies. Extensive local surveys were subsequently undertaken by Murray (1988a, b) in 1985–87 and Gregory (summarised in 1995, 1997) in 1991–94 while based at Tabubil. In recent decades a great many additional birders have visited the Tabubil area as a birding 'hotspot' and standard stopover for New Guinea bird-tour itineraries (Gregory 2007, 2013). Notable records from these visits have regularly appeared in publications of the PNG Bird Society (e.g. Eastwood 1989, Hicks 1990a, b, 1992, Gregory 2007, 2009a, Eastwood and Gregory 1994, 1995).

The area around Tabubil is thus among the most thoroughly documented areas in PNG. However, most of this work was conducted at elevations below 1,500 m, with survey above these heights largely restricted to a few peaks at operational mine sites on the eastern slopes of the Star Mountains west of Ok Tedi River. A visit by Coates and Lindgren (1978) to Bultem village (1,700 m) provides a notable exception.
At higher elevations, and on the Hindenburg Range itself, survey coverage is far less complete. In 1954 E. Thomas and Margaret Gilliard collected birds from the Hindenburg and Victor Emanuel ranges on behalf of the American Museum of Natural History (Gilliard 1961, Gilliard and LeCroy 1961). Based at Telefomin on the upper Sepik, their itinerary included the eastern sector of the Hindenburg Range immediately north of the Fly River headwaters, some 40 km east of the Ok Tedi, sampling at elevations of 1,500–2,450 m. Tim Flannery and Lester Seri subsequently made a small collection of birds from incidental captures while studying mammals at various localities in the Star Mountains, Hindenburg (2,200–2,400 m) and Victor Emanuel ranges in the 1980s (reported in Rowland 1994, 1995a–c).

[3] Of more than 200 species found only on mainland New Guinea, nearly three quarters (153/208; 74%) are restricted to, or found predominantly at, elevations above 500 m (elevational limits provided in Coates 1985, 1990, Beehler et al. 1986).

Further afield, in 1936 A. L. Rand collected birds from Mount Mabion (780 m asl) at the Palmer River headwaters, ca. 60 km east of the Ok Tedi, as part of the second Archbold Expedition (Rand and Brass 1940, Rand 1940). Logistic constraints limited sampling at this site. West of the present study area, in 1959 Brongersma and Venema (1960; results reported in Mees 1964) collected birds (from up to 3,400 m on Mt Antares) while surveying mammals on the southern slopes of the Star Mountains in modern day Papua, Indonesia. In 1970–71, A. B. Mirza (Bishop Museum, Hawaii) collected birds incidentally from the Star Mountains and at Lake Louise (PNG) while collecting mammal ectoparasites (T. Pratt and M. Hagemann *in litt.* 2013). Ornithological results were not written up, though vouchers are held at the Bishop Museum. More recently, Gregory and Johnston (1993) surveyed birds over four days at 3,200 m at Dokfuma in the Star Mountains of PNG in 1991. In 1993 Jared Diamond and David Bishop surveyed birds in the Ketengban area of the Indonesian Star Mountains, near the border with PNG (1,190–3,660 m asl) (Diamond and Bishop 1999).

Methods

Birds were surveyed during 6–28 February 2013 from two locations in the western Hindenburg Range-Tabubil area. Additional samples were collected by Ken Aplin while mist netting for bats west of the main survey site in the eastern Star Mountains. Table 1 lists the camp/base position and effort summaries for each location. The habitats, coverage and methods used to survey birds in each location are described below.

Table 1. Position and effort summaries for each survey location. All dates are for the year 2013. Search hours are shown for the main bird surveyor: Ken Aplin (KA), Bensolo Ken (BK), and Iain Woxvold (IW).

Detail	Bilbilokabip	Minni	Tabubil
Camp/base coordinates	S5.12033° E141.25121°	S5.0775° E141.1505°	S5.26569° E141.21997°
Camp/base elevation (m asl)	1,770	2,383	546
Elevations covered (m)	1,700–1,990	2,400–2,490	350–1,075
Dates present	11–25 Feb.	24–28 Feb	6–11 & 25–28 Feb.
Personnel	IW & BK	KA	IW & BK
Sampling method			
Search hours (IW)	91.5	–	19.75
No. mist nets	21	5	–
Mist net-metre-hours (day and night)	34, 117.50	3, 960	–
No. camera traps	12	–	–
Camera trap hours	2,422.50	–	–

Bilbilokabip

The main survey effort was conducted in the upper Ok Tupnon catchment (Tupnonbil), an eastern tributary of the upper Ok Tedi that drains the western section of the northern Hindenburg Wall west of Mt Aiyang and Atembip village (as shown on the PNG National Mapping Bureau's 1:100,000 scale Ok Tedi (7187) map sheet). The camp was located at Bilbilokabip, a small hunting/gardening hamlet occupied intermittently by local residents of Bultem village. Bilbilokabip is situated along the main walking track linking Bultem and Tabubil in the south with Tifalmin in the upper Sepik catchment.

Natural vegetation in the Tupnonbil area spans the transition between Lower Montane Rain Forest (Zone 2) and low altitude Midmontane Rain Forest (Zone 3) as characterised for the Ok Tedi headwaters by Hyndman and Menzies (1990). Habitats surveyed included:

- Lower Montane Rain Forest – south of Bilbilokabip and below 1,800 m, along the ridge between the Ok Tupnon and Ok Atem, canopy dominated by the oak *Castanopsis*.
- Low altitude Midmontane Rain Forest – predominant at 1,800–2,000 m north of Bilbilokabip and to the base of the Hindenburg Wall.
- Converted habitats – east of Bilbilokabip, and across the Ok Tupnon, at 1,800–1,900 m asl was a large area (ca. 1 km^2) of shifting cultivation – a mosaic of active gardens, grassland, scrub and secondary forest in various stages of regeneration, some as old as 50 years (F. Venter, see Chapter 2).

Birds were surveyed by Iain Woxvald and Bensolo Ken over a period of 15 days (Table 1). Survey methods included 'active' searches, call recording and playback, mist netting and camera trapping. These techniques were combined to maximise completeness of the bird species inventory in the time available. Active searches were conducted along pre-existing walking trails within a 2 km radius of camp. Birds were surveyed at all times of day and identified visually and/or by their calls. Effort was weighted to early morning and late afternoon and included time before dawn and after dusk to cover active periods of both diurnal and nocturnal birds.

Birdcalls were routinely recorded on a Sony PCM-D50 Linear PCM Recorder. Selected calls were played aloud using a Logitech Z515 3-watt portable speaker. Twenty-one (21) mist nets (9–12 m, 31 mm mesh) were deployed by the bird and mammal survey teams in a variety of habitats, including primary forest on slopes, ridges, flats and gullies, and in open areas along watercourses or in gardens/regrowth. All nets were erected close to the ground (<6 m high) on trimmed saplings, were left open continuously (24 hours) and checked every 2–3 hours during daylight.

Captured birds were measured (bill, head, tarsus, wing), photographed and blood sampled (70% ethanol). Most birds were released, with the terminal end of three outer rectrices clipped for identification on recapture. Select individuals were collected as voucher specimens preserved in 70% ethanol. All samples and vouchers are deposited at Museum Victoria (Melbourne, Australia).

Eleven white-flash digital camera traps (ScoutGuard SG565) were deployed along animal trails with sign of recent activity. These were baited with rice and left undisturbed for eight to nine days. One infrared camera trap (ScoutGuard) was positioned at an active MacGregor's Bowerbird *Amblyornis macgregoriae* nest over a period of three days (information on parental care to appear elsewhere).

Direct observational data were supplemented with information provided by local residents.

Minni camp

Minni Camp was located in the Kawarobip area, at 2,383 m asl in the headwaters of the Kauwol River (upper Digul River catchment) in the eastern Star Mountains. Weather and logistic constraints prevented a scheduled deployment to this high elevation camp, with only the botany and mammal teams transferring there from Bilbilokabip. Mist nets deployed at Minni for bat survey were left open during the day, and 13 birds captured in nets were collected as voucher specimens by Ken Aplin and deposited at Museum Victoria. Mist nets were deployed in Midmontane Rain Forest (*sensu* Hyndman and Menzies 1990) or across stream beds in same.

Tabubil

In addition to the main survey program, birds were recorded in Tabubil and nearby accessible areas before and after deployment at Bilbilokabip. Logistic constraints limited survey time outside of Tabubil, and land ownership issues prevented visit to some of the better known local birding sites (e.g. Ok Menga and the Ok Ma road, although Chris Muller and Michael Hammer visited Ok Menga while Iain Woxvald and Bensolo Ken were based at Bilbilokabip).

All areas outside of Tabubil were accessed from the Kiunga-Tabubil Road. These included:

- On 8 February, a ca. 6.7 km section of the Kiunga-Tabubil Road (between 5.3092°S and 5.3419°S), commencing ca. 5 km south of Tabubil and covering elevations of 350–440 m.
- On 9 and 10 February, ca. 1.7 km along the Dablin (Makulim) Creek track and water pipeline, covering from 690 m to 1,100 m asl above the water source.
- On 27 February, hills above the Ok Umansim, a tributary creek draining hills north of the Ok Tedi and crossing the Kiunga-Tabubil Road ca. 4.5 km north-northwest of the Ok Tedi-Ok Menga confluence.
- Birds were also recorded opportunistically on the Tabubil township plateau, including above the Ok Tedi escarpment behind the Cloudlands Hotel and the airport/golf course area.

Throughout the region surveyed, most of the forest along the Kiunga-Tabubil Road had been cleared or heavily disturbed. Where the view permitted this was regularly observed for more than 200 m either side. Most of the surveyed area thus comprised a mosaic of converted and regenerating habitats. Undisturbed forest was surveyed only along the upper slopes of Dablin Creek at the transition zone between the Foothill Rain Forest (Zone 1) and Lower Montane Rain Forest vegetation zones (*sensu* Hyndman and Menzies 1990).

Climate

This is one of the wettest regions in New Guinea (McAlpine et al. 1983). Annual rainfall shows great variation within a small area – the mean at Tabubil is ca. 7 m, while that at the nearby Ok Tedi mine ranges from 8–10 m (depending on gauge position) with a maximum of 10.7 m recorded in 2005 (Müller et al. 2011). The climate is only weakly seasonal, the wettest months being March-April (Gregory 1995) and cloud cover being generally highest during New Guinea's southeast 'trade winds' season of May-October (McAlpine et al. 1983).

Conventions used

Taxonomy (including subspecies) and nomenclature (common and scientific names) follow the International Ornithological Congress (IOC) World Bird List (version 3.4) (Gill and Donsker 2013). Where species are mentioned in the text the scientific name appears with the common name on first mention 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.

Conservation listed species include those listed in the IUCN Red List of Threatened Species (IUCN 2013) as threatened or Near Threatened (no Data Deficient species were recorded) and those listed as protected under the *PNG Fauna (Protection & Control) Act 1966*. The list of nationally protected species was obtained from Kula and George (1996).

A Garmin 60CSx GPS unit was used to record coordinates and elevations in the field.

Results

At least 155 species were recorded directly during the surveys (Appendix 1), including 84 from Tabubil, 75 at Bilbilokabip and eight at Minni. Three additional species are included based on reliable information provided by local residents (Wattled Brushturkey *Aepypodius arfakianus*, Papuan Eagle *Harpyopsis novaeguineae*, Black/Brown Sicklebill *Epimachus fastosus/mayeri*). Two hundred and one (201) birds from 36 species were mist netted (188 birds, 33 species), photographed by camera trap (eight birds, five species) or otherwise captured (five birds, four species)(Appendix 1). Bird measurements are listed in Appendix 2. Nine conservation listed species were recorded (Table 2). They include four birds listed by the IUCN as Vulnerable (Papuan Eagle, Pesquet's Parrot, Black Sicklebill) or Near Threatened (Dwarf Cassowary) and eight species that are protected under PNG law. Conservation listed species are discussed individually below (see species accounts).

Table 2. Conservation listed bird species recorded from Tabubil or Bilbilokabip.
Status indicates species listed as globally threatened (VU – Vulnerable) or Near Threatened (NT) by the IUCN, and those listed as protected (P) under the *PNG Fauna (Protection & Control) Act 1966*.

Species	Status	Tabubil	Bilbilokabip
Dwarf Cassowary *Casuarius bennetti*	NT		X
Papuan Eagle *Harpyopsis novaeguineae*	VU, P		X
Pesquet's Parrot *Psittrichas fulgidus*	VU, P	X	
Loria's Satinbird *Cnemophilus loriae*	P		X
Short-tailed Paradigalla *Paradigalla brevicauda*	P		X
Queen Carola's Parotia *Parotia carolae*	P		X
Superb Bird-of-paradise *Lophorina superba*	P		X
Black Sicklebill *Epimachus fastuosus*	VU, P		(X)
Magnificent Bird-of-paradise *Diphyllodes magnificus*	P	X	

Species accounts
Species accounts follow for conservation listed taxa, rarely recorded species, and wherever records extend a species' known geographical or elevational limits. All dates refer to the year 2013.

Dwarf Cassowary: *Casuarius bennetti* (NT)
The Dwarf Cassowary replaces its congeners at higher elevations, occurring mostly in hill and montane forest (Coates 1985). As with all cassowaries, it is a near obligate frugivore (Pratt 1982a, Mack 1995), plays a crucial role in forest ecosystem dynamics by dispersing the seeds of rainforest trees (Mack 1995, Mack and Wright 2005) and is vulnerable to hunting by humans (Johnson et al. 2004). As well as being hunted for food, cassowary skin, quills, feathers and bone may be used for tools or cultural items, and captive chicks are reared by hand for food or trade (Coates 1985, Johnson et al. 2004, pers. obs.). Multiple cassowary droppings present in a small area a few hundred metres from Bilbilokabip camp were presumed to be of this species and provided the only firm evidence of cassowary presence. Local residents indicated that cassowaries are locally widespread but patchy, and confirmed that they hunt it. The scarcity of cassowary sign along the well-used walking trails is unsurprising; it may be more numerous in less visited areas.

Wattled Brushturkey: *Aepypodius arfakianus*
Local informants reported that a megapode with white eggs was present locally in the Tupnonbil area, indicating an area northwest of Bilbilokabip, but that it could not be found close to camp. Not recorded directly.

New Guinea Scrubfowl: *Megapodius decollatus*
One bird camera trapped at 1,820 m on 15 February is referred to New Guinea Scrubfowl based on leg colour and the extensive area of bare skin showing on the side of the head and upper neck (Jones et al. 1995). This is the third confirmed and published record from south of the divide (Ogilvie-Grant 1915, Sinclair 2001). Additional unpublished records have been obtained from the upper Fly River area and the Strickland (Carrington) River headwaters in Western Province (Woxvold, in prep.). Possible additional localities at Moroka District (Central Province), Lake Kutubu (Southern Highlands Province) and Mt Sisa (Hela Province) remain unconfirmed (Mayr 1941, Coates 1985, Jones et al. 1995).

Based on current data, the Orange-footed Scrubfowl *M. reinwardt* and New Guinea Scrubfowl appear largely allopatric, with the former replacing the latter in the southern watershed. Unfortunately, many prior records of *Megapodius* from southern New Guinea refer to the Dusky (Common) Scrubfowl *M. freycinet*, within which both the New Guinea and Orange-footed Scrubfowls (*inter alia*) were formerly subsumed (Mayr 1938). Difficulties with observing these species in the field, and with collecting detailed and reliable information from local informants, mean that many prior records cannot be safely assigned to

either taxon (e.g. Diamond 1972, Dwyer 1981, Sillitoe 2003). This is the case for previous records of *Megapodius* from the Ok Tedi area (Gregory 1995, P. Gregory in litt.2013).

The Hindenburg record joins a growing body of evidence that the New Guinea Scrubfowl is widespread along the southern slopes of the Central Cordillera. Where their ranges overlap the two may segregate altitudinally, with the Orange-footed Scrubfowl confined to lower elevations. A similar story is gradually emerging with the northern and southern *Talegalla* species (Jones et al. 1995, Mack and Wright 1996, IW, unpublished data). However, for all New Guinea megapodes a good deal more information is required to determine patterns of distribution and ecological segregation at the local scale. Camera trapping will likely prove instrumental in this endeavour.

Meyer's Goshawk: *Accipiter meyerianus*
A scarce inhabitant of hill and lower montane forest. At 0745 on 13 February a Meyer's Goshawk was observed from the Bilbilokabip camp helipad cruising low over the forest canopy. It made a single pass along each of two ridge lines west and south of camp before moving out of sight.

Papuan Eagle: *Harpyopsis novaeguineae* (VU, P)
New Guinea's largest raptor, the Papuan Eagle inhabits forested habitats from sea-level to over 3,000 m. This low density species is uncommon throughout its range and is vulnerable to hunting (Coates 1985, Watson and Asoyama 2001). Visually inconspicuous (does not soar), it is most readily detected by its distinctive and far-carrying call. Local informants reported that one was present and calling loudly in forest on the ridge west of the Bilbilokabip helipad on the first morning they arrived to build the camp. Not recorded directly.

Peregrine Falcon: *Falco peregrinus*
Scarce in New Guinea (Coates 1985) and uncommon but regular in the Tabubil area (Gregory 1995). One of the dark resident race (*ernesti*) in Tabubil on 7 February, in a tree behind the Cloudlands Hotel on the escarpment above the Ok Tedi.

Bronze Ground Dove: *Gallicolumba beccarii*
Fairly common at Bilbilokabip with four mist netted and two camera trapped. Not unexpected, though not recorded for the Ok Tedi area (Gregory 1995) or by Gilliard and LeCroy (1961).

Pesquet's Parrot *Psittrichas fulgidus* (VU, P)
At ca. 1830 on 19 February, C. Muller and J. Watson observed a Pesquet's Parrot at the Ok Menga dam site. Plumes of Pesquet's Parrot are commonly used for ceremony and trade, and hunting has resulted in its decline or loss from the vicinity of many settled areas (Coates 1985, Kocher Schmidt 1993, Mack and Wright 1998). Gregory (1995) reported decline of this species in the Ok Tedi area, though it is still reliably recorded away from the town environs (G. Dutson, *in litt.* 2013).

Rufous-throated Bronze Cuckoo: *Chrysococcyx ruficollis*
Heard on 14 and 25 February. Not unexpected, but not recorded for the Ok Tedi area (Gregory 1995) or by Gilliard and LeCroy (1961).

Macgregor's Bowerbird: *Amblyornis macgregoriae*
Fairly common at Bilbilokabip, where it was seen or heard on most days. A bower was located by F. Venter on a forested slope across the valley west of camp (Ok Bilbao) on 21 February. On 14 February a female was mist netted east of camp, and on 17 February Bensolo Ken located a cup-shaped nest with one nestling attended by the netted bird. The nest was constructed of interwoven twigs and placed ca. 2 m above the ground in the crown of a tree fern. An infrared camera trap was placed at the nest during 22–24 February to collect data on parental care. After dusk on 24 February the nestling was measured (88.5 g, tarsus 42.9 mm) and blood sampled.

Yellow-browed Melidectes: *Melidectes rufocrissalis*
Melidectes honeyeaters of the *belfordi/rufocrissalis* group were common at Bilbilokabip with multiples seen and heard daily. Three birds seen well in garden trees or at the forest edge were assigned to *rufocrissalis* based on their showing pale forehead, pale bill, yellow brow and red facial wattles. No other sightings were inconsistent with these features.

The distributions of and hybridisation between *M. rufocrissalis* and *M. belfordi* have been the topic of some debate (e.g. Gilliard 1959, Gilliard and LeCroy 1961, Diamond 1972). Gregory (1995) reports only *M. rufocrissalis* from the Ok Tedi area, while the Gilliard's collected *M. rufocrissalis* and *M. belfordi* from similar elevations (ca. 2,200–2,300 m) in the Hindenburg and Victor Emanuel ranges respectively, with an apparent hybrid taken from the Mittag Mountains north of Telefomin (Gilliard 1959, Gilliard and LeCroy 1961). While the strong *M. rufocrissalis* features shown in the Bilbilokabip birds are consistent with these findings, detailed examination of captured individuals, and/or molecular studies, would be required to definitively assess the 'purity' of local populations.

Olive Straightbill: *Timeliopsis fulvigula*
Four birds mist netted at Bilbilokabip. Recorded previously from the Hindenburg Range at Luplupwintem cave (Gregory 1995) and from the Victor Emanuel Range by Gilliard and LeCroy (1961). Not reported previously from the Ok Tedi area (Gregory 1995).

Loria's Satinbird: *Cnemophilus loriae* (P)
A hen-plumed bird seen close to camp on 14 February was foraging in the mossy sub-canopy. Another was shot by a local and brought into camp on 22 February.

Berrypecker sp: *Melanocharis sp.*
On 24 February Iain Woxvold observed briefly at close range an olive green *Melanocharis* berrypecker, paler below, with dark streaking on the sides of the breast and yellow gape, east of Bilbilokabip camp at ca. 1,860 m in an area of disturbed forest close to edge with gardens/regrowth. The bird alighted in a low shrub adjacent to a small stream before moving off into secondary forest canopy. Its call, a repeated series of 2–10 scratchy piping notes, was recorded.

Gregory (1997, p. 306) reported that: "Coates and Lindgren (1978) recorded a drab olive *Melanocharis* of the *striativentris/longicauda* type at 2220 m on Mt. Binnie in moss forest, but with strong black streaking down the sides of the abdomen and white pectoral tufts. There have been no further sightings as yet and its identity remains unknown."

Wattled Ploughbill: *Eulacestoma nigropectus*
A female was mist netted at Minni on 28 February. Not recorded previously for the Ok Tedi area (Gregory 1995) or by Gilliard and LeCroy (1961) for the Hindenburg Range. Although this record is from the extreme east of the Star Mountains, its proximity to the Hindenburg Range and the apparent continuity of suitable intervening habitat means that it is almost certain to occur there.

Sooty Shrikethrush: *Colluricincla tenebrosa*
A rare and poorly known species, the main body of the known population occurs in two narrow elevational bands (known: 1,400-2,150 m, Boles 2007) on the northern and southern slopes of the Central Cordillera in West Papua, extending east into PNG as far as the Hindenburg Range and Sepik Mountains (Gilliard and LeCroy 1961, Coates 1990). It is also known from the Schrader Range (Madang Province)(Stresemann 1923), with no intervening examples reported.

One was mist netted on 17 February, collected from 2–3 m above the ground at 1,800 m in low altitude Midmontane Rain Forest (*sensu* Hyndman and Menzies 1990) ca. 100 m north of the Bilbilokabip clearing. It conforms to subspecies *tenebrosa* as described by Rand and Gilliard (1967). The species is said to be very shy (Coates 1990), and with its song still undescribed, detailed census is difficult. However, with records from at least four other sites locally (Gregory 1995), and with much suitable habitat remaining, this species is likely to be widespread and secure in the Ok Tedi headwaters area.

Pygmy Drongo: *Chaetorhynchus papuensis*
Not uncommon at Bilbilokabip, with one responding strongly to playback in oak forest at 1,775 m on 17 February, one in low altitude Midmontane Rain Forest at 1,820 m on 21 February, and two mist netted. Predominantly a hill forest species, until recently it had not been recorded above 1,600 m (Rocamora and Yeatman-Berthelot 2009). Freeman et al. (2013) have since reported it from over 2,100 m on the Huon Peninsula. The Bilbilokabip record appears to be the highest for the Central Cordillera.

Lesser Melampitta: *Melampitta lugubris*
Not common at Bilbilokabip, where it was heard three times over successive days (13–15 February) in one location, at 1,850 m in low altitude Midmontane Rain Forest.

Short-tailed Paradigalla *Paradigalla brevicauda* (P)
One mist netted (see photograph) a short distance east of Bilbilokabip camp on 17 February. One seen there on 24 February was perhaps the same bird.

Queen Carola's Parotia: *Parotia carolae* (P)
Commonly encountered at Bilbilokabip, where a male was resident in the forest around camp (ca. 1,800 m). Additional records include a female seen near camp on 17 February and another male ca. 900 m south of camp on 18 February (ca. 1.775 m).

Superb Bird-of-paradise: *Lophorina superba* (P)
Fairly common at Bilbilokabip, with one or two heard on half of the survey days, a hen-plumed bird seen on 23 February, and a subadult male on 24 February. Most were encountered in disturbed areas, including forest edge, secondary forest or garden trees.

Black/Brown Sicklebill: *Epimachus fastuosus/mayeri* (VU/LC, P)
No sicklebills were recorded directly during the survey. On 23 February locals walking south into camp brought with them an *Epimachus* that they had caught *en route*, location unknown. When Iain Woxvold and Bensolo Ken returned to camp the bird had already been consumed. Photographs taken earlier by Fanie Venter show a (thoroughly) plucked bird with four removed tail feathers. The few remaining head and chin feathers show a hen-plumed bird, with short bill and incomplete emergence of tail and head feathers suggesting it had recently fledged. Eye colour was not shown, and it was not possible to determine whether the bird was a Black or Brown Sicklebill.

Magnificent Bird-of-paradise: *Diphyllodes magnificus* (P)
One heard, and a hen-plumed bird seen, at Dablin Creek on 9 February, and one heard in hill forest above Ok Umansim on 29 February.

Greater(/Raggiana) Bird-of-paradise: *Paradisaea apoda(/raggiana)* (P)
A hen-plumed Greater Bird-of-paradise flew low overhead across the Kiunga-Tabubil Road on 8 February. *Paradisaea* song heard along the Kiunga-Tabubil Road on 8 February and at Ok Umansim on 27 February may have been Greater and/or Raggiana birds, though the former are said to be more common locally (Gregory 1995).

White-eyed Robin: *Pachycephalopsis poliosoma*
One heard above Dablin Creek at 1,040 m on 9 February. Rare in the Ok Tedi area (Gregory 1995).

Garnet Robin: *Eugerygone rubra*
A female and juvenile mist netted at 1,800 m in low altitude mid-montane Rain Forest on 16 February, and birds heard near that location on 19, 21 and 24 February.

Lesser Ground Robin: *Amalocichla incerta*
This shy terrestrial species was common at Bilbilokabip, with four mist netted, two camera trapped and up to 4+ heard daily. Not recorded previously for the Ok Tedi area (Gregory 1995) or by Gilliard and LeCroy (1961).

Eurasian Tree Sparrow: *Passer montanus*
At least 10 birds at Tabubil on the runway fence on 10 February. Sparrows heard elsewhere in town on one other day were not sighted. The Eurasian Tree Sparrow occurs naturally throughout Eurasia from the British Isles east to coastal Siberia and southeast to Sulawesi and the Lesser Sundas (Summers-Smith 2009). An accomplished colonist, its recent arrival in New Guinea has been followed by a rapid expansion into settled areas. A 2009 summary of New Guinea records described populations as apparently newly established in Indonesia at Sorong and Jayapura "as well as some villages", and a single record from mainland PNG at Port Moresby in April of that year (Gregory 2009b). To our knowledge no additional records have been documented. Additional sightings by IW prior to the Tabubil record include (in chronological order): (1) Nena River catchment, West Sepik (Sandaun) Province, at an isolated industrial site in hill forest at 450 m, first observed 9 October 2009 (group of six), still present March 2011 (at least 12); (2) in Morobe Province, at the Valley view('9 mile') residential estate, located on the Highlands Highway ca. 10 km northwest of Lae city centre, first observed 22 November 2010, still present May 2012 (up to 100+ birds); (3) Kerema Airport, Gulf Province, one bird on 4 July 2011, multiple sparrows subsequently heard (but not seen) there February and July 2012. Samuel Kepuknai, an experienced naturalist from Kiunga, first noticed Eurasian Tree Sparrows in Kiunga during May–June 2010 and in Tabubil in July 2012 (S. Kepuknai, pers. comm.).

Discussion

Comparison between sites
Comparing the two main survey locations, only 6.0% (9/151) of species recorded at Tabubil or Bilbilokabip were found in both areas (Papuan Mountain Pigeon *Gymnophaps albertisii*, Asian/Pacific Koel *Eudynamys scolopaceus/orientalis*, White-eared Bronze Cuckoo *Chrysococcyx meyerii*, Glossy Swiftlet *Collocalia esculenta*, White-shouldered Fairywren *Malurus alboscapulatus*, Mountain Peltops *Peltops montanus*, Black-bellied Cuckoo shrike *Coracina montana*, Papuan Grassbird *Megalurus macrurus*, Red-capped Flowerpecker *Dicaeum geelvinkianum*). This near complete turnover is attributable to a range of factors.

Foremost among them is elevation, an important determinant of avian distributions in New Guinea (Diamond 1972, 1973, Beehler 1982). Disparate inventories from Tabubil and Bilbilokabip reflect a general shift from lowland/hill to montane forest bird communities, recognised by Pratt (1982b) as occurring in New Guinea broadly about 1,500 m. While this shift is not abrupt at the community level, Hyndman and Menzies (1990) noted a compression of ecological zonation in the Ok Tedi headwaters area due to the extreme local climate (rainfall and cloud cover), resulting in notable changes in biotic community structure within a comparatively small area.

Second, the short amount of time spent in upland hill forest near Tabubil limited the opportunity for overlap in community composition between these locations. Some 23 species recorded only at Bilbilokabip have been recorded previously below 1,000 m in the Ok Tedi area (Gregory 1995). Most of these are forest species, so that additional time in forest habitat at Dablin Creek would be expected to reduce the distinction between these inventories.

Finally, extensive land conversion around Tabubil supports a greater diversity and abundance of non-forest species. Those found in anthropogenic habitats include seven resident land birds (Buff-banded Rail *Gallirallus philippensis*, Black-billed Coucal *Centropus bernsteini*, White-shouldered Fairywren, Rufous-banded Honeyeater *Conopophila albogularis*, Willie Wagtail *Rhipidura leucophrys*, Pied Bush Chat *Saxicola caprata*, Papuan Grassbird), three resident aerial foragers (Moustached Treeswift *Hemiprocne mystacea*, Great Woodswallow *Artamus maximus*, Pacific Swallow *Hirundo tahitica*), three northern hemisphere migrants ([Swinhoe's] Snipe *Gallinago[megala]*, Common Sandpiper *Actitis hypoleucos*, Grey Wagtail *Motacilla cinerea*) and one introduced commensal (Eurasian Tree Sparrow). Some 25 additional land birds recorded at Tabubil are notably tolerant of open and disturbed habitats. Converted habitats present at Bilbilokabip supported two of the nine shared species (White-shouldered Fairywren, Papuan Grassbird). Additional non-forest specialists may have been missed there, but were certainly less abundant, owing perhaps to a combination of relative extent of available habitat, elevation and hunting.

Tabubil area

Surveys from Tabubil yielded the highest species tally. This is attributable to: (1) the broad elevational coverage (more than 700 m), providing access from lowland hill to lower montane (>1,000 m) environments, and; (2) the variety of habitat conditions surveyed, from intact forest (though limited) through degraded and secondary habitats to converted lands. Despite these factors, limited survey time (Table 1) means that our inventory for this area is far from complete.

Fortunately the Tabubil area is one of the most thoroughly documented locations in New Guinea. Gregory (1995, 1997) summarised records from the first three decades of survey, listing 329 bird species from the broader Ok Tedi area. Excluding vagrants, waterbirds and migratory waders, 224 of these have been recorded from below 1,400 m. Our list of 82 (excluding two waders) from the Tabubil area thus constitutes less than 37% of the low elevation hill zone land birds regularly expected to occur there.

What can our brief visit add to the existing corpus of knowledge? Unfortunately, there is no comprehensive list of reliable records since Gregory's (1995, 1997) summary works. In-migration and population growth have since led to extensive clearance of forest habitat (S. Richards, pers. comm.). While our limited coverage restricts opportunity to comment on community-level changes in that time, it is interesting to note that a few birds regularly encountered during our visit were listed as rare or unrecorded by Gregory. Two of these were reported previously from Tabubil: Buff-banded Rail *Gallirallus philippensis*, "rarely seen since 1988" (Gregory 1995, p.10), and Papuan Grassbird *Megalurus macrurus*, with "no records since 1986" (as Tawny Grassbird *M. timoriensis*; Gregory 1995, p.26), were both reliably present on 9 and 10 February in scrub/grassland atop the escarpment at the southern end of the golf course. Two others are recent colonists: Rufous-banded Honeyeater, seen and heard daily during 6–9 February in town trees near the Cloudlands Hotel, and Eurasian Tree Sparrow (see above). Each of these species was exclusively recorded in anthropogenic habitats in Tabubil.

Also of note was the scarcity of some large frugivores that are typically fairly common away from settled areas. In particular, no hornbills were recorded and only one Sulphur-crested Cockatoo *Cacatua galerita* was seen (by M. Hammer at Ok Menga). Many avian frugivores are nomadic within a landscape in response to seasonal patterns in food availability (e.g. Bell 1982), and may therefore be seasonally rare or absent at various sites. However, given the size of the area covered and the proximity of suitable forest habitat, their scarcity in this case was conspicuous. Gregory (1995) implicated hunting in the local decline of a number of avian frugivores, including hornbills and Pesquet's Parrot.

Bilbilokabip

Completeness of survey

The total of 75 bird species (excluding records from local informants) recorded from Bilbilokabip compares favourably with results of surveys conducted at comparable elevations elsewhere in New Guinea (e.g. Mack et al. 2000: Wapoga RAP, western Papua, 1,890 m, 64 species; Diamond and Bishop 2000: Mount Sisa, Hela Province, 1,840–2,380 m (two camps), 85 species; Igag 2011: Muller Range, Hela and Western Provinces, 1,300–2,000 m, 51 species). The Gilliards collected a total of 63 species from four sites on the Hindenburg Range (Gilliard and LeCroy 1961), though their survey methods are not comparable with those of a modern rapid assessment protocol.

In the present environment, no single-visit survey can result in a complete inventory of the avifauna regularly occurring at any one site. A variety of techniques were combined in an effort to document as many species as possible in the time available (see Methods), though by the end of survey new bird species were still being recorded. A number of locally uncommon/inconspicuous species were recorded only once (e.g. Black-mantled Goshawk *Accipiter melanochlamys*, Meyer's Goshawk, Madarasz's Tiger Parrot *Psittacella madaraszi*, Berrypecker sp., Torrent-lark *Grallina bruijni*), and it follows that additional taxa may have been missed. Additional visits to Bilbilokabip, or nearby sites at similar elevation, would therefore be expected to reveal additional taxa (e.g. Beehler et al. 2011).

Many of these are already known to occur locally. Excluding waterbirds and migrants, of those birds recorded previously from the Ok Tedi area, Hindenburg and/or Victor Emanuel ranges, the regular elevational ranges (from Coates 1985, 1990) of some 74 species extend or occur above 1,700 m, the lowest

point reached during survey from Bilbilokabip. Sixty (60) of these overlap with elevations covered during survey from Bilbilokabip, and 36 with elevations covered at Minni (Table 1).

Five species from Bilbilokabip and Minni are previously unrecorded from the Hindenburg Range and upper Ok Tedi catchment – New Guinea Scrubfowl, Bronze Ground Dove, Rufous-throated Bronze Cuckoo, Wattled Ploughbill and Lesser Ground Robin. While the Wattled Ploughbill was recorded from the eastern extremities of the Star Mountains, it is expected also to occur locally in the Hindenburg Range. Macgregor's Bowerbird was previously unrecorded from the Ok Tedi area (below the Hindenburg Wall – Gregory 1995), but is known from further east along the Hindenburg Range (Gilliard and LeCroy 1961). The New Guinea Scrubfowl is rarely recorded south of the divide, though it may occur more widely there than is presently known (see species accounts). Each of the other species was reasonably expected to occur, illustrating the paucity of presently available data.

Excluding waterbirds and migrants, at least 17 resident land birds still unrecorded from the Hindenburg Range (Gilliard and LeCroy 1961, Rowland 1994) or the upper Ok Tedi catchment (Gregory 1995, 1997) may be expected to occur in the Hindenburg Range at elevations above 1,700 m (Table 3). Most are forest species, though a few are birds of open habitats. The list presented in Table 3 is conservative: it excludes a number of species with disjunct distributions along the Central Cordillera whose presence in underexplored areas between known populations cannot be ruled out (e.g. Archbold's Bowerbird *Archboldia papuensis*, Papuan Whipbird *Androphobus viridis*, Black Sittella *Daphoenositta miranda*).

Table 3. Resident land birds not previously recorded from the Hindenburg Range or the Ok Tedi area but that may be expected to occur in the Hindenburg Range based on known distribution. Elevation shows regular limits (Coates 1985, 1990). Prior records from Victor Emanuel Range (including Telefomin) taken from Gilliard and Lecroy (1961).

English name	Scientific name	Elevation		Victor Emanuel Range
		lower	upper	
King Quail	*Excalfactoria chinensis*	0	2200	X
White-breasted Ground Dove	*Gallicolumba jobiensis*	0	2400	
Sooty Owl	*Tyto tenebricosa*	1000	2500	
Eastern Grass Owl	*Tyto longimembris*	1000	2500	
Rufous Owl	*Ninox rufa*	0	1800	
Archbold's Owlet-nightjar	*Aegotheles archboldi*	1350	3600	X
Bare-legged Swiftlet	*Aerodramus nuditarsus*	900	1800	
Shovel-billed Kookaburra	*Clytoceyx rex*	0	2400	X
Marbled Honeyeater	*Pycnopygius cinereus*	1000	2000	X
Belford's Melidectes	*Melidectes belfordi*	1600	3350	X
Bicolored Mouse-warbler	*Crateroscelis nigrorufa*	1220	2500	
Crested Satinbird	*Cnemophilus macgregorii*	2600	3500	
Streaked Berrypecker	*Melanocharis striativentris*	1150	2300	
Papuan Sittella	*Daphoenositta papuensis*	1400	2200	
Long-tailed Shrike	*Lanius schach*	1100	2750	X
White-winged Robin	*Peneothello sigillata*	2400	3900	X
Papuan Parrotfinch	*Erythrura papuana*	1200	2600	

Biogeography of Hindenburg avifauna
In terms of avian distributions, the Hindenburg and Victor Emanuel ranges behave more or less as a single biogeographical unit, with "[v]irtually no differentiation… found between the birds of these two closely situated mountain masses which in reality are adjacent high spots on a continuous mountain range" (Gilliard and LeCroy 1961, p. 27). Located approximately midway along the Central Cordillera, these ranges represent a zone of intersect between eastern and western faunas.

Among western forms, the Hindenburg Range lies at or close to the eastern distributional limits of numerous taxa. At the species level, those recorded during the present survey include Lorentz's Whistler *Pachycephala lorentzi*, Capped White-eye *Zosterops fuscicapilla* and, but for (at present) isolated records in the Schrader Range, Sooty Shrikethrush. Additional species known to occur locally include Chestnut Forest Rail *Rallicula rubra*, Striated Lorikeet *Charmosyna multistriata*, Archbold's Owlet-nightjar *Aegotheles archboldi* and Splendid Astrapia *Astrapia splendidissima*. The pattern continues among subspecies, with the Hindenburg Range reported as the easterly limit of (for example) Macgregor's Bowerbird *A.m.mayri*, Papuan treecreeper *Cormobates placens steini* (also Tari Gap), Black-throated Honeyeater *Lichenostomus subfrenatus utakwensis*, Leaden Honeyeater *Ptiloprora plumbea granti*, Mountain Mouse Warbler *Crateroscelis robusta sanfordi*, Fan-tailed Berrypecker *Melanocharis versteri meeki*, Superb Bird-of-paradise *L.s. feminine* (also Victor Emanuel Range), Slaty Robin *Peneothello cyanus atricapilla* and Mountain Firetail *Oreostruthus fuliginosus pallidus*. The resident race of Mountain Mouse Warbler, along with *C. r. bastille*, may warrant elevation to species status (Beehler and Prawiradilaga 2010).

Counter-examples of predominantly eastern tax are fewer. Among species, the Hindenburg Range lies towards the western limit of Yellow-browed Melidectes and Brown-backed Whistler *Pachycephala modesta*, and among subspecies, Large Scrubwren *Sericornis nouhuysi stresemanni* and Long-tailed Shrike *Lanius schach stresemanni*.

As noted previously by Gilliard and LeCroy (1961), a distinctly western flavour is apparent in the Hindenburg Range avifauna.

Conservation value and ecotourism potential

At the landscape level, the Hindenburg Wall area is of high conservation value due to its size, remoteness, low human population and high degree of connectivity among a variety of intact habitats. The broad contiguity of multiple biotic zones across an elevational gradient (Hyndman and Menzies 1990), as well as high connectivity with adjacent upland biogeographical units to the west, north and east, provide for vital evolutionary processes and opportunity for climate change adaptation among local biotic communities. Moreover, given the extreme and local climate, the conditions under which these processes take place are unique in the New Guinea context (Hyndman and Menzies 1990).

In terms of avifauna, the Hindenburg Range is of high conservation value for its supporting a combination of central, western and eastern montane taxonomic forms, as well as a suite of rare, threatened and nationally protected bird species. In addition to the Dwarf Cassowary (NT) and Papuan Eagle (VU) recorded at Bilbilokabip, at least five other IUCN listed (above Least Concern) taxa known to occur locally or are likely on the Hindenburg range (above 1,500 m) – Pesquet's Parrot (VU), Striated Lorikeet *Charmosyna multistriata* (NT), Three-toed Swiftlet *Aerodramus papuensis* (DD), Yellow-breasted Satinbird *Loboparadisea sericea* (NT), Black Sicklebill (VU) (Gilliard and LeCroy 1961, Rowland 1994, Gregory 1995). Rare (or rarely recorded) species found at Bilbilokabip include Meyer's Goshawk, Olive Straightbill, Sooty Shrikethrush and a possible Black Sicklebill (see *species accounts*), with further survey expected to uncover additional examples.

The Hindenburg Range and its avifauna hold great potential for ecotourism. In addition to the spectacular scenery afforded by the Hindenburg Wall, a variety of features combine to provide a strong attractant to bird enthusiasts from around the globe. It provides an opportunity to encounter a variety of western montane taxa not readily viewed elsewhere in PNG, notably Chestnut Forest Rail, Striated Lorikeet,

Archbold's Owlet-nightjar, Mountain Mouse Warbler (western form *C. r. sanfordi*), Lorentz's Whistler, Sooty Shrikethrush, Capped White-eye and Splendid Astrapia.

The Hindenburg Range lies within an area that is second only to the Mendi and Mount Hagen areas in terms of the number of birds-of-paradise (17 species, excluding cnemophilines, within a 1° square) present anywhere within the family's range (Heads 2001), a number of which cannot be viewed at other established PNG localities (e.g. Splendid Astrapia, Greater Bird-of-paradise).

The western sector of the Hindenburg Range, including the Hindenburg Wall area, lies at the northern end of a standard New Guinea bird-tour itinerary. If suitable infrastructure and/or logistic arrangements were to afford safe and reliable passage to this area, it would provide welcome access for an existing industry into western PNG's montane forest habitats and to a suite of rare and endemic taxa.

At the local scale, present hunting practices reduce both the conservation value and the ecotourism potential of the Bilbilokabip area and forest along the well-travelled Tabubil-Tifalmin trail. Hunting of terrestrial wildlife is a core pursuit of the Mountain Ok people (Pernetta and Hyndman 1982, Schuurkamp 1995). Hunting in the Ok Tedi drainage has seen the local decline of a number of species, including hornbills, Pesquet's Parrot and Black Sicklebill, in the Ok Tedi headwaters area (Coates and Lindgren 1978, Gregory 1995). In terms of cultural and nutritional significance, cassowaries are the most important avian quarry (Pernetta and Hyndman 1982), but as is the case in many New Guinea societies (e.g. Diamond 1972, Kocher Schmid 1993), nearly all types of birds are eaten, with even the smallest species hunted opportunistically. Species taken by local residents during our stay at Bilbilokabip include Large Scrubwren, Hooded Cuckooshrike *Coracina longicauda*, Loria's Satinbird and Black/Brown Sicklebill. Accordingly, birds were noticeably shy in the Bilbilokabip area. Hunting has also no doubt reduced the local numbers of some preferred game species, such as cassowaries and megapodes. However, given the rugged terrain and extent of suitable habitat, many sites in the foothills below and on the plateau above the Hindenburg Wall are expected to support most or all species in numbers at or close to their natural abundance.

Future conservation strategies should aim to preserve existing habitats, and their functioning at the landscape scale, and to prevent the escalation of hunting. Further survey of the Hindenburg Range, at a range of sites and elevations, is recommended to provide a more detailed understanding of the bird communities present, including species composition and the distribution and status of a suite of rare, threatened and endemic taxa.

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Short-tailed Paradigalla *Paradigalla brevicauda* from Tupnonbil. *(Photo I.Woxvold)*

Appendix 1. Birds recorded at Bilbilokabip, Tabubil and Minni. Birds are listed as present based on direct observation (X), evidence from local residents (L) or feathers in the field (f). Capture data show the number of birds captured in mist nets (raw figures), photographed remotely by camera trap (c), shot by local residents (s) or taken on the nest (n). Conservation listing is shown for those species listed by the IUCN as Vulnerable (VU) or Near Threatened (NT) (no other non-Least Concern categories were represented), and those species protected (P) by lawunder the *PNG Fauna (Protection & Control) Act 1966*.

Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Casuariidae							
Casuarius bennetti	Dwarf Cassowary	X				NT	
Megapodiidae							
Aepypodius arfakianus	Wattled Brushturkey	L					
Megapodius decollatus	New Guinea Scrubfowl	X			c1		
Accipitridae							
Henicopernis longicauda	Long-tailed Honey Buzzard		X				
Haliasturindus	Brahminy Kite		X				
Accipiter hiogaster	Variable Goshawk		X				
Accipiter melanochlamys	Black-mantled Goshawk	X					
Accipiter meyerianus	Meyer's Goshawk	X					
Harpyopsis novaeguineae	Papuan Eagle	L				VU	P
Falconidae							
Falco peregrinus	Peregrine Falcon		X				
Rallidae							
Gallirallus philippensis	Buff-banded Rail		X				
Amaurornis moluccana	Pale-vented Bush-hen		X				
Scolopacidae							
Gallinago [megala]	[Swinhoe's] Snipe		X				
Actitis hypoleucos	Common Sandpiper		X				
Columbidae							
Macropygia amboinensis	Slender-billed Cuckoo-Dove		X				
Macropygia nigrirostris	Bar-tailed Cuckoo-Dove	X					
Reinwardtoena reinwardtsi	Great Cuckoo-Dove		X				

Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Gallicolumba beccarii	Bronze Ground Dove	X			4,c2		
Ptilinopus ornatus/rivoli	Ornate/White-bibbed Fruit Dove	X					
Ptilinopus superbus	Superb Fruit Dove		X				
Ptilinopus pulchellus	Beautiful Fruit Dove		X				
Gymnophaps albertisii	Papuan Mountain Pigeon	X	X				
Cacatuidae							
Cacatua galerita	Sulphur-crested Cockatoo		X				
Psittacidae							
Psittrichas fulgidus	Pesquet's Parrot		X			VU	P
Micropsitta bruijnii	Red-breasted Pygmy Parrot	X					
Pseudeos fuscata	Dusky Lory	X					
Trichoglossus haematodus	Coconut Lorikeet		X				
Charmosyna papou	Papuan Lorikeet	X					
Neopsittacus musschenbroekii	Yellow-billed Lorikeet	X					
	Lorikeet sp(p)	X	X				
Psittacella madaraszi	Madarasz's Tiger Parrot	X					
Geoffroyus simplex	Blue-collared Parrot		X				
Eclectus roratus	Eclectus Parrot		X				
Cyclopsitta gulielmitertii	Orange-breasted Fig Parrot		X				
Cuculidae							
Centropus menbeki	Ivory-billed Coucal		?				
Centropus bernsteini	Black-billed Coucal		X				
Eudynamys scolopaceus/orientalis	Asian/Pacific Koel	X	X				
Scythrops novaehollandiae	Channel-billed Cuckoo		X				
Chrysococcyx ruficollis	Rufous-throated Bronze Cuckoo	X					
Chrysococcyx meyerii	White-eared Bronze Cuckoo	X	X				
Cacomantis leucolophus	White-crowned Cuckoo	X					
Cacomantis castaneiventris	Chestnut-breasted Cuckoo		X				

Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Cacomantis castaneiventris/flabelliformis	Ch-brstd/Fan-tailed Cuckoo	X					
Cacomantis variolosus	Brush Cuckoo		X				
Cuculusoptatus(/saturatus)	Oriental(/Himalayan) Cuckoo		X				
Strigidae							
Ninox theomacha	Papuan Boobook	X					
Podargidae							
Podargus sp.	Frogmouth sp.		f				
Aegothelidae							
Aegotheles insignis	Feline Owlet-nightjar	X			3		
Hemiprocnidae							
Hemiprocne mystacea	Moustached Treeswift		X				
Apodidae							
Collocaliaesculenta	Glossy Swiftlet	X	X				
Aerodramus vanikorensis(/hirundinaceus)	Uniform(/Mountain) Swiftlet		X				
Aerodramus hirundinaceus(/vanikorensis)	Mountain(/Uniform) Swiftlet	X					
Alcedinidae							
Dacelo gaudichaud	Rufous-bellied Kookaburra		X				
Syma megarhyncha	Mountain Kingfisher	X			1		
Meropidae							
Merops ornatus	Rainbow Bee-eater	X					
Ptilonorhynchidae							
Amblyornis macgregoriae	MacGregor's Bowerbird	X			1,n1,c2		
Maluridae							
Malurus cyanocephalus	Emperor Fairywren		X				
Malurus alboscapulatus	White-shouldered Fairywren	X	X				
Meliphagidae							

Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Xanthotis flaviventer	Tawny-breasted Honeyeater		X				
Lichenostomus subfrenatus	Black-throated Honeyeater	X					
Meliphaga albonotata	Scrub Honeyeater		X				
Meliphaga sp(p).	Honeyeater sp(p).		X				
Pycnopygius stictocephalus	Streak-headed Honeyeater		X				
Philemon novaeguineae	New Guinea Friarbird		X				
Melipotes fumigatus	Common Smoky Honeyeater	X		X	4		
Melidectes rufocrissalis	Yellow-browed Melidectes	X					
Ptiloprora perstriata	Grey-streaked Honeyeater	X		X	12		
Melilestes megarhynchus	Long-billed Honeyeater		X				
Conopophila albogularis	Rufous-banded Honeyeater		X				
Myzomela cruentata	Red Myzomela		X				
Myzomela rosenbergii	Red-collared Myzomela	X					
Timeliopsis fulvigula	Olive Straightbill	X			4		
Acanthizidae							
Crateroscelis murina	Rusty Mouse-warbler	?	X				
Crateroscelis robusta	Mountain Mouse-warbler	X		X	4		
Sericornis nouhuysi	Large Scrubwren	X			9		
Sericornis perspicillatus	Buff-faced Scrubwren	X			8		
Gerygone ruficollis	Brown-breasted Gerygone	X					
Gerygone cinerea	Ashy Gerygone	X					
Gerygone chloronota	Green-backed Gerygone		X				
Pachycare flavogriseum	Goldenface		X				
Cnemophilidae							
Cnemophilus loriae	Loria's Satinbird	X			s1		P
Melanocharitidae							
Melanocharis versteri	Fan-tailed Berrypecker	X		X	22		
Melanocharis sp.	Berrypecker sp.	X					

Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Oedistoma iliolophus	Dwarf Longbill		X				
Toxorhamphus poliopterus	Slaty-headed Longbill	X			5		
Paramythidae							
Oreocharis arfaki	Tit Berrypecker	X					
Psophodidae							
Ptilorrhoa leucosticta	Spotted Jewel-babbler	X					
Ptilorrhoa castanonota	Chestnut-backed Jewel-babbler		X				
Machaerirhynchidae							
Machaerirhynchus nigripectus	Black-breasted Boatbill	X			1		
Cractidae							
Cracticus quoyi	Black Butcherbird		X				
Cracticus cassicus	Hooded Butcherbird		X				
Peltopsblainvillii	Lowland Peltops		X				
Peltopsmontanus	Mountain Peltops	X	X				
Artamidae							
Artamus maximus	Great Woodswallow		X				
Campephagidae							
Coracina caeruleogrisea	Stout-billed Cuckooshrike		X				
Coracina longicauda	Hooded Cuckooshrike	X			s2		
Coracina incerta	Black-shouldered Cicadabird		X				
Coracina schisticeps	Grey-headed Cuckooshrike		X				
Coracina montana	Black-bellied Cuckooshrike	X	X				
Campochaera sloetii	Golden Cuckooshrike		X				
Lalage leucomela	Varied Triller		X				
Incertaese dis							
Eulacestoma nigropectus	Wattled Ploughbill			X	1		
Pachycephalidae							
Rhagologus leucostigma	Mottled Whistler	X			2		

Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Pachycephala soror	Sclater's Whistler	X			11		
Pachycephala lorentzi	Lorentz's Whistler	X			1		
Pachycephala schlegelii	Regent Whistler			X	2		
Pachycephala monacha	Black-headed Whistler		X				
Colluricincla tenebrosa	Sooty Shrikethrush	X			1		
Colluricincla megarhyncha	Little Shrikethrush		X				
Pitohui kirhocephalus	Variable Pitohui		X				
Pitohui dichrous	Hooded Pitohui		X				
Pitohui ferrugineus	Rusty Pitohui		X				
Pitohui cristatus	Crested Pitohui		X				
Pitohui nigrescens	Black Pitohui	X			1		
Aleadryasrufinucha	Rufous-naped Whistler	X			2		
Oriolidae							
Oriolusszalayi	Brown Oriole		X				
Dicruridae							
Chaetorhynchus papuensis	Pygmy Drongo	X					
Dicrurus bracteatus	Spangled Drongo		X				
Rhipiduridae							
Rhipidura leucophrys	Willie Wagtail		X				
Rhipidura threnothorax	Sooty Thicket Fantail		X				
Rhipidura leucothorax	White-bellied Thicket Fantail		X				
Rhipidura atra	Black Fantail	X			18		
Rhipidura albolimbata	Friendly Fantail	X		X	12		
Rhipidura brachyrhyncha	Dimorphic Fantail	X			1		
Monarchidae							
Symposiachrus axillaris	Black Monarch	X			5		
Grallina bruijni	Torrent-lark	X					
Corvidae							

Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Corvustristis	Grey Crow		X				
Incertae sedis							
Melampitta lugubris	Lesser Melampitta	X					
Ifrita kowaldi	Blue-capped Ifrita	X					
Paradisaeidae							
Paradigalla brevicauda	Short-tailed Paradigalla	X			1		P
Parotia carolae	Queen Carola's Parotia	X					P
Lophorina superba	Superb Bird-of-paradise	X					P
Epimachus fastosus/mayeri	Black/Brown Sicklebill	L			s1	VU/ –	P
Diphyllodes magnificus	Magnificent Bird-of-paradise		X				P
Paradisaea apoda(/raggiana)	Greater(/raggiana) Bird-of-paradise		X				P
Petroicidae							
Heteromyias albispecularis	Ashy Robin	X			3, c1		
Poecilodryas albonotata	Black-throated Robin	X					
Peneothello cyanus	Slaty Robin	X		X	16		
Peneothello bimaculatus	White-rumped Robin		X				
Pachycephalopsis poliosoma	White-eyed Robin		X				
Monachella muelleriana	Torrent Flyrobin		X				
Microeca papuana	Canary Flyrobin	X					
Eugerygone rubra	Garnet Robin	X			2		
Amalocichla incerta	Lesser Ground Robin	X			4, c2		
Hirundinidae							
Hirundo tahitica	Pacific Swallow		X				
Phylloscopidae							
Phylloscopus poliocephalus	Island Leaf Warbler	X					
Locustellidae							
Megalurus macrurus	Papuan Grassbird	X	X				
Zosteropidae							

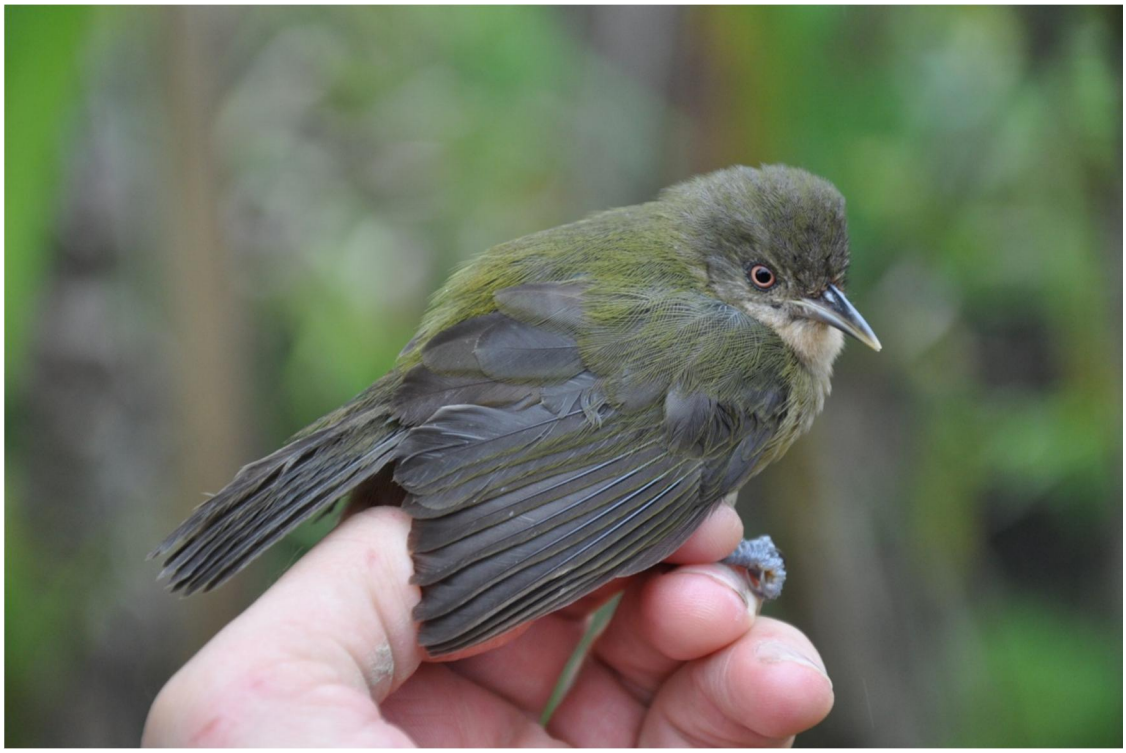
Scientific name	English name	Bilbilokabip	Tabubil	Minni	Captures	IUCN	PNG
Zosterops fuscicapilla	Capped White-eye	X					
Sturnidae							
Aplonis metallica	Metallic Starling		X				
Mino dumontii	Yellow-faced Myna		X				
Muscicapidae							
Saxicola caprata	Pied Bush Chat		X				
Dicaeidae							
Dicaeum geelvinkianum	Red-capped Flowerpecker	X	X				
Nectariniidae							
Leptocoma sericea	Black Sunbird		X				
Passeridae							
Passer montanus	Eurasian Tree Sparrow		X				
Estrildidae							
Erythrura trichroa	Blue-faced Parrotfinch	X			24		
Motacillidae							
Motacilla cinerea	Grey Wagtail		X				

Appendix 2. Morphometrics of birds sampled in the field, including body mass (bm), tarsus, bill (from base), head, wing (flattened cord) and tail. Body mass measured in grams (nearest 0.5 g), all lengths in millimetres (tarsus, culmen and head to nearest 0.1 mm, wing and tail to nearest 1 mm). Ranges are shown where samples >1and mean (in brackets) for samples >2. Gender/age is specified where known (from field markings and/or dissection).

Scientific name	Common name	Sex/age	no.	bm	tarsus	bill	head	wing	tail
Gallicolumba beccarii	Bronze Ground Dove	M	1	62	31.2	14.2	37.7	100	62
Gallicolumba beccarii	Bronze Ground Dove		3	50–57 (53.5)	26.8–30.4 (28.6)	15.8–16.3 (16.1)	36.3–37.6 (37.0)	100–105 (102)	57–66 (62)
Aegotheles insignis	Feline Owlet-nightjar	M	1	79.5	22.9	26.3	50.8	151	133
Aegotheles insignis	Feline Owlet-nightjar		1	80.5	23.8	23	50.9	69	127
Syma megarhyncha	Mountain Kingfisher	M	1	61	17	49.3	75.7	89	74
Amblyornis macgregoriae	MacGregor's Bowerbird	F	1	121	40.3	30.7	62	131	90
Amblyornis macgregoriae	MacGregor's Bowerbird	nestling	1	88.5	37.6				
Ptiloprora perstriata	Grey-streaked Honeyeater	F	2	n/a	27.3–30.4	24.9–29.1	44.2–49.2	88–96	84–96
Ptiloprora perstriata	Grey-streaked Honeyeater		10	21–30 (26.5)	26.4–30.6 (28.6)	23.5–29.2 (26.8)	42.5–48.2 (46)	84–99 (93)	79–96 (86)
Melipotes fumigatus	Common Smoky Honeyeater	M	2	n/a	32–32.3	21.7–23.3	44.9–47	104–119	100–106
Melipotes fumigatus	Common Smoky Honeyeater		2	52.5–54.5	34.5–34.5	23.6–25.9	46.9–47.2	111–121	118 (n=1)
Timeliopsis fulvigula	Olive Straightbill		3	17.5–19 (n=2)	22.3–23.2 (22.7)	19.1–19.7 (19.4)	35.1–35.6 (35.4)	68–72 (70)	53–55 (54)
Crateroscelis robusta	Mountain Mouse-warbler	M	2		29.6–30.5	14.9–15.2	36.1–36.3	65-66	45
Crateroscelis robusta	Mountain Mouse-warbler		2		28.2–30.1	14.1–16.8	34.7–37.6	57–65	
Sericornis nouhuysi	Large Scrubwren		6	14–17 (15.5)	23.1–24.4 (23.7)	13.9–16.2 (14.7)	31.8–34.7 (33.3)	60–64 (63)	43–49 (46)
Sericornis perspicillatus	Buff-faced Scrubwren		5	7–9.5 (8.5, n=4)	18.6–19.7 (18.9)	11.3–12.2 (11.9, n=4)	27.6–29.6 (28.5, n=3)	50–55 (52)	39–40 (40, n=4)
Cnemophilus loriae	Loria's Satinbird	F	1	92	38.1	24.7	52.3	99	73
Melanocharis versteri	Fan-tailed Berrypecker	M	8	10.5–13 (11.5)	22.6–24.2 (23.6)	13–13.9 (13.4)	28.6–29.8 (29.1)	60–63 (61)	74–83 (78)
Melanocharis versteri	Fan-tailed Berrypecker	F	3	15.5–16 (n=2)	23.2–24.8 (23.8)	12.6–14.3 (13.7)	29.9–31.3 (30.5)	66–69 (67)	62–69 (67)
Melanocharis versteri	Fan-tailed Berrypecker		7	13–17.5 (14.5)	23.1–24.5 (23.8)	13.1–15 (3.9)	28.8–31.7 (30.2)	62–69 (65, n=6)	58–69 (65, n=6)
Toxorhamphus poliopterus	Slaty-headed Longbill		3	13.5–14.5 (14)	17.5–18.5 (18)	33.5–34.5 (33.9)	48.8–49.5 (49.2)	69–72 (70.7)	42–44 (43)
Coracina longicauda	Hooded Cuckooshrike	M	1	99	31.1	27.7	57.7	173	152
Eulacestoma nigropectus	Wattled Ploughbill	F	1		20.4	14.1	32.1	68	49
Rhagologus leucostigma	Mottled Whistler	F	1	26	20.5	16.4	35.8	87	64
Rhagologus leucostigma	Mottled Whistler		1	24	19.8	16.7	36.8	78	63
Pachycephala lorentzi	Lorentz's Whistler	M	1		23.5	14.2	35.1	87	65

Scientific name	Common name	Sex/age	no.	bm	tarsus	bill	head	wing	tail
Pachycephala schlegelii	Regent Whistler	M juv.	1		24.7	14.2	37.7	86	68
Pachycephala schlegelii	Regent Whistler	F	1		24.4	15	37.2	85	66
Pachycephala soror	Sclater's Whistler	M	4	23–26 (24)	22–23.7 (23.1)	15.5–26.3 (15.9)	38.3–39.2 (38.8)	87–92 (90)	60–66 (63)
Pachycephala soror	Sclater's Whistler	F	4	22.5–27.5 (25)	22.1–23.2 (22.8)	15.3–16.3 (15.9)	38.2–39.8 (39)	85–89 (88)	61–66 (64)
Colluricincla tenebrosa	Sooty Shrikethrush		1	41.5	30.5	23.4	47.6	97	80
Pitohui nigrescens	Black Pitohui	M	1	70	30.2	27.9	55.2	124	106
Aleadryas rufinucha	Rufousnaped Whistler		1	36.5	31.7	21.6	42.6	79	64
Chaetorhynchus papuensis	Pygmy Drongo		2	29.5–33.5	17.6–18.8	18.6–18.9	41.9–42.1	104–105	88–92
Rhipidura atra	Black Fantail	M	3	11.5–13.5 (12.5)	21.4–22.7 (22.1)	13.1–14 (n=2)	30.5–31.3 (n=2)	80–82 (81)	90–95 (93)
Rhipidura atra	Black Fantail		6	10–11 (10.5, n=5)	20.1–21.7 (21.1)	12.5–13.2 (12.8)	29.2–29.9 (29.5, n=5)	71–74 (72)	81–92 (85)
Rhipidura albolimbata	Friendly Fantail	M	2	n/a	18–18.1	11–12.3	26.7–28	76–84	81–89
Rhipidura albolimbata	Friendly Fantail		5	8–9.5 (9)	17.9–18.4 (18.1, n=4)	10.9–12.9 (11.9)	25.9–28.3 (27.3)	71–80 (77)	80–85 (82)
Rhipidura brachyrhyncha	Dimorphic Fantail		1	8	20	10.7	25.7	61	76
Symposiachrus axillaris	Black Monarch		5	14.5–16 (15)	19.2–20.2 (19.7)	13.7–15 (14.2)	32.6–34.5 (33.7)	76–82 (79)	77–82 (80)
Paradigalla brevicauda	Shorttailed Paradigalla		1	151	43.5	39.3	70.3	152	66
Heteromyias albispecularis	Ashy Robin	M	1	37	35.2	20.5	45.8	96	61
Heteromyias albispecularis	Ashy Robin		1	28.5	32.6	18	42	90	55
Peneothello cyanus	Slaty Robin		9	18.5–29 (22.5)	24.1–27 (25.2)	15.2–16.7 (15.9)	36.6–40.2 (38.1)	81–91 (85)	55–66 (59, n=8)
Peneothello cyanus	Slaty Robin	juv.	1	19	24.7	15.3	37.5	85	55
Eugerygone rubra	Garnet Robin	F	1	7	15.8	11.4		59	49
Eugerygone rubra	Garnet Robin	juv.	1	6.5		10.2		59	35
Amalocichla incerta	Lesser Ground Robin		2	29–33	37.2–38.4	17.9–18	41.7–41.9	79–79	60–64
Erythrura trichroa	BluefacedParrotfinch		10	13.5–16.5 (15, n=9)	17.8–19.5 (18.4)	14.6–15.5 (15)	27.5–29 (28.2)	60–65 (62)	39–47 (43, n=9)

Sooty Shrikethrush *Colluricincla tenebrosa* from Tupnonbil. (Photo I.Woxvold)



Olive Straightbill *Timeliopsis fulvigula* from Tupnonbil. *(Photo I.Woxvold)*

Chapter 9

Non-Flying Mammals

Ken P. Aplin and John S. Lamaris

Summary

We surveyed mammals around two sites at elevations of c. 1,800 m (Bilbilokabip) in the southern foothills of the Hindenburg Range and c. 2,500 m (Minni) at the eastern end of the Star Mountains, Western Province, Papua New Guinea. We used a combination of trapping and spotlighting to survey non-volant mammals. Additional information came from discussions with experienced hunters, the examination of hunters' trophies, and the analysis of food remains in discarded fire pit ashes at Bilbilokabip. In addition, the fortuitous discovery of a small bone deposit in a rock-shelter at an elevation of 2529 m on Mt Minni provided a number of significant additional records.

The survey produced new regional records of 14 species of non-volant mammals, including six marsupials and eight rodents. At least two of the rodents are undescribed species but in each case these are known from prior collections. Our records of the Great-tailed Triok (*Dactylopsila megalura*), the Mountain Mammelomys (*Mammelomys lanosus*) and Louise's Mirzamys (*Mirzamys lousieae*) represent the first occurrence of these taxa on the southern side of the Hindenburg Range; and the occurrence of Brass's Mouse (*Brassomys* cf. *albidens*) in the Mt Minni bone deposit represents only the second known locality for this species and the first record from Papua New Guinea.

The results of the Hindenburg Range survey confirm and extend previous suggestions regarding the richness and distinctiveness of the mammalian fauna of the upper Ok Tedi River region. The richness of the extant fauna attests to the continued presence of large areas of high quality habitat. However, the rarity of many of the locally occurring species in other parts of New Guinea is a reminder of their vulnerability, especially to direct hunting pressure and the novel use of firearms. Taking into account the remoteness of the southern flanks of the Hindenburg Range, the survival of these species into the future will depend in large part on the effectiveness of traditional systems of stewardship and protection, perhaps combined with new approaches that provide direct rewards for conservation actions. However, lessons learned elsewhere in Papua New Guinea highlight some of the difficulties associated with both implementing and then maintaining these approaches over meaningful time scales.

Introduction

The Hindenburg Range, with its series of dramatic southern escarpments known collectively as the Hindenburg Wall, provides one of the most breathtaking landscapes to be found anywhere in the world. Previous scientific studies in the area suggest that it is no less remarkable biologically, with many endemic species known from nowhere else and a species richness in many groups that is almost unrivalled. This biological splendour no doubt owes in part to the central geographic position of the Star Mountains and Hindenburg Range within the Central Cordillera of New Guinea – the great chain of interlinked mountain ranges that make up the spine of the altogether remarkable island of New Guinea.

Prior to the development of the Ok Tedi Mine project in the 1980s the headwaters of the Ok Tedi River was among the most remote and biologically least explored regions of Papua New Guinea. Despite considerable interest in the region due to the apparent access provided by the Fly and Strickland Rivers, the Star Mountains themselves had proven remarkably resilient to European exploration. Notable early attempts to access the western interior of British New Guinea via the Fly and Strickland Rivers were made by d'Albertis in 1876–1877 and Sir William MacGregor in 1889. In 1914 the Hindenburg Range was approached from the northern side and named as such by Richard Thurnwald (Thurnwald 1916). The southern side was finally reached by Papuan administration Patrol Officer Leo Austen in 1922 and 1924 (Austen 1926). The range was soon thereafter crossed from south to north by Charles Karius and Ivan Champion with the invaluable assistance of men from Bolobip village (Champion 1966). Gold exploration in the mid-1930s lead to the establishment of a landing strip at Telefomin and this was extended during the Second World War, with Telefomin Patrol Post opened by the Territory administration in 1948. A second regional patrol post opened at Olsobip in the upper Fly catchment, about 12 km south of the Hindenburg Wall. Subsequent development of Tabubil as a base for the Ok Tedi Mining operations greatly facilitated access into the southern foothills of the Hindenburg Range.

The first biological studies in the Star Mountains were carried out by members of the Australian Star Mountains Expedition that worked out of Telefomin to explore some of the major northern catchments as well as Mts Capella and Scorpion (Shepherd 1974). A few bats but no non-volant mammals were collected during the survey. In 1973 David Hyndman commenced studies of human ecology and ethnobiology among Wopkaimin people inhabiting the southern margin of the Hindenburg Range. His own studies as well as subsequent collaborations with various specialists including James Menzies and John Pernetta from the University of Papua New Guinea resulted in significant collections of all vertebrates as well as a benchmark understanding of the regional distributions of plants and animals, their biogeographic patterns, and the complex interrelationships of biotic and human factors (Hyndman 1979, 1984, 1986, Pernetta and Hyndman 1982, Hyndman and Menzies 1990). Contemporaneous with Hyndman's studies, significant collections of mammals were being made in the northern catchments of the Star Mountains by collectors working for the Bernice P. Bishop Museum, Hawaii. In a series of expeditions between 1968 and 1980 they amassed large collections from numerous localities including Bafunmin at 1,600–2,300 m above sea level (asl), Bokubet at 2,850 m asl, Feramin at 1,400 m asl, Lake Loiuse at 2,800 m asl, Oksapmin at 1,900 m asl, Telefomin at 1,500 m asl, Tifalmin at 1,400–2,400 m asl, Urapmin at 1807m asl, and an unspecified locality at 3,200 m asl. These collections were never written up in any unified way but parts of the collection have been reported by various workers including Helgen and Flannery (2004), Musser et al. (2008), Musser and Lunde (2009), Helgen and Helgen (2009) and Helgen et al. (2010). Starting in 1984, Tim Flannery of the Australian Museum and various colleagues including Lester Seri of the Papua New Guinea Department of Environment and Conservation also carried out extensive mammal surveys in the Upper Sepik catchment, with significant work undertaken in the Telefomin, Tifalmin, Nong and Sol River Valleys and in the Dokfuma Basin, the latter a subalpine herbfield at 3,200 m asl on the southern slopes of Mt Capella. A synthesis of this work was presented by Flannery and Seri (1990).

The 2013 WCS Survey provided an opportunity to further explore the mammal diversity of the southern margin of the Hindenburg Range. Given the focus of previous studies in this area, we decided to direct our major effort into the smaller non-volant mammals and the bats, two groups which had received lesser attention during Hyndman's studies with their emphasis on the larger game animals. In this paper we describe our findings for the non-volant mammals; a second paper in this volume (Armstrong et al., Chapter 10) documents the parallel findings for bats.

Methods

Data collection and sampling methods
Surveys for terrestrial and arboreal mammals were carried out with a combination of camera traps and capture traps. Camera traps generally were set on obvious animal trails and were 'baited' with piles of cooked rice to encourage passing animals to spend some in the area, thereby increasing the chance of obtaining diagnostic images. We used a variety of capture traps including live 'box' traps (Elliott traps), two different sizes of cage traps, and lethal 'break-back' traps. These were set at irregular intervals alongside an existing or purpose cut walking track passing through representative habitat, with trap placement chosen to maximize likelihood of capture. Traps were set either on the ground (e.g. on animal run ways, under logs, among or under rocks) or suspended above ground (e.g. on logs or hanging branches). No traps were set in the canopy. The trapping effort was supplemented by daytime searches for burrows and other animal signs, and night time spotlight surveys, mostly along walking trails and larger tracks. Other participants also spent time out of camp at night and they sometimes reported sightings of mammals.

Every opportunity was taken to discuss local mammal distributions, habits and significance with the Wopkaimin landowners that helped us at the two camps. In general the most productive discussions took place with specimens at hand – either a captured animal or a trophy jaw. Whenever possible, multiple specimens were presented for discussion simultaneously so that differentiating characters could be identified with reference to actual examples. Broader discussions of mammal habitats and their economic cultural importance were conducted by other team members and are reported by Kagl et al. (see Chapter 1).

Protocols for capturing and handling of mammals followed guidelines of the American Society of Mammalogists (Gannon et al. 2007). Captured mammals judged to be important for taxonomic purposes were euthanized and fixed for long term preservation as museum voucher specimens, thereby allowing detailed comparative study of both external and internal features (e.g. skull and teeth). Most vouchers were fixed whole in 10% formalin and subsequently transferred to 70% ethanol for long-term storage. A few were skinned in the field and fixed in 70% ethanol for future preparation as puppet skins. Tissue samples were preserved in 95% ethanol for all captured animals to allow efficient extraction of DNA. Additional tissue and organ samples along with visible ecto- and endo-parasites were taken from the majority of specimens to screen for a variety of pathogens including viruses and bacteria.

Specimens from the WCS Hindenburg Wall Survey are deposited in the United States National Museum, Washington D.C., U.S.A. and the Australian Museum, Sydney, Australia, identified by the prefix USNM and AM, respectively. Other institutional abbreviations used here are: AMNH (American Museum of Natural History) and UP (University of Papua New Guinea Natural Sciences Resource Centre). Taxonomic usage generally follows Flannery and Groves (1998) for monotremes, Groves (2005) for marsupials, and Musser and Carleton (2005) for rodents. Any departure from these sources is discussed under individual species accounts. For common names we follow the recommended usage in the IUCN Red List (www.iucn.org).

Study sites
Mammal survey was conducted out of two sites, giving a total altitudinal range from 1,750–2,529 m asl.

Bilbilokabip Camp (5.1203°S, 141.2512°E) was situated at ~1,800 m asl and is close to a former location of Bultem village in an area known as Tupnonbil. This area is still in regular and varied use by occupants of Bultem and supports a mosaic of active gardens, ericoid scrub, and secondary forest, as well as substantial patches of primary Montane and *Nothofagus* forest. The survey camp was established at a seasonal hunting and gardening hamlet belonging to the Keikei clan. A walking track that runs between Bultem and Tifalmin in the Upper Sepik catchment passes beside the camp and was in regular use during the survey period. Thirteen nights were spent at the camp – the nights of the 11th–23rd February 2013. The two buildings at Bilbilokabip (a general purpose building and men's house) both contained hunters' trophy material including numerous mammal mandibles, a few other bones and some bird feathers.

Minni Camp (5.0775°S, 141.1505°E) was situated at 2, 440 m asl at a former exploration drill-pad. The immediate surrounds of the helipad is dense regrowth scrub but this gives way with 100m or less in all directions to a primary cover of *Nothofagus* and cloud forest (Venter, see Chapter 2). Forest cover

continues to the summit of Mt Minni but it is broken in several areas by sizeable patches of dense ericoid scrub, each covering areas of several hectares. One of these is located downslope of the camp at 2,385 m asl and also contained an exploration drill-pad with remnants of wooden structures still standing. Areas immediately around the camp and helipad showed signs of cutting of building materials but, at greater remove, the forest was entirely undisturbed. A walking track from Kawarobip to Tifalmin passed within 100m of the camp but was overgrown in many places and clearly had not been used in recent times. A small rockshelter beside the walking track at 2,529 m asl was known to our field assistants. This was visited and proved to contain a small bone deposit as a consequence of occasional use by an avian predator, most likely a Sooty Owl, *Tyto tenebriciosa*. Four nights were spent at the camp – the nights of the 24th – 28th April 2009 – but no sampling was carried out on the first night.

Aplin and Lamaris worked together on the mammal survey at both camps. Highly skilled assistance was provided by locals from Bultem (including Brian Yapi and the late Jason Yapi) and Kawarobip.

Results

General survey results

The survey period and effort deployed at each of the three mammal sampling sites is summarized in Table 1. Additional hunting and general survey effort on the part of our Wopkaimin hosts is not included in this table but their significant contribution to the survey results is mentioned during the individual species accounts.

Table 1. Details of survey camps and survey effort for non-volant mammals.

Site details	Bilbilokabip	Minni camp
Coordinates	5.1203°S, 141.2512°E	5.0775°S, 141.1505°E
Dates surveyed	11–24 Feb.	24–28 Feb
Elevations covered (m asl)	1,750–1,900	2,208–2,529
Sampling method		
Trapping effort (trap nights)	946	99
Night search hours (KPA and JSL)	23.5	3.5
No. camera trap positions	11	–
Camera trap hours	2,422.5	–

Non-volant mammal trapping

A total of 75 small mammals were captured in traps. Represented among the captures were eight rodent species and one marsupial (Table 2). Two species of rodents – the Mountain Paramelomys (*Paramelomys* cf. *rubex*) and the Moss Forest Rat (*Rattus* cf. *niobe*) accounted for 84% of all captures.

The overall capture rate from all trapping effort was 7.8% at Bilbilokabip and 6.1% at Minni. At Bilbilokabip the highest capture rate (10.5%) was observed in areas of intact but lightly disturbed or advanced secondary forest and the lowest (0% – nothing!) in a recently planted out taro garden surrounded by dense scrub and degraded forest. All captures at Minni came from traps set in forest and none from a patch of ericoid scrub. However, the latter habitat contained signs of small mammal activity in the form of runways and active burrows and are in no doubt that further trapping effort would have brought good results.

Table 2. Trapping results for each of the major survey sites and for sampled habitats within each site.

Mammal species	Bilbilokabip					Minni camp			Total captures
	Helipad scrub	Forest along track	Primary forest	Taro garden	All habitats	Forest	Ericoid scrub	All habitats	
Dasyuridae									
Murexia cf. *naso*		1			1	1		1	**2**
Muridae									
Anisomys imitator			1		1				**1**
Lorentzimys sp.			1		1				**1**
Mammelomys lanosus		2	1		3				**3**
Mirzamys louisae						1		1	**1**
Parahydromys ellermani			1		1				**1**
Paraleptomys sp.		1			1	2		2	**3**
Paramelomys cf. *rubex*		31	13		44	1		1	**45**
Rattus cf. *niobe*	3	9	5		17	1		1	**18**
TOTALS	**3**	**44**	**22**	**0**	**69**	**6**	**0**	**6**	**75**
Trap nights	45	421	280	140	886	84	15	99	985
Trap success	6.7%	10.5%	7.9%	0.0%	7.8%	7.1%	0.0%	6.1%	7.6%

Trapping returns were considerably higher at these sites than at similar altitudes in the Muller Range (Aplin and Kale 2011). This may reflect the lower degree of disturbance at the Muller Range camps, all of which were remote from human settlements.

Camera trapping

Eight mammal species were imaged by camera trap units placed in relatively undisturbed forests around Bilbilokabip (Table 3). Two rodents species, the Uneven-toothed Giant Rat (*Anisomys imitator*) and a Mountain Paramelomys (*Paramelomys* cf. *rubex*) were imaged at more camera positions than other species.

Table 3. Camera trapping results. Camera positions 1–5 were in relatively undisturbed Montane forest dominated by *Nothofagus* at 1810–1825 m asl.; camera positions 6–11 were in relatively undisturbed forest dominated by oak species at 1780–1795 m asl.

Taxon	Camera trap position										
	1	2	3	4	5	6	7	8	9	10	11
Dasyuridae											
Murexia sp.											+
Macropodidae											
Dorcopsulus cf. *vanheurni*		+							+		
Phalangeridae											
Phalanger gymnotis	+										
Petauridae											
Dactylopsila palpator									+		
Muridae											
Anisomys imitator	+	+							+	+	
Mallomys sp.		+									
Paramelomys cf. *rubex*		+	+				+		+		
Rattus cf. *niobe*											+

Observations

Five species of non-volant mammals were sighted at night by team members. All of these species were also recorded by other means. The sightings are noted in the individual species accounts.

Trophy collections

The two hunters' trophy series contained a total of 138 mandibles of hunted wild mammals (Table 4) along with 14 pig mandibles. The latter were said to be all from domestic or wild caught but hand reared pigs that had been killed and eaten at Bilbilokabip. The wild mammal trophies contained representatives of 12 species including 11 marsupials and one rodent. The smallest species represented in the trophy collection were an Ornate Bandicoot (*Microperoryctes ornata*) and the Masked Ringtail (*Pseudochirulus larvatus*), both with adult body weights of ~600–800 g.

The trophy collections in both huts were dominated by the remains of two possums, the Coppery Ringtail (*Pseudochirops cupreus*; 33% of all trophies) and the Silky Cuscus (*Phalanger sericeus*; 28% of all trophies). Pig mandibles were present only in the men's house, while mandibles of the Woolly Giant Rat (*Mallomys* sp.; N= 7) were confined to the general purpose house. Although there are some other differences in the composition of the trophy series between the two huts, the contrasts may be simply due to the relatively small sample sizes. Far greater contrast is observed with a trophy collection reported by Pernetta and Hyndman (1982; data repeated here in Table 4) from the men's house in the Wopkaimin village of Megalsimabip, located c. 10 km south of Bilbilokabip. This village is at a lower elevation and has local hunting territory extending up to c.1400m asl Major contrasts are the much higher frequency of wallaby (*Dorcopsulus* cf. *vanheurni*) and the occurrence of several typical species of lower elevations (e.g. *Phalanger mimicus*; reported as *P. orientalis*).

Image of *Mallomys* sp captured by camera trap at Tubnobil. *(Photo WCS)*

Image of *Dorcopsulus* cf. *vanheurni* captured by camera trap at Tubnobil *(Photo WCS)*

Table 4. Animal trophy jaws present in the two houses at Bilbilokabip; comparative data are included for the Men's house at Megalsimabip, located approximately 10 km south of Bilbilokabip and with local hunting territory extending up to c. 1400m asl (data from Pernetta and Hyndman 1982).

Taxon	Bilbilokabip				Megalsimabip	
	House 1	House 2	Both houses	% for both houses	Men's house	% representation
Peramelidae						
Echymipera kalubu/rufescens					11	8%
Microperoryctes ornata	2	1	3	2%	1	1%
Peroryctes raffrayana		1	1	1%		
Macropodidae						
Dendrolagus notatus / stellarum	3	4	7	5%	4	3%
Dorcopsulus vanheurni	1		1	1%	85	62%
Petauridae						
Dactylopsila palpator	1		1	1%		
Phalangeridae						
Phalanger carmelitae	4		4	3%		
Phalanger gymnotis	14	4	18	13%		
Phalanger orientalis					5	4%
Phalanger sericeus	29	10	39	28%	16	12%
Pseudocheiridae						
Pseudochirulus larvatus	3	1	4	3%		
Pseudochirops corinnae	6	1	7	5%	4	
Pseudochirops cupreus	32	14	46	33%	23	17%
Muridae						
Mallomys sp.	7		7	5%		
Pteropodidae						
Pteropus neohibernicus					14	
Suidae						
Sus scrofa	14		14		18	
Casuaridae						
Cauarius bennetti					23	
TOTAL **(excluding bats, pigs, cassowary)**	102	36	138		138	

The Mt Minni bone deposit
The rockshelter visited from Minni was in a rock pile positioned midway up a steep slope. It offered a sheltered but rocky sleeping area of approximately 3 m^2 with a central fireplace and a narrower and lower side chamber which opened below into a narrow fissure. The chamber contained a single freshly deposited raptor pellet and a surface scatter of small mammal bones. Shallow, loose soil to a depth of c. 10–15 cm in a pocket among rocks also contained bones. The entire deposit was bagged and carried back to the camp where it was washed through fly screen, dried and sorted.

The deposit contained the remains of a minimum of 36 individuals representing 14 species of mammals as well as a small number of birds and one frog (Table 5). The most abundant species in the sample is the Pygmy Ringtail (*Pseudochirulus mayeri*), followed by a Long-footed Mouse (*Lorentzimys* sp.), the Moss Forest Rat (*Rattus* cf. *niobe*), and Shawmayer's Mouse (*Coccymys shawmayeri*). Notable occurrences in the assemblage are a White-toothed Mouse (*Brassomys* cf. *albidens*) and Menzies' Mouse (*Abeomelomys* cf. *sevia*), the former of which represents only the second main locality for a member of this genus and an eastwards range extension of c. 250 km.

The presence of a regurgitated pellet identifies the predator as a raptor and the dominance of small to medium-sized mammal species points to an owl rather than a diurnal hunter. At this elevation in New Guinea the only likely candidate species are the Grass Owl (*Tyto capensis*) and the Sooty Owl (*Tyto tenebricosa*), and the forest habitat would favour the latter species. The size range and emphasis on arboreal mammals in the assemblage is also consistent with prior information on Sooty Owl diet (Higgins 1999, Helgen and Opiang 2011a: Table 20.1).

Wopkaimin mammal classification
A list of Wopkaimin names collected during the survey is given in Table 6 where they are compared with names recorded previously by Hyndman (1979, 1984) and Pernetta and Hyndman (1982). Although there are numerous points of agreement, there are also various discrepancies. Some of these are clearly variant spellings or endings that might be gender/age or context markers (e.g., Aboyo vs Aboim for *Dasyurus albopunctatus*) while others probably reflect either genuine or confused usage of the same name for two or more morphologically similar species [e.g., Somkam recorded for *Hyomys* sp. by Pernetta and Hyndman (1982) and for *Anisomys imitator* by us; these giant rats have very similar tails and this feature was consulted by our informants to make the determination). A notable feature of the comparison is that many of the names recorded for the first time by us were used for small mammals which were of lesser concern to either Hyndman (1979) or Pernetta and Hyndman (1982) than the game animals (e.g., the names Boyim and Abilkan for garden and forest small mammals, and Bibiyanim).

Some discrepancies are less readily explained such as the use of *nomin* vs *kinfeik* for *Pseudochirulus mayeri* (the latter name is also recorded by Whithead (1995) for Seltaman] and of Domkam vs Waiangim for *Uromys anak*; neither name appears in an extensive list of 'giant rats' recorded by Whithead (1995). To reconcile these differences would require extensive questioning of multiple informants. Whithead (1995) discusses the numerous complicating factors in any attempt to establish 'tok ples' names for animals, especially for species that are infrequently encountered even by experienced hunters. One of these is the occurrence of secret names (often referred to as 'hide' names) that are used by initiated clan members to call up favour or in the performing of ceremonies or rituals. In our experience of communities with multiple clans, taxa of particular cultural significance can have numerous names, some public, some private, others now regarded as superseded due to a process of revision of 'hide' names.

Table 5. Taxonomic composition of the Mt Minni bone deposit. Values for each species are NISP = number of individual specimens; and MNI = minimum number of individuals represented.

Taxon	NISP	MNI
Dasyuridae		
Murexia naso	2	1
Peramelidae		
Microperoryctes ornata	7	2
Burramyidae		
Cercartetus caudatus	14	5
Petauridae		
Petaurus breviceps	2	1
Pseudocheiridae		
Pseudochirulus mayeri	28	7
Muridae		
Abeomelomys sevia	2	1
Brassomys cf. *albidens*	4	1
Coccymys cf. *shawmayeri*	5	3
Lorentzimys sp.	12	4
Mammelomys sp.	4	2
Paramelomys cf. *rubex*	1	1
Pogonomys sp.	2	1
Rattus cf. *niobe*	10	4
Pteropodidae		
Syconycteris sp.	1	1
Unidentified small birds	5	1
Unidentified frog	1	1
TOTALS	100	36

Table 6. 'Tok ples' (local) names for mammals in various Ok languages and compiled from various sources. Species marked with an ***** appear in earlier compilations but are not known to occur in the southern foothills of the Star Mountains. Faiwol (Wopkaimin) names marked with † were obtained with direct reference to a captured animal; those qualified with '?' were obtained through discussion alone and/or were applied to captured specimens in an ambiguous way.

Family/English Name	Scientific Name	Faiwol (Wopkaimin)			Telefol	Faiwol (Seltaman)	Mian		
		Hyndman (1979, 1984)	Pernatta & Hyndman (1982)	Aplin and Lamaris (this study)	Flannery (1995)	Whitehead (1995)	Morren (1989)	Flannery (1995)	Aplin (unpub 2010)
All game animals			Nuk	Nuk		Nuk			
All rats and bandicoots				Sanok					
All flying animals (bats, birds; some other mammals)			Awon (includes *Petaurus*)	Awon		Auon			
Tachyglossidae									
Long-beaked Echidna	*Zaglossus* sp.	Yakil	Yakil	Yakil	Egil/Igil	Yakhail	Yakel	Yakeil	Yakeil
Dasyuridae									
New Guinean Quoll	*Dasyurus albopunctatus*	Aboim	Aboim	Aboyo	Kutinim	Aboyim, Aboysip		Tangtangib	Tangtangibo Hom
Black-tailed Dasyure	*Murexia melanurus*			Bibiyanim†			Temiyap	Bumtaing	
Speckled Dasyure	*Neophascogale lorentzii*		Takinok						
Peramelidae									
Raffray's Bandicoot	*Peroryctes raffrayana*			Lawin?	Ibin	Kimisok, Dein	Duwin	Duwin	Duwin
Clara's Spiny Bandicoot*	*Echymipera clara*		Luwen				Kiyok	Kiyok	Kiyok
Common Spiny Bandicoot	*Echymipera kalubu*	Kaial	Kaial		Aiyal	Bakhonkaak, Kayaar	Aiyal	Aiyal	Aiyal

Family/English Name	Scientific Name	Faiwol (Wopkaimin)			Telefol	Faiwol (Seltaman)	Mian		
		Hyndman (1979, 1984)	Pernatta & Hyndman (1982)	Aplin and Lamaris (this study)	Flannery (1995)	Whitehead (1995)	Morren (1989)	Flannery (1995)	Aplin (unpub 2010)
Striped Bandicoot	*Microperoryctes longicauda*	Sanok	Sanok, lawin	Kayak	Warem	Waar, waarim			Duwin
Phalangeridae									
Mountain Cuscus	*Phalanger carmelitae*	Norim	Norim	Kitam†	Matanim	Ngorim, nuk masem	Satol		Satol
Ground Cuscus	*Phalanger gymnotis*	Koyam	Kwiam		Quoyam	Kwemnok, Kwiam, Koyam	Kwiyam	Quoyam	Kwiyam
Southern Common Cuscus	*Phalanger orientalis*		Nareim		Aligin (male) Ibim (female)	Arik (male) Deim (female)	Ibim (male); Ariken (female)	Maetol; Aligin; Ibim	Aligin*; Ibim*
Silky Cuscus	*Phalanger sericeus*	Kitam	Kitam	Kitam†	Kutip	Kitem			
Stein's Cuscus	*Phalanger vestitus*	Nareim	Nareim		Nelem	Ngerem, Nerem			Nelem
Common Spotted Cuscus	*Spilocuscus maculatus*		Daiop			Sarip, Dionim, Taban	Tekep Duruku or Tekep Nema (male); Tekep Gaong (female)	Tekeib	Tekep*
Black-spotted Cuscus	*Spilocuscus rufoniger*		Sarip			Sarip, Dionim, Taban	Tekep Derakeman (male); Tekep Asul (female)	Tekeib?	Tekep*

Family/English Name	Scientific Name	Faiwol (Wopkaimin)			Telefol	Faiwol (Seltaman)	Mian		
		Hyndman (1979, 1984)	Pernatta & Hyndman (1982)	Aplin and Lamaris (this study)	Flannery (1995)	Whitehead (1995)	Morren (1989)	Flannery (1995)	Aplin (unpub 2010)
Pseudocheiridae									
Pygmy Ringtail Possum	*Pseudochirulus mayeri*		Kinfeik	Nomin†	Dom	Kinfiik, Kinfeik			
Plush-coated Ringtail	*Pseudochirops corinnae*	Dawam	Dawam		Dabam	Kayang, Dafaam, Arukiok			
Coppery Ringtail Possum	*Pseudochirops cupreus*	Kaiyan	Kaian	Kaiyang†	Kayang	Kayang	Nenem (male?); Kiyong (female?)		
Petauridae									
Striped Possum	*Dactylopsila trivirgata*	Dubem	Dubem		Triok?	Ngarfem, Ngarfemnok, Fiok	Kwidiaim	Kwidiaim	Kwidiaim
Great-tailed triok	*Dactylopsila megalura*			Galwemyap†	Defem, Triok	Ngarfem, Ngarfemnok, Fiok, Titok?			
Long-fingered Triok	*Dactylopsila palpator*	Galwem	Galwem		Triok				
Sugar Glider	*Petaurus breviceps*	Slakim			Silek	Fapkoyok, Fapkiok	Befagam	Mayfagam	Befagam
Burramyidae									
Long-tailed Pygmy-possum	*Cercatetus caudatus*			Bibiyanim?	Finareng				
Macropodidae									
Montane Tree Kangaroo	*Dendrolagus notatus / stellarum*	Dubol	Dubol	Dubol	D'bol	Dubol	Debalim Asul/Melil		Debalim

Family/English Name	Scientific Name	Faiwol (Wopkaimin)			Telefol	Faiwol (Seltaman)	Mian		
		Hyndman (1979, 1984)	Pernatta & Hyndman (1982)	Aplin and Lamaris (this study)	Flannery (1995)	Whitehead (1995)	Morren (1989)	Flannery (1995)	Aplin (unpub 2010)
Small Mountain Dorcopsis	*Dorcopsulus vanheurni*	Watom	Watom	Watom	Autom	Watom	Sumul		Soyabu
Brown's Pademelon*	*Thylogale browni*	Watom	Watom		Simulim	Sumolim		Sumul	Sumul
Muridae									
Giant rats	various					Mein, El Dakhon, Ngatip; Ki Dakhon; Farenki, Farenkiok; Kuter; Wares; Somin, Som			
small rats	various		Yaram	Iram, Boyim, Senok?		Et, Komei; Senok, Senokiok; Ibiok; Iram, El Iram, Nuk Em, Brusek; Ubil, Ubaar, Uwaar			
forest rats	various			Abilkan†					
garden rats	various			Boyim†					
Uneven-toothed Rat	*Anisomys imitator*			Somkam†	Apsal				
Eastern White-eared Giant Rat	*Hyomys goliath*		Somkan		Trosin		Afut (male?); Debam (female?)_		

Family/English Name	Scientific Name	Faiwol (Wopkaimin)			Telefol	Faiwol (Seltaman)	Mian		
		Hyndman (1979, 1984)	Pernatta & Hyndman (1982)	Aplin and Lamaris (this study)	Flannery (1995)	Whitehead (1995)	Morren (1989)	Flannery (1995)	Aplin (unpub 2010)
Giant Wooly Rats	*Mallomys* spp.	Frim	Frim	Filimyap	Resen				
Montane Mammelomys	*Mammelomys lanosus*			Abilkan†					
Waterside Rat	*Parahydromys asper*		Bilbilok						
Paraleptomys	*Paraleptomys* sp.		Awanbitbit	Abilkan†					
Mountain Mosaic-tailed Rat	*Paramelomys rubex*		Abilim	Abilkan†				Briazu	
Montane Rat	*Rattus niobe*			Abilkan†					
Spiny Rat	*Rattus praetor*						Sanuk	Senok	Sanuk
Stein's Rat	*Rattus steini*		Munapnok, Gargirim	Boyim?, Senok	Senok	Senokiok, Senok		Senok	Sanuk
Giant naked-tailed Rat	*Uromys anak*		Waiangim	Domkam†	Kutel, Quotel				Kwaimo
Suidae									
Feral Pig	*Sus scrofa*		Kong Samin			Kung	El Halap		
Domestic Pig	*Sus scrofa*		Kong Kong	Kung					
Canidae									
Dog	*Canis lupus domesticus*		Maian			Maan			
Pteropodidae									
Moluccan Bare-backed Fruit Bat	*Dobsonia moluccensis*			Sikam		Singaam	Wan Katep	Ketab	Katep
Common Blossom Bat	*Syconycteris australis*			Siminok	Timinim	Tirimin?	Wan Timinim Wafume	Timinim	Timinim
Small bats	various			Ok					Diril

Table 7. The non-volant mammal fauna of the southern flanks and crest of the Star Mountains, PNG, based on previous records and new information gathered during the 2013 WCS survey. Taxa located for the first time during the 2013 survey are highlighted in grey. The 5 ecological zones recognized by Hyndman and Menzies (1990) are 1. Foothill rainforest (<1,000 m asl); 2. Lower montane rainforest (c.1,000–2,300 m asl.); 3. Secondary forest within the Lower montane zone; 4. Low altitude Midmontane rainforest (c.1,800–2,200 m asl); and 5. Midmontane rainforest (>2,300 m asl). Included under 'Other sources' are Helgen and Flannery (2004), Musser et al. (2008), Musser and Lunde (2009), Helgen and Helgen (2009) and Helgen et al. (2010).

Taxon	**Hyndman and Menzies (1990)** (Ecological zones)					**Flannery & Seri (1990) 3,200 m**	**Other sources***	**Bilbiliokabip ~1,800 m**		**Minni ~2,500m**	
	1	2	3	4	5			Survey	Trophies	Camp	Rockshelter
Tachyglossidae											
Zaglossus sp.		+		+				+			
Dasyuridae											
Dasyurus albopunctatus	+							I			
Murexia cf. *melanurus*								+			
Murexia naso								+		+	+
Neophascogale lorentzi		+		+							
Peramelidae											
Echymipera kalubu	+										
Microperoryctes ornata		+	+		+	+			+		+
Peroryctes raffrayana									+		
Macropodidae											
Dendrolagus stellarum / notatus				+		+			+		
Dorcopsulus vanheurni		+				+		+	+		
Burramyidae											
Cercartetus caudatus						+					+
Petauridae											
Dactylopsila megalura								+	+		

Taxon	Hyndman and Menzies (1990) (Ecological zones)					Flannery & Seri (1990) 3,200 m	Other sources*	Bilbiliokabip ~1,800 m		Minni ~2,500m	
Dactylopsila palpator				+							
Dactylopsila trivirgata	+	+	+								
Petaurus breviceps					+						+
Phalangeridae											
Phalanger carmelitae		+	+	+				+	+		
Phalanger gymnotis	+	+	+		+				+		
Phalanger mimicus	+*										
Phalanger sericeus				+	+			+	+		
Phalanger vestitus	+	+									
Spilocuscus maculatus	+*										
Spilocuscus rufoniger	+										
Pseudocheiridae											
Pseudochirulus larvatus									+		
Pseudochirulus mayeri		+	+		+	+		+			+
Pseudochirops corinnae				+					+	+	
Pseudochirops cupreus				+	+			+	+		
Muridae											
Abeomelomys sevia											+
Anisomys imitator								+			
Brassomys cf. *albidens*											+
Coccymys ruemmleri						+					+
Coccymys cf. *shawmayeri*							1,850 m				
Hyomys sp.		+	+								
Lorentzimys sp.				+				+			+
Mallomys sp.	+	+	+	+	+			+	+		

Taxon	Hyndman and Menzies (1990) (Ecological zones)					Flannery & Seri (1990) 3,200 m	Other sources*	Bilbiliokabip ~1,800 m	Minni ~2,500m	
Mammelomys lanosus								+		+
Melomys rufescens						+				
Mirzamys louisae							1,900–3,200 m		+	
Parahydromys asper		+								
Paraleptomys sp.		+		+				+	+	
Paramelomys lorentzi	+									
Paramelomys cf. rubex		+		+	+			+	+	
Pseudohydromys ellermani							1,400–2,300 m	+		
Pseudohydromys occidentalis							2,300–2,600 m			
Pogonomys sp.										+
Rattus leucopus	+									
Rattus cf. *niobe*					+	+		+	+	+
Rattus steini		+	+							
Rattus verecundus		+								
Uromys anak		+	+					+		

Summary of mammal records
The combined survey methods produced direct evidence of 33 species of non-volant mammals – one monotreme, 17 marsupials and 15 rodents (Table 7). At least two of the rodents are undescribed species though in both cases there are previous records from the Star Mountains and/or wider regions. Several of the marsupials may also be undescribed but these too are likely to be known from elsewhere in the region.

We obtained the first records for the Upper Ok Tedi region of six marsupial and eight rodent species (these are highlighted in Table 6). Most of these extra species were anticipated on the basis of wider geographic distributions and in view of the limited representation of small mammals in the hunting returns that were the focus of previous studies in the area (Hyndman 1979, 1984, Hyndman and Menzies 1990, Pernetta and Hyndman 1982). More surprising were the new records of Raffray's Bandicoot (*Peroryctes raffrayana*), Marked Ringtail (*Pseudochirulus larvatus*) and Uneven Toothed Giant Rat (*Anisomys imitator*). Each of these definitely qualifies as a game animal and it is unclear why they have evaded detection up until now.

Among the small mammals, two of our new distributional records are of particular interest. The Upper Ok Tedi population of the Mountain Mammelomys (*Mammelomys lanosus*) represents the first occurrence of this taxon on the southern side of the Hindenburg Range; and the occurrence of Brass's Mouse (*Brassomys* cf. *albidens*) in the Mt Minni bone deposit represents the first record of this recently described genus from Papua New Guinea.

Annotated species list
IUCN Red List ratings are drawn from the 2008 assessment available at http://www.redlist.org/.

Order Monotremata
Family Tachyglossidae

Zaglossus sp.: Long-beaked Echidna (Yakheil)
IUCN Red List rating: Critically Endangered

Landowners of both survey sites were familiar with long-beaked echidnas and claimed that they could be obtained in the vicinity of each site. However, both groups emphasised that dogs are necessary to efficiently locate echidnas in their daytime burrows and other resting places (e.g., among rocks). Hyndman and Menzies (1990) also documented a Long-beaked Echidna in both Lower Montane and Midmontane Rainforest habitats in the Upper Ok Tedi region.We found *Zaglossus* remains in recently discarded fire-pit ashes collected at Bilbilokabip. We also observed several patches of disturbed litter and soil consistent with foraging activity by a long-beaked echidna in an area of climax forest close to camp. We are uncertain as to which species or subspecies of *Zaglossus* might occur in the Upper Ok Tedi region. The distributions mapped by Flannery and Groves (1998) show *Z. bartoni diamondi* as occurring throughout the Central Cordilleran ranges, from the Snow Mountains in the west to the Kratke Range in the east; and *Z. bartoni bartoni* in the Owen Stanley Range and also along the southern foothills of the Central Cordillera in Papua New Guinea, including the Middle Fly region. Aplin has recently confirmed the occurrence of Long-Beaked Echidnas in Hill Forest habitats of the Middle Purari River and the Upper Strickland River but to date has not had the opportunity to examine a live animal on which to base a taxonomic determination. At present, we remain open as to the identity of these southern lowland populations, including the possibility that they represent a population distinct from all others. In this regard, it is interesting to note that Long-beaked Echidnas seem not to occur in the Hill Forest zone on the northern side of the cordillera (Flannery and Seri 1990; Flannery and Groves 1998), even in areas of pristine forest rarely if ever visited by hunters (Aplin, unpublished data from West Sepik Province).

Order Dasyuromorphia
Family Dasyuridae

Murexia cf. melanurus (Thomas 1899): Black-tailed Dasyure (Bibiyanim? or Abilkan?)
IUCN Red List rating: Least concern

An adult male dasyure belonging to the *M. melanurus* group was captured in a mist net set at ground level in climax forest in the vicinity of Bilbilokabip. Apart from the gingery ear patches that characterise members of this group, it is very plainly patterned and lacks the strongly contrasting black tail typically associated with *M. melanurus*. It is also much smaller than more typically patterned populations in which adult males can attain 70 g. It may represent the form *modesta* (Thomas, 1912) which was described from Mt Goliath in the Orange Range and is usually listed as a synonym of *M. melanurus* (e.g., Flannery 1995, Groves 2005). A more typical example of *M. melanurus* was collected recently by Aplin in the Upper Strickland catchment. Flannery and Seri (1990: 179) reported captures of this group (as *Antechinus melanurus*) from between 200 and 2,300 m in the Upper Sepik region and also noted that "specimens from lower altitude are larger than those from higher". Hyndman and Menzies (1990) did not obtain regional records for any of the smaller dasyures. On the other hand, they reported captures of two larger dasyures, the New Guinea Quoll (*Dasyurus albopunctatus*) and the Speckled Dasyure (*Neophascogale lorenzti*). The captured individual was identified as Bibiyanim by our Wopkaimin informants at Bilbilokabip. However, at Minni a captured specimen of *M. naso* (which is not too dissimilar to *M.* cf. *melanurus* in appearance) was identified as Abilkan (a name used for many different kinds of forest rat; see below). Inquiries about whether the name Bibiyanim might apply met with strong denial – Bibiyanim was said to be a very different kind of animal with black facial markings, a more arboreal lifestyle and a distinctive habit of sleeping inside tree ferns. These attributes fit with what is known of the appearance and habits of the New Guinea Pygmy Possum, *Cercartetus caudatus*, a form of which is present in the local forests (see below).

Murexia naso (Jentink 1911): Long-nosed Dasyure
IUCN Red List rating: Least Concern

Two individuals of this relatively drab, unpatterned dasyure were captured, an adult male weighing 53.5 g captured in disturbed forest at Bilbilokabip and an adult female weighing 35.2g from Minni. The pouch of the female contained four teats, two of them enlarged and lactating. Both were captured in snap traps baited with sweet potato and set on the ground. The disparity in adult size of the male and female is typical for this species. Flannery and Seri (1990) reported a specimen of *M. naso* (as *Antechinus naso*) from 1,400 m asl at Ofektamin in the Upper Sepik catchment. The type locality is Hellwig Mountains, south of Mt Wilhelmina in the Snow Mountains, at c. 2000 m asl

Order Peramelemorphia
Family Peramelidae

Microperoryctes ornata (Thomas 1904): Ornate Bandicoot (Kayang? Kaial)
IUCN Red List rating: Least Concern

This small bandicoot was represented by three trophy mandibles in the Bilbilokabip men's house and by the remains of three individuals in the Mt Minni bone deposit. An indistinct image of a bandicoot on a camera trap set near Bilbilokabip may be of this species. A member of the *M. longicauda* group (presumably this species) was recorded by Hyndman and Menzies (1990; as *Peroryctes longicauda*) in secondary forest within the Lower Montane zone and also in Midmontane Rain Forest. The Ornate Bandicoot has been collected at elevations between 1,400 m and 2,600 m asl on the northern flanks of the Star Mountains (Helgen and Flannery 2004). This represents the westernmost limit of a distribution that includes most of the Central Ranges of Papua New Guinea. At higher elevations, it is replaced by the similar-sized Striped Bandicoot (*M. longicauda*) which has a broader geographic and elevational distribution in the western half of New Guinea. These taxa are often treated as subspecies (of *P. longicauda*) but their overlap in the Star Mountains demonstrates their specific distinction (see also Flannery 1995, Helgen and Flannery 2004). Hyndman (1979, 1984) recorded the Wopkaimin name Sanok for this species. We were also given Sanok as a 'tok ples' name for a bandicoot by some informants. However, other informants claimed that Sanok was an informal or 'slang' name used by women and children for bandicoots and rats. They provided the

alternative name name Kayuk for a small patterned 'mumut' that builds leaf nests at the base of trees and among rocks – a good description of *M. ornata*.

Peroryctes raffrayana (Milne-Edward, 1878): Raffray's Bandicoot (Lawin?)
IUCN Red List rating: Least Concern

Raffray's Bandicoot was identified from a single trophy mandible in the Bilbilokabip men's house. Hyndman and Menzies (1990) did not document this species in the Upper Ok Tedi region though they recorded the Wopkaimin name Luwin as pertaining to a possibly uncollected bandicoot. Our informants used this name (which we transcribed as Lawin) for a large, unpatterned bandicoot found in their territory. Whether Luwin/Lawin really pertains to *Peroryctes raffrayana* needs to be confirmed with a specimen in the hand. However, in support of this association, we note that Mianmim use the name Duwin for this species (Morren 1989, Flannery 1995), while Seltamam hunters sometimes call it Dein (alternatively Kimisok; Whitehead 1989). The Telefol name, as recorded by Flannery (1995), is Ibin. Flannery and Seri (1990) recorded multiple captures between 600 m and 1,800 m asl in the Upper Sepik catchment. Aplin (unpublished data) has found *P. raffrayana* to be moderately abundant between 1900 and 2000 m asl in the Upper Kikori catchment but relatively scarce at elevations below 600 m in the Purari catchment. Everywhere it seems to be most prevalent in primary forest and to avoid heavily disturbed contexts.

Order Diprotodontia
Family Macropodidae

Dorcopsulus cf. *vanheurni* (Thomas 1922): Small Dorcopsis (Watom)
IUCN Red List rating: Near Threatened

We found five mandibles of a *Dorcopsulus* in the men's house at Bilbilokabip and also captured images of individuals on two camera traps set in the vicinity of this camp. This animal is called Watom in Wopkaimin (Hyndman 1979, 1984; this study) and the same name is used more widely by Faiwol language group speakers at Seltaman (Whithead 1995) and Telefomin (recorded as Autom; Flannery 1995). Hyndman and Menzies (1990) recorded this species from trophies at the Bakonabip men's house at 1500 m asl in the Upper Ok Tedi region and there is a trophy mandible (UP 1304) from Megalsimabip on the Ok Menga at c. 800 m asl in the collection of the Biology Department, University of Papua New Guinea. Our local assistants at Minni, residents of Kawarabip, claimed that Watom was found only below the elevation of the camp, and also claimed that no wallaby occurs in the higher elevation forests or subalpine scrubs. Flannery and Seri (1990: 186) reported its elevational range in the Upper Sepik catchment as between 1000 m and 2,300 m asl but also noted that "foot bones of a small macropodid (probably this species) were found in wild dog droppings at Dokfuma (3,200 m)". Given our conflicting information on the elevational range of Watom, the identity of this high elevation population requires further investigation. Referral of these Star Mountains to *D. vanheurni* is provisional, pending completion of taxonomic studies currently underway. The type locality of *D. vanheurni* is Doormanpad-bivak at 1,410 m asl in the Upper Lorentz River on the southern side of the Snow Mountains.

D. stellarum (Flannery and Seri 1990): Central Ranges Tree Kangaroo and/or
Dendrolagus notatus (Matchie 1916): Montane Tree Kangaroos (Dubol)
IUCN Red List rating: Endangered

Firm evidence for the local occurrence of tree kangaroos was obtained at both sites. At Bilbilokabip trophy jaws representing a total of seven individuals were recorded in the men's house and bones and teeth were also present in recently discarded fire-pit ashes. At Minni a live tree kangaroo was glimpsed briefly by Wopkaimin field assistants in the forest above the camp on the morning of the 25th February 2013. The trophy jaws and the live animal were identified by local informants as examples of Dubol. This name has been recorded previously among Faiwol speakers and has been associated with members of the *Dendrolagus dorianus* group [Hyndman and Menzies 1990, Flannery 1995 (as D'bol), Whitehead 1995]. Hyndman and Menzies (1990) reported trophy remains of *D. dorianus* group tree kangaroos from two localities, Kavorabip (west of the Ok Tedi River at 1600 m asl) and Bakonabip (north of the Ok Kam River at 1500 m asl). The jaws from Bilbilokabip are clearly referrable to a member of the *D. dorianus* group. No

other tree kangaroo was said to be present locally, though a 'red' tree kangaroo was mentioned as occurring at the elevation of Tabubil; this is presumably a member of the *Dendrolagus goodfellowi* group, and variously could be a race of *D. goodfellowi* itself, *D. spadix*, the Lowland Tree Kangaroo, or possibly even *D. deltae* if this is a valid taxon (see discussion in Helgen and Opiang 2011b).The Upper Ok Tedi records of tree kangaroos are difficult to reconcile with current understanding of tree kangaroo distributions in Western Province. According to Flannery et al. (1996) and as reflected in current IUCN Red List mapping, the Star Mountains is near the eastern limit of distribution of Seri's Tree Kangaroo, *D. stellarum*, which occurs east to the Victor Emmanuel Range. However, Flannery and Seri (1990) reported that it occurs only at higher elevations, typically above 2800 m asl Further east, the montane forest tree kangaroo is *D. notatus*, the Central Ranges Tree Kangaroo, for which the closest records are from the Upper Strickland catchment in the Muller Range (Aplin and Kale 2011) and the Wanakipa area (Helgen and Opiang 2011b). This species has a broad elevational range, between 900 and 3100 m asl, but the lower elevation records come from localities within the 'midaltitude fringe high rainfall zone' (as defined by Brookfield and Hart 1971; annual rainfall > 5000 mm) that runs along the southern foothills of the central cordillera of New Guinea. Intriguingly, at both sites local informants claimed that Dubol comes in two forms that are said to differ in both appearance and behaviour. 'Brown' Dubol are said to be smaller, to have a yellow tail and to move about during the day, whereas 'black' Dubol are said to be larger, to have a black tail and to move about at night. The two forms were said to both occur in the less frequently hunted forests around Bilbilokabip as well as on Mt Minni. Based on these descriptions it is tempting to identify the 'brown' Dubol is *D. stellarum* and the 'black' Dubol is *D. notatus*. This would require a significant westward range extension for *D. notatus* which is not currently mapped as occurring west of the Strickland River, and a significant downward elevational extension for *D. stellarum*. If confirmed, regional sympatry between *D. stellarum* and *D. notatus* would remove any remaining doubt as to their specific distinction. Both forms of Dubol were said to be easily captured with the assistance of skilled hunting dogs. As an aside, niche segregation by activity period would make sense of the chromatic distinction between the sombre *D. notatus* and the more brightly patterned *D. stellarum* – the latter would be better camouflaged moving through dappled light.

Order Diprotodontia
Family Burramyidae

Cercartetus cf. *caudatus (*Milne-Edwards 1877) New Guinea Pygmy Possum (Bibiyanim?)
IUCN Red List rating: Least Concern

The highly distinctive jaws and teeth of a Pygmy Possum were identified in the Mt Minni bone deposit. A species of *Cercartetus* was not recorded during Hyndman's studies on the southern slopes of the Star Mountains but Flannery trapped a single individual in the Dokfuma herbfield at 3,200 m asl and also recorded the species at elevations above 1500 m asl in the Upper Sepik catchment (Flannery and Seri 1990). Pygmy Possums are not easily trapped in forest environments and is easily overlooked during surveys, especially when the emphasis is on game animals. Judging from its abundance in the bone deposit, it is probably quite common on Mt Minni and probably occurs throughout the mid- to high elevation forests and scrubs.The qualified referral of this material to *C. caudatus* reflects the unpublished taxonomic conclusions of K. M. Helgen who recognizes at least two species of *Cercartetus* within New Guinea.As noted above, the Wopkaimin name Bibiyanim may apply to this species. However, confirmation is needed through examination and discussion of a captured specimen.

Order Diprotodontia
Family Petauridae

Dactylonax megalura (Rothschild and Dollman 1932): Great-tailed Triok (Galnemyap)
IUCN Red List rating: Least Concern

An adult female weighing 345g was shot with an airgun during the night of the 17th February 2013 in the vicinity of Bilbilokabip. The pouch was distended and contained two teats, one of which was enlarged and lactating. A semi-independent young had presumably escaped. Interestingly, the tail of this specimen is nowhere near as bushy as in both sexes of the Weyland Range population [a female was illustrated by Rothschild and Dollman (1933: Plate 1) and a male illustrated by Menzies and Singadaun (2005: Fig. 5)].

Previous knowledge of this rarely collected species was reviewed by Menzies and Singadaun (2005) who located only five complete specimens, including two from Feramin and Urapmin. Flannery and Seri (1990) additionally reported four partial skins obtained as *bilas* items at Telefomin and Tifalmin. All of these localities are in the Upper Sepik River catchment and it appears that *D. megalura* has not previously been encountered in the southern watersheds of New Guinea. The elevational range of all previous records is between 1400 and 2000 m and thus includes the elevation of Bilbilokabip. The *tok ples* name Galwem was recorded by Hyndman (1979, 1984) for *D. palpator* and by us for the specimen of *D. megalura*. It is not clear whether Wopkaimin hunters distinguish the two species. Telefol hunters do, according to Flannery and Seri (1990), and they prefer skins of the more 'showy' *D. megalura* for *bilas*.

Dactylonax palpator (Milne-Edwards 1888) Long-fingered Triok (Galwem)
IUCN Red List rating: Least Concern

Two lower laws of this species were present in the men's house at Bilbilokabip. In addition, an individual was photographed on a camera trap on the 18th of February 2013 at Bilbilokabip. On this occasion it appears to be investigating a pile of cooked rice placed on the ground as camera bait but whether or not this species regularly descends to the ground is not known. The image shows two features characteristic of *D. palpator* – an elongate fourth finger on the hand and a white tuft on the end of a tail that is not especially bushy.Menzies and Singadaun (2005) noted that *D. megalura* is sympatric with *D. palpator* throughout its range. The latter species also extends to higher elevations, while various forms of *D. trivirgata* are found below 1500 m asl Hyndman and Menzies (1990) recorded *D. trivirgata* in the Foothill Rainforest and Lower Montane Rainforest zones.

Petaurus cf. *breviceps* (Waterhouse 1838): Sugar Glider (Slakim)
IUCN Red List rating: Least Concern

A small number of jaws and teeth of a Sugar Glider were identified in the Mt Minni bone deposit. This species was not recorded during Hyndman's studies on the southern slopes of the Star Mountains and it may be restricted to higher elevations. Flannery and Seri (1990) reported populations in the Upper Sol River and Tifalmin valleys between 1500 and 2300 m asl and noted that these were smaller and darker than populations in the Sepik lowlands. The degree of genetic and morphological variation diversity among New Guinea Sugar Gliders is strongly suggestive of multiple species (Colgan and Flannery 1992, Malekian et al. 2010). Judging from its abundance in the bone deposit, this small Glider it is probably only moderately common on Mt Minni.

Order Diprotodontia
Family Phalangeridae

Phalanger carmelitae (Thomas 1898): Mountain Cuscus (Kitam)
IUCN Red List rating: Least Concern

Two Mountain Cuscuses were shot with an airgun at night in the vicinity of the Bilbilokabip. One was an adult male weighing 2.2 kg, the other a juvenile female weighing 440g. The Bilbilokabip men's house contained a total of five mandibles of this species, significantly fewer than either Silky Cuscus (*P. sericeus*; 39 mandibles) or ground Cuscus (*P. gymnotis*; 18 mandibles). Hyndman and Menzies (1990) denote *P.carmelitae* as a common species between 1400 and 2000 m in the Upper Ok Tedi catchment. In contrast, the Bilbilokabip hunting trophies indicate that the Mountain Cuscus is one of the less frequent of cuscuses captured between 1800 and 1900 m asl Flannery and Seri (1990) reported it to be uncommon in the Upper Sepik catchment, with only scattered records between 1500 and 2,400 m asl. This species and the Silky Cuscus (*P. sericeus*) were not distinguished by our Wopkaimin informants.

Phalanger gymnotis (Peters and Doria 1875): Ground Cuscus (Koyam)
IUCN Red List rating: Least Concern

An individual of this species was imaged on a camera trap on the night of the 17th February. A total of 18 mandibles were present in the men's house at Bilbilokabip, making this the second most frequently captured cuscus after *P. sericeus*. It was much less common in trophy collections reported by Hyndman and

Menzies (1990). Hyndman (1979, 1984) recorded the name Koyam for this species. Our informants used the same name for a 'kapul' that lives among rocks and tree roots and has a black stripe on the back, both attributes of the Ground Cuscus.

Phalanger sericeus (Thomas 1907): Silky Cuscus (Kitam)
IUCN Red List rating: Least Concern

A subadult male weighing 870g was shot with an airgun at night in the vicinity of the Bilbilokabip. The Bilbilokabip men's house contained a total of 39 mandibles of this species, and was outnumbered only by mandibles of the Coppery Ringtail (*Pseudochirops cupreus*). This species and the Mountain Cuscus (*P. carmelitae*) were not distinguished by our Wopkaimin informants.

Order Diprotodontia
Family Pseudocheiridae

Pseudochirulus larvatus (Förster and Rothschild 1911): Masked Ringtail
IUCN Red List rating: Least Concern

Four trophy mandibles of this species from the Bilbilokabip men's house provide the first evidence of this species in the Upper Ok Tedi region. Hyndman and Menzies (1990) remarked on the regional rarity or absence of this species (as *P. forbesi*) which is typically abundant in mid-montane primary and secondary forests throughout New Guinea including the Tiflamin and Telefomin valleys in the Upper Sepik catchment (Flannery and Seri 1990). Aplin (unpublished data) recently recorded *P. larvatus* from sites at c. 650 m asl, east of the Fly River in a southern outlier range of the Star Mountains. At this locality it is greatly outnumbered by the similar-sized Lowland Ringtail (*Pseudochirulus canescens*).We are currently unable to explain the seemingly patchy distribution of the Masked Ringtail. However, it appears to fare particularly well in disturbed and secondary forests and its apparent rarity in the Upper Ok Tedi region may reflect the low human population density in this area.

Pseudochirulus mayeri (Rothschild and Dollman, 1932): Pygmy Ringtail (Nomin)
IUCN Red List rating: Least Concern

Two Pygmy Ringtails were shot with an airgun at night in the vicinity of the Bilbilokabip. One was an adult male weighing 187 g, the other a subadult male weighing 63 g. No mandibles of this species were present among the trophy collection the men's house but its jaws and teeth were numerous in the Mt Minni bone deposit at 2659 m. This species was recorded by Hyndman and Menzies (1990) in both Lower Montane and Midmontane Rainforests of the Upper Ok Tedi region and by Flannery and Seri (1990) in the Tifalimin and Telefomin Valleys in the Upper Sepik catchment. The Pygmy Ringtail has a broad geographic and elevational range (1200–4200 m asl according to Helgen 2007) but it remains poorly represented in collections. Our results and those of Helgen and Opiang (2011a) suggest that it can be locally abundant, especially at higher elevations within its range.

Pseudochirops corinnae (Thomas 1897): Plush-coated Ringtail (Dawam)
IUCN Red List rating: Near Threatened

Seven mandibles of this species were present in the trophy collection at Bilbilokabip and one more was picked up at a seismic exploration camp below Minni. Hyndman and Menzies (1990) recorded the species from Midmontane Rainforests of the Upper Ok Tedi region and Flannery and Seri (1990) noted its occurrence between 1800 and 2200 m in the Upper Sepik catchment.Hyndman (1979, 1984) recorded the Wopkaimin name Dawam for this species.

Pseudochirops cupreus (Thomas 1897): Coppery Ringtail (Kaiyang)
IUCN Red List rating: Least Concern

At least four Coppery Ringtails were either shot with airguns or captured by felling small trees during our stay at Bilbilokabip. Two of these were measured – an adult male weighing 1.49 kg and an adult female with an unexpanded pouch weighing 1.34 kg. The name Kaiyang was consistently applied to these animals

by multiple informants. The abundance of the Coppery Ringtail around Bilbilokabip is further indicated by the presence of 46 mandibles in the men's house – more than any other species and approached only by the Silky Cuscus with 39 mandibles. Hyndman and Menzies (1990) found this species to be restricted to but locally abundant in Midmontane Rainforest habitats of the Upper Ok Tedi region, including low altitude patches of this habitat. In contrast, no specimens were obtained from Lowe Montane Rainforest. Flannery and Seri (1990) also reported its restricted occurrence above 2,300 m in the Sol River Valley and above 2,200 m at Tifalmin in the Ilam River Valley, both in the Upper Sepik catchment. Elsewhere in New Guinea it occurs as low as 1350 m asl (Helgen 2007). The name Kaiyang is in wide usage for *P. cupreus* among Faiwol language group speakers [e.g., Wopkaimin (Hyndman 1979, 1984; as Kaiyan); Seltaman (Whitehead 1989; as Kayang); Mianmin (Morren 1989; as Kiyong, possibly only for females); Telefolmin (Flannery 1995; as Kayang)]. Whithead (1995) records occasional usage of this name among Seltaman speakers for the morphologically similar Plush-coated Ringtail (*Pseudochirops corinnae*; with alternative names Dafaam and Arukiok).

Order Rodentia
Family Muridae

Abeomelomys cf. *sevia* (Tate and Archbold 1935): Menzies' Mouse
IUCN Red List rating: Least Concern

One maxilla and one dentary of a species of *Abeomelomys* were identified in material from the Mt Minni bone deposit. These are a good match in general size and morphology for regional material referred to *A. sevia* [e.g., a specimen reported by Flannery and Seri (1990) from Ofektamin at between 1,400 and 1,800 m asl] but we hesitate to make a final determination until a complete specimen is available for study. The Mt Minni specimens represent the westernmost record of the genus *Abeomelomys*. Flannery (1995) regarded this as a rare species in the Upper Sepik River catchment.

Anisomys imitator (Thomas 1904): Uneven-toothed Rat (Somkam)
IUCN Red List rating: Least Concern

This poorly-known, medium-sized rat appears to be moderately abundant in the vicinity of Bilbilokabip. A subadult female weighing 380 g was captured in a Tomahawk cage trap set in climax forest at 1843 m asl and images were obtained on camera traps set at three and possibly five localities (two being consistent with this taxon but not in themselves fully diagnostic). The Wopkaimin name Somkam was applied to the captured animal by several different experienced hunters. The only other available 'tok ples' name for this taxon is the Telefol Apsal recorded by Flannery (1995). Flannery and Seri (1990) reported two captures in the Upper Sepik catchment, near Tifalmin at c. 1800 m asl and in the Sol River Valley at 2,200 m asl and they characterise the species as 'probably rare locally'. Helgen (2007) gives the known elevational range as 1200–2900 m asl

Brassomys cf. *albidens* (Tate 1951): White-toothed Mouse
IUCN Red List rating: Data Deficient

A partial skull and a single mandible from the Mt Minni bone deposit is referred with confidence to the only recently described genus *Brassomys* (Musser and Lunde 2009). Although the specimens agree metrically with the type series of *B. albidens*, we are inclined to make only a tentative referral until such time as a whole animal is available for comparisons. At present, the species *albidens* is known from modern specimens from only two localities in the Snow Mountains (Bele River valley at 2800 m asl and Lake Habbema at 3225 m asl; Tate 1951) and from one Pleistocene cave deposit in the same area (Kelanggur Cave at 2950 m asl) (Musser and Lunde 2009). These localities are c.250 km to the west of Mt Minni. *Brassomys albidens* is one of New Guinea's most restricted and potentially rarest rodents and the discovery of either a second population of this species or a new, closely related species in the Star Mountains, while not entirely unexpected given the other biogeographic links between these areas, is nonetheless an important and exciting outcome of the 2013 WCS Hindenburg Expedition.

Coccymys cf. *shawmayeri* (Hinton 1943): Hinton's Mouse
IUCN Red List rating: Not Evaluated

Five dentaries of a species of *Coccymys* were recovered from the Mt Minni bone deposit. The specific identity of these specimens is unclear as the locality falls close to records of two, morphologically similar species – *C. ruemmleri* (Tate and Archbold, 1941) of western New Guinea with an easternmost record of Dokfuma at 3200 m asl, and *C. shawmayeri* of the Central Ranges with regional records in the Upper Sepik catchment at Oksapmin at 1850 m asl and Lake Louise at 2800 m asl We suspect that *C. shawmayeri* occurs at lower elevation in the Star Mountains than *C. ruemmleri* and tentatively refer the Mt Minni specimens to the former taxon. Both species are recorded from upper montane rainforests and from various subalpine habitats including scrub and grassland (Flannery 1995, Musser and Lunde 2009, Aplin and Kale 2011).

Lorentzimys sp.: A long-footed tree mouse
IUCN Red List rating: Not Evaluated

Long-footed tree mice are one the most distinctive of all New Guinean rodents and they can be found almost anywhere from lowlands to the limit of tree growth. In many localities they are abundant and with patience, they can be observed running around on the trunks of trees. However, their incredible speed and arboreal agility makes them extremely difficult to trap and they are overlooked in many surveys. Current listings recognise only one species (*Lorentzimys nouhuysi*) but there is general acknowledgement that the genus is polytypic (e.g., Flannery 1995, Musser and Carleton 2005). *Lorentzimys* has not been taxonomically revised since Tate (1951), and much new material has been collected since that time. A morphological overview of museum holdings by Aplin indicates as many as 5–6 species may be represented in the genus. We trapped one specimen of a *Lorentzimys* in pristine midmontane rainforest at Bilbilokabip and identified seven dentaries and three maxillae in the Mt Minni bone deposit. The Bilbilokabip individual is being analysed in a pilot genetic survey of *Lorentimys* currently underway. Wopkaimin informants identified the captured *Lorentizmys* as a juvenile Abilkan – a name applied to multiple species of rodents captured in forest.

Mallomys rothschildi (Thomas 1898) or *M. aroaensis* (de Vis 1907): A Woolly Rat (Filimyap)
IUCN Red List rating: Least Concern

Seven mandibles of Woolly Rats were present in the men's house at Bilbilokabip. These were very uniform in molar size and morphology and probably represent a single species but without locally obtained reference specimens it is not possible to determine whether these come from *M. rothschildi* or *M. aroaensis*, both of which probably occur in the vicinity of the site, though evidently at differing abundance. Wopkaimin informants identified the mandibles as coming from a 'kapul' called Filimyap. Hyndman (1979, 1984) recorded the name Frim for species of *Mallomys*. Filimyap is evidently quite common around Bilbilokabip. An adult individual was observed and very nearly caught (look out for those teeth!) close to camp on the 15th February and individuals were imaged by camera traps at two different localities. Hyndman and Menzies (1990) recorded them in both Lower Montane and Midmontane Rainforest zones. Flannery and Seri (1990) reported six captures of *M. rothschildi* and one of *M. aroaensis* at elevations between 1,500 and 1,800 m in the Upper Sepik River catchment.

Mammelomys lanosus (Thomas 1922): Highland Mammelomys (Abilkan)
IUCN Red List rating: Least Concern

Four individuals of this species were captured in relatively undisturbed forest habitats at Bilbilokabip and the remains of one individual were identified in the Mt Minni bone deposit. Local informants identified captured examples as Abilkan – a name that seems to be applied to almost any small to medium-sized forest rat.The Bilbilokabip *Mammelomys* compares well with specimens obtained by Flannery and Seri (1990) at localities between 1,800 m and 2,300 m asl in the Upper Sepik River catchment and referred by them to *M. lanosus* (Thomas, 1922) (as *Melomys lanosus*). This regional population is very similar to typical *lanosus* of the Snow Mountains but differs in a number of ways from other populations currently referred to this species [e.g. *shawmayeri* from the Kratke Mountains to the east; referred to *M. lanosus* by Menzies (1996), Flannery (1995) and Musser and Carleton (2005)]. Further taxonomic revision of this group is clearly

needed. Capture of this species at Bilbilokabip came as something of a surprise as the genus *Mammelomys* has not previously been reported from any locality on the southern slopes of the Central Cordillera.

Mirzamys louiseae (Helgen and Helgen 2009) Star Mountains Mirzamys (Abilkan)
IUCN Red List rating: not evaluated.

A subadult male weighing 25.6 g was captured in a snap trap set on the ground at Minni. It represents the first record of this recently described species from the southern catchment of the Star Mountains, and the first capture of this species since 1980 (Helgen and Helgen 2009). Other regional records come from localities on the northern flanks of the Hindenburg and Victor Emmanuel Ranges, between 1900 and 3200 m asl.This western cordilleran PNG endemic was only recently recognised as distinct (at both specific and generic levels) from *Pseudohydromys occidentalis*, a superficially similar but smaller shrew mouse that is also present in the Star Mountains and with which it had long been wrongly associated. When shown the captured specimen of *M. loiuseae* our Wopkaimin informants offered the general 'forest rat' name Abilkan.

Paraleptomys sp.: An undescribed Paraleptomys (Abilkan)
IUCN Red List rating: Not Evaluated

The Short-haired Hydromyine (*P. wilhelmina*) has been recorded in both Lower Montane and Midmontane Rainforest zones of the Upper Ok Tedi region (Hyndman and Menzies 1990) and at 1,800 m asl in the Tifalmin Valley (Flannery and Seri 1990). We caught individuals of what is almost certainly the same taxon in relatively undisturbed forest at both of our survey camps. The IUCN Red List account for *P. wilhelmina* states that each of its three known populations 'represent separate unpublished species' (Helgen 2008). We compared our specimens with examples of *Paraleptomys* from the Tifalmin Valley and from the Snow Mountains (near the type locality) and support this assessment that the two Star Mountains populations represent a very distinctive new species that will be described by K. Helgen in the near future. It appears to be a moderately common rat in the Upper Ok Tedi region. The craniodental morphology of all *Paraleptomys* species is suggestive of an insectivorous or vermivorous (worm eating) lifestyle (Musser et al. 2008). Wopkaimin informants applied the name Abilkan to examples of this species and grouped them with specimens of *Paramelomys* cf. *rubex* when asked to sort a mixed pile of captures into species.

Paramelomys cf. *rubex* (Thomas, 1922): Mountain Paramelomys (Abilkan, Boyim, Iram)
IUCN Red List rating: Least Concern

A small member of the genus *Paramelomys* is by far the most abundant small ground mammal in the forests around Bilbilokabip. A total of 45 individuals were captured, 31 from traps set in disturbed forest along tracks emanating from Bilbilokabip, 13 in a patch of climax forest near Bilbilokabip, and one in undisturbed forest at Minni. The Mt Minni bone deposit produced only a single molar tooth of this species, thereby confirming the relative scarcity of this taxon at the higher elevation site. Despite progress made by Menzies (1995) towards taxonomic revision of the genus *Paramelomys*, it is clear that additional species still lie hidden within the current arrangement. This is most clearly the case with the small montane species *P. rubex* which show much external and cranio-dental variation across its wide geographic and elevational range. Our large sample of *P.* cf. *rubex* from Bilbilokabip is variable in pelage colour, especially in the intensity of a gingery wash over the ventral surface, and in the relative length of the tail. However, examination of skulls from selected individuals shows no obvious correlated differences in morphology to suggest the presence of multiple species within this sample. On the other hand, comparisons between this sample and two other regional samples from sites between 1,400 m and 2,200 m in the Upper Sepik River catchment and between 650 and 1000 m asl in a southern outlier range of the Star Mountains, east of the Fly River, revealed multiple points of distinction between each of the three populations. A large effort clearly will be needed to resolve the taxonomic complexity that remains within the *P. rubex* group. Wopkaimin informants generally applied the name Abilkan to examples of this species but the alternative names Boyim and Iram were sometimes applied. Whithead (1995) recorded various Seltaman names for 'small rats' including Iram, El Iram and Ubil. Flannery (1995: 339) reported the Telefomin name Titok for *R. niobe* (as *Stenomys niobe*).

Pogonomys sp.: A Tree-mouse
IUCN Red List rating: indeterminate for species

A few isolated molar teeth from the Mt Minni bone deposit provide the first evidence for tree mouse of the genus *Pogonomys* in the Upper Ok Tedi region. Hyndman and Menzies (1990) made special note of the rarity or absence of any member of this genus in their regional collections from the Upper Ok Tedi region, especially in view of the typical abundance of *Pogonomys* spp. in other parts of New Guinea. We also failed to detect them in any other way during our survey but are not particularly surprised by this failure. All *Pogonomys* species seem to nest below ground but typically ascend into the canopy to forage. They are rarely ever captured in traps and must either dug from their burrows or captured by shooting or by hand after being observed at night.We cannot do more than speculate about the specific identity of the Mt Minni *Pogonomys*, as all members of this genus have very similar dental morphology. Molar size does vary among *Pogonomys* spp. and this provides some clues. We can report that all of teeth are larger than a large regional sample of *P. macrourus* (Milne-Edwards, 1887) from sites at c. 650 m asl, east of the Fly River in a southern outlier range of the Star Mountains, but smaller than the teeth of a sample of *P. loriae* (Thomas, 1897) from the same locality. *Pogonomys championi* Flannery, 1988, which is known exclusively from between 1,400 and 2,300 m asl in the Tifalmin and Telefomin Valleys, Upper Sepik River catchment, has molars that are smaller even than those of *P. macrourus* (Flannery 1988. The only other known possibility is a previously undocumented montane population of *P. mollipilosus* (Peters and Doria, 1881), a poorly known species that is otherwise known only from the Fly-Strickland lowlands (Aplin, unpublished data). The molar dimensions of the Mt Minni specimens are consistent with the latter taxon but until a full specimen becomes available for study, we are reluctant to suggest even a tentative affiliation given the stark contrast in habitat.

Pseudohydromys ellermani (Laurie and Hill 1952): One-toothed Shrew Mouse
IUCN Red List rating: Least Concern

An adult male of this species was captured in a snap trap set in climax forest close to the Bilbilokabip. It weighed 22.3 g and was the first record of this species, or indeed of any Shrew Mouse, from the Upper Ok Tedi region. Helgen and Helgen (2009) reported specimens of *P. ellermani* from several localities on the Sepik side of the Star Mountains – Feramin at 1400 m asl in the Victor Emmanuel Range and the vicinity of Bakfunmin (1600 to 2,300 m asl) in the Tifalmin Valley.

Rattus cf. *niobe* (Thomas 1906): Moss Forest Rat (Abilkan, Boyim, Iram)
IUCN Red List rating: Least Concern

Small *Rattus* weighing around 50 g as adults occur throughout the montane forests of the main island of New Guinea. Although at least seven taxonomic names have been applied to these animals, it has been customary to refer all of these populations to the single species *R. niobe*, despite their frequent isolation from each other (e.g., Rümmler 1935, Laurie and Hill 1954, Menzies and Dennis 1979, Taylor et al. 1982, Flannery 1995). However, there is mounting evidence for sympatry or elevational replacements within the group (Flannery and Seri 1990, Flannery 1995, Musser and Carleton 2005, Aplin and Kale 2011) and in the last taxonomic arrangement of the group by Musser and Carleton (2005) a total of four species are distinguished, albeit without morphological characterisation. Until such time as these morphological studies are undertaken, and also tested by genetic studies, we prefer to avoid future complications by referring all regional populations of this group to *R.* cf. *niobe*, though without implying any special relationship to the nominotypical population of *R. niobe* from the Upper Angabunga River on the southern slopes of the Owen Stanley Range.We captured a total of 17 individuals at Bilbilokabip and one at Minni. Many of the Bilbilokabip *R. cf. niobe* came from disturbed habitats such as the dense scrub around the helipad and along the various walking tracks. However, they were trapped in all habitat types through to climax forest. Like many other regional samples of *R.* cf. *niobe*, the Upper Ok Tedi sample is heteromorphic, with two recognisable forms – a larger form (male body weights up to 55 g) with a relatively longer tail and a mostly pale hindfoot; and a smaller form (males to 42 g) with a relatively shorter tail and a more darkly furred hindfoot. These forms co-occur in the vicinity of Bilbilokabip and were taken from the same traplines, with the larger form outnumbering the smaller about 2 to 1; both types occurred in both forest and non-forest habitats. Only one individual of this group was captured at Minni; an adult male with a body weight of 54.2 it is referred to the larger form. Whether or not each of the two forms distinguished here

represents a different species is a matter for future study, as is the determination of appropriate taxonomic name or names.These small rats were variously identified by Wopkaimin informants as Abilkan or Boyim, depending mostly on the site of capture – Abilkan for rats from forest and *Boyim* for rats from disturbed areas. Sometimes they were also named as Senok though this would generally be revised if questioned. *Senok* appears to be foremost a higher category that includes both Boyim and Abilkan (as well as some or all bandicoots). Interestingly enough, Senok is also used for various *Rattus* species among Telefol, Mianmin and Seltaman people (Morren 1989, Whitehead 1989, Flannery 1995).

Rattus steini (Rümmler 1935): Small Spiny Rat (Boyim, Sanok?)
IUCN Red List rating: Least Concern

A recently killed individual (probably by a cat) of this species was seen at Kawarabip at 1085 m asl (5.5338 S 141.56266 E) during the walk out from Minni Camp. Kawarabip inhabitants identified the carcass as Senok. Pernetta and Hyndman (1982) reported the names Munapnok and Gargirim for this species. Hyndman and Menzies (1990) reported *R. steini* as an occupant of the Lower Montane Rainforest zone in the Upper Ok Tedi region. However, we suspect that this species also occurs at higher elevations into the Midmontane Rainforest zone, including the area around Bilbilokabip. Our informants at this camp spoke of a rat larger than *Rattus niobe* and *Paramelomys rubex* (our two most common captures) that was abundant in the taro gardens during the growing season. Our trapping effort in this habitat failed to produce any captures of either this species or any other, despite the fact that we could see evidence of previous rat activity in the form of disused burrows throughout the garden area which had recently been planted out with taro. We suspect that the population of *R. steini* undergoes pronounced seasonal cycles at this elevation where the cropping is also strongly seasonal. Our failure to capture *R. steini* in the forest or in the disturbed habitats further suggests that it is not particularly competitive against *R. niobe* and *P. rubex* in these habitats.

Uromys anak (Thomas 1907): Black-tailed Giant Rat (Domkam)
IUCN Red List rating: Least Concern

An adult female weighing 960 gm was shot at night with an airgun by a visitor travelling between Bultem and Bilbilokabip. The animal was identified as the Wopkaimin taxon Domkam. We did not obtain any other record of the species. Hyndman and Menzies (1990) recorded this species in both primary and secondary forest within the Lower Montane zone. Pernetta and Hyndman (1982) reported the name Waiangim for this species.

Flannery and Seri (1990: 189) reported several captures of *U. anak* in the Nong and Tifalmin Valleys between 1,400 and 1,800 m asl but they characterised the species as "uncommon in the study area". The species is widely distributed along the Central Cordillera of New Guinea; in the Snow Mountains its elevational range extend to the limit of tree growth (Flannery 1995).

Discussion

Additions to knowledge of the Upper Ok Tedi mammal fauna
Our study added a further 15 species to the recorded non-volant mammal fauna of the Upper Ok Tedi region (Table 7). This total comprised seven marsupials and eight rodents, the majority being small species that fall below the body weight of typical 'game' animals. As smaller-bodied mammals had not previously been the subject of any systematic trapping program in the Upper Ok Tedi region, this result was anticipated. More surprising was the novel discovery of populations of two larger marsupials [Raffray's Bandicoot (*Peroryctes raffrayana*) and the Masked Ringtail Possum (*Pseudochirulus larvatus*)] and one giant rat [the Uneven-toothed Rat (*Anisomys imitator*)]. Each of these species is definitely large enough to attract the interest of hunters and the reason for their previous omission from previous listings is not clear.

Significant new records
The most significant new record is the White-toothed Mouse (*Brassomys* cf. *albidens*). The partial skull recovered from the Mt Minni bone deposit is the first record of the genus *Brassomys* in Papua New Guinea and only the second locality for this genus and species which was described from the vicinity of Lake

Habbema in the Show Mountains, some 250 km to the west of Mt Minni. We will not be surprised to find that the Mt Minni species is distinct from *B. albidens*; however, to test this proposition we (or others) will need to catch a live specimen so that detailed comparisons can be made of fur colour and texture, body proportions, and the entire cranium.

Other significant records are the first occurrences of two rodent species south of the Central Cordillera – *Mammelomys lanosus* and *Mirzamys louiseae*.

Mammal species diversity in the midmontane rainforest

Taking all sources into account, we can reliably list 37 non-volant mammal species as present in the Midmontane Rainforest zone the Upper Ok Tedi catchment – one monotreme, 20 marsupials and 16 rodents (38 if both *Dendrolagus notatus* and *D. stellarum* are confirmed). As shown in Table 8, this total is intermediate between totals for similar elevation forests in the Upper Sepik catchment (47 species; including sites in both the Star Mountains and the Victor Emmanuel Range) and on Mt Sisa (43 species), and equivalent values available for each of the Upper Kikori catchment (28 species), the Muller Range (22 species), and Mt Bosavi (14 species).

We suspect that these differences are mainly due to contrasting amounts of survey effort. The Upper Sepik catchment and the southwest slopes of Mt Sisa are two of the most intensively surveyed sites for mammals in Papua New Guinea and the lists of species from these sites are probably close to complete, with the caveat that taxonomic revision in some groups (e.g., *Rattus* cf. *niobe*; *Paramelomys* cf. *rubex*) will raise the number of species found in the Midmontane to Upper Montane zones in these areas. In contrast, localities such as the Muller Range and Mt Bosavi remain incompletely surveyed, and future work in these areas is expected to produce many new discoveries. In the case of the Upper Kikori catchment, much of the survey effort associated with the PNG LNG project (Mamu et al. 2006, Mamu 2008) relied on informant testimony which we do not consider a reliable technique for species inventory of most groups of small mammals; our list of 28 taxa for this area is a subset of those listed by Mamu et al. (2006) and Mamu (2008).

Table 8. Current estimates of non-volant mammal diversity in the Upper Ok Tedi region and in five nearby, physiographically similar regions of PNG.

Taxon	Upper Ok Tedi	Upper Sepik	Muller Range	Mt Sisa	Mt Bosavi	Upper Kikori
Number of monotreme species	1	1	1	1	1	1
Number of marsupial species	20	20	12	22	6	16
Number of rodent species	16	26	9	21	8	12
TOTAL for all non-volant mammals	**37**	**47**	**22**	**44**	**15**	**29**

Major sources as follows: **Upper Sepik** (Flannery and Seri 1990, Flannery 1995, Helgen and Flannery 2004, Musser et al. 2008, Musser and Lunde 2009, Helgen and Helgen 2009, and Helgen et al. 2010); **Muller Range** (Worthy and Flannery 1998, Aplin and Kale 2011); **Mt Sisa** (Dwyer 1990, Flannery 1995, Leary and Seri 1997, Aplin unpublished data); **Mt Bosavi** (Flannery 1995, Leary and Seri 1997, Musser et al. 2008, Musser and Lunde 2009, Helgen and Helgen 2009); **Upper Kikori (**Flannery 1995, Leary and Seri 1997, Mamu et al. 2006, Mamu 2008, Musser et al. 2008, Aplin unpublished data). For the Upper Kikori, some of the rodent taxa listed by Leary and Seri (1997), Mamu et al. (2006) and Mamu (2008) are excluded from our tally; this either reflects reassessment of voucher identifications or the fact that the original records were based solely on informant testimony which is an unreliable method for inventory of many groups of rodents.

Biogeography of the Star Mountains mammal fauna
Hyndman and Menzies (1990: 256) concluded that the biogeographic relationship of the biota of the Upper Ok Tedi region were "in many respects more toward the west", although they also remarked for birds that the region is "an important overlap zone of eastern and western species supported by a diverse forested environment". Both statements have continued resonance for the mammal fauna.

The Star Mountains represent the easternmost limit of a primarily western montane distribution for six mammal species: Microperoryctes dorsalis, Dendrolagus stellarum, Dactylopsila megalura, Brassomys cf. albidens, Coccymys ruemleri, Mammelomys lanosus, and Pseudohydromys occidentalis. In counterpoint, three species with essentially eastern montane distributions reach their westernmost limit in the same area: Microperoryctes ornata, Crossomys moncktoni and Coccymys shawmayeri. Interestingly enough, two of these eastern species shows geographic overlap but elevational segregation in the Star Mountains with a sibling species (Helgen and Flannery 2004, Musser and Lunde 2009). If two tree kangaroos occur in the Upper Ok Tedi region, as postulated above, this would be another case of the same phenomenon, with the eastern D. notatus occurring at lower elevation that the western D. stellarum. We note but leave unexplained the fact that in each case it is the western taxon that occupies the higher elevation zone.

Several other essentially western, montane mammal species extend past the Victor Emmanuel Range to find their distributional limit in the ranges of Western Highlands Province or Southern Province. Examples are *Neophascogale lorenzti*, *Phalanger vestitus* and *Pseudochirulus mayeri*.

Four non-volant mammal species are endemic (i.e., restricted) to the region of the Star Mountains: *Phalanger matanim*, *Pogonomys championi*, *Mirzamys loiuseae* and an undescribed *Paraleptomys* sp. Only the last two of these species has been recorded in the Upper Ok Tedi region but the others may yet be found to occur there. All were recognised taxonomically since the review of Hyndman and Menzies (1990). This degree of endemism is unusual for a component of the central cordilleran mountain chain in New Guinea and is more akin to that observed in the isolated ranges of the Bird's Head and the Huon Peninsula, and in the north coastal ranges (Flannery 1995, Aplin 1998, Helgen 2007). However, we note that a similar level of mammalian endemism is found in the Weyland Range and Paniai Lakes area at the western end of the Snow Mountains, where known endemics are *Microperoryctes murina, Hydromys hussoni*, *Macruromys elegans*, and *Paramelomys shawi*.

Conservation recommendations

Conservation based on good science
It is often touted that conservation must rest on a solid foundation of good science – good survey work, good taxonomy, and good understanding of ecological processes including threats. The results of the short 2013 Hindenburg Range survey show us how far short we still are on several of these counts. Remarkably, given the brevity of our survey, we added 15 species to the list of non-volant mammal species known to occur in the Upper Ok Tedi region. Of course we should note that prior work in this region was heavily focused on mammals of economic significance and that many of our 'new' discoveries are of small-bodied animals that may be taken on an opportunistic basis but are typically not targeted by male hunters. Yet three of the newly located mammal species fall into the priority size range (typically > 250 g) for targeted hunting or trapping activities. The fact that these species were missed prior to our survey suggests that others may still remain unlocated. Possible candidates include two cuscuses that are rated Critically Endangered by IUCN; namely, the Telefomin Cuscus (*Phalanger matanim*) which is known to occur in the vicinity of Tifalmin, and the Black-spotted Cuscus (*Spilocuscus rufoniger*) that was recorded by Hyndman and Menzies (1990) in the upper Ok Tedi region but requires further verification.

An important general conclusion is that full inventory of a regional mammal fauna in New Guinea is a task that demands recourse to many different methods and techniques. Reliance on hunters will produce species lists heavily biased towards larger game animals, while reliance on trapping activities will result in better coverage of terrestrial and scansorial small mammals but an unsampling of arboreal and larger species. Spotlighting as a survey method clearly has the potential to sample mammals across all forest

strata but its applicability in the New Guinea context is limited by the naturally low population densities of many species, the great height and density of the canopy in most forest types, and the high frequency of rain, all of which make it difficult to observed mammals at all, and to identify them to species level when they are encountered.

In our experience, women often have intimate knowledge of the habits of local mammals, including both the larger and smaller species, and they may be more adept than men at capturing many of the smaller species. However, in the typically male-dominated world of traditional Melanesian societies, it is rare for women to become involved in faunal survey work. Hopefully this will change. However, we note that effective change may also require a greater level of participation by women in the traditionally male-dominated business of New Guinean biological surveys (with homage paid to some notable exceptions). Our results also demonstrate the generally poor state of taxonomic knowledge of New Guinean mammals. Numerous species cannot be associated with confidence to any particular named form, and several of the species that we collected almost certainly lack a prior scientific name. Remarkably, the taxonomic uncertainty pertains not only to some of the smallest and rarest taxa (e.g., the undescribed *Paraleptomys* sp.) but also some of the largest (e.g., the small forest wallaby, *Dorcopsulus* cf. *vanheurni*) and the most abundant species (e.g., *Paramelomys* cf. *rubex* and *Rattus* cf. *niobe*). In most cases, ample material exists in the world's museum collections to resolve these taxonomic problems using modern morphometric and genetic techniques, and the fact that they remain unaddressed speaks loud of the continued worldwide decline of taxonomic studies.

Poor taxonomy has a suffocating effect on conservation planning. To follow one example, what value should be placed on the Upper Ok Tedi population of Small Forest Wallaby (*Dorcopsulus* cf. *vanheurni*)? While the taxonomic status is up in the air, should it be treated as of low conservation importance because it might be the same species as one found far away in the Snow Mountains and potentially in between? Or should it be given higher emphasis because it might be restricted to the Upper Ok Tedi region. It is certainly different from *Dorcopsulus* populations found only a short distance to the east, and there are other mammal species that are endemic to the Star Mountains. Without good taxonomy, decision-making and planning for conservation retains a large measure of subjectivity.

Ecological knowledge of the mammal fauna is also rudimentary for remote parts of PNG including the Upper Ok Tedi region. To be sure, it is sometimes possible to make reasonable decisions about conservation on the basis of more general understanding of ecological processes and threats, and in this regard the broad-based ecological work in the study area by David Hyndman and his colleagues provides an unusually solid foundation for conservation planning in this unique and sensitive region. Notably, Hyndman also pioneered the use of indigenous ecological knowledge in New Guinea and the lessons that that he learned remain every bit as pertinent today. Even more so in fact, as traditional knowledge of the natural environment everywhere slowly fades with the death of elderly members of societies. Capturing the knowledge and wisdom of such people surely represents one of the most important (and undeniably the most urgent) of the numerous imperatives for wildlife conservation in PNG for the next decade or two.

Future protection

The results of the Hindenburg Range survey confirm and extend previous suggestions regarding the richness and distinctiveness of the mammalian fauna of the upper Ok Tedi River region. Various factors have created this rich and distinctive fauna but only one really needs to be invoked as the reason for its persistence to the present day – the continued presence of large areas of high quality habitat. This in turn is readily understood – it reflects the nexus of rugged terrain, traditionally low human population densities, and the former remoteness of the region from colonial services. We say former here because these remarkably intact ecosystems now lie in close proximity to the Ok Tedi mine and to Tabubil. To date this proximity appears to have worked to reduce pressure on the natural forest resources including wildlife. However, the survival of these resources into the future will depend in large part on the effectiveness of traditional systems of stewardship and protection, perhaps combined with new approaches that provide direct rewards for conservation actions. However, lessons learned elsewhere in Papua New Guinea highlight some of the difficulties associated with both implementing and then maintaining these approaches over meaningful time scales.

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The Coppery Ringtail, *Pseudochirops cupreus.* (Photo S.J. Richards)

Left: the Possum *Pseudochirulus mayeri*. Right: the dasyurid *Murexia* sp. cf. *melanurus.* (Photos S.J. Richards)

Chapter 10

Bats

Kyle N. Armstrong, Ken P. Aplin and John S. Lamaris

Summary

We used a combination of netting, trapping and passive acoustic recordings to survey the bat fauna around two sites at elevations of 1,750–1,900 m (Bilbilokabip) in the southern foothills of the Hindenburg Range, and at 2,208–2,529 m (Minni) on the southern flanks of the Star Mountains, Western Province, Papua New Guinea. The survey produced records of three species of pteropodid bats and eight insectivorous bats. Only one of the insectivorous bats was captured, the remainder being detected acoustically.

Notable results of the survey include the capture of three species of the blossom bat genus *Syconycteris* in strict syntopy at 1,820 m asl, including multiple examples of the IUCN Vulnerable Montane Blossom Bat, *Syconycteris hobbit*; and the potential acoustic detection of the IUCN Data Deficient Fly River Leaf-nosed Bat, *Hipposideros muscinus*, at an elevation 1000 m higher than any previous record.

Although we did not obtain any direct evidence of the IUCN Critically Endangered Bulmer's Fruit Bat, *Aproteles bulmerae*, our Wopkaimin informants reported that large flying-foxes are currently using Luplupwintem Cave where the species was rediscovered in the late 1970s and monitored through to the early 1990s. Urgent conservation priorities for the region are a renewal of monitoring of Bulmer's Fruit Bat at this important site on the Hindenburg Range, and the development an expanded research programme to produce basic data on the broader distribution, pattern of habitat use, and basic biology of this highly threatened species.

Introduction

Previous mammal survey work in the southern foothills of the Star Mountains has focussed strongly on groups of economic importance (Hyndman 1979, 1984, Pernetta and Hyndman 1982, Hyndman and Menzies 1990), with much less attention given to the many species that are rarely utilised or even seen by people. In particular, bats have been almost entirely neglected by previous studies in this area. Hyndman and Menzies (1990) listed only six species for this region, five of them members of the family Pteropodidae (the flying-foxes). Notably, however, their list included Bulmer's Fruit Bat (*Aproteles bulmerae*), which was rediscovered as a living animal in the Star Mountains in the late 1970s (Hyndman and Menzies 1980) shortly

after its description from fossil remains (Menzies 1977). In comparison, physiographically comparable but better surveyed regions of Papua New Guinea (PNG) are known to support at least 15 species of bats including representatives of six or seven families (Flannery and Seri 1990, Armstrong and Aplin 2011). The northern flanks of the Star Mountains are better known in regard to bats (Flannery and Seri 1990, Flannery 1995, Bonaccorso 1998). The first records were obtained by the Australian Star Mountains Expedition that worked out of Telefomin in 1969 to explore some of the major northern catchments as well as Mts Capella and Scorpion (Shepherd 1974). Subsequently, Flannery of the Australian Museum together with various colleagues including Lester Seri of the Papua New Guinea Department of Environment and Conservation surveyed bats and other mammals in the Telefomin, Tifalmin, Nong and Sol River Valleys and in the Dokfuma Basin, the latter a subalpine herbfield at 3,200 m asl on the southern slopes of Mt Capella (Flannery and Seri 1990).

The 2013 survey provided a welcome opportunity to investigate bat diversity in the southern foothills of the Hindenburg Range. In line with other recent surveys for development assessments, research programmes and RAPs (Richards 2008, Armstrong and Aplin 2011, Robson et al. 2012), we employed acoustic detection methods in addition to more traditional methods to collect information on the local bat fauna.

Methods

Study sites

The bat survey was conducted at two localities, along an altitudinal range of 1,750 m to 2,529 m asl. *Bilbilokabip Camp* (5.1203°S, 141.2512°E) was situated at 1,770 m asl and is close to a former location of Bultem village in an area known as Tupnonbil. This area supports a mosaic of active gardens, ericoid scrub and secondary forest, as well as substantial patches of primary Montane and *Nothofagus* forest (for detailed description of habitats see Venter, this volume). Thirteen nights were spent at the camp—the nights of the 11th–23rd February 2013. Nets and bat detectors were deployed to sample each of the major habitats.

Minni Camp (5.0775°S, 141.1505°E) was situated at 2,440 m asl and was the site of a former exploration drill-pad. Dense regrowth scrub around the helipad gives way within 100 m or less to primary *Nothofagus* forest. Forest cover is continuous to the summit of Mt Minni but it is broken in several areas by sizeable patches of dense ericoid scrub, each covering areas of several hectares. Four nights were spent at the camp: the nights of the 24th–27th February 2013 but no sampling was carried out on the first two nights. Bats were surveyed at this site only through mist netting.

Both sites lacked any karst landforms due to an absence of local limestone exposure. Several small outcrops of metamorphic rocks on the flanks of Mt Minni were checked for caverns or fissures that might contain bats. At one site we located a small bone deposit produced by an avian predator, most likely the Sooty Owl (*Tyto tenebricosa*), but no bats were observed in the shallow rockshelter or associated fissure. The bone deposit included remains of one bat species (*Syconycteris* sp.) along with a variety of small rodents and marsupials (Aplin and Lamaris, Chapter 9).

Ken Aplin and John Lamaris undertook the fieldwork at both camps. Kyle Armstrong performed the analysis and interpretation of the bat detector records. All authors contributed to the text.

Data collection and sampling methods

Bats were surveyed with a combination of mist nets, harp traps, and acoustic 'bat detectors' deployed both actively and passively. For mist netting we used a combination of double-strand 'bird' nets and monofilament 'bat' nets. These were variously set up by the bird or mammal teams, with placement reflecting a variety of factors. The majority of nets set by the bird surveyors were placed close to the ground to maximize capture of understorey birds. Nets set by the mammal team were generally placed across gullies and other gaps in the understorey. Two double-bank harp traps were deployed on the survey. These were set at ground level and positioned in narrow gaps predicted to be used as flyways, such as across narrow gullies or on tracks through dense understorey.

Protocols for the capture and handling of mammals followed the guidelines of the American Society of Mammalogists (Gannon et al. 2007). Captured mammals were euthanized for long term preservation as museum voucher specimens, thereby allowing detailed comparative study of both external and internal features (e.g. skull and teeth). Most vouchers were fixed whole in 10% formalin and subsequently transferred to 70% ethanol for long-term storage. Tissue samples were preserved in 95% ethanol for all captured animals to allow efficient extraction of DNA. Additional tissue and organ samples along with visible ecto- and endo-parasites were taken from the majority of specimens to screen for a variety of pathogens including viruses and bacteria.

Specimens from the WCS Hindenburg Wall Survey are deposited in the United States National Museum, Washington D.C., U.S.A. and the Australian Museum, Sydney, Australia, identified by the prefix USNM and AM, respectively. Other institutional abbreviations used here are: AMNH (American Museum of Natural History); and UP (University of Papua New Guinea Natural Sciences Resource Centre). Taxonomic usage is discussed under individual species accounts. For common names we follow the recommended usage in the IUCN Red List (www.iucn.org).

Bat detector deployment at passive recording sites

Recordings of echolocation calls were made in high quality full spectrum WAV format with both Pettersson Elektronik D500x and zero-crossings format with Titley Scientific AnaBat SD2 bat detectors (with green Hi-Mic microphones). Reference echolocation recordings were made from captured bats with a Wildlife Acoustics EchoMeter EM3 (sampling frequency 384 kHz). The following settings were used for the D500x: sampling frequency 500 kHz, Pre-trigger off, Recording length 1 sec, HP filter yes, Autorec yes, Trigger source 0, Trigger sensitivity 1 High, Input Gain 45, Trigger level 30, Interval 0, Timer 19:00–06:30. AnaBat detectors were also set to turn on automatically at 19:00 and off at 06:30. Bat detectors 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. The detectors were employed as passive stationary acoustic recorders, being set in position by dusk and collected after dawn, and placed with microphones tied off the ground to trees. The equipment was placed in a variety of habitats, including adjacent to streams, within forest, along tracks, facing into clearings, and in open habitats.

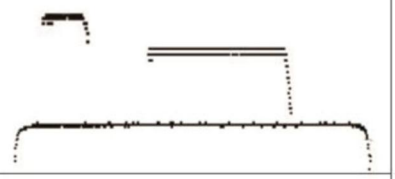
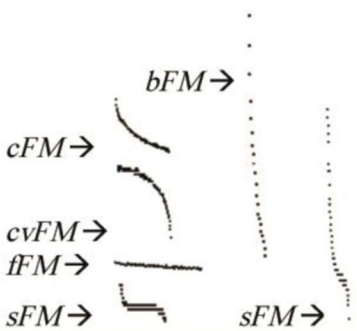
Acoustic analysis of bat echolocation calls

The raw recordings in full spectrum WAV format from the D500x detectors were first downloaded and date-time stamped with D500x Utility version 1.5 (Pettersson Elektronik). The WAV files were then opened and inspected in Adobe Audition CS6 version 5.0.2. Signals recorded with the AnaBat SD2 detectors were downloaded and interpreted with CFC Read software 4.4n and individual sequence files were examined in AnalookW 3.8s. The frequency division ratio was set to a factor of eight.

Echolocation call types were named according to a standardised nomenclatural scheme developed for this purpose (Armstrong and Aplin 2011; shown here in Table 1). 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 a recognisable initial upward frequency sweep, and all have a terminating frequency sweep, so the IFS and TFS descriptors are not used for this Body Sub Type.

A subset of call types were identified to species based on either published reference calls (Leary and Pennay 2011) or unpublished reference calls collected elsewhere in PNG by Armstrong and Aplin. For the remaining, unallocated call types we assessed the possible identity on the basis of known call characteristics of related species.

Table 1. Echolocation call categories based on the morphology of the dominant type of search-phase pulses in high quality sequences [adapted from de Oliveira (1998a, b) and Corben and O'Farrell (1999); examples are not scaled equally].

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*→ *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 following the characteristic frequency	

Results

General survey results

The effort deployed and results obtained at each of the sampling sites are summarized in Table 2.

Table 2. Summary of mist netting effort and capture rate at the two survey sites.

Locality	Mist netting effort		Captures			
	Mist net nights	Mist net meter/hrs	*S.* cf. *australis*	*S. 'montane'*	*S. hobbit*	All species
Bilbilokabip	126	18,072	4	83	2	89
Minni	10	1,152	0	2	9	11

Locality	**Capture rate** (indiv/net night)				**Capture rate** (indiv/100 net meter/hrs)			
	S. cf. *australis*	*S. 'montane'*	*S. hobbit*	All species	*S.* cf. *australis*	*S.* 'montane'	*S. hobbit*	All species
Bilbilokabip	0.032	0.659	0.016	0.706	0.022	0.459	0.011	0.492
Minni	0.00	0.20	0.90	1.10	0.00	0.174	0.781	0.955

Mist netting

All mist net captures were blossom bats of the pteropodid genus *Syconycteris*. Although current taxonomy recognises only two species of this genus in New Guinea (Flannery 1995, Bonaccorso 1998), we confidently distinguish three species among our captures, which we herein designate as *S.* cf. *australis*, *S. hobbit*, and *S.* 'montane sp'. Our total captures for the three *Syconycteris* species combined totalled 100 individuals across the two study sites—a large enough sample to establish some patterning in elevational and habitat usage, and to provide some data on seasonal reproductive activity (see individual species accounts, below). Overall capture rates in mist nets averaged 0.71 bats per mist net 'night' for Bilbilokabip and 1.10 bats per mist net 'night' for Minni (i.e. slightly more or less than one bat per net per night; see Table 2). There was no clear bias toward either kind of net (data not shown).

Harp traps

Although two harp traps were deployed for 11 nights each, they captured only two individuals of a single species of bat (a Mountain Pipistrelle, *Pipistrellus* cf. *collinus*). Both were captured in traps set on well-established trackways where bats were observed in flight during night patrols.

Acoustic survey

D500x recordings contained three of the call types present in the AnaBat SD2 recordings and one additional type (Fig. 1). Seven call types were identified on the AnaBat SD2 recordings (Fig. 2).

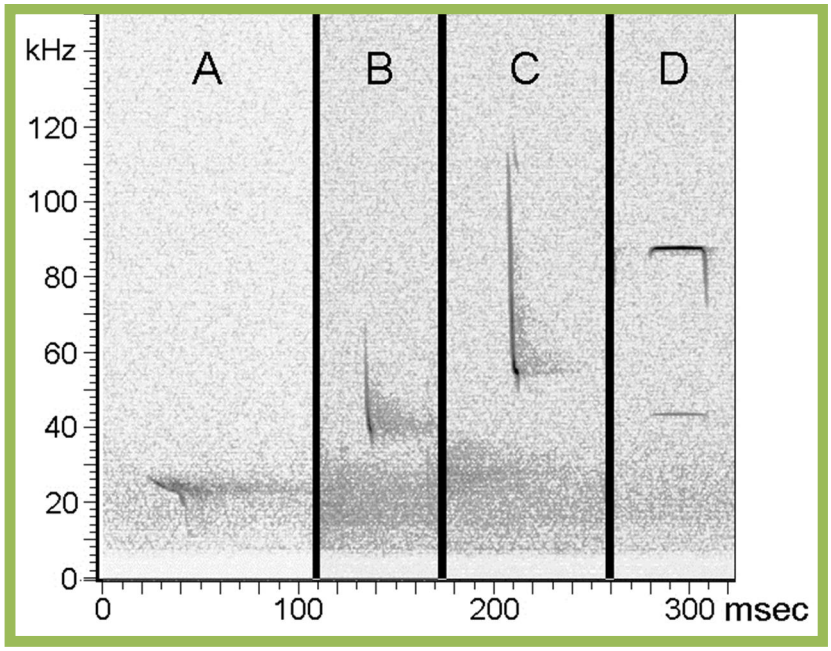


Figure 1. Representative pulses for the echolocation call types identified from D500x recorders in full spectrum format (A: *25 sFM.d*; B: *37 st.cFM Miniopterus* sp.; C: *53 st.sFM.d Pipistrellus* sp.; D: *89 mCF H. cf. muscinus*; see Table 1 for an explanation of the call type codes).

Table 3. Species and call types of echolocating bats recorded at each passive recording site. Habitat codes: ES – ericoid scrub beside helipad; FC – into forest canopy in primary forest; FT – track through secondary forest; LC – large clearing, a new taro garden.

Unit and Date	13 cFM *T. kuboriensis*	25 sFM.d Molossidae or Emballonuridae	30 cFM cf. *Miniopterus* sp.	37 st.cFM *Miniopterus* sp.	44 st.cFM cf. *Miniopterus* sp.	45 ifFM.d *E. raffrayana*	53 st.sFM.d *Pipistrellus* sp.	89 mCF *H. cf. muscinus*	Habitat
AnaBat SD2 5395									
11/02/2013	•	—	•	•	—	•	•	•	ES
18/02/2013	—	—	—	•	—	—	—	—	LC
19/02/2013	—	—	—	•	—	—	•	•	FC
20/02/2013	—	—	—	•	—	—	•	•	FC
21/02/2013	—	—	—	•	—	—	•	—	FC
22/02/2013	—	—	—	•	—	—	•	•	FC
AnaBat SD2 81220									
19/02/2013	—	—	•	•	•	—	•	—	ES
21/02/2013	—	—	•	•	—	•	•	•	ES
D500x 162									
18/02/2013	—	•	—	•	—	—	•	•	FT

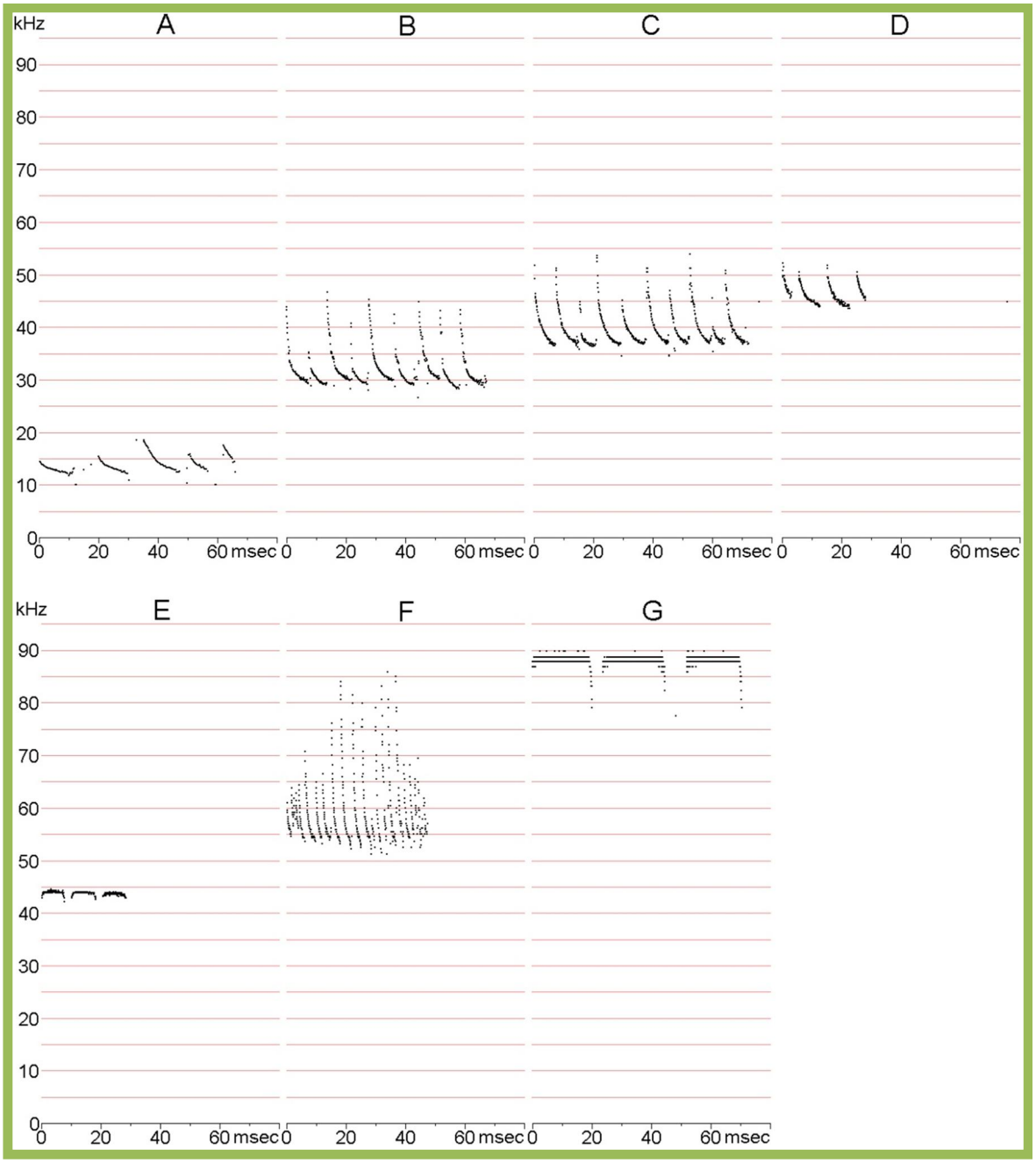


Figure 2. Representative echolocation call types identified from AnaBat SD2 recordings in ZCA format (time is compressed between pulses) (A: *13 cFM T. kuboriensis*; B: *30 st.cFM*; C: *37 st.cFM Miniopterus* sp.; D: *44 st.cFM*; E: *45i.fFM.d E. raffrayana*; F: *53 st.sFM.d Pipistrellus* sp.; G: *89 mCF H. muscinus*; see Table 1 for an explanation of the call type codes).

The distribution of the eight call types by habitat is shown in Table 3. Detectors placed on the margin of patches of ericoid scrub (around the Bilbilokabip camp and helipad) recorded the highest diversity of call types (4–6 call types), followed by an established trackway through disturbed forest (4 call types), the canopy of primary forest (detector placed on a steep slope; 3 call types), and a newly established taro garden (1 call type).

Four call types were recorded only in ericoid scrub adjacent to forest, and one call type exclusively on an established trackway through disturbed forest.

Annotated species list

Order Chiroptera
Family Pteropodidae

Syconycteris cf. *australis* (Peters 1867): Lowland Blossom Bat (Siminok)
IUCN Red List rating: Least Concern

Four individuals of this species were captured at the Bilbilokabip locality. They are slightly larger than the undescribed 'montane' *Syconycteris* and have shorter, more reddish fur, larger ears, and more prominent nostrils (see photograph). This taxon is known from numerous localities along the southern lowlands of New Guinea and is usually the single most abundant capture in mist nets set up to elevations of 1500 m asl. The tentative referral of this population to *S. australis* (Peters, 1867) reflects our suspicion, based on extensive recent collections, that two different species of *Syconycteris* are present in the southern lowlands of New Guinea. At present it is unclear which, if either, of these is conspecific with any Australian population. The type locality of *S. australis* is Rockhampton, Queensland, and there has been no formal comparison of Australian and New Guinean *Syconycteris*. All four individuals captured at Bilbilokabip came from highly disturbed habitats. Two were captured in ericoid scrub beside the helipad and the others at the edge of a recently established taro garden within an extensive zone of gardens, regrowth, and secondary and degraded forest. All four were adult females of which two were pregnant and one lactating. Body weights ranged from 18.9 to 22.7 g. The net in ericoid scrub also yielded examples of the undescribed 'montane' *Syconycteris* (see below) while nets in the garden and regrowth zone yielded numerous individuals of the 'montane' *Syconycteris* and rare examples of *S. hobbit*. The Faiwol name Siminok was applied to examples of all three *Syconycteris* species. The differences, when pointed out to our informants, were attributed to differences in gender and maturity.

Syconycteris hobbit (Ziegler 1982): Moss-forest Blossom Bat (Siminok)
IUCN Red List rating: Vulnerable

This species was captured at both sites. Two individuals were captured at Bilbilokabip, one in the taro garden and the other in a small patch of remnant forest within the gardening zone. At this locality *S. hobbit* was much less abundant than the montane *Syconycteris*, of which 85 individuals were captured. At Minni this situation is reversed, with captures of *S. hobbit* (9) outnumbering those of the montane *Syconycteris* (2). The Moss-forest Blossom Bat is readily distinguished from the other species of *Syconycteris* by its darker, woollier fur, its shorter, more rounded and emarginated ears, and by its conspicuously hairier feet (from which it derived its name; Ziegler 1982) (see photograph). Body weights of our series ranged from 18.7 to 22.8 g for males (n=3) and 17.4 to 19.7 g for females (n=8). One female was lactating and in another lactation appeared to have ceased recently. Flannery and Seri (1990) reported the occurrence of *S. hobbit* at 2,300 m asl in the upper Sol River Valley. Later work revealed another population in the vicinity of Luplupwintem Cave on the Hindenburg Range (Flannery 1995). Other known localities for this species cluster in two areas – the Snow Mountains, Indonesian Papua (Maryanto and Boeadi 1994, Flannery 1995), and the mountains that straddle the border of Morobe, Gulf and Central Provinces (Ziegler 1982, Bonaccorso 1998). In each of these high elevation areas it appears to be locally common, as we can now confirm for the southern flank of the Hindenburg range. Our record from c. 1800 m asl at Bilbilokabip represents the lowest known elevational occurrence of this species. This species is listed as Vulnerable "because its extent of occurrence is less than 20,000 km^2, all individuals are in only three locations, and there is believed to be a continuing decline in the extent and quality of its habitat" (Helgen and Bonaccorso 2008).

Syconycteris sp.: An undescribed Blossom Bat (Siminok)
IUCN Red List rating: Not Evaluated

We captured 85 individuals of this undescribed blossom bat. All but two were captured around Bilbilokabip, where they seem to utilize all habitats including ericoid scrub, gardens and regrowth, and secondary and primary forest. Two individuals were taken in primary forest at the Minni site. This species is most similar to *S.* cf. *australis* but it differs in having thicker and darker fur, slightly smaller ears, and less prominent nostrils

(see photograph). It is also slightly less robust in body form, with body weights between 13.2 and 16.7 g for adult females (excluding pregnant individuals) and rarely exceeding 18.0 g for adult males. Previous workers who have observed these differences between lowland and montane populations of *Syconycteris* (e.g. Ziegler 1982) have quite reasonably deferred to a bioclimatic interpretation—montane populations of a species often being smaller, darker and more thickly furred than those from the lowlands. However, as reported also by Aplin and Kale (2011) for the Muller Range, the capture of the two phenotypic 'forms' in sympatry begs a different interpretation—that they are fully distinct biological species. To date this remains untested by genetic evidence. However, we have noted consistent cranio-dental differences between these forms across multiple sites along the southern flanks of the Central Cordillera, as has Kris Helgen (pers. comm., November 2012) of the United States National Museum, Smithsonian Institution for sites throughout New Guinea. Remarkably, this distinctive and at least locally super-abundant bat appears to lack an available taxonomic name. Around Bilbilokabip, the 'montane' *Syconycteris* was captured in the greatest numbers in the garden and regrowth zone, where 37 individuals were captured in a single 12 m long 'bird' net set near the edge of newly established taro garden over a four night period. In contrast, nets set in primary and secondary forest or in dense regrowth scrub typically captured one or two individuals over the same period. This suggests that population densities are generally low in both forest and regrowth habitats, but that congregations might occur in response to the availability of particular resources. In this case, there we no obvious flowering or fruiting trees in the vicinity but the net was positioned to intercept movement between a remnant forest patch and more open air space. For such common animals, furthermore for a group that is likely to play a major role in forest dynamics through pollination and seed dispersal, it is truly remarkable how little is known of the ecology of *Syconycteris*. Our sample of 44 females of the montane *Syconycteris* provides some basic information on reproductive biology. The largest nulliparous and non-pregnant female weighed 15.1 g, while the smallest pregnant female weighed 13.6 g. A total of 18 females were pregnant (various stages from early to terminal) and 17 were either lactating or had recently ceased doing so. The small number of sexually immature individuals captured suggests either a strong behavioural segregation that allowed young individuals to avoid capture or a strongly seasonal pattern of breeding coupled with relatively rapid maturation, such that only the latest young of the previous season were still reproductively immature. We prefer the latter interpretation but emphasize that it needs to be tested by fieldwork in different seasons.

Order Chiroptera
Family Vespertilionidae

Pipistrellus cf. *collinus* (Thomas 1920): Mountain Pipistrelle
IUCN Red List rating: Least Concern

Harp traps set al.ong established track ways through forest captured two individuals of a large *Pipistrellus*. An adult male weighed 5.6 g and had a forearm length of 37 mm. It lacked the conspicuously concave cranial profile of *P. angulatus* and is substantially larger than *P. papuanus*. Of currently recognized taxa within *Pipistrellus*, the best match is with the Mountain Pipistrelle, *P. collinus*, which has been recorded from the upper Sol River Valley (Flannery and Seri 1990) as well as from scattered localities along the Central Cordillera of New Guinea (Flannery 1995, Bonaccorso 1998). However, pending further morphological and genetic studies, we are hesitant to provide a firm identification within this morphologically conservative genus.

Although neither of the captured pipistrelles yielded useful reference calls when flying inside a large tent, a *53kHz st.sFM.d* call type (Figs 1–2) that appears on passive recording sessions is here associated with the captured animals with a moderate degree of confidence. This call type resembles that of other species of *Pipistrellus* and the fact that it was recorded on almost every passive detector session indicates that it is a locally abundant taxon. Our only cause for hesitation derives from the fact that Robson et al. (2012) reported the call of *P. collinus* as having a characteristic frequency (in flight upon release) of around 40 kHz, based on animals captured at 2050 m on the Huon Peninsula. However, this difference could well be indicative of taxonomic differentiation among the montane pipistrelles of New Guinea, rather than a problem of association.

Order Chiroptera
Family Molossidae

Tadarida kuboriensis (McKean & Calaby 1968): New Guinea Free-tailed Bat
IUCN Red List rating: Least Concern

This species is listed here on the basis of a 13 kHz *cFM* call type (Fig. 2) that was recorded at the helipad clearing at Bilbilokabip. This call type conforms closely with one reported by Armstrong and Aplin (2011) from the high elevation (2,900m asl.) site of Apalu Reke on the Muller Range, and attributed by them to the genus *Tadarida* on the basis of structural similarity to calls of *T. australis* in Australia. The only molossid bat known to occur at such elevations in New Guinea is *T. kuboriensis* (Flannery 1995, Bonaccorso 1998). It is recorded from widely scattered localities along the Central Cordillera of New Guinea, from 1900 m to 2950 m asl. (Flannery 1995, Bonaccorso 1998)

Order Chiroptera
Family Miniopteridae

Miniopterus spp.: Bent-winged Bats
IUCN Red List rating: Least Concern

Three call types are allocated to species of *Miniopterus*, albeit with varying degrees of confidence. The most certain is a 37 kHz *st.cFM* call type (Figs 1–2) that conforms closely with the vouchered reference calls of a large species of *Miniopterus* from elsewhere in southern New Guinea. Lesser certainty is attached to two *cFM* call types with characteristic frequencies of 30 kHz and 44 kHz, respectively (Fig. 1). These call types were recorded exclusively above patches of ericoid scrub, whereas the more common 37 kHz *st.cFM* call type was recorded in every passive recording session (Table 3). A regional co-occurrence of three or more *Miniopterus* species is quite plausible given what is currently known of the distributions and ecology of this group of bats (Flannery 1995, Bonaccorso 1998). However, for three reasons we prefer not to associate the calls with any particular taxonomic names. The first is the paucity of vouchered reference calls for New Guinean *Miniopterus*. The second is that species of *Pipistrellus* are known to produce echolocation calls with a characteristic frequency between 40–55 kHz. The third is the fact that almost all of the taxonomic names currently employed for *Miniopterus* species within Melanesia were proposed originally for populations from outside of this region. For example, *M. australis* Tomes, 1858 was described from the Loyalty Islands, *M. magnater* Revilliod, 1913 from New Caledonia, *M. tristis* (Waterhouse, 1845) from the Philippines, *M. medius* Thomas and Wroughton, 1909 from Java, and *M. schreibersii* (Kuhl, 1819) from Hungary. The notion that any single species of *Miniopterus* would cover such huge geographic ranges is entirely at odds with everything that is now known from Europe, Madagascar and Australia regarding the reproductive biology and demographic structure of *Miniopterus* species. In eastern Australia each of the Large Bent-winged Bats *M. oceanensis* and the Little Bent-winged Bat *M. 'australis'* follow an annual cycle of movements that revolves around maternity caves where females congregate in 1,000s to 100,000s for the birth and development of young. Males also roost in caves but typically in smaller congregations. Outside of the breeding season, they are joined at these dispersed roosts by females and young. The foraging territory of a colony typically extends for several hundreds of kms around the maternity cave. Little is known about reproduction of Bent-winged Bats in Melanesia (Bonaccorso 1998). The only report of large maternity colonies in Melanesia is for *M. australis* on New Britain (Smith and Hood 1981). However, it is likely that all Melanesian species follow the same reproductive pattern as the better known members of the genus. The unusual biology of *Miniopterus* species very likely guarantees that every regional population is genetically isolated to a high degree from every other. This has been demonstrated most convincingly in Europe for *M. schreibersii* (Rodrigues et al., 2010) and there is strongly suggestive evidence from Australia for *M. oceanensis* (Appleton et al. 2004). We caution strongly against the continued application of extra-regional taxonomic names to New Guinean *Miniopterus*, and urge the development of a new taxonomic framework that more faithfully portrays the biology and evolutionary history of this important genus.

Order Chiroptera
Family Emballonuridae

Emballonura raffrayana (Dobson 1879): Raffray's Sheath-tailed Bat
IUCN Red List rating: Least Concern

Call pulses with a characteristic frequency of c. 45 kHz and an *i.fFM.d* shape are attributed to *E. raffrayana* with a moderate level of confidence, based on reference calls collected elsewhere in PNG (Armstrong and Aplin, unpublished data). Capture and DNA barcoding are required for confirmation.This call type was recorded exclusively above patches of ericoid scrub (Table 3). All *Emballonura* species prefer to forage in relatively open spaces.

Order Chiroptera
Family Emballonuridae or Molossidae

Unidentified call type *25 sFM.d*

This call type shows similarities to calls of some of the larger species within Emballonuridae (e.g. *Saccolaimus* spp.) and to some Molossidae (e.g., *Chaerephon jobensis*), especially in the characteristic frequency and drooped termination of the pulses. However, there are insufficient reference echolocation recordings available to take the identification further on acoustic grounds alone. All *Saccolaimus* species in Melanesia are known only from lowland habitats and typically from more open forest types or savannahs (Flannery 1995, Bonaccorso 1998). Molossids too are mostly confined to lowland habitats, though two species – *Chaerephon jobensis* (Miller, 1902) and *Otomops secundus* Hayman, 1952 – are known to range up into lower montane forest. In Australia the characteristic call frequency of *C. jobensis* is usually 15–20 kHz (Kutt et al. 2008). No reference calls are available for a species of the genus *Otomops*.

Order Chiroptera
Family Hipposideridae

Hipposideros cf. *muscinus* (Thomas and Doria 1886): Fly River Leaf-nosed Bat
IUCN Red List rating: Data Deficient

A *mCF* call type with a characteristic frequency of 89 kHz was recorded in almost every passive recording session. An essentially indistinguishable call type was recently collected from captured individuals of both sexes of *H. muscinus* by Aplin at a nearby site in Western Province (locality subject to contractual confidentiality). Despite this close match in call types, we hesitate to make a confident referral on account of the apparent mismatch in habitat. In addition, there is significant call variation in *H. wollastoni*, and there is a possibility that the calls can also be attributed to this species as relatively high frequency examples. To date *H. muscinus* has only been collected from sea level to 600 m asl. (Flannery 1995, Bonaccorso 1998) along the southern side of the Central Cordillera. However, it is one of the rarest of all New Guinean *Hipposideros* species and it cannot be excluded that its elevation range extends much higher than currently understood. Capture and DNA barcoding are required for confirmation.

Discussion

Remarks on inventory completeness
Our relatively brief survey produced some notable bat species records but also some noteworthy absences. Among the notable records are the captures of the Moss Forest Blossom Bat and the possible acoustic record of the Fly River Leaf-nosed Bat, the latter representing a possible elevational range extension of more than 1000 m. Among the most noteworthy absences are any species of tube-nosed bat (*Nyctimene* or *Paranyctimene*) and any record of the genus *Rhinolophus*. Tube-nosed bats are commonly mist netted at lower elevation sites in New Guinea but they appear to become scarce above 1000 m asl. Only one species, *N. certans*, is recorded above 1500 m asl (Flannery 1995); Flannery and Seri (1990) reported one capture of

this species in the Upper Sol River Valley near Telefomin. Given the mist-netting effort on the 2013 Hindenburg Range survey we can only conclude that *N. certans*, if present at all in the southern foothills of the Star Mountains, is either a very rare animal or else undergoes some seasonal pattern of local movements that made it inaccessible at the time of our survey.

Horseshoe Bats of the genus *Rhinolophus* are also relatively frequent captures in mist nets and harp traps, and they are also readily detectable in an acoustic environment through their distinctive echolocation call types (e.g. Leary and Pennay 2011, Robson et al. 2012, Armstrong and Aplin, unpublished data). At least two species were anticipated in the southern foothills of the Star Mountains, the Western Horseshoe Bat (*R. arcuatus*) and the New Guinea Horseshoe Bat (*R. euryotis*). The absence of any record of this group on our passive detector sessions is puzzling but leads us to speculate that these bats may remain at low density and relatively close to roosting sites in karst environments, at least through part of each year. The absence of local cave systems might also explain the low diversity among the Hipposideridae or Leaf-nosed Bats, as in our experience, cave roosting species of *Hipposideros* are more frequently encountered either as captures or as acoustic records at sites close to roost caves.

We also failed to obtain any evidence for the regional occurrence of Bulmer's Fruit Bat (*Aproteles bulmerae*). However, this failure is unsurprising given the lack of potential cave roost in the immediate vicinity of our survey sites, the fact that few trees were in flower or fruit during the time of our visit (Venter, Chapter 2), and the lack of any specific effort to capture the larger pteropodid bats such as the setting of canopy nets. Active survey for these larger bats, while undeniably important, is a specialist activity that would have diverted a significant amount of effort away from other survey priorities.

A high priority for future bat work in the Upper Ok Tedi River region is the capture and acoustic recording of some of the species responsible for the unallocated call types. This might be accomplished by the more extensive use of harp traps. However, we note that whilst harp traps have proven successful for capturing insectivorous bats in closed forests in Australia (Duffy *et al*. 2000) and Southeast Asia (Kingston et al. 2003), they seem to give generally poor returns when deployed in New Guinean closed forest habitats. A similar conclusion has been expressed by various other bat surveyors (e.g., Helgen 2007, Richards 2008, Armstrong and Aplin 2011).

Community composition among the pteropodid bats

Our capture of three species of *Syconycteris* in the one area (and indeed, in a single net set on the edge of a taro garden) is noteworthy and might even be unprecedented. Elsewhere in New Guinea *S. hobbit* has been captured together with another species of *Syconycteris* which is usually mentioned as *S. australis*. In most cases, these records probably refer to the unnamed 'montane' species of *Syconycteris* which can be quite abundant in lower montane forests and superabundant in disturbed habitats at this elevation. However, the 'montane' *Syconycteris* is not often distinguished from the one or more lowland forms currently grouped under the name *S. australis*. By distinguishing all three taxa as distinct, we have opened the door to more detailed studies of elevational range interactions and niche partitioning within the genus *Syconycteris*.

In our opinion it is possible that the lowland form of *Syconycteris* (*S.* cf. *australis*) may only extend to higher elevations when it has access to disturbed habitats. This phenomenon has been observed by Aplin for several New Guinean pteropodid bats, including *Nyctimene aello* and *Macroglossus minimus*, both of which appear to be confined to elevations <150 m asl. in primary forest, and to only attain higher elevations where disturbance has created breaks in the canopy (Aplin, unpublished data). Whether or not this includes both human and natural disturbances such as landslides is not known. Nevertheless, observations of this kind it urge caution about the use of elevational ranges to predict species occurrences without specifying habitat types.

Conservation recommendations

Although our survey resulted in a marked improvement of scientific knowledge of the bats of the upper Ok Tedi River region, we suspect that a significant number of species remained undetected, including both

non-echolocating and echolocating forms. Future surveys could usefully focus on sampling both a wider elevational range and a range of both karstic and non-karstic landforms.

Our survey failed to shed any additional light on the status and distribution of Bulmer's Fruit Bat. This species is widely regarded as one of the world's most critically endangered bats, with only one locality known to have contained a viable population in recent times. This site, the cave known as Luplupwintem to Wopkaimin people, is located at c. 2,300 m near the rim of the Hindenburg Wall and while remote from any human habitation, it is relatively easily accessed from the walking track that links Bultem in the Upper Ok Tedi catchment and Tifalmin in the Ilam River Valley to the north. A second extant colony of Bulmer's Fruit Bat was located in 2006 near Crater Mountain in Chimbu Province by University of PNG student Kone Tau Na'au (www.ibr.org/team.htm) but it has not been subject to detailed census.

The Luplupwintem population of Bulmer's cave appears to have been last assessed in 1993, at which time around 160 bats appeared to be in residence (Flannery and Seri 1993). Our Wopkaimin informants told us that the population had declined again after Flannery's last visit but that the cave once more contains bats. Whether these are Bulmer's Fruit Bat as opposed to the morphologically similar Bare-backed Fruit Bat (*Dobsonia moluccensis*) is not known. Also unknown at present are the answers to many other important questions regarding Bulmer's Fruit Bat and Luplupwintem. For example: Does the colony remain in the vicinity of the cave through the course of a year or does it disperse and congregate on a seasonal basis, as is the case for many other large pteropodid bats? What do the bats eat and how far do they fly each night in search of food? Do individuals from this colony also use other caves as casual roosts throughout the year or even for social congregations or breeding? Without answers to these very basic questions regarding the biology of Bulmer's Fruit Bat it is difficult to predict the impact of changes in regional habitat quality or human visitation on the future of the colony. We strongly recommend that answers to these questions regarding the Luplupwintem colony of Bulmer's fruit Bat be pursued by the scientific community as a matter of urgency. We also urge that additional populations of Bulmer's Fruit Bat be sought in other regions of PNG and Indonesian Papua, targeting areas of rugged and remote karst where human hunting pressure is likely to be minimal.

We suspect that with sufficient survey effort in suitable terrain, Bulmer's Fruit Bat will be found elsewhere and quite possibly in many different localities across southern New Guinea. However, until this occurs, the Luplupwintem locality must be treated as a regionally unique site of the highest conservation significance. As part of that process, the site ideally should be afforded a special emphasis by traditional landowners and/or custodians, and actively protected against wanton exploitation that might further endanger its precious cargo.

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Three species of the blossom bat genus *Syconycteris*. Top: a lowland taxon *S.* cf. *australis*; Middle: an unnamed mid-montane taxon; Bottom: upper montane taxon *S. hobbit*. (*Photos K.P.Aplin*)

Ealy morning on the final day of the Bilbilokabip camp. *(Photo N.Whitmore)*