A Rapid Biodiversity Survey of Papua New Guinea's Manus and Mussau Islands

edited by
Nathan Whitmore

WILDLIFE CONSERVATION SOCIETY

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This report is dedicated to the memory of our colleague, David Posa, who passed away as this report was being prepared. David was a young man who worked as a WCS Community Facilitator on Manus. He participated in many WCS community projects and biodiversity surveys including the Manus-Mussau expedition of 2014.

David, wen iau hepke lindriam eh mburiam masih irpoh porndro wu!!
Yowu masih topo hangorwen wou!

Pa awet a nukwue ra bona papalum u paitia! Tuk da'at a war barat mulai!

Acknowledgements

Many people and organisations helped to facilitate the 2014 WCS biodiversity surveys of Manus and Mussau. First and foremost we are most grateful to CEPF for their financial support, without which the project could not have been undertaken. We would especially like to thank Jack Tordoff of CEPF for his input and guidance. We are also grateful to the Department of Environment and Conservation, and the Provincial Governments of Manus, and New Ireland for granting us the necessary approvals and permits, and for supporting our work in the region.

This survey also would not have been possible without the support, aid and goodwill of the leaders, councillors, and residents of Tulu 1 and Piri on Manus; and Nae and Lolieng on Mussau. Over one hundred and twenty local people participated in the establishment of the camps and/or assisted with specimen collection, and directly contributed to the success of the survey.

Thanks also goes to the staff and crew of the M.V. Pationg and M.V. Kavieng who organised for our safe return from Mussau during a night passage which could be best described as nerve-racking.

We would also like to acknowledge the efforts of the support crew and other colleagues in helping with the logistics, prior community work, design and copy editing of this document especially: Julian Benjamin, Lisa Capon, Daniel Charles, Centy Gerson, John Kuange, Max Kudak, John Lamarais, John Ole, June Polomon, Annisah Sapul, Lilly Ugi, Junior Walker, Marygrace Wanamp-Puri, and Wallace Takendu.

Organisational profiles

Criticial Ecosysytems Partnership Fund

www.cepf.net

The Critical Ecosystem Partnership Fund (CEPF) is designed to safeguard the world's biologically richest and most threatened regions, known as biodiversity hotspots. It is a joint initiative of l'Agence Française de Développement, Conservation International (CI), the European Commission, the Global Environment Facility, the Government of Japan, the John D. and Catherine T. MacArthur Foundation, and the World Bank. A fundamental purpose of CEPF is to engage civil society, such as community groups, nongovernmental organizations (NGOs), academic institutions and private enterprises, in biodiversity conservation in the hotspots. To guarantee their success, these efforts must complement existing strategies and programs of national governments and other conservation funders. To this end, CEPF promotes working alliances among diverse groups, combining unique capacities and reducing duplication of efforts for a comprehensive, coordinated approach to conservation. One way in which CEPF does this is through preparation of "ecosystem profiles" — shared strategies, developed in consultation with local stakeholders, which articulate a five-year investment strategy informed by a detailed situational analysis.

Papua New Guinea Conservation and Environment Protection Authority (formerly Papua New Guinea Department of Environment and Conservation)

www.dec.gov.pg

The Department of Environment and Conservation (DEC) was 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 was to ensure PNG's natural resources were managed to sustain environmental quality, human wellbeing and support improved standards of living. The Directive Principles of DEC included 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. In January 2015, the PNG Government set up a new Conservation and Environment Protection Authority which now replaces the Department of Environment and Conservation as the government agency responsible for administering and safeguarding the environment.

Wildlife Conservation Society (WCS)

www.wcspng.org and www.wcs.org

The Wildlife Conservation Society is a US nonprofit, tax-exempt, private organization established in 1895 that saves wildlife and wild places worldwide through science, conservation action, education, and inspiring people to value nature. 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. Our vision for PNG is: "*Gutpela sindaun, gutpela solwara, gutpela bus*" (Empowered communities with healthy forests and seas).

Letter of support

Conservation and Environment Protection Authority

In Papua New Guinea we are blessed with multitudes of different plants, animals and landforms. While the mainland of our nation is renowned for its high biodiversity our island environments are often over-looked. The islands of Manus and Mussau are amongst the most remote of our island environments, and as a consequence of that distance have sat beyond the scientific horizon. What little ecological knowledge we had of these places suggested that they were biological hotspots not only of Papua New Guinea but of Melanesia, and worthy of our attention.

In October 2014 the Wildlife Conservation Society with the support of the Critical Ecosystems Partnership Fund began the process of documenting the biodiversity of these islands. A few short weeks on the islands resulted in the discovery of more than a dozen new species, and documentation of hundreds more.

Yet, we must acknowledge that scientific understanding is only one part of conservation puzzle and that in Papua New Guinea the most critical element for successful conservation is the inclusion of communities. Only by first acknowledging the relationship between human communities and nature and then seeking to understand it, do we allow the possibility of a common pathway to a sustainable future. So, I am delighted that Wildlife Conservation Society and the Critical Ecosystems Partnership Fund are focusing their projects on harmonising the biodiversity and social aspects of conservation. It is a vision that my newly formed Conservation and Environmental Protection Authority wholeheartedly supports, and we wish them every success with their ongoing work in the region.

Gunther Joku

Managing Director

Conservation and Environment Protection Authority

Foreword

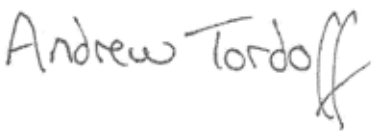
Critical Ecosystem Partnership Fund

Biodiversity hotspots are regions of exceptionally high endemism combined with elevated levels of threat. These characteristics are exemplified by Manus and Mussau islands, on the northern edge of the Bismarck Sea. Both islands support diverse faunas and floras, with many species found nowhere else on earth, but both have witnessed significant degradation and loss of their natural ecosystems, particularly due to past forestry operations. As well as threatening their irreplaceable biodiversity values, degradation of the islands' ecosystems has serious implications for the wellbeing of local communities, whose livelihoods they underpin.

During October 2014, a team from the Wildlife Conservation Society (WCS), with the support and assistance of local customary landowners, carried out biological surveys on Mussau island and the central part of Manus island. Both sites are recognized as Key Biodiversity Areas, and prioritized for support by the Critical Ecosystem Partnership Fund (CEPF), which funded the surveys, as part of an eight-year program of investment in the East Melanesian Islands Hotspot. The results were impressive: major gaps in the baseline knowledge of the islands' biodiversity were filled; and at least 12 new species to science were discovered.

CEPF is a joint initiative of l'Agence Française de Développment, Conservation International, the European Union, the Global Environment Facility, the Government of Japan, the John D. and Catherine T. MacArthur Foundation, and the World Bank. It is a global program that provides grants to nongovernmental organizations and other private sector partners to protect critical ecosystems. A fundamental goal of the Fund is to engage civil society in efforts to conserve biodiversity. Within the East Melanesian Islands Hotspot, CEPF's approach has been to recognize local people as the true custodians of biodiversity, and to empower them to make informed choice about how to manage their naturally resources sustainably, with support from civil society organizations at local, national and global levels.

This approach is very much needed on Manus and Mussau, where local people have legitimate needs and aspirations, and must be incentivized to conserve their forests, as an alternative to the development visions being advanced by the proponents of logging and mining. In this context, the findings of the WCS-led surveys help establish a platform for informed conservation action by customary landowners. Such action can be supported by external resources and technical expertise, and informed by the experiences of other communities in similar situations, but must be owned and led by local people themselves. CEPF welcomes the survey results, as an essential first step, and stands ready to support the next stage of the journey.



Andrew "Jack" Tordoff

Grant Director

Executive summary

Aim

The relatively remote islands of Manus and Mussau, located in the northern portion of the Bismark sea have been long identified as key biodiversity areas in Papua New Guinea and within greater Melanesia. Manus Island has long been known for its endemism and relatively intact forest, while Mussau Island, although relatively unstudied, has been recognised as an Endemic Bird Area. This report documents the findings of a series of rapid biodiversity surveys focusing on terrestrial flora and fauna, funded by the CEPF, encompassing four sites across the islands of Manus and Mussau; undertaken by a WCS led team of national and international taxonomic specialists in October 2014. The objective of these surveys was to investigate the biodiversity values of these areas. In conjunction with participatory community work conducted prior to, and following the surveys the wider WCS project aims to identify options for natural resource management in the region which addresses both community and biodiversity needs.

Location

We established two base camps on each of Manus and Mussau (Plate 1). The two Manus camps were both in the largely intact central forest. The first camp on Mt Sabomu targeted a high elevation site on the south coast, while the second camp targeted a riverine, lowland area near the banks of the Yeri river on the north coast. On Mussau the first camps targeted a pocket of remanent forest on the east coast at Nae, while the second targeted a forest patch on the west coast some distance from Lolieng village. Unfortunately, on Mussau, we were not able to establish a camp inland as only a handful of inland locations have a reliable water source and we were not able to secure consent to work in these particular areas during this expedition. Camps were sequential with the exception of Lolieng. Due to the mammal team finding a plethora of caves near Nae camp they opted to stay at Nae while the rest of the team surveyed the area around the Lolieng camp.

Expedition dates

Camp	Latitude	Longitude	Dates	Taxa targeted
Manus				
Mt Sabomu	S 2.193°	E 146.967°	2–7 October 2014	Odonata Herpetofauna Mammals
Yeri	S 2.001°	E 146.819°	9–13 October 2014	Odonata Herpetofauna Mammals
Mussau				
Nae "Taowasa"	S 1.504°	E 149.731°	16–26 October 2014	Plants Butterflies Odonata Herpetofauna Birds Mammals
Lolieng "Eutangeu"	S 1.422°	E 149.510°	21–26 October 2014	Plants Butterflies Odonata Herpetofauna Birds

Major results

Plant biodiversity of Mussau

The vegetation on the uplifted fossil coral terrace of Mussau is floristically rich with 243 plant species recorded during the rapid taxonomic inventory. Of these, six are new to science (*Garcinia* sp., 2 x *Phlegmariopsis* spp., *Pandanus* sp., *Phyllanthus* sp., and *Bikkia* sp.). The central and largest part of Mussau is of igneous origin and still needs to be surveyed which will no doubt more than double the number of plant species for the island. There are still large areas on Mussau Island that are covered in undisturbed rainforest and it is these areas which may become a future target for logging companies. Additionally, potential mineral exploration, especially the drilling and associated destruction of areas of forest will potentially cause long-term negative effects on the environment specifically in areas with high clay content in the soil. These areas are associated with the central igneous complex situated in the middle of the island.

Butterfly biodiversity of Mussau

47 butterfly species were encountered during the survey, 22 of which were previously unrecorded from the island. Approximately equal diversity was encountered at each of the two survey sites. The early stages of several species were recorded for the first time. One species, *Papilio demoleus*, represents a potential threat to cultivated *Citrus* on Mussau Island. Potential threats to the butterflies of Mussau Island include logging and displacement of native vegetation and food plants by invasive plant species, as well as degradation of suitable butterfly habitats by pigs. Any future logging should be approached with caution and be well planned in order to preserve large tracts of original forest, or at least allow secondary forest to attain maturity. Eradication of pigs is a global challenge but on Mussau Island, a community effort to contain pigs within domestic confines would benefit the forest and its resident butterflies.

Odonata of Manus and Mussau

A total of 21 species of Odonata were documented from Manus and Mussau Islands, comprising 9 damselflies and 12 dragonflies. Nineteen of the 21 species were found on Manus and 12 were found on Mussau. One damselfly species in the genus *Drepanosticta* (family Platystictidae) from Manus Island is new to science. No species listed by the IUCN as Data Deficient, or in any threatened category, was detected. The odonate fauna of both Manus and Mussau islands is dominated by widespread species, a feature common to remote oceanic islands. However two species of damselflies, the recently described *Nososticta manuscola* Theishinger and Richards (in press) and the new *Drepanosticta* reported for the first time here, appear to be endemic to Manus Island. Management of the forests in central Manus to ensure long-term persistence of the clear streams and riparian vegetation inhabited by the two endemic species is a high conservation priority. Surveys of the interior of Mussau Island should also be conducted to determine whether additional, and potentially new and endemic, species occur there away from the coastal fringe.

Herpetofauna of Manus and Mussau

A total of 40 species of herpetofauna were documented from Manus and Mussau Islands, comprising 11 frogs and 29 reptiles. No species listed by the IUCN as Data Deficient, or in any threatened category, was detected but at least three frogs (*Cornufer* spp.) and one reptile (*Gehyra* sp.) encountered during the survey are new to science (two frogs on Manus, one frog on Mussau and one lizard shared by both islands). Additional studies of a further five reptile species are required to confirm their taxonomic status. The reptile fauna of both Manus and Mussau islands is dominated by widespread species with only five (17%) of the 29 species found being endemic to the Manus group, to Mussau, or to the two island groups combined. In contrast the frogs show an exceptionally high level of endemism with eight of the eleven species encountered (73%) known only from the Manus Island group or from Mussau Island. The major conservation priority for both islands is to encourage the development of management plans that minimise the impacts of broad-scale clearing on local forest-dwelling species.

Birds of Mussau

The distinct avifauna of the St Matthias Islands in the Northern Bismarck Sea is recognised with its status as an Endemic Bird area and Key Biodiversity Area due to the occurrence of at least two endemic species and 15 endemic sub-species. Despite this recognition the island is seldom visited and the avifauna remains little studied. A total of 45 species were recorded during the survey, with 33 of these being land birds including three endemics (the Mussau Fantail *Rhipidura matthiae,* Mussau Monarch *Symposiachrus menckei* and Mussau Flycatcher *Myiagra hebetior*). While the survey recorded 40 resident species it did not find a further ten species that have previously been recorded as resident. The status of the Russet-tailed Thrush *Zoothera heinei eichhorni*, Mussau Flycatcher, and Mussau Triller *Lalage conjuncta* as species needs to be undertaken against established quantitative criteria to verify the species/sub-specific status of these three forms and establish whether in light of current information a petition should be submitted to the IUCN to reclassify the threat status of these species. Additionally, given our failure to find the Mussau Triller a team should endeavour to return Mussau Island to undertake further work on the distribution and conservation status on this species, which based on the current survey is potentially very rare and restricted to higher altitude areas or localised areas of the island.

Mammals of Manus and Mussau

The mammal fauna of Manus and Mussau Islands was investigated with a view to extending the inventory of species and establishing the current status of several previously known and potentially rare species. Targeted searches for a previously recorded but unnamed endemic rat species failed to find evidence of its survival, although a disused burrow complex located on Mt Sabomu was probably dug by this species. No native ground mammals were found on Mussau Island though two introduced species were confirmed present: the Pacific Rat *Rattus exulans* and a Spotted Cuscus *Spilocuscus* sp. (*maculatus* group). Three bat species were added to the fauna of Manus, two of them identified from acoustic recordings (with the potential for three more pending further study). Overall, fifteen species of bats were recorded or captured on Mussau Island, ten of them new for the island. The final tally of echolocating call types on Mussau was ten, increasing the known echolocating bat faunal richness by eight species, from the previous total of just two species. Of the vouchered bat species at least one is new to science (*Pteropus* sp.), while two others are likely new to science (*Hipposideros* sp. 2 and *Nyctimene* sp. 2) either as full species or well-defined subspecies. Conservation priorities for both islands include further searches for the unnamed endemic rat and more targeted surveys for some of the most elusive bat species.

Mussau: additional notes

While the survey focused on species aligned to the taxonomic expertise of the team, two species on Mussau deserve notable mention: Green Turtles *Chelonia mydas*, and Coconut Crabs *Birgus latro*. Both the inshore areas of Nae and Lolieng appear to supported large populations of Green Turtle with several members of the team reporting large numbers surfacing. An underwater video taken by N. Whitmore on 24 October 2014 shows three individuals within ~20m of each other and allowed accurate identification to species level. Large coconut crabs were seen on corraline escarpments and within caves. One photographed specimen was estimated to have a span of ~55 cm in a relaxed state and the local assistants who witnessed it claimed, while big, it did not qualify as large by village standards.

Table 1. Overall summary of species detected during the course of the 2014 biodiversity survey.

Taxon	Manus		Mussau	
	Total species	New/Undescribed	Total species	New/Undescribed
Plants	-	-	243	6
Butterflies	-	-	47	0
Odonata	21	1	12	0
Herpetofauna	22	4*	20	2*
Birds	-	-	45	0
Mammals	18	0	12	1
SUB TOTAL	**61**	**5**	**379**	**9**
GRAND TOTAL OF NEW OR UNDESCRIBED SPECIES				**13**

**Gehyra* sp. shared between both islands

Key conservation recommendations

This survey demonstrates that the islands of Manus and Mussau hold high biodiversity values and are appropriately identified as key biodiversity areas in Papua New Guinea and within the wider Melanesia region.

Manus Island

Central Manus currently possesses a large intact area of rainforest which helps ensure its high biodiversity. However, the retention of such a forest is not guaranteed and logging initiatives, in different guises, are being tabled with some regularity. Logging of the central forest will result in the loss of biodiversity and will push a number of threatened species closer to extinction (especially the elusive Superb Pitta *Pitta superba,* Manus Masked Owl *Tyto manusi* and Manus Melomys *Melomys matambuai*). Of particular concern is the, as yet unnamed, large *Rattus* species which appears to be extremely rare and seldom encountered even in intact habitat.

The low abundance we observed for rodents and bandicoots on Manus has clear ramifications for the subsistence harvest of Admiralty Cuscus. Given that there are no alternative prey in any great quantity precautions must be made to ensure the harvest of Admiralty Cuscus is sustainable.

Our primary recommendations are:

1. The central forest of Manus be formally recognised by government for its biodiversity and ecosystem importance and support be given to plans and initiatives to retain it.

2. Incentives be developed to benefit communities who seek to retain their forests.

Our secondary recommendations are:

1. The species most at risk of extinction and in need of research is the unnamed, large *Rattus* species.

2. The Admiralty Cuscus is the priority species requiring the development of sustainable management.

Mussau Island

Mussau lost much of its primary rainforest during the last decades of the twentieth century. While our surveys recorded a comparatively large number of new species for the island this should not be misinterpreted as a claim that deforestation has had no effect, but rather its effect now cannot be measured. Due to a lack of any "before" survey we have no way of knowing exactly what impacts deforestation had, and whether or not certain species were adversely affected. Additionally, we deliberately focused our searches within the more intact portions of the Mussau forest and consequently our findings are unlikely to be representative of the island as a whole. Our inability to detect the Mussau Triller (potentially a distinct species in itself) is concerning and warrants closer investigation.

It is clear that by following the Seventh Day Adventist dietary laws the population of Mussau have relieved certain species such as green turtle, bats and coconut crabs from harvesting pressure, and as a result these species have benefited substantially by becoming numerous and, in the case of coconut crabs, attaining a particularly large size. The corollary of such dietary laws is that pigs are not subjected to intense hunting pressure and as a result are a major pest species on the island.

Our primary recommendations are:

1. A plan needs to be enacted to ensure the forests of Mussau are allowed to rehabilitate, and if any future logging is undertaken it adheres to strict provisions with proper benefit distribution to the impacted communities.

2. Pigs are a known agricultural and, likely, conservation pest for the island. Initial research needs to be undertaken to establish the true scale of the problem.

Our secondary recommendations are:

1. In order to complete a good overview of biodiversity the interior of Mussau should be surveyed, along with surrounding marine and coastal habitats.

2. The Manus Triller should be the priority for future surveys and research.

Plate 1. A. Location of Manus and Mussau Islands in relation to mainland Papua New Guinea. B. Location of camps on Manus Island. C. Location of camps on Mussau Island.

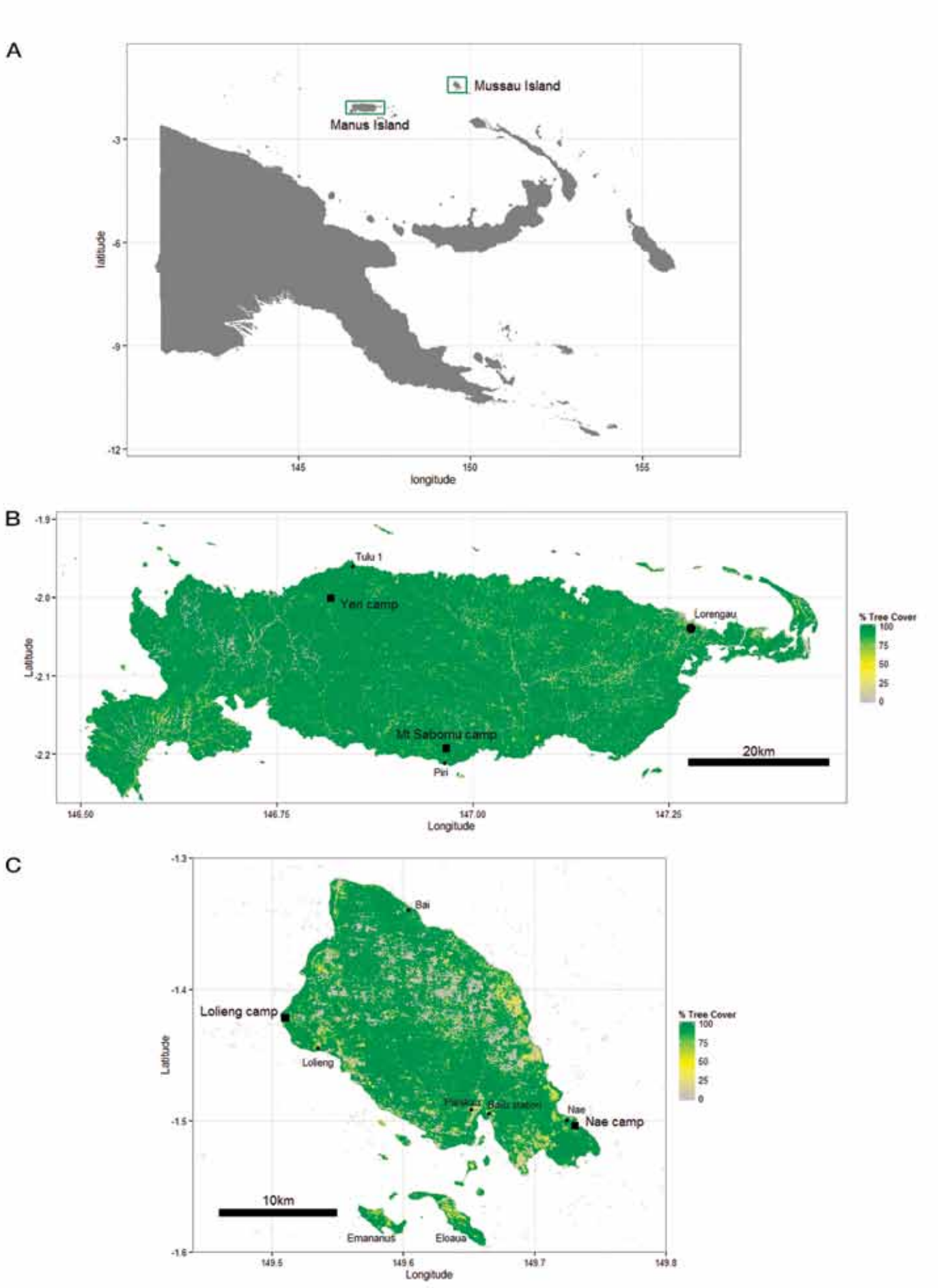


Plate 2. Manus environs

Typical habitat Mt Sabomu credit Stephen J. Richards

Survey team Mt Sabomu Camp credit Anon

Yeri Camp credit Stephen J. Richards

Piri base for Mt Sabomu Camp credit Nathan Whitmore

View from Mt Sabomu credit Nathan Whitmore

Plate 3. Mussau environs

Lolieng village credit Nathan Whitmore

Nae Camp credit Nathan Whitmore

Coralline terrrain near Lolieng Camp credit Nathan Whitmore

Coastal vegetation Nae Camp vicinity credit Nathan Whitmore

Mangrove forest Lolieng Camp credit Nathan Whitmore

Coralline terrace Nae Camp vicinity credit Nathan Whitmore

Plate 4. Plants

Pandanus sp. nov. credit Fanie Venter

Bikkia sp. nov. credit Fanie Venter

Garcinia sp. nov. credit Fanie Venter

Phlegmariurus sp. nov. credit Fanie Venter

Plate 5. Butterflies

A freshly emerged male of *Papilio demoleus* credit Chris Müller

A mature larvae of *Hypochrysops scintillans*, with attendant ant credit Chris Müller

Hypochrysops scintillans credit Chirs Müller

The eggs of *Hypolimnas pithoeka* credit Chirs Müller

The Camouflaged pupa of the invasive *Papilio demoleus* credit Chris Müller

A distinctive new subspecies of *Danis danis* - female shown credit Chris Müller

Plate 6. Odonates

Archibasis mimetes credit Stephen J. Richards

Drepanosticta sp. nov. credit Stephen J. Richards

Nesoxenia mysis credit Stephen J. Richards

Rhyothemis resplendens credit Stephen J. Richards

Plate 7. Herpetofauna

Cyrtodactylus sp. credit Stephen J. Richards

Cornufer sp. nov. 1 credit Stephen J. Richards

Hypsilurus schoedei credit Nathan Whitmore

Plate 8. Birds

Gallicolumba beccari eichhorni - Bronze Ground Dove
credit Richard Cuthbert

Rhipidura mattihae - Mussau Fantail
credit Richard Cuthbert

Monarcha cinerascens perpallidus - Island Monarch
credit Richard Cuthbert

Symposiachrus menckei - Mussau Monarch
credit Richard Cuthbert

Zoothera heinei eichhorni Russet-tailed Thrush
credit Richard Cuthbert

Todiramphus chloris matthiae -Collared Kingfisher
credit Richard Cuthbert

Plate 9. Mammals

Hipposideros sp. 2 credit Ken Aplin

Macroglossus minimus credit Stephen J. Richards

Nyctimene sp. 2 credit Ken Aplin

Kerivoula myrella credit Stephen J. Richards

Team collecting bats from Nae cave credit Nathan Whitmore

Spilocuscus kraemeri credit Nathan Whitmore

Introduction

Nathan Whitmore

Summary

The relatively remote islands of Manus and Mussau, located in the northern portion of the Bismark sea have been long identified as key biodiversity areas in Papua New Guinea and within greater Melanesia. Manus Island has long been known for its endemism and relatively intact forest, while Mussau Island, although relatively unstudied, has been recognised as an endemic bird area.

This report documents the findings of a series of rapid biodiversity surveys encompassing four sites across the islands of Manus and Mussau; undertaken by a team of national and international taxonomic specialists in October 2014. The scientific surveys were accompanied by follow up participatory community engagement work to identify the pressures currently faced by the communities, the risks they perceived to their environment, and the identification of natural resources issues[1] . In addition, the survey team was accompanied by two scientists from the Papua New Guinean Institute of Medical Research who sampled animal specimens for zoonotic (animal bourne) diseases and parasites[2].

Owing to previous research on plants and birds conducted by WCS on Manus the 2014 survey focused on mammals, herpetofauna (reptiles and amphibians) and the odonate family (i.e. dragonflies and damselflies). Given the sparse historic species records for Mussau the survey team was supplemented with additional experts and focused on a wider range of taxa: mammals, herpetofauna, birds, plants, and two insect groups (butterflies, and odonates).

The objective of this report is to document the biodiversity uncovered during this particular set of surveys so as to form a baseline. It is envisaged that this document, in conjunction with participatory community work conducted prior to, and following the surveys will help identify options for natural resource management in the region which address both community and biodiversity needs.

Manus Island

Manus Island (here after referred to as Manus) is a 1,900 km^2 densely forested island of volcanic origin to the north of Papua New Guinea (PNG). The island has been consistently identified as a high biodiversity area and a priority for conservation (Beehler 1993; Lipsett-Moore et al. 2010; Aalbersberg et al. 2012)

Manus Island is over 230 km from the nearest significant land (Mussau Island) and is currently believed to have been settled at some time prior to 13,000 BP (Fredericksen, etal, 1993) with occupation by the Lapita culture occurring between 3000- 2100 years BP (Specht and Gosden 1997).

The inhabitants of Manus have been exposed to comparatively high degree of western influence having been annexed by Germany in 1884, and during World War II it was estimated that over a million soldiers passed through the island (Minol 2000). Despite this exposure to the Western world, the people of Manus maintain many of their cultural practices, including their indigenous languages, of which more than 30 survive today (Minol 2000). The majority of the resident Manusians have a subsistence lifestyle and are concentrated in the interior of the eastern half of the island with the balance distributed in small coastal villages around the island (Hide et al. 2002). Manusians identify themselves as Christian with communities aligned to a variety of denominations.

While the island, especially the central portion, remains densely forested Shearman et al. (2008) has estimated ~ 10% of the forest on Manus Island had been removed through forestry between 1972 and 2002 with a total of ~32 % of forest being deforested or degraded over the same period. While forestry has slowed in recent times forest clearance is an ongoing threat with proposed logging, mining, road development and agro-forestry developments currently being tabled and promoted under different guises.

WCS has been working extensively with the communities of central Manus since 2010. Many of these communities have expressed a desire to retain their forests, and are actively engaging with WCS to plan for the ongoing sustainable use of their environment.

1 the outcome of this community engagement work is summarised in another report.

2 PNGIMR portion of the work was funded independently of the CEPF grant, and their research is beyond the scope of this document.

Mussau Island

The Mussau Group also known as the St. Matthias Group lies about 160 km north-west of Kavieng, New Ireland on the northern arc of the Bismarck Archipelago, part of the New Ireland Province of Papua New Guinea. The island group is dominated by a large, high island possessing a spine of volcanic origin (today called Mussau, although traditionally unnamed) which is about 30 km long, 15km wide, and rises to a peak of 650 m. The main island of Mussau is recognised as a high biodiversity area having been classified as an Endemic Bird Area (Birdlife International 2015) and as a Key Biodiversity Area (Aalbersberg et al. 2012). On the south side of Mussau are a number of smaller, lower islands which are uplifted reefs; the largest of which are Eloaua and Emanaus.

The archaeology of Mussau is well studied (Steadman and Kirch 1998). The St. Matthias Group group is currently believed to have been first occupied by a wave of the Lapita culture which established settlements possibly as early as 1600 BC until 800 BC at which point there is a gap in the archaeological evidence until the appearance of a post-Lapita culture around 500 AD (Kirch 2001). The island is now inhabited by Austronesian-language speakers who abandoned their traditional culture upon conversion by the Seventh Day Adventist (SDA) mission church in the 1930s (Brownie & Brownie 2007). During the war the Japanese over-ran Mussau and used it as a stepping stone, together with Emirau, for their advance on Rabaul (Hare 1956).

The inhabitants of St Matthias group are matrilineal and speak a single language known as Mussau-Emira, of which 5,000 speakers are thought to exist and of which 3,500 are estimated to be in the island group at any given time (Brownie and Brownie 2007).

The inhabitants of the region are dispersed around the coast of the main island and on Eloaua and Emananus in the form of small villages. The local economy is oriented toward semi-traditional subsistence gardening and marine exploitation, with some cash-cropping of copra. Shifting cultivation continues to be limited to the periphery of the main island but is reported as being extensive across many of the smaller islands (Lepofsky 1992). The islanders remain entirely self-sufficient for all their basic needs, with there being no place to buy basic provisions of any type at any of the communities we visited during our surveys.

Historically, Mussau Island was covered in thick tropical rainforest. However, a succession of commercial logging operations over the latter half of the 20th Century have reduced primary forest cover on the island dramatically, leaving comparatively few areas of primary vegetation but substantial amounts of secondary vegetation.

As Seventh Day Adventists, the population follow the dietary laws of Leviticus, in which the consumption of shellfish, fish without scales, pigs, turtles, coconut crabs, fruit bats and cuscus, are prohibited. Large deposits of these species are found in archaeological middens thereby indicating they were, however, consumed historically.

Prior to the initial community engagement work undertaken for the biodiversity surveys WCS had no previous contact with the communities on Mussau, although, WCS had on occasion, been invited to the island. Beyond periodic ongoing interactions with the SDA ministry, historic logging operations, past exploratory and archaeological expeditions, and sporadic visits from boat based tourism (especially bird watchers) the islanders have no regular exposure to outsiders. In the lead up to WCS securing consent to work on the island some communities refused due to suspicion of our motives and a legacy of misunderstandings and a lack of community engagement by prior outside groups. For the communities who consented to our work and with whom we engaged this represents their first encounter with a conservation organisation.

Study locations

We established four base camps (Plate 1, Table 1). These were designed to encompass the greatest cross section of habitats that could be accessed by a large team on foot. Unfortunately, on Mussau, we were not able to establish a camp inland as only a handful of inland locations have a reliable water source and we were not able to secure consent to work in these particular areas during this expedition.

Conventions

Species threat status listings given in this report follow the abbreviation system of the IUCN Red List (http://www.iucnredlist.org): NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU =Vulnerable, EN = Endangered, CE = Critically Endangered.

For the sake of consistency with past literature in this document we retain the "e" prefix for some locations in the St Matthias group. Brownie and Brownie (2007) point out that many Mussau-Emira names have an initial "e" on maps, which reflects the locative marker, and the local name lacks this initial "e". Hence, Loaua is labelled Eloaua on maps, and Mananus as Emananus. Additionally, Emira is labelled as Emirau on many maps.

Table 1. Base camp locations

Camp	Latitude	Longitude	Dates	Taxon targeted
Manus				
Mt Sabomu	S 2.193°	E 146.967°	2–7 October 2014	Odonata Herpetofauna Mammals
Yeri	S 2.001°	E 146.819°	9–13 October 2014	Odonata Herpetofauna Mammals
Mussau				
Nae "Taowasa"	S 1.504°	E 149.731°	16–26 October 2014	Plants Butterflies Odonata Herpetofauna Birds Mammals
Lolieng "Eutangeu"	S 1.422°	E 149.510°	21–26 October 2014	Plants Butterflies Odonata Herpetofauna Birds

References

Aalbersberg, B., Avosa, M.,James, R., Kaluwin, C., Lokani, P., Opu, J., Siwatibau, S., Tuiwawa, M., Waqa-Sakiti, H. and Tordoff, A.W. 2012. Ecosystem Profile: East Melanesian Islands Biodiversity Hotspot. Critical Ecosystems Partnership Fund.

Beehler, B. 1993. Papua New Guinea Conservation Needs Assessment. Volume 2. The Biodiversity Support Program. Corporate Press Inc. Landover, Maryland, USA.

BirdLife International 2015. Endemic Bird Area factsheet: St Matthias Island. Downloaded from <<www.birdlife.org>> on 22/02/2015

Brownie, J. and Brownie, M. 2007. Mussau Grammar Essentials. Data Papers on Papua New Guinea Languages Volume 52. SIL-PNG Academic Publications. Ukarumpa, Papua New Guinea.Fredericksen, C., Spriggs, M., and Ambrose, W. 1993. Pamwak rockshelter: a Pleistocene site on Manus Island, Papua New Guinea. *In* M.A. Smith, M. Spriggs and B. Fankhauser (eds.). Sahul in Review: Pleistocene Archaeology in Australia, New Guinea and Island Melanesia. Pp 144-154.

Hare, R.E 1956. Mussau Co-operative Society. *Australasian Record and advent World Survey* 24: 1.

Hide, R.L., Allen, B.J., Bourke, R.M., Fritsch, D., Grau, R., Helepet, J.L., Hobsbawn, P., Lyon, S., Poienou, M., Pondrilei, S., Pouru, K., Sem, G. & Tewi, B. 2002. Agricultural Systems of Papua New Guinea Working Paper no 18: Manus Province. Australian Agency of International Development.

Kirch, P.V. 2001. A radiocarbon chronology for the Mussau Islands. *In* P.V.Kirch and N. Araho (eds.). Lapita and its Transformations in Near Oceania. Pp196-222.

Lepofsky D. 1992. Arboriculture in the Mussau Islands, Bismarck Archipelago. *Economic Botany* 46(2): 192-211.

Lipsett-Moore, G, E. Game, N. Peterson, E. Saxon, S. Sheppard, A. Allison, J. Michael, R. Singadan, J. Sabi, G. Kula and R. Gwaibo 2010. Interim National Terrestrial Conservation Assessment for Papua New Guinea: Protecting Biodiversity in a changing Climate; Pacific Island Countries Report No. 1/2010.

Minol, B. 2000. Manus from the legends to year 2000: A history of the people of Manus. UPNG Press, Port Moresby, Papua New Guinea.

Shearman, P.L., Bryan, J.E., Ash, J., Hunnam, P., Mackey, B. & Lokes, B. 2008. The State of the Forests of Papua New Guinea. Mapping the Extent and Condition of Forest Cover and Measuring the Drivers of Forest Change in the Period 1972-2002. University of Papua New Guinea, Port Moresby, Papua New Guinea.

Specht, J., and Gosden, C. 1997. Dating Lapita Pottery in the Bismark Archipelago, Papua New Guinea. *Asian Perspectives* 36 (2): 175-99.

Steadman, D.W. and Kirch, P.V. 1998. Biogeography and Prehistoric Exploitation of Birds in the Mussau Islands, Bismarck Archipelago, Papua New Guinea. *Emu* 98: 13-22.

Chapter 1:

Plants of Mussau Island

Fanie Venter and Arison Arihafa

Summary

WCS conducted a botanical survey of Mussau Island 16–26 October 2015. Prior to this current survey very little was known about the flora of the island. Here we describe the vegetation formations from two sites ranging from sea level to 180 m asl. The vegetation on the uplifted fossil coral terrace of Mussau is floristically rich with 243 plant species recorded during the rapid taxonomic inventory. Of these, six are new to science. The central and largest part of Mussau is of igneous orgin and still needs to be surveyed which will no doubt more than double the number of plant species for the island.

Introduction

There have been very few botanical collections made from Mussau in the past. The Danish *Noona Dan* expedition (1961-1962) from the University of Copenhagen was the first multidisciplinary expedition to Mussau Island. The expedition lasted a month with five members collecting botanical material (Hansen & Sandermann Olsen 1967). A number of plant specimens were also collected by members of archaeological expeditions to the St. Mathias Islands (Kirch 1987). But currently with so little known about the flora of Mussau Island we can merely say that the flora is essentially an extension of the East Malesian floristic zone (Van Steenis 1950; Van Balgooy 1971).

Historically, Mussau Island was covered in thick tropical rainforest. However, a succession of commercial logging operations operating from the 1980s onwards has reduced primary forest cover. Logging operations included the Singapore based United Timbers (1980s), the local landowner company Mussau Timbers, and the Malaysian owned Concord Pacific (1994-1997). As a consequence only a few large blocks of primary vegetation remain (most notably around Nae and Bai) but substantial amounts of secondary vegetation, now taller than 5m, have re-established in logged areas. However, substantial areas of the central and eastern portions of the island remain partially denuded or with low vegetation cover (Plate 1). Comparatively little deforestation has occurred since 2000, with tree cover gain exceeding loss over this period (Hansen et al. 2013).

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, 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. All plants in flower were collected, pressed and dried, as this was the first specific plant-collecting trip on the island. Fertile specimens of all taxa not known to the authors or those not well represented in herbarium collections, were also collected. Collections were field-packed in large strong plastic bags in 75% ethanol and sent for further drying and processing at Lae. 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 the Papua New Guinea National Herbarium by the authors. Family and generic assignments follow Kramer and Green (1990) and Brummit (1992) for ferns and lycophytes, de Laubenfels (1988) for gymnosperms and the Angiosperm Phylogeny Group (2003, 2009) for the angiosperms.

Study locations

Nae camp vicinity

Nae Village

The survey area stretched from sea level to the top of the fossil coral plateau at 115m altitude. This brittle fossil coral rock changes to a fine-grained limestone in areas where it was exposed to intense heat and pressure from the ultramafic rock. The vegetation varied from strand vegetation to coastal rainforest to closed evergreen woodland. A number of transects 20m wide and of various lengths were surveyed each day and all the plant species were recorded along these transects.

Road to Talu Nalu Beach
This road leads from the Village of Nae southwards to Talu Nalu Beach which was the main transport route of copra during the production years. The coral road has been taken over by pioneer plant species for approximately 40% of its surface area. Pioneer species include the sword fern *Nephrolepis hirsutula,* shrubs *Pipturus argenteus, Lasianthus sylvestroides* and the trees *Breynia cernua, Glochidion philippicum, Homalanthus novoguineensis, Macaranga polyadeni and Rapanea densiflora*.

Coconut Palms (*Cocos nucifera*) were planted in two areas near Nae village, the first close to Nae camp and directly behind the beach vegetation, and the other and much larger area at Talu Nalu Beach. The cement foundation of the plantation manager's house and scattered pieces of tractors indicate the location of the original buildings. A wooden pole structure built by fishermen is the only structure still standing. The beachfront vegetation at Talu Nalu Beach was recently slashed down over an area of approximately 300 x 50 m but the reason behind the action is unknown.

The original coconut plantation has been colonized by native vegetation to such an extent that in some areas it is difficult to imagine that it is only secondary forest that you are looking at. The composition and structure of this forest is only marginally different from that of the primary forest with the result that there is little difference in the number of fauna utilizing it for food and shelter.

Gardens above Nae camp
There are some 'Gardens' on top of the coral plateau west of Nae camp and directly above the fresh water spring. The vegetation was found to be quite disturbed directly around these gardens. The primary reason for the disturbance around the gardens was the enlarging of the gardens and also the removal of wood. There were signs of past fires here as this plant community normally has a lot of burnable material present year round.

Natural areas
The natural forest near Nae camp is classified as Admiralty Islands Lowland Rain Forest on fossilized coral rock (Mueller-Dombois 1998). The soil depth varied from 5 – 300 mm with the leaf litter layer under developed in most areas except in a few areas in the primary forest between Talu Nalu Beach road and the beach behind Nae camp and also in the forest northwest of Talu Nalu Beach. Most of this area is covered in three different vegetation types, and the plateau area in closed woodland.

Tall Coastal Strand Vegetation
Calophyllum inophyllum–Tournefortia sarmentosa–Scaevola taccada
This plant association showed two distinct zones (Müller-Dombois 1998). The first zone is exposed to the ocean and its resultant salt spray, and represented by the following tree species: *Barringtonia asiatica, Calophyllum inophyllum, Cocos nucifera, Cordia subcordata, Guettarda speciosa, Hernandia nymphaefolia, Pemphis acidula, Soulamea amara, Terminalia samoensis and Tournefortia sarmentosa.* Shrub speciesin this zone are: *Crinum asiaticum, Sophora tomentosa and Scaevola taccada* and the forbs *Dendrobium mussauense* (epiphyte) and *Truimfetta procumbens*.

The second zone is protected from salt spray and has a well-developed undergrowth or shrub layer growing in dense shade on fairly deep sand with a well-developed layer of leaf litter. This zone was represented by the tree species: *Calophyllum inophyllum, Cycas rumphii, Ficus indigofera,*and *Rapanea densiflora*; the shrubs *Alpinia oceanica* and *Cordyline fruticosa*, and the forb *Tacca leontopetaloides.*

Low Coastal Rainforest
Calophyllum europhyllum–Codiaeum variegatum–Alpinia oceanicum
Most of this forest association was found to still be intact except for a ~100 m wide and 600 m long area starting in the beach forest. The soil was a fairly deep sandy soil with scattered outcropping of coral rock. The layer of leaf litter was fairly well developed and up to 60 mm deep in some areas. There were no emergent species and the upper and mid tree stratum was represented by *Calophyllum euryphyllum, Callophyllum soulattri, Horsfieldia laevigata* and *Intsia bijuga*, the shrub stratum by *Alpinia oceanica, Codiaeum variegatum,* and *Polyscias macgillivrayi* and the ground stratum by *Nephrolepis hirsutula*. The most dominant vine was *Flagellaria indica*. The epiphyte flora was depauperate, with the occasional orchid species and the only fern was *Asplenium nidus*.

Tall Lowland Rainforest
Calophyllum–Garcinia–Ficus
This plant community covers the area of the coral cliff and the slopes above the cliffs at Talu Nalu Beach.The soil is a shallow (10–40 cm deep) light brown to dark reddish brown loam soil in between outcropping coral rock but there are areas of very little soil and full outcropping of coral rock with no soil present and plants growing in the rock cracks. The forest floor is in deep shade except in areas where there are forest gaps in various stages of regrowth.

The emergent genera in this forest are *Calophyllum, Ficus* and *Pommetia*. The vegetation is represented by the trees *Calophyllum euryphyllum, C. soulattri, C. vexans, Cerbera floribunda, Chionanthus ramiflora, Garcinia celebica, G. dioica, Ficus indigofera, laevigata* and *Syzygioum nemorale* with *Flagellaria indica* and *Rhaphidiphora novoguineensis* as the dominant vines, the shrubs *Ardisiaimperalis, Clerodendrum buchananii* and *Ixora amplifolia*, with the forb *Dianella nemorosa* and ferns *Asplenium macrophyllum, Diplazium esculentum, Humata deltoidea, Nephrolepis hirsutula* and *Ophioglossum pendulum*.

Tall Evergreen Woodland
Calophyllum europhyllum–Decaspermum fruticosum–Nephrolepis hirsutula
This woodland type was recorded covering most of the coral plateau above Nae camp. Superficially this woodland appeared

to be much drier than the surrounding forest but there were some scattered forest pockets throughout the area. The shallow compact soil and exposed conditions result in higher temperatures and light intensity, and this is reflected in the vegetation which is made up primarily of nanophylll species. Dominant tree species are *Decaspermum fruticosum, Rapanea densiflora, Garcinia hunsteinii, Cleistanthus* sp. nov.,and the dominant shrubs *Timonius timon,* and *Ixora amplifolia*. *Hoya gigas* and *Flagellaria indica* are the dominant climbers, with *Myrmecodia tuberosa* being the most common epiphyte and *Nephrolepis hirsutula* the most common fern species. The isolated forest patches are small in extent consisting of *Syzygium nemorale, S. rambutyense, Chionanthus ramiflora, Planchonella obovata, Horsfieldia laevigata, Proteum macgregorii, Pommetia pinnata,* and on the forest floor *Alpinia oceanicum* and the vines *Flagellaria indica* and *Piper caninum*.

Lolieng Camp
The natural forest at Lolieng camp is also classified as Admiralty Islands Lowland Rain Forest on fossilized coral rock (Mueller-Dombois 1998). The soil depth varied from 5–400 mm with the leaf litter layer well developed in most areas except in a few places where there was hardly any soil between the fossil coral rocks.

There were three distinct vegetation types recorded in the survey area around Lolieng camp: limestone coral cliff vegetation, mangroves and tall lowland rainforest.

Low Cliff Flora
***Syzygium furfuraceum–Rapanea densiflora–Bikkia* sp.nov.**
The coral cliffs vary in height from 15–60 m with 30m the average. The lower part of the cliff is devoid of vegetation as a result of the ever-present salt spray. Moving upwards from the spray zone *Bikkia* sp.nov. shrubs become established followed by *Rapanea densiflora* and later a few *Syzygium furfuraceum* plants with *Rapanea densiflora* forming a dense stand on top of the cliff. *Graptophyllum pictum* and *Ardisia imperialis* are the most dominant shrubs in this plant association with *Boea hemsleyana* and *Procris frutescens* forming dense populations on the bare coral rocks underneath the *Syzygium furfuraceum* trees.

Mangroves
The mangrove populations on Mussau Island are all small, typical of small Pacific Islands (Percival &Womersley 1975, Stemmernan 1981). The mangrove community at Lolieng camp is relatively small, ~5 ha in size and situated at the head of a tidal creek. There were no distinct mangrove species zones recorded, however the largest and tallest mangrove tree grew in the middle of the mangrove area. This plant community is fairly open for a mangrove community. The following were the tallest tree species: *Bruguiera gymnorrhiza, B. sexangula, Rhizophora apiculata, Heritiera littoralis* and *Xylocarpus granatum.* Shrubs included the following: *Ceriops tagal, Excoecaria agallocha, Pandanus* spp. and *Lumnitzera littoralis*. A single group of *Nypa fruticans* palms were recorded at the head of the creek and judging from the size of the plants this appears to be a recent introduction.

Tall Lowland Rainforest
Syzygium–Calophyllum–Garcinia
This type of rainforest covers the inland areas at Lolieng camp. The rocks are all fossil coral that occasionally form outcrops. The soil is mostly dark brown to reddish brown clay loam and varies from 5-400 mm thick. The layer of leaf litter also varies in thickness but is never thicker than 100 mm. The roots of the trees penetrate the porous coral rock to tap into the water reserves deeper down. In spite of the logging that took place in this area, there are still a good number of large and tall trees that survived the chainsaws; surprisingly even large specimens of *Calophyllum* and *Aglaia* have survived.
The emergent genera in this forest are *Calophyllum, Ficus* and *Pommetia*. The dominant tree species are *Syzygium furfuraceum, S. nemorale, Calophyllum euryphyllum, C. soulattri, Cerbera floribunda, Garcinia celebica, G. dioica, Ficus indigofera, Horsfieldia laevigata,* with *Flagellaria indica* and *Rhaphidiphora novoguineensis* as the dominant vines. Dominant shrubs are the following: *Ardisiaimperalis, Clerodendrum buchananii* and *Ixora amplifolia,* with the dominant forbs the following: *Dianella nemorosa* and the ferns *Asplenium macrophyllum, Diplazium esculentum, Humata deltoidea, Nephrolepis hirsutula* and *Ophioglossum pendulum* on the forest floor.

Species accounts

Species new to science

Clusiaceae *Garcinia* sp. nov. (Venter 15419)
A tree growing up to 16 m tall with prominent stilt roots. Bark smooth and dark brown. The branches spread horizontally. The leaves are thickly leathery and glossy dark green. The flowers are cream coloured. The fruit is fleshy and light yellow. Known from an isolated population at the upper end of the mangrove community at Lolieng camp. This is the first record of a *Garcinia* species growing in a mangrove community.

Lycopodiaceae *Phlegmariopsis* sp. nov. (Venter 15363)
High-level epiphyte with pendant stems and very stiff light green glossy leaves. Only three plants found in trees in the forest very close to the beach. This taxon is the most robust of all *Phlegmariopsis* species.

Lycopodiaceae *Phlegmariopsis* sp. nov. (Venter 15410)
High-level epiphyte with many branched pendulous stems with small light green leaves. Known from six plants growing in trees on the edge of the mangrove swamp at Lolieng camp.

Pandanaceae *Pandanus* sp.nov. (Venter 15420)
A Pandan with stems reaching up to maximum 4 m and stems up to 20 mm diam. The leaves are very hard and light green. The inflorescence bracts are pure white and the flowers whitish green. The fruit is succulent when mature and bright orange-red. Known from a small population growing in the mangrove community at Camp 2. A miniature *Pandanus* species.

Phyllanthaceae *Phyllanthus* sp.nov. (Venter 15334)
Tree up to 12 m tall with a stem DBH 30 cm. The bark is dark brown and flaking in long strips. The branches are erect-spreading. The leaves are light green but prominently glaucous below. The flowers are small and light yellow. It is the largest and tallest member of the genus. Occurs as scattered individuals along the coastal plateau at Nae camp.

Rubiaceae *Bikkia* sp.nov. (Venter 15413)
A many branched shrub up to 1 m tall. The bark is smooth and greyish brown. The leaves are thickly leathery, glossy green with a red midrib. The flowers are highly scented, white on the inside and pink on the outside. It is common on the coastal limestone cliffs at Lolieng camp. The size of the flowers and the size and shape of the calyx separates this taxon from all known species.

IUCN listed species

Table 1. IUCN Red Listed plant species on Mussau Island with their distribution status.

Species	IUCN Status	Distribution status
Intsia bijuga	Vulnerable	Common
Cycas rumphii	Near Threatened	Common
Aglaia sapindina	Least Concern	Common
Alstonia scholaris	Least Concern	Occasional
Barringtonia asiatica	Least Concern	Common
Bruguiera gymnorrhiza	Least Concern	Common
Bruguiera sexangula	Least Concern	Common
Bruguiera parviflora	Least Concern	Occasional
Calophyllum euryphyllum	Least Concern	Common
Calophyllum inophyllum	Least Concern	Common
Calophyllum peekelii	Least Concern	Occasional
Calophyllum soualattri	Least Concern	Common
Calophyllum vexans	Least Concern	Occasional
Ceriops tagal	Least Concern	Common
Diplazium esculentum	Least Concern	Common
Excoecaria agallocha	Least Concern	Occasional
Gnetum latifolium	Least Concern	Occasional
Heritiera littoralis	Least Concern	Occasional
Lumnitzera littoralis	Least Concern	Occasional
Lygodium microphyllum	Least Concern	Occasional
Nypa fruticans	Least Concern	Rare
Podocarpus neriifolius	Least Concern	Rare
Rhizophora apiculata	Least Concern	Common
Tacca leontopetaloides	Least Concern	Common
Xylocarpus granatum	Least Concern	Occasional

Vulnerable species (VU)

***Intsia bijuga* (Leguminosae)**

Intsia bijuga is one of the species targeted by the logging companies. In the survey area it is recorded as scattered specimens throughout, especially in the forest behind the beach. These plants all have crooked boles and are thus in little danger of being logged. Plants of *I. bijuga* growing in the tall forest at Lolieng camp have not been logged, presumably not having a large enough diameter and straight boles.

Near Threatened species (NT)

***Cycas rumphii* (Cycadaceae)**

This is a common species growing behind the strand vegetation at Nae camp. The seed was utilised as a food source in the past specifically as a source of starch but the preparation was a long and tiresome process and this practice has now been abandoned. No signs were found of the local people making use of the bark for medicinal purposes. No threat present at the moment.

Least Concern species (LC)

***Aglaia sapindina* (Meliaceae)**

Aglaia sapindina occurs as scattered individuals throughout the area with a good recruitment of young plants and seedlings. Specimens with a diameter of 30 cm are still common. No threats recorded at the moment. This is an occasional timber species and sold under the trade name 'Aglaia'. Logging Companies targeted this species in the past with all the tall specimens having been logged near Nae camp and Lolieng camp.

***Alstonia scholaris* (Apocynaceae)**

Only a few isolated specimens were recorded from the plateau area above Nae camp. Only young plants and seedlings were present with the adult specimens logged and sold under the trade name of 'White Cheesewood'. No threats present at the moment.

***Barringtonia asiatica* (Lecythidaceae)**

Recorded as a common species in the strand vegetation and together with *Calophyllum inophyllum* they are the largest trees on the beach. No threats present at the moment.

***Bruguiera gymnorrhiza* (Rhizophoraceae)**

Bruguiera gymnorrhiza specimens are restricted to the small mangrove community at Lolieng camp. The logging companies regard this as an occasional timber species. No signs of logging in the mangrove community were detected. No threats to this species at the moment.

***Bruguiera sexangula* (Rhizophoraceae)**

Bruguiera sexangula specimens are restricted to the small mangrove community at Lolieng camp. The resident population is stable with no threats being recorded.

***Bruguiera parviflora* (Rhizophoraceae).**

Bruguiera parviflora plants are restricted to the small mangrove community at Lolieng camp. The species population is stable with a balanced ratio of adult : young : seedlings. There are no threats present at the moment.

***Calophyllum euryphyllum* (Calophyllaceae)**

The strongly flattened 4-angled puberulent twigs, large and broad leaves with inconspicuous venation, flowers with four petals and puberulent ovary is diagnostic for this species (Stevens 1995). Only a limited number of fruiting specimens were recorded. No threats present at the moment.

***Calophyllum inophyllum* (Calophyllaceae)**

The largest tree recorded on the beachfront at Mussau Island. This is a common species of the strand vegetation and coastal forest. Stems and branches are usually covered in epiphytes (Orchids and ferns) and the primary host of the Mussau endemic epiphytic orchid *Dendrobium mussauense* (Ormerod 1997). This species is not under any threat at the moment in spite of the local people harvesting the inflorescences and flowers for use in festivities.

***Calophyllum peekelii* (Calophyllaceae)**

A very distinct species with its stout, strongly 4-angled twigs, large obovate to oblong lamina (85-170 mm long) with the apices rounded to retuse and the perceptually large fruit (45-70 mm diameter) (Stevens 1980). A few scattered specimens were recorded in the forest near Talu Nalu Beach at Nae camp. No threats present at the moment.

Calophyllum soulattri (Calophyllaceae)

A common species recorded throughout the forest but most of the mature specimens near Lolieng camp have all been logged with only the stumps remaining. This is a major export hardwood and is specifically targeted by logging companies. No present threats at the moment.

***Calophyllum vexans* (Calophyllaceae)**
Recognised by the flattened terminal bud, angled twigs and the lamina that is widest near the middle and the midrib prominent on the upper leaf surface and that narrows gradually from the base (Stevens 1974, 1980, 1995). A few scattered individuals recorded near Talu Nalu Beach (Nae camp) and the upper slopes at Lolieng camp. No threats present at the moment.

***Ceriops tagal* (Rhizophoraceae)**
Ceriops tagal plants are restricted to the small mangrove community at Lolieng camp. This species has a stable population at this locality with a balanced ratio between adult : young : seedlings. There are no threats present to this species at the moment.

***Diplazium esculentum* (Athyriaceae)**
A common fern species recorded at all the fresh water springs on the small coral escarp at Nae camp and at Lolieng camp. This species is popular as a 'greens' side dish with only the young leaves harvested. No direct threats present although there was one population recorded at a seepage area that was seen to be dying out as a result of opening of the forest at the seepage to build a 'garden'.

***Excoecaria agallocha* (Euphorbiaceae)**
Excoecaria agallocha specimens are restricted to the small mangrove community at Lolieng camp. The small population at this locality is structurally stable with a high number of young plants and seedlings especially on the drier parts of the mangrove area. There are no threats to this species at present.

***Gnetum latifolium* (Gnetaceae)**
Known from a few scattered populations near Lolieng camp. All plants recorded were adults with a few individuals fruiting having the fruit initially white turning pinkish when ripe. The leaves of this species are not edible but the fruit are, and the plant is only occasionally used for rope. No threats were recorded for this species.

***Heritiera littoralis* (Malvaceae)**
Heritiera littoralis specimens are restricted to the small mangrove community at Lolieng camp. The logging companies regard this species as an occasional timber species. No signs of logging were detected in the mangrove community. There are a few very large specimens growing in this community. No threats to this species at present.

***Lumnitzera littoralis* (Combretaceae)**
Lumnitzera littoralis specimens are restricted to the small mangrove community at Lolieng camp. The small population (30+ individuals) at this locality is structurally stable with a high number of young plants. There are no threats recorded for this species at the moment.

***Lygodium microphyllum* (Lygodiaceae)**
Only a small population of six plants was recorded at the spring near Nae Village. The population seems to be stable but it is situated next to the footpath leading up the hill and can be damaged if the local people need to open up the footpath by slashing the vegetation bordering the footpath.

***Nypa fruticans* (Arecaceae)**
A single group of *Nypa fruticans* palms was recorded at the head of the creek at Lolieng and judging from the size of the plants this appears to be a recent introduction.

***Podocarpus neriifolius* (Podocarpaceae)**
Only a few young trees with a diameter of 15-20 cm were recorded growing as scattered individuals on the flat area between the beach and small coral cliff of the plateau at Nae camp. This is a species of low montane rainforest and larger specimens will no doubt be growing on the slopes of the high peaks in the centre of the island. No threats were recorded as being present. This species is a popular softwood timber species sold under the trade name of 'Brown Pine' and is a target species for the logging companies.

***Rhizophora apiculata* (Rhizophoraceae)**
Rhizophora apiculata specimens are restricted to the small mangrove community at Lolieng camp. The logging companies regard this species as an occasional timber species but no signs of logging in the mangrove community were detected. There is no threat to this species at the moment.

***Tacca leontopetaloides* (Taccaceae)**
Tacca leontopetaloides is a common geophytic species growing on the forest floor behind the strand vegetation. There are large stable populations with many seeds being produced at the moment. Unlike other islands in the Pacific, the people of Mussau Island do not utilize the tuber as a food source. No threats were detected whilst doing the survey.

***Xylocarpus granatum* (Meliaceae)**
Xylocarpus granatum specimens are restricted to the small mangrove community at Lolieng camp. The logging companies regard this species as an occasional timber species but no signs of logging in the mangrove community were detected. There is no threat to this species at the moment.

Table 2. Exotic plant species recorded in the survey area.

Plant species	Food Plant	Ornamental Plant	Weed
MONOCOTS			
Amaryllidaceae			
Crinum latifolium		*	
Crinum xanthophyllum		*	
Hymenocallis speciosa		*	
Apocynaceae			
Allamanda cathartica		*	
Araceae			
Syngonium podophyllum		*	*
Asparagaceae			
Cordyline terminalis cv.*'Rouge'*		*	
Dracaena reflexa cv. *'Song of India'*		*	
Bromeliaceae			
Ananas comosus	*		
Cannaceae			
Canna indica		*	
Commelinaceae			
Tradescantia pallida cv..		*	
Dioscoreaceae			
Dioscorea nummularia	*		
Musaceae			
Musa acuminata cv. *'Lady Finger'*	*		
Apocynaceae			
Allamanda cathartica		*	
Calotropis gigantea		*	
Catharanthus roseus		*	
Araliaceae			
Polyscias scutellaria		*	
Asteraceae			
Sphagneticola trilobata (L.) Pruski			*
Balsaminaceae			
Impatiens walleriana X I. auricoma		*	
Caricaceae			
Carica papaya	*		
Cistaceae			
Cistus ladanifer		*	
Halimium lasianthum subsp. *formosum*		*	
Convolvulaceae			
Ipomoea batatas	*		
Euphorbiaceae			
Acalypha hispida		*	
Codiaeum variegata various cultivars.		*	
Euphorbia heterophylla			*
Euphorbia hirta			*
Euphorbia tithymaloides		*	
Manihot esculenta	*		

Plant species (cont)	Food Plant	Ornamental Plant	Weed
Lamiaceae			
Clerodendrum paniculatum		*	*
Orthosiphon aristatus		*	
Lagerstroemia indica		*	
Malvaceae			
Hibiscus rosa-sinensis		*	
Hibiscus schizopetalus		*	
Theobroma cacao	*		
Nyctaginaceae			
Bougainvillea spectabilis cv.		*	
Oxalidaceae			
Averrhoa carambola	*		
Polygalaceae			
Polygala paniculata			*
Rubiaceae			
Ixora coccinea		*	
Rutaceae			
Citrus maxima	*		
Citrus reticulata	*		
Murraya paniculata		*	
Salicaceae			
Flacourtia jangomas	*		
Solanaceae			
Capsicum annuum var. *glabriusculum*	*		
Urticaceae			
Pileamicrophylla			*
Verbenaceae			
Lantana camara			*
Lantana montevidensis		*	
Stachytarpheta cayennensis			*

Table 3. Checklist of the plant species recorded during the survey with their locality and IUCN status. † Indicates exotic species either as weeds or horticultural taxa.

Plant species	Nae Camp	Lolieng Camp	Nae Village	Lolieng Village	IUCN Status
FERNS AND LYCOPHYTES					
Aspleniaceae					
Asplenium polyodon		*			
Asplenium macrophyllum	*				
Asplenium nidus	*	*			
Athyriaceae					
Diplazium esculentum	*				LC
Davalliaceae					
Humata deltoidea		*			
Humata heterophylla	*				
Lycopodiaceae					
Huperzia phlegmaria	*				
Hymenophyllaceae					
Cephalomanes boryanum		*			
Hymenophyllum polyanthos		*			
Lygodiaceae					
Lygodium circinnatum	*				
Lygodium microphyllum	*				LC
Nephrolepidaceae					
Nephrolepis hirsutula	*	*	*	*	
Ophioglossaceae					
Ophioglossum pendulum	*	*			
Polypodiaceae					
Belvisia mucronata	*				
Ctenopteris sp.		*			
Microsorum linguiforme		*		*	
Microsorum scolopendria	*				
Myrmecophila sinuosa	*	*			
Prosaptia sp.		*			
Phymatosorus scolopendria	*				
Psilotaceae					
Psilotum complanatum		*			
Psilotum nudum	*	*			
Pteridaceae					
Acrostichum speciosum		*			
Antrophyum alatum		*			
Schizaeaceae					
Schizaea dichotoma		*			
Tectariaceae					
Tectaria mulleri	*	*			
Thelypteridaceae					
Pneumatopteris sogerensis		*			
Vittariaceae					
Vittaria elongata	*	*			
GYMNOSPERMS					
Cycadaceae					
Cycas rumphii	*				NT

Plant species (cont)	Nae Camp	Lolieng Camp	Nae Village	Lolieng Village	IUCN Status
Gnetaceae					
Gnetum latifolium		*			LC
Podocarpaceae					
Podocarpus neriifolius	*				LC
MONOCOTS					
Amaryllidaceae					
Crinum asiaticum	*	*			
†*Crinum latifolium*				*	
†*Crinum xanthophyllum*				*	
†*Hymenocallis speciosa*				*	
Araceae					
Amydrium zippelianum	*				
Epipremnum pinnatum	*	*			
Rhaphidophora neoguineensis	*	*			
†*Syngonium podophyllum*				*	
Arecaceae					
Caryota rumphiana	*				
Cocos nucifera	*	*	*	*	
Metroxylon sagu			*		
Nypa fruticans		*			LC
Asparagaceae					
Cordyline fruticosa	*	*			
†*Cordyline terminalis* cv.'Rouge'			*	*	
Dracaena angustifolia	*	*		*	
†*Dracaena reflexa* cv. 'Song of India'				*	
Bromeliaceae					
†*Ananas comosus*			*	*	
Cannaceae					
†*Canna indica*				*	
Commelinaceae					
†*Tradescantia pallida* cv.				*	
Cyperaceae					
Cyperus distans	*				
Dioscoreaceae					
†*Dioscorea nummularia*			*		
Flagellariaceae					
Flagellaria indica	*	*			
Musaceae					
†*Musa acuminate* cv. *'Lady Finger'*			*	*	
Orchidaceae					
Agrostophyllum lamellatum		*			
Appendicula reflexa		*			
Bulbophyllum longipedicellatum		*			
Bulbophyllum sp.		*			
Dendrobium bracteosum		*			
Dendrobium comatum		*			
Dendrobium lawesii		*			
Dendrobium mussauense	*				
Dendrobium schwartzkopfianum		*			
Grammatophyllum scriptum	*				

Plant species (cont)	Nae Camp	Lolieng Camp	Nae Village	Lolieng Village	IUCN Status
Orchidaceae cont.					
Liparis condylobulbon	*				
Luisia tristis	*				
Phreatia micrantha		*			
Phreatia stenophylla		*			
Spathoglottis papuana	*	*			
Pandanaceae					
Freycinetia ancistrosperma	*	*			
Freycinetia lanceolata		*			
Freycinetia manusensis		*			
Pandanus dubius	*	*			
Pandanus krauelianus	*	*			
Pandanus sp.nov.		*			
Pandanus tectorius	*	*			
Poaceae					
Cynodon dactylon		*	*	*	
Oplismenus compositus	*	*			
Sporobolus virginicus		*			
Smilacaceae					
Smilax australis	*	*			
Stemonaceae					
Stemona javanica	*				
Taccaceae					
Tacca leontopetaloides	*				LC
Xanthorrhoeaceae					
Dianella cf. D. ensifolia	*	*			
Zingiberaceae					
Alpinia oceanica	*	*	*		
DICOTS					
Acanthaceae					
Graptophyllum pictum		*			
Pseuderanthemum curtatum	*				
Anacardiaceae					
Buchanania macrocarpa	*	*			
Mangifera minor				*	
Apocynaceae					
†*Allamanda cathartica*			*	*	
Alstonia scholaris		*			LC
†*Calotropis gigantea*				*	
†*Catharanthus roseus*				*	
Cerbera mangas	*				
Cerbera floribunda	*	*			
Dischidia hirsuta		*			
Hoya gigas	*	*			
Marsdenia sp.	*				
Araliaceae					
Polyscias macgillivrayi	*	*			
†*Polyscias scutellaria*			*	*	
Asteraceae					
†*Sphagneticola trilobata* (L.) Pruski				*	

Plant species (cont)	Nae Camp	Lolieng Camp	Nae Village	Lolieng Village	IUCN Status
Balsaminaceae					
†*Impatiens walleriana* X *I. auricoma*			*	*	
Boraginaceae					
Cordia subcordata	*	*		*	
Tournefortia sarmentosa	*	*			
Burseraceae					
Proteum macgregorii	*				
Calophyllaceae					
Calophyllum euryphyllum	*				LC
Calophyllum inophyllum	*	*	*	*	LC
Calophyllum peekelii	*				LC
Calophyllum soulattri	*	*			LC
Calophyllum vexans	*	*			LC
Capparaceae					
Capparis callophylla	*				
Caricaceae					
†*Carica papaya*			*	*	
Casuarinaceae					
Casuarina equisetifolia	*				
Celastraceae					
Hippocratea sp.		*			
Cistaceae					
†*Cistus ladanifer*				*	
†*Halimium lasianthum* subsp. *formosum*				*	
Clusiaceae					
Garcinia sp.nov.		*			
Garcinia celebica	*	*			
Garcinia dioica	*				
Garcinia hollrungii	*				
Garcinia hunsteinii	*	*			
Combretaceae					
Lumnitzera littorea		*			LC
Terminalia catappa		*			
Terminalia samoensis	*				
Convolvulaceae					
†*Ipomoea batatas*			*	*	
Elaeocarpaceae					
Elaeocarpus sp.	*	*			
Escalloniaceae					
Polyosma integrifolia Blume	*	*			
Euphorbiaceae					
†*Acalypha hispida*			*	*	
Codiaeum variegatum	*				
†*Codiaeum variegate* various cultivars.			*	*	
†*Euphorbia heterophylla*				*	
†*Euphorbia hirta*				*	
†*Euphorbia tithymaloides*				*	
Excoecaria agallocha		*			LC
Homalanthus novoguineensis	*	*			
Macaranga polyadenia	*				

Plant species (cont)	Nae Camp	Lolieng Camp	Nae Village	Lolieng Village	IUCN Status
Euphorbiaceae cont.					
Macaranga tanarius	*				
†*Manihot esculenta*			*	*	
Gesneriaceae					
Boea hemsleyana		*		*	
Goodeniaceae					
Scaevola taccada	*	*			
Hernandiaceae					
Hernandia nympheafolia	*				
Lamiaceae					
Clerodendrum buchananii	*				
Clerodendrum inerme		*			
†*Clerodendrum paniculatum*			*	*	
Clerodendrum tracyanum	*	*			
†*Orthosiphon aristatus*				*	
Plectranthus scutellarioides	*		*	*	
Premna serratifolia		*			
Lauraceae					
Neolitsea brassii		*		*	
Cassytha filiformis		*			
Leguminosae					
Archidendron sp.	*	*			
Derris trifoliata		*			
Dendrolobium umbellatum		*			
Intsia bijuga	*	*			VU
Sophora tomentosa	*				
Vigna marina	*				
Lecythidaceae					
Barringtonia asiatica	*	*			LC
Barringtonia edulis		*	*	*	
†*Lagerstroemia indica*				*	
Loganiaceae					
Fagraea berteroana	*	*			
Strychnos minor		*			
Lythraceae					
Pemphisacidula	*				LC
Malvaceae					
Heritiera littoralis		*			LC
†*Hibiscus rosa-sinensis*			*	*	
†*Hibiscus schizopetalus*				*	
Hibiscus tiliaceus		*		*	
Sterculia ampla	*	*			
Sterculia shillinglawii	*				
†*Theobroma cacao*			*		
Triumfetta procumbens	*				
Meliaceae					
Aglaia sapindina	*	*			LC
Xylocarpus granatum		*			LC
Menispermaceae					
Stephania japonica	*				

Plant species (cont)	Nae Camp	Lolieng Camp	Nae Village	Lolieng Village	IUCN Status
Moraceae					
Ficus benjamina				*	
Ficus copiosa	*	*			
Ficus indigofera	*				
Ficus septica		*			
Ficus subulata	*	*			
Myristicaceae					
Horsfieldia laevigata	*				
Myrsinaceae					
Ardisia imperalis	*	*			
Rapanea densiflora	*	*			
Myrtaceae					
Decaspermum fruticosum	*	*			
Syzygium aqueum		*			
Syzygium nemorale	*	*			
Syzygium furfuraceum		*			
Syzygium rambutyense		*			
Syzygium sp.nov.		*			
Syzygium tiernayanum		*	*	*	
Nyctaginaceae					
†*Bougainvillea spectabilis* cv.				*	
Oleaceae					
Chionanthus ramiflorus Roxb.	*	*			
Jasminum sp.	*				
Opiliaceae					
Cansjera leptostachya	*	*			
Oxalidaceae					
†*Averrhoa carambola*			*	*	
Passifloraceae					
Adenia heterophylla		*		*	
Phyllanthaceae					
Antidesma excavatum var. *indutum*		*			
Breynia cernua	*	*			
Glochidion philippicum	*				
Glochidion sumatranum	*	*			
Phyllanthus sp.nov.	*				
Piperaceae					
Peperomia brassii		*			
Piper caninum	*	*			
Piper celtidiforme		*			
Pittosporaceae					
Pittosporum ferrugineum	*				
Polygalaceae					
†*Polygala paniculata*	*	*	*	*	
Primulaceae					
Ardisia imperalis	*	*			
Maesa haplobotrys		*			
Rapanea densiflora	*	*			
Rapanea umbellulata	*	*			

Plant species (cont)	Nae Camp	Lolieng Camp	Nae Village	Lolieng Village	IUCN Status
Rhizophoraceae					
Bruguiera gymnorhiza		*			LC
Bruguiera sexangula		*			LC
Bruguiera parviflora		*			LC
Ceriops tagal		*			LC
Rhizophora apiculata		*			LC
Rubiaceae					
Bikkia sp.nov.		*			
Guettarda speciosa	*				
Ixora amplifolia	*	*			
†*Ixora coccinea*				*	
Lasianthus sylvestroides	*	*			
Morinda citrifolia	*	*	*	*	
Myrmecodia tuberosa	*	*			
Nauclea orientalis		*			
Neonauclea sp.		*			
Tarenna sambucina var. *buruensis*	*	*			
Timonius timon	*	*			
Rutaceae					
†*Citrus maxima*			*	*	
†*Citrus reticulata*				*	
Melicope burttiana	*	*			
Micromelum minutum		*			
†*Murraya paniculata*				*	
Salicaceae					
†*Flacourtia jangomas*				*	
Sapindaceae					
Pometia pinnata	*	*			
Pometia tomentosa	*	*			
Solanaceae					
†*Capsicum annuum* var. *glabriusculum*			*	*	
Sapotaceae					
Planchonella obovata	*	*			
Simaroubaceae					
Soulamea amara	*				
Strychnaceae					
Strychnos minor	*				
Urticaceae					
Elatostema novoguineense	*	*			
Leucosyke australis		*			
†*Pilea microphylla*				*	
Pipturus argenteus	*				
Procris frutescens		*			
Verbenaceae					
†*Lantana montevidensis*				*	
†*Stachytarpheta cayennensis*			*	*	
Vitacea					
Leea indica	*	*			
Tetrastigma lauterbachianum	*				

Discussion

Due to logistic and consent restrictions there was no survey of the vegetation of the larger igneous interior of the island during this survey. A comparison of the Mussau flora with those of the rest of the Bismarck Archipelago and mainland Papua New Guinea will be dependent on such a survey.

The Australian company MIL Resources Ltd. has the Exploration title ELA 1818 registered over the whole Mussau Island (1,051 km^2) to carry out exploration for gold (MIL Resources 2010). Previous geological exploration work has been conducted on Mussau Island by CRA (1969-70) Kennecott – Niugini Mining (1984-85) and BHP-Auralia (1986-87). Titan Metals Ltd. is planning a low level airborne magnetic survey followed by surface work and drilling in the near future. The exploration, especially the drilling and associated destruction of areas of forest, will potentially cause long-term negative effects on the environment specifically in areas with high clay content in the soil. These areas are associated with the central igneous complex situated in the middle of the island.

It was very interesting to note the lack of knowledge of the local population regarding edible and medicinal native plant species. In spite of living so far from shops, medicinal and edible plants play a small role in the lives of people in the villages near the two camps although 26 native tree species are cultivated in tree gardens in villages for both food and non-food purposes (Lepofsky 1992). According to a number of people at Lolieng, medicinal plants played a prominent role in society 20 or more years ago.

Logging in the past concentrated on the areas close to the coast and on the coralline plateau that stretches around the island to the base of the volcanic mountains in the middle of the island. The vegetation in the logged areas showed signs of secondary damage to surrounding vegetation where target specimens were logged. Under normal circumstances when a tree is felled an area of surrounding vegetation the height of the tree and width of its canopy is damaged (Woods 1989, Alder 1998, Shearman et al. 2008). The impact of logging roads on the surrounding vegetation could clearly be seen in the drier type of vegetation flanking the roads. This type of vegetation also becomes more prone to fire damage (Shearman et al. 2008). There are still large areas on Mussau Island that are covered in undisturbed rainforest and it is these areas which may become a future target for logging companies.

Recommendations

A survey of the vegetation on the igneous centre of the island is necessary before one can discuss the general biogeography of the various flora elements. The Danish *Noona Dan* expedition (1961-1962) concentrated their botanical efforts on the coral limestone areas in the northern part of the island but they did make some collections in the rainforests on the slopes of Mt. Taleanuane (Hansen & Sandermann Olsen 1967). The vegetation of the greater part of Mussau has thus never been collected or surveyed. Vegetation on igneous substrates also tend to be far more biodiverse than the vegetation on coral limestone on Pacific Islands. Additionally, it is likely logging had a comparatively minor impact on much of this area. Consequently, in terms of understanding the botantical values of Mussau a survey of the island interior is a priority.

References

Alder, D. 1998. PINFORM: A growth model for lowland tropical forests in Papua New Guinea. Forest Research Institute, Lae. ITTO/PNG Project PD 162/91, Consultancy Report. Global Invasive Species Database. 2013.

Angiosperm Phylogeny Group 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* 141: 399–436.

Beehler, B. and Alonso L.E. (eds.). 2001. Southern New Ireland, Papua New Guinea: A Biodiversity Assessment. RAP Bulletin of Biological Assessment 21. Conservation International. Arlington, Virginia.

Brummitt, R. K. (comp.) 1992. Vascular Plant Families and Genera. Royal Botanic Gardens, Kew.

de Laubenfels, D.J. 1988. Coniferales. *Flora Malesiana Series I* 10: 337–453.

Hansen, B. & Sandermann Olsen, S.E. 1967. Botanical Report of the Danish Noona Dan Expedition 1961–62 to the Philippines, the Bismarck Archipelago, and the Solomon Islands. *Dansk botanisk arkiv* 25(2).

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., & Townshend, J.R.G. (2013) High-resolution Global Maps of 21st-Century Forest Cover Change. *Science* 342: 850–853.

Kirch, P.V. 1987. Lapita and Oceanic Cultural Origins: Excavations in the Mussau Islands, Bismarck Archipelago, 1985. *Journal of Field Archaeology* 14(2): 163–180.

Kramer, K.U. and P. S. Green 1990. The families and genera of vascular plants. *In* K.U. Kramer and Green, P.S. (eds.). Volume 1, Pteridophytes and Gymnosperms. Springer-Verlag, Berlin. Pp 68–74.

Lepofsky, D. 1992. Arboriculture in the Mussau Islands, Bismarck Archipelago. *Economic Botany* 46(2): 192–211.
MIL Resources 2010.<<www.milresources.com/files/pdf/news/MIL_news_100831.pdf>> (accessed: 22.11.2014).
Mueller-Dombois, D. 1998. Vegetation of the Tropical Pacific Islands. Springer.
Ormerod, P. 1997. *Australian Orchid Review* 62(3): 13.
Percival, M. and Womersley, J.S. 1975. *Floristics and Ecology of the Mangrove Vegetation of Papua New Guinea.* Botany Bulletin No. 8, Department of Forests. Division of Botany, Lae.
Ridsdale, C. E. 2000. Trees of the Wapoga River Area, Irian Jaya, Indonesia. *In* A.L. Mack and L.E. Alonso (eds.). A Biological Assessment of the Wapoga River Area of Northwestern Irian Jaya, Indonesia. RAP Bulletin of Biological Assessment 14. Conservation International. Arlington, Virginia.
Shearman, P., Bryan, J., Ash, J., Hunnam, P., Mackey, B. & Lokes, B. 2008.The State of the Forests of Papua New Guinea. Port Moresby.
Stemmermann, L. 1981. A guide to Pacific wetland plants. U.S. Army Corps of Engineers, Honolulu, Hawaii.
Stevens, P.F. 1974. A Review of *Calophyllum* L. (Guttiferae) in Papuasia. *Australian Journal of Botany* 22(2): 349–411.
Stevens, P.F. 1980. A Revision of the Old World species of *Calophyllum* (Guttiferae). *Journal of the Arnold Arboretum* 61(2): 575.
Stevens, P.F. 1995. Guttiferae. *Handbook of the Flora of Papua New Guinea* 3: 61–112.
Takeuchi, W. 1998. Botanical Survey of the Lakekamu basin, Papua New Guinea. *In* A. Mack (ed.). A Biological Assessment of the Lakekamu basin, Papua New Guinea. RAP Bulletin of Biological Assessment 9. Conservation International. Arlington, Virginia.
Takeuchi, W. 2007. Vascular plants of the Kaijende Highlands, Papua New Guinea: taxonomic and vegetation survey. *In* S.J. Richards (ed.). A Rapid Biodiversity Assessment of the Kaijende Highlands, Enga Province, Papua New Guinea. RAP Bulletin of Biological Assessment 45. Conservation International. Arlington, Virginia. Pp 25–39.
Takeuchi, W. 2011. Vascular plants of the Strickland Basin, Papua New Guinea: taxonomic and vegetation survey. *In* S.J. Richards and B.G. Gamui (eds.). A Rapid Biodiversity Assessment of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments. RAP Bulletin of Biological Assessment 60. Conservation International. Arlington, Virginia. Pp 119-157.
Van Balgooy, M.M.J. 1971. Plant geography of the Pacific. *Blumea* Suppl 6:1–222.
Van Steenis, C.G.G.J. (ed.) 1950. The delimitation of Malaysia and its main plant geographical distributions. *Flora Malesiana* 1(1).
Woods, P. 1989. Effects of Logging, Drought, and Fire on Structure and Composition of Tropical Forests in Sabah, Malaysia. *Biotropica* 21(4): 290–298.

Chapter 2:

Butterflies of Mussau Island (Lepidoptera: Rhopalocera)

Chris J. Müller

Summary

Mussau Island, New Ireland Province, Papua New Guinea (PNG), is very poorly known from a biological perspective. A terrestrial biodiversity study was undertaken by Wildlife Conservation Society (WCS) in October, 2014, to document the diversity of various animal and plant orders and determine any anthropogenic impacts on their ecology. This report documents the results from the survey of butterflies at two camp sites and surrounding areas, situated at the eastern and western extremities of the island.

We encountered 47 butterfly species during the survey, 22 of which were previously unrecorded from the island. Approximately equal diversity was encountered at each of the two survey sites. The early stages of several species were recorded for the first time. One species, *Papilio demoleus*, represents a potential threat to cultivated *Citrus* on Mussau Island.

Potential threats to the butterflies of Mussau Island include logging and displacement of native vegetation and food plants by invasive plant species, as well as degradation of suitable butterfly habitats by pigs. Mitigations are proposed to minimise further impacts on butterfly populations.

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 1000 described butterfly species, of which approximately 840 are recorded from Papua New Guinea (PNG) (Tennent, 2006). Within the Bismarck Archipelago, approximately 300 species are recorded, the majority of which are restricted to either or all of the main islands (New Britain, New Ireland and New Hanover).

Mussau Island is the largest island within the remote St. Matthias group (Map 1) and is orientated northwest-southeast along its long axis and is approximately 30 x 15km. Several small satellite islands are situated off the south coast of Mussau Island. The island group is part of the strike extensive Tabar-Lihir-Tanga-Feni (TLTF) island arc chain composed essentially of alkaline volcanoes of Pliocene to Recent age (Kamenov 2004). Currently, travel by sea or airis the only way to reach Mussau Island. An airstrip is located on Emirau Island, approximately 30 km to the southeast of Mussau Island.

Mussau Island, and the St. Matthias group generally, has been poorly studied for butterflies. Only one previous confirmed expedition to the St. Matthias group to survey butterflies is known, from that of A. F. Eichhorn during May - July 1924 (Tennent 2006). All of the specimens from this expedition are located in the Natural History Museum, London. A terrestrial biodiversity study of butterflies and various other groups was undertaken by WCS in October, 2014, to expand the knowledge. Survey sites were situated at both ends of the island along its long axis (Plate 1), allowing for comparison of localised geographical influences.

Methods

Nae Camp was located at the eastern end of the island, at sea level, within 200 metres of the coast and centred at S 1.504° and E 149.731° (Plate 1). It was within an old plantation, situated about 1 km to the southeast of the village. The vegetation at this site is essentially early to semi-advanced secondary regrowth. Butterfly searching transects were carried out over several kilometres, especially towards the eastern end of Mussau Island, including the far eastern extremity. Most of the forays were undertaken along pre-existing old logging roads, or along the coastline, but additional transects of limestone bluffs inland were also carried out. Several vegetation types were surveyed, including coastal littoral scrub, secondary forest that had been previously logged and primary, closed canopy rainforest in precipitous terrain. Significant tracts had been degraded and consisted of only a few introduced plant species. Temperatures recorded at this site ranged from 22.9 – 33.8°C, with humidity ranging from 55 – 82% (excepting occasional spells of rain showers).

Lolieng Camp consisted of two areas surveyed, including one at the very western extremity of the island, where the main camp was established (centred at S 1.422°, E 149.510°), while the other was conducted in the vicinity of Lolieng Village, on the south coast of Mussau Island (Plate 1). The two survey sites were approximately four km apart, but differed in their vegetational character. The camp site, though it had been logged previously, was essentially uninhabited bar for a periodic encampment where the survey team stayed. The camp was situated at the edge of a mangrove-lined estuary and lagoon. Extensive coastal littoral scrub fringed the beach and secondary forest, largely disturbed and uprooted by pigs was present in the intervening areas. A steep north-south trending limestone ridge surrounded the extent of search transects. In the vicinity of Lolieng Village, several transects were completed, from sea level to about 300m. Much of the forest surrounding the village has been converted to food and ornamental gardens, while an extensive logging road network persists inland. Nearly all of the forest at this locality is secondary, with sporadic patches of primary forest in steeper areas. Temperatures and humidity recorded at Lolieng Camp were 23.0 – 34.4°C and 85 – 94% humidity (not including periods of rain).

The main objective of the butterfly survey 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. Surveying was carried out along transects, often pre-existing trails and/or following natural features, e.g. along streams and ridges. Surveying of as many micro-habitats as possible was conducted.

Butterflies were searched for along transects and either visually determined or collected with long-handled nets. Voucher specimens of most observed species were collected, even if recognised, for comparison of intraspecific characters with other subspecies from the Bismarck Archipelago. Adults and early stages of many species were photographed in the field.

The maximum amount of daylight was used for surveying and crepuscular species were searched for in the evenings. Flowering plants, e.g., those of *Mikania* sp., were sought as adults of many species are often attracted to these. The early stages of butterflies were also sought and the team botanist, Fanie Venter, kindly assisted with the identification of nectar source plants for adults and larval food plants.

Nomenclature in this report follows that of Hancock (1983), Parsons (1998), Vane-Wright & de Jong (2003) and Tennent (2006). Since only a few butterflies in New Guinea have common names, this report uses standard scientific names but draws on Australian references to common names of Braby (2000).

Results

47 butterfly species were recorded during the survey of Mussau Island (Table 1). 39 species were recorded at Nae Camp and 38 species at Lolieng Camp, with 30 species shared between the two sites. Nearly half (22) of the recorded butterfly species were previously unknown from Mussau Island. 35 butterfly species had been recorded previously. Together with these new records, and those in literature from the Eichhorn expedition to the St. Matthias Islands (Parsons, 1998; Tennent, 2006), the results of this survey increase the documented butterfly fauna by 34.3%.

While much work has been carried out to determine the conservation status of butterflies globally for mainland PNG only a proportion of the fauna have been assessed using IUCN criteria (Müller & Tennent, in press; Tennent & Müller, in press) (see Section 3.1.5). No conservation listed species were, or have been, recorded from Mussau Island, although one Birdwing, *Ornithoptera priamus*, is present.

One exotic species (*Papilio demoleus malayanus*) was recorded during the survey. This species was clearly seen to be damaging *Citrus* crops at Lolieng village. The species was previously unrecorded on Mussau and has likely spread there recently (see species accounts).

A number of butterfly early stages were encountered during the survey. These are documented, with identified foodplants, in Table 2.

Table 1. Butterflies recorded from Mussau Island.

Family	Subfamily	Taxon	Author, Date	Camp 1 Nae	Camp 2 Lolieng	Lit. records	New Mussau record
Hesperiiidae	Pyrginae	*Tagiades japetus*	Stoll, 1781	*	*	*	-
Hesperiiidae	Hesperiinae	*Cephrenes moseleyi*	Butler, 1884	-	*	*	-
Hesperiiidae	Hesperiinae	*Telicota argeus*	Plötz, 1883	-	-	*	-
Hesperiiidae	Hesperiinae	*Telicota colon*	Fabricius, 1775	*	-		*
Hesperiiidae	Hesperiinae	*Telicota solva*	Evans, 1949	*	-	*	-
Hesperiiidae	Hesperiinae	*Borbo cinnara*	Wallace & Moore, 1866	-	-	*	-
Hesperiiidae	Hesperiinae	*Pelopidas agna*	Moore, 1886	-	-	*	-
Hesperiiidae	Hesperiinae	*Pelopidas matthias*	Fabricius, 1789	-	-	*	-
Papilionidae	Papilioninae	*Ornithoptera priamus*	Linnaeus, 1758	*	-	*	-
Papilionidae	Papilioninae	*Graphium browni*	Godman & Salvin, 1879	-	-	*	-
Papilionidae	Papilioninae	*Papilio demoleus*	Linnaeus, 1758	-	*	-	*
Papilionidae	Papilioninae	*Papilio phestus*	Guérin-Méneville, 1831	*	*	-	*
Pieridae	Coliadinae	*Catopsilia pomona*	Fabricius, 1775	*	*	-	*
Pieridae	Coliadinae	*Eurema hecabe*	Linnaeus, 1758	*	*	*	-
Pieridae	Coliadinae	*Eurema blanda*	Boisduval, 1836	-	-	*	-
Pieridae	Coliadinae	*Eurema candida*	Stoll, 1780	*	*	-	*
Pieridae	Pierinae	*Elodina primularis*	Butler, 1882	*	*	*	-
Pieridae	Pierinae	*Cepora perimale*	Donovan, 1805	*	*	*	-
Pieridae	Pierinae	*Belenois java*	Sparrman, 1768	*	-	-	*
Lycaenidae	Lycaeninae	*Hypochrysops scintillans*	Butler, 1882	*	*	*	-
Lycaenidae	Lycaeninae	*Arhopala eurisus*	Druce, 1891	*	*	*	-
Lycaenidae	Lycaeninae	*Arhopala philander*	C. & R. Felder, 1865	*	*	-	*
Lycaenidae	Lycaeninae	*Arhopala thamyras*	Linnaeus, 1758	*	*	*	-
Lycaenidae	Lycaeninae	*Hypolycaena periphorbas*	Butler, 1882	-	*	-	*
Lycaenidae	Lycaeninae	*Deudorix epijarbus*	Moore, 1858	-	*	*	-
Lycaenidae	Lycaeninae	*Bindahara phocides*	Fabricius, 1793	*	-	*	-
Lycaenidae	Lycaeninae	*Anthene paraffinis*	Fruhstorfer, 1916	*	*	*	-
Lycaenidae	Lycaeninae	*Nacaduba novaehebridensis*	Druce, 1892	-	-	*	-
Lycaenidae	Lycaeninae	*Nacaduba kurava*	Moore, 1857	*	*	*	-
Lycaenidae	Lycaeninae	*Tartesa astarte*	Butler, 1882	-	*	*	-
Lycaenidae	Lycaeninae	*Erysichton lineata*	Murray, 1874	*	*	*	-
Lycaenidae	Lycaeninae	*Danis danis*	Cramer, 1775	*	*	-	*
Lycaenidae	Lycaeninae	*Prosotas gracilis*	Röber, 1886	-	-	*	-
Lycaenidae	Lycaeninae	*Catopyrops ancyra*	C. Felder, 1860	*	*	*	-
Lycaenidae	Lycaeninae	*Catopyrops kokopona*	Ribbe, 1899	-	-	*	-
Lycaenidae	Lycaeninae	*Zizina labradus*	Godart, 1824	*	*	-	*
Lycaenidae	Lycaeninae	*Zizula hylax*	Fabricius, 1775	*	*	-	*
Lycaenidae	Lycaeninae	*Euchrysops cnejus*	Fabricius, 1798	*	*	-	*
Nymphalidae	Danainae	*Danaus affinis*	Fabricius, 1775	-	-	*	-
Nymphalidae	Danainae	*Euploea phaenareta*	Schaller, 1785	*	-	-	*
Nymphalidae	Danainae	*Euploea leucostictos*	Gmelin, 1790	*	*	*	-
Nymphalidae	Danainae	*Euploea charox*	Kirsch, 1877	*	-	*	-
Nymphalidae	Danainae	*Euploea treitschkei*	Boisduval, 1832	*	*	*	-
Nymphalidae	Danainae	*Euploea modesta*	Butler, 1866	*	-	*	-
Nymphalidae	Nymphalinae	*Doleschallia tongana*	Hopkins, 1927	*	*	-	*
Nymphalidae	Nymphalinae	*Doleschallia browni*	Salvin & Godman, 1877	-	*	-	*
Nymphalidae	Nymphalinae	*Doleschallia rickardi*	Grose-Smith, 1890	*	*	*	-

Family (cont)	Subfamily	Taxon	Author, Date	Camp 1 Nae	Camp 2 Lolieng	Lit. records	New Mussau record
Nymphalidae	Nymphalinae	*Hypolimnas bolina*	Linnaeus, 1764	-	*	*	-
Nymphalidae	Nymphalinae	*Hypolimnas antilope*	Cramer, 1777	*	-	-	*
Nymphalidae	Nymphalinae	*Hypolimnas pithoeka*	Kirsch, 1877	*	*	-	*
Nymphalidae	Nymphalinae	*Yoma algina*	Boisduval, 1832	*	*	-	*
Nymphalidae	Nymphalinae	*Junonia hedonia*	Linnaeus, 1764	*	*	-	*
Nymphalidae	Nymphalinae	*Junonia villida*	Fabricius, 1787	*	*	-	*
Nymphalidae	Heliconiinae	*Vindula arsinoe*	Cramer, 1777	*	*	-	*
Nymphalidae	Heliconiinae	*Vagrans egista*	Stoll, 1780	-	*	*	-
Nymphalidae	Heliconiinae	*Cupha prosope*	Fabricius, 1775	*	*	-	*
Nymphalidae	Heliconiinae	*Acraea moluccana*	C. Felder, 1860	*	*	*	-

Table 2. Butterfly life histories recorded from Mussau Island.

Butterfly taxon	Foodplant taxon	Foodplant family	Botanical notes
Tagiades japetus	*Dioscorea sp.*	Dioscoraceae	No plants in flower/fruit for ID
Cephrenes moseleyi	*Cocos nucifera*	Arecaceae	
Papilio demoleus	*Citrus maxima*	Rutaceae	
Papilio demoleus	*Citrus reticulata*	Rutaceae	
Papilio phestus	*Micromelum minutum*	Rutaceae	
Catopsilia pomona	*Senna alata*	Fabaceae	
Eurema hecabe	*Falcataria moluccana*	Fabaceae	
Hypochrysops scintillans	*Scaevola taccada*	Goodeniaceae	
Hypochrysops scintillans	*Guettarda speciosa*	Rubiaceae	
Hypochrysops scintillans	*Barringtonia asiatica*	Lecythidaceae	
Hypochrysops scintillans	*Pometia pinnata*	Sapindaceae	
Hypochrysops scintillans	*Terminalia catappa*	Combretaceae	
Hypochrysops scintillans	*Terminalia samoensis*	Combretaceae	
Hypochrysops scintillans	*Cordia subcordata*	Boraginaceae	
Arhopala philander	*Pometia pinnata*	Sapindaceae	
Arhopala thamyras	*Syzygium nemorale*	Myrtaceae	
Hypolycaena periphorbas	*Terminalia catappa*	Combretaceae	
Euchrysops cnejus	*Pueraria phaseoloides*	Fabaceae	
Euploea treitschkei	*Hoya gigas*	Apocynaceae	
Doleschallia tongana	*Jadunia biroi*	Acanthaceae	
Doleschallia browni	*Pseuderanthemum curtatum*	Acanthaceae	
Hypolimnas pithoeka	*Procris frutescens*	Urticeae	
Cupha prosope	*Flacourtia jangomas*	Salicaceae	
Acraea moluccana	*Passiflora sp.*	Passifloraceae	No plants in flower/fruit for ID

Species Accounts

***Ornithoptera priamus* Priamus Birdwing**

Though a Birdwing species, this is the only one in the genus occurring in PNG that is not protected by the PNG Fauna Act. This species was recorded on Mussau Island by Parsons (1998) and Tennent (2006) under the New Ireland and Solomon subspecies *urvilleanus*. The taxon was only observed at a distance during this survey and the only known specimens from Mussau Island are in the Natural History Museum, London. None have been examined as yet. The species is prevalent in the Tabar Group (C. Müller, pers. obs.) and is generally common throughout New Guinea and its satellite islands, the Bismarck Archipelago and the Solomon Islands, from sea level to at least 1,000m.

***Papilio demoleus* Chequered Swallowtail**
Parsons (1998) only recorded subspecies *novoguineensis* in Papua New Guinea, from a localised area of savannah forest in the Port Moresby region. However, the South-East Asian subspecies *malayanus* has spread through the northern New Guinea mainland and has reached many islands of the Bismarck Archipelago. While the latter taxon had been observed by the author on Simberi Island (Tabar Group) in 2004 (Tennent 2006), it is unknown when the species reached Mussau Island. It appears to be very well established in and around Lolieng village, where it feeds on cultivated *Citrus* (*C. maxima* and *C. reticulata*) in gardens and groves. It is a notable threat to orange, pomelo and lemon trees on the island, with some smaller trees having been defoliated to the point of die back. The larva generally only feeds on new growth and younger leaves and does not affect the fruit. The early stages are camouflaged and difficult to detect. However, affected trees would likely be inhibited in fruit production when under attack by quantities of *P. demoleus* larvae and thus *P. demoleus* could be regarded as a pest species, despite its overall beauty as an adult butterfly. *P. demoleus* appears to be spreading rapidly, even into the Americas (Eastwood et al. 2006; Homziak and Homziak 2006; Garraway et al. 2009).

Papilio phestus
This species occurs on all of the main islands of the Bismarck Archipelago as a distinct described subspecies but was previously unknown from the St. Matthias Group. Specimens from the Tabar Group are unsurprisingly most similar to those from New Ireland but those from Mussau Island have yet to be compared in detail to described subspecies. Preliminary assessment suggests that those from Mussau Island may have a slightly different configuration of white and red on both surfaces of the hind wing, possibly representing an undescribed subspecies.

***Cepora perimale* Australian Gull**
Parsons (1998: 294) and Tennent (2004) report a distinct undescribed subspecies from 'St Matthias Island'. Preliminary examination of the specimens suggests that they are indeed quite distinct from other neighbouring taxa in New Guinea and the Solomons, with rather rounded termen borders.

Hypochrysops scintillans
This striking species is known from Mussau Island from a very short series collected by Eichhorn and these form the type series of subspecies *carolina*, described by d'Abrera (1971). It is given special mention here since the life history was previously unrecorded but the immature stages were found to be polyphagous on a number of plant species across a range of food plant genera, always in attendance of an unidentified small brown ant . The genus *Hypochrysops* is renowned for polyphagy as larvae (Sands 1986).

***Danis danis* Large Green Banded Blue**
Previously unrecorded from the St. Matthias Group, a distinct subspecies is here recognised. The subspecies on Mussau Island is small but intensely coloured. It was found to be relatively common at both camps. Males would occupy perches and chase butterflies of their own kind or other small species, while females were usually encountered deep in the forest, presumably searching for oviposition sites.

Dolleschallia browni
Though known to be quite widely occurring in the Bismarck Archipelago, Solomon Islands and Vanuatu, this butterfly was previously unknown from the St. Matthias Group. Additionally, its early stages, previously unrecorded, were located during the survey. In particular, the larvae and pupa are striking and dramatically distinct to those of the related, sympatric *D. tongana*.

Hypolimnas pithoeka
H. pithoeka was previously unrecorded from the St. Matthias group. A distinctive subspecies was discovered during the survey, at both sites. The sexes are similar and it differs from other subspecies in the Bismarck Archipelago due to the presence of very pale margins to both wings on the upperside, which are unicolorous brown in described subspecies. The early stages were located at Lolieng Camp and photographed.

Discussion

The butterfly survey of Mussau Island increased the known fauna by approximately 35%. However, many species that are common on New Ireland and in the offshore Tabar group appear to be absent on Mussau Island. The New Ireland mainland boasts more than 250 species, the Tabars around 100 species and Mussau Island now has 57 species recorded. This pattern is typical of colonisation founder effects, with diversity decreasing with island size and isolation. It is likely that some additional species occur on Mussau but it is considered very unlikely that any endemic taxa (at the species level) occur there. Some of the subspecies from Mussau (in the broader St. Matthias Group) have been described as distinct subspecies. It is apparent that others discovered during this survey may well represent distinct subspecies, though overall most are very similar to the populations present in New Ireland and New Hanover, suggesting that the origin of Mussau populations is from these islands. Where there are differences in specimens from Mussau versus those from neighbouring islands, they are very slight generally, implying recent dispersal to Mussau Island. Certain butterflies have developed into quite distinctive subspecies (e.g., *Cepora perimale, Danis danis* and *Hypolimnas pithoeka*), whereas others are almost identical to those from New Ireland, suggesting that there have been different waves over time, or equally that gene flow has been uninterrupted for the latter species. Other variables include differing mutation rates between various groups.

Butterfly dispersal (influx) to the two main islands of the St. Matthias Group (Mussau Island and Emirau Island) does not appear to have been equal. For example, some distinction exists between the taxa of the two islands, with separate subspecies being recognised for *Hypochrysops scintillans* (Lycaenidae) and even sister species for two members in the *Deudorix 'epijarbus* complex' (also Lycaenidae), with the widespread *D. epijarbus* present on Mussau, whereas the distinctive *D. emira* appears to exist in isolation on Emirau Island.

It is hardly surprising that the butterfly fauna of Mussau Island is relatively impoverished, compared to other islands of similar size in the Bismarck Archipelago (e.g. Simberi, Tatau and Big Tabar Islands in the Tabar Group). As mentioned above, this likely owes to its remoteness. Certain species that are abundant and ubiquitous on other islands in the archipelago (e.g., *Badamia exclamationis, Parthenos sylvia* and *Jamides celeno*) are seemingly entirely absent from Mussau Island, yet occur in far eastern islands of the Santa Cruz group of the Solomon Islands and the well separated Reef Islands of Vanuatu. Equally surprising is the fact that a relatively long expedition, spanning more than two months, to Mussau Island (as part of a study of the St. Matthias Island Group) by the Eichhorn brothers in 1924 did not turn up species commonly encountered during this survey such as *Papilio phestus, Catopsilia pomona* and *Eurema candida*. With the exception of the invasive species, *Papilio demoleus* (see Results section), it is unlikely that any of these species have arrived since the time of Eichhorns visit, as they appear to be well established and, in the case of *P. phestus* and *E. candida*, exhibit subtle differences to neighbouring populations. Certain butterfly subfamilies, with representatives in New Hanover and the Tabar Group, are entirely absent from Mussau Island (Coeliadinae, Ithomiinae, Morphinae, Satyrinae, Charaxinae, Apaturinae). As well as *Papilio demoleus*, another pest butterfly species that has spread to the Bismarck Archipelago through mainland NG from SE Asia is *Erionata thrax* (Hesperidae). The larvae of this taxon feeds on bananas and is a threat to banana crops in other Bismarck islands (e.g., New Ireland, New Britain) but was not recorded during the survey of Mussau Island.

Recommendations

The butterfly fauna of Mussau Island is worthy of preservation, especially considering the presence of certain distinctive subspecies. Habitat loss and degradation is the most significant threat to butterflies and this is evident at both survey sites on Mussau Island and is undoubtedly similar for much of the island. Logging operations and associated flourishing of invasive plant species, together with degradation of forest understorey by pigs, are prominent causes of such habitat loss. If logging is to proceed in the future it needs to be carefullyplanned and monitored, to preserve large tracts of original forest, or at least allow secondary forest to attain maturity. Eradication of pigs is a global challenge but on Mussau Island, a community effort to contain pigs within domestic confines would benefit the forest and its resident butterflies.

References

Braby, M.F. 2000. Butterflies of Australia. Their identification, biology and distribution. CSIRO Publishing, Canberra.

d'Abrera, B. 1971. Butterflies of the Australian Region. Lansdowne, Melbourne.

Dincă V., Lukhtanov, V. A., Talavera, G. and Vila, R. 2011. Unexpected layers of cryptic diversity in wood white Leptidea butterflies. *Nature Communications* 2: 324.

Eastwood, R., Boyce, S. L. and Farrell, B. D. 2006. The provenance of Old World Swallowtail Butterflies, *Papilio demoleus* (Lepidoptera: Papilionidae), recently discovered in the New World. *Annals of the Entomological Society of America* 99: 164–168.

Garraway, E., Murphy, C.P. and Allen, G.A. 2009. *Papilio demoleus* (the lime swallowtail) (Lepidoptera: Papilionidae), a potential pest of citrus, expanding its range in the Carribean. *Tropical Lepidoptera Research* 19: 58–59.

Hancock, D.L. 1983. Classification of the Papilionidae (Lepidoptera): a phylogenetic approach. *Smithersia*, Supplement 2.

Homziak, N.T. and Homziak, J. 2006. *Papilio demoleus* (Lepidoptera: Papilionidae): a new record for the United States, Commonwealth of Puerto Rico. *Florida Entomologist* 89: 485–488.

Kamenov, G.D. 2004. Magmatism and ore deposit formation in SW Pacific island arcs. Unpublished PhD thesis, University of Florida.

Kerr, J.T. 2001. Butterfly species richness patterns in Canada: energy, heterogeneity, and the potential consequences of climate change. *Conservation Ecology* 5(1): 10.

Kitching, R.L., Li, D., & Stork, N.E. (2001). Assessing biodiversity 'sampling packages': how similar are arthropod assemblages in different tropical rainforests? *Biodiversity & Conservation* 10(5), 793-8

Parsons, M. J. 1998. The butterflies of Papua New Guinea: their systematics and biology. Academic Press, London.

Sands, D. P. A. 1986. A Revision of the Genus *Hypochrysops* C. & R. Felder. *Entomonograph* **7**: 1–116.

Tennent, W. J. 2006. A checklist of the butterflies of Melanesia, Micronesia, Polynesia and some adjacent areas. *Zootaxa* 1178: 1–209.

Vane-Wright, R. I. and de Jong, R. 2003. The butterflies of Sulawesi: annotated checklist for a critical island fauna. *Zoologische Verhandelingen* 343: 1–267.

Chapter 3:

Dragonflies and damselflies (Odonata) of Manus and Mussau Islands

Stephen J. Richards, Gunther Theischinger and William Tamarua

Summary

A total of 21 species of Odonata were documented from Manus and Mussau Islands, comprising 9 damselflies and 12 dragonflies. Nineteen of the 21 species were found on Manus and 12 were found on Mussau. One damselfly species in the genus *Drepanosticta* (family Platystictidae) from Manus Island is new to science. No species listed by the IUCN as Data Deficient, or in any threatened category, was detected. The odonate fauna of both Manus and Mussau islands is dominated by widespread species, a feature common to remote oceanic islands. However two species of damselflies, the recently described *Nososticta manuscola* Theishinger and Richards (in press) and the new *Drepanosticta* reported for the first time here, appear to be endemic to Manus Island. Management of the forests in central Manus to ensure long-term persistence of the clear streams and riparian vegetation inhabited by the two endemic species is a high conservation priority. Surveys of the interior of Mussau Island should also be conducted to determine whether additional, and potentially new and endemic, species occur there away from the coastal fringe.

Introduction

Manus and Mussau Islands are the two most northerly oceanic islands in Papua New Guinea. Located just ~2.0 and 1.4 degrees south of the equator respectively, these small and remote islands are virtually unknown odonatologically. The earliest record of a dragonfly from Manus Island appears to be that of *Nesoxenia mysis dahli*, collected in 1944 and reported by Lieftick (1949). The next species to be encountered on Manus Island was the widespread libellulid dragonfly *Tramea liberata*, collected during the Noona Dan Expedition in 1962 (Watson 1967). That expedition also collected material of *T. liberata* on Mussau Island. The total known odonate fauna of Mussau Island remained just one species, and of Manus two species, until S. J. Richards collected a new species of the platycnemidid damselfly genus *Nososticta* on the south coast of Manus Island in 2011 (Theischinger and Richards 2015).

Here we report the first attempt to comprehensively sample the odonate faunas of several sites on Manus and Mussau islands. A checklist of species currently known from the two islands is presented and comments on significant species are provided.

Methods

Survey effort was focused at two main sites on Manus Island (Mount Sabomu and Yeri Camp), and two sites on Mussau Island (Lolieng and Nae) (Plate 1). Lower, but significant sampling effort was expended at Piri Village on southern Manus Island en route to Mt Sabomu.

Locations and altitudes of all sites are presented in Table 1 and more detailed habitat descriptions for all sites are provided by Venter (Chapter 1, this volume). The collection locality for Yeri Camp reported here was slightly downstream from the site described for Yeri River by Venter (WCS, unpublished), but the habitat features of the two sites were extremely similar. All sampling was undertaken by S. J. Richards and 1–2 local assistants on Manus Island, and by W. Tamarua and 1–2 local assistants on Mussau Island.

Intensive searches using hand-nets were conducted for adult dragonflies and damselflies along and around all available water-bodies, during the morning, on sunny afternoons, and in the evenings. Activity patterns of odonates vary among species, with some taxa preferring to perch in early-morning sun patches in the forest, others defending territories along streams, and others flying in forest gaps predominantly at dusk, and rarely perching. Water-bodies examined included seepages, small closed-canopy streams, larger streams, small forest pools and larger ponds in garden habitats. Additional surveys were conducted along forest trails and in clearings, especially the Telecom Tower on Mt Sabomu, where large dragonflies often hunt for small flying insect prey.

Larval odonates were not targeted during this study because the larvae of most New Guinean taxa remain unknown. Larvae are predaceous and providing sufficient prey to rear individuals to metamorphosis for identification in the field would have

been labour intensive and, based on studies of other tropical species, development rates of most species encountered would have been too slow to permit successful rearing in the field.

Mt Sabomu

The Mount Sabomu camp was located just below the summit of the mountain at 569 m asl, and gave access to altitudes of about 400–589 m asl. Sampling focused on the clearing around the communications tower at the mountain's summit, where several species hawked regularly for insects, and at a small stream below the camp that was visited regularly to search for stream-dwelling species. Additional search effort was made in the largely intact forest on both the steep ridge-lines and in moist gullies around camp.

Piri Village

Several hours were spent surveying for odonates in and around Piri Village during two days while en route to and from Mt Sabomu. The immediate environs of the village are a patchwork of gardens and highly disturbed remnant forest, but two small streams draining the southern slopes of Mt Sabomu traverse the village and these retain remnant forest patches containing a moderate diversity of odonates. A series of small ponds right on the coast on the southern edge of the village harboured a number of additional species.

Yeri River

The Yeri Camp was located in relatively undisturbed lowland forest, and gave access to a series of small and larger streams and several swampy areas. Closer to the river the forest is more disturbed, and is dominated by a patchwork of gardens and sago plantations.

Nae Camp

Nae camp gave access to patches of coastal forest and scrub, and to extensive tracts of open forest interspersed with dense vine thickets on a series of limestone benches and slopes at elevations between sea level and ~100 m a.s.l.. Very little free standing water existed in the vicinity except for small spring-fed creeks at the camp site and at Nae village.

Lolieng Camp

This camp gave access to a range of coastal vegetation types including tall lowland forest, mangroves, and a low cliff flora growing on the coral cliffs. The only freshwater of note was a freshwater spring below the camp site. The spring was adjacent to a large estuarine mangrove area which resulted in the water often being brackish.

Table 1. The five main survey locations on Manus and Mussau Islands.

Camp	Latitude	Longitude	Altitude (m asl)	Dates
Manus				
Mt Sabomu	S 2.193°	E 146.967°	400–569	2–5 October 2014
Piri Village	S 2.211°	E 146.965°	0–40	6–7 October 2014
Yeri	S 2.001°	E 146.819°	10–60	9–13 October 2014
Mussau				
Nae	S 1.504°	E 149.731°	0 – 104	16–26 October 2014
Lolieng	S 1.422°	E 149.510°	~33	21–26 October 2014

Results

A total of 21 species of Odonata were documented from Manus and Mussau Islands, comprising 9 damselflies and 12 dragonflies. Nineteen of the 21 species were found on Manus Island and 12 were found on Mussau Island. One additional species, *Tramea liberata*, is known from both islands, bringing the total number of species known from Manus to 20, and from Mussau to 13.

The fauna is dominated by common, widespread species in the damselfly family Coenagrionidae and in the dragonfly family Libellulidae. Indeed at least 17 of the 22 species now known from the islands also occur on mainland New Guinea, although several represent insular subspecies. One specimen of *Indolestes* collected at Piri Village is too damaged to permit accurate identification but is also probably a widespread species. The coenagrionid damselfly *Mortonagrion martini* was considered by

Polhemus et al (2004) to be a 'very rare' species but it was common on both Manus and Mussau islands and its apparent rarity may be more a reflection of its unusual habitat preferences – the species appears to be most common in low, coastal and near-coastal areas with small seepages and bogs, and has been found within the littoral forest at the back of sandy beaches on islands of the Admiralty and Bismarck archipelagos.

No species listed by the IUCN as Data Deficient, or in any threatened category, was detected but one damselfly in the genus *Drepanosticta* (family Platystictidae) from Manus Island is new to science and it, and the recently described *Nosticta manuscola* Theischinger and Richards (2015) appears to be endemic to Manus Island.

Table 2. Odonate species documented on Manus and Mussau islands.

Odonate species	Piri	Mt Sabomu	Yeri	Mussau †	IUCN	Endemism ††
Damselflies (Zygoptera)						
Coenagrionidae						
Agriocnemis femina	*			*	LC	W
Archibasis mimetes	*	*			NE	W
Mortonagrion martini	*		*	*	NE	W
Pseudagrion microcephalum				*	LC	W
Teinobasis dominula	*	*	*	*	NE	W
Xiphiagrion cyanomelas	*			*	NE	W
Lestidae						
Indolestes sp.	*				NE	W?
Platycnemididae						
Nosticta manuscola	*	*	*		NE	MAN
Platystictidae						
Drepanosticta sp. nov.	*	*			NE	MAN
Dragonflies (Anisoptera)						
Aeshnidae						
Agyrtacantha dirupta		*			NE	W
Corduliidae						
Hemicordulia? silvarum	*	*		*	NE	W
Libellulidae						
Agrionoptera insignis similis			*		LC	W
Brachydiplax duivenbodei	*				LC	W
Nesoxenia mysis dahlei	*		*		NE	W
Neurothemis stigmatizans	*	*	*	*	NE	W
Orthetrum serapia	*			*	LC	W
Orthetrum villosovittatum	*	*	*	*	NE	W
Pantala flavescens	*			*	LC	W
Rhyothemis phyllis	*				LC	W
Rhyothemis resplendens	*	*		*	NE	W
Tramea aquila				*	NE	W
Tramea liberata	?	?	?	*	NE	ND

†Mussau sites are combined ††MAN = Manus Island group only: W = widespread outside Manus and/or Mussau islands. ND = Noona Dan Exped.

Species Accounts for Significant Species

Family Coenagrionidae
***Drepanosticta* sp. nov.**
A very small, slender, darkly coloured damselfly in the platystictid genus *Drepanosticta* was found on several streams draining Mt Sabomu. Like other members of the genus on mainland New Guinea it is a secretive species, perching motionless for long periods in densely vegetated shady areas adjacent to clear forest streams. This species was found at several locations between

about 40 m a.s.l. near the coast at Piri Village, and was also observed at the small stream below the summit of Mount Sabomu at 456 m a.s.l. Despite intensive searches there, it was not found along the lower-gradient streams at Yeri Camp, and it is probably a species restricted to high-gradient forest streams on Manus Island.

Mortonagrion martini

A small, slender, rather strikingly coloured damselfly with a creamy-white abdomen, *Mortonagrion martini* has a distribution centred among the islands of the Admiralty and Bismarck archipelagos (Michalski 2012). Polhemus et al. (2004) commented that this species is 'very rare' but it was abundant at both lowland sites on Manus Island, and was also common on Mussau. This species appears to occur most frequently in coastal or near-coastal habitats on the islands north and east of New Guinea, and its presence in these littoral zones, a habitat rarely occupied by odonates, may in part explain its apparent rarity.

Nosticta manuscola

This recently-described species (Theischinger and Richards 2015) was previously known only from a single male specimen and a photograph of a female, both taken at Pelipowai Village to the west of Mount Sabomu in 2011. During the 2014 WCS survey it was abundant along the small streams draining Mount Sabomu, where the greatest density occurred in sunny patches along densely vegetated forest streams. It was also found at very low densities in streams traversing the disturbed forest and gardens around Piri Village, and several individuals were also seen at Yeri Camp. This species is probably widely distributed across Manus Island in well-forested areas with clear flow streams, and it is probably endemic to Manus Island.

Discussion

This WCS survey represents the first attempt to comprehensively assess the odonate faunas of Manus and Mussau island. The 2014 WCS inventory led to the discovery of one new damselfly species in the genus *Drepanosticta*, to important new distributional records for the recently-described *Nosticta manuscola*, and to significant new distribution records for many species including the infrequently encountered damselfly *Mortonagrion martini*. The number of odonate species known from Manus has increased from three to 20, and from Mussau it has increased from one to 13. It is important to note that the survey on Mussau Island was restricted predominantly to coastal regions and it is possible that additional significant island records, if not additional new and endemic species, may be found in the island's interior.

Recommendations

The results of this survey reinforce the importance of the central forests of Manus for the long-term survival of Manus's endemic odonate species. Both of the endemic damselflies now known to occur on Manus Island are stream-dwelling species that occurred either exclusively (*Drepanosticta*) or predominantly (*N. manuscola*) along shallow, clear, flowing streams in good quality forest with dense riparian vegetation. These discoveries highlight the importance of careful management of the forest that remains in the central Manus region and management of the forests in central Manus to ensure long-term persistence of the clear streams and riparian vegetation inhabited by the two endemic species is a high conservation priority. Surveys of the interior of Mussau Island should also be conducted to determine whether additional, and potentially new and endemic, species occur away from the coastal fringe.

References

Lieftinck, M.A. 1949. The dragonflies of New Guinea and neighbouring islands (part VII). *Nova Guinea*, new series 5: 1–271.

Michalski. J. 2012. A manual for the identification of the dragonflies and damselflies of New Guinea, Maluku and the Solomon Islands. Kanduaman Books. Morristown, USA.

Polhemus, D.A., Englund, R. A. and Allen, G.R. 2004. Freshwater biotas of New Guinea and nearby islands: analysis of endemism, richness, and threats. Final report prepared for Conservation International, Washington, D.C.

Theischinger, G. and Richards, S.J. 2015. The genus *Nosticta* Hagen (Odonata: Platycnemididae) from the Papuan region with descriptions of ten new species group taxa. *Odonatologica* 44: (in press).

Watson, J.A.L. 1967. An analysis of *Trapezostigma eurybia* (Selys, 1878) and related Indo-Australian species (Odonata, Libellulidae). *Nova Guinea*, new series. 10: 377–400.

Chapter 4:

Herpetofauna of Manus and Mussau Islands

Stephen J. Richards and Kenneth P. Aplin

Summary

A total of 40 species of herpetofauna were documented from Manus and Mussau Islands, comprising 11 frogs and 29 reptiles. No species listed by the IUCN as Data Deficient, or in any threatened category, was detected but at least three frogs and one reptile encountered during the survey are new to science (two frogs on Manus, one frog on Mussau and one lizard shared by both islands). Additional studies of a further five reptile species are required to confirm their taxonomic status. The reptile fauna of both Manus and Mussau islands is dominated by widespread species with only five (17%) of the 29 species found being endemic to the Manus group, to Mussau, or to the two island groups combined. In contrast the frogs show an exceptionally high level of endemism with eight of the eleven species encountered (73%) known only from the Manus Island group or from Mussau Island. The major conservation priority for both islands is to encourage the development of management plans that minimise the impacts of broad-scale clearing on local forest-dwelling species.

Introduction

Manus and Mussau Islands are the two most northerly major islands in Papua New Guinea, located just ~2.0 and 1.4 degrees south of the equator respectively. Although poorly documented herpetologically, given their small size, remoteness, and lack of any historical landbridge connection to New Guinea, a relatively depauperate herpetofauna dominated by reptiles with good over-water dispersal abilities would be expected on both islands. For example the broader Admiralty Archipelago, of which Manus Island is a part, is dominated by widespread lizards of the family Scincidae and more than 80% of the terrestrial herpetofauna there is shared with New Guinea (Allison 1996).

Early studies that contributed to our knowledge of Admiralty Archipelago (including Mussau) herpetofauna included important works by Sternfeld (1920) and Hediger (1933). Other significant contributions included the description of *Hypsilurus schoedei* from Rambutyo Island in the Manus Island group by Vogt in 1932 (Manthey and Denzer 2006) and of the endemic scincid lizard *Tribolonotus brongersmai* from Manus Island by Cogger (1972). More recently monographic reviews of the scincid genera *Emoia* (Brown 1991) and *Carlia* (Zug 2004) have reported on a number of species from both Manus and Mussau Islands and Brown (1997) provided an important synthesis of knowledge about amphibians of the south-west Pacific to that date.

On Manus Island, a series of surveys by S. Richards from the South Australian Museum over the past 12 years (Richards et al. 2007, 2014) resulted in the discovery and description of several endemic ceratobatrachid frogs in the genus *Cornufer* (for use of *Cornufer* vs *Platymantis* see Brown et al. 2015), and fieldwork there by R. Fisher in 2010 resulted in the discovery of *Nactus kunan*, a brightly-coloured gecko endemic to the island (Zug and Fisher 2012).

While these studies greatly improved knowledge about the herpetofauna of Manus Island in the past 12 years, the herpetofauna of Mussau Island remained largely neglected. Although a number of reptile species have long been known to occur in the St Matthias group of islands to which Mussau belongs (e.g. Brown 1955; 1991, Zug 2004), modern studies are few. Schleip (2008) argued that the population of pythons (*Leiopython albertisii*) on Emirau Island adjacent to Mussau is the result of an artificial introduction, and O'Shea (1996) reported the presence of *Morelia amethistina* on Mussau Island. However there have been no modern attempts to comprehensively document, or to synthesise information about, the herpetofauna of this most northerly outpost of Papua New Guinea.

This report presents the results of a herpetofauna survey conducted at three sites on Manus Island and two sites on Mussau Island during November 2014.

Methods

Survey effort was focused at two main sites on Manus Island (Mt Sabumu and Yeri Camp), and two sites on Mussau Island (Lolieng and Nae Camps) (Plate 1). Lower, but significant sampling effort was expended at Piri Village on southern Manus Island en route to Mt Sabomu.

Locations and altitudes of all sites are presented in Table 1 and more detailed habitat descriptions for all sites are provided by Venter (Chapter 1, this volume). The collection locality for Yeri Camp reported here was slightly downstream from the site described for Yeri River by Venter (WCS unpublished), but the habitat features of the two sites were extremely similar. All sampling was undertaken by S. Richards and 1–2 local assistants on Manus Island, and by K. Aplin, N. Whitmore, F. Venter and 1–2 local assistants on Mussau Island and other members of the research team also contributed important observations and voucher material.

At each site we conducted intensive searches for frogs and reptiles along trails established for this purpose. During the day we searched for 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.

Because most frogs on Manus and Mussau islands have life cycles that are independent of freestanding water, we conducted extensive visual and aural searches along trails at night in forest away from water. However we also searched for frogs by conducting visual-encounter and aural surveys along streams, and in and around small ponds. Frog calls are an important diagnostic character that assist greatly with species identification so whenever possible we recorded the advertisement calls of frogs with an Edirol R-05 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 for larger reptiles.

Specimens were fixed in 10% formalin solution, and then stored in 70% ethanol. Samples of liver tissue for DNA analyses were extracted from representative specimens of each species and stored in 95% ethanol. Voucher specimens will be deposited in the Papua New Guinea National Museum and Art Gallery, Port Moresby, and in the South Australian Museum, Australia.

Mt Sabomu

The Mount Sabomu camp was located just below the summit of the mountain at 569 m asl, and gave access to altitudes of about 400–589 m asl. Sampling focused on the largely intact forest, with access to closed canopy forest on steep ridge-lines and moist gullies. A small stream below the camp was visited several times to search for aquatic herpetofauna.

Piri Village

Several hours were spent surveying for herpetofauna in and around Piri Village during two days while en route to and from Mt Sabomu. Although the immediate environs of the village are a patchwork of gardens and highly disturbed, two small streams draining the southern slopes of Mt Sabomu traverse the village and these retain remnant forest patches containing a moderate diversity of herpetofauna. A series of small ponds right on the coast on the southern edge of the village was also sampled for aquatic-breeding frogs.

Yeri River

The Yeri Camp was located in relatively undisturbed lowland forest, and gave access to a series of small and larger streams and several swampy areas. Closer to the river the forest is more disturbed, and is dominated by a patchwork of gardens and sago plantations.

Nae Camp

Nae camp gave access to patches of coastal forest and scrub, and to extensive tracts of open forest interspersed with dense vine thickets on a series of limestone benches and slopes at elevations between sea level and ~100 m a.s.l.

Lolieng Camp

This camp gave access to a range of coastal vegetation types including tall lowland forest, mangroves, and a low cliff flora growing on the coral cliffs.

Results

A total of 40 species of herpetofauna were documented from Manus and Mussau Islands, comprising 11 frogs and 29 reptiles. Diversity was higher at the Manus sites, with a combined species total of 29, including 20 reptiles and nine frogs. In comparison the Mussau Island sites had a combined species total of 20, including 18 reptiles and two frogs. No species listed by the IUCN as Data Deficient, or in any threatened category, was detected but at least four, and probably five, species are new to science including two frogs of the genus *Cornufer* from Manus Island, one frog of the genus *Cornufer* from Mussau Island,

and a giant gecko of the genus *Gehyra* found on both Manus and Mussau islands. Additional studies of a further five reptile species are required to confirm their taxonomic status, and some of these may also prove to be undescribed.
The reptile fauna of both Manus and Mussau islands is dominated by widespread species with only five (17%) of the 29 species found endemic to the Manus group, Mussau, or the two island groups combined. In contrast the frogs show an exceptionally high level of endemism with seven of the nine species encountered at the Manus sites (77.8%) known only from the Manus Island group and one of the two species (50%) found on Mussau known only from that island.

A comprehensive checklist of species encountered is presented in Table 2, and additional species accounts are presented below for each of the significant species documented during this survey.

Table 1. The five main survey locations on Manus and Mussau Islands

Camp	Latitude	Longitude	Altitude (m asl)	Dates
Manus				
Mt Sabomu	S 2.193°	E 146.967°	400–569	2–5 October 2014
Piri Village	S 2.210°	E 146.965°	0–40	6–7 October 2014
Yeri	S 2.001°	E 146.819°	10–60	9–13 October 2014
Mussau				
Nae	S 1.504°	E 149.731°	0 – 104	16–26 October 2014
Lolieng	S 1.422°	E 149.510°	~33	21–26 October 2014

Table 2. Herpetofauna documented at five sites on Manus and Mussau Islands, Papua New Guinea.

Species	Manus			Mussau			
	Mt Sabomu (summit)	Piri Village	Yeri	Nae	Lolieng	IUCN Status	Endemism*
Frogs							
Ceratobatrachidae							
Cornufer admiraltiensis		*	*			LC	MAN
Cornufer custos	*	*	*			NE	MAN
Cornufer latro	*	*	*			LC	MAN
Cornufer manus	*	*	*			NE	MAN
Cornufer vogti	*	*	*			LC	MAN
Cornufer sp. nov. 1 (tiny)	*	*	*			NE	MAN
Cornufer sp. nov. 2 (arboreal)	*	*	*			NE	MAN
Cornufer sp. nov. 3 (Mussau)				*	*	NE	MUS
Hylidae							
Litoria eurynastes		*				NE	W
Litoria infrafrenata		*	*			LC	W
Ranidae							
Hylarana papua				*	*	LC	W
Reptiles - Lizards							
Agamidae							
Hypsilurus schoedei				*	*	LC	MAN/MUS
Gekkonidae							
Cyrtodactylus cf. *sermowaiensis*			*			NE	MAN?
Gehyra oceanica	*	*	*	*	*	NE	W
Gehyra sp. nov.			*			NE	MAN/MUS
Gekko vittatus			*	*	*	NE	W
Hemidactylus garnotii		*				NE	W
Lepidodactylus lugubris		*				LC	W
Nactus kunan	*					NE	MAN
Nactus 'pelagicus'				*	*	NE	W?

Species	Manus			Mussau			
	Mt Sabomu (summit)	Piri Village	Yeri	Nae	Lolieng	IUCN Status	Endemism*
Scincidae							
Carlia ailanpalai	*	*	*			LC	MAN
Carlia mysi				*	*	NE	W
Emoia caeruleocauda	*	*	*	*	*	LC	W
Emoia cyanogaster				*		LC	W
Emoia jakati	*	*	*	*		NE	W
Emoia kordoana			*			NE	W
Emoia longicauda			*	*		NE	W
Eugongylus rufescens	*			*	*	NE	W
Lamprolepis smaragdina		*	*	*	*	NE	W
Lipinia noctua				*		NE	W
Sphenomorphus jobiensis	*					NE	W
Sphenomorphus cf *solomonis*					*	NE	W?
Varanidae							
Varanus indicus			*	*		LC	W
Reptiles – Snakes							
Boidae							
Candoia carinata				*		NE	W
Colubridae							
Boiga irregularis		*				NE	W
Dendrelaphis sp.	*	*	*	*		NE	W?
Stegonotus sp. cf *modestus*			*			NE	W?
Pythonidae							
Morelia amethistina				*		LC	W
Leiopython albertisii				*		NE	W
Typhlopidae							
Ramphotyphlops depressus	*		*			LC	W

*MAN = Manus Island group only; MUS = Mussau Island only; MAN/MUS = shared between Manus group and Mussau only; W = also widespread outside of Manus and/or Mussau islands.

Species Accounts for Significant Species

Frogs

***Cornufer admiraltiensis* (LC)**
A moderate sized (to ~46 mm) terrestrial species exhibiting extremely variable dorsal colouration. The call is a long series of slowly repeated yapping notes. This abundant species is endemic to the Manus Island group and it occurs widely across Manus Island in both closed-forest and moderately disturbed habitats. It was described recently by Richards et al. (2007).

Cornufer custos
A small (to 30 mm), slender frog with an extremely narrow snout. The call is a very harsh 'machine-gun' like rattle, uttered from leaves up to 2 m above the ground. This species is endemic to the Manus Island group and it occurs widely across Manus Island from sea level to the summit of Mt Dremsel at 718 m a.s.l. in both closed-forest and in heavily disturbed habitats including village gardens. It was described only recently by Richards et al. (2014).

***Cornufer latro* (LC)**
A moderate sized (to ~56 mm) terrestrial species that is characterised by having a distinct black band through the eye. The call is complex, consisting of two distinct components: a short rattle followed by ~1-3 musical notes. Endemic to the Manus Island group, this species is abundant throughout Manus Island in both closed forest and in heavily disturbed habitats including village gardens. The call of *C. latro* is one of the dominant sounds in the gardens of Lorengau town, but despite this it was described only recently by Richards et al. (2007).

Cornufer manus
A small (to 32 mm) scansorial (shrub-dwelling) species with a moderately wide snout and large finger and toe discs. The call is a series of loud bell-like notes uttered from leaves up to 5 m above the ground. Endemic to the Manus Island group, this

species is abundant throughout Manus Island from sea level to the summit of Mt Dremsel (718 m a.s.l.) in both closed forest and in heavily disturbed habitats including village gardens. It was described only recently, by Kraus and Allison (2009).

***Cornufer vogti* (LC)**
A very large (to ~120 mm) and robust riparian frog with long, muscular legs. The call is a series of very loud squawks, uttered from the banks of rivers and streams into which the animal leaps when disturbed. Endemic to the Manus Island group, this species occurs from sea level to at least several hundred meters above sea level and appears to tolerate at least moderately disturbed habitats if clear, flowing water is present. Although *C. vogti* is closely associated with flowing streams, at Piri Village several individuals were encountered adjacent to permanent ponds with only limited water movement. However these ponds were fed by small, clear streams draining the Sabomu massif and the species has not otherwise been associated with temporary or isolated aquatic habitats. Despite its close association with streams, like all other ceratobatrachid frogs *C. vogti* almost certainly reproduces via direct-development, bypassing an aquatic tadpole stage.

***Cornufer* sp. nov. 1 (tiny)**
A very small (to 22 mm) terrestrial species exhibiting extremely variable dorsal colouration. The call is a long series of harsh clicking notes, normally uttered from semi-concealed positions within dense leaf litter on the forest floor. This species is unusual among frogs from Manus Island in calling almost exclusively during the day, with peak calling periods at dawn, at dusk and after heavy rain at any time during daylight hours. Few individuals were heard calling at night even after rain. Currently known only from Manus Island, this species occurs widely across the island from sea level to the summit of Mt Dremsel at 718 m. This species is new to science and is currently being described by S.J. Richards.

***Cornufer* sp. nov. 2 (arboreal)**
A moderately large (to 72 mm) arboreal frog with an extremely broad, flat head and greatly enlarged finger and toe disks. The call is a series of loud, melodious 'chuckling' notes uttered from high in the forest canopy. This species is endemic to Manus Island where it occurs widely from sea level to the summit of Mt Dremsel in both closed-forest and in moderately disturbed habitats. This species is new to science and is currently being described by S.J. Richards.

***Cornufer* sp. nov. 3 (Mussau)**
A moderately large (to 76 mm) terrestrial species exhibiting extremely variable dorsal colouration. Morphologically similar to *P. admiraltiensis* from Manus Island and *P. schmidti* from New Ireland, this species has a distinctive call that immediately distinguishes it from them; a very rapid series of ~4-12 yapping notes, uttered from the ground or from perches on top of limestone blocks. Calling was sporadic during the day following rain or in overcast conditions, and then was vigorous from dusk and throughout night. This species is known only from Mussau Island, where it was discovered during the WCS survey. It was common at both sites, and was found in both primary and secondary forest and in old coconut plantations. Although this species was particularly abundant in the coastal forest/scrub it was also more patchily common but locally abundant on the limestone terraces. This species is new to science and is being described by the authors.

Reptiles: Lizards

***Hypsilurus schoedei* Vogt's Forest Dragon (LC)**
A moderately small (SVL to 150 mm), slender, long-tailed forest dragon matching the description of *Hypsilurus schoedei* was encountered at both sites on Mussau Island. *H. schoedei* was described more than 80 years ago from Rambutyo Island, a large island to the south-east of Manus Island in Manus Province and until the 2014 WCS survey was known only from that site. Although Manthey and Denzer (2006) predicted that the species is likely to occur on nearby islands in the Manus group including Manus Island, recent surveys including this one have failed to find it there. On Mussau this species was very common in coastal areas, where it was always observed in trees and shrubs. In these coastal habitats individuals appeared to move high into the canopy during the day but were often seen sleeping quite low (2-5 m off the ground) at night when they were usually perched near the ends of thin branches, presumably to avoid predation by pythons and the Pacific Tree Boa *Candoia carinata* (one juvenile *H. schoedei* was extracted from the jaws of a *Candoia carinata*). Although *H. schoedei* was not observed on the limestone hills and terraces further inland, this could have been due at least partly to different search effort because most night surveys (when many individuals were seen sleeping) were focused on the sandy coastal flats. The hill forest also tended to have a sparser shrub layer so sleeping dragons might have been higher in the trees and more difficult to see.

This species exhibits striking sexual dimorphism in adult colouration. Juveniles of both sexes were green with a pale yellow throat. However with maturity males develop brown dorsal blotches and then become fully brown with a broad pink band on the base of the tail, blue colouration on the vertebral crest, and the throat becomes white instead of pale yellow. In contrast females remain green with increasing maturity and develop a more vividly yellow throat.

The Mussau records of this species represent only the second known location for this poorly-known species.

***Cyrtodactylus* cf. *sermowaiensis* Ring-Tailed Gecko**
A large (SVL 105 mm), attractively marked gecko with claws on each digit and a tail distinctly marked with black and white rings was found in undisturbed forest at Yeri Camp on Manus Island. This species closely resembles, but appears to be

genetically distinct from, *Cyrtodactylus sermowaiensis*, a species with a broad distribution on northern mainland New Guinea. Studies are under way to determine whether it is new to science.

***Gehyra* sp. nov.**
A very large (SVL 140 mm) and robust gecko with large pads on the fingers and toes, was seen at Yeri Camp on Manus Island, and a single individual was captured on Mussau Island where it was found sitting exposed on the roof of the entrance chamber to a large limestone cave (Cave 3; see Aplin et al. Chapter 6, for a description of the cave) around mid-morning.

This species is new to science and had previously been found at a site on Manus Island. The Mussau locality is the first record for this species on that island, and this spectacular new species is currently being described.

***Nactus kunan* Bumblebee Gecko**
A moderately large (SVL to 59 mm) and brightly coloured gecko, this striking species was described by Zug and Fisher (2012) from two specimens collected at Sohoniliu Village in central-eastern Manus Island. Those authors predicted that the species is 'Probably widespread in the highlands of Manus Island where forest patches remain intact'. Several individuals of this poorly-known species found in undisturbed forest below the summit of Mt Sabomu during this survey extend the known distribution of this Manus Island endemic approximately 25 km to the west, represent only the second known locality for the species, and confirm Zug and Fisher's prediction.

***Nactus* 'sp'**
Geckos of the genus *Nactus* are widespread throughout the Melanesian region but, with the exception of *Nactus kunan* (see above) the taxonomic status of most populations on the islands north of New Guinea remains unclear and numerous undescribed species are known to occur in the region. In their description of *N. kunan*, Zug and Fisher (2012) compared that species to, among others, Admiralty Islands populations of *Nactus pelagicus*, a Fijian species, that they proposed was an alien introduction to Manus Island. During the 2014 WCS survey no *N. pelagicus* were encountered on Manus Island, but several individuals of a *Nactus* species were encountered on Mussau Island and this is presumably the same *Nactus* species that was reported from nearby Emirau island in 1955 (Brown 1955, in Zug and Fisher 2012). The Mussau population is remarkable for its large size, with one female exceeding 65 mm SVL, a size not approached by any of the large series of *pelagicus* from Manus Island examined by Zug and Fisher. This suggests that the Mussau/Emirau *Nactus* may represent a distinct and undescribed member of the genus. Further studies will be conducted to determine the status of the Mussau *Nactus* population.

***Varanus indicus* Mangrove Monitor (LC)**
Varanus indicus has a very wide distribution across lowland mainland New Guinea and occurs throughout most of the Melanesian island groups. This monitor lizard was observed on both Manus and Mussau islands, and an individual was photographed by a camera trap on Mussau Island.

Reptiles: Snakes

***Dendrelaphis* sp. Treesnake**
Treesnakes of the genus *Dendrelaphis* are taxonomically difficult and their species boundaries and distributions remain very poorly known. There appear to be no published records of the genus from either Manus or Mussau islands (e.g. O'Shea 1996, Van Rooijen et al. 2015) although *D. punctulatus* is known to occur on New Ireland, just south of Mussau. We observed several *Dendrelaphis* on both Manus Island and Mussau Island, and captured one individual at Piri Village on Manus. Further studies will be conducted to determine whether the Manus population belongs to *D. punctulatus* or represents an undescribed species.

***Stegonotus* cf. *modestus* Northern New Guinea Ground Snake**
One species of Ground Snake of the genus *Stegonotus* was encountered at Yeri Camp, where two individuals were active at night on the forest floor. These animals exhibit slight morphological differences from mainland New Guinean populations of the only *Stegonotus* previously reported from Manus Island, *S. modestus* (ie in lacking dark edges to the subcaudal scales), so the Manus material will be studied further to confirm whether they are conspecific with mainland populations of *S. modestus*.

Leiopython albertisii
Several individuals of the large python *Leiopython albertisii* were encountered on Mussau Island, including one in Cave 3 and one in Cave 6 (see Aplin et al. Chapter 6, for a description of the caves) where they were possibly hunting for the numerous bats roosting inside. Schleip (2008) argued that the population of *L. albertisii* known from nearby Emirau Island represents an introduction and, if so, it is likely that the population on Mussau Island originated from this same invasive event.

***Morelia amethistina* Amethistine Python (LC)**
This is one of the largest snakes in the New Guinea region, exceptional individuals growing to more than 8 m long (O'Shea, 1996). *Morelia amethistina* was recorded from Mussau by O'Shea (1996) and an individual was encountered at Nae Camp during this survey. It is not clear whether the Mussau population of this widespread species has been introduced, either accidentally in cargo or as food – the species is a popular food item for locals on mainland New Guinea - but this appears likely given the isolation of Mussau Island and the apparent successful introduction of another python species, *Leiopython albertisii* (see above).

Discussion

The results of this survey reinforce the importance of the central forests of Manus as a significant refuge for a number of herpetofauna species. The 2014 WCS survey discovered only the second known population of the recently discovered Bumblebee Gecko (*Nactus kunan*) on the slopes of Mt Sabomu, and recorded a potentially new and endemic Ring-Tailed Gecko (*Cyrtodactylus*) from the northern lowlands. The forest at the Yeri site also supports a population of giant, undescribed *Gehyra* gecko, a species known only from Manus and Mussau islands. These discoveries highlight the importance of careful management of the forest that remains in the central Manus region.

The WCS survey also represented the first comprehensive herpetofauna inventory of Mussau Island, and led to the discovery of one new frog species in the genus *Cornufer* and to significant rediscoveries of and range extensions for, poorly-known species such as the forest dragon *Hypsilurus schoedei*. The survey on Mussau Island was restricted predominantly to coastal regions and it is highly likely that additional significant herpetological discoveries remain to be made in the island's interior.

Recommendations

On both Manus and Mussau islands broad-scale loss of forest has the potential to dramatically reduce the herpetofaunal diversity and it is important to develop management plans for both regions that consider the impacts of broad-scale clearing in particular on local forest-dwelling species.

References

Allison, A. 1996. Zoogeography of amphibians and reptiles of New Guinea and the Pacific region. *In* A. Keast and S. E. Miller (Eds) The origin and evolution of Pacific Island biotas, New Guinea to Eastern Polynesia: patterns and processes SPB Academic Publishing, Amsterdam. Pp 407–436.

Brown, W.C. 1955. A collection of lizards from Emirau Island (Saint Matthias Group). *The Silliman Journal* II: 87–92.

Brown, W. C. 1991. Lizards of the genus *Emoia* (Scincidae) with observations on their evolution and biogeography. *Memoirs of the California Academy of Sciences* 15: 1–94.

Brown, W.C. 1997. Biogeography of amphibians in the islands of the southwest pacific. *Proceedings of the California Academy of Sciences* 50: 21–38.

Brown, R.M., Siler, C.D., Richards, S.J., Diesmos, A.C. and Cannatella, D.C. 2015. Multilocus phylogeny and a new classification for Southeast Asian and Melanesian forest frogs (family Ceratobatrachidae). *Zoological Journal of the Linnean Society* 173.

Cogger, H.G. 1972. A new scincid lizard of the genus *Tribolonotus* from Manus Island, New Guinea. *Zoologische Mededelingen* 47: 201–210.

Hediger, H. 1933. Über die von Herrn Dr. A. Buhler auf der Admiralitäts-Gruppe und einigen benachbarten Inseln gesammelten Reptilien und Amphibien. *Verhandlungen der Naturforschenden Gesellschaft in Basel* 44: 1–25.

Kraus F., Allison A. 2009. New species of frogs from Papua New Guinea. *Bishop Museum Occasional Papers* 104: 1–36.

Manthey, U. and W. Denzer. 2006. A revision of the Melanesian-Australian angle head lizards of the genus *Hypsilurus* (Sauria: Agamidae: Amphibolurinae), with description of four new species and one new subspecies. *Hamadryad* 30: 1–40.

O'Shea, M. 1996. A guide to the snakes of Papua New Guinea. Independent Publishing. Port Moresby. Papua New Guinea.

Richards, S.J., Mack, A.L. and Austin, C.C. 2007. Two new species of *Platymantis* (Anura: Ceratobatrachidae) from the Admiralty Archipelago, Papua New Guinea. *Zootaxa* 1639: 41–55.

Richards, S.J., Oliver, P. and Brown, R.M. 2014. A new scansorial species of *Platymantis* Günther, 1858 (Anura: Ceratobatrachidae) from Manus Island, Admiralty Archipelago, Papua New Guinea. *In* Telnov, D. (ed.). Biodiversity, Biogeography and Nature Conservation in Wallacea and New Guinea. Vol. 2. Pp. 123–133.

Schleip, W.D. 2008. Revision of the genus *Leiopython* Hubrecht 1879 (Serpentes: Pythonidae) with the rediscription of taxa recently described by Hoser (2000) and the description of new species. *Journal of Herpetology* 42: 645–667.

Sternfeld, R. 1920. Zur Tiergeographie Papuasiens und der pazifischen Inselwelt. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* 36: 373–436.

Van Rooijen, J., Vogel, G. and Somaweera, R. 2015. A revised taxonomy of the Australopapuan species of the colubrid genus *Dendrelaphis* (Serpentes: Colubridae). *Salamandra* 51: 33–56.

Zug, G. 2004. Systematics of the *Carlia "fusca"* lizards (Squamata: Scincidae) of New Guinea and nearby islands. *Bishop Museum Bulletin in Zoology* 5: 1–84.

Zug, G. and Fisher, R. 2012. A preliminary assessment of the *Nactus pelagicus* species group (Squamata: Gekkonidae) in New Guinea and a new species from the Admiralty Islands. *Zootaxa* 3257: 22–37.

Chapter 5:

Birds of Mussau Island

Richard Cuthbert

Summary

The distinct avifauna of the St Matthias Islands in the Northern Bismarck Sea is recognized with its status as an Endemic Bird area and Key Biodiversity Area due to the occurrence of at least two endemic species and 15 endemic sub-species. Despite this recognition the island is seldom visited and the avifauna remains little studied. Over the course of an 11 day visit in October 2014 a team of biologists from the Wildlife Conservation Society visited Mussau Island to undertake a biodiversity assessment. Survey areas were located close to the communities of Nae in the southeast of the island and Lolieng in the southwest. Birds were surveyed through a combination of observations and mist-netting and in a variety of habitats from garden areas and young secondary forest, to mature closed canopy secondary forest and primary forest. A total of 45 species were recorded during the survey, with 33 of these being land birds including three endemics (the Mussau Fantail *Rhipidura matthiae,* Mussau Monarch *Symposiachrus menckei* and Mussau Flycatcher *Myiagra hebetior*).

While the survey recorded 40 resident species it did not find a further ten species that have previously been recorded as resident.

Introduction

Mussau and the wider St Matthias group have long attracted the interest of ornithologists due to the presence of between two (BirdLife International 2015a) and four (Dutson 2011) endemic species and a further 15 to 17 endemic sub-species. These species include the Mussau Fantail *Rhipidura matthiae* and Mussau Monarch *Symposiachrus menckei*, and two species or sub-species the Dull Flycatcher *Myiagra hebetior* and the Mussau Triller *Lalage conjuncta* (Dutson 2011[3]). This distinctive avifauna has resulted in the St Matthias group being classified as an endemic bird area (EBA) (BirdLife International 2015a). Previously the St Matthias islands have been grouped as part of the wider Admiralty Islands EBA (BirdLife International 2015c), but the lack of a clear affinity of the species in the St Matthias Islands to the avifauna of the Admiralty Islands (which includes the main island of Manus) has resulted in its separate EBA status.

Despite the importance of the bird life on the St Matthias Islands the avifauna remains poorly known and the island is infrequently visited by ornithologists or bird watchers. The island was first visited by a scientific team in 1901 by members of the Mencke Expedition, including the ornithologist Dr. O. Heinroth. Their visit was short, as their camp was attacked and Mencke and other members were killed (Rothschild and Hartert 1923). Despite only spending one day on the island Heinroth collected specimens of the endemic Mussau Fantail, Mussau Monarch and Collared Kingfisher (now considered a sub-species). The next ornithological expedition to the island was in 1923 when A. F. Eichhorn visited and made a more extensive collection of birds. This collection included further specimens of the three species collected by Heinroth, as well as a variety of new sub-species (or species; depending on the authority) that are described in papers by Hartert (1924) and Rothschild and Hartert (1923). Further ornithological visits to the St Matthias Islands that are known (from publication and trip reports) include those made by the Whitney South Sea Expedition (Mayr 1931, 1937, 1955; Mayr and Ripley 1941), and scattered visits during the 1970s (Silva 1973, 1975), 1980s (Finch 1985) and 1990s (Eastwood 1996; Dutson 2001). The most recent visit occurred in 2007 (Gregory 2007). Information from these visits are summarized and reported in Dutson's (2011) field guide to the Melanesia region.

Methods

The main focus of the fieldwork was Mussau Island's endemic and resident species and consequently more time and effort was put in these species in comparison to more widespread and common seabird and shorebird species. Avian species were surveyed through a combination of field observations and mist-netting. Field observations were undertaken along the paths, tracks and roads on Mussau, as well as from walks through areas of mature secondary and primary forest. Additional observations were made in garden areas and secondary growth areas at both sea-level and at 100 m (mainly around Nae)

[3]Dutson (2011) lists the Mussau Flycatcher and Mussau Triller as full species, however BirdLife International (2015b) currently only recognize these as sub-species.

and 220 m (above Lolieng). Observations were combined with visits to establish and check mist-nets, as well as dawn and dusk walks. As many habitat types as possible were surveyed, as well as surveying a range of altitudes. Few observations were possible of seabirds on the trip, other than from incidental observations made of both seabirds and shorebirds during boat journeys to and from Nae and Lolieng.

Mist-netting methods and localities

Mist-nets were established at five main sites, with two main sites at Nae and three sites at Lolieng (Plate1, for exact locations see Appendix 1). Sites at Nae included six nets located close to the main field camp (altitude 10-17 m above sea level) and from here running inland (westerly direction) up a steep path through mature secondary forest to a plateau with scrub habitat (in limestone areas with thin soil) and scrub adjoining cleared areas of gardens (altitude 34 to 79 m). Four other nets were located in mature closed-canopy secondary forest and areas of primary forest to the south of the field camp (altitude 73-82 m). This area contained some of the most undisturbed and unlogged areas that the team visited and nets were located in understory vegetation among large (estimated as 30-40 m in height) trees. Two further nets (Net 6 and Net 7 on the map) at Nae were situated along the main lowland path (altitude 32 and 37 m) from the field camp to Emerald Beach and were established to capture bats. Birds captured from these nets were brought back to camp for processing. At Lolieng seven mist-nets were established to the north of the main field camp. These nets were all located in an area of mature closed canopy secondary forest on top of a plateau at altitudes of 152-180 m. The final two sets of nets were established near the pastor's house, located above the main village areas of Lolieng. Seven nets were located to the east of the house along a ridge line that ran through a mix of mature secondary forest and young forest adjoining garden areas at an altitude of 146 to 168 m. A further seven nets were established to the west of the pastor's house in a mature area of secondary forest and included one canopy net (altitude 194 to 202 m). Maps of all net locations and GPS coordinates for all nets are included in Appendix 1.

Nets were run in as wide a variety as habitats as possible and included garden areas, young regenerating scrub and forest, mature secondary forest and primary forest. The majority of species that were present in garden and young regenerating scrub/forest habitats were captured at Nae, and consequently mist-netting effort at Lolieng focused on mature secondary and primary forest and at a wider variety of elevations. Mist-nets were established the day before and sited along natural flight paths or within dense vegetation. Net lengths varied from 8 to 15 m and apart from one canopy net were placed close to ground level from ~0.3 m to ~3.0 m in height. One canopy net was established in mature secondary forest, located at a height of 20-30 m. Nets were run from before dawn (05:30-06:00) until mid to late morning (10:00 to 11:30). Upon capture all birds were removed from the net and placed in cotton bird bags, and they were either processed at the camp or in the field.

After capture all birds were identified, sexed and aged (where plumage, moult or other features enable this), weighed with Pesola spring-balances (accurate to the nearest 1 g or 2.5 g for birds <100g or >100g in weight, respectively) and measured. Standard mensural data collected for all birds included bill length, bill depth, bill width, total head length, tarsus length, wing chord length and tail length. Measurements were made with a stopped rule or Vernier callipers, accurate to 1 mm and 0.1 mm respectively. The presence or absence of a brood patch was recorded, along with observations on body, tail and wing moult, and if wing moult was present the order and sequence of primary moult. Measurements and moult scores followed standard guidelines (as detailed in Lowe 1989). For certain species whose taxonomic status is uncertain additional measurements of head width and head depth were also recorded, along with more detailed observations on plumage colouration, photographs and DNA samples. All captures were marked with a small dot of nail-polish on the tarsus and/or toe to allow any recaptures to be easily determined.

There is some confusion and disagreement between authorities on the names and specific status of the birds on Mussau. For ease of reference nomenclature and species status follows Dutson (2011). Field guides used during the visit include Coates and Peckover (2001), Dutson (2011) and Pratt and Beehler (2015). Statistics for measurement data reports means, standard deviation, ranges and sample size. The analyses do not include any attempt to report captures per net hour or net length, due to the relatively small number of nets (5 to 8), limited number of days at each site (1 to 3) and variation in habitat types and weather conditions.

Results

A total of 45 species were recorded from Mussau during the survey, with 33 of these being land birds, and 12 consisting of seabirds and shorebirds. A plot of the cumulative number of species against survey team indicates that the number of new species reaches a relative plateau after 6-7 days (Figure 1), however new species continued to be recorded up until the last day (8) of the survey; suggesting that insufficient survey time was available to comprehensively survey all species.

Mist-netting on Mussau recorded a total 75 birds from 14 species, all of which were Passerines. The number of individuals captured varied from 1 to 14 individuals for each species, with captures dominated by seven species which comprised 89% of all individuals caught. Catch totals for all species are indicated in Table 1. Mensural data was recorded for all species and is included in the individual species accounts. A full species list is given in Appendix 2.

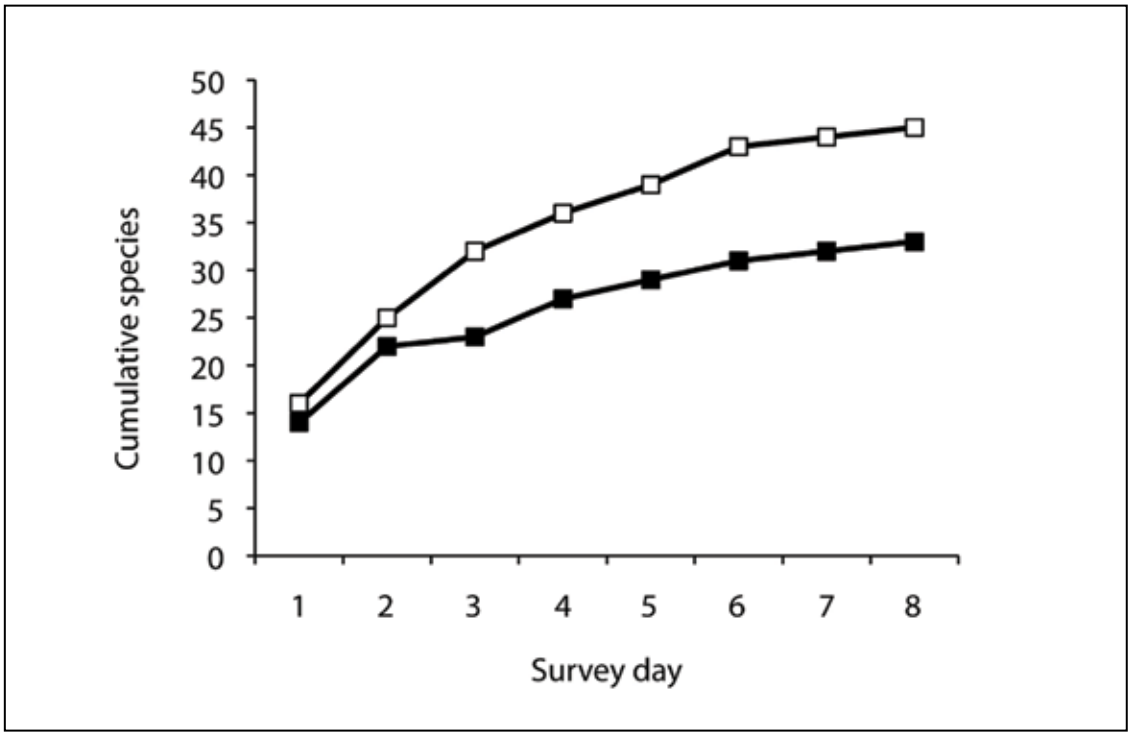


Figure1. Plot of cumulative species number against survey day for landbirds (black symbols) and all species including seabirds and shorebirds (open symbols) on Mussau during the survey.

Table 1. Species and number captured in mist-nets and through other methods during fieldwork at Nae and Lolieng, Mussau Island.

Common name	Scientific name	Total	% catch
Bismarck Whistler	*Pachycephala citrogaster sexuvaria*	7	9%
Black Myzomela	*Myzomela pammelaena hades*	11	15%
Blue-faced Parrot Finch	*Erythrura trichoa sigillifera*	5	7%
Bronze Ground Dove	*Gallicolumba beccarii eichorni*	1	1%
Collared Kingfisher	*Todiramphus chloris matthiae*	1	1%
Island Monarch	*Monarcha cinerascens perpallidus*	13	17%
Knob-billed Fruit Dove	*Ptlinopus insolitus inferior*	1*	1%
Metallic Starling	*Aplonis metallica nitida*	1	1%
Mussau Fantail	*Rhipidura matthiae*	2	3%
Mussau Monarch	*Symposiachrus menckei*	14	19%
Northern Fantail	*Rhipidura rufiventris mussai*	1	1%
Olive-backed Sunbird	*Cinnyris jugularis flavigaster*	1*	1%
Russet-tailed Thrush	*Zoothera heinei eichhorni*	8	11%
Yellow-bibbed Fruit Dove	*Ptlinopus solomonensis johannis*	9	12%
TOTAL		**75**	

* These two birds were shot with a catapult by a local boy in Nae and brought to the camp

Species accounts

Melanesian Megapode, *Megapodius eremita* – (observed)
Individual birds were regularly seen in areas of mature secondary forest and primary forest at both Nae and Lolieng. Birds were not seen in old gardens or younger areas of forest. No nesting mounds were seen of the species, but insufficient time was spent to properly search for and find these.

Lesser Frigatebird, *Fregata ariel* – (observed)
Single individuals were seen at sea off the camp at Nae and during the boat journey from Nae to Lolieng. A larger number of birds (25-30) were also seen flying high over the camp at Nae in the late afternoon and were presumably returning to a roost site.

Pacific Reef Heron, *Egretta sacra* – (observed)
A single bird was seen on one day along the shore close to the camp at Nae.

Eastern Osprey, *Pandion cristatus* – (observed)
One bird was seen flying along the shore line close to the camp at Nae.

Brahminy Kite, *Haliastur indus* – (observed)
A single bird was recorded flying over the village of Nae on the day of our arrival. No other birds were seen at Nae or Lolieng.

White-bellied, Sea Eagle *Haliaeetus leucogaster* – (observed)
One individual was seen soaring high over mature primary and secondary forest above the main camp at Lolieng.

Variable Goshawk, *Accipiter hiogaster matthiae* – (observed)
A pair was frequently present in a large tree situated in new and old garden areas close to the camp at Nae. While a nest was not observed the behaviour of the pair suggested that they had or were about to nest in the tree.

Whimbrel, *Numenius phaeopus* – (observed)
One Whimbrel was seen on the beach and shoreline at Nae close the camp area.

Common Sandpiper, *Arctitus hypoleucos* – (observed)
Individual birds were commonly seen along the shoreline at Nae in areas from the camp to Emerald Beach.

Grey-tailed Tattler, *Tringa brevipes* – (observed)
A single bird was recorded on the beach and in low tidal lagoon areas adjoining the camp area at Nae.

Great Crested Tern, *Thalasseus bergii* – (observed)
Small numbers of individuals, numbering between 1 and 3 birds, were seen offshore at Nae, either flying at sea or resting on marker poles in the water.

Black-naped Tern, *Sterna sumatrana* – (observed)
Individual birds and small flocks of 2-4 birds were seen at sea during the boat journey from Nae to Lolieng.

Brown Noddy, *Anous stolidus* – (observed)
Small flocks of Brown Noddy were commonly seen at sea and from shore at Nae and Lolieng and during boat trips between the two sites. No birds were seen breeding or roosting on shore.

Slender-billed, Cuckoo-dove *Macropygia amboinensis admiralitatis* – (observed)
The species was commonly heard calling in secondary forest and mature closed-canopy forest habitat at both Nae and Lolieng.

Mackinlay's Cuckoo-dove, *Macropygia mackinlayi arossi* – (observed)
The species was commonly seen and heard in old garden areas, secondary forest and mature closed-canopy forest at both Nae and Lolieng.

Bronze Ground Dove, *Gallicolumba beccarii eichhorni* – (observed/captured)
Up to seven sub-species of the Bronze Ground Dove are recognised (Dutson 2011) with *Gallicolumba beccarii eichorni* endemic to Mussau and Emirau. Birds were infrequently seen in areas of young secondary forest and in more mature secondary forest and primary forest. The Bronze Ground-dove was relatively scarce in comparison to other pigeons and doves on the island. One individual was captured in a mist-net in mature closed canopy secondary/primary forest above the main field camp at Lolieng. Morphometric measurements for this individual were: body mass 72.5 g, bill length 14.2 mm, bill depth 4.5 mm, bill width 3.6 mm, total head length 39.6 mm, tarsus 28.3 mm, wing chord 105 mm and tail 68 mm. This bird was a male, based on its prominent white eye-ring and pale breast (Figure 3; Dutson 2011).

Stephan's Emerald Dove, *Chalcophaps stephani stephani* – (observed)
Stephan's Emerald Dove was commonly seen in lowland areas around Nae, including in old gardens, young secondary forest and old coconut plantations close to Emerald Beach. Few birds were seen at Lolieng, however more time was spent at higher altitudes and in mature forest areas in this area of Mussau. Dutson (2011) reports the Stephan's Emerald Dove as more common in lowlands and degraded forest (including coconut plantations), which supports the species' distribution and abundance on Mussau.

Nicobar Pigeon, *Caloenas nicobarica* – (observed)
The Nicobar Pigeon was most commonly observed in mature closed canopy secondary forest and primary forest areas where it was frequently seen and flushed from the forest floor. One bird was also seen in an area of old coconut plantations, close to the camp site at Nae. The species was recorded at both Nae and Lolieng and at all altitudes surveyed. Only individual birds were observed and no larger flocks were seen. The Mussau population might be nesting on Tench Island, the closest-known breeding site (G. Dutson pers. com.).

Yellow-bibbed Fruit Dove, *Ptlinopus solomonensis johannis* – (observed/captured)
The Yellow-bibbed Fruit Dove was the most commonly encountered member of the Columbidae family on Mussau, and was recorded in all habitat types from garden areas to primary forest, at all altitudes surveyed (10 to 200 m) and at both Nae and Lolieng. A total of nine birds were captured in mist nets and body measurements are recorded in Table 2 below.

Knob-billed Fruit-dove, *Ptlinopus insolitus inferior* – (observed/captured)
The Knob-billed Fruit-dove is endemic to the St Matthias Islands and Bismarcks with the sub-species *Ptlinopus insolitus inferior* being considered endemic to Mussau and Emirau on account of its smaller size and plumage colouration (Dutson 2011). Single birds were seen and heard in the vicinity of the camp area in Nae in old and new garden areas and secondary regrowth. The species was not recorded from closed canopy secondary forest or primary forest, or from higher altitude areas of Mussau. No birds were captured in mist-nets however one Knob-billed Fruit-dove was shot and killed with a catapult by a small boy in the village of Nae and brought in to the camp area. Morphometric measurements for this individual were: body mass 76 g, bill length 9.0 mm (bill tip to the start of the knob), bill depth 4.8 mm (measured just in front of the knob), bill width 6.7 mm, total head length 41.6mm, tarsus 22.0 mm, wing chord 120 mm and tail 63 mm. This bird had a rusty-brown plumage colouration on its neck and coverts beside the grey shoulder patch that is characteristic of *Ptlinopus insolitus inferior* (Dutson 2011).

Island Imperial Pigeon, *Ducula pistrinaria rhodinolaema* – (observed)
Single individuals of what were presumed to be Island Imperial Pigeons were seen flying high over forest areas above the camp at Lolieng, and heard calling in other thick forested areas. Identification is tentative as while Tarburton (2014) only records this species as present on Mussau, Dutson 2011 records the Island Imperial Pigeon and Pacific Imperial Pigeon *Ducula pacifica* as both being present, although notes that the latter is rare on large islands where congeners are present. The high flight and short views of these individual birds did not enable species identification to be certain, but based on Dutson (2011) it is more likely that these were Island Imperial Pigeons rather than the Pacific Imperial Pigeon.

Meek's Pygmy Parrot, *Microspitta meeki pusio* – (observed)
Small foraging groups of two to four individuals were seen at Nae. These sightings all occurred within a 50-100 stretch along one of the main paths at an altitude of ~20 m a.s.l. and occurred in young regenerating scrub and secondary growth bordering old garden areas. The sub-species *Microspitta meeki proxima* is endemic to the St Matthias Islands.

Coconut Lorikeet, *Trichoglossus haematodus* – (observed)
Small flocks of Coconut Lorikeets were commonly heard in lowland areas around Nae and Lolieng, however the species was infrequently observed. Most birds were heard from young secondary forest areas and in adjoining areas of old coconut plantations. No birds were captured and along with the lack of good sightings this prevented any information being gathered on whether the sub-species *Trichoglossus haematodus flavicans* was present, as suspected by Dutson (2011).

Long-tailed Cuckoo, *Urodynamis taitensis* – (observed, new record)
A single Long-tailed Cuckoo was observed flying from a tree high up on the main road above the village of Lolieng, in the vicinity of the pastor's house. The species nests in New Zealand and is an uncommon non-breeding migrant to small islands in Melanesia. Neither Dutson (2011) nor Tarburton (2014) record this species as being present on Mussau and this sighting is a new record for the island.

White-rumped Swiftlet, *Aerodramus spodiopygius eichhorni* – (observed)
The White-rumped Swiftlet was commonly seen in all areas of the island; foraging in village areas, gardens and young secondary forest, and above the canopy in closed canopy secondary and primary forest.

Uniform Swiftlet, *Aerodramus vanikorensis coultasi* – (observed)
As for the above species, the Uniform Swiftlet was commonly seen in all areas of the island; foraging in village areas, gardens and young secondary forest, and above the canopy in closed canopy secondary and primary forest.

Common Kingfisher, *Alcedo atthis hispidoides* – (observed)
This species was seen along coastal areas close to the camp site at Nae as well as along the coast in the main village of Nae. It was not seen at Lolieng, as less survey time was spent in coastal areas at this site.

Collared Kingfisher, *Todiramphus chloris matthiae* – (observed/captured)
This species was fairly commonly seen in young secondary forest and garden areas at Nae and one individual was captured in a mist-net. Morphometric measurements for this bird were: body mass 69 g, bill length 48.4 mm, bill depth 5.1 mm, bill width 6.8 mm, total head length 84.2 mm, tarsus 6.5 mm, wing chord 110 mm and tail 74 mm. All birds observed (and captured) had the pale crown, black mask and darker blue mantle and wings that characterise the St Matthias sub-species *Todiramphus chloris matthiae* .

Beach Kingfisher, *Todiramphus saurophagus saurophagus – (observed)*
One Beach Kingfisher was seen along the shoreline close to the camp site at Nae. Other members of the team reported seeing this species at Emerald Beach and in coastal areas at Lolieng.

Sacred Kingfisher, *Todiramphus sanctus sanctus* – (observed)
A single Sacred Kingfisher was seen along the shoreline at Nae. No other birds were observed. This species is a migrant to Mussau and other Admiralty Islands.

Bismarck Black Myzomela, *Myzomela pammelaena hades* – (observed/captured)
The Bismarck Black Myzomela was frequently seen in all habitat types at both Nae and Lolieng and was also commonly captured in mist-nets in both garden/disturbed forest areas as well as in mature closed canopy forest. Body measurements for this species are reported below (Table 2).

Bismarck Whistler, *Pachycephala citrogaster sexuvaria* – (observed/captured)
The Bismarck Whistler was seen and captured at both Nae and Lolieng and was found in young regenerating forest adjoining lowland garden areas through to mature secondary and primary forest in higher altitude areas of the island. A total of seven birds were caught in mist-nets and morphometric measurements are listed in Table 2.

Willie Wagtail, *Rhipidura leucophyrs melaleuca* – (observed)
Commonly observed in village areas, new and old gardens and at all altitudes visited. Not recorded from closed canopy secondary or primary forest.

Northern Fantail, *Rhipidura rufiventris mussai* – (observed/captured)
The Northern Fantail was regularly seen in old gardens, young secondary forest and mature forest, although it was less common and less conspicuous than the Mussau Fantail. One bird was captured along the main path at Nae. Morphometric measurements of this individual were: body mass 16.5 g, bill length 15.4 mm, bill depth 4.7 mm, bill width 7.5 mm, total head length 37.3 mm, tarsus 17.5 mm, wing chord 95 mm and tail 82 mm.

Mussau Fantail, *Rhipidura matthiae* – (observed/captured)
The Mussau Fantail was commonly seen in all habitat types and was common at lowland and higher altitude sites. This endemic was one of the most abundant and conspicuous species in the forest areas. Two birds were captured in mist-nets. Measurements are detailed in the Table 2.

Mussau Monarch, *Symposiachrus menckei* – (observed/captured)
The Mussau Monarch and Island Monarch were two of the most commonly encountered forest birds on Mussau and were seen in regenerating secondary forest and mature closed canopy secondary and primary forest, from sea-level to 200 m. These two monarch species comprised more than one third of all captures in mist-nets and a total of 14 Mussau Monarchs were caught. Morphometric measurements are detailed below in Table 2.

Island Monarch, *Monarcha cinerascens perpallidus* – (observed/captured)
As with the previous species, the Island Monarch was commonly seen in regenerating secondary forest and more mature closed canopy forest and at a range of altitudes. A total of 13 birds were captured and measurement information is presented in Table 2. All birds observed and captured had very pale orange/buffy colouration on their underparts as well as generally pale grey uniform colouration to the upperparts. Dutson (2011) reports the St Matthias and New Ireland sub-species *Monarcha cinerascens perpallidus* as having slightly brighter colouration and being darker below than the *Monarcha c. fulvientris*, and that both these sub-species are lighter than *Monarcha c. impediens* which is darker grey with a deeper rufous belly. The colouration of birds captured on Mussau in this trip is far paler (above and particularly below) than the illustration of *Monarcha cinerascens perpallidus* in Dutson's (2011) field-guide, and it is unclear whether this is due to island variation or inaccurate colouration in the field-guide.

Mussau Flycatcher, *Myiagra hebetior* – (observed)
The Mussau Flycatcher (sometimes also treated as a conspecific with the Velvet or Dull Flycatcher *Myiagra eichhorni*) is a Mussau endemic and considered "fairly common" and "moderately common" by Dutson (2011) and Tarburton (2014), respectively. The species was recorded during the current survey from primary forest and mature secondary forest, although appeared more common in forest areas close to Nae than in Lolieng (although it was seen in the latter). Male and female birds were most frequently seen in thick understory vegetation in these forest areas. It was not recorded in adjoining young secondary growth or old garden areas and appeared restricted to mature forest areas. Mist nets were established in areas of understory in the primary forest areas near Nae; however we were not successful in capturing any birds. One nest was observed by F. Venter during his vegetation surveys and was found in the understory vegetation in mature secondary/primary forest near Nae. The simple cup nest was located in a tree fork at around 2 to 2.5 m in height, and contained a single chick.

Island Leaf Warbler, *Phylloscopus poliocephalus matthiae* – (observed)
Small flocks of Island Leaf Warbler were observed and heard around the camp site at Nae in young forest regrowth and scrub areas, as well as in forest areas adjoining gardens and young secondary forest in upland areas of Lolieng. The Island Leaf Warbler forms a species complex with seven sub-species present in Melanesia (including *Phylloscopus poliocephalus matthiae* on Mussau; Dutson 2011) and further sub-species present in Indonesia and New Guinea. Other *Phylloscopus* species complexes are increasingly being split into constituent species, so it is possible that *matthaie* will in future be considered a full species. The species appeared to be locally common in abundance during this visit, although was not recorded in some localities or in closed canopy forest areas.

Metallic Starling, *Aplonis metallica nitida* – (observed/captured)
The Metallic Starling was commonly observed in lowland garden areas and in young regenerating scrub and forest areas, with a large colony close to the main camp at Nae. It was not recorded from closed canopy forest areas during the survey. A single bird was captured in a mist-net. Morphometric measurements for this bird were: body mass 51.5 g, bill length 18.4 mm, bill depth 6.7 mm, bill width 7.8 mm, total head length 47.1 mm, tarsus 23.7 mm, wing chord 111 mm and tail 94 mm.

Singing Starling, *Aplonis cantoroides* – (observed)
Similar to the Metallic Staring in distribution the Singing Starling was commonly observed in lowland garden areas and in young regenerating scrub and forest areas, and not seen in more mature forest areas. It was less abundant than the former species, but nonetheless seen relatively frequently at Nae and Lolieng.

Russet-tailed Thrush, *Zoothera heinei eichhorni* – (observed/captured)
The Russet-tailed Thrush is one of Mussau's more intriguing species due to the fact that the sub-species *Zoothera heinei eichhorni* which is endemic to Mussau is relatively distinct from the endemic Choiseul form *Zoothera heinei choiseuli* and also distinct from the more widespread New Guinea *Zoothera heinei papuensis* and Australian *Z. h. heinei* This distinctiveness has led some authors (Rothschild and Hartert 1923; Dutson 2011) to suggest that it could be treated as a separate species. The Russet-tailed Thrush was a comparatively common species during the survey with 8 birds captured in mist-nets. The species was recorded in all major habitat types from new and old gardens and re-growth, through to mature secondary forest and unlogged primary forest. Dutson (2011) suggests it was especially common in overgrown gardens and secondary growth and while it was recorded from these habitats in this survey it appeared as common in closed-canopy secondary forest and primary forest and in areas with an understory of leaf litter. Contact calls and alarm calls of the Russet-tailed Thrush were frequently heard in the early morning. However its song was rarely heard (or could not be identified). Morphometric measurements for the species are listed below. More detail on this species' measurements, plumage and voice will be published in a separate paper discussing its species status.

Island Thrush, *Turdus poliocephalus heinrothi* – (observed)
The island thrush forms a species complex whose range is scattered across Melanesia and whose species status is poorly known. The sub-species *Turdus poliocephalus heinrothi* is endemic to Mussau. One individual was flushed from the ground along the path between Nae and Emerald Beach in young secondary forest bordering an old coconut plantation, but otherwise the species was not recorded during the survey. Dutson (2011) describes the species' song as similar to the Common Blackbird *Turdus merula* (which the observer is very familiar with), however such a song was not heard during the time on Mussau. Tarburton (2014) reports the species as locally moderately common in mountain forest and mountain scrub on Mussau, whereas Dutson (2011) describes it as fairly common at all altitudes. Its relative scarcity in the current survey is puzzling; however like the Mussau Triller it is possible that most survey efforts were at too low an altitude to commonly encounter this species, supporting Tarurton's indication that it is more frequent at higher altitudes.

Olive-backed Sunbird, *Cinnyris jugularis flavigaster* – (observed/captured)
The Olive-backed Sunbird was commonly seen in village and garden areas at both Nae and Lolieng. It was not recorded from mature closed canopy forest. Despite its relative abundance in garden and young forest areas it was not captured in mist-nets and was seen more frequently in the tree-tops and above the level of most nets. One individual was shot with a catapult by a small boy in the village of Nae and brought in to the camp area. Morphometric measurements were: body mass 6.5 g, bill length 15.2 mm, bill depth 2.9 mm, bill width 4.8 mm, total head length 32.7 mm, tarsus 15.2 mm, wing chord 52 mm and tail 28 mm. This bird was stunned by the catapult shot, but recovered and was released.

Blue-faced Parrotfinch, *Erythrura trichoa eichhorni* – (observed/captured)
The Blue-faced Parrotfinch was commonly seen in open grassy areas in villages at Nae, as well as in new and overgrown gardens in Nae and Lolieng, including in coastal and higher altitude (200 m) areas. The species was also recorded in mature closed canopy secondary forest and two birds were captured in the canopy net at Lolieng. The sub-species *Erythrura trichoa eichhorni* is endemic to Mussau and Emirau. A total of five birds were captured in mist-nets. Body measurements are reported in Table 2.

Table 2. Morphometric measurements of selected species.

Species	Value	Body Mass	Bill Length	Bill Depth	Bill Width	Total Head	Tarsus	Wing Chord	Tail
Island Monarch	mean (mm)	20.5 ± 1.3	16.7 ± 0.8	5.5 ± 0.2	8 ± 0.5	41.1 ± 1	20.9 ± 0.4	85.5 ± 1.6	73.2 ± 2.1
	range (mm)	18 – 22	15.7 – 18.4	5.2 – 5.9	7.4 – 8.8	38.8 – 42.1	20.1 – 21.6	82 – 88	70 – 77
	n	13	13	13	13	13	13	13	13
Yellow-bibbed Fruit Dove	mean (mm)	70.1 ± 19.8	16.6 ± 1.2	6.6 ± 0.8	6.8 ± 0.3	43.2 ± 1.6	21.7 ± 2	118.1 ± 7.2	64.9 ± 4.1
	range (mm)	34.5 – 94	15.5 – 19.2	5.7 – 8	6.3 – 7.2	40 – 45.4	18.8 – 25.6	106 – 126	59 – 71
	n	9	9	9	9	9	9	9	9

Species (cont)	Value	Body Mass	Bill Length	Bill Depth	Bill Width	Total Head	Tarsus	Wing Chord	Tail
Bismarck Black Myzomela	mean (mm)	11 ± 1.1	15.7 ± 1.2	3.5 ± 0.3	4.1 ± 0.4	32.7 ± 1.4	18.5 ± 0.9	63.7 ± 2.9	43.1 ± 3
	range (mm)	9.5 – 13	14.3 – 18	3.1 – 4.2	3.3 – 4.5	31.3 – 35.5	17 – 19.7	60 – 68	39 – 47
	n	11*	10	10	10	10	10	10	10
Bismarck Whistler	mean (mm)	26.4 ± 0.9	16.6 ± 0.7	6 ± 0.3	7.1 ± 0.2	42.3 ± 0.9	24.4 ± 0.8	87 ± 1.3	62 ± 1.9
	range (mm)	25.5 – 27.5	15.5 – 17.4	5.8 – 6.5	6.9 – 7.5	41.5 – 43.3	23.1 – 25	85 – 88	60 – 64
	n	7*	6	6	6	6	6	6	6
Mussau Fantail	mean (mm)	10.3 ± 1.1	10 ± 0.1	3.3 ± 0.4	6.3 ± 0.3	29.4 ± 0.4	20.6 ± 0.4	80 ± 14.1	74.5 ± 4.9
	range (mm)	9.5 – 11	9.9 – 10	3 – 3.6	6.1 – 6.5	29.1 – 29.6	20.3 – 20.8	70 – 90	71 – 78
	n	2	2	2	2	2	2	2	2
Mussau Monarch	mean (mm)	13 ± 0.9	11.8 ± 0.5	4.2 ± 0.3	6.4 ± 0.5	33.6 ± 0.5	19.6 ± 0.3	71 ± 1.9	64.5 ± 2.1
	range (mm)	11 – 14.5	10.7 – 12.7	3.7 – 4.7	5.5 – 7.2	32.7 – 34.3	19.1 – 20	67 – 74	61 – 68
	n	14	14	14	14	13	14	14	14
Russet-tailed Thrush	mean (mm)	66.8 ± 2.5	21 ± 0.9	7.1 ± 0.4	8.1 ± 0.7	50.3 ± 1	32.7 ± 1	111.9 ± 3.1	70.8 ± 3.2
	range (mm)	62.5 – 70	19.6 – 22.2	6.7 – 7.9	7.4 – 9.4	48.5 – 51.8	31.3 – 34	107 – 116	65 – 74
	N	8	8	8	8	8	8	8	8
Blue-faced Parrotfinch	mean (mm)	12.1 ± 0.65	10.6 ± 0.38	6.5 ± 0.16	6 ± 0.22	26.4 ± 0.98	16.7 ± 0.53	57.8 ± 2.28	38.3 ± 5.44
	range (mm)	11 – 12.5	10.2 – 11.2	6.2 – 6.6	5.7 – 6.2	25 – 27.3	15.8 – 17.1	54 – 60	34 – 46
	n	5	5	5	5	5	5	5	4*

Discussion

The total number of species (45) from this short survey is less than the 70 species listed for Mussau Island by Tarburton (2014), although the latter is based on all field visits and includes a wider range of vagrants, migrants and seabird species that were not recorded or targeted in this survey. Of the 50 species recorded as resident by Tarburton (2014) the current survey recorded 40 species. Species not recorded include seabirds; the Wedge-tailed Shearwater *Puffinus pacificus* and Black Noddy *Anous minutus* that may not have been breeding during the visit and/or are more likely to be present on smaller offshore islands; two species of herons (Striated Heron *Butorides striata solomonensis* and Black Bittern *Dupetor flavicollis australis*); and the island's two species of Rallidae (the Red-necked Rail *Rallina tricolor laeta* and White-browed Crake *Poliolimnas cinereus meeki*). Both the Striated Heron and Black Bittern are recorded as rare and solitary, with the latter also being crepuscular or nocturnal (Dutson 2011), and the wet, swampy and mangrove habitats that these species are most often found in was not targeted during the trip. Crakes and rails are notoriously cryptic and often crepuscular or nocturnal: hence their absence from the survey is also not unexpected. The remaining four species that were not recorded are all apparently resident breeders and their absence from the current survey may either simply reflect too short a survey period along with too few sites to be representative of the island, and/or a genuine scarcity of the species in question. These species are the Moustached Tree-swift *Hemiprocne mystacea*, Oriental Dollarbird *Eurystomus orientalis*, Slender-billed Cicadabird *Coracina tenuirostris matthiae* and the Mussau Triller *Lalage conjuncta*. The absence of these species is discussed in more detail below.

Notable records from the survey include observations and/or capture of three endemics (the Mussau Fantail, Mussau Monarch and Mussau Flycatcher), as well as 13 sub-species that are either endemic to Mussau or to the St Matthias group. The survey also recorded one new species for the island: the Long-tailed Cuckoo *Urodynamis taitensis*. This species is recorded as an uncommon or rare migrant across Melanesia (Dutson 2011), and has been recorded from New Britain and Duke of York islands in PNG, as well as many islands in the Solomon Islands. It migrates to Polynesia and Micronesia March – April and returns to breed in New Zealand in September – October. Given its distribution and migration route it is unsurprising that some individuals stopover at Mussau and the individual seen was most likely on passage to New Zealand.

Species that occur on Mussau currently include three species that are classified as Near Threatened by the IUCN Red List (BirdLife International 2015). These are the widely distributed Nicobar Pigeon which is threatened by over-hunting and forest loss throughout its range, and the endemic Mussau Fantail and Mussau Monarch. Both of the latter two species are classified as Near Threatened on the basis that the species may be threatened if they are poorly tolerant to large areas of degraded habitat and/or to highly degraded habitat. Introduced predators are also listed as a possible threat to the Mussau Fantail.

Records from this visit to Mussau Island indicated that both these species (the Mussau Fantail and Mussau Monarch) were widespread and common and occurred in disturbed forest bordering garden areas, as well as within more mature secondary forest which had previously been cut-over during large-scale extractive logging. No conclusions can be made about likely population trends of these species on Mussau, nor on the potential impact of introduced predators, however their relative abundance (including in areas of regenerating secondary forest) suggest they may be tolerant of degraded habitat and should survive on the island provided large-scale logging does not impact the whole island during one short period. Based on their widespread occurrence and tolerance of disturbed habitat an IUCN classification of Least Concern may be more appropriate than the current classification of Near Threatened.

Dutson (2011) classifies two further species as full endemic species, the Mussau Flycatcher and Mussau Triller. Currently these two Mussau forms are not recognized by BirdLife International as full species and are treated as forms of the Velvet or Dull Flycatcher and the Varied Triller, respectively. Should further work classify these two forms as full species then, based on the threat classification for the Mussau Fantail and Mussau Monarch, they would at a minimum qualify as Near Threatened. Observations of the Mussau Flycatcher from this study suggest that unlike the endemic fantail and monarch it is relatively uncommon and restricted to areas of mature closed canopy secondary forest and primary forest. As a consequence if it is confirmed as a full species then it would appear more vulnerable to further logging than either of the current two endemic species recognized by BirdLife International and would therefore justify a threat status of Near Threatened. Given the apparent scarcity of the Mussau Triller (not observed during this trip), its possible restriction to closed canopy forest areas (Dutson 2011) and apparent occurrence in forest areas above at least 100 m (Gregory 2007; this study) the form would again justify a threat status of Near Threatened if it were recognised as a full species. Further work on the full status of these two forms along with their distribution is urgently required to assess their threat status.

One final species, the Russet-tailed Thrush is also potentially a full species and this will be written up separately. If this is determined and accepted, it would then again likely fall in to the Least Concern threat status on the IUCN Red List, as like the Mussau Fantail and Mussau Monarch it appears common and tolerant of all habitat types including old gardens and degraded forest. Consequently, it would likely be more tolerant of logging activities than the Mussau Flycatcher and Mussau Triller.

As well as the records above the survey was notable for not recording four species previously observed on Mussau. These are the Moustached Tree-swift, Oriental Dollarbird, Slender-billed Cicadabird and the Mussau Triller. The sub-species of Moustached Tree-swift *Hemiprocne mystacea aeroplanes* was recorded on one occasion by Dutson (G. Dutson pers. com.), Tarburton (2014) recorded only a single bird and only single specimens were recorded as collected by Hartert (1924) and Salomonsen (1983). These records, together with the absence of the species from the current survey, suggest that the species is an uncommon or scarce resident. Further survey time may well have recorded this species, particularly at higher altitude sites of the island. The apparent status of the Oriental Dollarbird on Mussau is based on the collection of a single individual (Hartert 1924) and Tarburton (2014) considers it a breeding resident. Dutson did not observe this species during his survey (G. Dutson pers. com.) Its relatively large size and its behaviour in other areas of the Admiralty Islands and New Guinea, foraging "from a high, exposed perch sallies out to capture passing insects, or flies continuously in the sky" (Pratt and Beehler 2014) would suggest that if it was present it would have been conspicuous and easily recorded. Pratt and Beehler (2014) describe two sub-species of Oriental Dollarbird; an endemic form *Eurystomus orientalis waigiouensis* to New Guinea and a migratory form *Eurystomus orientalis pacificus* that breeds in Australia and is seasonally common in New Guinea in the Austral winter. It is unclear what sub-species was collected by Hartert (1924), but it may be possible (and likely) that this was the migratory form and the species is not typically resident on the island. As with the previous two species, the Common Cicadabird was not recorded during the survey period, despite time spent in apparently suitable habitat types (forest, including secondary forest and forest edge; Dutson 2011). The absence of this species was surprising although Dutson (2011) reports it as "rather unobtrusive in canopy and mid-storey" and Tarburton (2014) describes it as uncommon on Mussau. Dutson reports that he only recorded a single bird in the lowlands and that is was more common at higher altitudes (G. Dutson pers. com.). It is therefore possible that this species, like the Mussau Triller (see below), was not observed because the current survey was mostly based at lower altitudes.

The most notable absentee was the Mussau Triller and this bird was one of the primary targets of the fieldwork due to its potential status as a full species (treated as such by Gregory 2007 and Dutson 2011) and the very limited sets of field observations (two; Dutson 2011) and specimens captured (a single bird; Hartert 1924). No individuals were seen or captured, despite considerable effort to locate this species. Gregory (2007) reports it "to be quite common above 100m in secondary or cut-over forest growth" and Dutson (2011) reports it as locally common, but possibly only occurring in closed forest in hills (Dutson observed groups of 3, 3, 1, 1 and 1 birds in 3.5 hours of survey effort at higher elevations on Mussau; G. Dutson pers. com.). It is possible that survey effort on this trip was restricted to areas that were lower than the main altitudinal range of this species: most observations and mist-netting at Nae and in the vicinity of the Lolieng field camp were at altitudes of ~5 to 120 m above sea level. However, the area near the pastor's house above Lolieng was at an altitude of 150 to 200 m and no birds were observed. One further afternoon was spent walking up from the main island road above the pastor's house up to an estimated height 200-250 m. This walk and road mostly went through relatively young secondary forest and garden areas; however it also reached one area of more mature closed-canopy secondary forest that based on Gregory's (2007) observations would be suitable habitat. No birds were observed. A local guide was confident he had seen one Mussau Triller at an altitude of 70-80 m in mature secondary/primary forest to the south of the camp at Nae. However repeat visits to this area (over two days) did not uncover the species. Without follow up surveys to assess the status of this species at higher altitude sites and across a wider area of forest its absence from the current survey remains a mystery.

Conclusions

This short survey recorded a total of 45 species on Mussau Island, including 33 land birds. The latter group included three endemic species and 13 endemic sub-species that are restricted to Mussau or the St Matthias group. Based on their widespread distribution on the island, abundance and tolerance of degraded habitats, the threat status of the Mussau Fantail and Mussau Monarch should be revisited on the IUCN Red List as they are current listed as Near Threatened.

Recommendations

I advocate that a desk-top analysis of the status of the Russet-tailed Thrush, Mussau/Velvet Flycatcher and Mussau/Varied Triller be undertaken against established quantitative criteria (Tobias et al. 2010) to verify the species/sub-specific status of these three forms and establish whether in light of current information a petition should be submitted to the IUCN to reclassify the threat status of these species. Additionally, given our failure to find the Mussau/Varied Triller a team should endeavour to return Mussau Island to undertake further work on the distribution and conservation status on this species, which based on the current survey is potentially very rare and restricted to higher altitude areas or localised areas of the island.

References

Beehler, B. M. 1993. Biodiversity and conservation of the warm-blooded vertebrates of Papua New Guinea. *In* Beehler, B.M. (ed.). Papua New Guinea: Conservation Needs Assessment. Biodiversity Support Program, Washington, DC. Pp 77–121.

Beehler, B.M., Pratt, T.K. and Zimmerman, D.A 1986. Birds of New Guinea, Princeton University Press, United States of America.

BirdLife International 2015a. Endemic Bird Area factsheet: St Matthias Island. Downloaded from <<www.birdlife.org>> on 22/02/2015.

BirdLife International 2015b. IUCN Red List for birds. Downloaded from <<www.birdlife.org>> on 22/02/2015.

BirdLife International 2015c. Endemic Bird Area factsheet: Admiralty Islands. Downloaded from <<www.birdlife.org>> on 22/02/2015.

Coates, B.J and Peckover, W.S. 2001. Birds of New Guinea and the Bismarck Archipelago, a photographic guide. Dove Publications Pty. Ltd. Australia.

Critical Ecosystem Partnership Fund 2012. Ecosystem Profile: East Melanesian Islands Biodiversity Hotspot. CEPF.

Dutson, G. 2001. New distributional range for Melanesian birds. *Emu* 101: 237–248.

Dutson, G. 2011. Birds of Melanesia: Bismarcks, Solomons, Vanuatu, and New Caledonia. Princeton University Press, Princeton, New Jersey, USA.

Eastwood, C. 1996. Kavieng, Djaul Island & Mussau Island, New Ireland – A trip report. *Muruk* 8(1): 28–32.

Finch, B.W. 1985. Noteworthy observations in Papua New Guinea and Solomons. *PNG bird Society Newsletter* 215: 7–15.

Gregory, P. 2007. Notes on the Mussau (St Matthias) Triller (*Lalage conjunctiva*). *Muruk* 8(3), 145.

Hartert, E. 1924. The birds of St Matthias Island. *Novitates Zoologicae* 31, 261–275.

Lowe, K.L 1989. The Australian Bird Bander's Manual. Australian National Parks and Wildlife Service, Canberra, Australia.

Mayr, E. 1931. Birds collected during the Whitney South Sea Expedition, the Parrot Finches (Genus *Erythrura). American Museum Novitates* 489: 1–10.

Mayr, E. 1937. Birds collected during the Whitney South Sea Expedition. 33. Notes on New Guinea Birds 1. *American Museum Novitates* 915: 1–19.

Mayr, E. 1955. Notes on the birds of Northern Melanesia. 3. Passeres. *American Museum Novitates* 1707: 1–46.

Mayr, E. and Ripley. 1941. Birds collected during the Whitney South Sea Expedition *American Museum Novitates.* 1116:1–18.

Pratt, T.K and Beehler, B.M. 2015. Birds of New Guinea, Second Edition. Princeton University Press, Princeton, New Jersey, USA.

Rothschild, W. and Hartert, E. 1923. [a collection from St Matthias Island]. *Bulletin of the British Ornithological Club* 44, 50–53.

Silva, K. 1973. Observations. *PNG bird Society Newsletter* 90, 1–3.

Silva, K. 1975. Observations from Manus, Tong, Mussau, Emirau, Loana & Tench Islands. *PNG bird Society Newsletter* 112: 4–7.

Tarburton, M.K. 2014. Mussau Is. (St Matthias) Bird Checklist. Downloaded from http://birdsofmelanesia.net/png8html/mussau.pdf on 13/09/2014.

Tobias, J.A., Seddon, N., Spottiswoode, C.N., Pilgrim, J.D., Fishpool, L.D.C. and Collar, N.K. (2010). Quantitative criteria for species delimitation. *Ibis* 152(4): 724–726.

Appendix 1. GPS coordinates for mist nets

Net	Area	Habitat	Latitude	Longitude	Elevation (m)
1	Nae - field camp	Secondary/Old garden	S 1.50371°	E 149.7313°	16
2	Nae - field camp	Mature secondary	S 1.50441°	E 149.7291°	34
3	Nae - field camp	Mature secondary	S 1.50475°	E 149.7291°	41
4	Nae - field camp	Mature secondary	S 1.50493°	E 149.7286°	76
5	Nae - field camp	Scrub/Old garden	S 1.50467°	E 149.7281°	79
6	Nae - main path	Young secondary/Old garden	S 1.50887°	E 149.7351°	32
7	Nae - main path	Young secondary/Old garden	S 1.51071°	E 149.7391°	37
8	Nae - field camp	Scrub/Old garden	S 1.50351°	E 149.7304°	10
10	Nae - mature forest	Primary/Closed-canopy secondary	S 1.51326°	E 149.7353°	73
11	Nae - mature forest	Primary/Closed-canopy secondary	S 1.51369°	E 149.7354°	75
12	Nae - mature forest	Primary/Closed-canopy secondary	S 1.51437°	E 149.7354°	81
13	Nae - mature forest	Primary/Closed-canopy secondary	S 1.51449°	E 149.7357°	82
21	Lolieng - field camp	Primary/Closed-canopy secondary	S 1.42722°	E 149.5144°	152
22	Lolieng - field camp	Primary/Closed-canopy secondary	S 1.42704°	E 149.5141°	167
23	Lolieng - field camp	Primary/Closed-canopy secondary	S 1.42660°	E 149.5139°	169
24	Lolieng - field camp	Primary/Closed-canopy secondary	S 1.42630°	E 149.5137°	170
25	Lolieng - field camp	Primary/Closed-canopy secondary	S 1.42627°	E 149.5138°	170
26 & 27	Lolieng - field camp	Primary/Closed-canopy secondary	S 1.42554°	E 149.5139°	157
31	Lolieng - Pastor house east	Closed-canopy secondary/Garden	S 1.43753°	E 149.5662°	151
32	Lolieng - Pastor house east	Closed-canopy secondary	S 1.43767°	E 149.5646°	147
33	Lolieng - Pastor house east	Closed-canopy secondary	S 1.43753°	E 149.5636°	146
34	Lolieng - Pastor house east	Closed-canopy secondary	S 1.43671°	E 149.5618°	168
35, 36 & 37	Lolieng - Pastor house east	Closed-canopy secondary	S 1.43751°	E 149.5592°	163
41	Lolieng - Pastor house west	Closed-canopy secondary	S 1.44176°	E 149.5465°	199
42	Lolieng - Pastor house west	Closed-canopy secondary	S 1.44165°	E 149.5474°	202
Canopy	Lolieng - Pastor house west	Closed-canopy secondary	S 1.44171°	E 149.5476°	197
43	Lolieng - Pastor house west	Closed-canopy secondary	S 1.44166°	E 149.5479°	195
44	Lolieng - Pastor house west	Closed-canopy secondary	S 1.44166°	E 149.548°	194
45	Lolieng - Pastor house west	Closed-canopy secondary	S 1.44167°	E 149.5483°	201

Appendix 2. Full species list from the survey with IUCN threat status.

Species	IUCN Status	Observed	Captured	Status	Nae	Lolieng	Other Location
Melanesian Megapode	LC	Yes	-	Resident	Yes	Yes	-
Lesser Frigatebird	LC	Yes	-	Resident	Yes	-	Coast
Pacific Reef Heron	LC	Yes	-	Resident	Yes	-	Coast
Eastern Osprey	LC	Yes	-	Resident	Yes	-	Coast
Brahminy Kite	LC	Yes	-	Resident	-	-	Coast
White-bellied Sea Eagle	LC	Yes	-	Resident	-	Yes	-
Variable Goshawk	LC	Yes	-	Resident	Yes	-	-
Whimbrel	LC	Yes	-	Migrant	Yes	-	Coast
Common Sandpiper	LC	Yes	-	Migrant	Yes	-	Coast
Grey-tailed Tattler	LC	Yes	-	Migrant	Yes	-	Coast
Great Crested Tern	LC	Yes	-	Resident	-	-	At sea
Black-naped Tern	LC	Yes	-	Resident	-	-	At sea
Brown Noddy	LC	Yes	-	Resident	-	-	At sea
Slender-billed Cuckoo-dove	LC	Yes	-	Resident	Yes	Yes	-
Mackinlay's Cuckoo-dove	LC	Yes	-	Resident	Yes	Yes	-
Bronze Ground Dove	LC	Yes	Yes	Resident	-	Yes	-
Stephan's Emerald Dove	LC	Yes	-	Resident	Yes	Yes	-
Nicobar Pigeon	NT	Yes	-	Resident	Yes	Yes	-
Yellow-bibbed Fruit-Dove	LC	Yes	Yes	Resident	Yes	Yes	-
Knob-billed Fruit Dove	LC	Yes	-	Resident	Yes	-	-
Island Imperial Pigeon**	LC	Yes	-	Resident	-	Yes	-
Coconut Lorikeet	LC	Yes	-	Resident	Yes	-	-
Meek's Pygmy Parrot	LC	Yes	-	Resident	Yes	-	-
Long-tailed Cuckoo	LC	Yes	-	Migrant	-	Yes	-
White-rumped Swiftlet	LC	Yes	-	Resident	Yes	Yes	-
Uniform Swiftlet	LC	Yes	-	Resident	Yes	Yes	-
Common Kingfisher	LC	Yes	-	Resident	Yes	Yes	-
Sacred Kingfisher	LC	Yes	-	Migrant	Yes	-	Coast
Collared Kingfisher	LC	Yes	Yes	Resident	Yes	-	-
Beach Kingfisher	LC	Yes	-	Resident	Yes	-	Coast
Mussau Fantail	NT	Yes	Yes	Endemic	Yes	Yes	-
Willie Wagtail	LC	Yes	-	Resident	Yes	Yes	-
Northern Fantail	LC	Yes	Yes	Resident	Yes	-	-
Mussau Monarch	NT	Yes	Yes	Endemic	Yes	Yes	-
Island Monarch	LC	Yes	Yes	Resident	Yes	Yes	-
Mussau Flycatcher	NE	Yes	-	Resident	Yes	-	-
Russet-tailed Thrush	LC	Yes	Yes	Endemic*	Yes	Yes	-
Island Thrush	LC	Yes	-	Resident	Yes	-	-
Island Leaf Warbler	LC	Yes	-	Resident	Yes	Yes	-
Bismarck Whistler	LC	Yes	Yes	Resident	Yes	Yes	-
Olive-backed Sunbird	LC	Yes	Yes	Resident	Yes	Yes	-
Bismarck Black Myzomela	LC	Yes	Yes	Resident	Yes	Yes	-
Blue-faced Parrotfinch	LC	Yes	Yes	Resident	Yes	Yes	-
Metallic Starling	LC	Yes	Yes	Resident	Yes	Yes	-
Singing Starling	LC	Yes	-	Resident	Yes	-	-

Chapter 6:

Mammals of Manus and Mussau Islands

Ken P. Aplin, Junior Novera and Kyle N. Armstrong

Summary

The mammal fauna of Manus and Mussau Islands was investigated with a view to extending the inventory of species and establishing the current status of several previously known and potentially rare species. Prior records were subjected to close scrutiny and some critical museum specimens were re-examined. The field survey employed a variety of methods including trapping and camera trapping for small ground mammals, spotlighting for arboreal mammals, mist netting and the setting of harp traps for bats, and active searches for signs of terrestrial mammals and for caves and other roosting sites of bats. A simultaneous acoustic survey used bat detectors to record echolocating bats. Three bat species were added to the fauna of Manus Island, two of them identified from acoustic recordings. At least one of the vouchered bat species is new to science. Targeted searches for a previously recorded but unnamed endemic rat species failed to find evidence of its survival, although a disused burrow complex located on Mt Sabomu was probably dug by this species. No native ground mammals were found on Mussau Island though two introduced species were confirmed present, the Pacific Rat and a Spotted Cuscus. Fifteen species of bats were recorded from Mussau Island, ten of them new for the island. At least two of the vouchered bats are new to science, either as full species or well-separated subspecies. Conservation priorities for both islands include further searches for the unnamed endemic rat and more targeted surveys for some of the most elusive bat species.

Introduction

Manus Island in the Admiralty Group and Mussau Island in the St Matthias Group are the two largest islands off the north coast of New Guinea. Both are remote oceanic islands with no history of land-bridge connection to any other major landmass. The minimum open-water crossing is 280 km between the north coast of New Guinea and Manus Island, 254 km between Manus Island and Mussau Island, and 104 km between Mussau Island and Lovengai Island to the immediate northeast of New Ireland.

Manus Island has been sampled for mammals on several occasions and is known to support a comparatively rich mammal fauna that includes two marsupials, several rodents and a moderate diversity of bats. Mussau Island, by contrast, appears to have been visited by mammalogists only twice, each time very briefly, and its mammal fauna remains virtually unknown. In this chapter we supplement the previous knowledge of the mammal fauna of both islands with new observations based on fieldwork carried out in October 2014.

Previous mammal surveys of Manus Island

The first mammal specimens from Manus Island were four examples of the Admiralty Island Flying-fox (*Pteropus admiralitatum*) obtained in 1875 during the Challenger Expedition (Thomas 1894). In September to October 1913 the professional collectors Mssrs Meek and Eichhorn obtained examples of seven species from Manus Island and one from the nearby Admiralty Island; these were purchased by Lord Walter Rothschild and described by Thomas (1914) along with specimens from Ruk (Umboi) Island.

Several large series of the Admiralty Cuscus (*Spilocuscus kraemeri*) were collected during the early decades of the 20th Century. Schwarz's (1910) description of the species was based on a series of 32 specimens, while Cohn's (1914) redescription (as *Phalanger maculatus minor*) was based on another series. Fewer specimens of other taxa were forthcoming: two examples of the Common Echymipera (*Echymipera cf. kalubu*) are held in the Museum fur Naturkunde, Berlin (ZMB; Flannery 1995a: 68), one collected by H. Schoede at Seeadlerhafn and the other from nearby Lou Island. A specimen of a Leaf-nosed Bat (*Hipposideros* sp. 1; see below) obtained on Manus Island in 1945 is held in the U.S. National Museum.

More systematic mammalogical exploration on Manus commenced with brief visits to Manus in February and June 1962 by the *Noona Dan* Expedition of the Natural History Museum of Denmark (Wolff 1968); specimens are held in the Zoological Museum, Natural History Museum of Denmark but there is no published inventory. In January and June 1988 staff of the Australian Museum conducted fieldwork on Manus Island, with the principal effort based out of the Department of Primary Industry (DPI) Field Station at Polomou in south-central Manus. Further specimens were obtained at Lorengau market in May 1990.

Two recent opportunitsic collections, both of an as yet undescribed native rodent, deserve special mention. Two specimens were collected in August 2002 by Ann Williams during a general biotic survey of Manus for Conservation International; more recently, in August 2012, Walter Weijola of the Zoological Museum, University of Turku, Finland obtained one specimen while conducting fieldwork on monitor lizards.

Another important source of information on the mammal fauna of Manus Island comes from animal bones excavated from archaeological sites. The most informative of these collections comes from the site of Pamwak located ~ 4 km inland from the south coast (see Fredericksen et al. 1993; Schmidt 1996). This collection was analysed by Corrie E. Williams (1997, 1999) who reported remains of two marsupials (*Spilocuscus kraemeri, Echymipera kalubu*), four rodents (*Rattus mordax, Rattus praetor, Rattus rattus* and *Melomys* sp.) and four bats (*Pteropus admiralitatum, Pteropus hypomelanus, Pteropus neohibernicus* and *Hipposideros maggietaylorae*). Flannery (1995a: 38) re-examined the Pamwak collection and among the rodents found only *R. exulans* and a "large species of *Rattus*, probably representing an undescribed species".

The Wildlife Conservation Society has been conducting detailed work on the Admiralty Cuscus (*Spilocuscus kraemeri*) on Manus Island since 2010, with a focus on home range, habitat use, and the sustainability of harvesting.

Previous mammal surveys of Mussau Island

Mussau Island is the largest of the St Matthias Group. Prior to the WCS survey in 2014 it appears to have been visited only twice by mammalogists. The first visit was on 16–18 February 1962 by members of the *Noona Dan* Expedition; any specimens obtained are held in the Zoological Museum, Natural History Museum of Denmark. The next visit was in 1979 during an intensive survey of the bats of the Bismarck Archipelago by J. D. Smith and C. S. Hood of the Los Angeles County Museum, staff of the Biology Dept of the University of Papua New Guinea and staff of the Wildlife Division of the Department of Lands and Environment of Papua New Guinea. Smith and Hood (1981) listed three sampling localities on Mussau Island: Emuru Cave, 4 km E of Elinke Aid Post; Pakasi Cave, 4 km W of Kuna Sawmill; and Kuna Sawmill—where they reported captures of four species of bats. They also noted previous records of bats from Emirau Island in the St Matthias Group; these appear to derive from collecting in August 1944 by David Johnson, carried out soon after occupation of the island by the U.S. military. Some of the Emirau Island records were noted earlier by Lidicker and Ziegler (1968).

Mussau and other islands of the St Matthias Group have attracted considerable attention from archaeologists (Egloff 1975; Bafmatuk et al. 1980; Kirch 1987, 1989; Burley 2003). Most work has been conducted on a cluster of coral reef islands on the southwest coast of Mussau, including Eloaua Island (7.6 x 1.7 km) and Emananus Island (4.4 x 1.6 km). One site on Eloaua Island produced a large quantity of vertebrate remains but this was dominated by turtle and fish bones and included only occasional remains of *Spilocuscus kraemeri*, bats and birds (Kirch 1987; see also Steadman and Kirch 1998).

Methods

Mammal surveys were conducted out of two main sites on Manus Island, and one on Mussau Island (Table 1, Plate 1). Some observations were also made at Piri Village during transit between the two sites on Manus Island.

Table 1. Survey locations visited during the 2014 WCS Manus-Mussau Expedition.

Locality	Latitude	Longitude	Elevations sampled (m a.s.l.)	Dates
Mt Sabomu, Manus Island	S 2.193°	E 146.967°	310 – 589	2 – 6 October 2014
Piri Village, Manus Island	S 2.211°	E 146.965°	0 – 25	6 October 2014
Yeri River, Manus Island	S 2.001°	E 146.819°	23 – 84	9 – 13 October 2014
Nae, Mussau Island	S 1.504°	E 149.731°	0 – 104	16 – 26 October 2014

The first camp on Manus Island was established near the summit of Mt Sabomu, the island's second highest peak at 589 m a.s.l. Access to the site was via the village of Piri, on the south coast of the island. Mt Sabomu supports a largely intact forest cover although one large patch of kunai grassland with *Pandanus* overstorey is present on the southern slope at ~ 310 m a.s.l. Survey effort concentrated on the upper slopes above the kunai grassland patch. One bat detector and some snap traps were set at Piri Village on the night of 6 October 2104.

The second camp on Manus Island was in the northern lowlands on Yeri River, with survey effort ranging between 23 m and 84 m a.s.l. The area supports relatively undisturbed lowland rainforest, interspersed with sago plantations and gardens, the latter mainly positioned close to the major waterways.

The first camp on Mussau Island was established ~3 km south of Nae Village near the southeast corner of the island. In this area the island is fringed by a coastal plain made up of coarsely comminuted shell and coral. At variable distance from the coast the coastal plain gives way to a series of raised coralline limestone terraces that rises steadily inland; at the front of each terrace is a scarp that often contains numerous small fissures and caverns, and occasional larger caves that probably originated as sea caves. The camp gave access to land at elevations between sea level and 104 m a.s.l., and to patches of coastal forest and scrub, and extensive tracts of open forest interspersed with dense vine thickets on the limestone benches and slopes. Some members of the survey team moved to a second site at Lolieng; however, the mammal survey team elected to spend more time around Nae to more fully explore its numerous cave systems.

The survey used a variety of methods including trapping and camera trapping for small ground mammals, spotlighting for arboreal mammals, mist netting and the setting of harp traps for bats, and active searches for signs of terrestrial mammals and for caves and other roosting sites of bats. Mist nets and harp traps were moved after one or two nights to counter the fact that bats learn quickly to avoid such apparatus. Local people were interviewed at every opportunity to document their experience of local mammals.

The scientific and common names used in this report follow those employed in the IUCN Red List wherever possible.

Results

The survey effort employed at each site is summarised in Table 2.

Table 2. Survey effort employed at each of the three sampling localities.

Locality	Ground trap nights	Mist net nights / net meter hrs	Harp Trap nights	Bat detector sessions	Camera trap nights
Mt Sabomu, Manus Island	178	32 / 4932	11	6	44
Piri Village, Manus Island	15	-	-	1	-
Yeri River, Manus Island	204	21 / 3240	12	23	64
Nae, Mussau Island	360	36 / 5688	14	28	45

Manus Island

Mt Sabomu is heavily forested, apart from some clearings on the lower slopes and the small clearing on the summit, which supports a communications tower. Access to the summit is by well-defined foot tracks from either the north or south, or by helicopter for servicing. The area is visited regularly for cuscus hunting but there is little else to be harvested. The forest appears to have low productivity, with few flowering or fruiting trees evident at the time of our visit, and little indication of prior periods of higher productivity, such as woody endocarps on the forest floor.

Ground mammals evidently occur at extremely low population densities in the forests of Mt Sabomu. Local landowners claimed that bandicoots and small rats are present in the forest but only ever in low numbers, such that they were not worth targeted hunting or snaring effort. These comments were borne out by our own observations and results. Spotlighting for several hours on each of four evenings resulted in no sightings of mammals other than bats, and no other members of the wider survey team reported seeing any mammals other than cuscus. Many hours of daytime searching for signs of small mammal activity in the form of footprints, chewed seeds and burrows produced only three definite signs apart from some well-worn pig trails, two woody endocarps with rodent gnaw marks and one burrow complex with multiple entrances spread over an area of ~ 10 m^2. Camera traps set with cooked rice and/or tinned fish as bait resulted in only one mammal encounter over 44 nights of imaging—a small *Rattus* active at the site of the burrow complex. Traps set at this site subsequently caught the animal, which turned out to be a Pacific Rat *Rattus exulans*, an introduced species, rather than a native rat (*Rattus* sp.) as anticipated from the size and complexity of the burrow complex. One trap set in the kunai grassland habitat produced another capture of the Pacific Rat, giving a total of two captures from 178 trap nights (an overall capture rate of 1.1%). By contrast, cuscuses were said to be sufficiently common on Mt Sabomu that targeted hunting was worthwhile. This was borne out by the capture of one cuscus and a sighting of one other during our time at the site.

The Yeri River site was more productive in terms of both sightings and trap returns. Rats were seen on three occasions during evening spotlighting patrols, though only one of the sightings (a Pacific Rat) was made by members of the mammal survey team. One of the other sightings was probably of a Manus Melomys (*Melomys matambuai*) and the third was not seen well

enough to be sure of its identity. Trapping at this site produced a total of eight individuals of the Pacific Rat out of 204 trap nights (capture rate of 3.9%) but only two of these animals were captured in forest habitats where most trapping effort was directed; the remainder came from a garden complex where there were abundant signs of rodent damage to pumpkins. Camera trapping in the forest habitat also produced a few images of Pacific Rat. Although local landowners claimed that bandicoots were present in the local forest and gardens, none of the characteristic conical diggings made by bandicoots were observed nor were their footprints seen in streamside sand or around muddy pools.

At Piri Village abundant signs of rat activity were observed around the buildings. A small trapping effort (total 15 trap nights) at Piri Village resulted in capture of three Pacific Rats.

Mist netting for bats was more productive at both sites on Manus Island (Table 3). Captures were particularly numerous at the Yeri River site where *Macroglossus minimus* accounted for 78% of all captures. On Mt Sabomu approximately equal numbers of *Macroglossus minimus* and *Nyctimene* sp. 1 were captured. The only insectivorous bat capture in a mist net was made on Mt Sabomu.

Harp traps resulted in a single capture at the Yeri River site and none on Mt Sabomu, despite 11 and 12 harp trap nights of effort, respectively. The capture at the Yeri River site was a critically important one, *Kerivoula myrella,* and this one result justified use of the equipment on Manus Island. Use of hand nets produced more captures of insectivorous bats, with important captures of *Mosia nigrescens* and *Pipistrellus angulatus* made in this way.

At both sites on Manus Island insectivorous bats were sometimes observed flying at dusk in large numbers, especially above clearings. Hand netting on these occasions resulted in captures of *Mosia nigrescens* and *Pipistrellus angulatus* but acoustic recordings made at these locations reveal the presence of additional species, most notably *Miniopterus* sp. 1 (*40 st.cFM*) and *Emballonura serii*.

Table 3. Mist net captures at each of the three sampling localities.

Taxon	Mt Sabomu, Manus Island	Yeri River, Manus Island	Nae, Mussau Island
Dobsonia anderseni	-	-	1
Macroglossus minimus	11	57	5
Nyctimene sp. 1	10	13	-
Nyctimene sp. 2	-	-	15
Pteropus sp.1	-	-	3
Rousettus amplexicaudatus brachyotis	-	3	13
Hipposideros calcaratus	1	-	-
Total captures	**22**	**73**	**37**

Table 4. Harp trap captures at each of the three sampling localities.

Taxon	Mt Sabomu, Manus Island	Yeri River, Manus Island	Nae, Mussau Island
Aselliscus tricuspidatus koopmani	-	-	3
Hipposideros cervinus	-	-	2
Kerivoula myrella	-	1	-
Miniopterus sp. 1	-	-	1
Total captures	**0**	**1**	**6**

Mussau Island

The vicinity of Nae Village on the southeast side of Mussau Island remains heavily forested apart from some garden clearings on the coastal plain and lower terraces, and some areas near the coast that are the sites of former commercial coconut plantations. Patches of mature forest are present on the coastal plain but are more extensive on the limestone terraces, which are largely unsuitable for agricultural activity. The whole area is subject to timber extraction for local use and harvesting of other forest products.

Pigs are present in large numbers in both the coastal forests and on the limestone terraces. Because the Mussau Island community is predominantly Seventh Day Adventist, pigs are not hunted for meat, but whenever possible they are pursued and killed on account of the damage they cause to peoples' gardens. Other wildlife is also generally not hunted or otherwise molested and this extends to bat colonies that occupy many caves formed within the limestone scarps.

The only ground mammals in the forest around Nae appear to be feral pigs and the Pacific Rat, a late prehistoric introduction. Pacific Rats were captured most often in the dense vegetation on the coastal plain and it appears to exist at much lower population densities in the more open and drier forests on the limestone slopes and terraces. Local landowners were aware of bandicoots from visits to New Ireland and elsewhere in the region and were adamant that no bandicoots occur today or in recent times on Mussau Island.

Mist netting for bats was less productive than at the survey sites on Manus Island (Table 3). The principal difference concerns the abundance of *Macroglossus minimus,* which accounted for 12 % of all captures on Mussau Island but 78% of captures on Manus Island. By contrast, *Rousettus amplexicaudatus brachyotis* was captured more often on Mussau Island than on Manus Island, perhaps because of the proximity of suitable cave roosts for this species.

Harp traps were employed with greater effect at Nae than elsewhere, with captures of three species (Table 4). Nevertheless, harp trap captures were still low (6 individuals from 14 harp trap nights) and regular movement of the traps was necessary to achieve even this degree of success.

Investigation of caves produced a wealth of information on the insectivorous bats of Mussau Island. Seven caves were investigated and care was taken in each case to determine the range of species present and their reproductive status. The results are summarised in Table 5.

Table 5. Location, characteristics and bat communities of each of the caves that contained roosting bats on Mussau Island.

Cave Number	Location & elevation (m)	Dimensions W x Ht x D (m)	Roosting species/ approximate numbers	Breeding status
1	S 1.517° E 149.739° 71 m	3 x 3 x 5	Insectivorous bat faeces only	
2	S 1.519° E 149.739° 73 m	5 x 4 x 25	~30 *Dobsonia* (both sexes) and ~100 H. cf. cervinus (both sexes)	Some *H*. cf. *cervinus* carrying young; some *Dobsonia* mid- to late pregnancy
3	S 1.524° E 149.737° 69 m	8 x 3 x 4 (+ deeper narrow extension)	Bats present in extension; not identified	
4	S 1.524° E 149.737° 78 m	outer chamber 8 x 4 x 2; inner chamber 6 x 10 x 30 (opening in roof)	~40 *Dobsonia* (both sexes) and ~30 *H*. cf. *cervinus* (both sexes)	Some *Dobsonia* mid- to late pregnancy
5	S 1.500° E 149.724° 85 m	3 x 5 x 15	~200 *Hipposideros* sp. 2 (both sexes)	Some *Hipposideros* sp. 2 carrying young
6	S 1.516° E 149.739° 58 m	20 x 5 x 40	~500 *Aselliscus*, ~300 *H*. cf. *cervinus*, ~50 *Hipposideros* sp. 2, ~150 *Miniopterus* sp. 40 st.cFM (both sexes)	Juvenile *Aselliscus* present; no evidence of breeding in *Miniopterus* sp.
7	S 1.514° E 149.74° 44 m	5 x 3 x 30	~100 *H*. cf. *cervinus*, ~100 *Hipposideros* sp. 2	Some juveniles of both species; some females of *H*. cf. *cervinus* carrying young

Summary of the island mammal faunas

Table 6. Summary of current knowledge of the island mammal faunas of the Admiralty and St Matthias Groups, based on prior knowledge and the results of the 2014 WCS Expedition. Code to symbols: * = introduced species; P = prior record; C = record confirmed in 2014; N = new record; + = same taxon present; - = taxon absent.

Species	Admiralty Island Group	St Matthias Group	New Guinea	Bismarck Archipelago
Marsupials				
Echymipera cf. *kalubu*	P	-	*E. kalubu*	*E.* cf. *kalubu*
Spilocuscus kraemeri	PC	-	-	+
Spilocuscus sp. (*maculatus* group)	-	PC	+	+
Rodents				
Melomys matambuai	P	-	-	-
Rattus sp.	P	-	-	-
*Rattus exulans**	PC	PC	+	+
*Rattus rattus**	P	-	+	+
Fruit and nectar-eating Bats				
Dobsonia anderseni	PC	PC	-	+
Macroglossus cf. *minimus*	PC	C	+	+
Nyctimene sp. 1	PC	-	?	?
Nyctimene sp. 2	-	N	-	-
Pteropus admiralitatum admiralitatum	P	-	-	+
Pteropus hypomelanus	P	-	+	+
Pteropus neohibernicus hilli	PC	-	*P. n. neohibernicus*	*P. n. neohibernicus*
Pteropus sp.	-	PC	-	-
Rousettus amplexicaudatus brachyotis	PC	PC	*R. a. amplexicaudatus*	+
Syconycteris australis finschii	P	-	*S. a. papuana*	+
Insectivorous bats				
Aselliscus tricuspidatus koopmani	?	N	*A. t. novaeguinea*	+
Emballonura cf. *dianae*	-	N	*E. d. fruhstorferi*	*E. d. rickwoodi*
Emballonura serii	PC	-	-	+
Hipposideros calcaratus calcaratus	PC	-	*H. c. cupidus*	+
Hipposideros cf. *cervinus*	-	PC	+	+
Hipposideros diadema mirandus	PC	-	*H. d. griseus*	*H. d. oceanitis*
Hipposideros sp. 1	PC?	-	+	+
Hipposideros sp. 2	-	?C/N	-	?
Kerivoula myrella	PC	-	-	+
Miniopterus sp. 1 (40 st.cFM)	?PC	C	?	?
Miniopterus sp. 2 (45 st.cFM)	?PC	C	?	?
Mormopterus cf. *beccarii*	-	N	*M. b. astrolabiensis*	?
Mosia cf. *nigrescens*	PC	PC	+	+
Myotis sp.	N	N	?	?
?*Nyctophilus* sp.	N	-	?	?
Pipistrellus angulatus	PC	P (Emirau)	+	+

Species Accounts

Family Peramelidae: Bandicoots

***Echymipera* cf. *kalubu*, Common Echymipera (LC)**

Relatively few specimens, including examples from Manus Island and Lou Island, are present in the world's museums (Flannery 1995a: 68). There has been no detailed comparison of these specimens with examples of *E. kalubu* from throughout its range,

and no samples of *E. kalubu* from Manus have been included in any molecular study of the genus (e.g. Westerman et al. 2012). Williams (1999) reported the first occurrence of bones of this species in layers of the Pamwak site that date to 12,000 years ago, corresponding to the first appearance of obsidian in the site. Williams (1999: 248) concluded that *E. kalubu* was "brought to the island by people either accidentally or as a food source". However, the current *IUCN Red List* assessment for this species questions the taxonomic identity of the Manus bandicoot population and raises the possibility that the taxon is naturally occurring.

On Mt Sabomu we saw no sign of bandicoot activity, though landowners said that they are present in low numbers and live primarily in areas of rockier habitat. No fresh signs were observed at Yeri River; however, landowners at this site claimed that bandicoots were plentiful and could be snared along runways. The same claim was made in 2012 to herpetologist W. Weijola (pers. com.) during his studies at Kawaliap Village in central Manus.

Clarification of the identity of the Manus Island *Echymipera* is a high priority for future research.

Family Phalangeridae: Cuscuses and their allies

***Spilocuscus kraemeri*, Admiralty Cuscus (NT)**
This species occurs on numerous islands of the Admiralty Group, including the islands of Manus, Los Negros, Ponam, Rambutyo, Lou, Luf, and Wuvulu (Cohn 1914; Menzies 1991; Singadan 1996). It may also occur on the Ninigo or L'Echiquier group, a cluster of 31 atolls to the south of Manus Island (Laurie and Hill 1954). Populations of spotted cuscus on islands of the St Matthias Group are not referrable to *S. kraemeri* but rather to an as yet unnamed species of *Spilocuscus* that occurs in northern New Guinea as well as in the Bismarck Archipelago as a result of human introductions (Helgen 2007).

Whether or not *S. kraemeri* is actually native to the Admiralty Group remains uncertain. Flannery (1995a: 105) argued against it being native and posited that "it has reached Manus recently, perhaps in the last one or two thousand years". One piece of evidence that might support Flannery's position is the presence of several specimens of *S. kraemeri* from New Britain (Helgen and Flannery 2004), thus providing an alternative source area. However, if *S. kraemeri* is native to New Britain rather than to the Admiralty Group then it is quite rare or geographically restricted within its area of natural occurrence, as it was not detected in areas of primary forest habitat surveyed by a recent Conservation International RAP of the Nakanai Mountains of East New Britain Province (Aplin and Opiang 2011). Other evidence that seems to run counter to this notion includes the occurrence of 11,000 year old remains of *S. kraemeri* in the Pamwak site (Williams 1999: 248). Final resolution of this issue requires either an older archaeological record from Manus (or New Britain) and/or a phylogeographic study to document patterns of genetic diversity within this species.

Flannery (1995a: 105) summarised his experience of this species in 1988 as follows: "I found the Admiralty Cuscus to be common in all vegetation types, from gardens to almost undisturbed forest. It is commonly hunted and eaten throughout Manus, and can be bought almost daily at Lorengau Market for around five Kina". The large numbers of specimens of this species collected in the early part of the 20th Century suggests that this abundance is not a modern phenomenon.

Since 2010 WCS staff and University of Papua New Guinea students John Lamaris and Wallace Takendu have studied the ecology of the Manus Island Cuscus at several localities. Because of this pre-existing focus, the 2014 WCS expedition did not go to special lengths to gather information on the status of this species. However, from discussions with landowners at each of the Mt Sabomu and Yeri River sites it was clear that Admiralty Cuscus are a primary focus of hunting activities in both areas. During the time spent on Mt Sabomu one adult female with a fully furred pouch young was captured by a landowner and one other individual was observed sleeping in the crown of a tree.

***Spilocuscus* sp. (*maculatus* group) Spotted Cuscus (LC)**
Modern specimens of a spotted cuscus are on record from Mussau Island (Flannery and Calaby 1987; specimens at NMV and USNM) and there are archaeological specimens from Elouau Island dating to several thousands of years ago (Kirch 1987). Helgen (2007) attributes these populations to an as yet unnamed species that occurs naturally in the northern lowlands of the main island of New Guinea; their dispersal from there to the St Matthias Group is probably linked to the phase of human dispersal that is linked to the spread of Lapita pottery, starting around 3,500 years ago.

Cuscus are said to be common on Mussau Island today and several were detected from their odour (but not seen) during the period of the survey.

Family Muridae: Rats and mice

***Melomys matambuai*, Manus Melomys (EN)**
This species was first collected in 1988 and is still known only from a handful of modern specimens (Flannery 1995a: 140); numerous additional specimens are present in the Pamwak archaeological collection.

We failed to obtain any evidence of the species on Manus Island either by trapping or camera trapping on the ground. By contrast, WCS staff and student Wallace Takendu obtained numerous camera trap images in 2013 and 2014 of this species on cameras mounted in trees while surveying for *Spilocuscus kraemeri*. Such results support Flannery's (1995a: 140) observation

that the species is largely arboreal, hence unlikely to be detected by any trapping effort situated on the ground. One probable sighting of this species was made at the Yeri River site by another team member who saw a "small orange rat" climbing at night in the forest subcanopy.

***Rattus* sp., Manus Rat (an unnamed species)**
This distinctive rat species is currently in the process of formal description (Timms et al. submitted). It is known from three modern specimens and a large sample of archaeological remains from the Pamwak site. It is a large, short-tailed species of *Rattus* with exceptionally coarse and spiny fur, and long, prominent black guard hairs. The tail is proportionally shorter than in other large New Guinean *Rattus* species (e.g. *R. jobiensis, R. leucopus, R. mordax,* and *R. praetor*).

The first modern specimen of the Manus Rat was collected in August 2002 by Ann Williams, working on a biotic survey of Manus for Conservation International. She obtained one specimen of a large *Rattus* from hunters at the near coastal village of Tulu no. 1 on the northwestern coast of Manus Island at 01°57′37″S, 146°50′28″E. The carcass was initially buried but the skeleton was subsequently dug up and presented to A. L. Mack who lodged the now clean skeleton (KU 163723) along with a second lower jaw (KU 163724) in the collection of the University of Kansas Natural History Museum, Lawrence, Kansas.

A full decade later, on 24 August 2012, Walter Weijola obtained a complete specimen of this large distinctive rat while conducting fieldwork on monitor lizards in the central hill forests of Manus Island. This specimen (AMS M45608), an adult female preserved in spirits, was snared in the vicinity of a small stream near the western end of Kawaliap Village (2°6′40″S, 147°3′40″E) at an elevation of ~200 m a.s.l.

The Pamwak archaeological deposit on the south coast of Manus Island produced a large numbers of jaws and other bones of this species. Williams (1997, 1999) identified a number of different *Rattus* species in this sample including the native Melanesian species *R. praetor* and *R. mordax*, and the introduced species *R. rattus*. Flannery (1995a: 38) re-examined the Pamwak assemblage and found it to contain the large *Rattus* mentioned here, along with numerous specimens of *Melomys matambuai* and a few *Rattus exulans* from surficial contexts. The earliest levels of the Pamwak site date to approximately 14,000 years ago, but most of the *Rattus* remains are derived from contexts younger than 9,000 years ago.

Despite much targeted effort, we failed to encounter this species during the 2014 WCS survey. At each of the Mt Sabomu and Yeri River sites we set traps and baited camera traps in positions judged likely to intersect the activity of a large *Rattus*. We also conducted intensive searches for footprints and runways along stream margins, under overhanging rocks and at the bases of buttressed trees, for burrows, and for faeces and caches of chewed nuts and seeds.

At Mt Sabomu this effort resulted in the discovery of a burrow complex spread across an area of ~10 m^2 and featuring six or more entrances, each with diameters of ~10–15 cm. Some of these entrances showed signs of recent entry, so a camera trap was set over several nights. Upon checking on 9 October 2014 the camera was found to contain images of a rat, so traps were set that day to attempt a capture. Although this was successful, the capture was of an adult male Pacific Rat *Rattus exulans* rather than the anticipated native rat. *Rattus exulans* does not normally construct burrows (Aplin et al. 2003) but it is known to occupy abandoned burrows of other species (Aplin unpubl. data). In this case, we suspect that the burrow complex was originally excavated by the Manus Rat.

The scarcity of signs of a large rat at both sites on Manus Island is compelling evidence that this species is either absent or present only in very low densities at both sites. Elsewhere in Melanesia large *Rattus* species are among the easiest of terrestrial mammals to trap and their footprints are also conspicuous in areas of damp soil, as are their faeces in sheltered areas among rocks and inside logs. Despite careful searches at both sites, these signs were not encountered at either site, bar the one burrow complex located on Mt Sabomu. Further survey effort is needed to locate viable populations of the Manus Rat and to identify factors that might favour its survival.

***Rattus exulans*, Pacific Rat (LC)**
Thomas (1914) identified three specimens (as *Epimys browni*) in the Meek-Eichhorn collection from Manus Island. Taylor et al. (1982) confirmed the identity of these specimens and also listed specimens from Emirau Island (MVZ and USNM). The Australian Museum has specimens from Bat Island in the Purdy Group, to the south of Manus Island.

We encountered *R. exulans* on both Manus and Mussau Islands. On Manus Island this species was encountered among the houses of Piri Village, in the patch of kunai grassland on the southern slopes of Mt Sabomu, in mature hill forest near the summit of Mt Sabomu, in a large garden complex on the bank of Yeri River, and in mature lowland forest close to Yeri River. They appeared to be most numerous in the garden and village habitats, and to be relatively scarce in the natural forest habitats. As mentioned above, an adult male of *R. exulans* trapped near the summit of Mt Sabomu appeared to be using a pre-existing burrow complex, most likely dug by the unnamed native Manus Rat (*Rattus* sp.).

On Mussau Island we encountered *R. exulans* in the dense coastal vegetation and also on the uplifted limestone terraces. It does not appear to be particularly numerous in either context.

***Rattus rattus*, Black Rat (LC)**
Taylor et al. (1982: 330) listed specimens (AMNH) of *Rattusrattus* from Lorengau on Manus Island. We did not encounter this species on either island. To date no samples from Manus Island have been examined genetically to determine which of the various lineages of the black rat group (*Rattus rattus* complex sensu Aplin et al. 2011) is represented.

Family Pteropodidae: Old World Fruit Bats

***Dobsonia anderseni*, Andersen's Bare-backed Fruit Bat (LC)**
This species was described from specimens obtained by Meek and Eichhorn on Manus Island (Thomas 1914). It was also recorded on Ruk Island (Umboi) and has since been found to be widely distributed through the Bismarck Archipelago, in the St Matthias Group (Mussau and Emirau Islands), and in the Tabar, Lihir and Tanga Groups to the northeast of New Ireland. It is also known from some small islands off the north coast of New Guinea, including Karkar and Bagabag (Koopman 1979; Flannery 1995a; Bonaccorso 1998).

Dobsonia anderseni is sometimes treated as a subspecies of *D. moluccensis* (e.g. Laurie and Hill 1954; Koopman 1979) but more commonly as a full species (e.g. Thomas 1914; Bergmans 1979; Bergmans and Sarbini 1985; Flannery 1995a; Bonaccorso 1998; Simmons 2005). The Australian Museum has a series collected at Polomou DPI Station, south-central Manus Island. Flannery (1995a: 190) mentions "differences ... between the Bismarck Archipelago and Admiralty Group populations that merit further investigation".

Dobsonia anderseni is commonly reported to roost in caves and fissures (Smith and Hood 1981; Flannery 1995a; Bonaccorso 1998). We located small roosting colonies of this species on both islands. On Manus Island a group of ~ 20 individuals were observed in a shallow overhang created by a resistant band of tuff on a very steep, densely forested slope at 310 m a.s.l. Landowners present at this site claimed that a much larger colony of the same species occurs within a cleft-shaped cave situated at lower elevation on the southwestern side of Mt Sabomu. On Mussau Island we located small groups of *D. anderseni* in each of Caves 2 and 4, with group size estimated at 30 and 40 individuals, respectively. Five individuals captured by hand nets at Cave 2 proved to be three adult males (body weights 206, 209, 226 g), a pregnant female (205 g), and a subadult female. No young were observed on the walls or being carried in flight. On Mussau Island we mist-netted an adult male in a grove of paw paw trees growing on a limestone terrace at 96 m a.s.l.

***Macroglossus* cf. *minimus*, Dagger-toothed Long-nosed Fruit Bat (LC)**
Macroglossus minimus has prior records from each of Manus Island (Thomas 1914; Flannery 1995a; Bonaccorso 1998) and Mussau Island (Smith and Hood 1981). All Melanesian populations are currently referred to a single subspecies *M. minimusnanus*, with type locality of the subspecies on New Britain (Hill 1983; Flannery 1995a; Bonaccorso 1998). An ongoing genetic and morphological study by Aplin and Armstrong suggests that this is a misrepresentation of the true taxic diversity within *Macroglossus* which appears to have some of its oldest lineages centred on New Guinea and its eastern islands.

This species appears to be exceptionally common on Manus Island but less so on Mussau Island. On Manus Island we captured 11 individuals on Mt Sabomu and 57 at the Yeri River site; a similar mist netting effort at Nae on Mussau Island captured only three individuals. The Australian Museum has a series of 33 specimens collected on 15-17 June 1988 at Polomou DPI Station in south-central Manus Island.

***Nyctimene* sp. 1, Manus Tube-nosed Bat**
There appears to be only one species of *Nyctimene* on Manus Island but there is a lack of clarity about the identity and wider relationships of this taxon. Flannery (1995) referred the Manus Island population to *N. albiventer papuanus* (type locality: Milne Bay, Papua New Guinea), and thus grouped it with populations from the Bismarck Archipelago and New Guinea. Bonaccorso (1998: 181-184) and Simmons (2005) followed Smith and Hood (1983) in distinguishing *N. vizcaccia* (type locality: Umboi Island) from *N. albiventer.* Like Thomas (1914), Smith and Hood (1983) and Bonaccorso (1998: 181) emphasised the tri-coloured banding of the dorsal fur as one of the more obvious distinguishing features of *N. vizcaccia*, contrasting with the simpler two-coloured fur of *N. albiventer papuanus*.

Bonaccorso referred all of the smaller tube-nosed bats in the Bismarck and Admiralty Groups to *N. vizcaccia*. This assessment differs from that of Smith and Hood (1983) who illustrated examples of both *N. vizcaccia* and *N. albiventer* from the Bismarck Archipelago, and from the more recent experience of D. Byrne (in Anthony et al. 2001) and Aplin and Opiang (2011) who also recorded two small-bodied *Nyctimene* spp. on New Britain. One possible reason for the ongoing confusion is that the dorsal fur on both species on New Britain is tri-coloured (Aplin and Opiang 2011: 94), contrary to the condition in the type specimens of typical *N. albiventer* (type locality: Morotai Island, Indonesia) and of *N. albiventer papuanus* (type locality: Milne Bay, Papua New Guinea). Whether or not these Bismarck Island populations are conspecific with New Guinean *papuanus* and with *albiventer* of the Moluccan Islands is an open question. Pending resolution of this issue, we prefer to leave the taxon unallocated to highlight the need for further research into taxic diversity within *Nyctimene*.

We captured 23 tube nosed bats on Manus Island including ten on Mt Sabomu and 13 at the Yeri River site, and examined seven more individuals from the Polomou DPI station in south-central Manus Island in the collection of the Australian Museum. All possess tri-coloured dorsal fur and thus resemble both *N. vizcaccia* and the Bismarck Island '*N. albiventer*' in this regard. However, of the two forms, the Manus Island population most closely resembles the '*N. albiventer*' pattern of cranio-dental morphology, most notably in the parallel-sided arrangement of the palatal dentition as illustrated by Smith and Hood (1983: Fig. 1).

***Nyctimene* sp. 2, Mussau Tube-nosed Bat (probable new species)**
Tube-nosed bats were collected on Mussau Island for the first time during the 2014 WCS expedition. A total of 12 individuals were mist-netted in the vicinity of Nae. These animals resemble the Manus Island population in possessing tri-coloured fur but they are smaller, with adult forearm measurements of 53.2–55.7 mm (n = 10) compared with 55.6–60.3 mm (n = 22), and they have smaller ears and higher-crowned post-canine teeth. The differences appear to at least warrant subspecific distinction but they may also reflect a deeper evolutionary divergence. Genetic analyses will be required to make this call, and to determine the true affinities of the other regional populations currently referred to *N. albiventer* and *N. vizcaccia*.

***Pteropus admiraltatum*, Admiralty Flying-fox (LC)**
The Admiralty Flying-fox was the first mammal to be named from a Manus Island population (Thomas 1894). Subsequent biological exploration turned up identical or closely related forms on New Britain (Koopman 1979: 4), on the Tabar Islands to the northeast of New Ireland (Koopman 1979: 4), on Mussau Island (*Noona Dan* Expedition) and the Solomon Islands where three subspecific names have been proposed (Laurie and Hill 1954; Flannery 1995a: 245–246).

We did not capture this species on Manus Island but medium-sized flying-foxes seen flying at dusk at Piri Village on the south coast and at the Yeri River site might have been individuals of this species or possibly of *P. hypomelanus*. The Australian Museum has six specimens (one male, five females) of *P. admiralitatum* captured at Polomou DPI Station in south-central Manus Island in June 1988; none of these females was visibly pregnant or lactating at the time. Bonaccorso (1998: 108–110) reported females from Los Negros Island as reproductively inactive on 15 July 1981.

***Pteropus hypomelanus*, Variable Flying-fox (LC)**
This species is considered to be closely related to *P. admiralitatum* but it is a more brightly coloured species. It is present on many of the smaller islands off the north and northeast coasts of New Guinea, as well as through the Solomon Islands, and thus shows a classic 'tramp' distribution. It is listed for Manus Island by Flannery (1995a: 261–262) but not by Bonaccorso (1998: 126–130). It is confirmed present on New Britain by specimens collected near Kandrian (Van Deusen 1969).

***Pteropus neohibernicus hilli*, Great Flying-fox (LC)**
The Great Flying-fox was represented in the Meek and Eichhorn collection reported by Thomas (1914). Felten (1961) described the Admiralty Islands population as a subspecies (*hilli*) and this action was supported by Koopman (1979: 5) after his independent study of material in the AMNH.

Flannery (1995a: 271) reported a catastrophic collapse of the Manus Island population of *P. neohibernicus* in 1985, evidently due to the action of an unknown disease. He noted that populations had started to recover by 1988. Individuals of this species, unmistakable on account of their very great size, were observed at Piri Village during the fieldwork in 2014.

***Pteropus* sp., St Matthias Flying-fox (potentially unnamed species)**
Mussau and Emirau Islands support populations of a distinctive flying-fox that represents a potentially unnamed species. It is most similar to *P. admiralitatum* in cranio-dental morphology but is a more brightly patterned species (K. M. Helgen, pers. com.).

Three specimens of this species are held in the USNM (USNM277106-277108. These were collected by D. Johnson on Emirau Island in 1944. We captured three individuals on 25 October 2014 by setting mist nets between pawpaw trees that showed signs of flying fox predation. An adult male weighed 410 g, while two female weighed 400 g (old adult) and 340 g (lactating young adult).

***Rousettus amplexicaudatus brachyotis*, Geoffroy's Rousette (LC)**
Rousettus amplexicaudatus is a remarkably widespread bat that occurs through parts of mainland and island Southeast Asia and across much of Melanesia. The subspecies *brachyotis* is one of the more distinctive geographic forms of this species, distinguished by its small size and proportionally small ears (Rookmaaker and Bergmans 1981; Bonaccorso 1998).

There are previous records of this subspecies from Manus Island (Flannery 1995a; Bonasccorso 1988) including a series of nine individuals in the Australian Museum obtained in 1988 at Polomou DPI Station in south-central Manus Island. We captured individuals of this species at the Yeri Creek site on Manus Island, typically in mist nets set across broad shallow streams that clearly served as flyways. On Mussau we netted them on tracks cut through the coastal scrub and we also located a colony of a few dozen individuals roosting in one of the larger of the caves in the vicinity of Nae.

***Syconycteris australis* subsp. Common Blossom Bat (LC)**
Bonaccorso (1998: 204–209) provided the only record of the genus *Syconycteris* from Manus Island. We failed to confirm this record or to detect a member of this genus on Mussau Island. The Australian Museum team also failed to capture this species in their sampling in 1988 at Polomou DPI Station in south-central Manus.

The genus *Syconycteris* in the New Guinea region is in need of full taxonomic revision. Bonaccorso (1998: 204-210) recognised the subspecies *S. a. finschi* for populations on Manus Island and the Bismarck Archipelago but Flannery (1995a: 308–309) failed to distinguish these from *S. a. papuana* of the main island of New Guinea.

Family Emballonuridae: Sheath-tailed Bats

***Emballonura* cf. *dianae* Large-eared Sheath-tailed Bat (LC)**
A *35 i.fFM.d* call type recorded on Mussau Island is referred tentatively to this species based on geographic proximity to known populations of *E. dianae rickwoodi* (New Ireland) and similarity in the call type to documented calls of *E. dianae fruhstorferi* from southern New Guinea (see full discussion in Armstrong et al. Chapter 7).

The *35 i.fFM.d* call type was recorded on two unattended (passive) recording sessions, one made on a beach front backed by a grove of coconut palms, and the other in a clearing within the dense stand of coastal forest. On New Ireland this species roosts in the twilight zone of limestone caves (Smith and Hood 1981), while on New Guinea large congregations have been observed within inner chambers of large cave systems. It was conspicuously absent from each of the seven caves examined in the vicinity of Nae Village.

***Emballonura serii*, Seri's Sheath-tailed Bat (LC)**
This species was described by Flannery (1994) to distinguish a large-bodied New Ireland *Emballonura* from *E. furax* of New Guinea (Smith and Hood 1981). Bonaccorso (1998: 232–233) recorded it for the first time from a locality in Manus Province (Jatat Cave). Simmons (2005) listed it for Manus and Los Negros Islands but did not indicate sources.

Although we did not capture any Sheath-tailed Bats on Manus Island, Armstrong et al. (Chapter 7) tentatively allocated a *45 i.fFM.d* call type recorded on both Manus and Mussau islands to *E. serii*. This call type featured on 4 out of 5 sessions recorded on Mt Sabomu and seven of 23 sessions recorded at Yeri River. At the latter site, recordings were made on units placed on tracks or in clearings but not on any units that sampled flight spaces over water.

On New Ireland this species roosts in the twilight zone of limestone caves (Smith and Hood 1981).

***Mosia nigrescens*, Lesser Sheath-tailed Bat (LC)**
The Australian Museum team collected two specimens at Polomou DPI Station in south-central Manus. Flannery (1995a: 322–323) referred these specimens to the subspecies *M. n. solomonis* which is otherwise distributed throughout the Bismarck Archipelago and the Solomon Islands (Koopman 1979; Smith and Hood 1981; Flannery 1995a). Bonaccorso (1998: 234–237) reported several other localities on each of Manus and Los Negros Islands and also recorded this subspecies from Emirau Island based on USNM specimens collected in 1944 by D. Johnson.

We captured three individuals by hand-netting at each of Mt Sabomu summit and at Piri Village. At both localities numerous individuals were seen flying for a brief period around dusk. The distinctive call type of *Mosia nigrescens* was recorded on the majority of passive recording sessions made on Manus Islands and less frequently on Mussau Island where it was recorded only on units placed on the coastal plain. No individuals were observed roosting in any of the caves examined on Mussau Island, despite previous records of caves and fissures elsewhere in New Guinea (Flannery 1995a).

The current subspecies arrangement for *Mosia* (typical *nigrescens* on New Guinea, *solomonis* on islands to the north and east of New Guinea) does not satisfactorily represent the observed morphological variation among populations of *Mosia*. A preliminary analysis of genetic variation also found patterns that do not appear to be congruent with the current arrangement (Colgan and Soheili 2008).

Family Hipposideridae: Leaf-nosed Bats

***Aselliscus tricuspidatus koopmani*, Trident Leaf-nosed Bat (LC)**
This species is distributed widely across Melanesia, including the Bismarck Archipelago and the Solomon Islands (Schlitter et al. 1982; Flannery 1995a; Bonaccorso 1998) but it was not recorded previously from any island in the Admiralty or St Matthias Groups. Island populations are generally grouped as a well-differentiated subspecies *A. t. koopmani,* which differs from New Guinean populations in body size, fur colouration and cranio-metric measures (Schlitter et al. 1982).

We found *Aselliscus* to be abundant on Mussau Island. Individuals were captured in harp traps and groups were found roosting in three caves. The call type was designated as *125 sCF* and we detected these signals on all but one of the 29 passive recording sessions (see Armstrong et al. Chapter 7). Vouchered individuals agree well in all external and cranio-metric traits with available examples of *A. t. koopmani* from the Solomon Islands. The *125 sCF* call type of the Mussau Island population is around 5 – 10 kHz higher than populations of *A. t. novaguinea* sampled at various localities in the eastern half of New Guinea. (Leary and Pennay 2011; K.P. Aplin and K.N. Armstrong unpublished data).

A *115 sCF* call type that features on 4 out of 23 recording sessions made at the Yeri River site on Manus Island (see Armstrong et al. Chapter 7) might indicate the presence of a population of *Aselliscus tricuspidatus* at this site. However, the lack of any other evidence for *Aselliscus* on Manus Island urges caution about making this association. As discussed below, we prefer a more parsimonious explanation that attributes this call type to another hipposiderid species, *Hipposideros calcaratus calcaratus* – for which there is already firm evidence of occurrence on Manus Island.

***Hipposideros calcaratus calcaratus*, Spurred Leaf-nosed Bat (LC)**
This species is known from several localities on Manus and Los Negros Islands (Bonaccorso 1988: 267–271). The Australian Museum has one specimen (AMM19912) from Polomou DPI Station in south-central Manus. The Manus Island population was referred to the nomino-typical form by Smith and Hill (1981), rather than *H. c. cupidus* of New Guinea. A previous record of this species from Emirau Island is discussed below under *Hipposideros* sp. 1 (see also Armstrong et al. Chapter 7).

We captured one individual of *Hipposideros calcaratus calcaratus* in a mist-net near the summit of Mt Sabomu. Unfortunately the animal was moribund and it was not possible to document its call type. The characteristic call type of *H. c. cupidus* in southern New Guinea is *133 sCF* (Leary and Pennay 2011; K.P. Aplin and K.N. Armstrong unpublished data); the call type of *H. c. calcaratus* has not been recorded. It is possible that the call type of *H. c. calcaratus* on Manus Island is the *115 sCF* call type discussed above under *Aselliscus tricuspidatus koopmani*. This call type was recorded at several sites on Manus Island though not commonly.

***Hipposideros* cf. *cervinus*, Fawn Leaf-nosed Bat (LC)**
This very widely distributed species is listed for Manus Island by Bonaccorso (1988: 272–276) but not by Flannery (1995a: 342–343). Both authors recorded it from Emirau Island. It is found throughout the New Guinea region and also occurs west to Malaysia; the type locality of *cervinus* is Cape York, Australia. The group has not been subject to taxonomic revision since Jenkins and Hill (1981) and is need of a modern reassessment.

We encountered roosting colonies of this species in three of the seven caves examined on Mussau Island, with each of the colonies numbering in the dozens to hundreds of individuals of mixed sex. The USNM has adult male (USNM 277130) and female (USNM 277129) specimens collected on Emirau Island in 1944 by D. Johnson. The forearm lengths (measured by Aplin on the dry skins) are 46.7 mm for the male and 45.8 mm for the female. These values are slightly lower than measurements taken on the Mussau Island series (males 47.5–48.0, n = 3; females 47.3–48.7 mm, n = 6) but there are no major observable differences in pelage, ear or noseleaf characteristics.

The call type of a series of Mussau Island *H.* cf. *cervinus* was determined as *145 sCF*. This agrees with the characteristic frequency of 144-145 kHz given by Bonaccorso (1998: 273) for *H. cervinus* (though without any geographic reference). Populations of *H. cervinus* on New Guinea have geographically variable call characteristic frequency that ranges from 135 kHz to 145 kHz (Armstrong and Aplin 2014; K.P Aplin and K.N. Armstrong unpublished data).

We recorded the *145 sCF* call type on the majority of the passive recording sessions made on Mussau Island. By contrast, this call type is conspicuously absent on the sessions recorded on Manus Island, although an even higher call type of *158 sCF* may derive from a related species (see below – *Hipposideros* sp. 2).

***Hipposideros diadema 'mirandus'*, Diadem Leaf-nosed Bat (LC)**
This species was recorded from Manus Island by Thomas (1914) who coined the name *H. demissus mirandus* based on two specimens collected by Messrs Meek and Eichhorn. Bonaccorso (1998: 279-284) reported additional specimens from Jekaula, Loniu (Jatut Cave), Naringel, and Ndoia Villages on Manus and Los Negros Islands. A partial taxonomic revision of *H. diadema* by Kitchener et al. (1992) did not include representative material of the subspecies *mirandus*, hence its degree of differentiation from other populations remains untested. Populations of *H. diadema* in the Bismarck Archipelago are referred to the subspecies *oceanitis* (type locality: Guadalcanal, Solomon Islands; Kitchener et al. 1992).

Armstrong et al. (Chapter 7) attributed a *60 mCF* call type to *H. diadema* based on similarity to the documented call type of this species on New Guinea (Leary and Pennay 2011; Armstrong and Aplin 2011). This call type was recorded on the majority of bat detector sessions made at the Yeri River site, but not on any sessions made on Mt Sabomu. The calls of *H. diadema* are usually of relatively high amplitude, and thus likely to be detected if the species is present within a particular sampled habitat.

Hipposideros diadema has not been recorded in the St Matthias Group (Flannery 1995a; Bonaccorso 1998), despite its occurrence on New Ireland and its apparent propensity for successful dispersal across wide open-water barriers. Its genuine absence from Mussau Island is further supported by our failure to detect the species in any of the seven caves visited or on any of the passive bat detector sessions recorded on the island.

***Hipposideros* sp. 1, Manus Island 'small Hipposideros' (probable new species)**
A specimen in the USNM (278680) collected on Manus Island by Lt Cmdr Emil Bogen in 1945 appears to represent a highly distinctive, unnamed species of *Hipposideros*. It is an adult female with well-formed inguinal 'false teats' and is a puppet skin with skull not removed. The forearm length measures 43.7 mm and the animal is much smaller overall than the Emirau Island examples of *H. cervinus* held in the same institution. However, close study of the well-preserved skin suggests affinity with *H. cervinus* rather than *H. ater* that is of comparable size but lacks accessory lappets to the nose leaf and has appreciably larger ears.

Our tentative conclusion, pending examination of the skull, is that this specimen represents an unnamed member of the *Hipposideros bicolor* Group. Re-examination of other specimens from Manus Island that have been referred to *H. cervinus* (e.g. Jatut Cave on Los Negros; listed by Bonaccorso 1998: 275) will reveal whether this taxon has been collected on other occasions.

We tentatively identify this tiny *Hipposideros* as the most likely producer of an otherwise enigmatic *158 sCF* call type that we recorded at Mt Sabomu and the Yeri River sites on Manus Island but not on Mussau Island. Further field work will also be necessary to unambiguously determine the call type of this species.

***Hipposideros* sp. 2, Mussau Island 'large *Hipposideros*' (probable new species)**
The caves in the vicinity of Nae contained colonies of a moderately large-bodied *Hipposideros* (body weights to 13.1 g). This species resembles *H. calcaratus* in general noseleaf anatomy but it has a proportionally larger noseleaf and ears (including the specimens from Manus Island). Acoustic recordings taken from a series of captive animals of both sexes also revealed an unexpectedly low frequency characteristic call frequency, and the call type *98 sCF* was allocated. This call type featured on 8 of the 29 passive sessions recorded on Mussau Island, but it was not recorded on any of the Manus Island passive sessions.

As documented above, New Guinean populations of *H. calcaratus cupidus* have a call type of *133 sCF* and while the call type of nomino-typical *H. c. calcaratus* from the Bismarck Archipelago and Solomon Islands is not known, we suspect that it may be the *115 sCF* call type recorded on certain passive recordings made on Manus Island. Both of these call types are appreciably higher than the *98 sCF* call type of the Mussau Island taxon. Such a difference is usually indicative of species-level differences but this possibility requires further investigation using genetic and morphological comparisons.

A prior record of *H. calcaratus calcaratus* from Emirau Island (Flannery 1995a: 340-341; Bonaccorso 1998: 267–271) might be referred to this species.

Family Miniopteridae: Bent-winged Bats

***Miniopterus* spp., Bent-winged Bats**
The genus *Miniopterus* is an ancient group of bats that has undergone wide dispersal and much speciation but often with relatively little morphological differentiation (Ramasindrazana et al. 2011). Current taxonomic arrangements for the Melanesian region are unreliable and show little concordance with the still limited available molecular assessments (Appleton et al. 2004). For this reason, we will not attempt to apply species nomenclature to the *Miniopterus* of Manus and Mussau Islands and prior usage is mentioned only for bibliographic completeness.

Four specimens collected by Meek and Eichhorn on Manus Island in 1913 were referred by Petersen (1981) to *M. propitristis insularis* (type locality: Rennell Island, Solomon Islands). Maeda (1982) subsequently described these as a new species, *M. bismarkensis*. Hill (1983) questioned both of these actions and concluded that the Meek and Eichhorn specimens are closest to *M. magnater* (type locality: Marienberg, Sepik River, New Guinea). Forearm lengths measured by Hill (1983: 189) on three adults of this series are 44.4, 45.0 and 46.4 mm. An adult male specimen (AMM20889) in the Australian Museum from Polomou DPI Station in south-central Manus Island has an appreciably shorter forearm (42.15 mm; body weight 8.0 gm) and it probably represents a different taxon. Smith and Hood (1981) recorded one species of *Miniopterus* (as '*tristis*') on Mussau Island, based on their own collecting.

Flannery (1995a) recorded one species of *Miniopterus* on each of Manus Island (as '*macrocneme*'; presumably based on AMM20889) and Mussau Island (as '*propitristis*'). By contrast, Bonaccorso (1998) listed three species of *Miniopterus* on Manus Island (as '*macrocneme*', '*propitristis*' and '*schriebersii*') and one on Emirau Island (as '*propitristis*') in the St Matthias Group.

The WCS fieldwork produced evidence of only a single species of *Miniopterus* on Manus Island, based on a call type *40 st.cFM* recorded on Mt Sabomu and at the Yeri River site (Armstrong et al. Chapter 7). No *Miniopterus* were captured on Manus Island.

On Mussau several colonies of a large *Miniopterus* sp. were located in caves. Captured individuals produced calls of a *40 st.cFM* call type, directly comparable to those recorded on Manus Island. The Mussau Island *Miniopterus* had adult forearm lengths of 48.4–50.5 mm (n = 7) and body weights of 9.7–11.7 g (n = 6); these measurements are within the general size range of *M. propitristis insularis* (e.g. Bonaccorso 1998: 403). Passive acoustic recordings on Mussau Islands usually included the *40 st.cFM* call type but they also sometimes recorded a distinct call type of *45 st.cFM*. Armstrong et al. (Chapter 7) considered this call type to be most likely that of a second species of *Miniopterus*.

Family Vespertilionidae: Evening Bats

***Kerivoula myrella*, Manus Island Woolly Bat (DD)**
Thomas (1914) based his description of *Kerivoula myrella* on one specimen from Manus Island (used as the holotype) and three from Ruk (Umboi) Island. Subsequent fieldwork in the region produced records of *K. myrella* from the Whiteman Range in west New Britain (collected by T. Gilliard in 1959; Koopman 1979) and Ulatawa Plantation in east New Britain (collected by S. Hamilton in 1997; Bonaccorso 1998: 377). The species is also recorded from Duke of York Island (MOV specimen; collected in the 1870s but unrecognised until the 1990s; Flannery 1995a: 371) and from Mioko Island (a satellite of Duke of York Island; Bonaccorso 1998). It has not been detected on New Ireland, despite the considerable survey effort on that island by teams from each of the Los Angeles County Museum, the Australian Museum, and Conservation International/United States National Museum.

A single adult female captured in a harp trap at the Yeri River site on 10 October 2014 represents the first evidence of the species on Manus Island since the original capture made by Mssrs Meek and Eichhorn on 8 September 1913; Thomas 1914: 439). The harp trap was set in a gap in vegetation beside a shallow stream. Importantly, this animal provided excellent recordings of the echolocation call signature for the species, thereby allowing it to be identified with confidence on passive acoustic recordings.

Two of the 23 recording sessions made at the Yeri River site contained calls of *K. myrella*. Both sessions recorded activity along narrow tracks running through dense forest understorey. No recordings of *K. myrella* were made at the Mt Sabomu or Piri Village sites, nor at the survey site on Mussau Island. The paucity of acoustic recordings of *K. myrella* may not reflect genuine rarity of this species. Like all other documented echolocation calls made by members of the genus *Kerivoula*, the call of *K. myrella* has relatively low energy and the species is unlikely to be detected unless it passes very close to the microphone.

***Myotis* sp., a large-footed or fishing bat**

No representative of the genus *Myotis* has been recorded on Manus Island or in the St Matthias Group. Armstrong et al. (Chapter 7) allocated a call type of *40 st.bFM* recorded on both islands to a species of *Myotis*, based on the similarity of pulse shape and characteristic frequency to reference calls of *Myotis* spp. obtained elsewhere in Papua New Guinea (K.N. Armstrong and K.P. Aplin, unpublished data) and of *Myotis macropus* from Australia (K.N. Armstrong unpublished data). Two of the four recordings of *Myotis* sp. on Manus Island were made on detectors sampling activity over broad, slow moving pools of a tributary of the Yeri River; the others were from narrow tracks running through dense forest understorey. On Mussau Island the recordings were made in three different contexts: one on the beachfront, one in the dense coastal scrub beside our camp, and one on a limestone hill overlooking the coastal plain. The one habitat in the vicinity with open water, a place where spring water flows in a shallow sheet across limestone, failed to produce any calls of *Myotis* sp.

Following the revision of Kitchener et al. (1995) the name *M. moluccarum* is applied to all populations of *Myotis* in New Guinea and islands to the east (e.g. Bonaccorso 1998; Simmons 2005). However, available genetic data (Cooper et al. 2001) hint at the presence of more than one species on New Guinea, while the morphometric analysis of Kitchener et al. (1995) suggest that Solomon Island populations (for which the name *solomonis* Troughton, 1929 is available) may be distinctive. Specimens from the Bismarck Archipelago have not been critically assessed either against the morphological or genetic frameworks.

On New Britain and New Ireland small numbers of *Myotis* sp. have been found roosting among clusters of bent-winged bats (*Miniopterus* spp.) or in deep cracks and crevices in cave walls (Smith and Hood 1981; Flannery 1995a: 382). None were located during searches of caves on Mussau Island.

***?Nyctophilus* sp. (a possible long-eared bat)**

A call type of *55 st.bFM* recorded only at the Yeri River site on Manus Island is tentatively attributed by Armstrong et al. (Chapter 7) to a species of long-eared bat, genus *Nyctophilus*. If confirmed, this would represent the first evidence of a species of *Nyctophilus* on Manus Island and potentially, only the second record of the genus from any island to the east or north of New Guinea. To date, the only confirmed record is a specimen in USNM attributed to *N. microtus* from the Weitin River Valley on New Ireland (Bonaccorso 1998; Emmons and Kinbag 2001). The call type recorded on Manus Island is similar to that recorded for *N. microtis* at various localities on New Guinea (K.N. Armstrong and K.P. Aplin, unpublished data). However, attribution to this species is premature as there is limited call differentiation between species of *Nyctophilus*, and ample opportunity to confuse calls of *Nyctophilus* with clutter calls of miniopterids and other vespertilionids.

Three passive recording sessions made at the Yeri River site featured the *55 st.bFM* call type. Two of these sampled activity along narrow tracks running through dense forest understorey; the other sampled activity over a broad, slow moving pool of a tributary of the Yeri River.

The current paucity of evidence for *Nyctophlus* spp. in the eastern Melanesian islands is consistent with the general poor-representation of this genus in collections from the wider New Guinea region (Flannery 1995a,b; Bonaccorso 1998; Parnaby 2009). This situation contrasts with the abundance and relative ease of capture of *Nyctophilus* in many habitats in Australia and it may indicate a true contrast in abundance of long-eared bats between wetter and drier habitats.

Echolocation calls of both Australian and New Guinean species of *Nyctophilus* are characteristically of very low amplitude, which reduces their detectability on passive recorders, especially if they are naturally uncommon in the environment. The fact that the *55 st.bFM* call type was detected on three separate passive recording sessions at Yeri River suggests that it might be moderately abundant at this site. Captures are required to progress our knowledge of this intriguing call type.

***Pipistrellus angulatus*, New Guinea Pipistrelle (LC)**

Pipistrellus angulatus was first recorded from Manus Island by Thomas (1914). A specimen in the Australian Museum from Polomou DPI Station in south-central Manus (AMM19841) is registered under this name. Its wider distribution includes New Guinea, the Bismarck Archipelago and the Solomon Islands (Flannery 1995a,b).

There are no prior records of *Pipistrellus* from Mussau Island. A specimen from Emirau Island has been variously referred to *P. imbricatus* (Lidicker and Ziegler 1968; type locality: Java) and *P. angulatus* (Hill 1983). Its identity was not assessed by Kitchener et al. (1986) in their morphometric reassessment of Australo-papuan *Pipistrellus*.

Two species of *Pipistrellus* are recorded from each of New Britain and New Ireland (*P. angulatus* and *P. papuanus*) (Bonaccorso 1998). On New Ireland *P. angulatus* is recorded to roost in caves as well as in wall cavities in buildings; by contrast, *P. papuanus* is said to roost inside cavities in coconut palm trunks (Smith and Hood 1981; Flannery 1995a; Bonaccorso 1998).
We captured examples of *P. angulatus* with hand nets at dusk on the summit of Mt Sabomu. Good recordings were obtained of their echolocation call type: *48 st.cFM*. This call type was recorded on every passive recording session made on Manus Island, including those made on Mt Sabomu, at Piri Village, and at the Yeri River site. This is clearly a super-abundant species at all elevations on Manus Island, with no strongly preferred habitat.

By contrast, the *48 st.cFM* call type was conspicuously absent on every passive recording session made on Mussau Island. If the record of *P. angulatus* from Emirau Island is genuine, then the absence of this species from Mussau Island seems unusual in view of the geographic proximity of the two islands. A plausible alternative explanation is that the Emirau Island record is erroneous.

Family Molossidae: Free-tailed Bats

***Mormopterus* cf. *beccarii* Beccari's Free-tailed Bat (LC)**
Armstrong et al. (Chapter 7) record this species from Mussau Island on the basis of its distinctive call type (*20 cFM*) that was recorded twice on a single passive recording session with the unit placed within a coconut grove close to the coast. *Mormopterus beccarii* has not been recorded previously either on Mussau Island or on Manus Island. There is a single record from the Bismarck Archipelago (Kapuluk River, West New Britain Province; Bonaccorso 1998: 414-415) and none from further east (Flannery 1995a). It is not surprising that a member of this genus should be overlooked on previous surveys since they typically roost in tree cavities rather than caves and they usually avoid dense vegetation due to their fast, direct flight pattern. Confirmation of this species on Mussau Island will require targeted effort such as the use of canopy nets for capture. It should also be sought on Manus Island through further use of acoustic detectors as well as use of canopy nets and acoustic lures.

A possibly erroneous record from Manus Island

***Rattus praetor*, Large Spiny Rat (LC)**
This species was listed for Manus Island by Menzies and Dennis (1979), though under a misapplied prior name *Rattus ruber*. Flannery (1995a) also listed *R. praetor* for Manus Island, presumably based on the Menzies and Dennis (1979) publication. Taylor et al. (1982) failed to detect any examples of *R. praetor* from Manus Island in their extensive studies of Melanesian *Rattus*. Corrie E. Williams (1999) referred subfossil jaws from the Pamwak site to *Rattus praetor* but, as intimated by Flannery (1995a: 160) and confirmed by our subsequent studies, the Pamwak assemblage contains only the large unnamed *Rattus* species, examples of *Melomys matambuai*, and a few *Rattus exulans* specimens from surficial contexts. Thus, we know of no verified records of *R. praetor* occurring on Manus Island, either in prehistoric or modern times. This is somewhat surprising given the wider evidence for human-assisted dispersal of this species to other remote island groups in Melanesia in prehistoric times (White et al. 2000).

Discussion

An ongoing process of inventory

By Melanesian standards the mammal fauna of Manus Island is relatively well-known. Even so, our relatively brief field survey produced entirely new records of two extra bat species, while our re-examination of previously collected specimens revealed at least one additional species (a member of the genus *Hipposideros*) that is very likely endemic to the island.

Mussau Island by contrast was known to be poorly documented and it is therefore not surprising that our field survey detected six additional mammal species, all bats, and that at least one and quite possibly two of these represent species new to science.

Both of the newly inventoried species on Manus Island, belonging to the genera *Myotis* and *Nyctophilus,* were detected by acoustic methods. This method is adequate to confirm the representation of these genera on the island but captures will be necessary to establish the species involved in each case. Given the geographic isolation of Manus Island from all other landmasses on which *Myotis* and *Nyctophilus* are found, it will not be at all surprising if both turn out to be distinctive endemics. Capture of the potentially new *Hipposideros* species on Manus Island is also highly desirable so that its relationships can be established using genetic means and so that its echolocation calls can be firmly established. At present we suspect that this species is responsible for the distinctive 158 sCF call type that we recorded at both sites on Manus Island but this can only be confirmed through a future capture.

Two of the six newly inventoried bat species on Mussau Island were found by visiting the many caves around Nae Village (*Aselliscus tricuspidatus koopmani* and *Hipposideros* sp. 2), one by mist netting (*Nyctimene* sp. 2), and three by acoustic detection (*Emballonura* cf. *dianae, Myotis* sp. and *Mormopterus* cf. *beccarii*). For each of the species inventoried by acoustic methods, captures are now required to firmly establish the species identities.

With this latest survey effort on Manus and Mussau Islands, we might ask again whether the process of basic inventory is now complete. For ground mammals we suspect that it is, though we have greater confidence for Manus Island and somewhat lesser for Mussau Island. In the case of Manus Island, the large sample of mammal remains recovered from the Pamwak archaeological site certainly reduces the likelihood that there are any additional extant native species, apart from *Spilocuscus kraemeri*, *Echymipera* cf. *kalubu*, *Melomys matambuai* and the unnamed native *Rattus* sp. Even so, we should acknowledge that some of the smallest ground mammals found in Melanesia such as shrew mice (species of *Pseudohydromys* etc.) would be unlikely to feature in human diets and are rarely captured even by owls; accordingly, it is not impossible that other native rodents are present on Manus Island. The most efficient way to detect any additional species will be through examination of additional samples of mammal bones from caves, especially deposits accumulated by owls rather than people. These should be actively sought in the karst landscape wherever this occurs across Manus Island.

For Mussau Island, there is no local knowledge of ground mammals other than the rats found around houses. However, it is possible that there are one or more native rodents living in the less disturbed forest habitats away from human activity. Large species would most likely be known to local residents but small species might not be distinguished from village rats. Caves are a less promising avenue for new insights into native ground mammals because Mussau Island seems to lack any cave roosting raptor that might accumulate bones for discovery. Many caves and fissures on Mussau Island were searched carefully for bones during the 2014 WCS survey and only a few small fragments were found, most likely the result of natural deaths of bats, gekkos and frogs, all of which spend time in these contexts.

For bats we are less confident that our inventory is complete. Other groups of bats that might yet be found on Manus Island include members of the genera *Rhinolophus, Murina, Philetor, Phoniscus, Chaerephon* and *Saccolaimus*. All of these genera are represented in the fauna of New Britain and they are all difficult to detect through conventional mist netting; moreover, the majority are not typically found roosting within caves. Further use of acoustic detection methods represents the best way to search for each of these groups of bats, followed by use of specific targeted capture methods such as canopy netting, more intensive use of harp traps, and possibly the use of acoustic 'lures' (see also Armstrong et al. Chapter 7). The same caveats apply to Mussau Island which probably has a richer bat fauna than represented by our current list.

Biogeography

The new discoveries on each of Manus and Mussau Island do not radically alter the current understanding of their biogeographic histories. Manus Island, the largest island of the Admiralty Group, is volcanic in origin. It is believed that the island became emergent in the Late Miocene, ~8–10 million years ago (Allison 1996). Despite the presence of small islands along volcanic subduction zones that might be taken as indicative of potential land bridges, the archipelago was never connected to the Bismarck Archipelago nor to the northern coastline of New Guinea (Allison 1996). All members of these island faunas presumably reached the islands through dispersal across wide stretches of ocean.

The Admiralty Group, and especially Manus, has a surprising number of endemic species and subspecies including mammals, birds, lizards, frogs, and invertebrates. At least two of the native ground mammals are well-differentiated endemic species: *Melomys matambuai* and *Rattus* sp., while *Spilocuscus kraemeri* may be shared naturally with New Britain. The taxonomic status of the bandicoot *Echymipera* cf. *kalubu* is unresolved.

At least one of the bats found on Manus Island appears to be an endemic species: *Hipposideros* sp. 1 while others are shared only with islands of the Bismarck Group (and in some cases, the Solomon Islands): *Kerivoula myrella*, *Hipposideros calcaratus calcaratus, Emballonura serii* and *Rousettus amplexicaudatus brachyotis*. Others are currently understood to be endemic at subspecies level: *Hipposideros diadema mirandus* and *Pteropus neobrittanicus hilli*. Further taxonomic research is needed to assess the taxonomic affinities of other members of the Manus Island bat fauna, including several species that are currently known only from their echolocation calls. The number of mammalian endemics for Manus Island seems likely to rise substantially, including species or subspecies of *Dobsonia*, *Nyctimene*, *Macroglossus*, *Nyctophilus*, *Myotis*, *Emballonura* and *Miniopterus*.

Mussau Island appears to have at least three endemic mammals (possibly all shared with Emirau Island): a *Pteropus,* a *Nyctimene* and a *Hipposideros*. All are currently unnamed. Otherwise the fauna shows clear biogeographic connections to New Ireland and the Admiralty Group, as would be expected. Its geological history is probably similar to that of Manus Island, though it may not have been emergent for as long.

Conservation needs

Our survey results cast a strong spotlight on the unnamed *Rattus* sp. as an urgent priority for conservation efforts on Manus Island. This species is known from two only modern localities and one prehistoric cave site, and there is one other tentative record (Mt Sabomu, based on the abandoned burrow) based on our survey work. The species is not known to be abundant at any of these sites and our survey results indicate that it is rare, if present at all, in seemingly suitable habitats at two contrasting sites, the upland forests of Mt Sabomu and the lowland forests along the lower reaches of the Yeri River.

The available records for the unnamed *Rattus* sp. suggest a potential area of occupancy of just over 2,000 km^2, including all of Manus Island, from near sea level to the most elevated forests, as well as some of its larger satellite islands, most notably the adjacent Los Negros. However, Manus Island has been subjected to considerable habitat degradation in the period since World War II and most of the lowland fringe has been converted to a mosaic of plantations and/or subsistence gardens and secondary forest. In addition, there is active forestry in many areas. Away from the coast, steeper terrain generally supports more or less intact forest cover but our experience on Mt Sabomu suggests that at least some of these upland forests on volcanic substrates have a naturally low productivity and may not be able to support high populations of this species.

Our survey effort at two sites on Manus Island in 2014 strongly suggests that the unnamed *Rattus* sp. may now be rare even in the best preserved habitats. Given this observation, we consider that it would be unwise to treat the species as widespread and common or even secure across its range, and instead urge further survey work to locate surviving populations, to understand their population dynamics, and to identify present threats to their continued existence.

Aside from further loss of forest habitats, the most serious of known threats are feral cats (*Felis catus*) and the impact of introduced rodents. Cats were introduced to Manus Island sometime in the 19th or 20th centuries and feral populations are likely to occur in many areas. Although we did not find any evidence of feral cats at either of our main survey sites, the survey effort was not sufficient to rule out their occurrence at either site. Feral cats would probably prey mainly on birds and lizards, as well as the introduced rodents, and they might well cause severe population depression in a native rodent and perhaps cause local extinctions.

Two introduced rodent species, *Rattus exulans* and *R. rattus*, are confirmed as present on Manus Island (Taylor et al. 1982; WCS survey results). *Rattus exulans* may have arrived in prehistoric times, although there is no compelling evidence for this from the Pamwak Site. *Rattus rattus* most likely arrived on the islands in colonial times or later. *Rattus exulans* is clearly widespread and occurs across a variety of habitats, including the remote and relatively undisturbed forest near the summit of Mt Sabomu. However, while it may be common in certain habitats including villages, gardens and patches of kunai grassland, it appears not to be universally abundant in forest, even in the absence of other *Rattus* species. Given the rarity of these introduced rodents in the Manus forests, interspecific competition seems unlikely in itself to present sufficient explanation for the rarity of the native *Rattus* sp.

Elsewhere in the Pacific region, the introduction of commensal *Rattus* spp. has been nominated as the proximate cause of extinction of insular *Rattus* species. On Christmas Island in the Indian Ocean the rat, *Rattus macleari* became extinct following the arrival of the black rat (*R. rattus*) (Wyatt et al. 2008). In this case the causal agent of extinction of the native rats was most likely a trypanosome carried by the introduced rat species (Wyatt et al. 2008). *Rattus rattus* is already established on Manus but thus far it appears not to be widely invasive into rural regions and/or natural habitats. Whether or not the *R. rattus* population on Manus Island carries the pathogenic trypanosome is not known. This should be determined as a matter of high priority so that a potentially avoidable repeat of history does not occur.

Wildlife conservation on Mussau Island is greatly advantaged by the dominant Seventh Day Adventist affiliation of the human population. This excludes most categories of wild animals from human predation. One clear indicator of the conservation benefit is the fact that easily accessible caves within a short walk of Nae Village contained large colonies of bats including both small insectivorous species and larger cave-roosting fruit bats. These species are generally intolerant of disturbance and caves this close to human settlements in parts of Melanesia where bats are consumed would be unlikely to contain resident colonies.

Recommendations

Our survey identified the unnamed *Rattus* sp. as the most urgent priority for mamal conservation effort on Manus Island. Additional biodiversity priorities for Manus Island mammals include:

1. Clarification of the taxonomic status of the bandicoot population and assessment of its current distribution.

2. Further studies on the population status of the Admiralty Cuscus and its and sensitivity to harvesting, habitat disturbance and conversion.

3. Investigation of the population status of the Manus Melomys.

4. Targeted efforts to capture and identify the as yet undetermined species of *Myotis* and *Nyctophilus*.

5. Wider application of acoustic methods to assess the current distribution, pattern of habitat use and sensitivity to habitat disturbance and conversion of each of the insectivorous bat species, including the various Manus Island endemics.

Biodiversity priorities for Mussau Island mammals include: further survey in other parts of the island including higher elevation forests, with special focus on the discovery of any endemic rodents; taxonomic studies of the Mussau Island *Nyctimene*, *Pteropus* and *Hipposideros* spp. to determine their level of endemism; targeted efforts to capture and identify the as yet undetermined species of *Emballonura*, *Myotis* and *Mormopterus*.

References

Allison, A. 1996. Zoogeography of amphibians and reptiles of New Guinea and the Pacific region. *In* A. Keast and S. E. Miller (eds.). The origin and evolution of Pacific island biotas, New Guinea to eastern Polynesia: patterns and processes. SBP Academic Publishing, Amsterdam, The Netherlands. Pp. 407–436.

Anthony, N., Byrnes, D., Foufopoulos, J. and Putnam, M. 2001. Biological Survey of New Britain Island, Papua New Guinea. Falcon Art Media. Madison, Wisconsin, U.S.A.

Aplin, K.P. and Opiang, M. 2011. Mammals of the Nakanai Plateau, West New Britain, Papua New Guinea.Conservation International Rapid Assessment Program. *In* S.J. Richards and B.G. Gamui (eds.). Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments. RAP Bulletin of Biological Assessment 60. Conservation International. Arlington, Viriginia. Pp. 85–103.

Aplin, K.P., Brown, P. R., Jacob, J., Krebs, C. and Singleton, G.R. 2003. Field methods for rodent studies in Asia and the Pacific. ACIAR Monograph No. 100. Australian Centre for International Agricultural Research, Canberra, Australia.

Appleton, B. R., McKenzie, J. A. and Christidis, L. 2004. Molecular systematics and biogeography of the bent-wing bat complex *Miniopterus schreibersii* (Kuhl, 1817) (Chiroptera: Vespertilionidae). *Molecular Phylogenetics and Evolution* 31: 431–439.

Bafmatuk, F., Egloff, B. and Kaiku, R. 1980. Islanders: Past and Present. *Hemisphere* 25: 77–81.

Bergmans, W. 1979. Taxonomy and zoogeography of *Dobsonia* Palmer, 1898, from the Louisiade Archipelago, the D'Entrecasteaux Group, Trobriand Island and Woodlark Island (Mammalia, Megachiroptera). *Beaufortia* 29: 199–214.

Bergmans, W. and Sarbini, S. 1985.Fruit bats of the genus *Dobsonia* Palmer, 1898 from the islands of Biak, Owi, Numfoor and Yapen, Irian Jaya (Mammalia, Megachiroptera). *Beaufortia* 34: 181–189.

Bonaccorso, F. 1998. Bats of Papua New Guinea.Conservation International. Washington, DC, USA.

Burley, D. 2003. Lapita and its transformations in the Mussau Islands, Papua New Guinea, 1985–1988: Volume 1, Introduction, Excavations and Chronology (review). Asian Perspectives 42: 178–181.

Cohn, L. 1914. Eine neue Varietät von *Phalanger maculates*. *Zoologische Anzeiger* 35: 507–516.

Colgan, D. J. and Soheili, S. 2008. Evolutionary Lineages in *Emballonura* and *Mosia* Bats (Mammalia: Microchiroptera) from the Southwestern Pacific. *Pacific Science* 62: 219–232.

Cooper, S. J. B., Day, P. R., Reardon, T. B. and Schulz, M. 2001. Assessment of species boundaries in Australian *Myotis* (Chiroptera: Vespertilionidae) using mitochondrial DNA. *Journal of Mammalogy* 82: 328–338.

Egloff, B. 1975.Archaeological Investigations in the Coastal Madang Area and on Eloaue Island of the St. Matthias Group. *Records of the Papua New Guinea Public Museum and Art Gallery* 5: 1–43.

Emmons, L. H. and Kinbag, F. 2001. Survey of mammals of southern New Ireland. Southern New Ireland, Papua New Guinea: A biodiversity assessment. RAP Bulletin of Biological Assessment 21. Conservation International. Arlington, Virginia. Pp 67–69.

Felten, H. 1961. Eine neue Unterart von *Pteropus neohibernicus*. *Senckenbergiana Biologica* 42: 417–418.

Flannery, T. F. 1994. Systematic revision of *Emballonura furax* Thomas, 1911 and *E. dianae* Hill, 1956 (Chiroptera: Emballonuridae), with description of new species and subspecies. *Mammalia* 58: 601–612.

Flannery, T. F. 1995a. Mammals of the South-West Pacific and Moluccan Islands. Comstock/Cornell. Ithaca, USA.

Flannery, T. F. 1995b. Mammals of New Guinea.Revised and updated edition. Reed Books. Chatswood, New South Wales, Australia.

Flannery T. F and Calaby J. H. 1987. Notes on the species of *Spilocuscus* (Marsupialia: Phalangeridae) from northern New Guinea and the Admiralty and St. Matthias island groups. *In* Archer M. (ed.). Possums and opossums: Studies in Evolution, volume 2. Surrey Beatty and Sons. Chipping Norton, New South Wales, Australia. Pp. 547–558.

Fredericksen, C., Spriggs, M. and Ambrose, W. 1993. Pamwak rockshelter: a Pleistocene site on Manus Island, Papua New Guinea. *In* M. A. Smith, M. Spriggs and B. L. Fankhauser (eds.). Sahul in Review: Pleistocene Archaeology in Australia, New Guinea and Island Melanesia. ANU Press. Canberra, Australia. Pp. 144–152.

Helgen, K. M. 2007. A reassessment of taxonomic diversity and geographic patterning in the Melanesian mammal fauna. Unpublished PhD Thesis, University of Adelaide, Australia.

Helgen, K. M. and Flannery, T. F. 2004. Notes on the phalangerid marsupial genus *Spilocuscus*, with description of a new species from Papua. Journal of Mammalogy 85: 825–833.

Hill, J. E. 1983. Bats (Mammalia: Chiroptera) from Indo-Australia. Bulletin of the British Museum (Natural History) *Zoology* 45: 103-208

Jenkins, P.D. and Hill, J. E. 1981.The status of *Hipposideros galeritus* Carter, 1846 and *Hipposideros cervinus* (Gould, 1854) (Chiroptera: Hipposideridae). Bulletin of the British Museum (Natural History), *Zoology*, 41: 279–294.

Kirch, P.V. 1987. Lapita and Oceanic cultural origins: excavations in the Mussau Islands, Bismarck Archipelago, 1985. *Journal of Field Archaeology 14*: 163–180.

Kirch, P.V. 1989. Second millennium B.C. arboriculture in Melanesia: Archaeological evidence from the Mussau Islands. *Economic Botany* 43: 225-240.

Kitchener, D. J., Caputi, N. and Jones, B. 1986. Revision of Australo-Papuan *Pipistrellus* and of *Falsistrellus* (Microchiroptera: Vespertilionidae). *Records of the Western Australian Museum* 12: 435–495.

Kitchener, D. J., Cooper, N., and Maryanto, I. 1995. The *Myotis adversus* (Chiroptera: Vespertilionidae) species complex in Eastern Indonesia, Australia, Papua New Guinea and the Solomon Islands. *Records of the Western Australian Museum*17: 191–212.

Kitchener, D. J., How, R. A., Cooper, N. K., and Suyanto, A. 1992. *Hipposideros diadema* (Chiroptera Hipposideridae) in the Lesser Sunda Islands, Indonesia: taxonomy and geographic morphological variation. *Records of the Western Australian Museum* 16: 1–60.

Koopman, K. F. and Diamond, J. M. 1979.Zoogeography of mammals from islands off the northeastern coast of New Guinea. *American Museum Novitates* 2690: 1–17.

Laurie, E.M.O. and Hill, J.E. 1954. List of land mammals of New Guinea, Celebes, and adjacent islands, 1758–1952. British Museum, London, UK .

Leary, T., and Pennay, M. 2011. Echolocation calls of eight microchiroptera from Papua New Guinea. *In* B. Law, P. Eby, D. Lunney and L. Lumsden (eds.). The biology and conservation of Australasian bats. NSW Royal Zoological Society of New South Wales, Mosman, NSW, Australia. Pp. 106–127.

Lidicker, W. Z. and Ziegler, A. C. 1968. Report on a collection of mammals from Eastern New Guinea: including species keys for 14 genera. University of California Press, Los Angeles, CA, USA.

Maeda, K. 1982. Studies on the classification of *Miniopterus* in Eurasia, Australia and Melanesia. *Honyurui Kagaku* (Mammalian Science) Supplement No. 1: 1–176.

Menzies, J. I. 1991. A handbook of New Guinea marsupials and monotremes. Kristen Press Inc., Madang, PNG.

Menzies, J. I. and Dennis, E. 1979. Handbook of the New Guinea Rodents.Wau Ecology Institute Handbook No. 6, PNG.

Parnaby, H. E. 2009. A taxonomic review of Australian Greater Long-eared Bats previously known as *Nyctophilus timoriensis* (Chiroptera: Vespertilionidae) and some associated taxa. *Australian Zoologist* 35: 39–81.

Peterson, R. L. 1981. Systematic variation in the *tristis* group of the bent-winged bats of the genus *Miniopterus* (Chiroptera: Vespertilionidae). *Canadian Journal of Zoology* 59: 828–843.

Ramasindrazana, B., Goodman, S. M., Schoeman, M. C. and Appleton, B. 2011. Identification of cryptic species of *Miniopterus* bats (Chiroptera: Miniopteridae) from Madagascar and the Comoros using bioacoustics overlaid on molecular genetic and morphological characters. *Biological Journal of the Linnean Society* 104: 284-302.

Rookmaaker, L. C. and Bergmans, W. 1981.Taxonomy and geography of *Rousettus amplexicaudatus* (Geoffroy, 1810) with comparative notes on sympatric congeners (Mammalia, Megachiroptera). *Beaufortia* 31: 1–29.

Schlitter, D. A., Williams, S. L. and Hill, J. E. 1983. Taxonomic review of Temminck's trident bat, *Aselliscus tricuspidatus* (Temminck, 1834) (Mammalia: Hipposideridae). *Annals of Carnegie Museum* 52: 337–358.

Schmidt, L. 1996. Tales told by Shells. Changing Patterns of Molluscan Exploitation: A Shell Midden Analysis, Pamwak Rockshelter, Manus Island, Papua New Guinea. BA Hons thesis, Australian National University, Canberra, Australia.

Schwarz, E. 1910. Eine anscheinend neuer Fleckenkuskus von den Admiralitäts-Inseln. *In* Gesellscaft Natuforschender Freunde Zu Berlin. Sitzungberichte. Pp 406–408.

Simmons, N. B. 2005. Order Chiroptera. *In* D. E. Wilson and D. M. Reeder (eds.). Mammal species of the world: a taxonomic and geographic reference. 3rd edition. Johns Hopkins University Press, Baltimore, USA. Pp. 312–529.

Singadan, R. K. 1996. Notes on hybrid spotted cuscus, *Spilocuscus maculatus* x *Spilocuscus kraemeri* (Marsupialia: Phalangeridae). *Science in New Guinea* 22: 77–82.

Smith, J. D. and Hill, J. E. 1981. A new species and subspecies of bat of the *Hipposideros bicolor*-group from Papua New Guinea, and the systematic status of *Hipposideros calcaratus* and *Hipposideros cupidus* (Mammalia: Chiroptera: Hipposideridae). *Contributions in Science* 331: 1–19.

Smith, J. D. and Hood, C. S. 1981. Preliminary notes on bats from the Bismarck Archipelago (Mammalia, Chiroptera). *Science in New Guinea* 8: 81–121.

Smith, J. D. and Hood, C. S. 1983. A new species of Tube-nosed Fruit Bat(*Nyctimene*)from the Bismarck Archipelago, Papua New Guinea. *Occasional Papers of the Museum of Texas Tech University* 81: 1–13.

Steadman, D. W. and Kirch, P. V. 1998. Biogeography and prehistoric exploitation of birds in the Mussau islands, Bismarck Archipelago, Papua New Guinea. *Emu* 98: 13–22.

Taylor, J. M., Calaby, J. H. and Van Deusen, H. M. 1982. A revision of the genus *Rattus* (Rodentia, Muridae) in the New Guinean region. *Bulletin of the American Museum of Natural* History 173: 177–336.

Thomas, O. 1894. Diagnosis of a new *Pteropus* from the Admiralty Islands. *Annals and Magazine of Natural History Series* 6 (13): 293.

Thomas, O. 1914. On mammals from Manus Island, Admiralty Group and Ruk Island, Bismarck Archipelago. *Annals and Magazine of Natural History Series* 8 (13): 434–439.

Troughton, E. le G. 1929. A new genus and species of bat (Kerivoulinae) from the Solomons, with a review of the genera of the sub-family. *Records of the Australian Museum* 17: 85–99.

Van Deusen, H.1969. Results of the 1958-1959 Gailliard New Britain Expedition 5. A New Species of *Pteropus* (Mammalia, Pteropodidae) from New Britain, Bismarck Archipelago. *American Museum Novitates.* 2371: 1–16.

Westerman M., Kear B. P., Aplin K. P. Meredith R. W., Emerling, C. and Springer M. S. 2012. Phylogenetic relationships of living and recently extinct bandicoots based on nuclear and mitochondrial DNA sequences. *Molecular Phylogenetics and Evolution* 62: 97–108.

White, J. P., Clark, G., and Bedford, S. 2000. Distribution, present and past, of *Rattus praetor* in the Pacific and its implications. *Pacific Science* 54: 105–117.

Williams, C. E. 1997. Zooarchaeology of Pamwak Site, Manus Island, PNG.Unpublished PhD Thesis, Monash University, Victoria, Australia.

Williams, C. 1999.Faunal composition of Pamwak site, Manus Island, PNG. *In* J.-C. Galipaud and I. Lilleyeds, (eds.) Le Pacifique de 5000 à 2000 avant le présent; suppléments à l'histoire d'une colonisation; actes du colloque Vanuatu, 31 Juillet–6 Août 1996. Institut de Recherche pour le Développement, Paris, France. Pp. 241–249.

Wolff, T. 1968. The *Noona Dan* Expedition (Rennell Section, 1962) and the Danish Rennell Expedition, 1965. *Natural History of the Rennell Island, British Solomon Islands* 5: 9–37.

Wyatt, K. B., Campos, P. F., Gilbert, M. T. P., Kolokotronis, S. O., Hynes, W. H., DeSalle, R., Daszak P., MacPhee R.D.E, and Greenwood, A. D. 2008. Historical mammal extinction on Christmas Island (Indian Ocean) correlates with introduced infectious disease. *PloS one*, *3*(11), e3602.

Chapter 7:

Acoustic survey of the echolocating bats of Manus and Mussau Islands

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Summary

In field surveys for bats, many species can be identified from acoustic recordings of their ultrasonic echolocation calls. Thus, an acoustic survey component included as part of a comprehensive effort can significantly increase the rate of encounter of bat species, and consequently maximises the value of richness that can be obtained. In conjunction with trapping effort, acoustic surveys for bats can be very useful even in areas where the bat assemblage has not been characterised previously. On the October 2014 WCS survey of Manus and Mussau islands in the Bismarck Archipelago north of the Papua New Guinea mainland, acoustic surveys detected a total of 16 echolocating species of bat. This added a maximum of five species to the known list of nine species for Manus Island, though the final tally will be dependent on follow up work given the uncertainty surrounding the taxonomic identity of several captured forms and associated echolocation call types. On Mussau Island, the final tally of echolocating call types was ten, increasing the known echolocating bat faunal richness by eight species, from the previous total of just two species. On Manus Island, three call types need further survey effort to capture specimens and undertake follow up identification work, and another two forms could be completely novel. On Mussau Island, four call types need further survey effort to capture specimens and undertake follow up identification work, and another three forms require follow up examinations, which includes one form that could be completely novel. The survey established that the volant mammal fauna of Manus Island has not been discovered and characterised completely, despite 140 years of collecting. On Mussau Island, the survey discovered that the echolocating bat fauna is at least five times richer than previous collection records and authoritative field guides would suggest.

On this survey, the acoustic component was useful for: 1) identifying members of the known bat assemblage; 2) documenting range extensions of described species not listed previously on the islands; 3) discovering potentially novel species, or subspecies/island forms/phonic types. The associated capture effort provided vouchers to support the acoustic identifications, the opportunity to collect vouchered reference calls; and provides for follow up identification and taxonomic work. Both islands, and their larger neighbours in the Bismarcks where virtually nothing is known about echolocation call types, are deserving of greater attention for field surveys and routine taxonomic and identification work as a foundation for their future conservation and management.

Introduction

Bats make up around 40% of the mammal fauna of the island of New Guinea (Flannery 1995a, Bonaccorso 1998, Helgen 2007) and a much higher proportion (up to 100%) for the various groups of smaller islands that comprise the remainder of the biogeographic realm of Melanesia (Flannery 1995b, Bonaccorso 1998). Seven families of bats are represented within the Melanesian bat fauna. The Pteropodidae includes a suite of fruit- and nectar-feeding bats, which range in size from relatively small (~ 10 g) to massive (>1.5 kg). While several species of pteropodid are known to echolocate in darkness with simple clicks produced from the tongue or wings (Roberts 1975; Boonman et al. 2014), they navigate principally by visual cues. This characteristic makes them relatively easy to capture, especially the smaller species, and capture effort is essential for surveying this group. In contrast, each of the remaining six families comprises smaller-bodied bats that navigate and forage using echolocation—the active emission of sounds from the nose or mouth and the interpretation of patterns of echoes that return from surrounding objects (Schnitzler and Kalko 2001). Many echolocating bats are adept at evading capture in mist nets (Kingston 2009), but some can be located relatively easily during the day when roosting in caves and fissures. Other species that spend the daytime hours in tree hollows, under loose bark or leaves, or within epiphytes are typically much harder to locate. A large range of specialised methods have been devised to increase the efficiency of the capture of echolocating bats in a variety of situations (Kunz et al. 2009), but an alternative approach: the identification of species from acoustic recordings of their echolocation signals brings numerous advantages in terms of maximising species detection and reducing the overall sampling bias of an inventory survey (Parsons and Szewczak 2009).

Contemporary bat surveys do not rely solely on capture methods: a comprehensive approach includes capture, direct observation, the examination of owl pellet remains, and particularly the acoustic recording of ultrasonic echolocation calls with 'bat detector' recording devices. This combination represents a synergy that produces an enhanced level of understanding of bat species presence and community structure, particularly in localities that have received little attention

from biologists. The concept of an acoustic survey for bats is founded on two key empirical observations: 1) that echolocation calls emitted by different species differ in their duration, frequency profile and harmonic structure, with different species of bats generally possessing diagnostic or 'signature' call types (Fenton and Bell 1981; Gannon et al. 2004); and 2) that members of a single species will show limited variation in echolocation call parameters amongst populations, in comparison to the inter-specific differences (e.g. Armstrong and Coles 2007; Reinhold et al. 2001). Acoustic recordings are generally incorporated into surveys to maximise the detection rate of bat taxa, and help achieve a complete inventory with minimal effort, without relying on the need to capture species that can be at low density or are adept at avoiding nets and traps. The use of bat detectors can also be an efficient way to discover hitherto unknown taxa and extend the known distribution of others. However, surveys in poorly characterised areas still benefit from capture effort, and surveys cannot rely exclusively on acoustic methods of survey. Not all calls have an equal likelihood of detection, since some have frequency or amplitude characteristics that reduce their detection range (Duffy et al. 2000). Captured bats also provide the opportunity to collect reference echolocation calls that can be associated with confidently identified individuals, voucher specimens or DNA barcodes, and these recordings allow understanding of the call types of both described and putatively novel species, as well as geographic differences in call frequency amongst regions or islands within species.

Acoustic recording of ultrasonic echolocation calls with bat detectors was pioneered in Papua New Guinea by G. Richards as part of the baseline surveys for the Papua New Guinea Liquid Natural Gas Project in the Kikori River catchment (Richards 2005, 2008). During that study, local reference calls were obtained for a few species, and for the remaining majority of call types detected, taxonomic identity was inferred on the basis of resemblance to related species in Australia and elsewhere. More recently, acoustic surveys were included in baseline surveys for resource development projects in West Sepik, Morobe, Gulf and Western Provinces (K.P. Aplin and K.N. Armstrong various unpublished reports) and for conservation projects in the Kikori River catchment in Southern Highlands and Gulf Provinces (Leary and Pennay 2011), on the Huon Peninsula in Morobe Province (Robson et al. 2012), in the Muller Range in Western and Enga Provinces (Armstrong and Aplin 2011), in the Hindenburg Range in Western Province (Armstrong et al. 2015), and in the Baiyer River region in Western Highlands Province (Armstrong and Aplin 2014a). Each of these regional studies also included efforts to capture and record echolocating bats, with the result that a comprehensive set of reference calls is now available for most of mainland Papua New Guinea. At present, only a portion of this reference call data is publically available (Leary and Pennay 2011, Armstrong and Aplin 2011, Robson 2012; Armstrong et al. 2015), with other data still confined to confidential industry reports that will be released upon completion of individual project assessments. However, despite the growing availability of information about the echolocation characteristics of the bats of Papua New Guinea, the acquisition of a complete inventory of bats in any one locality is still hindered by a lack of taxonomic resolution in some groups, and the discovery of putatively novel cryptic species is a frequent reality (K.P. Aplin and K.N. Armstrong unpublished confidential reports). The situation for bats inhabiting PNG's offshore islands is less advanced, since virtually no information on echolocation has been published (Grinnell and Hagiwara 1972), and numerous taxonomic issues remain.

The 2014 WCS survey of Manus Island and Mussau Island incorporated acoustic bat detection methods for several reasons. For Manus Island, the primary reason was to assess the degree of completeness of the existing species list based on captures over the last 140 years (see Aplin et al. Chapter 6 for summary of prior mammal survey of both islands). Additional reasons for Manus Island included: 1) the assessment of current distribution and abundance of the Manus Island Woolly Bat, *Kerivoula myrella*, a species that is listed as *Data Deficient* in the IUCN Red List, and which has not been recorded on Manus Island since the time of its original capture in 1914; and 2) the discovery of call types from bats that might represent previously undocumented taxonomic diversity, such as *Miniopterus*, *Pipistrellus* and *Hipposideros*. For Mussau Island, where much less prior mammal survey has been conducted (see Aplin et al. Chapter 6), the acoustic survey work was exploratory in nature, with the primary emphasis on documentation of species richness. At a higher level, the acoustic sampling of the two island bat faunas represented an opportunity to assess the degree of differentiation of bat call types, and therefore potential taxonomic differences, between isolated populations of conspecifics on these islands, and on the main island of New Guinea. Lastly, the acoustic surveys were undertaken to provide a foundation for future monitoring of the island bat faunas in the face of ongoing degradation of natural habitats. This chapter reports the results and interpretations of the acoustic component of the mammal survey only.

Methods

Field activities

Acoustic surveys of echolocating bats are carried out as a two-stage process. The first stage is conducted in the field, and involves the recording of bat calls within the available terrestrial ecological habitats at a maximised number of recording locations, which incorporate as many as possible different bat 'flight spaces' (*sensu* Schnitzler and Kalko 2001; Schnitzler et al. 2003; Denzinger et al. 2004; Denzinger and Schnitzler 2013) amongst these sites. This may include the interior or entrances of caves, situations where bats are likely to feed (such as around lights, around flowering trees that might attract insects, over water bodies), and likely paths or 'fly-ways' used by bats to move around their environment. Recordings are made with 'bat detectors': specialised electronic equipment that records environmental sounds at a high sampling rate, which allows signals with components over 200 kHz to be acquired. Bat detectors can be used as mobile devices (i.e. carried around) or they can be left unattended in one position to record an entire night of bat activity. The latter practice is called 'passive recording' and one night's recording of anonymous calls is termed a 'session'.

Recordings were made with six Pettersson Elektronik D500x bat detectors connected to an external microphone on a 1 metre cable. These units are suitably robust for deployment in areas that experience high rainfall, and have several desirable characteristics for bat species detection: they record in high quality full spectrum WAV format and thus capture the harmonic structure of calls and a good representation of the pulse shape, which can be critical for the discrimination of some species; and they have a wide zone of microphone reception and good sensitivity at relatively high frequencies, which maximises call detection rate.

Each bat detector was moved to a new location before sunset and set to record unattended over a full night. At the recording sites, microphones were oriented horizontally, and attached to a tree trunk or branch, or positioned on a rock outcrop. The detectors were waterproofed in plastic boxes, and microphones were placed in a curved funnel made from a drink bottle. The funnel reduces the zone of detection but is a necessary compromise for wet areas. For each recording site a GPS position was noted and associated with the serial number of the recording unit and deployment date. The habitat at each passive recording station was also noted and subsequently coded according to a scheme that describes both the major habitat type and the flight space type (Table 2 and 3). Habitat codes: BF = beach front; PF = primary forest; SF = secondary forest. Suffix codes for flight space: LC = large clearing; LR = large river; SC = small clearing; SR = small river/stream; SU = subcanopy; T = track; U = understorey.

The recording settings for the D500x units were as follows: 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 sunset to sunrise time. In addition to the systematic deployment of D500x detectors, 'mobile' recordings were made in caves and during night traverses through open habitats with a Wildlife Acoustics EchoMeter EM3 bat detector.

A second field-based activity is the recording of reference calls from captured echolocating bats. Calls were recorded from nasal-emitting bats (hipposiderids) while they were stationary (either held in the hand or suspended in a fine entomological net and emitting freely), and from mouth-emitting bats (vespertilionids and miniopterids) when in free flight within a large tent (~6 m x 3 m x 2.5 m), and in some instances, following release of a captured animal. Making reference recordings of mouth-emitting bats in a small space is not ideal (Parsons and Szewczak 2009) but sometimes a necessary compromise that gives at least some information when the individual needs to be kept as a voucher specimen. Calls were recorded in full spectrum WAC0 format with the EM3 bat detector (sample rate 384 kHz), and in WAV format with a D500x detector (sample rate 500 kHz). Recordings were also made with both detector models in caves. Capture and other observational methods are described elsewhere by Aplin et al. (Chapter 6).

The majority of individuals from which reference calls were recorded were kept as voucher specimens, with tissue samples taken for later genetic analysis. Collection of voucher specimens associated with reference calls is important for independent taxonomic identification and to allow identifications to be updated in the context of any future taxonomic revision. Comparison of acoustic signatures of echolocating bats is also an important component of modern taxonomic practice, with the most informative specimens being those for which a voucher specimen is accompanied by acoustic recordings as well as a genetic profile (e.g. Ramasindrazana et al. 2011).

Analysis of anonymously recorded calls

The passive recording sessions were analysed with a multi-step semi-automated acoustic analysis procedure developed to process large full spectrum echolocation recording datasets from insectivorous bats. The WAV files were scanned for bat echolocation calls using several parameter sets in the software SCAN'R version 1.7.7 (Binary Acoustic Technology), and post-processing involved Discriminant Function Analysis and manual checking of each call type for each session using a custom-written R language script (Armstrong and Aplin 2014b). In the present survey, the attribution of signals to known species or previously recognised call types was based on an echolocation call classification scheme (Figure 1) and an extensive reference call collection developed from numerous sites across mainland Papua New Guinea in recent years (Armstrong and Aplin 2011, 2014a; Leary and Pennay 2011; Robson et al. 2012; Armstrong et al. 2015; Aplin and Armstrong, unpublished confidential reports). Taxonomy and nomenclature used here conforms within that used in the IUCN Red List (http://www.redlist.org/), and draws upon information in Bonaccorso (1998), Simmons (2005) and relevant taxonomic papers on individual species as required (Appleton et al. 2004; Tian et al. 2004). For Melanesian *Miniopterus* we regard the current attribution of species names to morphological forms to be futile and misleading, given that there has been no application of modern genetic methods to confirm the number of taxa and their relationships with named forms described from localities outside of Melanesia (e.g. Indonesia, Loyalty Islands). Thus, until such time as the taxonomy of this genus in South East Asia and Australasia is resolved, and there are reliable acoustic, morphological and/or genetic markers for *Miniopterus* in Melanesia, we suggest reference to forms in a survey locality based on the combination of their forearm length and/or characteristic echolocation frequency, as we have done here (see also Armstrong and Aplin 2014a, Aplin et al. Chapter 6).

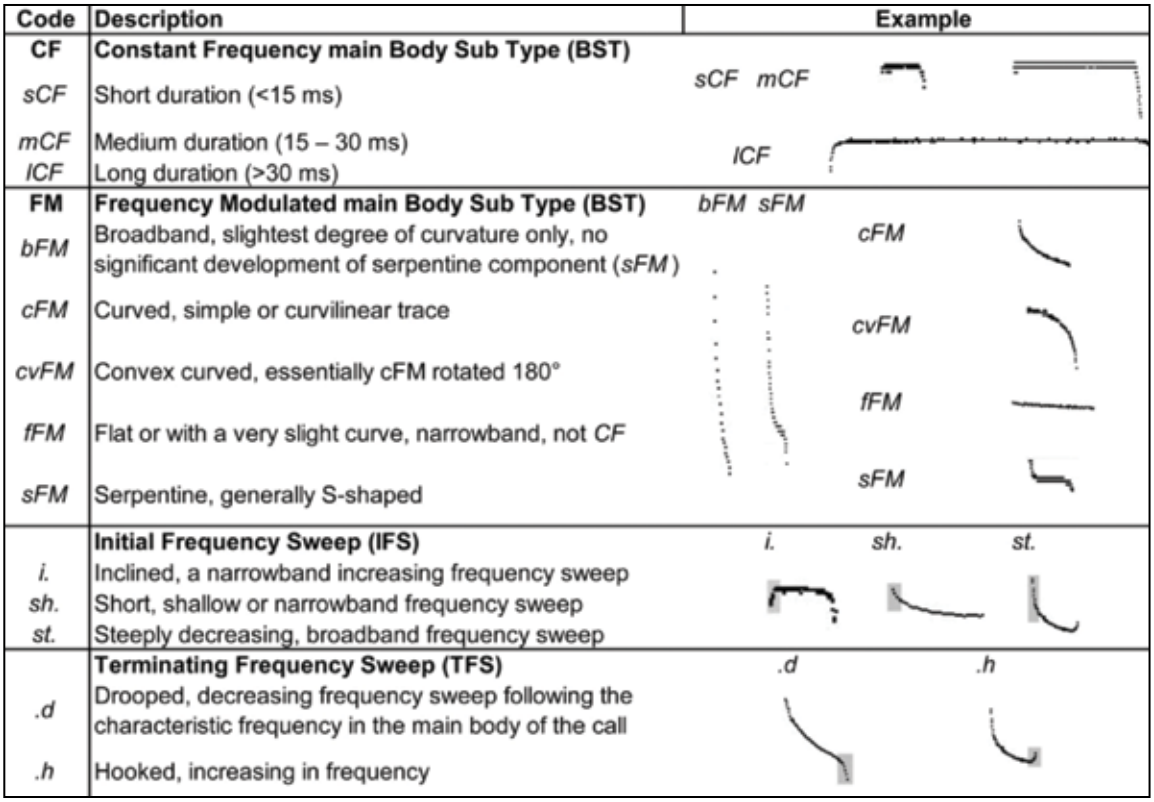

Figure 1. Echolocation call categories based on the morphology of the dominant type of search-phase pulses in high quality sequences (adapted from de Oliveira (1998a,b), Corben and O'Farrell (1999), Gannon et al. (2004), Armstrong and Aplin (2011); Armstrong et al. (2015); examples are from a Zero Crossings Analysis output and are not scaled equally). Pulses generally consist of three main sections: an initial frequency sweep (IFS), followed by the main body (BST: Body Sub Type), and ending in a terminating frequency sweep (TFS). The shape of the pulse is represented by the codes in the form '*IFS.BST.TFS*', prefixed by a value representing the mean characteristic frequency in kHz.

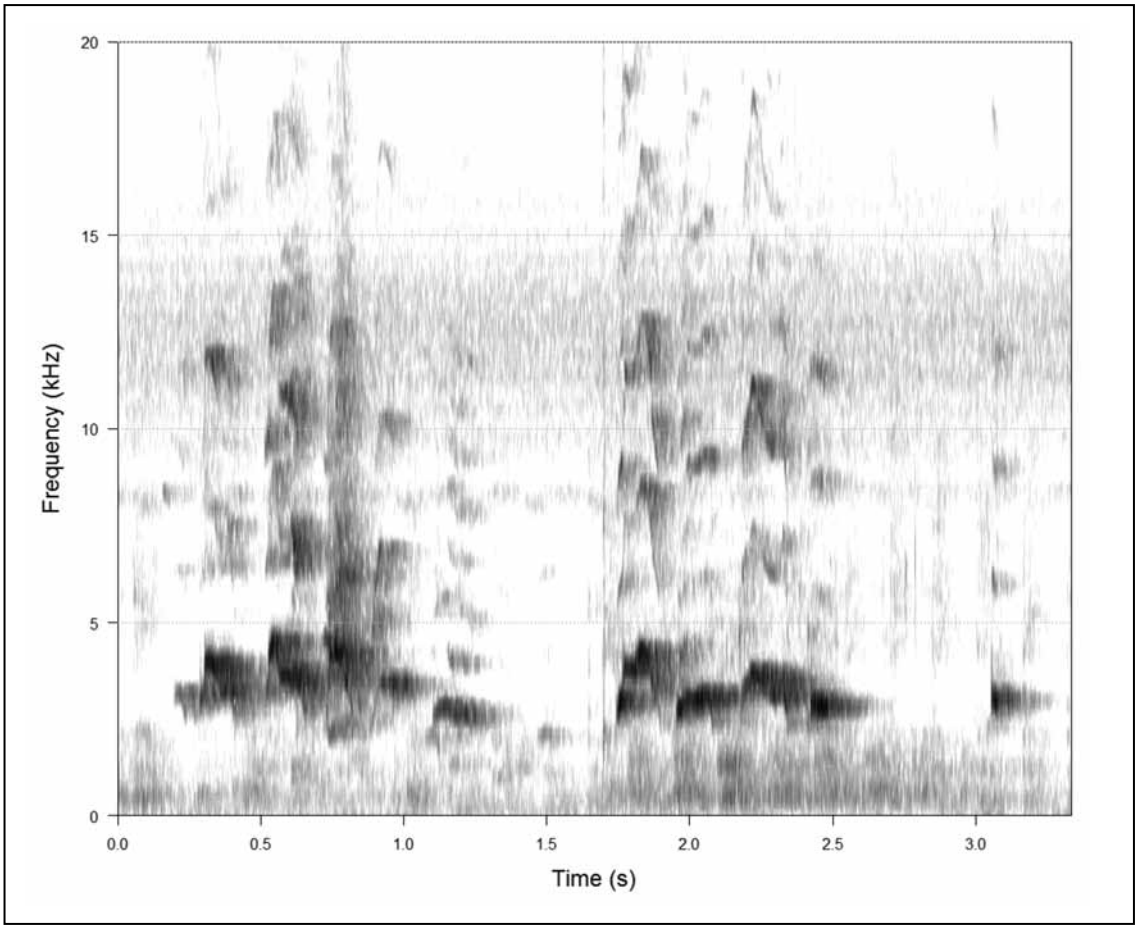

Figure 3. Spectrographic representation of typical social interaction calls of *Dobsonia anderseni* from Mussau Island.

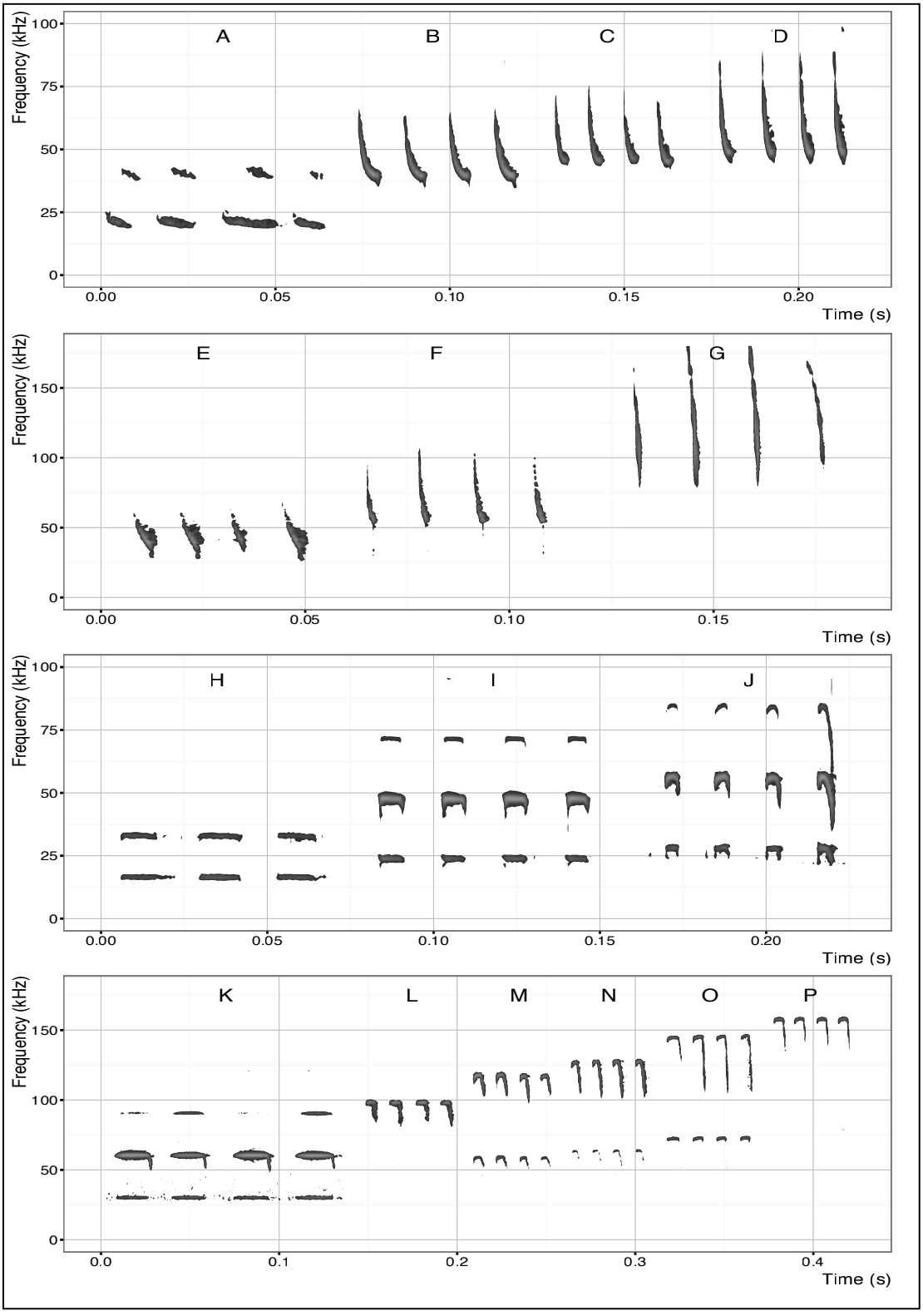

Figure 2. Representative call types encountered on the survey (**A**: *22 cFM Mormopterus* cf. *beccarii*; **B**: *40 st.cFM Miniopterus* sp. 1; **C**: *45 st.cFM Miniopterus* sp. 2; **D**: *48 st.cFM P. angulatus*; **E**: *40 st.bFM Myotis* sp.; **F**: *55 st.bFM ?Nyctophilus* sp.; **G**: *80 st.bFM Kerivolua myrella*; **H**: *35 i.fFM.d Emballonura* cf. *dianae*; **I**: *45 i.fFM.d Emballonura serii*; **J**: *55 i.fFM.d Mosia nigrescens*; **K**: *60 mCF Hipposideros diadema*; **L**: *98 sCF Hipposideros* sp. 2; **M**: *115 sCF* Hipposideridae; **N**: *125 sCF Aselliscus tricuspidatus*; **O**: *145 sCF Hipposideros* cf. *cervinus*; **P**: *158 sCF Hipposideros* sp. 1).

Survey locations

Acoustic recordings were made in three localities on Manus Island, and in one on Mussau Island (Table 1, Plate 1).

Table 1. Survey locations visited during the 2014 WCS Manus-Mussau Expedition.

Locality	Latitude	Longitude	Elevations sampled (m a.s.l.)	Dates	Sessions
Mt Sabomu, Manus Island	S 2.193°	E 146.967°	310 – 589	2 – 6 October 2014	6
Piri Village, Manus Island	S 2.211°	E 146.965°	0 – 25	6 - October 2014	1
Yeri River, Manus Island	S 2.001°	E 146.819°	23 – 84	9 – 13 October 2014	23
Nae, Mussau Island	S 1.504°	E 149.731°	0 – 104	16 – 26 October 2014	29

The first field camp on Manus Island was established near the summit of Mt Sabomu, the island's second highest peak at 589 m a.s.l. Access to the site was via the village of Piri, on the south coast of the island. Mt Sabomu supports a largely intact forest cover, although one large patch of kunai grassland with *Pandanus* overstorey is present on the southern slope at ~ 310 m a.s.l. Survey effort concentrated on the upper slopes above the kunai grassland patch. One bat detector was set at Piri Village on the night of 6 October 2014.

The second field camp on Manus Island was in the northern lowlands on Yeri River, with survey effort at elevations ranging between 23 m and 84 m a.s.l. The area supports relatively undisturbed lowland rainforest, interspersed with sago plantations and gardens, the latter mainly positioned close to the major waterways.

The acoustic recordings on Mussau Island were made ~ 3–5 km south of Nae Village, near the southeast corner of the island. In this area the island is fringed by a coastal plain made up of coarsely comminuted shell and coral. At variable distances from the coast the coastal plain gives way to a series of raised coralline limestone terraces that rises steadily inland. At the front of each terrace is a scarp that contains numerous small fissures and caverns, and occasional larger caves that probably originated as sea caves. Passive recordings were made at elevations between sea level and 104 m a.s.l., and in patches of coastal forest and scrub, in and around cave systems, and in extensive tracts of open forest interspersed with dense vine thickets on the limestone benches and slopes.

Results

Recordings from a total of 58 sessions were available for later analysis: 29 recording sets from each of the two islands, and from a variety of habitats (Tables 2 and 3).

A total of 16 echolocation call types were detected from the combined acoustic recordings made on both islands, with each of these types representing a single distinct species (Figure 2). A total of 10 echolocation call types was detected on Manus Island (Table 2), with six of these represented only on this island, and a maximum total of 13–14 echolocating species (pending taxonomic enquiries). The number of echolocation call types detected per detector night on Manus Island averaged 3.4 (ranging between 1 and 6 types per detector per night).

A total of 10 echolocation call types was also detected on Mussau Island (Table 3), with six of these represented only on this island, and a maximum total of 10 echolocating species (pending taxonomic enquiries) apparently present. The number of echolocation call types detected per detector night on Mussau Island averaged 4 (ranging between 2 and 6 types per detector per night). Only four of the 16 call types are shared between the two islands. Species attributions are the best that can be made currently, requiring DNA barcoding, or more comprehensive genetic comparisons in some cases, to confirm the identifications.

On Mussau Island, hand-held bat detector recordings were made of *Dobsonia anderseni* at Cave 4 on 16/10 and Cave 2 on 18/10. *Rousettus amplexicaudatus* were also recorded at Cave 6 on 21/10, which contained at least three insectivorous bat species (call types *98 sCF*, *125 sCF Aselliscus tricuspidatus* and *40 st.cFM Miniopterus* sp. 1). The physical attributes of the caves are described in Aplin et al. (Chapter 6). Examples of the human-audible calls of *D. anderseni* are presented for future reference (Figure 3; good examples of *R. amplexicaudatus* are unavailable).

Table 2. Species and echolocation call types detected acoustically on Manus Island in October 2014. Habitat codes: BF = beach front; PF = primary forest; SF = secondary forest. Suffix codes for flight space: LC = large clearing; LR = large river; SC = small clearing; SR = small river/stream; SU = subcanopy; T = track; U = understorey.

		Mormopterus cf. *beccarii*	*Miniopterus* sp. 1	*Miniopterus* sp. 2	*Pipistrellus angulatus*	*Myotis* sp.	?*Nyctophilus* sp.	*Kerivoula myrella*	*Emballonura* cf. *dianae*	*Emballonura serii*	*Mosia nigrescens*	*Hipposideros diadema*	*Hipposideros* sp. 2	*Hipposideridae*	*Aselliscus tricuspidatus*	*Hipposideros.* cf. *cervinus*	*Hipposideros* sp. 1	Species Recorded	Habitat code
D500x serial	**Rec night**	***20 cFM***	***40 st.cFM***	***45 st.cFM***	***48 st.cFM***	***40 st.bFM***	***55 st.bFM***	***80 st.bFM***	***35 i.fFM.d***	***45 i.fFM.d***	***55 i.fFM.d***	***60 mCF***	***98 sCF***	***115 sCF***	***125 sCF***	***145 sCF***	***158 sCF***		
162	3/10				*													**1**	SF-T
628	3/10		*		*					*	*							**4**	PF-LC
631	3/10		*		*					*								**3**	SF-LC
162	5/10				*					*	*						*	**4**	PF-U
628	5/10				*					*	*						*	**4**	PF-SC
627	6/10				*													**1**	SF-LC
161	9/10				*						*							**2**	SF-LR
162	9/10				*						*							**2**	PF-LC
627	9/10		*		*			*		*	*						*	**6**	SF-T
628	9/10				*	*	*				*	*		*				**6**	PF-T
630	9/10				*						*							**2**	SF-LC
631	9/10				*	*	*							*				**4**	PF-T
161	10/10				*					*	*	*						**4**	PF-SC
162	10/10				*						*	*						**3**	SF-LC
627	10/10				*	*					*	*						**4**	PF-SR
630	10/10				*	*					*							**3**	PF-SR
631	10/10				*						*	*					*	**4**	PF-T
161	11/10				*						*	*		*				**4**	PF-T
162	11/10		*		*						*	*						**4**	PF-SR
627	11/10				*						*	*					*	**4**	PF-SC
628	11/10				*							*							**2**	PF-SC
630	11/10				*		*				*	*						**4**	PF-SR
631	11/10		*		*					*	*	*						**5**	PF-SC
161	12/10				*			*				*						**3**	PF-T
162	12/10				*					*								**2**	SF-LC
627	12/10				*					*		*					*	**4**	PF-SC
628	12/10				*					*	*	*		*				**5**	PF-T
630	12/10				*						*						*	**3**	PF-SC
631	12/10				*					*	*							**3**	SF-LC

Table 3. Species and echolocation call types detected acoustically on Mussau Island in October 2014. Habitat codes: BF = beach front; PF = primary forest; SF = secondary forest. Suffix codes for flight space: LC = large clearing; LR = large river; SC = small clearing; SR = small river/stream; SU = subcanopy; T = track; U = understorey.

		Mormopterus cf. *beccarii*	*Miniopterus* sp. 1	*Miniopterus* sp. 2	*Pipistrellus angulatus*	*Myotis* sp.	?*Nyctophilus* sp.	*Kerivoula myrella*	*Emballonura* cf. *dianae*	*Emballonura serii*	*Mosia nigrescens*	*Hipposideros diadema*	*Hipposideros* sp. 2	Hipposideridae	*Asellisicus tricuspidatus*	*Hipposideros.* cf. *cervinus*	*Hipposideros* sp. 1	Species Recorded	Habitat code
D500x serial	**Rec night**	*20 cFM*	*40 st.cFM*	*45 st.cFM*	*48 st.cFM*	*40 st.bFM*	*55 st.bFM*	*80 st.bFM*	*35 i.fFM.d*	*45 i.fFM.d*	*55 i.fFM.d*	*60 mCF*	*98 sCF*	*115 sCF*	*125 sCF*	*145 sCF*	*158 sCF*		
161	16/10		*												*			**2**	PF-U
162	16/10		*	*						*			*		*	*		**6**	Entrance Cave 2
627	16/10		*													*		**2**	PF-U
628	16/10		*												*	*		**3**	Interior Cave 4
630	16/10		*												*			**2**	PF-U
631	16/10		*										*		*	*		**4**	Interior Cave 3
161	17/10		*	*									*		*	*		**5**	SF-T
162	17/10		*	*									*		*	*		**5**	SF-T
627	17/10		*	*							*		*		*	*		**6**	SF-T
628	17/10		*	*											*	*		**4**	PF-SU
630	17/10														*	*		**2**	SF-T
631	17/10		*	*							*		*		*	*		**6**	SF-T
161	18/10		*	*									*		*	*		**5**	SF-U
162	18/10		*												*	*		**3**	SF-U
627	18/10		*	*											*	*		**4**	PF-T
628	18/10		*	*											*	*		**4**	PF-U
161	19/10		*	*											*			**3**	BF
162	19/10	*	*	*					*						*			**5**	PL-U
627	19/10		*	*											*	*		**4**	PL-U
628	19/10		*	*											*	*		**4**	PL-U
630	19/10		*	*											*			3	PL-U
631	19/10		*	*		*			*						*			5	BF
161	20/10		*	*		*					*				*			5	SF-LC
162	20/10		*	*											*	*		4	PF-SU
627	20/10		*	*											*	*		4	PF-U
628	20/10		*	*							*				*			4	SF-SC
630	20/10		*	*											*			3	PF-SU
631	20/10		*	*		*							*		*	*		6	PF-C
630	21/10			*											*	*		3	PF-SU

Reference calls

Reference calls were recorded from 42 individuals representing seven species (Table 4; capture methods for each species are detailed in Aplin et al. Chapter 6). Other call types were assigned to species on the basis of information from mainland Papua New Guinea.

On the present survey, the confidence in the attribution of taxonomic names to call types varied, and three categories can be defined:

1. Unambiguous attribution to species is based on the availability of a local reference call: species name is given.

2. Identification is ambiguous, but there exists a candidate species based on both the availability of a similar reference call from a different geographic area, *and* a range extension that encompasses the survey area is biogeographically plausible—species name is prefixed with 'cf.'.

3. An unambiguous attribution cannot be made, even at the level of genus, but the call type is attributed to the most likely source—genus name is prefixed with '?'.

Table 4. Echolocating bat reference calls recorded during the survey.

Bat species	Call type	Manus Island	Mussau Island
Aselliscus tricuspidatus koopmani	*125 sCF*	-	2
Hipposideros cf. *cervinus*	*145 sCF*	-	22
Hipposideros sp. 2	*98 sCF*	-	12
Kerivoula myrella	*80 st.bFM*	1	-
Miniopterus sp. 1	*40 st.cFM*	-	1
Mosia nigrescens	*55 i.fFM.d*	3	-
Pipistrellus angulatus	*48 st.cFM*	1	-

Attribution of *cFM* call types

Call type *20 cFM*: *Mormopterus* cf. *beccarii* (Molossidae) Beccari's Free-tailed Bat
Two poor quality sequences recorded on Mussau Island are attributed with reasonable confidence to *Mormopterus* cf. *beccarii* (Table 3), based on comparison with reference calls available from the Northern Territory of Australia (Milne 2002). The call type is typical of a molossid bat, having the fundamental frequency around 20 kHz, with the second harmonic at around 40 kHz. *Mormopterus beccarii* is recorded from a single capture on New Britain, and it is not surprising that this species should be overlooked on previous surveys since they often require targeted effort such as the use of canopy nets for detection.

Call type *40 st.cFM*: *Miniopterus* sp. 1 (Miniopteridae) a large unidentified Bent-winged Bat
This call type was emitted by captured individuals of a large species of *Miniopterus* on Mussau Island (consistent with *M. propitristis insularis*; Bonaccorso 1998) and the same call type was recorded on numerous passive sessions (Table 3). The same call type was also recorded on some of the Manus Island sessions, and could derive from the same, or a different, species (Table 2). No capture of bats emitting this call type was made on Manus Island, so comparison at the morphological level is dependent on the effort of future surveys. On mainland Papua New Guinea, up to three *Miniopterus* are generally present in any one region, with the largest of them emitting calls with the lowest characteristic frequency.

Call type *45 st.cFM*: an unidentified Bent-winged Bat *Miniopterus* sp. 2 (Miniopteridae)
This call type is most likely emitted by a second species of *Miniopterus*, based on pulse shape and characteristic frequency. It is possible (though less likely, taking into account details of pulse shape) that it is attributable to a species of *Pipistrellus*. One possible candidate is *P. papuanus* that has been recorded on New Britain and New Ireland (Bonaccorso 1998; Aplin and Opiang 2011), but calls of this species have not been characterised.
Calls of this type were recorded only on Mussau Island (Table 3). Aplin et al. (Chapter 6) reported a specimen held in the Australian Museum that is substantially smaller than the Mussau Island population sampled during this study. This call type is most likely attributable to this smaller species of *Miniopterus*. Bonaccorso (1998) lists three species of *Miniopterus* for Manus Island, so it is surprising that the *45 st.cFM* call type was not recorded there.

Call type *48 st.cFM*: *Pipistrellus angulatus* (Vespertilionidae) New Guinea Pipistrelle
This call type was emitted by individuals captured on Mt Sabomu on Manus Island and it was encountered on every passive session recorded on that island (Table 2). In contrast, this call type was not encountered on Mussau Island, despite the fact that *P. angulatus* has been collected on Emirau Island in the St Matthias Group (Hill 1983, Bonaccorso 1998). While it is possible that

P. angulatus is present on Emirau Island, yet not on Mussau Island, it is also possible that the Emirau Island record, which dates from 1944, may be in error since other islands including some the Admiralty Group were sampled around the same time. More survey effort and follow up identification work is required to correctly attribute the various *cFM* call types on both Manus and Mussau Islands.

Attribution of *bFM* call types

Call type *40 st.bFM*: *Myotis* sp. (Vespertilionidae) an unidentified Myotis
This call type is attributable to a species of the genus *Myotis* based on the similarity of pulse shape and characteristic frequency to reference calls of *Myotis* spp. obtained from elsewhere in Papua New Guinea, and to examples of *Myotis macropus* from Australia (K.N. Armstrong unpublished data). The call type was detected on passive sessions on each of Manus and Mussau Islands (Tables 2 and 3) but no specimen of a *Myotis* was captured during the WCS survey or on any prior occasion.

The species name *M. moluccarum* is currently applied to all *Myotis* populations within New Guinea and the Bismarck Archipelago (Kitchener et al. 1995, Simmons 2005, Reardon and Bonaccorso 2008). However, genetic studies (Cooper et al. 2001) suggested the likely presence of a second species of *Myotis* within this geographic range. Given that isolation of island populations leads frequently to species-level differences, a third taxon endemic to Manus and Mussau Islands is also a possibility. Species identity needs to be confirmed by capture and genetic barcoding in the first instance, with the haplotypes of Cooper et al. (2001) used as genetic context.

Call type *55 st.bFM*: *?Nyctophilus* sp. (Vespertilionidae) a possible Long-eared Bat
Calls of a *bFM* type with a characteristic frequency around 55 kHz were recorded on Manus Island on three separate occasions (Table 2). In other parts of Papua New Guinea, similar calls have been emitted by captured individuals of *Nyctophilus microtis* or a closely related species (K.P. Aplin and K.N. Armstrong unpublished data). All species of *Nyctophilus* emit very low amplitude calls, hence they are only encountered on acoustic recordings if they fly very close to the microphone.

Nyctophilus has not been recorded on Manus Island previously, but members of this genus are encountered uncommonly in rainforest habitats in Melanesia, and they might easily have been overlooked by prior survey effort. *Nyctophilus microtis* has been recorded from New Ireland (Bonaccorso 1998). Robson et al. (2012) recorded a lower characteristic frequency of around 40 kHz for this species on the Huon Peninsula.

The attribution needs confirmation from a capture, especially since the *55 st.bFM* calls could actually represent higher frequency clutter calls of the species producing the call type *48 st.cFM*, which was relatively common.

Call type *80 st.bFM*: *Kerivoula myrella* (Vespertilionidae) Manus Island Woolly Bat
Capture of an individual of this species at the Yeri River site is the first record from Manus Island since it was first described, though it is known from a number of other localities in the Bismarck Archipelago (Bonaccorso 1998). Excellent recordings were made of its echolocation call type of *80 st.bFM*. The call is of low amplitude and detection on an unattended recording session would be dependent on the animal passing close to the microphone.

Calls of this species were identified on two of the anonymous recording sessions made at the Yeri River site on Manus Island (Table 2). No calls of this type were recorded on Mussau Island, but given the scarcity of recordings where it does occur, it would be premature to rule out the possibility of its occurrence there.

Attribution of *i.fFM.d* call

Call type *35 i.fFM.d*: *Emballonura* cf. *dianae* (Emballonuridae) unidentified Sheath-tailed Bat
Several pulses resembling calls of this species (as documented from sites in Gulf Province, K.P. Aplin and K.N. Armstrong, unpublished) were recorded on Mussau Island (Table 3). The calls were of reasonable quality, and contained both the fundamental frequency and the second harmonic. This species is not known from either Manus or Mussau Islands, but it is represented by the subspecies *E. d. rickwoodi* on both New Ireland and New Britain. The call type of the Bismarck Archipelago subspecies has not been documented. Capture of this species on Mussau Island is needed to confirm the record.

Call type *45 i.fFM.d*: *Emballonura serii* (Emballonuridae) Seri's Sheath-tailed Bat
Calls with the typical pulse shape of an emballonurid bat, but of lower frequency than those of *Mosia nigrescens* (see below), were encountered relatively often on sessions recorded on Manus Island (Table 2). They were also recorded on one session on Mussau Island (Table 3). Both sets of calls are most likely attributable to *E. serii*, which was described from New Ireland and is also recorded from Manus Island. However, it is also possible that the calls recorded on Mussau Island were emitted by a population of *E. raffrayana* as they are similar to reference calls of *E. r. raffrayana* from the main island of New Guinea. The subspecies *E. r. cor* is present on New Ireland but its call type has not been documented. Capture of this species on Mussau Island is needed to confirm its identity.

Call type *55 i.fFM.d*: *Mosia nigrescens* subsp. (Emballonuridae) Lesser Sheath-tailed Bat
Captured individuals of *M. nigrescens* on Manus Island emitted the call type *55 i.fFM.d*. The same call type was recorded on many passive sessions on Manus Island and on fewer sessions on Mussau Island. The characteristic frequency of free-ranging bats in flight was between ~50 – 58 kHz, which is around 5 kHz lower than the calls of the subspecies *M. n. papuanus* on the main island of New Guinea (Leary and Pennay 2011, Armstrong and Aplin 2011; K.P. Aplin and K.N. Armstrong unpublished data). The call type of *M. n. solomonis* of the Bismarck Archipelago and Solomon Islands remains unknown. As reported by Aplin et al. (Chapter 6), the Manus Island population differs morphologically from each of these two named forms and they may represent a third taxon.

On mainland New Guinea, the calls of *M. nigrescens* overlap with those of *Emballonura beccarii meeki* (K.P. Aplin and K.N. Armstrong unpublished data), and it is possible that this call type on Mussau Island could be attributable to *E. b. beccarii,* for which a call type is not yet documented. This might account for the difference in relative abundance of the *55 i.fFM.d*. call type between the two islands.

Attribution of *mCF* and *sCF* call types

Call type *60 mCF*: *Hipposideros diadema mirandus* (Hipposideridae) Diadem Leaf-nosed Bat
The Diadem Leaf-nosed Bat was not captured on the survey, but it was identified with confidence on numerous passive sessions from the characteristic frequency and duration of its echolocation calls (Table 2). The subspecies *H. diadema mirandus* was described from Manus Island and has not been recorded from any other locality. The degree of distinction of this island population has not been tested in any modern taxonomic assessment.

While there are numerous subspecies named from across Indonesia and Australasia, they generally all produce calls with a characteristic frequency between 55 and 62 kHz. This call type was not recorded on Mussau Island (Table 3). This is likely to reflect a genuine absence, as the calls of *H. diadema* are typically of relatively high amplitude, and are thus likely to be recorded on a bat detector survey in any area in which they occur.

Call type *98 sCF*: *Hipposideros* sp. 2 (Hipposideridae) an unidentified Leaf-nosed Bat
This species of *Hipposideros* was recorded in large numbers in two caves on Mussau Island (Aplin et al. Chapter 6). It most closely resembles *H. calcaratus* in size and general features but it differs from the two recognised subspecies (*calcaratus* of the Bismarck Archipelago and *cupidus* of New Guinea) in having a relatively larger noseleaf and ears.

Reference calls taken from 13 individuals are consistently and substantially lower (by almost 40 kHz) than calls documented for *H. c. cupidus* on mainland New Guinea (Grinnell and Hagiwara 1972; K.P. Aplin and K.N. Armstrong, unpublished data). Such a difference is usually indicative of species-level distinctness. This possibility will be further explored by morphological and genetic studies.

A prior record of *H.* '*calcaratus*' from Emirau Island in the St Matthias Group needs to be reassessed in the light of the discovery of this putatively distinct species on Mussau Island.

Call type *115 sCF*: Hipposideridae
A call type with slightly lower characteristic frequency than *Aselliscus tricuspidatus koopmani* (see call type *125 sCF* on Mussau Island), but consistent with the mainland form *A. t. novaguinea* (Leary and Pennay 2011; K.P. Aplin and K.N. Armstrong, unpublished data) was encountered on several passive recording sessions on Manus Island. There are no prior records of *A. tricuspidatus* on Manus Island, and we did not capture this species, which is usually amongst the easiest of the hipposiderids to encounter via mist nets and harp traps (K.P. Aplin and K.N. Armstrong, unpublished observations). Thus, we have no basis for attributing this call type to *Aselliscus*, and a more parsimonious explanation is that the call is from an island form of another hipposiderid that has coincidently a similar mean characteristic frequency as mainland PNG *Aselliscus*.

A second possibility is *Hipposideros calcaratus calcaratus*. This species is known from several localities on Manus and Los Negros islands (Bonaccorso 1988: 267–271), and it was captured once by the WCS survey team on Mt Sabomu. Unfortunately the captured animal was moribund and it was not possible to document its call type. The characteristic call frequency of *H. c. cupidus* in southern mainland New Guinea is 133 kHz (Aplin and Armstrong, unpublished), and 123–124 kHz in Madang Province (Grinnell and Hagiwara 1972; though the taxonomic identity of the source individuals has been questioned: see Smith and Hill 1981). It is quite possible that Manus Island *H. c. calcaratus*, which were referred to the nomino-typical form by Smith and Hill (1981), could be the source of the *115 sCF* call type, given that it is typical to have island forms differ in emitted characteristic frequency from their mainland counterparts. The call type of *H. c. calcaratus* has not been recorded, though the present survey established that *H.* cf. *calcaratus* on Mussau Island emitted calls with a characteristic frequency of 98 kHz. If the *115 sCF* call type on Manus Island is not attributable to *H. c. calcaratus*, then this species is not present on the passive recording sessions. Further effort is obviously required to resolve the origin of call type *115 sCF*, as well as the relationships amongst populations attributed to *H. calcaratus*.

Call type *125 sCF*: *Aselliscus tricuspidatus koopmani* (Hipposideridae) Trident Leaf-nosed Bat
This species was captured in harp traps and located in several caves on Mussau Island. They resemble *A. t. koopmani* from the Bismarck Archipelago and Solomon Islands and represent the first records of this taxon from Mussau Island. Captured animals

emitted call type *125 sCF,* which was also was recorded on almost every passive session. The call frequency of this population is around 5–10 kHz higher than that of *A. t. novaguinea* on the main island of New Guinea (Leary and Pennay 2011; K.P. Aplin and K.N. Armstrong, unpublished data). The call frequency of Bismarck Archipelago and Solomon Islands populations of *A. t. koopmani* has not been recorded previously. It is relevant to note that the same call type of *125 sCF* is attributable to *Hipposideros maggietaylorae erroris* on mainland New Guinea (Leary and Pennay 2011; K.P. Aplin and K.N. Armstrong, unpublished data). The nominotypical form of *H. maggietaylorae* occurs on both New Britain and New Ireland, but its call frequency has not been documented, and this subspecies has not been captured previously on Mussau Island.

Call type *145 sCF*: *Hipposideros* cf. *cervinus* (Hipposideridae) Fawn-coloured Leaf-nosed Bat
A leaf-nosed bat similar to the remarkably widespread *Hipposideros cervinus* of mainland and island South East Asia, Australia and Melanesia was encountered in many of the caves investigated on Mussau Island. A sample of 22 captured individuals (Table 4) emitted call type *145 sCF,* and this was also encountered on the majority of passive recordings made on Mussau Island. There is no equivalent call type on any of the passive recordings made on Manus Island.

The call frequency of *H.* cf. *cervinus* on Mussau Island is consistent with nomino-typical populations of *H. cervinus* from Cape York in Australia (Pavey and Burwell 2000; K.N. Armstrong unpublished data), and with some populations referred to this subspecies on the southern side of the central ranges of New Guinea (K.P. Aplin and K.N. Armstrong, unpublished data). However, they are 10 kHz higher than calls of *H. cervinus* recorded by Robson et al. (2012) on the Huon Peninsula of Morobe Province and by K.P. Aplin and K.N. Armstrong (unpublished data) at sites in West Sepik Province. All Melanesian populations are currently referred to a single subspecies, *H. c. cervinus*, but this seems likely to change with further investigation of diversity amongst regional populations.

Call type *155 sCF*: *Hipposideros* sp. 1 (Hipposideridae) an unidentified Leaf-nosed Bat
Calls of this type were recorded at six sites on Manus Island (Table 2). This frequency of encounter suggests that the species may be common in the environment, since calls of such high frequency are usually only detectable within two metres or less of a microphone.

Call type *sCF* with a characteristic frequency of 155 kHz is usually attributed on mainland New Guinea and in Australia to the Dusky Leaf-nosed Bat *Hipposideros ater*. This species is not known from prior captures on Manus Island and it was not captured during the WCS survey. Although it is possible that *H. ater* occurs on Manus Island, a more parsimonious possibility noted by Aplin et al. (Chapter 6) would associate this call type with a small species of *Hipposideros* that is currently represented by a single specimen in the collection of the Smithsonian Institution. This specimen is similar to *H. ater* in size but it has shorter ears and a complex noseleaf with accessory lappets, and thus may be more closely related to the larger-bodied *H. cervinus*. Populations referred to *H. cervinus* in the Melanesian region and Australia are variable in morphology and call frequency (K.P. Aplin and K.N. Armstrong, unpublished data) and the group is clearly in need of taxonomic revision. The Manus Island taxon is probably distinct and will almost certainly warrant specific recognition.

Comparison with prior knowledge of regional bat faunas

Prior knowledge of regional bat faunas was sourced from several resources, including Flannery (1995a, 1995b), Bonaccorso (1998), Simmons (2005), Aplin and Opiang (2011), and the IUCN Red List website. From these combined sources, it appears that nine species of echolocating bat were recorded previously on Manus Island, and only two from Mussau Island, compared with 21 species on New Britain and 19 species on New Ireland (Table 5). The bat fauna of these larger two islands, as well as that of the main island of New Guinea, provide important context for attributing the calls of some call types that do not derive from species already known from Manus and Mussau Islands.

The acoustic survey of Manus Island produced records of almost all species known from the island. The only possible exceptions are *Hipposideros c. calcaratus* (unless the *115 sCF* call type from Manus Island is correctly attributable to this species) and a species of *Miniopterus*, if Bonaccorso (1998) is correct in that prior material is divisible into three species rather than the two recorded by our results. Our acoustic survey also provided records of two or three additional species: one species each of *Myotis* and *Nyctophilus*, and possibly *Aselliscus tricuspidatus* if the *115 sCF* call type is emitted by this species rather than *H. c. calcaratus*. In addition, our results highlighted the prior collection of a distinctive hipposiderid that has been incorrectly reported as *Hipposideros cervinus* but which is considerably smaller and has a substantially higher call frequency. The attribution of call types is supported by the capture and recording of reference calls of three previously recorded species: *Mosia nigrescens, Kerivoula myrella and Pipistrellus angulatus.*

The acoustic survey of Mussau Island produced records of both species known from the island (*Hipposideros* cf. *cervinus* and a species of *Miniopterus*) plus at least eight additional species: *Emballonura* cf. *dianae, Emballonura serii, Mosia nigrescens* (previously known from Emirau Island)*, Hipposideros* sp. 2 (potentially also present on Emirau Island but potentially misallocated to *H. calcaratus*)*, Aselliscus tricuspidatus, Myotis* sp., *Mormopterus* cf. *beccarii* and another species of *Miniopterus.* Four species including two of these additional species were captured. Thus, from 29 recording nights, plus associated capture effort, it is clear that echolocating bat diversity on Mussau Island is five times greater than previously known.

Table 5. Bats of the Admiralty and St Matthias Groups and the major islands of the Bismarck Archipelago (*explanation below).

			Expected / Possible				Observed	
Scientific name	**Common name**	**IUCN**	**Admiralty Group**	**St Matthias Group**	**New Britain**	**New Ireland**	**Manus Island**	**Mussau Island**
Emballonuridae								
Emballonura serii	Seri's Sheath-tailed Bat	LC	X			X	*45 i.fFM.d*	*45 i.fFM.d*
Mosia nigrescens	Lesser Sheath-tailed Bat	LC	*solomonis*	*(solomonis)*	*solomonis*	*solomonis*	*55 i.fFM.d, C6*	***55 i.fFM.d***
Emballonura beccarii	Beccari's Sheath-tailed Bat	LC				nominate		
Emballonura dianae	Large-eared Sheath-tailed Bat	LC			*rickwoodi*	*rickwoodi*		
Emballonura cf. *dianae*	Unidentified Sheath-tailed Bat							***35 i.fFM.d***
Emballonura raffrayana	Raffray's Sheath-tailed Bat	LC				*cor*		
Saccolaimus saccolaimus	Bare-rumped Sheath-tailed bat	LC			*nudiclu-niatis*			
Hipposideridae								
Hipposideros calcaratus	Spurred Leaf-nosed Bat	LC	nominate	(nominate)	nominate	nominate		
Hipposideros cervinus	Fawn-coloured Leaf-nosed Bat	LC	X	X	X	X		
Hipposideros diadema	Diadem Leaf-nosed Bat	LC	*mirandus*		*oceanitus*	*oceanitus*	*60 mCF*	
Aselliscus tricuspidatus	Trident Leaf-nosed Bat	LC			*koopmani*	*koopmani*		***125 sCF, C8***
Hipposideros cf. *calcaratus*	Unidentified Leaf-nosed Bat							***145 sCF, C12***
Hipposideros sp. 1	Unidentified Leaf-nosed Bat						***155 sCF***	
Hipposideros sp. 2	Unidentified Leaf-nosed Bat							***98 sCF, C16***
Hipposideridae	Unidentified Leaf-nosed Bat						***115 sCF, C1***	
Hipposideros ater	Dusky Leaf-nosed Bat	LC			*aruensis*	*aruensis*		
Hipposideros maggietaylorae	Maggie Taylor's Leaf-nosed Bat	LC			nominate	nominate		
Miniopteridae								
Miniopterus macrocneme	Small Melanesian Bent-winged Bat	**DD**	X		X	X		
Miniopterus tristis (=*propitristis*)	Greater Bent-winged Bat	LC	*insularis*	*insularis*	*insularis*	*insularis*		
Miniopterus sp. 1	Unidentified Bent-winged Bat						***40 st.cFM***	***40 st.cFM, C8***
Miniopterus sp. 2	Unidentified Bent-winged Bat							***45 st.cFM***
Miniopterus australis	Little Bent-winged Bat	LC			X	X		
Miniopterus medius	Medium Bent-winged Bat	LC			X	X		

			Expected / Possible				Observed	
Scientific name	**Common name**	**IUCN**	**Admiralty Group**	**St Matthias Group**	**New Britain**	**New Ireland**	**Manus Island**	**Mussau Island**
Miniopteridae (cont)								
Miniopterus oceanensis	Australasian Bent-winged Bat	LC				X		
Vespertilionidae								
Kerivoula myrella	Manus Island Woolly Bat	DD	X		X		*80 st.bFM, C1*	
Pipistrellus angulatus	New Guinea Pipistrelle	LC	nominate	(nominate)	nominate	nominate	*48 st.cFM, C3*	
Murina florium	Flute-nosed Bat	LC			X			
Myotis moluccarum	Maluku Myotis	LC			X	X		
Myotis sp.	Unidentified Myotis						***40 st.bFM***	***40 st.bFM***
Nyctophilus microtis	Papuan Long-eared Bat	LC				X		
?Nyctophilus sp.	Unidentified vespertilionid						***55 st.bFM***	
Philetor brachypterus	Short-winged Pipistrelle	LC			X	X		
Phoniscus papuensis	Golden-tipped Bat	LC			X			
Pipistrellus papuanus	Papuan Pipistrelle	LC			X	X		
Molossidae								
Chaerephon jobensis	Northern Free-tailed Bat	LC			*colonicus*			
Mormopterus beccarii	Beccari's Free-tailed Bat	LC			X			
Mormopterus cf. *beccarii*								***20cFM***
Total			**9**	**2**	**21**	**19**	**10**	**10**

* No shading: recorded previously from New Britain and/or New Ireland only; light shading: recorded previously from Manus Island and/or Mussau Island; darkest shading: records with captures; X: recorded as present and no subspecific taxa, otherwise the subspecies is indicated (parentheses used when only recorded from Emirau Island in the St Matthias group); C: indicates a capture, with the number of individuals; call types are attributed to species (except for *Miniopterus* where this is not currently possible); **bold**: indicates a record new for the island.

Discussion

State of inventory of the island bat faunas

The use of acoustic methods and the associated capture effort increased the known echolocating bat diversity by up to five species on Manus Island. In addition, the new acoustic data coupled with reassessment of prior collections highlighted the presence of at least two other morphologically discrete taxa, namely the small leaf-nosed bat *Hipposideros* sp. 1 and the island form of *Mosia nigrescens*. The entirely new records from Manus Island represent: an unknown hipposiderid, a species of *Myotis*, and possibly a species of *Nyctophilus*. These are significant additions to knowledge for an island that was thought to have a relatively well-documented echolocating bat fauna. Further recording effort might also lead to recordings of additional call types on Manus Island. The most likely additions would be one or more species of molossid bats, as this family is currently unrepresented on Manus Island, despite records from the Bismarck Archipelago and Mussau Island (new from this study).

For Mussau Island the echolocating bat fauna has grown from two confirmed species to a total of ten. This fivefold increase in knowledge is a remarkable result in itself. However, what is even more notable is the fact that only four of the ten species

have yet been captured. At least one of these is a new addition to the island fauna: a member of the genus *Hipposideros* that is almost certainly a species new to science. Six species are known solely from their echolocation calls and in each case, the possibility remains open that upon capture they too also prove to be endemic at subspecies level or higher. Several of the species are known only from a small number of calls and it is quite likely that, with further recording effort, additional call types will be detected. In particular, it would not be surprising to find evidence on Mussau Island of *Kerivoula myrella*, a species of *Nyctophilus*, and an additional molossid bat.

These results provide abundant demonstration of the major gaps that remain in the basic inventory of the echolocating bat fauna of Melanesia, and also the extent of deficiencies in our understanding of the taxonomy of many genera throughout their extensive geographic ranges within Melanesia and the wider Australasian region.

Abundance, detectability and rarity

The bat call types encountered on the passive recording sessions varied enormously in their relative abundance. A few call types on each island are represented on virtually every session: *Pipistrellus angulatus* and *Mosia nigrescens* on Manus Island, and *Aselliscus tricuspidatus koopmani* and *Hipposideros* cf. *cervinus* on Mussau Island; while others such as those attributed to *Kerivoula myrella*, *Nyctophilus* sp. and *Mormopterus* cf. *beccarii* were each recorded only a couple of times each. To interpret these contrasts in terms of natural abundances within the environment requires knowledge of a range of factors that influence the likelihood of detection, most importantly the frequency and amplitude characteristics of their calls, foraging habitat preference, and the rates of attenuation in different habitat types and under different atmospheric conditions.

Further effort at deriving a complete inventory on the islands would benefit from an increased number of recording sites with greater coverage over the island, but will still be limited by issues of unresolved taxonomy. Thus, targeted capture effort would be necessary for providing material for taxonomic studies. On Manus Island, this would need to involve cave searches for the small *Hipposideros* that produces call type *158 sCF*, and ideally the use of 'acoustic lures' (Hill and Greenaway 2005; Hill et al. 2014, 2015) at harp traps to increase the chance of obtaining any *Nyctophilus* that might be present. On Mussau Island, it would involve the use of acoustic lures on canopy-mounted mist net arrays that target *Mormopterus*. It might be possible to demonstrate higher relative abundance for all of these species if a more targeted approach to their detection is taken.

The use of techniques that could increase the detectability of bats with low amplitude and high frequency calls, such as *Kerivoula myrella*, would also benefit from acoustic lures in association with either harp traps, mist nets arranged in funnels or acoustic recorders. This species might be useful as an indicator of forest quality, since their conspecifics elsewhere in the wider Asian region are generally restricted to foraging within rainforest patches (e.g. Kingston et al. 2003). Other species that might be considered worthwhile for targeted conservation effort or population monitoring, are those that roost in caves and may be vulnerable to intrusion and disturbance. Estimating abundance and relative rates of activity might require both acoustic and video recordings (e.g. Sabol and Hudson 1995; Adams 2013), and efficient methods of data analysis, much like the approach taken to monitoring the Pilbara leaf-nosed bat *Rhinonicteris aurantia* in Western Australia (K.N. Armstrong unpublished reports).

Recommendations

Appreciation of how these scientific studies will inform our perception of the island faunas of Melanesia also helps to cast light on a number of priorities for regional field research. For bats, one of the most pressing needs is the revisiting of the bat fauna of New Ireland which was studied intensively in the 1970s and for which there is no data on echolocation calls, and only a small amount of genetic material available for taxonomic and phylogeographic studies. In the case of New Britain, the recent survey reported by Aplin and Opiang (2011) resulted in tissue collections but there are gaps in coverage and no echolocation calls. Until the bat faunas of these two major islands in the Bismarck Archipelago are more completely documented, attempts to understand the biogeographic history of Manus Island and of the St Matthias Group will fail to progress due to lack of essential context. For both larger islands, the use of acoustic surveys methods might also lead to the discovery of additional diversity within the echolocating bat faunas, and the recognition of new priorities for conservation efforts, as they have done on Manus and Mussau islands.

References

Adams, A.M. 2013. Assessing and analysing bat activity with acoustic monitoring: challenges and interpretations. PhD Thesis. University of Western Ontario, London, Ontario, Canada.

Aplin, K.P. and Opiang, M. 2011. Mammals of the Nakanai Plateau, West New Britain, Papua New Guinea. Conservation International Rapid Assessment Program. *In* S.J. Richards and B.G. Gamui (eds.). Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments. RAP Bulletin of Biological Assessment 60. Conservation International. Arlington, Virginia. Pp 85–103.

Appleton B.R., MacKenzie J.A. and Christidis L. 2004. Molecular systematics and biogeography of the bent-wing bat complex *Miniopterus schreibersii* (Kuhl, 1817) (Chiroptera, Vespertilionidae). *Molecular Phylogenetics and Evolution* 31: 431–439.

Armstrong, K.N. and Coles, R.B. 2007. Echolocation call frequency differences between geographic isolates of *Rhinonicteris aurantia* (Chiroptera: Hipposideridae): implications of nasal chamber size. *Journal of Mammalogy* 88: 94–104.

Armstrong K.N. and Aplin K.P. 2011. Bats of the Muller Range, Papua New Guinea. *In* S.J. Richards and B.G. Gamui (eds.). Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments. RAP Bulletin of Biological Assessment 60. Conservation International. Arlington,Virginia. Pp 222–234.

Armstrong, K.N. and Aplin K.P. 2014a. Chapter 7. A survey of bats (Chiroptera) in the Baiyer River Wildlife Sanctuary, Western Highlands Province, Papua New Guinea. *In* S.J. Richards, (ed.). A rapid biodiversity assessment of the Baiyer River region, Western Highlands Province, Papua New Guinea. A report to the Mul Baiyer Lumusa District Administration. Pp 111–133.

Armstrong, K.N. and Aplin, K.P. 2014b. Identifying bats in an unknown acoustic realm using a semi-automated approach to the analysis of large full spectrum datasets. Oral presentation at the 16th Australasian Bat Society Conference 22–25 April 2014, Townsville, Queensland.

Armstrong, K.N., Aplin K.P. and Lamaris J.S. 2015. Chapter 10. Bats. *In* S.J. Richards and N. Whitmore (eds.) A rapid biodiversity assessment of Papua New Guinea's Hindenburg Wall region. Wildlife Conservation Society Papua New Guinea Program. Goroka, Papua New Guinea. Pp 166–180.

Bonaccorso F.J. 1998. Bats of Papua New Guinea. Conservation International Tropical Field Guide Series. Conservation International, Washington, D.C.

Bonaccorso, F. and Leary, T. 2008. *Pipistrellus angulatus*. The IUCN Red List of Threatened Species. Version 2014.3. <<www.iucnredlist.org>>

Boonman, A., Bumrungsri, S. and Yovel, Y. 2014. Nonecholocating fruit bats produce biosonar clicks with their wings. *Current Biology* 24, 2962–2967.

Cooper, S.J.B., Day, P.R. Reardon, T.B. and Schulz, M. 2001. Assessment of species boundaries in Australian *Myotis* (Chiroptera: Vespertilionidae) using mitochondrial DNA. *Journal of Mammalogy* 82: 328–338.

Corben C. and O'Farrell M.J. 1999. AnaBat system user's guide. AnaBat system manual, 2nd ed.

de Oliveira M.C. 1998a. Towards standardized descriptions of the echolocation calls of microchiropteran bats: pulse design terminology for seventeen species from Queensland. *Australian Zoologist* 30: 405–411.

de Oliveira M.C. 1998b. Anabat system practical guide. Queensland Department of Natural Resources.

Denzinger A., Kalko E.K.V. and Jones G. (2004). Ecological and evolutionary aspects of echolocation in bats. *In* J.A. Thomas, C.F. Moss and M. Vater (eds.). Echolocation in bats and dolphins. University of Chicago Press, Chicago. Pp 311–326.

Denzinger, A. and Schnitzler, H.-U. 2013. Bat guilds, a concept to classify the highly diverse foraging and echolocation behaviors of microchiropteran bats. *Frontiers In Physiology* 4, Article 164: 1–15.

Duffy, A.M., Lumsden, L.F. Caddle, C.R. Chick, R.R. and Newell, G.R. 2000. The efficacy of Anabat ultrasonic detectors and harp traps for surveying microchiropterans in south-eastern Australia. *Acta Chiropterologica* 2: 127–144.

Fenton, M.B. and Bell, G.P. 1981. Recognition of species of insectivorous bats by their echolocation calls. *Journal of Mammalogy* 62: 233–243.

Flannery, T.F. 1995a. Mammals of New Guinea. Revised edition. Chatswood, NSW: Reed Books.

Flannery T.F. 1995b. Mammals of the South-West Pacific and Moluccan Islands. Comstock/Cornell, Ithaca, USA.

Gannon W.L., O'Farrell M.J., Corben C. and Bedrick E.J. 2004. Call character lexicon and analysis of field recorded bat echolocation calls. *In* J.A. Thomas, C.F. Moss and M. Vater (eds.) Echolocation in Bats and Dolphins. University of Chicago Press, Chicago. Pp 478–484.

Grinnell, A.D. and Hagiwara, S. 1972. Adaptations of the auditory nervous system for echolocation. Studies of New Guinea bats. *Zeitschrift fuer Vergleichende Physiologie* 76: 41–81.

Hill, J. E. 1983. Bats (Mammalia: Chiroptera) from Indo-Australia. Bulletin of the British Museum (Natural History) *Zoology* 45: 103–208.

Hill D.A. and Greenaway F. 2005. Effectiveness of an acoustic lure for surveying bats in British woodlands. *Mammal Review* 35:116–122.

Hill, D.A., Fukui, D., Agetsuma, N. and Macintosh, A.J.J. 2014. Influence of trap environment on the effectiveness of an acoustic lure for capturing vespertilionid bats in two temperate forest zones in Japan. *Mammal Study* 39:229–236.

Hill, D.A., Armstrong, K.N. and Barden, P.A. 2015. Preliminary assessment suggests that acoustic lures can increase capture rates of Australian echolocating bats. *Australian Mammalogy* 37: 104–106.

Helgen, K.M. 2007. A taxonomic and geographic overview of the mammal fauna of Papua. *In* A.J. Marshall and B.M. Beehler (eds.). The ecology of Papua. Ecology of Indonesia series Singapore: Periplus Editions vol. 6: 689–749.

Kingston, T. 2009. Analysis of species diversity of bat assemblages. *In* T.H. Kunz and S. Parsons (eds.). Ecological and behavioural methods for the study of bats 2nd edition. Johns Hopkins University Press, Baltimore. Pp 195–215.

Kingston, T., Francis, C.M., Akbar, Z. and Kunz, T.H. 2003. Species richness in an insectivorous bat assemblage from Malaysia. *Journal of Tropical Ecology* 19: 67–79.

Kitchener, D.J., Cooper, N., and Maryanto, I. 1995. The *Myotis adversus* (Chiroptera: Vespertilionidae) species complex in Eastern Indonesia, Australia, Papua New Guinea and the Solomon Islands. *Records of the Western Australian Museum* 17: 191–212.

Koopman, K.F. and Diamond, J.M. 1979. Zoogeography of mammals from islands off the northeastern coast of New Guinea. *American Museum Novitates*. 2690: 1–17.

Kunz, T.H., Hodgkison, R. and Weise, C.D. 2009. Methods and devices for marking bats. *In* T.H. Kunz and S. Parsons (eds.). Ecological and behavioural methods for the study of bats 2nd edition. Johns Hopkins University Press, Baltimore. Pp 36–56.

Leary T. and Pennay M. 2011. Echolocation calls of eight microchiroptera from Papua New Guinea. *In* B. Law, P. Eby, D. Lunney and L. Lumsden (eds.). The biology and conservation of Australasian bats. Royal Zoological Society of New South Wales, Mosman, NSW. Pp 106–127.

Milne, D.J. 2002. Key to the bat calls of the Top End of the Northern Territory. Parks and Wildlife Commission of the Northern Territory, Technical Report No. 71.

Parsons, S. and Szewczak, J.M. 2009. Detecting, recording, and analysing the vocalizations of bats. *In* T.H. Kunz and S. Parsons (eds.) Ecological and behavioural methods for the study of bats 2nd edition. Johns Hopkins University Press, Baltimore. Pp 91–111.

Pavey, C.R. and Burwell, C.J. 2000. Foraging ecology of three species of hipposiderid bats in tropical Australia. *Wildlife Research* 27: 283–287.

Ramasindrazana, B., Goodman, S.M., Schoeman, M.C. and Appleton, B. 2011. Identification of cryptic species of *Miniopterus* bats (Chiroptera: Miniopteridae) from Madagascar and the Comoros using bioacoustics overlaid on molecular genetic and morphological characters. *Biological Journal of the Linnean Society* 104: 284–302.

Reardon, T. and Bonaccorso, F. 2008. *Myotis moluccarum*. IUCN Red List of Threatened Species. Version 2013.2, 2008.

Reinhold, L., Herr, A., Lumsden, L., Reardon, T., Corben, C., Law, B., Prevett, P., Ford, G., Conole, L., Kutt, A., Milne, D. and Hoye, G. 2001. Geographic variation in the echolocation calls of Gould's Wattled Bat *Chalinolobus gouldii*. *Australian Zoologist* 31: 618–624.

Richards, G.C. 2005. The PNG gas project: a study of bat faunal biodiversity and an assessment of potential impacts. Prepared by Greg Richards and Associates Pty Ltd for Enesar Consulting Pty Ltd, July 2005. Included as 'Annex 05. Biodiversity survey results: Bats at Hides, Nogoli and Benaria in 2005.' in the 'PNG LNG Project Environmental Impact Statement Part II. Existing Environment', prepared by Coffey Natural Systems Pty Ltd for Esso Highlands Ltd, January 2009.

Richards, G.C. 2008. The PNG liquefied natural gas project: a study of bat faunal biodiversity and an assessment of potential impacts. Prepared by Greg Richards and Associates Pty Ltd for Coffey Natural Systems Pty Ltd, July 2008. Included as 'Annex 06. Biodiversity survey results: Bats at Juha North, Juha South, Baia River, South Karius and Deviation Camp in 2008.' in the 'PNG LNG Project Environmental Impact Statement Part II. Existing Environment', prepared by Coffey Natural Systems Pty Ltd for Esso Highlands Ltd, January 2009.

Roberts, L.H. 1975. Confirmation of the echolocation pulse production mechanism of *Rousettus*. *Journal of Mammalogy* 56: 218–220.

Robson, S.K.A., Inkster, T.E. and Krockenberger, A.K. 2012. Bats of the YUS Conservation Area, Papua New Guinea. Result 5. Task 3.1. Centre for Tropical Biodiversity and Climate Change, and Centre for Tropical Environmental and Sustainability Science, School of Marine and Tropical Biology, James Cook University, Australia.

Sabol, B.M. and Hudson, M.K. 1995. Technique using thermal infrared-imaging for estimating populations of gray bats. *Journal of Mammalogy* 76: 1242–1248.

Schnitzler, H.-U. and Kalko, E.K.V. 2001. Echolocation by insect-eating bats. *Bioscience* 51: 557–569.

Schnitzler, H.-U., Moss, C.M. and Denzinger, A. 2003. From spatial orientation to food acquisition in echolocating bats. *Trends in Ecology and Evolution* 18: 386–394.

Simmons N.B. 2005. Order Chiroptera. *In* D.E. Wilson and D.M. Reeder (eds.). *Mammal species of the world: a taxonomic and geographic reference.* 3rd edition. Johns Hopkins University Press, Baltimore. Pp 312–529.

Smith, J.D. and Hill, J.E. 1981. A new species and subspecies of bat of the *Hipposideros bicolor* group from Papua New Guinea, and the systematic status of *Hipposideros calcaratus* and *Hipposideros cupidus* (Mammalia: Chiroptera: Hipposiderodae). *Contributions in Science*, *Natural History Museum of Los Angeles County* 331: 1–19.

Tian, L., Liang, B., Maeda, K., Metzner, W. and Zhang, S. 2004. Molecular studies on the classification of *Miniopterus schreibersii* (Chiroptera: Vespertilionidae) inferred from mitochondrial cytochrome b sequences. *Folia Zoologica* 53: 303–311.