FRIEDA RIVER

Frieda River Limited
Sepik Development Project
Environmental Impact Statement

Appendix 8b – Terrestrial Biodiversity Field Assessment in the May River and Upper Sepik River Catchments

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Terrestrial Biodiversity Field Assessment in the May River and Upper Sepik River Catchments

Sepik Development Project (Infrastructure Corridor)

August 2018

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Wayne is a retired tropical forest research biologist from the Harvard University Herbaria and Arnold Arboretum. He is one of the leading floristicians in Papuasian botany and is widely known in professional circles for wide-ranging publications in vascular plant taxonomy and conservation. His 25-year career as a resident scientist in Papua New Guinea began in 1988 at the Wau Ecology Institute (subsequently transferring to the PNG National Herbarium in 1992) and included numerous affiliations as a research associate or consultant with academic institutions, non-governmental organisations (NGOs) and corporate entities. Despite taking early retirement at age 57, botanical work has continued to the present on a selective basis. He has served as the lead botanist on at least 38 multidisciplinary surveys and has 97 peer-reviewed publications on the Malesian flora.

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Stephen Richards is a research scientist and independent environmental consultant who specialises in biodiversity assessments and has more than 25 years' experience working in Papua New Guinea and other tropical regions. During that time he has designed and led numerous multi-disciplinary biodiversity studies, participating in a total of more than 40 biodiversity surveys in remote areas of Papua New Guinea since 1991. With more than 130 peer-reviewed scientific publications Stephen is considered one of the world's leading experts on the taxonomy, biogeography and conservation status of Melanesian herpetofauna (frogs and reptiles) and odonata (dragonflies and damselflies) and is the Regional Chair for Melanesia of the IUCN's Amphibian Specialist Group. He has worked extensively with PNG Non-Government Organisations, Universities, and the Government's Environment Department to provide capacity building opportunities for local scientists through training programs and hands-on field experience.

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PREFACE

This document is an independent report to support the Environmental Impact Statement (EIS) for the Sepik Development Project (the Project). Frieda River Limited (FRL) is assessing the feasibility of the Project in northwest Papua New Guinea (PNG). The Sepik Development Project is underpinned by the Frieda River Copper-Gold Project and supported by three separate but interdependent projects, which provide key infrastructure including hydroelectric power, an ocean port at Vanimo, airport at Green River, a 325 km road and transmission line.

The Sepik Development Project consists of four interdependent projects:

- Frieda River Copper-Gold Project (FRCGP). Includes the open-pit, process plant, site accommodation camp and mine access roads.
- Frieda River Hydroelectric Project (FRHEP). Includes the integrated storage facility (ISF), hydroelectric power facility, Frieda River Port, FRHEP access road and quarries to support construction of the FRHEP. Hydroelectric power generation will peak at 400 MW once the reservoir has filled.
- Sepik Infrastructure Project (SIP). Including the Vanimo Ocean Port (an upgrade to the existing Port of Vanimo), Green River Airport and a public road from Vanimo to Hotmin.
- Sepik Power Grid Project (SPGP). A 370 km 275 kV Northern Transmission Line from the FRHEP to the Indonesian border via Vanimo.

The Project is primarily located within the Sepik River catchment and comprises development of a copper-gold deposit in Sandaun Province, and supporting infrastructure and facilities in the Sandaun and East Sepik provinces.

The Project is located in one of the least biologically explored parts of New Guinea. In recognition of the lack of biological data, the Project commissioned a series of terrestrial biodiversity surveys from 2009 to 2011, with the objective of gathering sufficient information for an impact assessment. The findings from these surveys forms a series of reports and packaged as Appendix 8a.

Since the completion of the initial biodiversity surveys the configuration of the Project was changed. The most notable change was the inclusion of a new infrastructure corridor from Vanimo to the mine site, which includes an access road, concentrate pipeline, transmission line and other ancillary infrastructure. Consequently, Coffey commissioned five specialists (see contributors) to complete surveys of the infrastructure corridor and prepare a standalone report of their survey findings.

The reports have been assembled into this document and appear as individual chapters in what is intended to be an integrated assessment.

A BOTANICAL ASSESSMENT OF ENVIRONMENTS IN THE SEPIK DEVELOPMENT PROJECT INFRASTRUCTURE CORRIDOR

A REPORT SUBMITTED TO COFFEY SERVICES AUSTRALIA PTY LTD

WAYNE TAKEUCHI
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GLOSSARY

adventive	a species introduced by man and subsequently becoming naturalised.
alluvium	adj. alluvial; detrital material (e.g., silt, sand, gravel) deposited by flowing water.
angiosperm	a flowering plant which produces seed-bearing fruits, represented either by monocots with a single cotyledon in the seed, or by dicots with two cotyledons.
aroid	a monocot in the family Araceae.
bivouac	a temporary camp
bryophyte	adj. bryophytic; a non-vascular, terrestrial plant; represented by mosses, liverworts, and hornworts.
cm	centimetre
colline	pertaining to environments with low, hilly terrain.
congener	a member of the same genus.
conspectus	content, synopsis; an enumeration of taxa comprising a particular group of plants.
cosmopolitan	worldwide, or of geographically extensive distribution.
cotyledon	an embryonic leaf; the first to appear from a germinating seed.
dbh	diameter at breast height, a standard measure of tree size.
deciduous	of parts falling at the end of a growing season or other period of development.
depauperate	poor, impoverished; lacking in diversity.
dicot	an angiosperm with two cotyledons in the seed.
disharmonic	unbalanced; a flora with many groups missing or poorly represented.
edaphic	pertaining or relating to the substrate.
emergent	a plant which is taller than the surrounding vegetation.
epiphytic	growing on another plant or other supporting object.
euphorbiaceous	of or relating to members of the dicot family Euphorbiaceae.
furfuraceous	provided with soft scales.
glaucous	covered with a whitish bloom.
gymnosperm	a vascular plant whose seeds are not enclosed in an ovary or fruit, represented inter alia by conifers and cycads.
heliophyte	a light-demanding plant, consisting primarily of pioneer or seral species establishing in forest gaps and newly cleared environments.
herbaceous	referring to non-woody plants that persist for a single growing season.
hirsute	invested with rough, coarse (usually ascending) hairs.
inflorescence	the collective structure formed from multiple flowers—or the pattern of their arrangement.
inter alia	among others.
lycophyte	lycopsid, a member of the *Lycopodium* group (Lycopsida).
m	metre
macrophyll	a leaf more than 250 mm long; one of the leaf types in a size classification including megaphyll, macrophyll, mesophyll, microphyll, nanophyll, and leptophyll (in descending order).
Malesia	a phytogeographic unit comprised of Malaysia, Indonesia, Brunei, the Philippines, and New Guinea (with its offshore islands). The region is often treated as a single entity in botanical studies because of similarities between its component floras.
monocaul	an unbranched plant.
monocot	an angiosperm with one cotyledon in the seed.
monographic	pertaining to a taxonomic treatise or revision dealing with a specific group of plants.
morphospecies	a group of organisms recognised as a taxonomic species solely on the basis of morphological criteria.
MSL	mean sea level
panicle	adj. paniculate; an indeterminate branching raceme; an inflorescence in which the branches of the primary axis are racemose and the flowers pedicellate.

Papuasia	the biogeographic region consisting of New Guinea, the Bismarck Archipelago, and the Solomon Islands. Due to pronounced floristic similarities between these three areas, they are often treated as a single unit in botanical studies.
pedate	palmately lobed or divided, the side lobes themselves divided.
peduncle	the stalk of a flower, inflorescence, or fruit.
phenology	the pattern of cyclical and seasonal biological events; in botany pertaining especially to the periodicity and timing of flowering, fruit set, leaf emergence, and seed germination.
physiognomy	the appearance and structure of a vegetation.
pteridophyte	a vascular plant that reproduces from spores rather than seeds; most often denoting ferns, but also encompassing fern allies like horsetails and clubmosses.
reflexed	abruptly bent downward or backward.
rubiaceous	of or relating to a member of the dicot family Rubiaceae.
senescence	the gradual deterioration of function and vigor with advancing age.
sensu	in the sense of: sensu lato (in a broad sense), sensu stricto (in a narrow sense).
Sepik Development Project Infrastructure Corridor	the 325 km strip consisting of a road alignment, concentrate pipeline, and transmission line between the mine site and Vanimo port.
seral	relating to an intermediate stage in ecological succession.
sister species	the two species formed through evolutionary divergence from a common ancestor.
species nova (sp. nov.)	a new species; one which has not been previously named or formally described.
speciose	containing many species.
stipe	a stalklike structure such as the petiole of a fern frond.
synusia	a vegetation stratum composed of species of similar stature and life form.
vascular	characterised by the presence of specialised tissues for conducting water and nutrients to different parts of a plant.
viz. (videlicet)	namely, that is to say
ultrabasic	referring to soil of very low silica content but enriched in magnesium, iron, and heavy metals.

EXECUTIVE SUMMARY

Botanical results are presented from a biological reconnaissance of the Sepik Development Project Infrastructure Corridor between the proposed Frieda River Copper-Gold Project and Vanimo. The investigation of floristic habitats encompassed the Infrastructure Corridor from Hotmin to the Sepik River (hereafter as the Study Area).

Three principal vegetation formations have been identified and characterised from two sampling sites. A taxonomic assessment of the flora (based on an inventory of 128 families, 350 genera, and at least 447 species) has revealed the presence of disharmonic forest communities where many expected taxa are missing. The findings include one species new to science, two range extensions of poorly documented plants, and four IUCN-listed taxa (three Vulnerable and one Near Threatened).

Survey outcomes are collectively indicative of environments substantially impoverished compared to equivalent forest types outside the Study Area. Discursive observations are presented for the reduction in diversity and its relevance to future management of the Infrastructure Corridor.

1. INTRODUCTION

1.1. Project description

Frieda River Limited (FRL) is assessing the feasibility of the Sepik Development Project (Project) in northwest Papua New Guinea (PNG). The Sepik Development Project is underpinned by the Frieda River Copper-Gold Project (FRCGP) and supported by three separate but interdependent projects which provide key infrastructure and power: the Frieda River Hydroelectric Power Project (FRHEP), the Sepik Power Grid Project (SPGP) and the Sepik Infrastructure Project (SIP).

The Project is primarily located within the Sepik River catchment. The FRCGP copper-gold deposits are located in Sandaun Province and supporting infrastructure and facilities in the Sandaun and East Sepik provinces (Figure 1). Figure 2 shows the general mine layout around the Horse-Ivaal-Trukai, Ekwai and Koki (HITEK) open pits and supporting infrastructure. Mined ore will be processed at a plant located approximately 8 km northeast of the open pits to produce a copper-gold concentrate.

Mine waste rock and tailings will be stored subaqueously in an integrated storage facility (ISF) located on the Frieda, Nena and Niar rivers downstream of the mine site. The ISF is part of the Frieda River Hydroelectric Project (FRHEP) which will generate hydroelectric power for the FRCGP commencing in Year 1.

A 325 km infrastructure corridor (the Study Area) will be developed between the mine site and Vanimo Port, located on the north coast of mainland PNG. A concentrate pipeline that follows the road alignment will transport the copper-gold concentrate produced at the process plant to a concentrate dewatering, storage and export facility located at the port. A transmission line will also run along the road alignment from the FRHEP to Vanimo.

1.2 Study objectives

The botanical survey of the Sepik Development Project Infrastructure Corridor was designed to meet the following goals and objectives:

- To identify and describe the principal plant communities using the Forest Inventory Mapping System (FIMS) as a reference baseline.
- To provide a floristic inventory of vascular plant species at two pre-established bivouac sites.
- To document and assess potential threats from alien species.
- To identify sensitive habitats and taxonomic assets of conservation value or significance.

1.3. Historical exploration within the Infrastructure Corridor

The upper Sepik (here regarded as the drainage interval above Ambunti) is a historically critical locality for botanical documentation in Papua New Guinea (PNG). Starting with the German

Augustafluss (Kaiserin-Augusta) Expedition of 1912–13, this region has long been recognised as one of the most fruitful venues for taxonomic discovery in Papuasia.

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

The May River (Maifluss) was a principal venue for the Augustafluss Expedition during a nine-day transit to the Frieda River drainage. The most productive part of the Maifluss itinerary was an ascent of Pfingstberg (Mt. Pentecost), between the present May River station and the village of Hotmin. Judging from modern monographic citations, at least some of the Pfingstberg collections are still extant, although no inventory of the surviving material has ever been compiled.

Following the construction of the PNG National Herbarium (LAE) in 1964-65, resident botanists from the modernised facility began exploring various parts of the Sepik basin on an irregular schedule. Although attention was primarily directed to easily accessed areas, several collections were taken from the May River by A. Bellamy in 1984, and a larger set (ca. 50 numbers) by D.G. Frodin in 1992. Specialists pursuing specific interests (e.g., A. Millar, F.A. Zich, S. Yoshida) have also entered the rivercourse from time to time on individually arranged travel plans. Despite the range of personalities involved, contributions from post-Augustafluss investigators have been collectively limited by selective sampling, and knowledge of the May River flora has hardly improved since the original German surveys.

Due to physical difficulties of access, most of the Augustafluss localities remain unknown to modern science. Using local airstrips, at least 10 Augustafluss localities were inventoried by Takeuchi et al. during a series of linked operations in 1989, 1990, 1994, 1995, 2001, 2004, 2005, and 2007 (partial account in Takeuchi and Golman 2002). With the advent of helicopter-supported logistics, the obstacles to comprehensive exploration are being dramatically reduced, and future prospects for botanical discovery are now considerable.

2. METHODS

2.1. Botanical inventory

The recently completed reconnaissance was based on the same sampling procedures used in other rapid assessments (e.g., Mack 1998; Mack and Alonso 2000; Beehler and Alonso 2001; Richards 2007, Richards and Gamui 2011). In conformity with modern botanical surveys, vascular plants (ferns, gymnosperms, and angiosperms) were checklisted with particular attention directed to taxa of probable conservation interest. Alien plants were also a focal group for assessment due to their potential project impact.

Exploratory surveys of poorly-known areas are usually accompanied by high-volume collecting, in order to maximise specimen outputs from one-off operations. Due to late delivery of preservatives to the bivouacs, the standard vouchering procedures were necessarily suspended in favour of greater reliance on sight-recognition checklisting and photographic documentation. Although herbarium specimens could only be preserved during the final three days of fieldwork, this limitation was offset by the exceptionally poor forest phenology and resulting lack of collectible material.

Physical gatherings (from December 7–9) were field-packed in 75% ethanol for subsequent processing by the PNG National Herbarium (LAE). Identifications were confirmed by the author using keys from the formal literature and/or by comparison to published descriptions. Family assignments are based on the following sources: ferns and lycophytes (Smith et al. 2006), gymnosperms (Laubenfels 1988), and angiosperms (Angiosperm Phylogeny Group 1998, 2003, 2009). First sets will be deposited at LAE. Duplicates will be distributed to international herbaria when appropriate protocols are established for the survey's biological products.

2.2 Forest typing

All forest communities in Papua New Guinea have been comprehensively mapped using aerial photography and Geographic Information System (GIS) typing algorithms (Saunders 1993a, b; Hammermaster and Saunders 1995a, b). From a total of 63 typing codes employed by the current Forest Inventory Mapping System (FIMS), three basic types have been recognised at the project bivouac sites. As an adjunct activity to the taxonomic assessment, forest communities at each survey locality have been ground-truthed against the FIMS classification. Adoption of the FIMS mapping protocols serves as a basis for standardisation of forest descriptions across Papua New Guinea, facilitating direct comparisons between diverse undertakings. The alternative procedure of customised or ad hoc descriptions would complicate comparison of vegetation units between different programs, and has been avoided.

2.3. Survey sites and schedule

The floristic team (the writer and one assistant) examined a total of two localities in the Study Area during the period 28 November 2017 to 10 December 2017. Each sampling site consisted of a fly camp ± centred within a network of access tracks into surrounding environments. The bush tracks were generally established ad hoc in the cardinal directions from bivouacs, and opportunistically directed to achieve optimum coverage of the habitat variation.

Botanical documentation and forest observations were obtained in accordance with procedures described previously. Geographic coordinates, elevation, survey dates, and work duration (as man-hours devoted to search by two surveyors) are indicated for each site in Table 1. All positional data are expressed in UTM format, WGS84 Zone 54.

Table 1. Site summary

locality	coordinates WGS84	UTM zone	elevation m (MSL)	survey dates (2017)	fieldwork ×2 (man-hrs)
Camp 1 Uriake	559126 easting 9494428 northing	54	71	28 Nov–3 Dec	84
Camp 2 Wara Kep	534344 easting 9539083 northing	54	126	4–10 Dec	92

3. RESULTS

3.1 Botanical inventory

The botanical checklist of the Study Area includes 128 vascular plant families, 350 genera, and at least 447 morphospecies (eight morphospecies are unconfirmed). The identifications are augmented by 2.7 gigabytes of GPS-enabled digital imagery. Table 2 presents a fractional tally of the enumerations according to vascular plant group.

The taxonomic results include one species new to science, two range extensions of plants rarely seen in New Guinea, and four IUCN-listed taxa (three Vulnerable, one Near Threatened). The distribution of botanical records and IUCN plants is summarised in Table 3.

Table 2. Taxonomic counts by vascular plant category.

	FERNS	GYMNOSPERMS	MONOCOTS	DICOTS	TOTALS
Families	20	3	22	83	128
Genera	37	3	78	232	350
Species	54	3	87	303	447

3.1.1 Undescribed species

3.1.1.1. Rubiaceae. *Psychotria* sp. nov., aff. *P. apdavisiana* Takeuchi. Figs.3,4.

With an estimated 120 + species in Papuasia, *Psychotria* is the principal component in a rubiaceous flora noted for diversity and endemism (Davis et al. 2009). Whenever poorly explored environments are subjected to scrutiny, modern expeditions have consistently added more taxa to the genus. The new *Psychotria* is the third novelty in its genus from the Sepik Development Project.

The species nova is a miniature monocaul with abruptly reflexed peduncles. Among Papuasian congeners, only *P. reflexapedunculata* from the Louisiade Archipelago and *P. apdavisiana* of Western Province have this bizarre combination of features (Sohmer 1988; Takeuchi 2013). Because of its small stature and downward-directed inflorescence, the fertile structures in the new plant are usually hidden beneath the foliage and deliberate effort is required to find identifiable specimens. This circumstance is probably responsible for historical failures at detection, despite the presence of large populations.

Although vegetatively similar to *P. apdavisiana*, the Sepik region novelty is instantly distinguished by its paniculate inflorescence and hirsute fruits. With their known ranges restricted to opposite-flowing drainages across the Central Divide, *Psychotria* sp. nov. and *P. apdavisiana* are possibly sister species.

3.1.2 IUCN-listed plants

3.1.2.1. Dipterocarpaceae. *Anisoptera thurifera* (Blanco) Blume. Appendix 1.

IUCN-listed as Vulnerable (IUCN 2017). A valuable timber from the Philippines, Indonesia, and New Guinea. Heavily logged throughout its range but with large stands still present in coastal environments of Morobe Province and elsewhere.

3.1.2.2. Fabaceae. *Intsia bijuga* (Colebr.) Kuntze. Appendix 2.

IUCN-listed as Vulnerable (IUCN 2017). The species is occasionally dominant in lowland canopies throughout New Guinea, and has been collected from virtually every part of Papuasia. Its range includes East Africa, Indochina, all of Malesia, and the Pacific islands of Melanesia and Micronesia (Verdcourt 1979; Ding Hou et al. 1996).

3.1.2.3. Fabaceae. *Pterocarpus indicus* Willd. Appendix 3.

IUCN-listed as Vulnerable (IUCN 2017). A common timber species distributed from continental Asia to the Santa Cruz Islands of the South Pacific (Verdcourt 1979). The species is in rapid decline due to commercial logging.

3.1.2.4. Araucariaceae. *Agathis labillardierei* Warb. Appendix 4. Fig. 5.

IUCN-listed as Near-Threatened (IUCN 2017). Endemic to New Guinea, the massive tree is one of the most highly-sought timbers on the island. Although still widespread and locally common, existing threats could adversely affect its future status (Farjon 2013).

3.1.3 Range extensions of noteworthy plants

3.1.3.1. Ebenaceae. *Diospyros fusicarpa* Bakh. Fig.6.

FBakhuizen (1941) described *Diospyros fusicarpa* from an incomplete specimen with immature fruits. The fertile gatherings obtained by the recent surveys will enable comprehensive re-description of the species.

There are no specimens of *D. fusicarpa* at LAE, but the diagnostic illustrations in Slooten (1955, plate 35) are in such precise agreement with the newly acquired vouchers as to leave no doubt about the identification. The Sepik collections are a PNG distributional record for this rare ebony, historically known only from the Cycloop Mountains of Irian Jaya.

3.1.3.2. Marattiaceae. ***Christensenia aesculifolia* (Blume) Maxon subsp. *korthalsii* (deVriese) Rolleri.** Fig. 7.

Christensenia has a wide but spotty distribution including northeast India, Burma, China (Yunnan), Vietnam, Malaysia, Indonesia, Philippines, Bismarck Archipelago and the Solomon Islands (Murdock 2008). It's absence from the historical record for New Guinea has been a long-standing and puzzling distributional anomaly (Braithwaite 1977). The apparent geographic disjunction was recently removed by the fern's discovery during the Frieda foundation surveys in 2009 (Takeuchi 2013). Based on the current taxonomy (Rolleri 1993; Rolleri et al. 1996), the Sepik populations are assignable to *C. aesculifolia* subsp. *korthalsii*, the same taxon present in the Bismarck Archipelago.

With the latest record from Camp 2, the mainland distribution for *C. aesculifolia* is extended 65 km to the northwest of the original Frieda sites. The range extension suggests the species is probably widespread in the upper Sepik and was merely overlooked by past workers, possibly owing to its superficial similarity with *Syngramma*.

Table 3. shows distributional summary of floristic records and IUCN taxa, by locality and forest types of occurrence. C1: Camp 1, C2: Camp 2. Hm: medium crowned hill forest. Po: open forest on lowland plains and fans. Ps: small crowned lowland forest on plains and fans.

Table 3. Distributional summary of floristic records and IUCN taxa

TAXON	C1	C2	OTHER LOCALITIES
Agathis labillardierei	Hm	Hm	throughout western New Guinea and eastward to the Sepik
Anisoptera thurifera		Hm	Philippines, Indonesia
Christensenia aesculifolia		Ps	northeast India to the Solomon Islands
Diospyros fusicarpa	Hm	Hm	Cycloop Mts. of Indonesian Papua
Intsia bijuga	Hm, Po	Hm, Ps	East Africa, Indochina, Malesia, Melanesia and Micronesia
Psychotria sp. nov.	Hm	Hm, Ps	none known
Pterocarpus indicus	Hm, Po	Hm, Ps	Asia to the South Pacific

3.1.4 Alien plants

At Camp 1 the alluvial environment along the May River has been extensively altered by subsistence gardening. The resulting anthropogenic landscape is copiously populated by alien weeds (mostly *Ageratum conyzoides, Axonopus compressus, Crassocephalum crepidioides, Cynodon dactylon, Hyptis capitata, Melastoma malabathricum, Melinis minutiflora, Passiflora foetida, Pennisetum macrostachyum, Pityrogramma calomelanos, Psidium guajava*, *Senna alata*; at least 33 alien spp. recorded). The alien tally includes 15 taxa confined to cultivated areas and apparently unable to establish spontaneously in surrounding habitats (e.g., *Canna indica, Capsicum annuum, Carica papaya, Citrus limon, Cymbopogon citratus, Sanchezia parvibracteata, Tagetes* sp.).

Introduced plants were similarly present around Camp 2, but the occurrences there were constrained by reduced exposure to human settlements and pedestrian traffic. Only seven adventives were recorded from the second site (*Achyranthes aspera, Ageratum conyzoides, Axonopus compressus, Erechtites valerianifolius, Euphorbia hirta, Passiflora foetida, Senna alata*).

All observed adventives in the Study Area are cosmopolitan plants of benign invasive competence. The species involved are visual nuisances but do not present significant conservation threats. There were no indications of deleterious aquatic weeds such as *Eichhornia crassipes* and *Salvinia adnata.*. In marked contrast to riverine habitats, colline environments above the camps were botanically pristine, with alien species absent even from established footpaths.

3.2 Vegetation description

In the following narrative, a character summary of the vegetation is presented first, in order to place the separate communities in holistic context by highlighting observations common to all sites. Each vegetation class recorded by ground reconnaissance is then described in relation to their

specific locality of occurrence. Descriptive terminology generally follows Paijmans (1976) or Hammermaster and Saunders (1995a, b).

Three forest types were verified during the survey, classified by the FIMS under typing codes Po, Ps, and Hm (hereafter also as hill or colline forest). Although examples of Hs (small crowned, low altitude forest on uplands below 1,000 m), Fsw (Mixed Swamp Forest) and Wsw (Swamp Woodland) are locally embedded within the Hm formation, these occurrences are too small for mapping acquisition at the 1: 250,000 scale resolution of the FIMS and have been incorporated into the larger Hm unit.

3.2.1. General features of the vegetation

Forest formations at Camps 1 and 2 are defined by a number of shared qualities which presumably reflect the overall character of surrounding environments. The most significant of these features is a pronounced depauperation in primary growth communities, as evidenced by diminished species counts and an abbreviated conspectus of rare or novel taxa. Even plants normally among the most common in New Guinea were not recorded by the sampling effort (e.g., *Adenia heterophylla, Amischotolype* sp., *Amyema friesiana, Conandrium polyanthum, Davallia solida, Decaisnina hollrungii, Dendrophthoe curvata, Floscopa scandens, Grammitis sumatrana, Morinda umbellata, Mycetia javanica, Neuburgia rumphiana, Oldenlandia pubescens, Pachystylus guelcherianus, Papuechites aambe, Pavetta platyclada, Psychotria leptothyrsa, P. membranacea, Sabia pauciflora, Salacia* spp., *Tecomanthe dendrophila*).

With the notable exception of adhesive aroids, many forest vines were conspicuous by their absence or low frequency (*Clematis*, *Connarus, Derris, Dichapetalum, Embelia, Gouania, Ichnocarpus, Jasminum, Marsdenia, Micrechites, Neoalsomitra, Parsonsia, Petraeovitex, Polyporandra, Rourea*). Epiphytes (especially stranglers from *Ficus* subseries *Hesperidiiformes*, orchids, *Hoya*, mistletoes, polypody ferns), were also seldom seen.

The unbalanced composition of the hill forest is further reflected in the absence (or infrequency) of light-demanding pioneers such as *Acalypha, Callicarpa, Commersonia, Dendrocnide, Macaranga, Mallotus, Omalanthus, Parasponia, Pipturus, Premna, Trema,* and *Trichospermum*. Rarity of pioneer heliophytes implies that forest regeneration is spatially and/or temporally restricted, precluding entry of taxa dependent on repetitive or prolonged disturbance events. Judging from the paucity of seral species, area-extensive disturbances (cyclonic storms, fires, large landslips, etc.) have not occurred here in the recent past. Canopy replacement probably occurs on a spotwise basis determined by attrition of individual trees through senescence or lightning strikes.

Species impoverishment was accompanied by apparent indications of low site capacity and productivity. Despite their status as unlogged mature growth, forest stands were predominantly populated by small diameter trees with very few timbers of merchantable size (dbh > 50 cm). This condition is reminiscent of limiting substrates such as limestone and ultrabasics, but the soils within the surveyed area are comprised only of river alluvium or conventional clays.

A consistent edaphic attribute of the hill forest is the presence of a thick groundlayer formed from undecomposed leaf litter (Fig. 8). Owing to widespread digging by feral pigs, a comparable buildup was absent in alluvial habitats (Po, Ps) even though leaf falls were probably equivalent to terrain on higher slopes. Colline accumulation of vegetative debris may be related to exceptionally unfavourable phenologies experienced during the survey (among the worst seen by the writer on any floristic assessment). An overwhelming majority of taxa were represented only by sterile plants, particularly in the larger genera.

3.2.2. Description of the Camp 1 vegetation

3.2.2.1. Po (Open forest on lowland plains and fans). Fig. 9.

The Camp 1 alluvial zone is a Po formation according to FIMS criteria but has been recently degraded by subsistence gardening. Except for native heliophytes adapted to repetitive disturbance (mainly *Cheilocostus speciosus, Ficus* spp., *Flagellaria indica, Hornstedtia scottiana, Kleinhovia hospita, Macaranga aleuritoides, Melanolepis multiglandulosa, Merremia peltata, Osmoxylon novoguineensis, Scleria polycarpa*, *Sphaerostephanos unitus, Trichospermum pleiostigma, Uncaria lanosa*) the naturally occurring vegetation below 5 m stature has been largely replaced by alien species (see section 3.1.4). Canopy trees from the original growth forest are represented by *Allophylus cobbe, Alstonia scholaris*, *Artocarpus altilis, Cananga odorata, Caryota rumphiana, Dillenia castaneifolia,*

Elaeocarpus angustifolius, *Intsia bijuga, Nauclea orientalis, Octomeles sumatrana, Pangium edule*, *Planchonia papuana, Pterocarpus indicus*, and *Terminalia* spp. (mainly the *canaliculata-complanata* morphotype).

Subsistence agriculture in the Po zone is devoted primarily to cultivation of *Abelmoschus manihot* (aibika), *Ananas comosus* (pineapple), *Arachis hypogaea* (peanut), *Areca catechu* (betel), *Citrullus lanatus* (watermelon), *Colocasia esculenta* (taro), *Cucumis sativus* (cucumber), *Dioscorea* spp.(yams), *Ipomoea batatas* (sweet potato), *Manihot esculenta* (casava, tapiok), *Musa* × *paradisiaca* (banana), *Saccharum spontaneum* var. *edulis* (pit pit) and *S. officinarum* (sugarcane). The prevalence of taro as the principal cropping choice is unusual for a culture customarily dependent on sago palm. There is no evidence of cultivated plants escaping into adjacent natural communities.

3.2.2.2. Hm (medium crowned, low altitude forest on uplands below 1,000 m). Figs. 10-12.

The foothill zone around Camp 1 is an Hm class forest of variable composition. Near the alluvial contact, overstories are conspicuously populated by macrophylls of wide geographic distribution, including *Alstonia macrophylla, Campnosperma brevipetiolata, Caryota rumphiana, Cerbera floribunda, Endocomia macrocoma, Hernandia guianensis, Neuburgia corynocarpa, Octomeles sumatrana, Pangium edule*, and *Sterculia macrophylla*. Higher slopes have a more endemic flora whose major elements are Achariaceae (*Erythrospermum candidum, Ryparosa calotricha, Trichadenia philippinensis*); Anacardiaceae (*Buchanania amboinensis, B. arborescens*); Burseraceae (*Canarium acutifolium, C. maluense, C. vitiense*); Cannabaceae (*Celtis* spp. possibly including *C. rigescens*); Combretaceae (*Terminalia* spp.); Dipterocarpaceae (*Vatica rassak*); Elaeocarpaceae (*Elaeocarpus* possibly including *E. dolichodactylis*, *E. dolichostylis, E. ledermannii*, *E. sepikanus*; *Sloanea* spp. mainly *S. sogerensis*); Fabaceae (*Archidendron clypearia*, *Falcataria moluccana, Maniltoa* spp.); Lamiaceae (*Gmelina* sp., *Teijsmanniodendron ahernianum*); Lauraceae (*Cinnamomum* spp., *Cryptocarya* spp., *Litsea* spp.); Malvaceae (*Microcos* spp., *Sterculia* spp. including *S. macrophylla*, *Taliparitis* spp. probably with *Taliparitis archboldianum*, *Thespesia populnea*); Meliaceae (*Aglaia* spp., *Chisocheton lasiocarpus*, *Dysoxylum* spp.); Myristicaceae (*Gymnacranthera farquhariana*, *Horsfieldia* spp. including *H. laevigata*, *Myristica* spp.); Myrtaceae (*Syzygium* spp.); Rosaceae (*Prunus arborea*); Rubiaceae (*Gardenia* sp., *Nauclea* spp., *Neonauclea* spp.); and Sapindaceae (*Guioa* spp., *Jagera javanica* var. *javanica*). The dominant families were Anacardiaceae, Elaeocarpaceae, Lauraceae, Meliaceae, and Myrtaceae but it has been impossible to ascertain the identity of most species present in those groups. Of lesser importance were *Chionanthus* sp., *Dillenia* sp., *Gordonia amboinensis, Hydriastele costata*, *Mastixia kaniensis, Schuurmansia henningsii*, *Ternstroemia merrilliana*, and Melastomataceae (*Astronia* sp., *Beccarianthus* sp.). Although *Agathis labillardierei* (to ca. 50 m height) can form a monospecific overstory, in many places the emergents are absent and the maximum height of the canopy is 20–30 m.

The shrub interval from 0.5–5 m height was often sparsely occupied, affording good visibility through understories. Highest in frequency were *Atractocarpus* spp., *Casearia macrantha, Eriandra fragrans, Garcinia* spp., *Gnetum gnemon*, *Gomphandra australiana*, *Horsfieldia subtilis*, *Hydriastele microspadix*, *Ixora* sp., *Lasianthus* cf. *cyanocarpus*, *Lunasia amara* var. *amara*, *Medusanthera laxiflora, Pittosporum sinuatum*, *Rhyticaryum longifolium*, and rosette stage rattans. Although sometimes locally common, *Actinodaphne* cf. *nitida*, *Aglaia* spp., *Barringtonia papuana*, *Dracaena angustifolia*, *Harpullia* spp., *Ixora novoguineensis*, *Melicope novoguineensis*, *Semecarpus magnifica*, and *Timonius grandifolius*, were of lesser aggregate count. Euphorbiaceous (*Actephila*, *Antidesma*, *Aporosa*, *Spathiostemon*) and rubiaceous shrubs (*Cyclophyllum*, *Pachystylus*, *Psychotria*, *Tarenna*) were remarkably absent or species-poor.

In comparison to other hill forests, the herbaceous groundcover was acutely depauperate. The highest counts were recorded for aroids, *Dianella ensifolia*, *Phrynium minor*, and *Selaginella* spp. (*S. velutina* inter alia). However *Argostemma*, *Cyrtandra* (excepting *C. bracteata*), gingers (*Alpinia*, *Riedelia*), ground orchids (e.g., *Calanthe*, *Malaxis*), *Ophiorrhiza*, urticates (*Cypholophus*, *Elatostema*, *Pilea*, *Procris*) were surprisingly absent or scarce. Although the climbing fern *Teratophyllum articulatum* was everywhere, pteridophytes were also not as prolific as in other lowland forests, with only *Saccoloma sorbifolium* occurring in the usual numbers. The atypically depauperate elements (compared to normal patterns of prevalence) included Aspleniaceae, Cyatheaceae, Lindsaeaceae, Marattiaceae, Pteridaceae, and the thelypterid ferns. Filmy ferns (Hymenophyllaceae) were very difficult to find.

3.2.3. Description of the Camp 2 vegetation

3.2.3.1.Ps (small crowned, lowland forest on plains and fans). Fig. 13.

The alluvial plain northwest of Camp 2 has most of the character genera listed for the P code (in Hammermaster and Saunders 1995a). *Allophylus cobbe, Intsia bijuga*, *Maniltoa* spp., *Terminalia* spp., and *Vatica rassak* are the principal elements in a canopy also comprised by *Artocarpus altilis*, *A. vriesianus*, *Calophyllum soulattri*, *Caryota rumphiana*, *Elaeocarpus angustifolius*, *Ficus* spp., *Nauclea orientalis*, *Octomeles sumatrana*, *Pandanus* spp., *Pangium edule*, *Planchonia papuana*, and *Pterocarpus indicus*. Understory gingers (*Alpinia*, *Pleuranthodium*, *Riedelia*) can be locally common but the periodically flooded forest floors are otherwise clear of herbaceous growth and populated mainly by woody shrubs (*Atractocarpus macarthurii*, *Barringtonia papuana*, *Leea indica*, *L. zippeliana*, *Lepisanthes senegalensis*, *Pisonia longirostris*, *Saurauia schumanniana, Syzygium longipes*, *Tabernaemontana aurantiaca*, *Timonius grandifolius*).

Faradaya splendida, *Flagellaria indica*, *Freycinetia* spp., *Merremia peltata*, *Mussaenda ferruginea*, *Poikilospermum amboinense*, rattans (*Calamus* spp., *Korthalsia zippelii*), and *Tetrastigma lauterbachianum* were common climbers in edge situations. *Ficus* was the most diversified woody genus in the regrowth phase.

3.2.3.2. Hm (medium crowned, low altitude forest on uplands below 1,000 m). Fig. 14.

The complementary discussion for Camp 1 (section 3.2.2.2.) is applicable here with a few refinements, including most notably the appearance or higher frequencies of Anacardiaceae (*Rhus taitensis*, *Semecarpus*), Chrysobalanaceae (*Maranthes corymbosa*, *Parastemon versteeghii, Parinari papuana*), *Erythroxylum ecarinatum*, Ebenaceae (*Diospyros buxifolia*, *D. papuana*), Fagaceae (*Castanopsis acuminatissima*, *Lithocarpus celebicus*), Icacinaceae (*Platea excelsa*), Lauraceae (*Beilschmiedia* cf. *acutifolia*., *Endiandra* sp.), *Polyosma* sp., Rhamnaceae (*Alphitonia macrocarpa*, *Ziziphus angustifolia*), Rubiaceae (*Gardenia* sp., *Nauclea* spp., *Neonauclea* spp.), Sapotaceae (*Planchonella* spp. possibly including *P. anteridifera*), *Symplocos cochinchinensis*, *Teijsmanniodendron ahernianum*, *Weinmannia fraxinea*, and a notable surge in dipterocarp counts (*Anisoptera thurifera*, *Hopea* sp*., Vatica rassak*). Understory enumerations were expanded by the addition of *Antidesma excavatum*, *Cryptocarya magnifolia, Dysoxylum variabile*, *Gonocaryum litorale*, *Justicia gendarussa,* and *Urophyllum britannicum*.

The most dominant genera were *Elaeocarpus* Group VI (sensu Coode 1981), *Sloanea*, *Syzygium*, *Teijsmanniodendron*, and *Terminalia*. In the secondary growth, the major woody plants were *Glochidion novoguineense*, *G. zeylanicum*, *Macaranga aleuritoides*, and *M. tessellata*. Except for the added tallies of individual taxa, the taxonomic structure of the hill forest is comparable to Camp 1.

4. DISCUSSION

4.1 Seasonality

Although meteorological records are not available for the surveyed localities, climatic data from nearby districts (e.g., Ambunti, in McAlpine et al. 1983) show uneven monthly rainfalls and the presence of a distinct dry season from May to August. Severe droughts can also occur at irregular intervals, accompanied by severe drops in the depth of the main rivercourse (Takeuchi and Golman 2002). While upper Sepik environments are generally humid, the temporal distribution of rainfall is thus inequitable, resulting in periodic water deficits across affected habitats.

From the amount of fallen leaves in hill forests, seasonal and synchronised foliage replacement seems to be a recurring feature of the local ecology. Organic decomposition is usually rapid under tropical conditions, but a deciduous mass event can temporarily overwhelm the recycling process, resulting in the observed excess on forest floors (cf. Richards 1952; Whitmore 1975, 1984). Prompted by periods of diminished rainfall, seasonal shifts in ecosystem productivity would also explain the suppression of flowering phenologies evident during the recent assessment.

4.2 Floristic impoverishment

Even in humid ecosystems, temporal interruptions in the availability of water will inhibit forest diversification (Gentry 1988). There are several indications of such influences in the Study Area, including suppression of vascular epiphytes, a general absence of brophytic growth, disharmonic fern compositions, and taxonomic impoverishment across angiosperm families. The missing floristic elements are probably the taxa least able to cope with the periodic deficits. Filmy ferns for example, were conspicuously absent from forest understories, yet the delicate plants are among the most common representatives of the terrestrial and epiphytic flora within the Frieda River drainage.

To at least some extent, the perception of floristic impoverishment has been influenced by poor phenology. Even though most genera can be identified with vegetative markers, the determination of their constituent species usually requires reproductive structures (viz., flowers and fruits). This circumstance applies especially to the larger groups, where taxonomic separations are compressed by the sheer size of the conspectus and sterile material becomes increasingly ineffective due to character overlap. Survey counts would have undoubtedly increased if flowering specimens had been available, but the potential size of the correction is unknowable. From the absence of many common (and easily identified plants), it is doubtful whether even an optimal phenology could have reversed the impression of low diversity. This flora is clearly less speciose than the Frieda River environments examined in 2009, where no signs of seasonal water stress were seen (Table 4).

Compared to botanical surveys outside the Sepik region, the latest assessment has produced the lowest floristic counts in the author's PNG career. Similar results have been obtained only from limestone substrates, historically recognised as depauperate environments. The 22-day survey on Pn'yang karst for example, recorded approximately 480 morphospecies; other operations from non-calcareous districts have yielded average totals of ca. 700 species.

Table 4. Comparison of taxonomic enumerations between the Frieda foundation surveys of 2009 and the present survey.

	FERNS	GYMNOSPERMS	MONOCOTS	DICOTS	TOTALS
Species	54 (209)	3 (14)	87 (207)	303 (924)	447 (1,354)
Genera	37 (90)	3 (10)	78 (140)	232 (495)	350 (735)
Families	20 (28)	3 (5)	22 (30)	83 (121)	128 (184)

Numbers in parentheses are the counts from 2009. In addition to the stark disparity in cumulative and fractional tallies, there were 23 species novae at Frieda and only one from the current assessment.

After the original Frieda reports were submitted in 2011, numerous nomenclatural changes were imposed by subsequent advances in plant taxonomy. The latest adjustments in botanical names were recently compiled into an updated species list for the foundation surveys and are also attached to this report as Appendix 5.

5. CONCLUSION

A. The forest communities examined by rapid assessment survey are probably seasonal environments subject to periodic water stress.

B. As a consequence of seasonality, the taxonomic composition of the flora is disharmonic and impoverished in comparison to more optimal habitats.

C. There are only a few plants of botanical or conservation significance. With the exception of *Christensenia aesculifolia* the highest value assets are found in hill forest, where the flora is composed entirely of native species.

D. The most significant threat to Study Area environments are alien weeds of proven habit-altering potential. Several of these are already known to be in the Vanimo area (*Chromolaena odorata*, *Cleome rutidosperma*, *Limnocharis flava*, *Mikania micrantha*) and will require diligent monitoring.

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APPENDIX 1. MERSAWA *ANISOPTERA THURIFERA*

Description

Anisoptera thurifera is a commercially valuable timber used for interior finishing, ship planking, veneer, plywood, and general construction (World Conservation Monitoring Centre 1998). The species is marketed locally as Mersawa (or as Palosapis in international commerce). Two subspecies are recognised: subsp. *thurifera* of the Philippines, and subsp. *polyandra* from all other stations in Malesia. Statures up to 50 metres have been reported for the New Guinea populations (Nir 2004).

Conservation Status

IUCN: Vulnerable.

PNG Fauna (Protection and Control) Act 1966: Act not applicable to flora.

PNG International Trade (Fauna and Flora) Act 1979: Not listed under CITES.

Distribution and Habitat Requirements

The species is found in the Philippines, eastern Indonesia, and New Guinea, at elevations from sea level to 750 metres (Ashton 1982). Monodominant stands are common in coastal forests of Morobe Province, especially on low ridges southeast of Kamiali, where canopies are typically comprised mostly of mersawa (pers. obs.). Unlike other dipterocarps, *Anisoptera thurifera* is a pioneer invader of disturbed habitats. Selective logging will actually improve its regeneration if at least 70% of a stand's basal area is not removed (Nir 2004).

Evidence for Occurrence in the Study Area

Anisoptera thurifera was recorded from Medium Crowned Hill Forest (Hm) at Camps 1 and 2.

Habitat Availability in the Study Area

Anisoptera thurifera habitat is abundant and widespread in the Study Area.

Threatening Processes

Anisoptera thurifera is among the 10 most frequently exported PNG timbers due to international demand for its wood. At present rates of resource depletion, local populations will decline by 40–45% during the present 100-year generation cycle (World Conservation Monitoring Centre 1998). In addition to direct losses from commercial overharvesting, the species is under increasing pressure from habitat conversion to subsistence agriculture, human settlements, and oil palm plantations.

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APPENDIX 2. MOLUCCAN IRONWOOD *INTSIA BIJUGA*

Description

Intsia bijuga is a timber tree capable of statures exceeding 40 metres. Among the New Guinea congeners it is readily distinguished by leaves with 1–2 pairs of leaflets (other species with 3–5 pairs of leaflets; Ding Hou et al. 1996). The dense, attractive wood (Moluccan Ironwood in international trade, Kwila in PNG commerce) is a highly valued source of flooring, furniture, and heavy construction timbers (Verdcourt 1979; World Conservation Monitoring Centre 1998).

Conservation Status

IUCN: Vulnerable.

PNG Fauna (Protection and Control) Act 1966: Act not applicable to flora.

PNG International Trade (Fauna and Flora) Act 1979: Not listed under CITES.

Distribution and Habitat Requirements

The species is often a canopy dominant in lowland forests throughout New Guinea, and has been collected from virtually every part of Papuasia. Its range includes East Africa, Indochina, all of Malesia, Australia, Melanesia, and Micronesia (Verdcourt 1979; Ding Hou et al. 1996). Although present in a variety of forest types, *Intsia bijuga* is particularly common and visually prominent on alluvial flatland.

Evidence for Occurrence in the Study Area

Intsia bijuga was recorded from Medium Crowned Hill Forest (Hm), and Open Forest on Lowland Plains and Fans (Po). The tree was checklisted at Camps 1 and 2.

Habitat Availability in the Study Area

Intsia bijuga habitat is abundant and widespread in the Study Area.

Threatening Processes

Logging and commercial overharvesting are the most important threats. In some areas the species has been eliminated as a timber resource.

References

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APPENDIX 3. BURMESE ROSEWOOD *PTEROCARPUS INDICUS*

Description

Known commercially as Burmese Rosewood or Red Sandalwood, *Pterocarpus indicus* is probably the most important leguminous tree in New Guinea (Verdcourt 1979). The species is a characteristic emergent in lowland canopies, capable of achieving statures up to 50 metres.

Conservation Status

IUCN: Vulnerable.

PNG Fauna (Protection and Control) Act 1966: Act not applicable to flora.

PNG International Trade (Fauna and Flora) Act 1979: Not listed under CITES.

Distribution and Habitat Requirements

The species is distributed from continental Asia to the Santa Cruz Islands of the South Pacific (Verdcourt 1979), in a variety of forest types.

Evidence for Occurrence in the Study Area

Pterocarpus indicus was recorded in the Study Area from Medium Crowned Hill Forest (Hm), and Open Forest on Lowland Plains and Fans (Po). The tree was checklisted at Camps 1 and 2.

Habitat Availability in the Study Area

Pterocarpus indicus habitat is abundant and widespread in the Study Area.

Threatening Processes

The species is heavily logged throughout its range. “The Viet Nam subpopulation has been extinct for some 300 years. An extensive forest survey in Sri Lanka failed to find the species, and information on subpopulations in India, Indonesia and the Philippines indicate the species is seriously threatened. Exploitation of the few known stands in Peninsular Malaysia may have caused its extinction there. What are believed to be the largest remaining subpopulations, in New Guinea, are being heavily exploited.” (World Conservation Monitoring Centre 1998).

References

Verdcourt, B. 1979. *A Manual of New Guinea Legumes. Botany Bulletin 11*. Madang: Kristen Press.

World Conservation Monitoring Centre. 1998. *Pterocarpus indicus*. IUCN Red List of Threatened Species. Version 2017-3. Accessed 13 January 2018. http://www.iucnredlist.org/

APPENDIX 4. NEW GUINEA KAURI *AGATHIS LABILLARDIEREI*

Description

Agathis labillardierei is a massive emergent in lowland canopies, capable of statures up to 60 metres (Laubenfels 1988). Known commercially as New Guinea Kauri, the species is highly valued for its size and timber quality.

Conservation Status

IUCN: Near Threatened.

PNG Fauna (Protection and Control) Act 1966: Act not applicable to flora.

PNG International Trade (Fauna and Flora) Act 1979: Not listed under CITES.

Distribution and Habitat Requirements

The species is found throughout western New Guinea (Indonesian Papua) and eastward to the Sepik basin, at 50–1,800 metres elevation (Laubenfels 1988). It has been recorded from a variety of environments including forests on peat, serpentine, and limestone. Successful in situ regeneration requires habitats to be left undisturbed for at least 100 years (Farjon 2013).

Evidence for Occurrence in the Study Area

Agathis labillardierei was recorded from Medium Crowned Hill Forest (Hm) at Camps 1 and 2.

Habitat Availability in the Study Area

Agathis labillardierei habitat is abundant and widespread in the Study Area.

Threatening Processes

Populations have been impacted by logging and habitat loss to oil palm plantations. The species remains widely distributed and common, but intensification of existing threats could adversely alter its status (Farjon 2013).

References

Farjon, A. 2013. *Agathis labillardierei*. The IUCN Red List of Threatened Species 2013: e.T42193A2960026. http://dx.doi.org/10.2305/IUCN.UK.2013 1.RLTS.T42193A2960026.en. Accessed 19 January 2018.

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APPENDIX 5. Updated Frieda species list from 2011

sequence number	Family	name from 2011	revised nomenclature	Family Changes	Reference for newly decribed species since 2011
1	Pteridophytes				
2	Adiantaceae	Adiantum hollandiae Alderw.		Pteridaceae	
3	Adiantaceae	Pityrogramma calomelanos (L.) Link		Pteridaceae	
4	Adiantaceae	Rheopteris cheesmaniae Alston		Pteridaceae	
5	Adiantaceae	Syngramma borneensis (Hook.) J. Sm.	Trichiogramme borneensis (Hook.) Kuhn	Pteridaceae	
6	Adiantaceae	Syngramma schlechteri Brause		Pteridaceae	
7	Adiantaceae	Taenitis blechnoides (Willd.) Sw.		Pteridaceae	
8	Adiantaceae	Taenitis sp.		Pteridaceae	
9	Aspleniaceae	Asplenium acrobryum Christ			
10	Aspleniaceae	Asplenium affine Sw.			
11	Aspleniaceae	Asplenium bipinnatifidum Baker			
12	Aspleniaceae	Asplenium contiguum Kaulf.			
13	Aspleniaceae	Asplenium cromwellianum Rosenst.			
14	Aspleniaceae	Asplenium cuneatum Lam.			
15	Aspleniaceae	Asplenium decorum Kunze			
16	Aspleniaceae	Asplenium foersteri Rosenst.			
17	Aspleniaceae	Asplenium macrophyllum Sw.			
18	Aspleniaceae	Asplenium musifolium Mett.			
19	Aspleniaceae	Asplenium nidus L.			
20	Aspleniaceae	Asplenium pellucidum Lam			
21	Aspleniaceae	Asplenium phyllitidus D. Don			
22	Aspleniaceae	Asplenium scandens J. Sm.			
23	Aspleniaceae	Asplenium subemarginatum Rosenst.			
24	Aspleniaceae	Asplenium tenerum G.Forst.			
25	Aspleniaceae	Didymochlaena truncatula (Sw.) J. Sm.		Hypodematiaceae	
26	Athyriaceae	Diplazium accedens Blume	Athyrium accedens (Blume) Milde		
27	Athyriaceae	Diplazium bantamense Blume	Asplenium bantamense (Blume) Baker	Aspleniaceae	
28	Athyriaceae	Diplazium cordifolium Blume			
29	Athyriaceae	Diplazium esculentum (Retz.) Sw.			
30	Athyriaceae	Diplazium stipitipinnula Holttum			
31	Athyriaceae	Diplazium weinlandii Christ			
32	Blechnaceae	Blechnum keysseri Rosenst.			
33	Blechnaceae	Blechnum orientale L.			
34	Blechnaceae	Stenochlaena areolaris (Harr.) Copel.			
35	Blechnaceae	Stenochlaena milnei Underw.			
36	Blechnaceae	Stenochlaena palustris (Burm. f.) Bedd.			
37	Cyatheaceae	Cyathea archboldii C. Chr.			
38	Cyatheaceae	Cyathea contaminans (Wall. ex Hook.) Copel.			
39	Cyatheaceae	Cyathea hornei (Baker) Copel.	Alsophila hornei Baker		
40	Cyatheaceae	Cyathea hunsteiniana Brause	Cyathea hunsteiniana Brause		
41	Cyatheaceae	Cyathea lepidoclada (C. Chr.) Domin			
42	Cyatheaceae	Cyathea perpelvigera Alderw.			
43	Cyatheaceae	Cyathea pulcherrima Copel.			
44	Cyatheaceae	Cyathea spp.			
45	Cyatheaceae	Cystodium sorbifolium (Sm.) J. Sm.	Saccoloma sorbifolium (Sm.) Christ	Saccolomataceae	
46	Davalliaceae	Davallia heterophylla Sm.	Fl. Males.does not accept Humata heterophylla (Sm.) Desv.		
47	Davalliaceae	Davallia pectinata Sm.			
48	Davalliaceae	Davallia pentaphylla Blume	Fl. Males. does not accept Scyphularia pentaphylla (Blume) Fée		
49	Davalliaceae	Davallia repens (L. f.) Kuhn	Fl. Males. does not accept Humata repens (L. f.) J. Small ex Diels		
50	Davalliaceae	Davallia solida (G. Forst.) Sw.			
51	Davalliaceae	Davallodes novoguineense (Rosenst.) Copel.			
52	Davalliaceae	Leucostegia pallida (Mett.) Copel.		Hypodematiaceae	
53	Dennstaedtiaceae	Dennstaedtia scandens (Blume) T. Moore			
54	Dennstaedtiaceae	Histiopteris integrifolia Copel.			
55	Dennstaedtiaceae	Microlepia speluncae (L.) T. Moore			
56	Dennstaedtiaceae	Orthiopteris campylura (Kunze) Copel.		Saccolomataceae	
57	Dennstaedtiaceae	Pteridium aquilinum (L.) Kuhn			
58	Dipteridaceae	Dipteris conjugata Reinw.			
59	Dipteridaceae	Dipteris lobbiana (Hook.) T. Moore			
60	Dipteridaceae	Dipteris novo-guineensis Posthumus	Dipteris novoguineensis Posth.		
61	Dryopteridaceae	Dryopolystichum phaeostigma (Ces.) Copel.			
62	Dryopteridaceae	Dryopteris sp			
63	Dryopteridaceae	Lastreopsis novoguineensis Holttum			
64	Dryopteridaceae	Polystichum bamlerianum Rosenst.			
65	Gleicheniaceae	Dicranopteris linearis (Burm. f.) Underwood			
66	Gleicheniaceae	Gleichenia hirta Blume			
67	Gleicheniaceae	Gleichenia milnei Baker	Sticherus milnei (Baker) Ching		
68	Gleicheniaceae	Gleichenia sp., subg. Diplopterygium	Diplopterygium sp.		
69	Grammitidaceae	Calymmodon clavifer (Hook.) T. Moore		Polypodiaceae	
70	Grammitidaceae	Ctenopteris eximia Copel.		Polypodiaceae	
71	Grammitidaceae	Ctenopteris subsecundodissecta (Zoll.) Copel.		Polypodiaceae	
72	Grammitidaceae	Ctenopteris taxodioides (Baker) Copel.		Polypodiaceae	
73	Grammitidaceae	Grammitis adspersa (Blume) Blume		Polypodiaceae	
74	Grammitidaceae	Grammitis pleurogrammoides (Rosenst.) Copel.		Polypodiaceae	
75	Grammitidaceae	Loxogramme sp.		Polypodiaceae	
76	Grammitidaceae	Oreogrammitis fasciata (Blume) Parris		Polypodiaceae	
77	Grammitidaceae	Prosaptia contigua (G.Forst.) C.Presl		Polypodiaceae	
78	Grammitidaceae	Scleroglossum minus (Fee) C. Chr.		Polypodiaceae	
79	Hymenophyllaceae	Abrodictyum meifolium (Bory ex Willd.) Ebihara & K. Iwats.			
80	Hymenophyllaceae	Abrodictyum obscurum (Blume) Ebihara & K. Iwats.			
81	Hymenophyllaceae	Abrodictyum schlechteri (Brause) Ebihara & K. Iwats.			
82	Hymenophyllaceae	Callistopteris apiifolia (C.Presl) Copel.	Cephalomanes apiifolium (C. Presl) K. Iwats.		
83	Hymenophyllaceae	Cephalomanes atrovirens C.Presl			
84	Hymenophyllaceae	Cephalomanes oblongifolium C.Presl			
85	Hymenophyllaceae	Cephalomanes singaporeanum Bosch			
86	Hymenophyllaceae	Crepidomanes aphlebioides (H. Christ) I.M. Turner			
87	Hymenophyllaceae	Crepidomanes intermedium (Bosch) Ebihara & K. Iwats.			
88	Hymenophyllaceae	Hymenophyllum brassii C. Chr.			
89	Hymenophyllaceae	Hymenophyllum denticulatum Sw.			
90	Hymenophyllaceae	Hymenophyllum ellipticosorum Alderw.			
91	Hymenophyllaceae	Hymenophyllum gorgoneum Copel.			
92	Hymenophyllaceae	Hymenophyllum pallidum (Blume) Ebihara & K. Iwats.			
93	Hymenophyllaceae	Hymenophyllum pilosissimum (C. Chr.) Copel.			
94	Hymenophyllaceae	Hymenophyllum sp.			
95	Hymenophyllaceae	Trichomanes humile G. Forst.	Crepidomanes humilis (G. Forst.) Bosch		
96	Lindsaea Group	Lindsaea bakeri (C. Chr.) C. Chr.		Lindsaeaceae	
97	Lindsaea Group	Lindsaea kingii Copel.		Lindsaeaceae	
98	Lindsaea Group	Lindsaea lucida Blume		Lindsaeaceae	
99	Lindsaea Group	Lindsaea microstegia Copel.		Lindsaeaceae	
100	Lindsaea Group	Lindsaea obtusa J. Sm.		Lindsaeaceae	
101	Lindsaea Group	Lindsaea repens (Bory) Thwaites		Lindsaeaceae	
102	Lindsaea Group	Lindsaea rosenstockii Brause		Lindsaeaceae	
103	Lindsaea Group	Lindsaea tenuifolia Blume		Lindsaeaceae	
104	Lindsaea Group	Sphenomeris chinensis (L.) Maxon		Lindsaeaceae	
105	Lindsaea Group	Sphenomeris retusa (Cav.) Maxon		Lindsaeaceae	
106	Lindsaea Group	Tapeinidium longipinnulum (Ces.) C. Chr.		Lindsaeaceae	
107	Lindsaea Group	Tapeinidium novoguineense K.U.Kramer		Lindsaeaceae	
108	Lomariopsidaceae	Bolbitis heteroclita (C.Presl) Ching		Dryopteridaceae	
109	Lomariopsidaceae	Bolbitis quoyana (Gaudich.) Ching		Dryopteridaceae	
110	Lomariopsidaceae	Bolbitis rivularis (Brack.) Ching in C.Chr.		Dryopteridaceae	
111	Lomariopsidaceae	Elaphoglossum novoguineense Rosenst.		Dryopteridaceae	
112	Lomariopsidaceae	Lomagramma sinuata C. Chr.		Dryopteridaceae	
113	Lomariopsidaceae	Lomariopsis kingii (Copel.) Holttum			
114	Lomariopsidaceae	Teratophyllum articulatum (Fée) Kuhn		Dryopteridaceae	
115	Lycopodiaceae	Huperzia nummularifolia (Blume) Jermy			
116	Lycopodiaceae	Huperzia phlegmaria (L.) Rothm.			
117	Lycopodiaceae	Huperzia squarrosa (G.Forst.) Trevis.			
118	Lycopodiaceae	Lycopodiella cernua (L). Pic. Serm.			
119	Lycopodiaceae	Lycopodium volubile G.Forst.			
120	Marattiaceae	Angiopteris evecta (G. Forst.) K.Hoffm.			
121	Marattiaceae	Christensenia aesculifolia (Blume) Maxon			
122	Marattiaceae	Marattia sp. A, pinnae glaucous	Ptisana sp. A		

sequence number	Family	name from 2011	revised nomenclature	Family Changes	Reference for newly decribed species since 2011
123	Marattiaceae	Marattia sp. B, not glaucous	Ptisana sp. B		
124	Oleandraceae	Arthropteris articulata (Brack.) C. Chr.		Tectariaceae	
125	Oleandraceae	Nephrolepis cordifolia (L.) C.Presl		Nephrolepidaceae	
126	Oleandraceae	Nephrolepis davallioides (Sw.) Kunze		Nephrolepidaceae	
127	Oleandraceae	Nephrolepis obliterata (R. Br.) J. Sm.		Nephrolepidaceae	
128	Oleandraceae	Nephrolepis sp.		Nephrolepidaceae	
129	Oleandraceae	Oleandra neriiformis Cav.	Oleandra pilosa Hook.		
130	Oleandraceae	Oleandra werneri Rosenst.			
131	Ophioglossaceae	Helminthostachys zeylanica (L.) Hook.			
132	Ophioglossaceae	Ophioglossum pendulum L.			
133	Parkeriaceae	Ceratopteris thalictroides (L.) Brongn.		Pteridaceae	
134	Polypodiaceae	Aglaomorpha drynarioides (Hook.) M.C.Roos			
135	Polypodiaceae	Aglaomorpha heraclea (Kunze) Copel.			
136	Polypodiaceae	Aglaomorpha novoguineensis (Brause) C. Chr.			
137	Polypodiaceae	Belvisia mucronata (Fée) Copel.			
138	Polypodiaceae	Belvisia spicata (L. f.) Mirbel ex Copel.			
139	Polypodiaceae	Drynaria rigidula Bedd.	Aglaomorpha rigidula (Sw.) Hovenkamp & S.Linds.		
140	Polypodiaceae	Drynaria sparsisora (Desv.) T. Moore	Aglaomorpha sparsisora (Desv.) Hovenkamp & S.Linds.		
141	Polypodiaceae	Goniophlebium demersum (Brause) Rodl-Linder			
142	Polypodiaceae	Goniophlebium percussum (Cav.) Wagner & Grether			
143	Polypodiaceae	Goniophlebium persicifolium (Desv.) Bedd.			
144	Polypodiaceae	Goniophlebium pseudoconnatum (Copel.) Copel.			
145	Polypodiaceae	Lecanopteris deparioides (Ces.) Baker			
146	Polypodiaceae	Lecanopteris sinuosa Copel.			
147	Polypodiaceae	Lemmaphyllum accedens (Blume) Donk			
148	Polypodiaceae	Leptochilus sp.			
149	Polypodiaceae	Microsorum linguiforme (Mett.) Copel.			
150	Polypodiaceae	Microsorum membranifolium (R. Br.) Ching	Phymatosorus membranifolium (R. Br.) S.G. Lu		
151	Polypodiaceae	Microsorum papuanum (Baker) Parris			
152	Polypodiaceae	Microsorum powellii (Hook. & Baker) Copel.			
153	Polypodiaceae	Microsorum pteropus (Blume) Copel.			
154	Polypodiaceae	Microsorum punctatum (L.) Copel.			
155	Polypodiaceae	Microsorum rampans (Baker) Parris			
156	Polypodiaceae	Pyrrosia foveolata (Alston) C.V.Morton			
157	Polypodiaceae	Pyrrosia lanceolata (L.) Farwell			
158	Polypodiaceae	Pyrrosia longifolia (Burm.) C.V.Morton			
159	Polypodiaceae	Pyrrosia novoguineae (H. Christ) Price	Pyrrosia novo-guineae (Christ) M.G. Price		
160	Polypodiaceae	Pyrrosia piloselloides (L.) M.G. Price			
161	Polypodiaceae	Pyrrosia princeps (Mett.) C.V.Morton			
162	Polypodiaceae	Selliguea albidosquamata (Blume) Parris			
163	Polypodiaceae	Selliguea enervis (Cav.) Ching			
164	Polypodiaceae	Selliguea hellwigii (Diels) Hovenkamp			
165	Polypodiaceae	Selliguea plantaginea Brack.			
166	Psilotaceae	Psilotum complanatum Sw.			
167	Psilotaceae	Psilotum nudum (L.) P. Beauv.			
168	Pteridaceae	Pteris ligulata Gaudich.			
169	Pteridaceae	Pteris moluccana Blume			
170	Pteridaceae	Pteris papuana Ces.			
171	Pteridaceae	Pteris tripartita Sw.			
172	Pteridaceae	Pteris wallichiana Agardh			
173	Pteridaceae	Pteris warburgii Christ in Warb.			
174	Salviniaceae	Azolla pinnata R. Br.			
175	Salviniaceae	Salvinia molesta Mitchell	Salvinia adnata Desv.		
176	Salviniaceae	Lygodium circinnatum (Burm. f.) Swartz		Lygodiaceae	
177	Schizaeaceae	Lygodium dimorphum Copel.		Lygodiaceae	
178	Schizaeaceae	Lygodium salicifolium C.Presl		Lygodiaceae	
179	Schizaeaceae	Lygodium scandens (L.) Sw.		Lygodiaceae	
180	Schizaeaceae	Lygodium versteegii H. Christ		Lygodiaceae	
181	Schizaeaceae	Schizaea dichotoma (L.) J. Sm.			
182	Schizaeaceae	Schizaea digitata (L.) Sw.			
183	Schizaeaceae	Schizaea malaccana Baker			
184	Schizaeaceae	Schizaea wagneri Selling			
185	Selaginellaceae	Selaginella angustiramea Muell.			
186	Selaginellaceae	Selaginella cf. durvillei (Bory) Brown			
187	Selaginellaceae	Selaginella velutina Ces.			
188	Selaginellaceae	Selaginella spp.			
189	Tectaria Group	Pleocnemia irregularis (C.Presl) Holttum		Tectariaceae	
190	Tectaria Group	Pteridrys sp.		Tectariaceae	
191	Tectaria Group	Tectaria bamleriana (Rosenst.) C. Chr.		Tectariaceae	
192	Tectaria Group	Tectaria decurrens (C.Presl) Copel.		Tectariaceae	
193	Tectaria Group	Tectaria menyanthides (C.Presl) Copel.		Tectariaceae	
194	Tectaria Group	Tectaria pleiosora (Alderw.) C. Chr.		Tectariaceae	
195	Thelypteridaceae	Ampelopteris prolifera (Retz.) Copel.			
196	Thelypteridaceae	Amphineuron immersum (Blume) Holttum			
197	Thelypteridaceae	Coryphopteris sp.	Thelypteris sp.		
198	Thelypteridaceae	Plesioneuron sp.	Cyclosorus sp.		
199	Thelypteridaceae	Pneumatopteris sp.	Cyclosorus sp.		
200	Thelypteridaceae	Pronephrium cf. micropinnatum Holttum	Cyclosorus sp.		
201	Thelypteridaceae	Sphaerostephanos invisus (G.Forst.) Holttum			
202	Thelypteridaceae	Sphaerostephanos multiauriculatus (Copel.) Holttum			
203	Thelypteridaceae	Sphaerostephanos unitus (L.) Holttum			
204	Thelypteridaceae	Sphaerostephanos warburgii (Kuhn & H. Christ) Holttum			
205	Thelypteridaceae	Sphaerostephanos spp.			
206	Vittariaceae	Antrophyum plantagineum (Cav.) Kaulfuss		Pteridaceae	
207	Vittariaceae	Anthrophyum sp., "reticulatum-callifolium group"		Pteridaceae	
208	Vittariaceae	Haplopteris elongata (Sw.) Crane	Vittaria elongata Sw.	Pteridaceae	
209	Vittariaceae	Haplopteris scolopendrina (Bory) C.Presl	Vittaria scolopendrina (Bory) Mett.	Pteridaceae	
210	Vittariaceae	Monogramma dareicarpa Hook.	Pleurofossa dareaecarpa (Hook.) Nakai ex H. Itô	Pteridaceae	
211	Gymnosperms				
212	Araucariaceae	Agathis labillardierei Warb.			
213	Cupressaceae	Libocedrus papuana F. Muell.	Papuacedrus papuana (F.Muell.) H.L.Li		
214	Cycadaceae	Cycas rumphii Miq.			
215	Gnetaceae	Gnetum gnemon (L.) Lauterb. & K. Schum.			
216	Gnetaceae	Gnetum gnemonoides Brongn.			
217	Gnetaceae	Gnetum latifolium Blume			
219	Podocarpaceae	Dacrycarpus imbricatus (Blume) de Laub.			
218	Podocarpaceae	Dacrycarpus sp.			
220	Podocarpaceae	Decussocarpus wallichianus (Presl) de Laub.	Nageia wallichiana (C. Presl) Kuntze		
221	Podocarpaceae	Phyllocladus hypophyllus Hook. f.			
222	Podocarpaceae	Podocarpus neriifolius D. Don			
223	Podocarpaceae	Podocarpus pilgeri Foxw.			
224	Podocarpaceae	Podocarpus rubens de Laub.			
225	Podocarpaceae	Prumnopitys amara (Blume) de Laub.	Sundacarpus amarus (Blume) C.N.Page		
226	Monocotyledons				
227	Amaryllidaceae	Crinum asiaticum L.			
228	Araceae	Aglaonema marantifolium Blume			
229	Araceae	Alocasia brancifolia (Schott) A. Hay			
230	Araceae	Alocasia hollrungii Engl.			
231	Araceae	Alocasia lauterbachiana (Engl.) A. Hay			
232	Araceae	Alocasia macrorrhizos (L.) G. Don			
233	Araceae	Alocasia nicolsonii A. Hay			
234	Araceae	Amydrium zippelianum (Schott) Nicolson			
235	Araceae	Caladium bicolor (Aiton) Vent.			
236	Araceae	Colocasia esculenta (L.) Schott			
237	Araceae	Cyrtosperma macrotum Becc. ex Engl.			
238	Araceae	Cyrtosperma sp.			
239	Araceae	Epipremnum amplissimum (Schott) Engl.			
240	Araceae	Epipremnum pinnatum (L.) Engl.			
241	Araceae	Holochlamys beccarii (Engl.) Engl.			
242	Araceae	Homalomena lauterbachii Engl.			
243	Araceae	Homalomena stollei Engl. & K. Krause			
244	Araceae	Homalomena sp.			
245	Araceae	Pothos falcifolius Engl. & K. Krause			
246	Araceae	Pothos tener Wall.			

sequence number	Family	name from 2011	revised nomenclature	Family Changes	Reference for newly decribed species since 2011
247	Araceae	Pothos versteegii Engl.			
248	Araceae	Rhaphidophora spp.			
249	Araceae	Schismatoglottis cf. acutangula Engl.	Schismatoglottis calyptrata (Roxb.) Zoll. & Moritzi		
250	Araceae	Scindapsus schlechteri K. Krause			
251	Araceae	Spathiphyllum schlechteri (Engl. & K. Krause) Nicolson			
252	Arecaceae	Actinorhytis calapparia H. Wendl & Drude			
253	Arecaceae	Areca catechu L.			
254	Arecaceae	Areca macrocalyx Zipp. ex Blume			
255	Arecaceae	Arenga microcarpa Becc.			
256	Arecaceae	Calamus hollrungii Becc.	Calamus aruensis Becc.		
257	Arecaceae	Calamus spp.			
258	Arecaceae	Calyptrocalyx spp.			
259	Arecaceae	Caryota rumphiana Mart.			
260	Arecaceae	Cocos nucifera L.			
261	Arecaceae	Cyrtostachys sp.			
262	Arecaceae	Heterospathe humilis Becc.	Heterospathe elegans subsp. humilis (Becc.) M.S.Trudgen & W.J.Baker		
263	Arecaceae	Heterospathe macgregorii (Becc.) H.E. Moore			
264	Arecaceae	Hydriastele costata F.M. Bailey			
265	Arecaceae	Hydriastele ledermanniana (Becc.) W.J. Baker & Loo			
266	Arecaceae	Hydriastele microspadix (Becc.) Burret			
267	Arecaceae	Korthalsia zippelii Blume			
268	Arecaceae	Licuala sp.			
269	Arecaceae	Linospadix albertisiana (Becc.) Burrett	Linospadix albertisianus (Becc.) Burret		
270	Arecaceae	Livistona sp.			
271	Arecaceae	Metroxylon sagu Rottb.			
272	Arecaceae	Orania glauca Essig			
273	Bromeliaceae	Ananas comosus (L.) Merr.			
274	Burmanniaceae	Burmannia longifolia Becc.			
275	Cannaceae	Canna indica L.			
276	Commelinaceae	Amischotolype mollissima Hassk.			
277	Commelinaceae	Aneilema acuminatum R. Br.			
278	Commelinaceae	Commelina diffusa Burm. f.			
279	Commelinaceae	Floscopa scandens Lour.			
280	Commelinaceae	Pollia thyrsiflora (Blume) Steud.			
281	Corsiaceae	Corsia sp.			
282	Costaceae	Costus speciosus (Koen.) J. Sm.	Cheilocostus speciosus (J.Koenig) C.D.Specht		
283	Costaceae	Tapeinochilos hollrungii Warb.			
284	Cyperaceae	Capitularina involucrata (Valck.Sur.) J.Kern			
285	Cyperaceae	Cyperus brevifolius (Rottb.) Hassk.	Kyllinga brevifolia Rottb.		
286	Cyperaceae	Cyperus cephalotes Vahl			
287	Cyperaceae	Cyperus cyperinus (Retz.) J.V. Suringar			
288	Cyperaceae	Cyperus diffusus Vahl			
289	Cyperaceae	Cyperus platystylis R. Br.			
290	Cyperaceae	Cyperus sp.			
291	Cyperaceae	Eleocharis sp.			
292	Cyperaceae	Fimbristylis dichotoma (L.) Vahl			
293	Cyperaceae	Fimbristylis littoralis Gaudich.			
294	Cyperaceae	Hypolytrum compactum Nees & Mey	Hypolytrum compactum Nees & Meyen ex Kunth		
295	Cyperaceae	Hypoletrum nemorum (Vahl) Spreng.			
296	Cyperaceae	Machaerina glomerata (Gaudich.) T.Koyama			
297	Cyperaceae	Mapania macrocephala (Gaudich.) K. Schum.			
298	Cyperaceae	Paramapania parvibractea (C.B.Clarke) Uittien			
299	Cyperaceae	Paramapania sp.			
300	Cyperaceae	Scirpodendron ghaeri (Gaertn.) Merr.			
301	Cyperaceae	Scirpus sp.			
302	Cyperaceae	Scleria ciliaris Nees			
303	Cyperaceae	Scleria polycarpa Boeckeler			
304	Cyperaceae	Scleria scrobiculata Nees & Meyen			
305	Cyperaceae	Thoracostachyum sumatranum (Miq.) Kurz	Mapania sumatrana (Miq.) Benth.		
306	Dioscoreaceae	Dioscorea bulbifera L.			
307	Dioscoreaceae	Dioscorea esculenta (Lour.) Burkill			
308	Dioscoreaceae	Dioscorea nummularia Lam.			
309	Flagellariaceae	Flagellaria indica L.			
310	Hanguanaceae	Hanguana malayana (Jack) Merr.			
311	Heliconiaceae	Heliconia papuana W.J. Kress			
312	Hypoxidaceae	Curculigo capitulata (Lour.) Kuntze	Molineria capitulata (Lour.) Herb.		
313	Hypoxidaceae	Curculigo orchoides Gaertn., or aff.			
314	Juncaceae	Juncus effusus L.			
315	Laxmanniaceae	Cordyline fruticosa (L.) A. Chev.		Asparagaceae	
316	Liliaceae	Dianella ensifolia (L.) DC.		Xanthorrhoeaceae	
317	Marantaceae	Cominsia gigantea (Scheff.) K. Schum.	status uncertain, may be syn. of Phrynium giganteum Scheff.		
318	Marantaceae	Donax cannaeformis (G.Forst.) K. Schum.	Donax canniformis (G.Forst.) K.Schum.		
319	Marantaceae	Phrynium sp.			
320	Musaceae	Musa paradisiaca L.	Musa × paradisiaca L.		
321	Musaceae	Musa sp.			
322	Nymphaeaceae	Hydrostemma motleyi (Hook. f.) Mabberley	Barclaya motleyi Hook.f.		
323	Orchidaceae	Acriopsis javanica Reinw.	Acriopsis liliifolia (J.Koenig) Seidenf.		
324	Orchidaceae	Agrostophyllum sp.			
325	Orchidaceae	Apostasia wallichii R. Br.			
326	Orchidaceae	Appendicula dendrobioides (Schltr.) Schltr.			
327	Orchidaceae	Appendicula reflexa Blume			
328	Orchidaceae	Bromheadia pulchra Schltr.			
329	Orchidaceae	Bulbophyllum chloranthum Schltr.			
330	Orchidaceae	Bulbophyllum digoelense J.J. Sm.			
331	Orchidaceae	Bulbophyllum longipedicellatum J.J. Sm.			
332	Orchidaceae	Bulbophyllum montense Ridl.			
333	Orchidaceae	Bulbophyllum werneri Schltr.			
334	Orchidaceae	Bulbophyllum spp.			
335	Orchidaceae	Calanthe cf. ventilabium Rchb. f.	Calanthe ventilabrum Rchb.f.		
336	Orchidaceae	Ceratostylis sp.			
337	Orchidaceae	Chilopogon cf. bracteatum Schltr.	Chilopogon oxysepalum (Schltr.) Schltr.		
338	Orchidaceae	Cleisostoma sp.			
339	Orchidaceae	Coelogyne asperata Lindl.			
340	Orchidaceae	Corymborkis veratrifolia (Reinw.) Blume			
341	Orchidaceae	Dendrobium cyperifolium Schltr.	Dendrobium violaceum subsp. cyperifolium (Schltr.) T.M.Reeve & P.Woods		
342	Orchidaceae	Dendrobium globiflorum Schltr.			
343	Orchidaceae	Dendrobium insigne (Blume) Rchb. f.			
344	Orchidaceae	Dendrobium lineale Lindl.			
345	Orchidaceae	Dendrobium pachystele Schltr.			
346	Orchidaceae	Dendrobium spectabile (Blume) Miq.			
347	Orchidaceae	Dendrobium spp.			
348	Orchidaceae	Diplocaulobium sp.			
349	Orchidaceae	Dipodium pandanum F.M. Bailey	Dipodium scandens (Blume) J.J.Sm.		
350	Orchidaceae	Eria sp.			
351	Orchidaceae	Galeola cf. gracilis Schltr.	Pseudovanilla gracilis (Schltr.) Garay		
352	Orchidaceae	Glomera sp.			
353	Orchidaceae	Goodyera sp.			
354	Orchidaceae	Grammatophyllum papuanum J.J. Sm.	Grammatophyllum speciosum Blume		
355	Orchidaceae	Habenaria dracaenifolia Schltr.			
356	Orchidaceae	Hippeophyllum sp.			
357	Orchidaceae	Hylophila sp.			
358	Orchidaceae	Liparis condylobulbon Rchb. f.			
359	Orchidaceae	Liparis pedicellaris Schltr.			
360	Orchidaceae	Malaxis sp.			
361	Orchidaceae	Mediocalcar sp.			
362	Orchidaceae	Nervillea sp.			
363	Orchidaceae	Oberonia sp.			
364	Orchidaceae	Phreatia spp.			

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365	Orchidaceae	Plocoglottis papuana Schltr.	Plocoglottis kaniensis Schltr.		
366	Orchidaceae	Plocoglottis cf. torana J.J. Sm.			
367	Orchidaceae	Podochilus imitans Schltr.			
368	Orchidaceae	Podochilus scapelliformis Blume			
369	Orchidaceae	Pseuderia cf. diversifolia J.J. Sm.			
370	Orchidaceae	Spathoglottis plicata Blume			
371	Orchidaceae	Tropidia similis Schltr.			
372	Orchidaceae	Vanilla planifolia Andrews			
373	Pandanaceae	Freycinetia angustissima Ridl.			
374	Pandanaceae	Freycinetia elegantula B.C. Stone			
375	Pandanaceae	Freycinetia elliptica Merr. & L.M.Perry	Freycinetia beccarii Solms		
376	Pandanaceae	Freycinetia klossii Ridl.			
377	Pandanaceae	Freycinetia marantifolia Hemsl.			
378	Pandanaceae	Freycinetia percostata Merr. & L.M.Perry			
379	Pandanaceae	Freycinetia spp.			
380	Pandanaceae	Pandanus adinobotrys Merr. & L.M.Perry			
381	Pandanaceae	Pandanus danckelmannianus K. Schum.			
382	Pandanaceae	Pandanus sp., sect. Maysops			
383	Pandanaceae	Pandanus spp.			
384	Philydraceae	Helmholtzia novoguineensis (K. Krause) Skottsb.			
385	Poaceae	Axonopus compressus (Sw.) P. Beauv.			
386	Poaceae	Bambusa forbesii (Ridl.) Holttum	Neololeba atra (Lindl.) Widjaja		
387	Poaceae	Bambusa vulgaris Schrad.			
388	Poaceae	Centotheca latifolia (Osb.) Trin.	Centotheca lappacea (L.) Desv.		
389	Poaceae	Chrysopogon aciculatus (Retz.) Trin.			
390	Poaceae	Coix lacryma-jobi L.			
391	Poaceae	Cyrtococcum accrescens (Trin.) Stapf.	Cyrtococcum patens var. latifolium (Honda) Ohwi		
392	Poaceae	Echinochloa stagnina (Retz.) Beauv.			
393	Poaceae	Eragrostis chariis (Schult.) Hitchc.	Eragrostis nutans (Retz.) Nees ex Steud.		
394	Poaceae	Ichnanthus vicinus (F.M. Bailey) Merr.	Ichnanthus pallens var. major (Nees) Stieber		
395	Poaceae	Imperata cylindrica (L.) Raeusch.			
396	Poaceae	Isachne albens Trin.			
397	Poaceae	Isachne sp.			
398	Poaceae	Leersia hexandra Sw.			
399	Poaceae	Leptaspis urceolata (Roxb.) R. Br.			
400	Poaceae	Lophatherum gracile Brongn.			
401	Poaceae	Nastus productus (Pilg.) Holttum			
402	Poaceae	Oplismenus sp.			
403	Poaceae	Paspalum conjugatum P.J.Bergius			
404	Poaceae	Paspalum longifolium Roxb.			
405	Poaceae	Paspalum scrobiculatum L.			
406	Poaceae	Pennisetum macrostachyum (Brogn.) Trin.			
407	Poaceae	Phragmites karka (Retz.) Trin. ex Steud.			
408	Poaceae	Saccharum officinarum L.			
409	Poaceae	Saccharum robustum Brandes & Jeswiet ex Grassl			
410	Poaceae	Sorghum sp.			
411	Poaceae	Thysanolaena maxima (Roxb.) Kuntze	Thysanolaena latifolia (Roxb. ex Hornem.) Honda		
412	Poaceae	Urochloa mutica (Forssk.) T.-Q.Nguyen			
413	Poaceae	Zea mays L.			
414	Pontederiaceae	Eichhornia crassipes (Mart.) Solms			
415	Ruscaceae	Pleomele angustifolia (Roxb.) N.E. Br.	Dracaena angustifolia (Medik.) Roxb.	Asparagaceae	
416	Smilacaceae	Smilax cf. zeylanica L.			
417	Smilacaceae	Smilax sp.			
418	Triuridaceae	Sciaphila sp.			
419	Zingiberaceae	Alpinia calycodes K. Schum.			
420	Zingiberaceae	Alpinia cf. pulchra (Warb.) K. Schum.			
421	Zingiberaceae	Alpinia sp. A			
422	Zingiberaceae	Alpinia sp. B			
423	Zingiberaceae	Curcuma australasica Hook. f.			
424	Zingiberaceae	Etlingera sp.			
425	Zingiberaceae	Hornstedtia cyathifera Valeton			
426	Zingiberaceae	Hornstedtia scottiana (F. Muell.) K. Schum.			
427	Zingiberaceae	Pleuranthodium sp.			
428	Zingiberaceae	Riedelia corallina Valeton			
429	Zingiberaceae	Riedelia longifolia Valeton			
430	Zingiberaceae	Riedelia macrantha K. Schum.			
431	Zingiberaceae	Riedelia spp.			
432	Zingiberaceae	Zingiber officinale Roscoe			
433	Zingiberaceae	Zingiber zerumbet (L.) Sm.			
434	Dicotyledons				
435	Acanthaceae	Coleus sp.		Lamiaceae (erroneous entry)	
436	Acanthaceae	Gendarussa vulgaris Nees	Justicia gendarussa Burm. f.		
437	Acanthaceae	Hemigraphis reptans (Forst.) T. And. ex Hemsl.			
438	Acanthaceae	Hulemacanthus densiflorus Bremek.			
439	Acanthaceae	Hypoestes floribunda R. Br.			
440	Acanthaceae	Lepidagathis sp.			
441	Acanthaceae	Ptyssiglottis pubisepala (Lindau) B. Hansen			
442	Acanthaceae	Ruellia sp.			
443	Acanthaceae	Sanchezia sp.			
444	Acanthaceae	Staurogyne novoguineensis (Kaneh. & Hatus.) B.L. Burtt			
445	Achariaceae	Erythrospermum candidum (Becc.) Gibbs			
446	Achariaceae	Pangium edule Reinw.			
447	Achariaceae	Ryparosa calotricha Mildbr.			
448	Achariaceae	Trichadenia philippinensis Merr.			
449	Actinidiaceae	Saurauia conferta Warb.			
450	Actinidiaceae	Saurauia schumanniana Diels			
451	Actinidiaceae	Saurauia stichophlebia Diels, or aff.			
452	Actinidiaceae	Saurauia sp.			
453	Amaranthaceae	Achyranthes aspera L.			
454	Amaranthaceae	Alternanthera sessilis (L.) R.Br. ex DC.			
455	Amaranthaceae	Amaranthus spinosus L.			
456	Amaranthaceae	Celosia argentea L.			
457	Amaranthaceae	Cyathula prostrata (L.) Blume			
458	Anacardiaceae	Buchanania amboinensis Miq.			
459	Anacardiaceae	Buchanania arborescens (Blume) Blume			
460	Anacardiaceae	Campnosperma brevipetiolata Volkens			
461	Anacardiaceae	Campnosperma montanum Lauterb.			
462	Anacardiaceae	Dracontomelon dao (Blanco) Merr. & Rolfe			
463	Anacardiaceae	Euroschinus papuanus Merr. & L.M.Perry			
464	Anacardiaceae	Mangifera minor Blume			
465	Anacardiaceae	Rhus caudata Lauterb.			
466	Anacardiaceae	Rhus taitensis Guill.			
467	Anacardiaceae	Semecarpus albicans Lauterb.			
468	Anacardiaceae	Semecarpus aruensis Engl.			
469	Anacardiaceae	Semecarpus bracteatus Lauterb.	Semecarpus bracteata Lauterb.		
470	Anacardiaceae	Semecarpus magnificus K. Schum.	Semecarpus magnifica K. Schum.		
471	Anacardiaceae	Semecarpus nidificans (Lauterb.) Ding Hou			
472	Anacardiaceae	Spondias cyatherea Sonnerat			
473	Annonaceae	Annona muricata L.			
474	Annonaceae	Artabotrys sp., "suaveolens-inodorus group"			
475	Annonaceae	Cananga odorata (Lam.) Hook. f. & Thoms.			
476	Annonaceae	Cyathocalyx sp.			
477	Annonaceae	Goniothalamus aruensis Scheff.			
478	Annonaceae	Goniothalamus imbricatus Scheff.			
479	Annonaceae	Haplostichanthus longirostris (Scheff.) Heusden			
480	Annonaceae	Mitrella kentii (Blume) Miq.			
481	Annonaceae	Papualthia longirostris (Scheff.) Diels	Haplostichanthus longirostris (Scheffer) Heusden		
482	Annonaceae	Polyalthia sp.			
483	Annonaceae	Popowia cf. pisocarpa Endl.			
484	Annonaceae	Pseuduvaria sp.			
485	Annonaceae	Schefferomitra subaequalis (Scheff.) Diels			
486	Annonaceae	Xylopia sp.			
487	Annonaceae	genus nov. ined.	Huberantha gen. nov.		Chaowasku, T. 2015. Huberantha, a replacement name for Hubera (Annonaceae: Malmeoideae: Miliuseae). Kew Bull. 70: 23.
488	Apiaceae	Centella asiatica (L.) Urb.			

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489	Apocynaceae	Alstonia macrophylla Wall. ex G. Don			
490	Apocynaceae	Alstonia scholaris (L.) R. Br.			
491	Apocynaceae	Alyxia acuminata K. Schum.			
492	Apocynaceae	Anodendron oblongifolium Hemsl.			
493	Apocynaceae	Cerbera floribunda K. Schum.			
494	Apocynaceae	Dischidia hirsuta Decne.			
495	Apocynaceae	Dischidia torricellensis (Schltr.) P.I. Forst.			
496	Apocynaceae	Dischidia sp.			
497	Apocynaceae	Gymnema sp.			
498	Apocynaceae	Hoya lauterbachii K. Schum.			
499	Apocynaceae	Hoya piestolepis Schltr.			
500	Apocynaceae	Hoya sussuela (Roxb.) Merr.			
501	Apocynaceae	Hoya torricellensis Schltr.			
502	Apocynaceae	Hoya sp.			
503	Apocynaceae	Ichnocarpus frutescens (L.) R. Br.			
504	Apocynaceae	Lepiniopsis ternatensis Valeton			
505	Apocynaceae	Marsdenia sp.			
506	Apocynaceae	Melodinus forbesii Fawc.			
507	Apocynaceae	Micrechites rhombifolius Markgr.			
508	Apocynaceae	Ochrosia citrodora Lauterb. & K. Schum.			
509	Apocynaceae	Papuechites aambe (Warb.) Markgr.			
510	Apocynaceae	Parsonsia curvisepala K. Schum.			
511	Apocynaceae	Parsonsia lata Markgr.			
512	Apocynaceae	Phyllanthera lancifolia (P.I. Forst.) Venter			
513	Apocynaceae	Phyllanthera sp. nov.	Phyllanthera piforsteriana Takeuchi		Takeuchi, W. 2014. Notes on *Phyllanthera* (Apocynaceae) from the upper Sepik of Papua New Guinea: *P. lancifolia* and *P.*
514	Apocynaceae	Tabernaemontana aurantiaca Gaudich.			
515	Apocynaceae	Tabernaemontana pandacaqui Lam.			
516	Apocynaceae	Tylophora cissoides Blume			
517	Apocynaceae	Voacanga grandifolia (Miq.) Rolfe			
518	Aquifoliaceae	Ilex scabridula Merr. & L.M.Perry			
519	Araliaceae	Arthrophyllum sp.	Polyscias sp.		
520	Araliaceae	Gastonia spectabilis (Harms) Philipson	Polyscias spectabilis (Harms) Lowry & G.M.Plunkett		
521	Araliaceae	Mackinlaya celebica (Harms) Philipson		Apiaceae	
522	Araliaceae	Mackinlaya radiata Philipson		Apiaceae	
523	Araliaceae	Osmoxylon boerlagei (Warb.) Philipson			
524	Araliaceae	Osmoxylon geelvinkianum Becc.			
525	Araliaceae	Osmoxylon novoguineense (Scheff.) Becc.			
526	Araliaceae	Polyscias zippeliana (Miq.) Valeton			
527	Araliaceae	Schefflera spp.			
528	Aristolochiaceae	Aristolochia "jackii" Steud.	Aristolochia chrismuelleriana Takeuchi		Takeuchi. 2013. Floristic records from the upper Sepik of Papua New Guinea: Aristolochia chrismülleriana sp. nov. (Aristolochiaceae), Monanthocitrus paludosa (Rutaceae), and Secamone timorensis (Apocynaceae). Phytotaxa 114 (1): 51–57.
529	Aristolochiaceae	Aristolochia lauterbachiana O.C.Schmidt or A. novoguineensis O.C.Schmidt			
530	Aristolochiaceae	Aristolochia tagala Cham.			
531	Asteraceae	Adenostemma lavenia (L.) Kuntze			
532	Asteraceae	Ageratum conyzoides L.			
533	Asteraceae	Bidens pilosa L.			
534	Asteraceae	Blumea arfakiana Martelli			
535	Asteraceae	Blumea riparia (Blume) DC.			
536	Asteraceae	Cosmos caudatus H.B.K.			
537	Asteraceae	Crassocephalum crepidioides (Benth.) S. Moore			
538	Asteraceae	Erechtites valerianifolia (Wolf) DC.	Erechtites valerianifolius (Wolf) DC.		
539	Asteraceae	Erigeron sumatrensis Retz.			
540	Asteraceae	Olearia sp.			
541	Asteraceae	Tagetes cf. patula L.	Tagetes erecta L.		
542	Asteraceae	Vernonia cuneata Less.	Decaneuropsis obovata (Gaudich.) H.Rob. & Skvarla		
543	Balanophoraceae	Balanophora papuana Schltr.			
544	Balsaminaceae	Impatiens hawkeri W.Bull			
545	Begoniaceae	Begonia brachybotrys Merr. & L.M.Perry			
546	Begoniaceae	Begonia kaniensis Irmscher			
547	Begoniaceae	Begonia papuana Warb.			
548	Begoniaceae	Begonia spp.			
549	Bignoniaceae	Neosepicaea viticoides Diels			
550	Bignoniaceae	Pandorea pandorana (Andrews) Steenis			
551	Bignoniaceae	Tecomanthe dendrophila (Blume) K. Schum.			
552	Bixaceae	Bixa orellana L.			
553	Boraginaceae	Tournefortia sarmentosa Lamk			
554	Brassicaceae	Rorippa nasturtium-aquaticum (L.) Hayek	Nasturtium officinale R.Br.		
555	Burseraceae	Canarium acutifolium (DC.) Merr.			
556	Burseraceae	Canarium indicum L.			
557	Burseraceae	Canarium maluense Lauterb.			
558	Burseraceae	Canarium oleosum Engl.			
559	Burseraceae	Canarium vitiense A. Gray			
560	Burseraceae	Haplolobus floribundus (K. Schum.) H.J. Lam			
561	Burseraceae	Santiria rubiginosa Blume			
562	Campanulaceae	Peracarpa carnosa (Wall.) Hook. & Thompson			
563	Capparaceae	Crateva religiosa G.Forst.			
564	Cardiopteridaceae	Citronella suaveolens (Blume) R.A.Howard			
565	Cardiopteridaceae	Gonocaryum litorale (Blume) Sleumer			
566	Caricaceae	Carica papaya L.			
567	Caryophyllaceae	Drymaria cordata (L.) Willd. ex Roemer & Schult			
568	Casuarinaceae	Gymnostoma papuana (S. Moore) L.A.S. Johnson	Gymnostoma papuanum (S. Moore) L.A.S. Johnson		
569	Celastraceae	Brassiantha pentamera A.C. Sm.			
570	Celastraceae	Perrottetia alpestris (Blume) Loes.		Dipentodontaceae	
571	Celastraceae	Salacia erythrocarpa K. Schum.			
572	Chloranthaceae	Ascarina philippinensis C.B. Rob.			
573	Chloranthaceae	Ascarina sp.			
574	Chloranthaceae	Chloranthus erectus (Buch.-Ham.) Verdc.	Chloranthus elatior Link		
575	Chloranthaceae	Sarcandra glabra (Thunb.) Nakai			
576	Chrysobalanaceae	Maranthes corymbosa Blume			
577	Chrysobalanaceae	Parastemon versteeghii Merr. & L.M.Perry			
578	Chrysobalanaceae	Parinari papuana C.T. White			
579	Clethraceae	Clethra canescens Reinw. ex Blume			
580	Clusiaceae	Calophyllum papuanum Lauterb.			
581	Clusiaceae	Calophyllum soulattri Burm.f.			
582	Clusiaceae	Calophyllum sp.			
583	Clusiaceae	Garcinia celebica L.	genus is under revision; all names may be subject to change		
584	Clusiaceae	Garcinia cymosa (K. Schum.) I.M. Turner & P.F. Stevens			
585	Clusiaceae	Garcinia dulcis (Roxb.) Kurz			
586	Clusiaceae	Garcinia hollrungii Lauterb.			
587	Clusiaceae	Garcinia hunsteinii Lauterb.			
588	Clusiaceae	Garcinia sp., sect. Cambogia			
589	Clusiaceae	Garcinia spp.			
590	Combretaceae	Combretum tetralophum C.B. Clarke			
591	Combretaceae	Combretum trifoliatum Vent.			
592	Combretaceae	Quisqualis indica L.	Combretum indicum (L.) DeFilipps		
593	Combretaceae	Terminalia canaliculata Exell			
594	Combretaceae	Terminalia complanata K. Schum.			
595	Combretaceae	Terminalia impediens Coode			
596	Combretaceae	Terminalia oreadum Diels			
597	Combretaceae	Terminalia rubiginosa K. Schum.			
598	Connaraceae	Connarus sp., "semidecandrus group"			
599	Connaraceae	Rourea minor (Gaertn.) Leenh.			
600	Connaraceae	Rourea radlkoferiana K. Schum.	Santaloides radlkoferanum (Schum.) G. Schellenb.		
601	Convolvulaceae	Ipomoea aquatica Forssk.			
602	Convolvulaceae	Ipomoea batatas (L.) Lam.			
603	Convolvulaceae	Ipomoea sp.			
604	Convolvulaceae	Lepistemon urceolatus F. Muell.	Lepistemon owariense (P. Beauv.) Hallier f.		
605	Convolvulaceae	Merremia gemella (Burm. f.) Hallier f.			
606	Convolvulaceae	Merremia peltata (L.) Merr.			
607	Convolvulaceae	Operculina sp.			
608	Cornaceae	Mastixia kaniensis Melch.			

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609	Crypteroniaceae	Crypteronia cumingii (Planch.) Planch. ex Endl.		Penaeaceae	
610	Cucurbitaceae	Benincasa hispida (Thunb.) Cogn.			
611	Cucurbitaceae	Citrullus vulgaris Schrad.	Citrullus lanatus (Thunb.) Matsum. & Nakai		
612	Cucurbitaceae	Cucumis sativus L.			
613	Cucurbitaceae	Neoalsomitra trifoliolata (F. Muell.) Hutch.	status uncertain, may be syn. of Neoalsomitra clavigera (M.Roem.) Hutch.		
614	Cucurbitaceae	Trichosanthes sp.			
615	Cucurbitaceae	Zanonia indica L.			
616	Cucurbitaceae	Zehneria sp.			
617	Cunoniaceae	Acsmithia reticulata (Schltr.) Hoogland			
618	Cunoniaceae	Aistopetalum multiflorum Schltr.			
619	Cunoniaceae	Aistopetalum viticoides Schltr.			
620	Cunoniaceae	Ceratopetalum succirubrum C.T. White			
621	Cunoniaceae	Gillbeea papuana Schltr.			
622	Cunoniaceae	Opocunonia nymanii (K. Schum.) Schltr.	status uncertain, may be syn. of Caldcluvia nymanii (K.Schum.) Hoogland		
623	Cunoniaceae	Pullea glabra Schltr.			
624	Cunoniaceae	Schizomeria sp.			
625	Cunoniaceae	Weinmannia fraxinea (D. Don) Miq.			
626	Cunoniaceae	Weinmannia urdanetensis Elmer			
627	Daphniphyllaceae	Daphniphyllum gracile Gage			
628	Datiscaceae	Octomeles sumatrana Miq.		Tetramelaceae	
629	Dichapetalaceae	Dichapetalum papuanum (Becc.) Boerl.			
630	Dichapetalaceae	Dichapetalum sp.			
631	Dilleniaceae	Dillenia castaneifolia (Miq.) Martelli ex Dur. & Jacks.			
632	Dilleniaceae	Dillenia montana Diels			
633	Dilleniaceae	Dillenia sp.			
634	Dilleniaceae	Tetracera lanuginosa Diels			
635	Dilleniaceae	Tetracera nordtiana F.Muell.			
636	Dipterocarpaceae	Anisoptera thurifera (Blanco) Blume			
637	Dipterocarpaceae	Hopea iriana Slooten			
638	Dipterocarpaceae	Hopea sp.			
639	Dipterocarpaceae	Vatica rassak (Korth.) Blume			
640	Ebenaceae	Diospyros buxifolia (Blume) Hiern.			
641	Ebenaceae	Diospyros fusicarpa Bakh.			
642	Ebenaceae	Diospyros papuana Valeton			
643	Ebenaceae	Diospyros sp. nov.			
644	Elaeocarpaceae	Aceratium brassii A.C. Sm.			
645	Elaeocarpaceae	Aceratium cf. ledermannii Schltr.			
646	Elaeocarpaceae	Aceratium oppositifolium DC.			
647	Elaeocarpaceae	Aceratium pittosporoides Schltr.			
648	Elaeocarpaceae	Elaeocarpus angustifolius Blume			
649	Elaeocarpaceae	Elaeocarpus bilobatus Schltr.			
650	Elaeocarpaceae	Elaeocarpus branderhorsti Pulle			
651	Elaeocarpaceae	Elaeocarpus culminicola Warb.			
652	Elaeocarpaceae	Elaeocarpus dolichodactylis Schltr.			
653	Elaeocarpaceae	Elaeocarpus dolichostylis Schltr.			
654	Elaeocarpaceae	Elaeocarpus ledermannii Schltr.			
655	Elaeocarpaceae	Elaeocarpus miegei Weibel			
656	Elaeocarpaceae	Elaeocarpus peistocarpus Schltr.			
657	Elaeocarpaceae	Elaeocarpus polydactylus Schltr.			
658	Elaeocarpaceae	Elaeocarpus prafiensis Weibel			
659	Elaeocarpaceae	Elaeocarpus schlechterianus A.C. Sm.			
660	Elaeocarpaceae	Elaeocarpus sepikanus Schltr.			
661	Elaeocarpaceae	Sericolea micans Schltr.			
662	Elaeocarpaceae	Sloanea cf. aberrans (Brandis) A.C. Sm.			
663	Elaeocarpaceae	Sloanea paradisearum F. Muell.			
664	Elaeocarpaceae	Sloanea pulchra (Schltr.) A.C. Sm.			
665	Elaeocarpaceae	Sloanea sogerensis Baker f.			
666	Elaeocarpaceae	Sloanea sp.			
667	Ericaceae	Dimorphanthera brevipes Schltr.			
668	Ericaceae	Dimorphanthera denticulifera Sleumer			
669	Ericaceae	Dimorphanthera kempteriana Schltr.			
670	Ericaceae	Diplycosia edulis Schltr.			
671	Ericaceae	Diplycosia morobeensis Sleumer			
672	Ericaceae	Diplycosia rufescens Schltr.			
673	Ericaceae	Rhododendron macgregoriae F. Muell.			
674	Ericaceae	Rhododendron zoelleri Warb.			
675	Ericaceae	Vaccinium finisterrae Schltr.			
676	Ericaceae	Vaccinium sp. A, sect. Oarianthe			
677	Ericaceae	Vaccinium sp. B, sect. Bracteata			
678	Erythroxylaceae	Erythroxylum ecarinatum Hochr.			
679	Euphorbiaceae	Acalypha hellwigii Warb.			
680	Euphorbiaceae	Acalypha longispica Warb.			
681	Euphorbiaceae	Actephila lindleyi (Steud.) Airy Shaw	Actephila discoidea Heijkoop & Welzen	Phyllanthaceae	
682	Euphorbiaceae	Agrostistachys borneensis Becc.			
683	Euphorbiaceae	Annesijoa novoguineensis Pax & K.Hoffm.			
684	Euphorbiaceae	Antidesma excavatum Miq.		Phyllanthaceae	
685	Euphorbiaceae	Antidesma rhynchophyllum K. Schum.		Phyllanthaceae	
686	Euphorbiaceae	Aporosa lamellata Airy Shaw		Phyllanthaceae	
687	Euphorbiaceae	Aporosa laxiflora Pax & K.Hoffm.		Phyllanthaceae	
688	Euphorbiaceae	Aporosa papuana Pax & K.Hoffm.		Phyllanthaceae	
689	Euphorbiaceae	Baccaurea papuana F.M. Bailey		Phyllanthaceae	
690	Euphorbiaceae	Breynia cernua (Poir.) Müll. Arg.		Phyllanthaceae	
691	Euphorbiaceae	Breynia vestita Warb.		Phyllanthaceae	
692	Euphorbiaceae	Bridelia penangiana Hook. f.	Bridelia insulana Hance	Phyllanthaceae	
693	Euphorbiaceae	Claoxylon sp.			
694	Euphorbiaceae	Cleistanthus sp.		Phyllanthaceae	
695	Euphorbiaceae	Codiaeum finisterrae Pax & K.Hoffm., or aff.			
696	Euphorbiaceae	Codiaeum variegatum (L.) Blume	Codiaeum variegatum (L.) Rumph. ex A.Juss.		
697	Euphorbiaceae	Croton muriculatus Airy Shaw			
698	Euphorbiaceae	Endospermum labios Schodde	Endospermum moluccanum (Teijsm. & Binn.) Kurz		
699	Euphorbiaceae	Euphorbia hirta L.			
700	Euphorbiaceae	Galearia celebica Koord.		Pandaceae	
701	Euphorbiaceae	Glochidion aff. chodrocarpum Airy Shaw		Phyllanthaceae	
702	Euphorbiaceae	Glochidion cf. fulvirameum Miq.		Phyllanthaceae	
703	Euphorbiaceae	Glochidion nesophilum Airy Shaw		Phyllanthaceae	
704	Euphorbiaceae	Glochidion novoguineense K. Schum.		Phyllanthaceae	
705	Euphorbiaceae	Glochidion perakense Hook. f.	Glochidion zeylanicum (Gaertn.) A.Juss.	Phyllanthaceae	
706	Euphorbiaceae	Glochidion sp. nov. aff. welzenii Takeuchi		Phyllanthaceae	
707	Euphorbiaceae	Macaranga aleuritoides F. Muell.			
708	Euphorbiaceae	Macaranga bifoveata J.J. Sm.			
709	Euphorbiaceae	Macaranga caudata Pax & K.Hoffm.			
710	Euphorbiaceae	Macaranga clavata Warb.			
711	Euphorbiaceae	Macaranga fallacina Pax & K.Hoffm.			
712	Euphorbiaceae	Macaranga gracilis Pax & K.Hoffm.			
713	Euphorbiaceae	Macaranga inermis Pax & K.Hoffm.			
714	Euphorbiaceae	Macaranga lanceolata Pax & K.Hoffm.			
715	Euphorbiaceae	Macaranga papuana (J.J. Sm.) Pax & K.Hoffm.			
716	Euphorbiaceae	Macaranga polyadenia Pax & K.Hoffm.			
717	Euphorbiaceae	Macaranga quadriglandulosa Warb.			
718	Euphorbiaceae	Macaranga reiteriana Pax & K.Hoffm.			
719	Euphorbiaceae	Macaranga strigosa Pax & K.Hoffm., or aff.			
720	Euphorbiaceae	Macaranga tessellata Gage			
721	Euphorbiaceae	Macaranga sp., "Longistipulata group"			
722	Euphorbiaceae	Mallotus floribundus (Blume) Müll. Arg.			
723	Euphorbiaceae	Mallotus paniculatus (Lam.) Müll. Arg.			
724	Euphorbiaceae	Mallotus peltatus (Geiseler) Müll. Arg.			
725	Euphorbiaceae	Mallotus penangensis Müll. Arg.	Hancea penangensis (Müll.Arg.) S.E.C.Sierra, Kulju & Welzen		
726	Euphorbiaceae	Mallotus repandus (Willd.) Müll.Arg.			
727	Euphorbiaceae	Mallotus sp.			
728	Euphorbiaceae	Manihot esculenta Crantz			
729	Euphorbiaceae	Melanolepis multiglandulosa (Blume) Rchb. f. & Zoll.			
730	Euphorbiaceae	Octospermum pleiogynum (Pax & K.Hoffm.) Airy Sh	Mallotus pleiogynus Pax & K.Hoffm.		

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731	Euphorbiaceae	Omalanthus novoguineensis (Warb.) K. Schum.			
732	Euphorbiaceae	Phyllanthus ciccoides Müll. Arg.		Phyllanthaceae	
733	Euphorbiaceae	Phyllanthus clamboides (F. Muell.) Diels		Phyllanthaceae	
734	Euphorbiaceae	Phyllanthus rheophilus Airy Shaw		Phyllanthaceae	
735	Euphorbiaceae	Pimelodendron amboinicum Hassk.			
736	Euphorbiaceae	Spathiostemon javensis Blume			
737	Euphorbiaceae	Syndrella? sp.			
738	Euphorbiaceae	Wetria insignis (Steud.) Airy Shaw			
739	Fabaceae	Abrus precatorius L.			
740	Fabaceae	Adenanthera novoguineensis Baker f.			
741	Fabaceae	Arachis hypogaea L.			
742	Fabaceae	Archidendron aruense (Warb.) de Wit			
743	Fabaceae	Archidendron clypearia (Jack) I.C.Nielsen			
744	Fabaceae	Archidendron lucyi F. Muell.			
745	Fabaceae	Archidendron sp. nov., aff. A. bellum Harms	Archidendron calliandrum de Wit; distr. record for northern PNG		Takeuchi, W. 2012. Modern sequels to the Kaiserin-Augusta-Fluss itinerary of Carl Ledermann: floristic discoveries from the upper Sepik of Papua New Guinea. Phytotaxa 60: 17–31.
746	Fabaceae	Cassia alata L.	Senna alata (L.) Roxb.		
747	Fabaceae	Clitoria ternatea L.			
748	Fabaceae	Crotalaria pallida Aiton			
749	Fabaceae	Dahlbergia spp.			
750	Fabaceae	Derris elegans Grah. ex Benth.			
751	Fabaceae	Derris sp.			
752	Fabaceae	Desmodium ormocarpoides DC.			
753	Fabaceae	Desmodium sp.			
754	Fabaceae	Entada pursaetha DC.	Entada rheedii Spreng.		
755	Fabaceae	Erythrina variegata L.			
756	Fabaceae	Inocarpus fagifer (Parkinson) Fosberg			
757	Fabaceae	Intsia bijuga (Colebr.) Kuntze			
758	Fabaceae	Kingiodendron alternifolium (Elmer) Merr. & Rolfe			
759	Fabaceae	Leucaena leucocephala (Lam.) de Wit			
760	Fabaceae	Maniltoa megacephala Harms			
761	Fabaceae	Maniltoa plurijuga Merr. & L.M.Perry			
762	Fabaceae	Maniltoa psilogyne Harms			
763	Fabaceae	Maniltoa schefferi K. Schum. & Hollrung			
764	Fabaceae	Milletia pinnata (L.) Panigrahi			
765	Fabaceae	Mimosa pudica L.			
766	Fabaceae	Mucuna cyanosperma K. Schum.	Mucuna mollissima Kurz		
767	Fabaceae	Mucuna novo-guineensis Scheff.			
768	Fabaceae	Paraserianthes falcataria (L.) Nielsen	Falcataria moluccana (Miq.) Barneby & J.W.Grimes		
769	Fabaceae	Phaseolus vulgaris L.			
770	Fabaceae	Pterocarpus indicus Willd.			
771	Fabaceae	Pueraria pulcherrima Merr. ex Koord.-Schum.			
772	Fabaceae	Pueraria triloba sensu Makino	Pueraria montana var. lobata (Willd.) Sanjappa & Pradeep		
773	Fabaceae	Rhynchosia acuminatissima Miq.			
774	Fabaceae	Strongylodon siderospermus Cordemoy	Strongylodon lucidus (G.Forst.) Seem.		
775	Fabaceae	Tephrosia vogelii Hook. f.			
776	Fabaceae	Tephrosia sp.			
777	Fagaceae	Castanopsis acuminatissima (Blume) A. DC.			
778	Fagaceae	Lithocarpus celebicus (Miq.) Rehder			
779	Fagaceae	Lithocarpus rufovillosus (Markgr.) Rehder			
780	Fagaceae	Nothofagus flaviramea Steenis		Nothofagaceae	
781	Gesneriaceae	Aeschynanthus spp.			
782	Gesneriaceae	Agalmyla sp.			
783	Gesneriaceae	Cyrtandra bracteata Warb.	genus under revision; all names may be subject to change		
784	Gesneriaceae	Cyrtandra cf. decurrens de Vriese			
785	Gesneriaceae	Cyrtandra fuscovellea K. Schum.			
786	Gesneriaceae	Cyrtandra hispidissima Schltr.			
787	Gesneriaceae	Cyrtandra janowskyi Schltr., or aff.			
788	Gesneriaceae	Cyrtandra schumanniana Schltr.			
789	Gesneriaceae	Cyrtandra sp. nov. A			cannot publish bc genus under revision by colleagues
790	Gesneriaceae	Cyrtandra sp. B, sect. Geodesme			
791	Gesneriaceae	Cyrtandra spp.			
792	Goodeniaceae	Scaevola oppositifolia R. Br.	Scaevola oppositifolia Roxb.		
793	Haloragaceae	Gonocarpus halconensis (Merr.) Orchard			
794	Haloragaceae	Gunnera macrophylla Blume		Gunneraceae	
795	Hernandiaceae	Hernandia ovigera L.	Hernandia guianensis Aubl.		
796	Himantandraceae	Galbulimima belgraveana (F. Muell.) Sprague			
797	Icacinaceae	Platea excelsa Blume			
798	Icacinaceae	Polyporandra scandens Becc.			
799	Icacinaceae	Rhyticaryum longifolium K.Schum. & Lauterb.			
800	Icacinaceae	Rhyticaryum novoguineense (Warb.) Sleumer			
801	Ixonanthaceae	Ixonanthes reticulata Jack			
802	Juglandaceae	Engelhardia rigida Blume			
803	Lamiaceae	Callicarpa longifolia Lam.			
804	Lamiaceae	Clerodendrum buruanum Miq.	Clerodendrum tracyanum (F.Muell.) Benth.		
805	Lamiaceae	Clerodendrum porphyrocalyx K.Schum. & Lauterb.			
806	Lamiaceae	Clerodendrum tracyanum (F. Muell.) Benth.			
807	Lamiaceae	Faradaya splendida F. Muell.			
808	Lamiaceae	Geunsia pentandra (Roxb.) Merr.	Callicarpa pentandra Roxb.		
809	Lamiaceae	Gmelina cf. ledermanni H.J. Lam			
810	Lamiaceae	Gmelina cf. moluccana Backer ex K. Heyne			
811	Lamiaceae	Hyptis capitata Jacq.			
812	Lamiaceae	Ocimum gratissimum L.			
813	Lamiaceae	Petraeovitex multiflora Merr.			
814	Lamiaceae	Plectranthus sp.			
815	Lamiaceae	Premna serratifolia L.			
816	Lamiaceae	Stachytarpheta jamaicensis (L.) Vahl		Verbenaceae	
817	Lamiaceae	Teijsmanniodendron ahernianum (Merr.) Bakh.			
818	Lamiaceae	Vitex cofassus Reinw. ex Blume			
819	Lauraceae	Actinodaphne nitida Teschner			
820	Lauraceae	Actinodaphne tomentosa Teschner			
821	Lauraceae	Alseodaphne sp.			
822	Lauraceae	Beilschmiedia acutifolia Teschner			
823	Lauraceae	Cinnamomum eugenoliferum Kosterm.			
824	Lauraceae	Cinnamomum spp.			
825	Lauraceae	Cryptocarya multipaniculata Teschner, or aff.			
826	Lauraceae	Cryptocarya cf. pusilla Teschner			
827	Lauraceae	Cryptocarya spp.			
828	Lauraceae	Endiandra sp.			
829	Lauraceae	Litsea guppyi (F. Muell.) F. Muell. ex Forman			
830	Lauraceae	Litsea ledermannii Teschner			
831	Lauraceae	Litsea spp.			
832	Lauraceae	Persea americana Mill.			
833	Lauraceae	Phoebe forbesii Gamble			
834	Lecythidaceae	Barringtonia acutangula (L.) Gaertn.			
835	Lecythidaceae	Barringtonia calyptrata (Miers.) R. Br. ex. Benth.			
836	Lecythidaceae	Barringtonia calyptrocalyx K. Schum.			
837	Lecythidaceae	Barringtonia josephstaalensis Takeuchi			
838	Lecythidaceae	Barringtonia papuana Lauterb.			
839	Lecythidaceae	Barringtonia sepikensis Lauterb.	Barringtonia apiculata Lauterb.		
840	Lecythidaceae	Planchonia papuana Merr. & L.M.Perry	Planchonia papuana R.Knuth		
841	Lentibulariaceae	Utricularia striatula Sm.			
842	Linaceae	Hugonia jenkinsii F.Muell.	status uncertain, may be syn. of Durandea jenkinsii (F.Muell.) Stapf		
843	Loganiaceae	Fagraea amabilis S. Moore	Fagraea gracilipes A.Gray	Gentianaceae	
844	Loganiaceae	Fagraea berteroana A. Gray ex Benth.		Gentianaceae	
845	Loganiaceae	Fagraea bodenii Wernham		Gentianaceae	
846	Loganiaceae	Fagraea ceilanica Thunb.		Gentianaceae	
847	Loganiaceae	Fagraea elliptica Roxb.	Picrophloeus javanensis Blume	Gentianaceae	
848	Loganiaceae	Fagraea racemosa Jack	Utania racemosa (Jack) Sugumaran	Gentianaceae	
849	Loganiaceae	Geniostoma rupestre J.R.Forst. & G.Forst.			
850	Loganiaceae	Geniostoma weinlandii K. Schum.			
851	Loganiaceae	Neuburgia corynocarpa (A. Gray) Leenh.			
852	Loganiaceae	Neuburgia rumphiana Leenh.			
853	Loganiaceae	Strychnos axillaris Colebr.			

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854	Loganiaceae	Strychnos minor Dennst.			
855	Loranthaceae	Amyema friesiana (K. Schum.) Danser			
856	Loranthaceae	Amyema seemeniana (K. Schum.) Danser			
857	Loranthaceae	Amyema squarrosa Danser			
858	Loranthaceae	Cecarria obtusifolia (Merr.) Barlow			
859	Loranthaceae	Decaisnina hollrungii (K. Schum.) Barlow			
860	Loranthaceae	Decaisnina sp.			
861	Loranthaceae	Dendrophthoe curvata (Blume) Miq.			
862	Loranthaceae	Macrosolen cochinchinensis (Lour.) Tiegh.			
863	Lythraceae	Lagerstroemia piriformis Koehne			
864	Magnoliaceae	Elmerrillia tsiampacca (L.) Dandy	Magnolia tsiampacca (L.) Figlar & Noot.		
865	Malpighiaceae	Ryssopterys timoriensis (DC.) Blume ex A.Juss.	Stigmaphyllon mariae C.E.Anderson		
866	Malvaceae	Abroma augusta L.			
867	Malvaceae	Commersonia bartramia (L.) Merr.			
868	Malvaceae	Hibiscus archboldianus Borss. Waalk.	Talipariti archboldianum (Borss. Waalk.) Fryxell		
869	Malvaceae	Hibiscus cf. d'albertisii F. Muell.	Talipariti dalbertisii (F. Muell.) Fryxell		
870	Malvaceae	Hibiscus ellipticifolius Borss. Waalk.	Talipariti ellipticifolium (Borss. Waalk.) Fryxell		
871	Malvaceae	Hibiscus rosa-sinensis L.			
872	Malvaceae	Hibiscus tiliaceus L.	Talipariti tiliaceum (L.) Fryxell		
873	Malvaceae	Kleinhovia hospita L.			
874	Malvaceae	Melochia umbellata (Houtt.) Stapf.			
875	Malvaceae	Microcos chrysothyrsa Burret			
876	Malvaceae	Microcos grandiflora Burret			
877	Malvaceae	Pterocymbium beccarii K. Schum.			
878	Malvaceae	Sida rhombifolia L.			
879	Malvaceae	Sterculia ampla Baker f.			
880	Malvaceae	Sterculia macrophylla Vent.			
881	Malvaceae	Sterculia schumanniana (Lauterb.) Mildbr.			
882	Malvaceae	Sterculia shillinglawii F.Muell.			
883	Malvaceae	Theobroma cacao L.			
884	Malvaceae	Thespesia populnea (L.) Solander ex Correa			
885	Malvaceae	Trichospermum pleiostigma (F. Muell.) Kosterm.			
886	Malvaceae	Triumfetta pilosa Roth			
887	Melastomataceae	Astronia atroviridis Mansf.			
888	Melastomataceae	Astronia crassiloba J.F. Maxwell			
889	Melastomataceae	Astronia grandiflora J.F. Maxwell			
890	Melastomataceae	Astronia hollrungii Cogn.			
891	Melastomataceae	Astronia rugata J.F. Maxwell			
892	Melastomataceae	Astronia sp.			
893	Melastomataceae	Beccarianthus sp. A			
894	Melastomataceae	Beccarianthus sp. B			
895	Melastomataceae	Catanthera longistylis (Mansf.) Nayar			
896	Melastomataceae	Catanthera paniculata (Nayar) Nayar			
897	Melastomataceae	Catanthera sp. nov.			
898	Melastomataceae	Creochiton novoguineensis (Baker f.) Veldkamp & Nayar			
899	Melastomataceae	Creochiton sp. nov.			cannot be described without anthetic flowers
900	Melastomataceae	Diplectria divaricata (Willd.) Kuntze			
901	Melastomataceae	Dissochaeta angiensis Ohwi	Dissochaeta angiensis Kaneh. & Hatus. ex Ohwi		
902	Melastomataceae	Dissochaeta schumannii Cogn.			
903	Melastomataceae	Medinilla auriculata Lauterb., or aff.			
904	Melastomataceae	Medinilla aff. compacta Bakh. f.			
905	Melastomataceae	Medinilla dentata Veldkamp			
906	Melastomataceae	Medinilla rubrifructus Ohwi			
907	Melastomataceae	Medinilla teysmannii Miq.			
908	Melastomataceae	Medinilla triplinervia Cogn.			
909	Melastomataceae	Medinilla versteegii Mansf.			
910	Melastomataceae	Medinilla sp. A, aff. M. maluensis Mansf.			
911	Melastomataceae	Medinilla sp. nov. B, sect. Heteroblemma	Heteroblemma barbatum (Bakh.f.) Cámara-Leret , Ridd.-Num. & Veldkamp		R. Cámara-Leret, J.W.A. Ridder-Numan, J.F. Veldkamp. 2013. Revision of Heteroblemma gen. nov. (Dissochaeteae – Melastomataceae) from Malesia and Vietnam. Blumea 58: 229-240.
912	Melastomataceae	Medinilla sp. nov. C, sect. Heteroblemma	Heteroblemma cf. barbatum (Bakh.f.) Cámara-Leret , Ridd.-Num. & Veldkamp		
913	Melastomataceae	Medinilla sp. D, "quadrifolia group"			
914	Melastomataceae	Melastoma malabathricum L.			
915	Melastomataceae	Memecylon cf. schraderbergense Mansf.			
916	Melastomataceae	Poikilogyne cordifolia (Cogn.) Mansf.			
917	Melastomataceae	Poikilogyne multiflora J.F. Maxwell			
918	Melastomataceae	Pternandra cf. galeata (Korth.) Ridl.			
919	Melastomataceae	Sonerila papuana Cogn.			
920	Melastomataceae	genus nov.			cannot be published; flowers unknown.
921	Meliaceae	Aglaia agglomerata Merr. & L.M.Perry			
922	Meliaceae	Aglaia argentea Blume			
923	Meliaceae	Aglaia euryanthera Harms			
924	Meliaceae	Aglaia lawii (Wight) C.J.Saldanha ex Ramamoorthy			
925	Meliaceae	Aglaia cf. lepiorrhachis Harms			
926	Meliaceae	Aglaia rimosa (Blanco) Merr.			
927	Meliaceae	Aglaia sapindina (F. Muell.) Harms			
928	Meliaceae	Aglaia subcuprea Merr. & L.M.Perry			
929	Meliaceae	Aglaia subminutiflora C. DC.			
930	Meliaceae	Aglaia tomentosa Teijsm. & Binn.			
931	Meliaceae	Anthocarapa nitidula (Benth.) T.D. Penn. ex Mabb.			
932	Meliaceae	Aphanamixis polystachya (Wall.) R.Parker			
933	Meliaceae	Chisocheton ceramicus Miq.			
934	Meliaceae	Chisocheton lasiocarpus (Miq.) Valeton, entity "weinlandi"			
935	Meliaceae	Chisocheton pohlianus Harms			
936	Meliaceae	Chisocheton sp. nov., aff. pachyrhachis Harms			
937	Meliaceae	Dysoxylum acutangulum Miq.			
938	Meliaceae	Dysoxylum alliaceum (Blume) Blume			
939	Meliaceae	Dysoxylum arborescens (Blume) Miq.			
940	Meliaceae	Dysoxylum brevipaniculum C. DC.			
941	Meliaceae	Dysoxylum excelsum Blume			
942	Meliaceae	Dysoxylum gaudichaudianum (A. Juss.) Miq.			
943	Meliaceae	Dysoxylum latifolium Benth.			
944	Meliaceae	Dysoxylum papuanum (Merr. & L.M.Perry) Mabb.			
945	Meliaceae	Dysoxylum parasiticum (Osbeck) Kosterm.			
946	Meliaceae	Dysoxylum sparsiflorum Mabb.			
947	Meliaceae	Dysoxylum variabile Harms			
948	Meliaceae	Vavaea amicorum Benth.			
949	Menispermaceae	Chlaenandra ovata Miq.			
950	Menispermaceae	Hypserpa polyandra Becc.			
951	Menispermaceae	Legnephora minutiflora Diels	status uncertain, may be syn. of Tinospora minutiflora K.Schum.		
952	Menispermaceae	Macrococculus pomiferus Becc.			
953	Menispermaceae	Parabaena tuberculata Becc.			
954	Menispermaceae	Pycnarrhena tumefacta Miers			
955	Menispermaceae	Stephania japonica (Thunb.) Miers			
956	Menispermaceae	Stephania zippeliana Miq.			
957	Menispermaceae	Tinospora dissitiflora Diels			
958	Monimiaceae	Kairoa villosa (Kaneh. & Hatus.) S.S.Renner & W.N.Takeuchi			
959	Monimiaceae	Kibara sp. nov.			
960	Monimiaceae	Kibara sp. A			
961	Monimiaceae	Levieria montana Becc.			
962	Monimiaceae	Palmeria arfakiana Becc.			
963	Monimiaceae	Palmeria hypargyrea Perkins			
964	Monimiaceae	Steganthera dentata (Valeton) Kaneh. & Hatus.			
965	Monimiaceae	Steganthera hirsuta Perkins			
966	Monimiaceae	Steganthera hospitans (Becc.) Kaneh. & Hatus.			
967	Moraceae	Antiaropsis decipiens K. Schum.			
968	Moraceae	Artocarpus altilis (Parkinson) Fosberg			
969	Moraceae	Artocarpus vriesianus Miq.			
970	Moraceae	Broussonetia papyrifera (L.) Vent.			
971	Moraceae	Ficus adelpha K.Schum. & Lauterb.			
972	Moraceae	Ficus cf. adenosperma Miq.			
973	Moraceae	Ficus arbuscula K.Schum. & Lauterb.			
974	Moraceae	Ficus arfakensis King			

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975	Moraceae	Ficus aff. aurita Blume			
976	Moraceae	Ficus botryocarpa Miq.			
977	Moraceae	Ficus casearioides King			
978	Moraceae	Ficus chrysolepis Miq.			
979	Moraceae	Ficus copiosa Steud.			
980	Moraceae	Ficus disticha Blume			
981	Moraceae	Ficus glandulifera Wall. ex Miq.			
982	Moraceae	Ficus gul K.Schum. & Lauterb.			
983	Moraceae	Ficus gymnorygma Summerh.			
984	Moraceae	Ficus cf. megalophylla Diels			
985	Moraceae	Ficus microcarpa L. f.			
986	Moraceae	Ficus mollior F. Muell. ex Benth.			
987	Moraceae	Ficus nasuta Summerh.			
988	Moraceae	Ficus nodosa Teijsm. & Binn.			
989	Moraceae	Ficus odoardii King			
990	Moraceae	Ficus phatnophylla Diels			
991	Moraceae	Ficus pungens Reinw. ex Blume			
992	Moraceae	Ficus septica Burm. f.			
993	Moraceae	Ficus subcuneata Miq.			
994	Moraceae	Ficus subtrinervia K.Schum. & Lauterb.			
995	Moraceae	Ficus subulata Blume			
996	Moraceae	Ficus trachypison K. Schum. & Lauterb.			
997	Moraceae	Ficus virgata Reinw. ex Blume			
998	Moraceae	Ficus wassa Roxb.			
999	Moraceae	Ficus sp., "augusta facies"			
1000	Moraceae	Ficus sp. A			
1001	Moraceae	Ficus sp. B			
1002	Moraceae	Parartocarpus venenosus (Zoll. & Moritzi) Becc.	Parartocarpus venenosa Becc.		
1003	Moraceae	Prainea scandens King ex Hook. f.			
1004	Moraceae	Streblus glaber (Merr.) Corner			
1005	Moraceae	Trophis scandens (Lour.) Hook. & Arn.	Alchornea scandens (Lour.) Müll.Arg.	Euphorbiaceae	
1006	Myristicaceae	Endocomia macrocoma (Miq.) W.J.de Wilde			
1007	Myristicaceae	Gymnacranthera farquhariana Warb.	Gymnacranthera farquhariana var. zippeliana (Miq.) R.T.A.Schouten		
1008	Myristicaceae	Horsfieldia ampliformis W.J.de Wilde			
1009	Myristicaceae	Horsfieldia basifissa W.J.de Wilde			
1010	Myristicaceae	Horsfieldia laevigata Warb.			
1011	Myristicaceae	Horsfieldia pilifera Markgr.			
1012	Myristicaceae	Horsfieldia schlechteri Warb.			
1013	Myristicaceae	Horsfieldia sepikensis Markgr.			
1014	Myristicaceae	Horsfieldia subtilis (Miq.) Warb.			
1015	Myristicaceae	Horsfieldia sylvestris Warb.			
1016	Myristicaceae	Myristica buchneriana Warb.			
1017	Myristicaceae	Myristica cornutiflora J. Sinclair			
1018	Myristicaceae	Myristica dasyneura W.J.de Wilde			
1019	Myristicaceae	Myristica fusca Markgr.			
1020	Myristicaceae	Myristica globosa Warb.			
1021	Myristicaceae	Myristica lancifolia Poir.			
1022	Myristicaceae	Myristica subalulata Miq.			
1023	Myristicaceae	Myristica spp.			
1024	Myrsinaceae	Ardisia forbesii S. Moore		Primulaceae	
1025	Myrsinaceae	Ardisia imperialis K. Schum.	Ardisia imperialis var. novoguineensis(Mez) C.M.Hu	Primulaceae	
1026	Myrsinaceae	Ardisia laciniata Mez		Primulaceae	
1027	Myrsinaceae	Ardisia ternatensis Scheff.		Primulaceae	
1028	Myrsinaceae	Ardisia sp. nov. A, aff. A. forbesii S. Moore		Primulaceae	
1029	Myrsinaceae	Ardisia sp. nov. B, aff. A. sogerensis S. Moore		Primulaceae	
1030	Myrsinaceae	Ardisia sp. C		Primulaceae	
1031	Myrsinaceae	Conandrium polyanthum (Lauterb. & K. Schum.) Mez		Primulaceae	
1032	Myrsinaceae	Discocalyx latepetiolata (Mez) Sleumer		Primulaceae	
1033	Myrsinaceae	Discocalyx sp. nov., aff. D. orthioneura K. Schum.	rediscovery of Discocalyx pygmaea Kaneh. & Hatus., previously known only from the Cycloop Mts. type coll.	Primulaceae	
1034	Myrsinaceae	Embelia cotinoides (S. Moore) Merr.		Primulaceae	
1035	Myrsinaceae	Fittingia tubiflora Mez		Primulaceae	
1036	Myrsinaceae	Maesa haplobotrys F. Muell.		Primulaceae	
1037	Myrsinaceae	Maesa montiswilhelmi P. Royen		Primulaceae	
1038	Myrsinaceae	Myrsine acrosticta (Mez) Pipoly		Primulaceae	
1039	Myrsinaceae	Myrsine coriifolia (Sleumer) Pipoly		Primulaceae	
1040	Myrsinaceae	Myrsine leucantha (K. Schum.) Pipoly		Primulaceae	
1041	Myrtaceae	Decaspermum bracteatum (Roxb.) A.J. Scott			
1042	Myrtaceae	Decaspermum sp.			
1043	Myrtaceae	Kania eugenioides Schltr.			
1044	Myrtaceae	Metrosideros eugenioides (Schltr.) Steenis	Kania eugenioides Schltr.		
1045	Myrtaceae	Metrosideros ramiflora Lauterb.			
1046	Myrtaceae	Octamyrtus behrmannii Diels			
1047	Myrtaceae	Octamyrtus pleiopetala (F. Muell.) Diels			
1048	Myrtaceae	Psidium guajava L.			
1049	Myrtaceae	Rhodomyrtus trineura (F.Muell.) Benth.			
1050	Myrtaceae	Syzygium buettnerianum (K. Schum.) Niedenzu			
1051	Myrtaceae	Syzygium cladopterum (Diels) Merr. & L.M.Perry			
1052	Myrtaceae	Syzygium dictyophlebium Merr. & L.M.Perry	Syzygium sayeri (F.Muell.) B.Hyland		
1053	Myrtaceae	Syzygium effusum (A.Gray) Müll.Berol.			
1054	Myrtaceae	Syzygium fastigiatum (Blume) Merr. & L.M.Perry			
1055	Myrtaceae	Syzygium furfuraceum Merr. & L.M.Perry			
1056	Myrtaceae	Syzygium aff. hemilamprum (F.Muell.) Craven & Biffin			
1057	Myrtaceae	Syzygium cf. hylophilum (K.Schum. & Lauterb.) Merr. & L.M.Perry			
1058	Myrtaceae	Syzygium kipidamasii Takeuchi			
1059	Myrtaceae	Syzygium lagerstroemioides Merr. & L.M.Perry			
1060	Myrtaceae	Syzygium longipes Merr. & L.M.Perry			
1061	Myrtaceae	Syzygium malaccense (L.) Merr. & L.M.Perry			
1062	Myrtaceae	Syzygium pachycladum (K.Schum. & Lauterb.) Merr. & L.M.Perry			
1063	Myrtaceae	Syzygium plumeum (Ridl.) Merr. & L.M.Perry			
1064	Myrtaceae	Syzygium tympananthum (Diels) Merr. & L.M.Perry			
1065	Myrtaceae	Syzygium versteegii (Lauterb.) Merr. & L.M.Perry			
1066	Myrtaceae	Syzygium xylopiaceum (Diels) Merr. & L.M.Perry			
1067	Myrtaceae	Syzygium spp.			
1068	Myrtaceae	Xanthomyrtus cf. polyclada Diels			
1069	Myrtaceae	Xanthomyrtus schlechteri Diels			
1070	Myrtaceae	Xanthomyrtus scolopacina (Ridl.) Diels			
1071	Nepenthaceae	Nepenthes ampullaria Jack			
1072	Nepenthaceae	Nepenthes mirabilis (Lour.) Druce			
1073	Nepenthaceae	Nepenthes neoguineensis Macfarl.			
1074	Nyctaginaceae	Pisonia longirostris Teijsm. & Binn.			
1075	Ochnaceae	Schuurmansia henningsii K. Schum.			
1076	Oleaceae	Chionanthus oxycarpus (Lingelsh.) Kiew	Chionanthus polygamus (Roxb.) Kiew		
1077	Oleaceae	Chionanthus ramiflorus Roxb.			
1078	Oleaceae	Chionanthus salicifolius (Lingelsh.) Kiew			
1079	Oleaceae	Chionanthus sessiliflorus (Hemsl.) Kiew			
1080	Oleaceae	Jasminum schumannii Lingelsh.	Jasminum gilgianum K.Schum.		
1081	Oleaceae	Jasminum turneri C.T. White	Jasminum longipetalum King & Gamble		
1082	Onagraceae	Ludwigia adscendens (L.) H.Hara			
1083	Onagraceae	Ludwigia hyssopifolia (D. Don) Exell			
1084	Onagraceae	Ludwigia octovalvis (Jacq.) P.H.Raven			
1085	Opiliaceae	Cansjera leptostachya Benth.			
1086	Opiliaceae	Opilia amentacea Roxb.			
1087	Oxalidaceae	Averrhoa bilimbi L.			
1088	Oxalidaceae	Averrhoa carambola L.			
1089	Oxalidaceae	Oxalis corniculata L.			
1090	Passifloraceae	Adenia heterophylla (Blume) Koord.			
1091	Passifloraceae	Hollrungia aurantioides K. Schum.	Passiflora aurantioides (K.Schum.) Krosnick		
1092	Passifloraceae	Passiflora foetida L.			
1093	Pentaphragmataceae	Pentaphragma grandiflorum Kurz			
1094	Piperaceae	Peperomia pellucida (L.) Kunth			
1095	Piperaceae	Piper amboinense (Miq.) C. DC.			
1096	Piperaceae	Piper betle L.			

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1097	Piperaceae	Piper caninum Blume			
1098	Piperaceae	Piper celtidiforme Opiz, or aff.			
1099	Piperaceae	Piper decumanum L.			
1100	Piperaceae	Piper interruptum Opiz			
1101	Piperaceae	Piper macropiper Pennant			
1102	Piperaceae	Piper majusculum Blume			
1103	Piperaceae	Piper mestonii F.M. Bailey			
1104	Piperaceae	Piper novo-guineense Warb.			
1105	Piperaceae	Piper pseudoamboinense C. DC.			
1106	Piperaceae	Piper rodatzii K. Schum. & Lauterb.			
1107	Piperaceae	Piper versteegii C. DC.			
1108	Pittosporaceae	Pittosporum pullifolium Burkill			
1109	Pittosporaceae	Pittosporum ramiflorum Zoll.ex Miq.			
1110	Pittosporaceae	Pittosporum sinuatum Blume			
1111	Polygalaceae	Epirixanthes cf. papuana J.J. Sm.			
1112	Polygalaceae	Eriandra fragrans P. Royen & Steenis			
1113	Polygalaceae	Polygala paniculata L.			
1114	Polygalaceae	Securidaca ecristata Kassau	Securidaca cacumina Wurdack		
1115	Polygalaceae	Xanthophyllum papuanum Whitm. ex Meijden			
1116	Polygonaceae	Polygonum chinense L.	Persicaria chinensis (L.) H. Gross		
1117	Polyosmaceae	Polyosma cf. cestroides Schltr.		Escalloniaceae	
1118	Polyosmaceae	Polyosma cf. dentata Schltr.		Escalloniaceae	
1119	Polyosmaceae	Polyosma integrifolia Blume		Escalloniaceae	
1120	Polyosmaceae	Polyosma sp.		Escalloniaceae	
1121	Portulacaceae	Portulaca oleracea L.			
1122	Proteaceae	Helicia odorata Diels			
1123	Proteaceae	Helicia oreadum Diels			
1124	Proteaceae	Helicia sp. nov., aff. H. macrostachya Lauterb.	*Helicia woxvoldiana*		New Guinea: Helicia woxvoldiana sp. nov. (Proteaceae), a large-flowered myrmecophyte from the upper Sepik. Phytotaxa 172: 94–100.
1125	Rhamnaceae	Alphitonia excelsa (Fenzl) Reiss.ex Endl.			
1126	Rhamnaceae	Alphitonia macrocarpa Mansf.			
1127	Rhamnaceae	Berchemia sp.			
1128	Rhamnaceae	Emmenosperma alphitonoides F. Muell.			
1129	Rhamnaceae	Gouania microcarpa DC.			
1130	Rhamnaceae	Rhamnus nipalensis (Wall.) Lawson ex Hook.	Rhamnus napalensis (Wall.) M.A.Lawson		
1131	Rhamnaceae	Zizyphus angustifolius (Miq.) Hatus.	Ziziphus angustifolia (Miq.) Hatus. ex Steenis	Cannabaceae	
1132	Rhamnaceae	Zizyphus papuanus Lauterb.	Ziziphus papuana Lauterb.	Cannabaceae	
1133	Rhizophoraceae	Carallia brachiata (Lour.) Merr.			
1134	Rhizophoraceae	Gynotroches axillaris Blume			
1135	Rosaceae	Prunus arborea (Blume) Kalkman			
1136	Rosaceae	Prunus dolichobotrys (Lauterb. & K. Schum.) Kalkman			
1137	Rosaceae	Prunus gazelle-peninsulae (Kaneh. & Hatus.) Kalkman			
1138	Rosaceae	Prunus osiana Takeuchi			
1139	Rosaceae	Prunus cf. pullei (Koehne) Kalkman			
1140	Rosaceae	Rubus moluccanus L.			
1141	Rosaceae	Rubus schlechteri (Koehne) Kalkman	Prunus schlechteri (Koehne) Kalkman (ENTERED INCORRECTLY AS RUBUS)		
1142	Rousseaceae	Carpodetus arboreus (Lauterb. & K. Schum.) Schltr.			
1143	Rubiaceae	Airosperma grandifolia Valeton	Airosperma grandifolia (Valeton) Takeuchi & Arifiani		Takeuchi & Arifiana in press, Harvard Pap. Bot.
1144	Rubiaceae	Amaracarpus brassii Merr. & L.M.Perry			
1145	Rubiaceae	Andira pseudoixoraeflora Ridsdale	nomen nudum; invalid name		
1146	Rubiaceae	Antirhea sp.			
1147	Rubiaceae	Argostemma bryophilum K. Schum.			
1148	Rubiaceae	Argostemma cf. callitrichum Valeton			
1149	Rubiaceae	Atractocarpus decorus (Valeton) Puttock			
1150	Rubiaceae	Atractocarpus macarthurii (F. Muell.) Puttock			
1151	Rubiaceae	Atractocarpus sessilis (F. Muell.) Puttock			
1152	Rubiaceae	Caelospermum salomoniense (Engl.) J.T. Johansso	Coelospermum salomoniense (Engl.) J.T.Johanss.		
1153	Rubiaceae	Coffea arabica L.			
1154	Rubiaceae	Coptosapelta fuscescens Valeton			
1155	Rubiaceae	Coptosapelta hameliaeblasta (Wernham) Valeton			
1156	Rubiaceae	Coptosapelta cf. maluensis Valeton			
1157	Rubiaceae	Cyclophyllum cf. caudatum (Valeton) A.P. Davis & Ruhsam			
1158	Rubiaceae	Cyclophyllum cf. longiflorum (Valeton) A.P. Davis & Ruhsam			
1159	Rubiaceae	Dolicholobium gertrudis K. Schum.			
1160	Rubiaceae	Dolicholobium linearilobum M.E. Jansen			
1161	Rubiaceae	Dolicholobium oxylobum K. Schum. & Lauterb.			
1162	Rubiaceae	Gardenia gjellerupii Valeton			
1163	Rubiaceae	Gardenia lamingtonii F.M. Bailey			
1164	Rubiaceae	Geophila repens (L.) I.M. Johnst.			
1165	Rubiaceae	Hedyotis lapeyrousii DC.	Oldenlandia lapeyrousii (DC.) Terrell & H.Rob.		
1166	Rubiaceae	Hedyotis pubescens (Valeton) Merr. & L.M.Perry	Oldenlandia pubescens Valeton		
1167	Rubiaceae	Hedyotis schlechteri (Valeton) Merr. & L.M.Perry			
1168	Rubiaceae	Hydnophytum ?moseleyanum Becc.			
1169	Rubiaceae	Hydnophytum sp.			
1170	Rubiaceae	Ixora cf. leptopus Valeton			
1171	Rubiaceae	Ixora sp.			
1172	Rubiaceae	Lasianthus cyanocarpus Jack			
1173	Rubiaceae	Mastixiodendron sp.			
1174	Rubiaceae	Mitragyna speciosa Korth.			
1175	Rubiaceae	Morinda bracteata Roxb.	Morinda citrifolia L.		
1176	Rubiaceae	Morinda citrifolia L.			
1177	Rubiaceae	Morinda cf. glomerata (Blume) Miq.			
1178	Rubiaceae	Morinda umbellata L.			
1179	Rubiaceae	Mussaenda chrysotricha Valeton			
1180	Rubiaceae	Mussaenda cylindrocarpa Burck			
1181	Rubiaceae	Mussaenda ferruginea K. Schum.			
1182	Rubiaceae	Mussaenda oreadum Wernham			
1183	Rubiaceae	Mussaenda scratchleyi Wernham			
1184	Rubiaceae	Mycetia javanica (Blume) Reinw. ex Korth.			
1185	Rubiaceae	Myrmecodia longissima Valeton			
1186	Rubiaceae	Myrmecodia cf. schlechteri Valeton			
1187	Rubiaceae	Nauclea orientalis (L.) L.			
1188	Rubiaceae	Nauclea sp.			
1189	Rubiaceae	Neonauclea obversifolia (Valeton) Merr. & L.M.Perry			
1190	Rubiaceae	Neonauclea sp.			
1191	Rubiaceae	Ophiorrhiza spp.			
1192	Rubiaceae	Pachystylus guelcherianus K. Schum.	Pachystylus zippelianus (Miq.) Bremek.		
1193	Rubiaceae	Pavetta platyclada K.Schum. & Lauterb.			
1194	Rubiaceae	Psychotria amplithyrsa Valeton			
1195	Rubiaceae	Psychotria dieniensis Merr. & L.M.Perry			
1196	Rubiaceae	Psychotria ectasiphylla Lauterb. & K. Schum.			
1197	Rubiaceae	Psychotria leptothyrsa Miq.			
1198	Rubiaceae	Psychotria leptothyrsa Miq.	redundant entry		
1199	Rubiaceae	Psychotria micrococca (Lauterb. & K. Schum.) Valeton			
1200	Rubiaceae	Psychotria olivacea Valeton			
1201	Rubiaceae	Psychotria petiolosa Valeton			
1202	Rubiaceae	Psychotria ramulosa Merr. & L.M.Perry			
1203	Rubiaceae	Psychotria sp. nov. A, aff. aquatilis Merr. & L.M.Perr	redet. Psychotria aurea Lauterb.		
1204	Rubiaceae	Psychotria sp. nov. B	Psychotria augustaflussiana Takeuchi & Arifiani		Takeuchi & Arifiani in press, Harvard Pap. Bot.
1205	Rubiaceae	Psychotria sp. nov. C			
1206	Rubiaceae	Psychotria spp., climbers			
1207	Rubiaceae	Rothmannia macromera (Lauterb. & K.Schum.) Fagerl.			
1208	Rubiaceae	Saprosma subrepandum (K. Schum. & Lauterb.) Valeton			
1209	Rubiaceae	Schradera novoguineensis (Valeton) Puff, Buchner & Greimler			
1210	Rubiaceae	Schradera ramiflora (Valeton) Puff, Buchner & Greimler			
1211	Rubiaceae	Tarenna buruensis (Miq.) Valeton	Tarenna sambucina var. buruensis (Miq.) Fosberg & Sachet		
1212	Rubiaceae	Tarenna sp.			
1213	Rubiaceae	Timonius avenis Valeton			
1214	Rubiaceae	Timonius caudatus Valeton, or aff.			
1215	Rubiaceae	Timonius flavescens Baker			
1216	Rubiaceae	Timonius grandifolius Valeton			
1217	Rubiaceae	Timonius kaniensis Valeton			

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1218	Rubiaceae	Timonius oblongus Valeton			
1219	Rubiaceae	Timonius pubistipulis S.P.Darwin			
1220	Rubiaceae	Timonius secundiflorus S.P.Darwin			
1221	Rubiaceae	Timonius subavenis (Valeton) S.P.Darwin			
1222	Rubiaceae	Timonius timon (Spreng.) Merr.			
1223	Rubiaceae	Timonius sp. nov., aff. grandifolius Valeton			
1224	Rubiaceae	Uncaria calophylla Blume ex Korth.			
1225	Rubiaceae	Uncaria cordata (Lour.) Merr.			
1226	Rubiaceae	Uncaria lanosa Wall.			
1227	Rubiaceae	Urophyllum britannicum Wernham			
1228	Rubiaceae	Urophyllum cf. glaucescens Valeton			
1229	Rubiaceae	Versteegia cauliflora (Lauterb. & K. Schum.) Valeton	Ixora novoguineensis Mouly & B.Bremer		
1230	Rubiaceae	Versteegia ?minor Valeton	Ixora minor (Valeton) Mouly & B.Bremer		
1231	Rubiaceae	Wendlandia paniculata (Roxb.) DC.			
1232	Rutaceae	Acronychia trifoliolata Zoll. & Moritzi			
1233	Rutaceae	Acronychia sp.			
1234	Rutaceae	Euodia cuspidata K. Schum.			
1235	Rutaceae	Flindersia pimenteliana F. Muell.			
1236	Rutaceae	Halfordia papuana Lauterb.			
1237	Rutaceae	Lunasia amara Blanco			
1238	Rutaceae	Melicope elleryana (F. Muell.) T.G. Hartley			
1239	Rutaceae	Melicope novoguineensis Valeton			
1240	Rutaceae	Melicope xanthoxyloides (F. Muell.) T.G. Hartley			
1241	Rutaceae	Melicope sp.			
1242	Rutaceae	Micromelum minutum (G.Forst.) Wight & Arn.			
1243	Rutaceae	Tetractomia tetrandra (Roxb.) Merr.	status uncertain, may be syn. of Melicope tetrandra Roxb.		
1244	Rutaceae	Triphasia aff. brassii (C.T. White) Swingle	redet. Monanthocitrus paludosa (Lauterb.) B.C.Stone		Takeuchi, W. 2013. Floristic records from the upper Sepik of Papua New Guinea: Aristolochia chrismülleriana sp. nov. (Aristolochiaceae), Monanthocitrus paludosa (Rutaceae), and Secamone timorensis (Apocynaceae). Phytotaxa 114 (1): 51–57.
1245	Rutaceae	Wenzelia dolichophylla (Lauterb. & K. Schum.) Tanaka			
1246	Sabiaceae	Meliosma pinnata (Roxb.) Maxim.			
1247	Sabiaceae	Sabia pauciflora Blume			
1248	Salicaceae	Casearia clutiaefolia Blume	Casearia clutiifolia Blume		
1249	Salicaceae	Casearia macrantha Gilg			
1250	Salicaceae	Flacourtia zippelii Slooten			
1251	Salicaceae	Homalium foetidum (Roxb.) Benth.			
1252	Salicaceae	Osmelia philippina Fern.-Vill.	status uncertain, may be syn. of Stachycrater philippinus Turcz.		
1253	Salicaceae	Xylosma papuana Gilg			
1254	Santalaceae	Cladomyza kaniensis (Pilg.) Stauffer			
1255	Santalaceae	Dendromyza sp.			
1256	Santalaceae	Scleropyrum aurantiacum Pilg.	status uncertain, may be syn. of Scleromelum aurantiacum K.Schum. & Lauterb.		
1257	Sapindaceae	Alectryon sp.			
1258	Sapindaceae	Cupaniopsis bilocularis Adema			
1259	Sapindaceae	Cupaniopsis macropetala Radlk.			
1260	Sapindaceae	Cupaniopsis stenopetala Radlk.			
1261	Sapindaceae	Dictyoneura obtusa Blume			
1262	Sapindaceae	Guioa sp.			
1263	Sapindaceae	Harpullia arborea (Blanco) Radlk.			
1264	Sapindaceae	Harpullia cf. cauliflora K. Schum. & Lauterb.			
1265	Sapindaceae	Harpullia ramiflora Radlk.			
1266	Sapindaceae	Jagera javanica (Blume) Kalkman			
1267	Sapindaceae	Lepisanthes senegalensis (Poir.) Leenh.			
1268	Sapindaceae	Mischocarpus sp.			
1269	Sapindaceae	Pometia pinnata J.R.Forst. & G.Forst.	Allophylus cobbe (L.) Raeusch.		
1270	Sapindaceae	Rhysotoechia sp.			
1271	Sapindaceae	Sarcopteryx squamosa (Roxb.) Radlk.			
1272	Sapindaceae	Toechima erythrocarpum (F. Muell.) Radlk.			
1273	Sapindaceae	Tristiropsis acutangula Radlk.			
1274	Sapotaceae	Beccariella sp. nov.			survey specimen too immature for typification (Swenson pers. com.)
1275	Sapotaceae	Palaquium sp.			
1276	Sapotaceae	Planchonella anteridifera (C.T. White & W.D. Francis ex Lane-Poole) H.J. Lam			
1277	Sapotaceae	Planchonella firma (Miq.) Dubard			
1278	Sapotaceae	Planchonella cf. obovoidea H.J. Lam	Planchonella myrsinodendron (F.Muell.) Swenson, Bartish & Munzinger		
1279	Sapotaceae	Planchonella xylocarpa (C.T. White) Swenson	Planchonella xylocarpa (C.T.White) Swenson, Bartish & Munzinger		
1280	Scrophulariaceae	Buddleja asiatica Lour.			
1281	Scrophulariaceae	Limnophila sp.		Plantaginaceae	
1282	Solanaceae	Capsicum anuum L.			
1283	Solanaceae	Nicotiana tabacum L.			
1284	Solanaceae	Physalis minima L.			
1285	Solanaceae	Solanum lycopersicum L.			
1286	Solanaceae	Solanum memecylonoides Bitter & Schltr.	Lycianthes memecylonoides (Bitter & Schltr.) Bitter		
1287	Solanaceae	Solanum oliverianum Lauterb. & K. Schum.	Lycianthes oliveriana (K. Schum. & Lauterb.) Bitter		
1288	Solanaceae	Solanum sp., subgenus Lycianthes	Lycianthes sp.		
1289	Solanaceae	Solanum sp., subgenus Solanum	Solanum sp.		
1290	Sonneratiaceae	Duabanga moluccana Blume		Lythraceae	
1291	Sphenostemonaceae	Quintinia ledermannii Schltr.		Paracryphiaceae	
1292	Sphenostemonaceae	Sphenostemon papuanum (Lauterb.) Steenis	status uncertain, may be syn. of Nouhuysia papuana Lauterb.	Paracryphiaceae	
1293	Staphyleaceae	Turpinia pentandra (Schltr.) B.L. Linden			
1294	Stemonuraceae	Gomphandra australiana F. Muell.			
1295	Stemonuraceae	Gomphandra montana (G.Schellenb.) Sleumer			
1296	Stemonuraceae	Medusanthera laxiflora (Miers) R.A.Howard			
1297	Stemonuraceae	Stemonurus monticolus (Schellenb.) Sleumer	Stemonurus monticola (G. Schellenb.) Sleumer		
1298	Styracaceae	Bruinsmia styracoides Boerl. & Koords.			
1299	Symplocaceae	Symplocos cochinchinensis (Lour.) S. Moore			
1300	Tetrameristaceae	Tetramerista glabra Miq.			
1301	Theaceae	Eurya tigang K. Schum. & Lauterb.			
1302	Theaceae	Eurya sp.		Pentaphylacaceae	
1303	Theaceae	Gordonia papuana Kobuski	Gordonia amboinensis (Miq.) Merr.		
1304	Theaceae	Ternstroemia britteniana F. Muell.		Pentaphylacaceae	
1305	Theaceae	Ternstroemia cherryi (F.M. Bailey) Merr.	Ternstroemia cherryi (F.M. Bailey) Merr. ex J.F.Bailey & C.T White	Pentaphylacaceae	
1306	Theaceae	Ternstroemia merrilliana Kobuski		Pentaphylacaceae	
1307	Thymelaeaceae	Gyrinops ledermannii Domke			
1308	Thymelaeaceae	Phaleria coccinea (Gaudich.) F. Muell.			
1309	Thymelaeaceae	Phaleria macrocarpa (Scheff.) Boerl.			
1310	Trimeniaceae	Trimenia papuana Ridl.			
1311	Ulmaceae	Celtis latifolia (Blume) Planch.		Cannabaceae	
1312	Ulmaceae	Celtis philippensis Blanco		Cannabaceae	
1313	Ulmaceae	Celtis rigescens (Miq.) Planch.		Cannabaceae	
1314	Ulmaceae	Gironniera celtidifolia Gaudich.		Cannabaceae	
1315	Ulmaceae	Gironniera hirta Ridl.		Cannabaceae	
1316	Ulmaceae	Gironniera rhamnifolia Blume		Cannabaceae	
1317	Ulmaceae	Gironniera subaequalis Planch.		Cannabaceae	
1318	Ulmaceae	Parasponia sp.		Cannabaceae	
1319	Ulmaceae	Trema cannabina Lour.		Cannabaceae	
1320	Ulmaceae	Trema orientalis (L.) Blume		Cannabaceae	
1321	Urticaceae	Cypholophus sp.			
1322	Urticaceae	Dendrocnide sp.			
1323	Urticaceae	Elatostema angulare H.J.P. Winkl.			
1324	Urticaceae	Elatostema beccarii H. Schroet.			
1325	Urticaceae	Elatostema macrophylla Brogn.	Elatostema macrophyllum Brogn.		
1326	Urticaceae	Elatostema novo-guineense Warb.	Elatostema novoguineense Warb.		
1327	Urticaceae	Elatostema sesquifolium (Reinw.) Hassk.	Elatostema integrifolium (D.Don) Wedd.		
1328	Urticaceae	Elatostema weinlandii K. Schum.			

sequence number	Family	name from 2011	revised nomenclature	Family Changes	Reference for newly decribed species since 2011
1329	Urticaceae	Elatostema spp.			
1330	Urticaceae	Laportea decumana (Roxb.) Wedd.	Urticastrum decumanum (Roxb.) Kuntze		
1331	Urticaceae	Leucosyke capitellata (Poir.) Chew	Leucosyke capitellata Wedd.		
1332	Urticaceae	Nothocnide melastomatifolia (K. Schum.) Chew			
1333	Urticaceae	Nothocnide repanda (Blume) Blume			
1334	Urticaceae	Pilea sp.			
1335	Urticaceae	Pipturus argenteus (G.Forst.) Wedd.	Pipturus argenteus (G.Forst.) Wedd.		
1336	Urticaceae	Poikilospermum amboinense Zipp. & Miq.			
1337	Urticaceae	Poikilospermum inaequale Chew			
1338	Urticaceae	Poikilospermum paxianum (H.J.P. Winkl.) Merr.			
1339	Urticaceae	Procris frutescens Blume			
1340	Urticaceae	Procris gruningii H.J.P. Winkl.	Procris grueningii (H.J.P.Winkl.) R.J.Johns		
1341	Urticaceae	Villebrunea rubescens (Blume) Blume	Oreocnide rubescens (Blume) Miq.		
1342	Violaceae	Rinorea horneri (Korth.) Kuntze	Rinorea horneri Kuntze		
1343	Vitaceae	Ampelocissus muelleriana Planch.			
1344	Vitaceae	Cayratia geniculata (Blume) Gagnep.			
1345	Vitaceae	Cayratia japonica (Thunb.) Gagnep.			
1346	Vitaceae	Cayratia trifolia (L.) Domin			
1347	Vitaceae	Cissus aristata Blume			
1348	Vitaceae	Cissus javana DC.			
1349	Vitaceae	Leea coryphantha Lauterb.			
1350	Vitaceae	Leea indica (Burm. f.) Merr.			
1351	Vitaceae	Leea zippeliana Miq.			
1352	Vitaceae	Nothocissus penninervis (F. Muell.) Latiff			
1353	Vitaceae	Tetrastigma lauterbachianum Gilg			
1354	Winteraceae	Drimys piperita Hook.f. entity myrtoides Vink	status uncertain, may be syn. of Tasmannia piperita (Hook. f.) Miers		
1355	Winteraceae	Dryadodaphne novoguineensis (Perkins) A.C. Sm.		Atherospermataceae	
1356	Winteraceae	Zygogynum sp. nov. A			cannot publish bc genus under revision
1357	Winteraceae	Zygogynum sp. B			as above
1358	Winteraceae	Zygogynum sp. C			as above

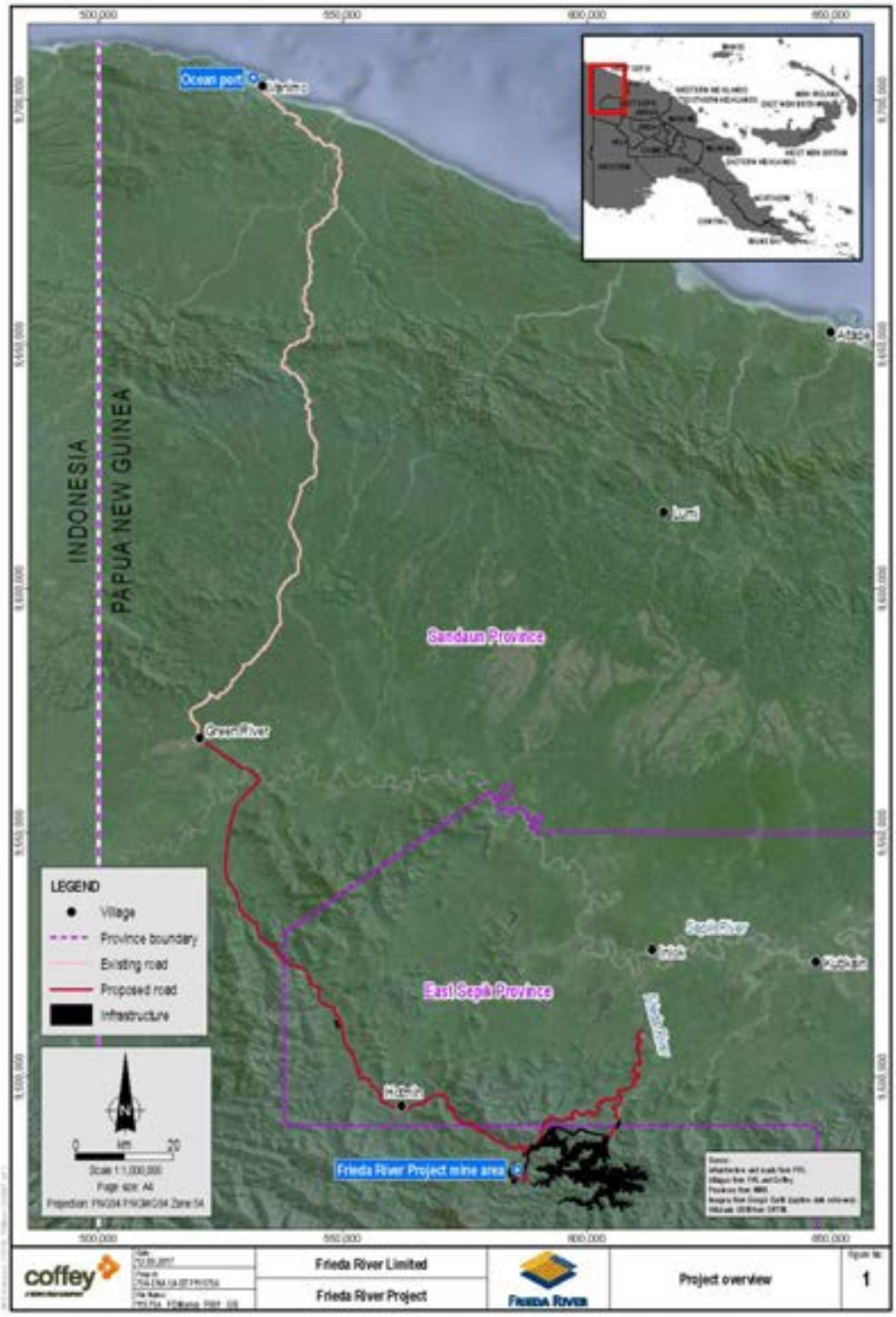

Figure 1. Location of project infrastructure in Sandaun and East Sepik Provinces.

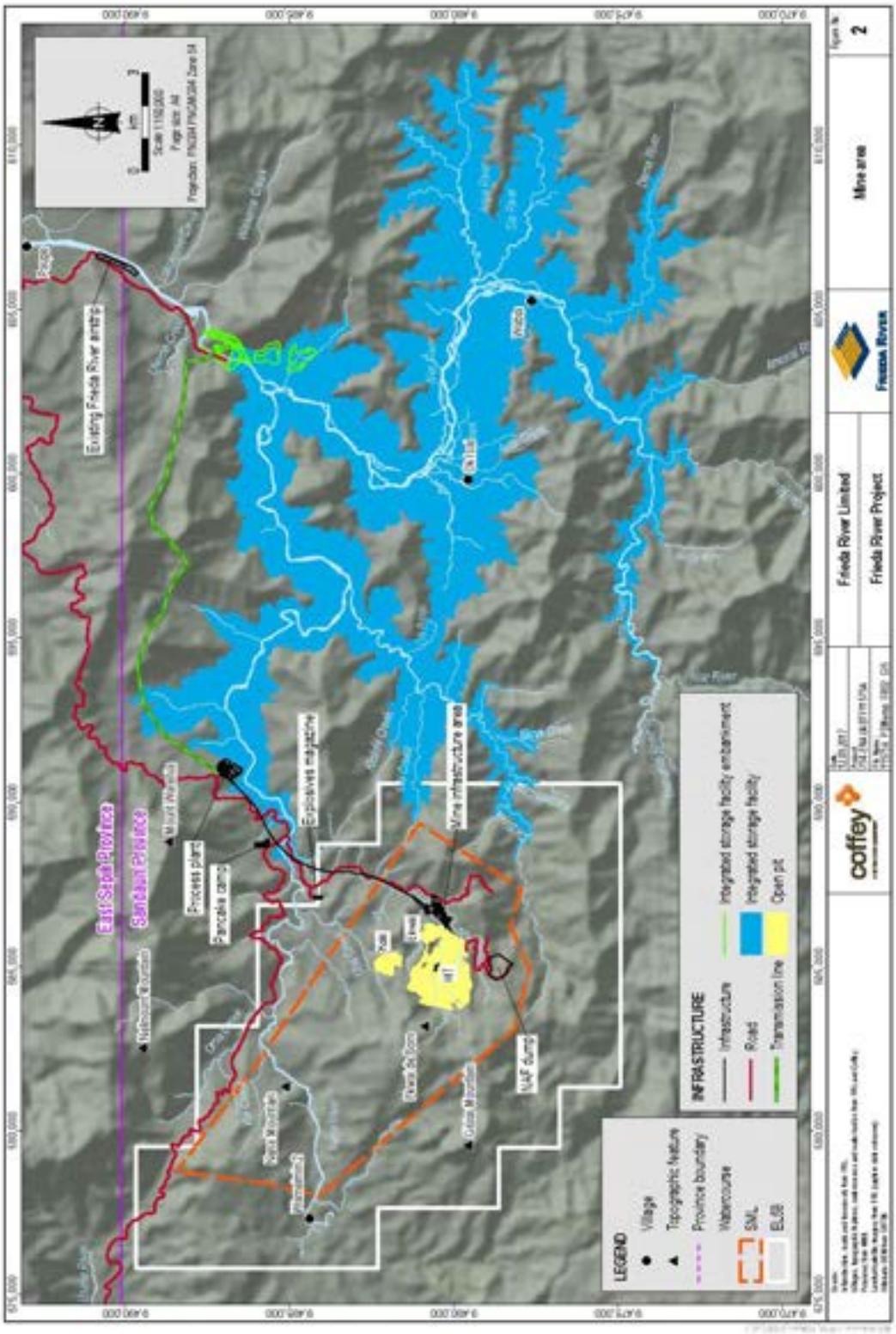

Figure 2. The Frieda copper-gold deposits and supporting infrastructure.

Figure 3. Psychotria sp. nov. Habit. Miniature monocauls in dark understory. From Camp 2, ridge base 1.1 km north of bivouac; UTM WGS84, 54M northing 9540132, easting 534393; December 10, 2017.

Figure 4. Psychotria sp. nov. Diagnostic structures. A. Fruits; B. Stipules. From Camp 2, ridge base 1.1 km north of bivouac; UTM WGS84, 54M northing 9540132, easting 534393; December 10, 2017.

Figure 5. *Agathis labillardierei*. A conspicuous component of Hm canopies due to its massive size and obliquely ascending branches. From Camp 1, Uriake River; UTM WGS84, 54M northing 9493444, easting 558625; December 3, 2017.

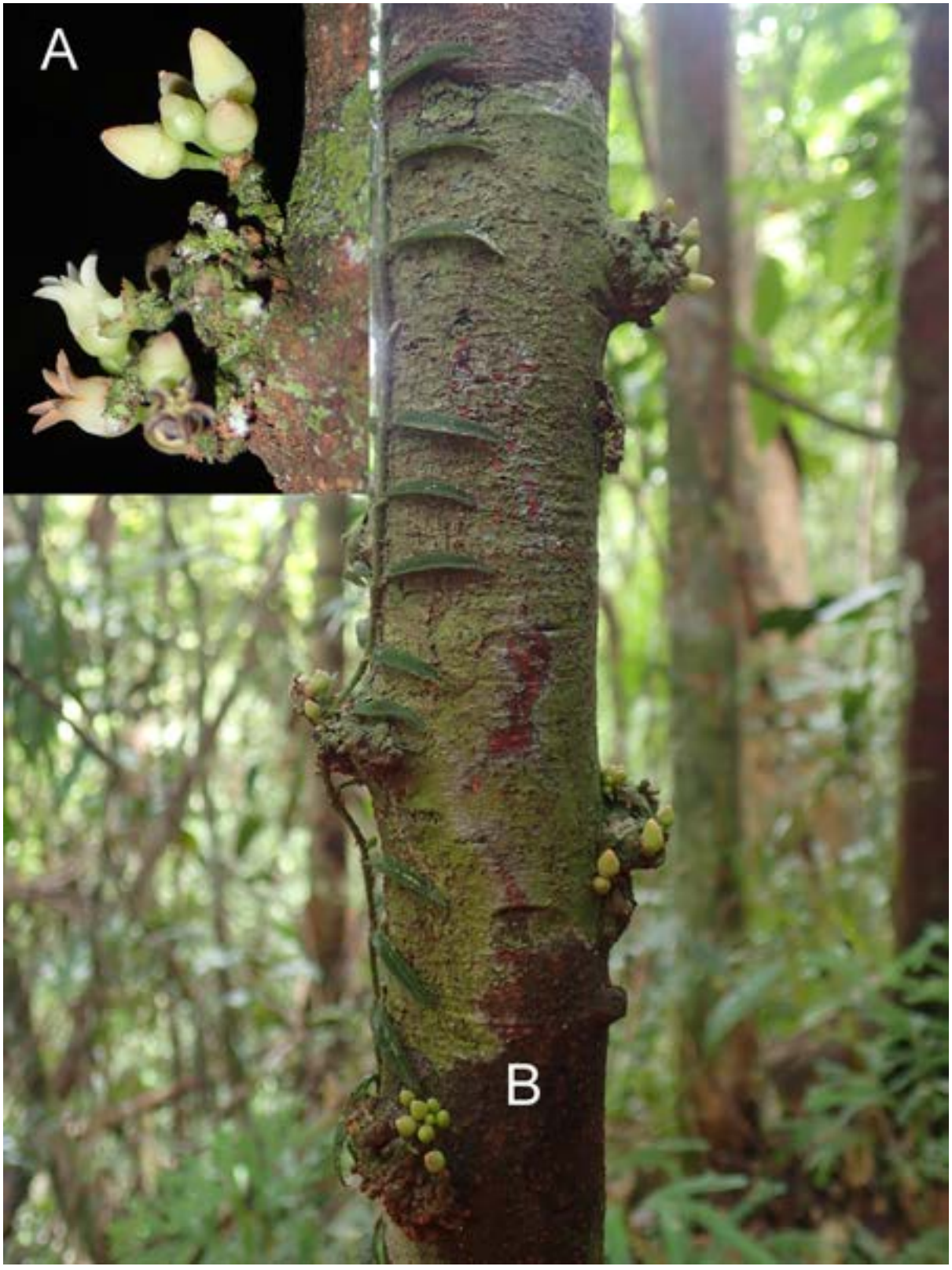

Figure 6. *Diospyros fusicarpa*. A. Inflorescence. B. Flowering stem from 3.5 m shrub. From Camp 2, ridgeline south of bivouac; UTM WGS84, 54M northing 9538246, easting 534250; December 6, 2017.

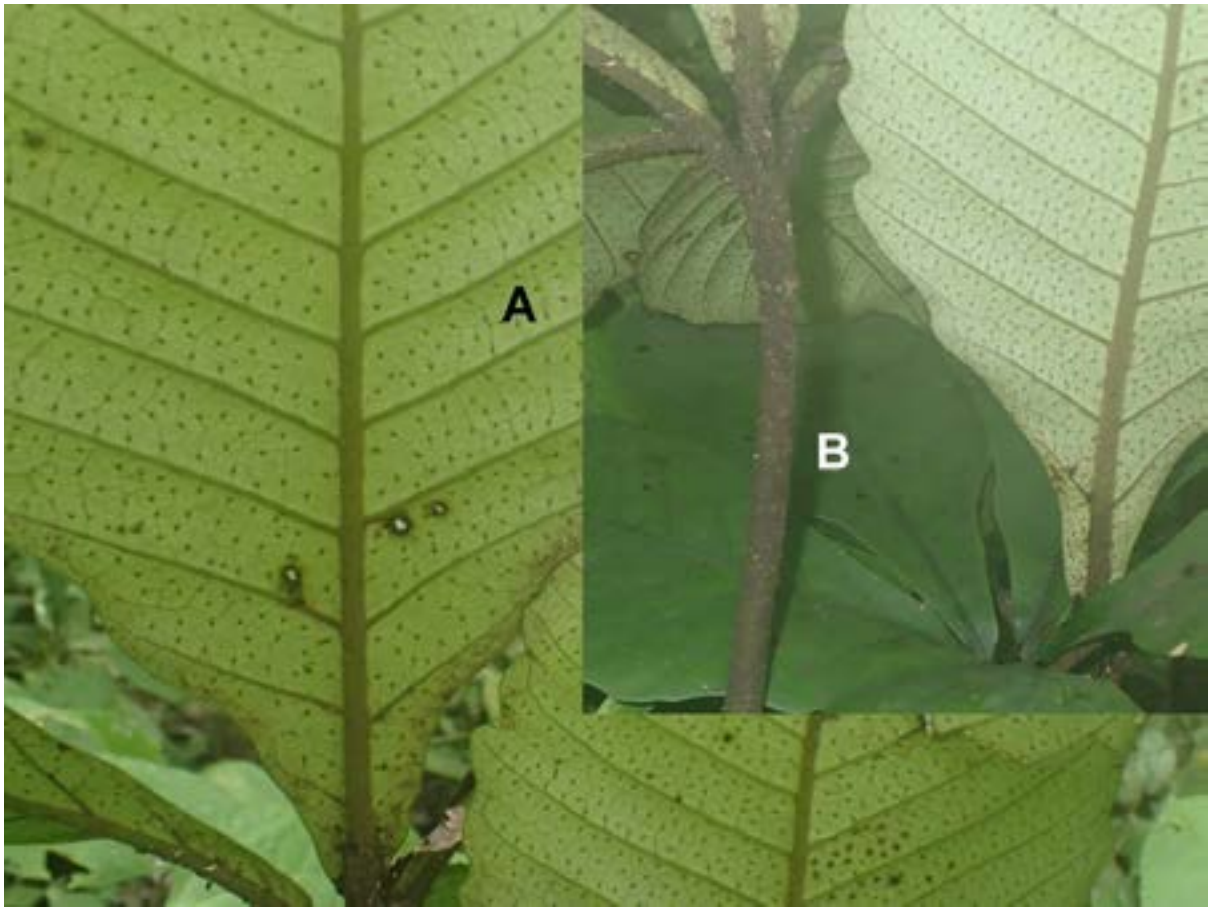

Figure 7. *Christensenia aesculifolia* subsp. *korthalsii*. A. Leaf undersurface showing the distinctive reticulate venation; B. Fronds are pedate, dull green above and glaucous beneath. The furfuraceous stipes are diagnostic for subsp. *korthalsii*. From Camp 2, alluvial flood plain east of bivouac; UTM WGS84, 54M northing 9539232, easting 534834; December 7, 2017.

Figure 8. Hm forest floor. The understory litter load is evidence of seasonal and synchronised leaf fall. From Camp 2, buttress ridge south of bivouac; UTM WGS84, 54M northing 9538268, easting 534273; December 6, 2017.

Figure 9. Margin of Po forest in the anthropogenic zone near Camp 1. Foreground: cultivated field of *Colocasia esculenta*. From Camp 1, alluvial plain north of bivouac; UTM WGS84, 54M northing 9495193, easting 558813; November 29, 2017.

Figure 10. Hm landscapes are visually heterogeneous, reflecting their presumed status as PNG's richest forest environment (Louman and Nicholls 1995). Canopies are multi-storied, polychromatic, and irregular in outline. From Camp 1, Uriake River; UTM WGS84, 54M northing 9493638, easting 558909; December 3, 2017.

Figure 11. Edge view of Hm forest, showing its characteristically complex stratification and interlocking occupation of all height intervals. From Camp 1, Uriake River; UTM WGS84, 54M northing 9493444, easting 558625; December 3, 2017.

Figure 12. Interior view of Hm forest. Sparse stocking densities and small boles are consistent with low ecosystem productivity on depleted clays. From Camp 1, ridge northwest of bivouac; UTM WGS84, 54M northing 9495075, easting 558663; November 29, 2017.

Figure 13. Ps forest along Wara Mifyap. The principal genera are *Intsia*, *Maniltoa*, *Pometia*, *Terminalia*, and *Vatica*. From Camp 2, alluvial plain northwest of bivouac; UTM WGS84, 54M northing 9540248, easting 534242; December 5, 2017.

Figure 14. The interior physiognomies of Hm forest are similar across all sampled habitats. Compare with Figure 12. From Camp 2, secondary ridge south of bivouac; UTM WGS84, 54M northing 9538246, easting 534250; December 6, 2017.

Mammals of the Sepik Development Project infrastructure corridor study area

A report prepared for Coffey Services Australia Pty Ltd and Frieda River Limited

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Contents

Front cover: A Common Spotted Cuscus *Spilocuscus maculatus* captured by hand on the survey. All photographs in this report were taken by Stephen .J. Richards.

1 EXECUTIVE SUMMARY

Frieda River Limited (FRL) is assessing the feasibility of developing the Sepik Development Project (the Project) in north-western Papua New Guinea. The Project is located primarily within the Sepik River catchment and comprises the development of a copper-gold deposit in Sandaun Province, and supporting infrastructure and facilities in the Sandaun and East Sepik provinces. Extensive terrestrial biodiversity field studies were conducted for the Project between 2009 and 2011. Since that time there have been changes to the Project design, including the development of a 325-km infrastructure corridor between the mine and Vanimo, which utilises in part the existing gazetted public road between Vanimo and Green River. To date there have been no terrestrial biodiversity surveys for the Project in the infrastructure corridor.

A field survey for mammals was undertaken between 28 November and 11 December 2017, centred on two main sites: Camp 1 (near Usaremin 2 village) and Camp 2, and a third site nearby along the Idam River at Idam 1 village. Mammals were detected using a variety of methods that included trapping, mist netting, ultrasonic acoustic recording of bat echolocation calls, and interviews with local hunters and examination of their hunting trophies.

A total of 16 non-volant (non-flying) mammal species was recorded on the survey, which included three marsupial families (one species of Macropodidae; three species of Peroryctidae; five species of Phalangeridae; one species of Dasyuridae) and six species in the rodent family Muridae. The majority of non-volant species were recorded as hunting trophies, highlighting the value of conducting interviews with local hunters.

A total of 26 bat species was detected, with 19 of those being represented in acoustic recordings of echolocation calls, seven captured (two of these also present in the acoustic recordings) and an additional two species of bat were identified amongst the trophies of local hunters.

The total number of mammal species detected on this relatively short and spatially limited survey was therefore 42, which indicates the presence of a diverse mammal assemblage.

Previous biogeographic analysis and extensive field surveys undertaken by Aplin and Armstrong (2011) reported the potential occurrence of 140 species of mammal and the actual/inferred detection of 81 species in the wider Project area. Due to the incompleteness of taxonomic resolution in several groups, the level of mammal diversity is likely to be greater than that actually compiled. Groups with unresolved taxonomy that conceals a higher level of diversity because of the presence of cryptic species include: the Lowland Paramelomys *Paramelomys platyops* group; bent-winged bats *Miniopterus* spp., the *Nyctimene albiventer* group and several other species that may contain one or two cryptic undescribed and/or undiscovered taxa.

One species inferred as present on the survey based on hunter testimony is listed as ‘Threatened’ by the IUCN: the Black-spotted Cuscus *Spilocuscus rufoniger* (CR), which was recorded based on diagnostic features of the species given in an interview with a local hunter. This species is also listed as ‘Protected’ under the *Papua New Guinea Fauna (Protection and Control) Act 1966*.

One species that may have been detected from echolocation calls is listed as IUCN Data Deficient: the Small Melanesian Bent-winged Bat *Miniopterus macrocneme.* Identification of all species of bent-winged bats from both external morphology and echolocation is problematic. Capture was not made, so the identification could not be verified.

ACRONYMS AND ABBREVIATIONS

Term	Definition
AMSL	Above Mean Sea Level
BST	Body Sub Type (part of the bat echolocation call type nomenclature)
c.	circa (approximately)
CEPA	Conservation and Environment Protection Authority
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CR	Critically Endangered (IUCN threat category)
DD	Data Deficient (IUCN threat category)
FIMS	Forest Inventory Mapping System
GPS	Global Positioning System
IFS	Initial Frequency Sweep (part of the bat echolocation call type nomenclature)
IUCN	International Union for the Conservation of Nature and Natural Resources
kHz	kiloHertz (unit of frequency; used to characterise bat echolocation calls)
km; km^2	kilometres; square kilometres
LC	Least Concern (IUCN threat category)
LIDAR	Light detection and ranging (remote sensing method)
m	metres
NA	not applicable, or not available
NT	Near Threatened (IUCN threat category)
P	Species protected under the Papua New Guinea Fauna (Protection and Control) Act 1966
PNG	Papua New Guinea
sp.	species (singular)
spp.	species (plural)
TFS	Terminating Frequency Sweep (part of the bat echolocation call type nomenclature)

GLOSSARY

Term	Definition
anonymous calls	Bat echolocation calls from an unattended overnight recording session that need to be identified to species or call type.
bat detector	A digital recording device that has a microphone sensitive to ultrasonic signals, and which can record these ultrasonic signals to flash memory media.
central cordillera	The central mountainous spine of New Guinea that runs from the eastern edge of the Bird's Head Peninsula in Indonesian New Guinea to the eastern tip of mainland Papua New Guinea.
commensal	Species that live in close association with people and derive resources from them.
cryptic species	Species that appear very similar or identical but are genetically distinct and reproductively isolated. Taxa with cryptic species-level diversity are suspected to contain more than one distinct species, requiring that taxonomic study determine how many reproductively isolated species are currently considered under a single name.
echolocation	The system of sonar that has evolved in bats to allow them to avoid obstacles and detect prey in darkness by emitting sound pulses and interpreting the echoes. To echolocate means to produce a sound signal used for echolocation.
insectivorous	Feeding entirely or mostly on insect (arthropod) prey.
karst	A landscape formed from the dissolution of soluble rocks, typically limestone, to form a variety of surface and underground features including karren, cavities and caves, and cave formations (speleothems).
marsupial	The branch of mammals (Metatheria) that includes pouched species, including kangaroos, wallabies, bandicoots, koalas, wombats and a variety of smaller carnivorous species in the medium and small size ranges.
nocturnal	Active during the night, during the hours between sunset and sunrise.
obligate	A type of requirement that a species is absolutely dependent on, e.g. a cave for roosting in some species of bat.
Project	Sepik Development Project
reference calls	Bat echolocation calls that are obtained from an individual bat that is then taken as a whole specimen voucher, so that the identification can be verified later if required. Anonymous calls (see above) are identified based on the information from reference calls.
relative abundance	A way of referring to how common a species is.
senescent	The gradual deterioration of function that ultimately leads to death. Trees generally die off after a period of senescence.
species new to science	A species or taxon that has not been encountered previously, and is effectively 'undiscovered' by western science. Differs from an 'undescribed species' as defined here.

study area	Terrestrial Biodiversity Study Area within the Project infrastructure corridor, comprising the survey sites ‘Camp1’, ‘Camp 2’ and ‘Idam River’.
sympatry/sympatric	Populations occurring together within the one locality or habitat. Often used as the basis for validating closely-related species.
taxa	Plural of taxon.
taxon	A general reference to a species or subspecies—whether it is described formally, or is suspected of being a distinct species or subspecies that has not yet been examined in a taxonomic study and described formally.
taxonomy	The science of naming, classifying and identifying organisms.
ultrasonic	Relating to the spectrum of sound frequencies above the level of human hearing, beginning at around 20 kHz, and in the context of this study, reaching to over 200 kHz.
volant	Able to fly.

2 INTRODUCTION

2.1. Background

Frieda River Limited (FRL) is assessing the feasibility of developing the Sepik Development Project (the Project) in northern Papua New Guinea (PNG). The Project is located primarily within the Sepik River catchment. It comprises the development of a copper-gold deposit in Sandaun Province and supporting infrastructure and facilities in the Sandaun and East Sepik provinces. Open pits include the Horse-Ivaal-Trukai, Ekwai and Koki (HITEK) porphyry copper-gold deposits. Mined ore will be processed at a process plant located approximately 8 km north-east of the open pits to produce a copper-gold concentrate.

Mine waste, including tailings and waste rock, will be stored sub-aqueously in an integrated storage facility located on the Frieda, Nena and Niar rivers downstream of the mine site. This facility forms part of the Frieda River Hydroelectric Project (FRHEP), which will generate hydroelectric power for the Project commencing in Year 1.

A 325-km infrastructure corridor will be developed between the mine site and Vanimo, located on the north coast of mainland Papua New Guinea, and incorporates the existing public road between Vanimo and Green River. A concentrate pipeline that follows the road corridor will transport the copper-gold concentrate produced at the process plant to a concentrate dewatering, storage and export facility located at Vanimo. A transmission line will also run along the road corridor to deliver power from the FRHEP to Vanimo.

Extensive terrestrial biodiversity field studies for the Project were conducted between 2009 and 2011. The Project design was changed subsequently to include the 325-km infrastructure corridor between the mine and Vanimo. To date there have been no terrestrial biodiversity surveys for the Project in the infrastructure corridor.

2.2. Objectives

The objectives of the mammal baseline characterisation study were to:

1. Characterise the existing mammals in the Project study area, and provide context at the local, national and international scale noting any sensitive environmental areas or habitats.

2. Document any rare, threatened, undescribed or otherwise noteworthy mammal species (i.e. those listed by the International Union for Conservation of Nature (IUCN), and those with significance to local communities), mammal communities and their habitats present within the study area.

3. Document any exotic and invasive mammal species.

3 EXISTING INFORMATION

3.1. Overview

The native terrestrial mammal fauna in Papua New Guinea comprises at least 265 species in three main groups: the monotremes (three species of long-beaked echidna *Zaglossus* spp. and one species of short-beaked echidna *Tachyglossus aculeatus*), the marsupials or metatherian mammals (74+ species), and the placental or eutherian mammals that comprises the rodents (93+ species) and bats (94+ species) (IUCN Red List; http://www.iucnredlist.org/initiatives/mammals; checked and reconciled against a list compiled by K.P. Aplin in October 2016; excluding dogs, pigs and other domesticated species).

A review of the broad habitats within the study area is given in Crome (2011), which cover an elevational range from approximately 30 m AMSL on the bed of the Sepik River to around 1,500 m AMSL on isolated peaks and ridges. The habitats used by mammals transition from a lowland zone, through a hill zone to a montane zone (Aplin and Armstrong 2011). The focus of the present survey effort was in habitats that ranged in elevation from 50 to 180 m AMSL, and a description of these is given in the following *Methods* sub-sections. Consideration is also given to habitats along the infrastructure corridor route that reach to just over 650 m AMSL in elevation.

A brief overview of the history of mammal studies in the general region was provided by Aplin and Armstrong (2011:151). The mammals in the Project area have received relatively little attention, with no previous systematic mammal surveys or significant casual visitation other than the most recent work conducted for the Project (Aplin and Armstrong 2011). There has been effort further afield in the East Sepik Province (e.g. McKean 1972); in the western Sepik lowlands and the north coastal ranges (Torricelli and Bewani mountains) in the mid-1980s to early 1990s by Flannery and others (Flannery and Seri 1990); in the vicinity of Telefomin by various workers from the American Museum of Natural History, Bernice P. Bishop Museum, the Australian Museum, and the PNG National Museum; in the Schrader Range (Western Highland Province) in the 1960s and 1970s by Bulmer and others (Majnep and Bulmer 2007); and in the Mamberamo River basin of Indonesian West Papua in the last decade by Pattiselanno (2003) (see further details in Aplin and Armstrong 2011).

There are two important considerations for the present mammal survey that have become apparent since the 2009–2011 terrestrial biodiversity studies for the Project. These have arisen from numerous other biodiversity surveys across PNG by the authors (K.N. Armstrong, E. Kale, both working together with K.P. Aplin), which were undertaken as part of both commercial consultancy projects and those led by conservation organisations.

Firstly, while there has been a long history of mammal discovery and description in PNG, knowledge of mammal taxonomy in the country is still incomplete. Authoritative field guides such as Flannery (1995) and Bonaccorso (1998) provide excellent summaries of the mammal fauna, but they give little indication of the considerable amount of cryptic and unnamed taxa that exist behind the names and photographs that are presented. Numerous examples of completely new taxa, plus well-known but unnamed or taxonomically unresolved forms have been revealed across numerous provinces in the past decade (Aplin and Kale 2011; Armstrong and Aplin 2011; Aplin 2014; Armstrong and Aplin 2014a; Aplin and Lamaris 2015; Aplin et al. 2015; Armstrong et al. 2015a,b; K.P. Aplin and K.N. Armstrong unpublished confidential reports). There has been relatively little published taxonomic work since Aplin and Armstrong (2011), with the exception of Irwin (2017). There are still many undescribed species

that are currently included under named species (Aplin 2015), and genetic studies are beginning to reveal the extent of this diversity (e.g. Aplin and Opiang 2017; Armstrong 2017; Armstrong and Aplin 2017a; K.N. Armstrong unpublished research).

Secondly, the acoustic survey for bats conducted for the Project (Aplin and Armstrong 2011 unpublished report) was only the third major systematic study of echolocating bat species in PNG that relied on ultrasonic recordings from bat detectors, the first being that of Richards (2005, 2008), and the second being the Conservation International survey of Armstrong and Aplin (2011). At that time, the part of the nocturnal ultrasonic realm in PNG derived from echolocating insectivorous bat species was almost completely undocumented, with only limited reference call information available from Leary and Pennay (2011). A standardised scheme of nomenclature for classifying the echolocation call types apparent in the recordings was used by Aplin and Armstrong (2011), which helped to compare bat diversity consistently across the study sites even though the source of many types was unclear. In subsequent studies, the call type nomenclature and knowledge of their attribution to the various species has been improved and refined. The call type attributions from Aplin and Armstrong (2011) are provided alongside the results of the present survey, which represent the current, refined understanding of PNG bat echolocation calls.

3.2. Expected list of species

Aplin and Armstrong (2011) provided a list of non-volant (non-flying) mammals and bats predicted to occur in the Project area at all elevations. Their biogeographic analysis predicted that the study area could support up to 140 mammal species, with 80 of those non-volant species and 60 bat species. Overall, the 2009–2011 terrestrial biodiversity studies for the Project recorded a total of 81 mammal species, including confirmed records of 31 non-volant mammals and a further nine non-volant mammals were listed as likely to occur in the study area based on unambiguous and plausible accounts by local residents; plus 41 species of bat. Most of the mammals detected in the study area were predicted by the biogeographic analysis, with the exception of five mammal species not recorded previously (two small rodent species, one species of small marsupial and two bat species).

Eleven families of non-volant mammal species occur on the island of New Guinea. A compiled list of non-volant mammal species expected to occur in the Project corridor was based on elevational range preferences, plus the distribution maps provided by Flannery (1995) and the updated versions available from the IUCN (2018). Representative species of eight non-volant mammal families are expected to occur in the study area, including: Dasyuridae, Peroryctidae, Macropodidae, Phalangeridae, Acrobatidae, Petauridae, Pseudocheiridae and Muridae (**Table 1**). The three non-volant mammal families that are deemed unlikely to occur include: Tachyglossidae, Peramelidae and Burramydiae.

The list of expected bat taxa was recompiled from distribution information in the IUCN Red List (http://www.iucnredlist.org/initiatives/mammals), plus the results of the 2009–2011 survey for the Project (Aplin and Armstrong 2011). A total of at least 44 bat species was either predicted or considered likely to occur because of nearby distribution limits (**Table 2**). Only one of these species is listed as Threatened by the IUCN: Bulmer's Fruit Bat *Aproteles bulmerae* (CR). One species was listed previously as Data Deficient: Telefomin Leaf-nosed Bat *Hipposideros corynophyllus* (now listed as LC), which was not a candidate species for the echolocation call type *75 mCF* recorded on the 2009–2011 survey but is now considered a likely source given its larger size relative to other '*cyclops*'-group *Hipposideros* in PNG.

Table 1. List of non-volant mammal taxa (rodents and marsupials) expected based on information in both the IUCN Red List and a review of the 2009–2011 Frieda River Project work (Aplin and Armstrong 2011) (**: species actually detected in the field on this 2017 survey; *: species documented from hunter testimony on this 2017 survey).

Family	Common name	Species	IUCN status	Likelihood IUCN	2011 study
MARSUPIALS					
Dasyuridae	New Guinea Quoll	*Dasyurus albopunctatus*	NT	Predicted	Recorded
	Short-furred Dasyure	*Murexia longicaudata*	LC	Not predicted	Recorded
	Black-tailed Antechinus	*Murexia melanurus*	LC	Not predicted	Not recorded
	Three-striped Dasyure	*Myoictis melas* **	LC	Not predicted	Recorded
Peroryctidae	Clara's Echymipera	*Echymipera clara* **	LC	Not predicted	Recorded
	Common Echymipera	*Echymipera kalubu* **	LC	Not predicted	Recorded
	Raffray's Bandicoot	*Peroryctes raffrayana*	LC	Not predicted	Recorded
	Long-nosed Echymipera	*Echymipera rufescens***	LC	Possible	Recorded
Phalangeridae	Ground Cuscus	*Phalanger gymnotis* **	LC	Not predicted	Recorded
	Mountain Cuscus	*Phalanger carmelitae***	LC	Not predicted	Recorded
	Northern Common cuscus	*Phalanger orientalis***	LC	Not predicted	Recorded
	Common Spotted Cuscus	*Spilocuscus maculatus* **	LC	Not predicted	Recorded
	Black-spotted Cuscus	*Spilocuscus rufoniger**	CR	Possible	Recorded
Pseudocheiridae	Lowland Ringtail	*Pseudochirulus canescens*	LC	Not predicted	Recorded
	Painted Ringtail	*Pseudochirulus forbesi*	LC	Not predicted	Not recorded
Petauridae	Striped Possum	*Dactylopsila trivirgata*	LC	Not predicted	Recorded
	Sugar Glider	*Petaurus breviceps*	LC	Not predicted	Recorded
Acrobatidae	Feather-tailed Possum	*Distoechurus pennatus*	LC	Not predicted	Not recorded
Macropodidae	Doria's Tree-kangaroo	*Dendrolagus dorianus*	VU	Predicted	Not recorded
	Goodfellow's Tree-kangaroo	*Dendrolagus goodfellowi*	EN	Possible	Recorded
	Grizzled Tree-kangaroo	*Dendrolagus inustus*	VU	Predicted	Not recorded
	White-striped Dorcopsis	*Dorcopsis hageni***	LC	Not predicted	Recorded
	Small Dorcopsis	*Dorcopsulus vanheurni*	NT	Predicted	Not recorded
	New Guinea Pademelon	*Thylogale browni*	VU	Predicted	Recorded

Family	Common name	Species	IUCN status	Likelihood IUCN	2011 study
RODENTS					
Muridae	Uneven-toothed Rat	*Anisomys imitator*	LC	Not predicted	Not recorded
	Common Water-rat	*Hydromys chrysogaster*	LC	Not predicted	Recorded
	Long-footed Tree-mouse	*Lorentzimys nouhuysi*	LC	Not predicted	Not recorded
	Lowland Mammelomys	*Mammelomys rattoides*	LC	Not predicted	Recorded
	Black-tailed Melomys	*Melomys rufescens*	LC	Not predicted	Recorded
	Lowland Melomys	*Paramelomys platyops***	LC	Not predicted	Recorded
	Shaw Mayer's Pogonomelomys	*Pogonomelomys mayeri*	LC	Not predicted	Not recorded
	Large Tree mouse	*Pogonomys loriae*	LC	Not predicted	Recorded
	Chestnut Tree-mouse	*Pogonomys macrourus*	LC	Not predicted	Recorded
	Large Spiny Rat	*Rattus praetor***	NE	Not predicted	Recorded
	Small Spiny Rat	*Rattus steini*	LC	Not predicted	Recorded
	Mottled-tailed Giant-rat	*Uromys caudimaculatus*	LC	Not predicted	Recorded
	Rock-dwelling Giant-rat	*Xenuromys barbatus*	LC	Not predicted	Recorded

Table 2. List of bat taxa (Chiroptera) expected based on information in both the IUCN Red List and a review of the 2009–2011 Frieda River Project work (Aplin and Armstrong 2011). An asterisk indicates the detection of a species not predicted to occur prior to its encounter by Aplin and Armstrong (2011).

Scientific name	Common name	IUCN status	Likelihood IUCN	2011 study	2011 call type description (if detected)
Pteropodidae					
Aproteles bulmerae	Bulmer's Fruit Bat	CR	Possible	Not Recorded	—
Dobsonia minor	Lesser Bare-backed Fruit Bat	LC	Predicted	Recorded	—
Dobsonia moluccensis	Moluccan Naked-backed Fruit Bat	LC	Predicted	Recorded	—
Macroglossus minimus	Dagger-toothed Long-nosed Fruit Bat	LC	Predicted	Not Recorded	—
Nyctimene aello	Greater Tube-nosed Fruit Bat	LC	Predicted	Recorded	—
Nyctimene albiventer	Common Tube-nosed Fruit Bat	LC	Predicted	Recorded	—
Nyctimene certans	Mountain Tube-nosed Bat	LC	Possible	Not Recorded	—
Nyctimene draconilla	Dragon Tube-nosed Fruit Bat	DD	Possible	Not Recorded	—
Paranyctimene raptor	Green Tube-nosed Fruit Bat	LC	Predicted	Not Recorded	—
Paranyctimene tenax	Steadfast Tube-nosed Bat	LC	Predicted	Not Recorded	—
Pteropus macrotis	Large-eared Flying-fox	LC	Predicted	Recorded	—
Pteropus neohibernicus	Great Flying-fox	LC	Predicted	Probably recorded	—
Rousettus amplexicaudatus	Common Rousette	LC	Predicted	Not Recorded	—
Syconycteris australis	Common Blossom Bat	LC	Predicted	Recorded	—
Emballonuridae					
Emballonura beccarii	Beccari's Sheath-tailed Bat	LC	Possible	Not Recorded	
Emballonura dianae	Large-eared Sheath-tailed Bat	LC	Possible	*Recorded	*34 i.fFM.d / sCF Emballonura* sp.
Emballonura furax	New Guinea Sheath-tailed Bat	LC	Possible	Not Recorded	
Emballonura raffrayana	Raffray's Sheath-tailed Bat	LC	Predicted	Recorded	*42 i.fFM.d Emballonura sp., 47 sCF / i.fFM.d Emballonura sp.*
Mosia nigrescens	Lesser Sheath-tailed Bat	LC	Predicted	Recorded	*64 sCF / i.cvFM M. nigrescens*
Saccolaimus saccolaimus	Bare-rumped Sheath-tailed Bat	LC	Not predicted	*Recorded	*24 cFM Saccolaimus* sp., *27 sh.cFM.d Emballonura* sp.

Scientific name	Common name	IUCN status	Likelihood IUCN	2011 study	2011 call type description (if detected)
Rhinolophidae					
Rhinolophus euryotis	New Guinea Horseshoe Bat	LC	Predicted	Not Recorded	
Rhinolophus philippinensis	Large-eared Horseshoe Bat	LC	Not predicted	*Recorded	*42 lCF R. philippinensis*
Hipposideridae					
Aselliscus tricuspidatus	Trident Leaf-nosed Bat	LC	Predicted	Recorded	*112 sCF A. tricuspidatus*
Hipposideros ater	Dusky Leaf-nosed Bat	LC	Predicted	Recorded	*144 sCF H. ater*
Hipposideros calcaratus	Spurred Leaf-nosed Bat	LC	Possible	Not Recorded	
Hipposideros cervinus	Fawn-coloured Leaf-nosed Bat	LC	Predicted	Recorded	*137 sCF H. cervinus*
Hipposideros corynophyllus	Telefomin Leaf-nosed Bat	LC	Possible	Not Recorded	*75 mCF Hipposideros semoni or H. muscinus?*
Hipposideros diadema	Diadem Leaf-nosed Bat	LC	Predicted	Recorded	*58 mCF H. diadema*
Hipposideros maggietaylorae	Maggie Taylor's Leaf-nosed Bat	LC	Predicted	Recorded	*124 sCF H. maggietaylorae*
Hipposideros muscinus	Fly River Leaf-nosed Bat	LC	Not predicted	*Recorded	*90 mCF Hipposideros semoni or H. muscinus?*
Hipposideros wollastoni	Wollaston's Leaf-nosed Bat	LC	Possible	Recorded	*82 mCF H. wollastoni*
Miniopteridae					
Miniopterus australis	Little Bent-winged Bat	LC	Predicted	Possibly recorded	*55 st.cFM.d / cFM*
Miniopterus macrocneme	Small Melanesian Bent-winged Bat	DD	Predicted	Possibly recorded	
Miniopterus magnater	Large Bent-winged Bat	LC	Predicted	Possibly recorded	
Miniopterus tristis	Greater Bent-winged Bat	LC	Predicted	Possibly recorded	*37 st.cFM M. magnater*
Vespertilionidae					
Kerivoula muscina	Fly River Woolly Bat	LC	Predicted	Not Recorded	
Myotis moluccarum	Maluku Myotis	LC	Predicted	Recorded	*40 st.fFM /st.sFM.d M. moluccarum*
Nyctophilus microtis	Papuan Long-eared Bat	LC	Predicted	Not Recorded	*53 st.fFM*
Philetor brachypterus	Short-winged Pipistrelle	LC	Predicted	Recorded	*30 st.cFM*
Pipistrellus angulatus	New Guinea Pipistrelle	LC	Predicted	Recorded	*47 st.cFM.h P. angulatus*
Pipistrellus collinus	Mountain Pipistrelle	LC	Predicted	Possibly recorded	
Pipistrellus papuanus	Papuan Pipistrelle	LC	Predicted	Possibly recorded	

Scientific name	Common name	IUCN status	Likelihood IUCN	2011 study	2011 call type description (if detected)
Molossidae					
Chaerephon jobensis	Greater Northern Free-tailed Bat	LC	Not predicted	Possibly recorded	*17 sh.cFM, 20 cFM*
Unidentified	—	—	—	Recorded	*42 cFM*

4 METHODS

4.1. Survey sites and timing

Surveys were conducted between 28 November and 11 December 2017, at the start of the December–March 'north-west (monsoon) season'. **Table 3** lists the location, timing and elevations covered at each survey site. The survey involved sampling over a total of 13 nights at two principal survey sites that were centred on temporary 'fly camps' constructed specifically for the purpose of the present study ('Camps 1 and 2'). A short one-night overstay visit was also made to Idam 1 village.

Table 3. The location and time spent at each fly camp during mammal surveys.

Site	Base location[A]	Elevations covered[B]	Arrival	Departure
Camp 1	559085 9494427	65–175	28/11/2017, 09:30	4/12/2017, 13:00
Camp 2	534344 9539086	85–180	4/12/2017, 13:15	7/12/2017, 09:30
			8/12/2017, 14:45	11/12/2017, 10:30
Idam River	Idam 1 village	50–65	7/12/2017, 09:45	8/12/2017, 14:30

[A] Coordinates: UTM, PNGMG94 Zone 54.
[B] All elevations in metres AMSL from LIDAR digital elevation model, to the nearest 5 m.

A brief description of each survey site and the habitats surveyed for mammals is given below. A detailed description of the vegetation (types, structure and floristics) present at each survey site is presented in the flora technical report (Takeuchi 2018 this volume).

4.1.1. Camp 1

Camp 1 was positioned in an area of post-garden regrowth on the banks of Dibiri Creek near its confluence with the Right May (Abei) River and about ten minutes' walk upstream from Usaremin 2 village (labelled 'Uriaka' on the 1:100,000 topographic map sheet). Usaremin 2 village is a small settlement of 38 households located on the Right May River approximately five river kilometres upstream from Hotmin village. Mammals were surveyed over six nights in areas accessed by trails through forest, gardens (current and former) and along tributary watercourses (Dibiri Creek and Uriake River).

Natural vegetation is mapped as open alluvial forest (FIMS code Po) on the floodplains and flanking terraces of the Right May and May rivers, and medium crowned hill forest (FIMS code Hm) on the adjacent hill slopes. Most of the alluvial forest accessible on foot from the camp had been converted to gardens, was in various stages of post-conversion regrowth or had been otherwise heavily disturbed. Less disturbed examples were observed from a boat further away from camp. Natural vegetation was more prevalent as hill forest on the spurs and ridges west of camp and on the terraces flanking Dibiri Creek, though these were also subject to regular visitation by local residents for hunting and small-scale resource extraction.

4.1.2. Camp 2

Camp 2 was located in a garden area adjacent to a hunting hut on the 'Wara Kep', a small creek that flows west and north across alluvial plains to meet the Idam River near Idam 1 village approximately 6.3 km northwest of the biodiversity survey camp. Mammals were surveyed in small crowned alluvial forest (FIMS code Ps), and in medium crowned hill forest on the foothill spurs and ridges present to the north and south of camp. The camp was situated approximately three hours walk from the large (>1,000 people) Idam 1 village. Aside from a few hunting huts and small adjacent gardens observed along the wara kep, and numerous walking trails through the forest, there was little sign of anthropogenic disturbance to forest habitats. Nevertheless, the area is evidently visited frequently by hunters. Local residents stated that some hunting-sensitive species, for example *Dorcopsis* wallabies, were formerly common, but are now scarce or absent.

4.1.3. Idam River

Two boat trips were made during 7–8 December 2017 along the lower reaches of the Idam River and parts of the Sepik River. Stops were made at a hunting hut to view hunting trophy material, and to place bat detectors at the edge of garden–hill forest–sago swamp woodland along a small tributary creek. Natural vegetation along the river is mapped as various forms of alluvial forest (FIMS codes Ps and Po), with medium crowned hill forest (Hm) present on the few foothill spurs and isolated hills that abut the river course—at Bisiabru village and on Sunday Hill near the Sepik River. Much of the vegetation observed along the river has been converted to villages or gardens or was otherwise disturbed heavily by local residents. Remaining areas of natural habitat along the meander floodplains are subject to frequent inundation.

4.2. Mammal sampling

4.2.1. Trapping

Live trapping and snap trapping were employed to sample rodents and marsupials. Both the live Elliott box traps (375 x 105 x 105 mm) and the snap traps (Kness MFG 139 x 76 mm) were baited with sweet potatoes (*Ipomea batatas*) and cassava (*Manihot esculenta*) sourced from local communities. Local baits were used to avoid introducing unfamiliar feed that could have reduced trapping success. Transects for mammal trapping were established in such a way to ensure adequate representation of habitats at each camp. Traps were checked each morning for trapped individuals and were rebaited depending on bait condition. Survey effort with Elliott traps totalled 246 trap-nights, comprising 196 Elliott trap-nights at Camp 1 and 50 Elliott trap-nights at Camp 2. Effort at Camp 2 was reduced due to nil trap success at Camp 1, with effort diverted to camera trapping and snap trapping, for which there was greater trapping success. Survey effort with snap traps totalled 300 trap-nights, comprising 70 snap-trap nights at Camp 1 and 230 snap-trap nights at Camp 2.

Bat species presence was assessed using mist nets (double-stranded nylon 'bird' mist nets), a triple-bank harp trap (three overlapping rectangular frames 2 m high containing fishing line strung vertically, and positioned over a catch bag), and 'bat detectors' that record the ultrasonic echolocation calls of bats. One triple-bank harp trap and 29 mist nets (equivalent to 4,446 nocturnal net-metre-hours) were set at ground level across gullies, in the gaps amongst vegetation and on tracks to maximise the capture of bats flying through the understorey (**Attachment 1**). Captured bats were photographed for later confirmation of the identifications.

4.2.2. Camera trapping

Camera traps (Reconyx HC550/PC850) were deployed at each camp by Dr Iain Woxvold as part of the survey effort for birds during the day and mammals at night. The camera traps were set with memory cards labelled against each camera serial number. The exact position of each camera was recorded with a Garmin GPS unit. The camera traps operate continuously through the day and night capturing images of birds and mammals that pass in front of the camera. Camera traps targeting mammals were baited with a variety of baits such as banana, sweet potatoes and cooked rice. Sixteen camera traps were operated at Camp 1 for a total of 1,543.25 hours, and 19 camera traps were operated at Camp 2 over a total of 2,073.25 hours, yielding a total camera trapping effort of 3,016.5 camera trap-hours.

4.2.3. Interviews with hunters

A visit was made to the Usaremin 2 village near Camp 1, where Enock Kale conducted interviews with local hunters and examined the skulls kept as hunting trophies. Interviews were also made with several experienced hunters from Idam 1 when they visited Camp 2. Local assistants were engaged to help determine the local names of each trophy species, and also their food value. Trophies were identified based on diagnostic morphological features, cross-checked with photographic images presented in Flannery (1995).

4.2.4. Opportunistic detections

At each camp opportunistic searches for mammals were conducted on clear nights with head lamps. Snap trapping was also conducted at Usaremin 2 village near Camp 1 to determine the presence of exotic commensal mammal species (such as *Rattus rattus*). Morphometric measurements, including head-body, ear and hind foot length, weight, and the sex were recorded from each captured individual. These measurements aided in the identification of species. Mammal species were identified using Flannery (1995) and the author's (EK) unpublished notes. Reproductive condition of females was also noted, which included observations on lactation and mammary formula. The collection of voucher specimens was not possible due to the unavailability of ethanol, with the sole exception of an unidentified species of *Rattus* that was trapped from Usaremin 2 village and preserved when alcohol arrived at the camp at a later time. This specimen was of relatively large-size and weighed 295 grams, compared to the mean weight of the most likely candidate species, *Rattus praetor*, which weigh 203 grams on average (Flannery 1995).

4.2.5. Acoustic recordings for bats

Most small, insect-eating bat species can be distinguished from each other based on the frequency and pulse shape characteristics of their ultrasonic echolocation calls. Recordings of bat calls were made in high quality full spectrum WAV format with Titley Scientific AnaBat Swift bat detectors (sampling frequency 500 kHz, recording length once triggered 2 sec, sensitivity 16, minimum event 2 ms, frequency range 10–250 kHz) on the nights of 18/11/2017–3/12/2017 at Camp 1, and the nights of 5/12/2017–9/12/2017 at Camp 2 (total three recording units; 27 recording nights).

Bat detectors were set to record between sunset and sunrise (specific to the location as determined by an internal GPS), placed on tree trunks before dusk and collected after dawn. The microphone was on a 2-metre cable, attached at c. 2.5 m in height, and enclosed within a funnel made from a plastic drink bottle to reduce the chance of water exposure. The bat

detectors were placed in a variety of habitats, including adjacent to streams, within forest, along tracks, facing into clearings, and in open habitats. Reference echolocation recordings were made from captured bats with a Titley Scientific Walkabout bat detector (sampling frequency 500 kHz).

4.2.6. Acoustic analysis

A customised, multi-step acoustic processing procedure that can filter large bat echolocation recording datasets from Papua New Guinea (Armstrong and Aplin 2014b; Armstrong et al. 2016) was applied to the recordings made on the survey. Processing first involved the recognition of bat echolocation 'call types', followed by a separate step of allocating a species identification to each of these. The 'call types' are defined based on a standardised naming scheme that has been used in many published and unpublished surveys across Papua New Guinea and Wallacea in recent years (Armstrong and Aplin 2011, 2014a; Armstrong et al. 2015a,b; Armstrong 2017; K.N. Armstrong and K.P. Aplin unpublished confidential reports; **Attachment 2**). The provision of illustrated examples of identified call types provides the opportunity for future verification of call identifications and retrospective correction of species names on the basis of updated information.

The recorded WAV files were scanned for bat echolocation calls using several parameter sets optimised for the main call types in the software SCAN'R version 1.7.7 (Binary Acoustic Technology), which also provides measurements from each putative bat pulse. A custom [R] statistical computing language script was then used to perform a Discriminant Function Analysis on training data comprising reference calls and representative call types of Papua New Guinean bats (Armstrong and Aplin 2011, 2014b; Armstrong et al 2015a; Armstrong 2017; K.N. Armstrong and K.P. Aplin unpublished data). The putative bat calls from each nightly recording were assigned to the confidence regions for the defined call types. Verification of the presence of a call type and its identification was facilitated in the [R] script by opening for inspection the original WAV files containing pulses of interest in a spectrogram within Adobe Audition CS6 version 5.0.2 software. Species were identified from the scored call types based on information in Armstrong and Aplin (2011, 2014a), Leary and Pennay (2011), Robson et al. (2012), Armstrong et al. (2015a), Armstrong (2017), and K.N. Armstrong and K.P. Aplin (unpublished data).

4.3. Protocols used

4.3.1. Taxonomic issues and nomenclature

Identifications were made based on characters in Flannery (1995), Bonaccorso (1998), and the unpublished notes of the authors. Usage of taxonomic nomenclature is based generally on Simmons (2005), the IUCN Red List accounts (IUCN 2018), and updated sources where necessary.

As mentioned in *section 3 Existing Information*, the taxonomic description of the mammals of PNG is still incomplete (Aplin 2015), with numerous biodiversity surveys in the past decade uncovering additional undescribed species to add to taxonomic problem areas that were already known. Consideration of currently undescribed species diversity is an important component of mammal surveys in Papua New Guinea is therefore important because it represents a significant (though not estimated) proportion of the fauna. Unrecognised 'cryptic' diversity is important to consider because an incomplete taxonomy may conceal losses in

diversity if extinction occurs before species discovery or resolution, and lead potentially to misdirected efforts and resources for conservation (Mace 2004).

For some mammals and echolocation call types, it is not possible to attribute a published name because of incomplete taxonomy and therefore ambiguity around an identification. In such cases, the following nomenclature is applied:

> 'sp.' (singular): used in cases where one taxon could not be identified to species level, and there was no close affiliation to a described species.
>
> 'spp.' (plural): used in general reference to more than one species within a genus without the need for more specific information.
>
> 'cf.': for example: *Miniopterus* cf. *australis*. This abbreviation is used to refer to species that are thought to be allied to a named taxon, but for which insufficient data are available to confidently assign specimens to any particular species. The taxon may be part of a known species complex, and/or may be scientifically undescribed (=unnamed), with further work required to determine its identity.

Species are described in this report as 'undescribed' if they remain scientifically unnamed but were previously known from either within, or outside of, the study area.

4.3.2. Conservation status

The conservation status of species is based on the listings of the IUCN Red List and the *Papua New Guinea Fauna (Protection and Control) Act 1966*. The IUCN Red List provides taxonomic, conservation status and distribution information on plants and animals. The IUCN Red List has four main categories: 'Threatened' (with three subcategories that reflect the severity of the threats and the likelihood of extinction: 'Critically Endangered' (CR), 'Endangered' (EN) and 'Vulnerable' (VU)), 'Near Threatened' (NT), 'Least Concern' (LC) and 'Data Deficient' (DD) (**Table 4**). A taxon listed as Data Deficient is worthy of consideration in environmental impact assessments. A status of 'Not Evaluated' (NE) is given to species that have not yet been assessed by the IUCN. The inclusive term 'conservation listed' is used here for any taxon that is listed in any category other than Least Concern in the IUCN Red List, or is listed as Protected under the *Papua New Guinea Fauna (Protection and Control) Act 1966*.

Table 4. Conservation classifications used by IUCN (International Union for Conservation of Nature and Natural Resources).

Category	Definition
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is Endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

5 RESULTS AND DISCUSSION

5.1. Species diversity

5.1.1. Non-volant mammals

Sixteen species of non-volant mammal were recorded on the survey through capture, observation and from inspection of hunting trophies. There were 10 species of marsupial in four families (one species of Macropodidae; three species of Peroryctidae; five species of Phalangeridae; one species of Dasyuridae) and six species in the rodent family Muridae were represented (**Table 5**; **Plates 1**–**2**). The five mammal families were represented at both camps, except the Dasyuridae, which was not detected at Camp 2. All species have wide distributions outside of the Project area.

Elliott live trapping made no contribution to capture rates at both sites. Snap trapping contributed two species of Muridae with a combined trap success of 1%. Trap success was limited to Camp 1, with nil success from snap trapping at Camp 2. Given the experience with trapping on this survey, species accumulation curves are not calculated. The majority (10) of non-volant mammal species were recorded as hunting trophies, highlighting the value of interviews with local hunters. The presence of one additional species is inferred based on diagnostic details given in an interview with a local hunter, which is listed on the IUCN Red List as Threatened: Black-spotted Cuscus *Spilocuscus rufoniger* (CR).

Species of Phalangeridae (species of cuscus possums) were well-represented in the hunting trophies at both camps, with ambiguity around the identification of the Mountain Cuscus *P. carmelitae*. The Ground Cuscus *Phalanger gymnotis* was observed on camera trap photography, and was also represented in the trophies at both sites. The Common Spotted Cuscus *Spilocuscus maculatus* was captured opportunistically during a night search by local assistants at Camp 1. Evidence of the presence of Black-spotted Cuscus *Spilocuscus rufoniger* (CR) was available from hunter testimony only.

Three species of Peroryctidae (rainforest bandicoots) were very well-represented in the hunting trophies, although most trophies were observed in Usaremin 2 village near Camp 1. These are the Common Echymipera *Echymipera kalubu,* Clara's Echymipera *E. clara* and Long-nosed Echymipera *E. rufescens*. The latter is also represented on the camera traps, mostly at Camp 2. The Three-striped Dasyure *Myoictis melas* (Dasyuridae) was only detected by camera trapping at Camp 1.

Six species of Muridae (Lowland Paramelomys *Paramelomys platyops,* Large Spiny Rat *Rattus praetor,* Mottled-tailed Giant Rat *Uromys caudimaculatus* and putatively an unidentified species of water rat *Hydromys* sp.) were surveyed in total. Snap traps produced two species (*R. praetor* and *P. platyops*). *Paramelomys platyops* and *U. caudimaculatus* also appeared on camera traps, mainly at Camp 1. A Rock-dwelling Giant Rat *Xenuromys barbartus* was detected amongst the hunting trophies at Usaremin 2 village near Camp 1. The unidentified *Hydromys* sp. was detected only by camera trapping at Camp 1, with the identification from the camera image uncertain due to poor image quality. Likewise, a putative unidentified *Rattus* on the camera trap images at Camp 2 could not be identified unambiguously.

5.1.2. Bats

In total, 19 echolocation call types, equivalent to at least 19 bat species, were detected on the survey from recordings of echolocation, seven species were captured, and an additional two species of bat were identified amongst the trophies of local hunters. The final tally of bat species detected from all methods combined was 26 (two of the echolocating species were also captured; summary of captures in **Table 5**; summary of acoustic detections in **Table 6**; examples of echolocation call types in **Figure 1**; summary of all detections from acoustic recordings in **Attachment 3**).

Five of the bat species captured in mist nets were smaller-sized representatives of the family Pteropodidae, and two additional larger pteropodids were encountered as hunting trophies (**Table 5**; **Plates 3–5**). Only one insectivorous bat was captured in a mist net—Fawn-coloured Leaf-nosed Bat *Hipposideros cervinus*; and two individuals of the Lesser Sheath-tailed Bat *Mosia nigrescens* were captured in a hand net.

Most of the echolocation call types could be attributed with confidence to a specific species. However, there are some that could not be identified reliably because either the calls of certain groups of species are too similar to distinguish from each other unambiguously, or there are unresolved taxonomic issues that prevent call attributions to one cryptic form. The most obvious example of the latter is the unreliability of identifying the three size forms of bent-winged bat *Miniopterus* spp. that typically co-occur throughout PNG, which could represent any of the six recognised species. In addition, these types of calls (*st.cFM* calls between approx. 40-55 kHz in characteristic frequency) can be confused with those produced by species of *Pipistrellus*. Despite some of these difficulties, the approach of encountering and identifying bat species from echolocation call recordings was highly efficient and produced 17 more records of echolocating bat species than trapping, with significantly greater encounter rates (**Table 6**; see **Attachment 4** for further comments on identifications).

Given that bat detectors were moved to a new acoustically-independent recording position on most nights, it was possible to obtain an approximation of how common each species was through calculations of Relative Abundance (proportion of recordings each species was detected within; **Table 6**). The most commonly recorded species were the Lesser Sheath-tailed Bat *Mosia nigrescens* and Temminck's Leaf-nosed Bat *Aselliscus tricuspidatus*. The most uncommon species were the Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus*, Maggie Taylor's Leaf-nosed bat *Hipposideros maggietaylorae*, Flute-nosed Bat *Murina florium*, and Maluku Myotis *Myotis moluccarum*. Some of these species, such as *H. maggietaylorae* and *M. florium*, produce calls that are typically of low detectability (low amplitude or high frequency/high attenuation-rate), and the other species might be at low density in the study area because of limited optimal foraging or roosting habitat near sampling points. Of particular note was the relatively high Relative Abundance values at Camp 1 of the Large-eared Horseshoe Bat *Rhinolophus philippinensis*, which are usually only recorded at low density. The records are also a significant range extension for this species, though it was also noted by Aplin and Armstrong (2011).

5.2. Exotic and invasive species

Exotic mammals were present around villages and included dogs *Canis familiaris*, some of which are used when hunting, and pigs *Sus scrofa*. Dogs are used by local villagers for hunting, and there is the potential for unaccompanied dogs (whether domestic and owned by local

villagers, or feral and free-living) to roam along logistics corridors and hunt a variety of small and medium-sized native mammals (e.g. Aplin and Opiang 2017).

No records of exotic invasive rodents, including the most likely species, the Black Rat *Rattus rattus,* Polynesian Rat *Rattus exulans* and House Mouse *Mus musculus*, were produced by the present survey. Exotic invasive rodents have been recorded in association with the infrastructure of other mining projects (e.g. Aplin and Opiang 2017), with their introduction occurring when materials used during the development of project infrastructure are brought into an area. In the past, these rodents were confined to major towns in PNG, but in the last decade or two they have invaded rural communities in both lowland and highland provinces of PNG (K.P. Aplin et al. unpublished data). In some areas of PNG, their recent arrival has been attributed by local people to the activities of resource development projects, which is likely to be accurate given that long-distance dispersal of invasive rodents is primarily by road and/or air (K.P. Aplin pers. comm.).

Table 5. Summary of mammal captures (see **Attachment 5** for a list of all captures and trophies).

Family	Genus species	Common name	Encountered by	Total individuals	IUCN
Camp 1					
Peroryctidae	*Echymipera clara*	Clara's Echymipera	Hunting trophy	1	LC
Peroryctidae	*Echymipera kalubu*	Common Echymipera	Hunting trophy	1	LC
Peroryctidae	*Echimipera rufescens*	Long-nosed Echymipera	Hunting trophy	1	LC
Macropodidae	*Dorcopsis hageni*	White-striped Dorcopsis	Hunting trophy	1	LC
Phalangeridae	*Phalanger carmelitae*	Mountain Cuscus	Hunting trophy	1	LC
Phalangeridae	*Phalanger gymnotis*	Ground Cuscus	Hunting trophy, camera trap	2	LC
Phalangeridae	*Phalanger orientalis*	Northern Common Cuscus	Hunting trophy	1	LC
Phalangeridae	*Spilocuscus maculatus*	Common Spotted Cuscus	Hand net, hunting trophy	2	LC
Dasyuridae	*Myoictis melas*	Three-striped Dasyure	Camera trap	1	LC
Muridae	*Hydromys* sp.	Unidentified water rat	Camera trap	1	—
Muridae	*Paramelomys platyops*	Lowland Paramelomys	Snap trap	2	LC
Muridae	*Rattus praetor*	Large Spiny Rat	Snap trap	1	LC
Muridae	*Uromys caudimaculatus*	Mottled-tailed Giant Rat	Hunting trophy	1	LC
Muridae	*Xenuromys barbatus*	Rock-dwelling Giant Rat	Hunting trophy	1	LC
Pteropodidae	*Macroglossus minimus*	Dagger-toothed Long-nosed Fruit Bat	Mist net	2	LC
Pteropodidae	*Nyctimene albiventer*	Common Tube-nosed Fruit Bat	Mist net	24	LC
Pteropodidae	*Syconycteris australis*	Common Blossom Bat	Mist net	22	LC
Hipposideridae	*Hipposideros cervinus*	Fawn-coloured Leaf-nosed Bat	Mist net	1	LC
Emballonuridae	*Mosia nigrescens*	Lesser Sheath-tailed Bat	Hand net	2	LC
Total spp. for Camp 1	***19 spp.***	***Total individuals for Camp 1***		***68***	
Camp 2					
Peroryctidae	*Echymipera clara*	Clara's Echymipera	Hunting trophy	1	LC
Peroryctidae	*Echymipera kalubu*	Common Echymipera	Hunted	2	LC
Peroryctidae	*Echymipera rufescens*	Long-nosed Echymipera	Hunting trophy, camera trap	2	LC

Family	Genus species	Common name	Encountered by	Total individuals	IUCN
Macropodidae	*Dorcopsis hageni*	White-striped Dorcopsis	Photographed live	1	LC
Phalangeridae	*Phalanger gymnotis*	Ground Cuscus	Hunting trophy	1	LC
Phalangeridae	*Phalanger orientalis*	Northern Common Cuscus	Hunting trophy	1	LC
Phalangeridae	*Spilocuscus rufoniger*	Black-spotted Cuscus	Interview	1	CR
Muridae	*Rattus* sp.	Unidentified rat	Hand capture	1	—
Muridae	*Uromys caudimaculatus*	Mottled-tailed Giant Rat	Camera trap	1	LC
Pteropodidae	*Dobsonia minor*	Lesser Bare-backed Fruit Bat	Mist net	1	LC
Pteropodidae	*Dobsonia moluccensis*	Moluccan Naked-backed Fruit Bat	Hunting trophy	1	LC
Pteropodidae	*Pteropus* sp.	Unidentified flying-fox	Hunting trophy	1	—
Pteropodidae	*Macroglossus minimus*	Dagger-toothed Long-nosed Fruit Bat	Mist net	4	LC
Pteropodidae	*Nyctimene albiventer*	Common Tube-nosed Fruit Bat	Mist net	6	LC
Pteropodidae	*Paranyctimene raptor*	Green Tube-nosed Fruit Bat	Mist net	1	LC
Pteropodidae	*Syconycteris australis*	Common Blossom Bat	Mist net	31	LC
Total spp. for Camp 2	***16 spp.***	***Total individuals for Camp 2***		***56***	
Grand total species	***26 spp.***				

Table 6. Summary of echolocating bat species and echolocation call types detected in the acoustic recordings. Values in coloured cells indicate Relative Abundance; species were listed as 'predicted' according to whether their IUCN Red List profile showed their distribution covering the study site, or whether the species had been detected previous by Aplin and Armstrong (2011). See **Attachment 6** for a summary of bat detector placements; **Attachment 7** for a reconciliation of species name and call type usage between the present survey and Aplin and Armstrong (2011).

Genus species	Common name	Call type	Predicted?	IUCN	Roost type	Camp 1	Camp 2	Idam River
EMBALLONURIDAE								
Emballonura dianae	Greater Sheath-tailed Bat	***35 i.fFM.d***	Yes	LC	cave	0.7	0.2	—
Emballonura furax	New Guinea Sheath-tailed Bat	***52 i.fFM.d***	Yes	LC	cave	0.4	0.2	0.3
Mosia nigrescens	Lesser Sheath-tailed Bat	***65 i.fFM.d***	Yes	LC	foliage	0.8	0.8	1.0
Saccolaimus saccolaimus	Bare-rumped Sheath-tailed Bat	***25 sFM***	Yes	LC	tree hollow cave	—	—	0.3
HIPPOSIDERIDAE								
Aselliscus tricuspidatus	Temminck's Leaf-nosed Bat	***115 sCF***	Yes	LC	cave	0.9	0.8	1.0
Hipposideros cervinus	Fawn-coloured Leaf-nosed Bat	***140 sCF***	Yes	LC	cave	0.3	—	—
Hipposideros diadema	Diadem Leaf-nosed Bat	***58 mCF***	Yes	LC	cave	0.6	0.4	0.7
Hipposideros maggietaylorae	Maggie Taylor's Leaf-nosed bat	***128 sCF***	Yes	LC	cave	—	0.1	—
Hipposideros wollastoni	Wollaston's Leaf-nosed Bat	***82 mCF***	Yes	LC	cave	0.6	—	—
Hipposideros* cf. *corynophyllus	Unidentified Leaf-nosed Bat	***75 mCF***	Yes	—	cave	0.3	—	—
Hipposideros muscinus	Fly River Leaf-nosed Bat	***92 mCF***	Yes	LC	cave	0.3	0.8	0.7
RHINOLOPHIDAE								
Rhinolophus* cf. *philippinensis	Large-eared Horseshoe Bat	***42 ICF***	Yes	LC	cave	0.5	—	—
VESPERTILIONIDAE								
Murina florium	Flute-nosed Bat	***100 bFM***	No	LC	foliage	0.1	0.1	—
Myotis moluccarum	Maluku Myotis	***40 bFM***	Yes	LC	cave	0.1	—	—
Nyctophilus microtis	Papuan Long-eared Bat	***50 bFM***	Yes	LC	tree hollow	—	0.5	0.7
***Pipistrellus* sp.**	Unidentified Pipistrelle	***42 st.cFM***	3 spp.	—	tree hollow	0.4	0.6	0.7
MINIOPTERIDAE								
Miniopterus* cf. *australis	Unidentified Bent-winged Bat	***55 st.cFM***	Yes	LC	cave	—	0.3	0.7
Miniopterus* cf. *macrocneme	Unidentified Bent-winged Bat	***48 st.cFM***	Yes	DD	cave	0.3	0.4	0.7
Miniopterus* cf. *tristis	Unidentified Bent-winged Bat	***38 st.cFM***	Yes	LC	cave	0.2	0.2	0.3
Total species detected		**19**				**15**	**13**	**11**
No. of recording nights		**Total 27**				**14**	**10**	**3**

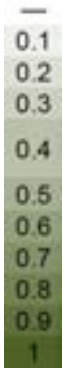

Plate 1. Photographs of rodents collected (Top: Large Spiny Rat *Rattus praetor*; Bottom: Lowland Paramelomys *Paramelomys platyops*).

Plate 2. Photographs of hunters trophies (Top, left to right: *Pteropus* sp.; *Echymipera* sp.; *Phalanger* sp.; Bottom: Common Spotted Cuscus *Spilocuscus maculatus* captured by hand).

Plate 3. Photographs of captured bats (Top, left to right: Lesser Sheath-tailed Bat *Mosia nigrescens*; Fawn-coloured Leaf-nosed Bat *Hipposideros cervinus*; Bottom: lowland form of the Common Blossom Bat *Syconycteris australis*).

Plate 4. Photographs of two cryptic taxa currently considered together as the Common Tube-nosed Fruit Bat *Nyctimene albiventer*.

Plate 5. Photographs of the Lesser Bare-backed Fruit Bat *Dobsonia minor*.

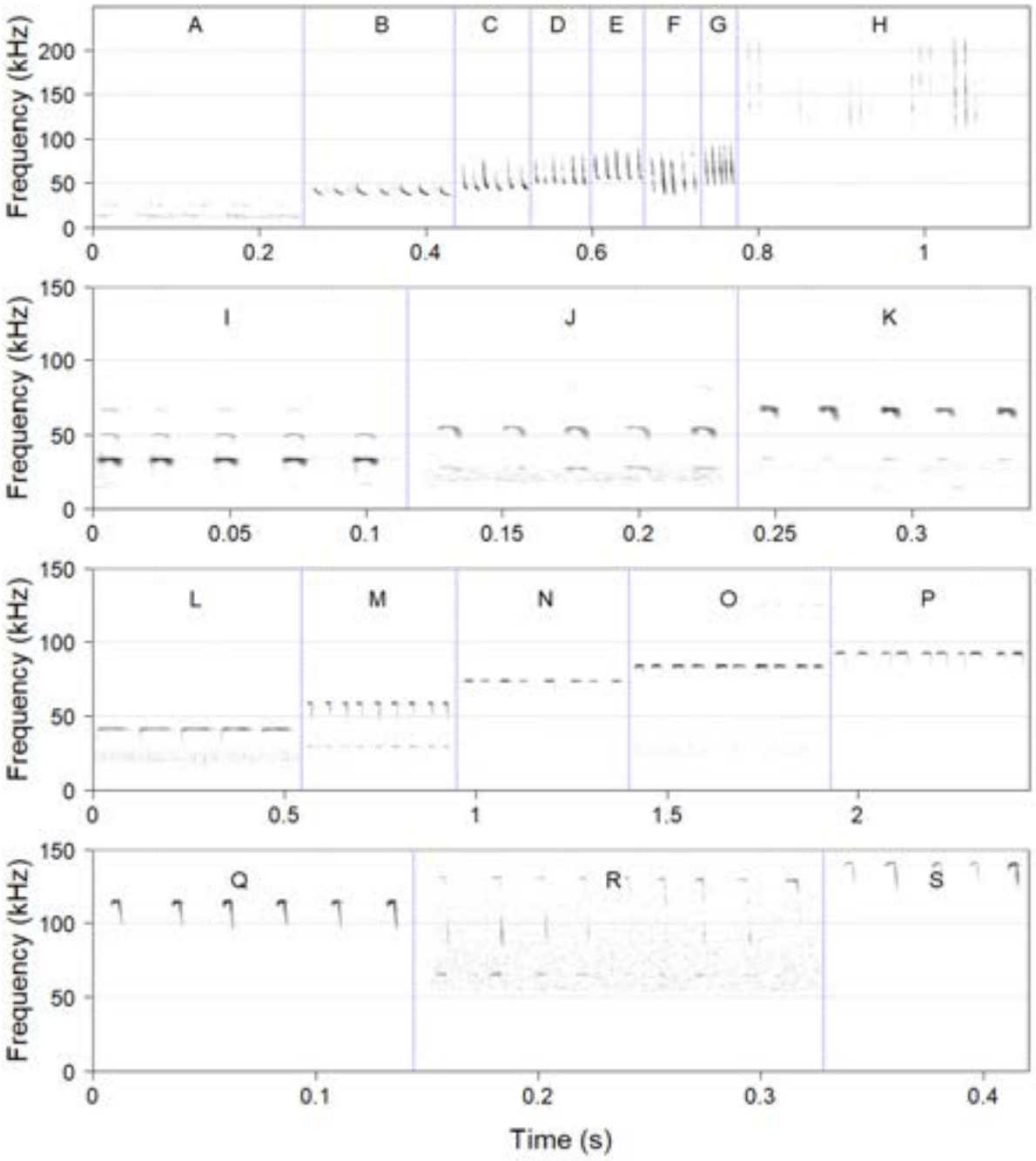

Figure 1. Examples of each echolocation call type recognised (time is compressed between pulses; note the x-axis and y-axis are scaled differently amongst the four plots).

A: *25 sFM Saccolaimus saccolaimus*
B: *38 st.cFM Miniopterus* cf. *tristis*
C: *42 st.cFM Pipistrellus sp.*
D: *48 st.cFM Miniopterus* cf. *macrocneme*
E: *55 st.cFM Miniopterus* cf. *australis*
F: *40 bFM Myotis moluccarum*
G: *50 bFM Nyctophilus microtis*
H: *100 bFM Murina florium*

I: *35 i.fFM.d Emballonura dianae*
J: *52 i.fFM.d Emballonura furax*
K: *65 i.fFM.d Mosia nigrescens*

L: *42 lCF Rhinolophus philippinensis*
M: *58 mCF Hipposideros diadema*
N: *75 mCF Hipposideros* cf. *cornophyllus*
O: *82 mCF Hipposideros wollastoni*
P: *92 mCF Hipposideros muscinus*

Q: *115 sCF Aselliscus tricuspidatus*
R: *128 sCF Hipposideros maggietaylorae*
S: *140 sCF Hipposideros cervinus*

6 SPECIES OF CONSERVATION SIGNIFICANCE

6.1. Species listed by the IUCN or Protected under PNG legislation

6.1.1. Black-spotted Cuscus Spilocuscus rufoniger (CR)

The most significant Threatened-listed species expected to be present based on an anecdotal account is the Black-spotted Cuscus *Spilocuscus rufoniger* (CR). This species is also listed as Protected under the *Papua New Guinea Fauna (Protection and Control) Act 1966*. No specimen was encountered, but a reliable indication of its contemporary presence in the proposed project corridor area was available from a local hunter, Abu Yanekeo of Idam 1 village near Camp 2. Other evidence of its presence is available from elsewhere in the Project area. A lower jaw of *S. rufoniger* was recorded from a hunter in Nekiei Village in the previous survey (Aplin and Armstrong 2011).

Spilocuscus rufoniger is widespread in the northern part of New Guinea, but distributed patchily, and most of the records are very old. It has been recorded from sea level to 1,200 m AMSL, preferring primary lowland and lower-montane tropical forests. It has disappeared from parts of its range through overhunting and its sensitivity to human disturbance (Leary et al. 2016a).

6.1.2. Small Melanesian Bent-winged Bat Miniopterus macrocneme (DD)

Species listed as Data Deficient by the IUCN have insufficient information available on their population size, distribution limits and operating threats to assess their conservation status. In the absence of such critical information relevant to their long-term persistence, it is prudent to summarise information from the survey relevant to a consideration of potential impacts of the proposed development. None of the bat species encountered on the present survey are listed on the IUCN Red List as Threatened or Near Threatened, but one with the potential to be present is listed as Data Deficient: Small Melanesian Bent-winged Bat *Miniopterus macrocneme*.

This name was allocated to an echolocation call type (*48 st.cFM*) that is attributable to a medium-sized species of bent-winged bat such as *M. macrocneme*. There are also other candidates for the call type *48 st.cFM*: *Pipistrellus* spp. (**Attachment 4**). The identification of all bent-winged bat species is problematic given an unresolved taxonomy and difficulties in making identifications from both external morphology and echolocation calls. The call type was allocated to *M. macrocneme* under the precautionary principle and on the basis that it was the most significant species amongst the candidates, and therefore the most relevant to an environmental impact assessment.

This species roosts in caves during the day in large aggregations where it is vulnerable to hunting and disturbance (Bonaccorso and Reardon 2008). Its IUCN has not yet been updated in the current review being undertaken, but its taxonomy is the subject of a larger funded study on all Indo-Australasian bent-winged bats (K.N. Armstrong and S. Wiantoro unpublished data).

6.2. Undescribed species

6.2.1. Non-volant mammals

Some mammal groups in PNG are suspected to have cryptic species-level diversity (see glossary) based on the examination of captures in numerous field studies (K.P. Aplin and K.N. Armstrong unpublished observations), but taxonomists have not yet had the opportunity to fully resolve them. There is potential for undiscovered cryptic taxa in some of the more widespread marsupials, but it is the rodents that are likely to contain the greatest undescribed diversity. Undescribed and previously undiscovered taxa are relevant to an environmental impact assessment because their distribution limits have not been defined, and therefore the proportion of their population within areas of the influence of a planned development are unknown.

Of those captured on the present survey, perhaps the best candidate for previously undiscovered diversity is Lowland Paramelomys *Paramelomys platyops*. In addition to being distributed over much of lowland New Guinea, it is present on New Britain and some near-shore islands (Wright et al. 2016). In a recent study in Southern Highlands Province, the application of mitochondrial DNA genetic markers highlighted the complex genetic relationships such as introgression or mitochondrial capture in forms identified as *P. platyops* (Aplin and Opiang 2017; Armstrong and Aplin 2017a). *P. platyops* is very likely a species complex with an unknown number of species. Taxonomic resolution will bring clarity to names and distributions, but it is likely that *platyops*-group taxa will not be assessed as Threatened, given how common they appear to be.

6.2.2. Bats

There is the possibility of cryptic undescribed or undiscovered species of bat within most of the genera in Papua New Guinea, but there are some groups where the lack of taxonomic resolution is not only well known, but is a regular source of difficulty in environmental impact studies.

The genus *Miniopterus* is acknowledged globally to be one of the most taxonomically complex and difficult of all groups of bats (e.g. Goodman et al. 2011). The genus is morphologically conservative, with few features obvious for distinguishing them beyond subtle variations in fur colour and body size. In recent years, progress has been made in several parts of the world to understand the taxonomic complexity of regional *Miniopterus* faunas (e.g. Appleton et al. 2004; Tian et al. 2004; Goodman et al. 2011). However, in PNG the overlapping size ranges (Bonaccorso 1998) and the possibility of cryptic taxa prevent any robust attempt at identification, especially in the field. An added complication is that most New Guinean *Miniopterus* are associated with species described from elsewhere (with the exception of *M. magnater* that was described from the Sepik Basin), including Java on the opposite of both Lydekker's Line and Wallace's Line. Thus, both the taxonomy and nomenclature of New Guinea *Miniopterus* is likely to be incorrect. Studies using advanced genome-scale genetic markers are currently addressing these issues (K.N. Armstrong and S. Wiantoro unpublished research).

The small fruit bat genera *Nyctimene* and *Paranyctimene* are also taxonomically unresolved (K.P. Aplin and K.N. Armstrong unpublished research and field observations). A recent publication by Irwin (2017) has brought clarity to the identification and taxonomic relationships of some part of the *Nyctimene albiventer* complex, with the confirmation of the existence of *N.*

certans, and the description of a new species *N. wrightae*, but the subfamily Nyctimeninae still contains forms of ambiguous taxonomic status. More than one form is likely to occur in *N. draconilla*, and more than the two currently recognised species are likely within *Paranyctimene*. Further studies using advanced genome-scale genetic markers are currently addressing these issues (K.N. Armstrong unpublished research). Identification to species or genetic group of those captured on the present survey was not possible without voucher specimens and running genetic analyses. In general, tube-nosed fruit bats are not as numerically abundant based on mist net captures as the Common Blossom Bat *Syconycteris australis*, but neither do they are appear to be uncommon.

The Flute-nosed Bat *Murina florium* is found in a highly allopatric distribution from the island of Flores in Nusa Tenggara (Lesser Sunda islands of Indonesia) across the southern islands of Maluku, a few locations in Papua New Guinea, New Britain and Cape York in Queensland, Australia. It is highly likely that this obligate forest-dwelling taxon is actually several species, with each confined to a specific island. It is also possible that there may be more than one taxon in New Guinea.

The Papuan Long-eared Bat *Nyctophilus microtis* is distributed mainly in lowland areas of northern Papua New Guinea, but recent surveys for other resource projects have uncovered at least two morphological forms, some of which are sympatric, that could represent distinct species. Genetic work to confirm this is underway (K.N. Armstrong unpublished research).

The species complex '*Rhinolophus philippinensis*' encompasses numerous size forms and phonic (echolocation call) types from the Philippines, Indonesia, Timor-Leste, New Guinea and northern Australia. A taxonomic revision is currently being undertaken (K.N. Armstrong unpublished research) that will build on previous work of Cooper et al. (1998), and the taxon is likely to be split into several species as a result. Two phonic types have been recorded from Papua New Guinea: one giving a call of *33 ICF* that is very similar to the large form in Australia now referred to as *Rhinolophus robertsi*, but which has not been captured (to our knowledge); and another form giving a call of *42 ICF* that is similar to the undescribed 'intermediate' of Cape York, and which all collected forms in New Guinea resemble (e.g. see photographs in Flannery 1995). Until genetic studies are complete, the final number of species in Australasia are pending.

6.3. Additional species of conservation significance that may occur

6.3.1. Eastern Long-beaked Echidna Zaglossus bartoni (VU)

The Eastern Long-beaked Echidna *Zaglossus bartoni* is listed as Vulnerable and its meat is highly prized by hunters. It ranges throughout the central mountains of New Guinea, with its upper elevational range extending to the highest available peaks, and on the southern side of the central cordillera it extends to low elevations close to sea level. By contrast, on the northern side of this mountain range it does not appear to occur below the lower limit of the montane forest (Leary et al. 2016b). It is therefore unlikely to occur presently in the study areas below around 650 m. The hunters interviewed at both study camps did not mention any of the Echidna species.

6.3.2. New Guinea Quoll Dasyurus albopunctatus (NT)

The New Guinea Quoll is widespread throughout much of New Guinea, with a wide elevational range (sea level to 3,600 m) but has a patchy distribution across its range. It occurs most often

at elevations of 1,000-1,300 m AMSL, and thus has the potential to occur in the Project area. It is widespread and locally abundant but listed as Near Threatened because declines have been recorded at a number of localities due to impacts of people (expanding agriculture) and hunting with dogs. There are also possible threats from feral cats and the potential loss of the lowland habitats to oil palms. The impacts from predation and competition have caused dramatic declines in Australian species (Woolley et al. 2016). There is a possibility this species occurs in the Project area, such as Crater Mountain Wildlife Management Area (Kale et al. 2012) and Mt. Gahavisuka Provincial Park (E. Kale, personal observation). Hunters at both camps indicated that the species is present but appear to have had few or no personal encounters with the species.

6.3.3. Goodfellow's Tree Kangaroo Dendrolagus goodfellowi (EN)

Goodfellow's Tree Kangaroo *Dendrolagus goodfellowi* (EN) was not recorded on the survey but has the potential to occur (range: sea level to 2,860 m AMSL; Leary et al. 2016c). It is known mainly from the mid-montane zone in excess of 1200 m AMSL both north and south of the central cordillera, the Torricelli Mountains and the Foja Mountains of West Papua but has been recorded at a lower elevation of 680 m AMSL in forests of the foothills (Flannery 1995). According to the most recent IUCN assessment (Leary et al. 2016c), there is an ongoing decline in the population of *D. goodfellowi* across its range. At least 50% of the population has been hunted over the past 30 years, which has led to the extirpation of some populations. Its absence is coupled with a decline in habitat quality brought about by anthropogenic activities. A detailed interview with an expert hunter at the Idam 1 (Camp 2) indicated that *D. goodfellowi* is absent from the study area.

6.3.4. Other tree kangaroos

A second species of tree kangaroo, *Dendrolagus notatus* (EN; no common name, previously a subspecies of *D. dorianus* now considered as a full species), may also be found within the Project area, but only in upper elevations (900–3,100 m AMSL; Leary et al. 2016d), and being unlikely to occur in the transmission corridor. Other species of tree kangaroo such as the Grizzled Tree-kangaroo *Dendrolagus inustus* (VU) that are found in the Torricelli Mountains also range down to 100 m (Leary et al. 2016e) and might be present in the transmission corridor, but others such as the range-limited Tenkile *Dendrolagus scottae* CR (Leary et al. 2008) are very unlikely to occur. Interviews with hunters at both study sites suggested they had no knowledge of these species.

6.3.5. Small Dorcopsis Dorcopsulus vanheurni (NT)

The Small Dorcopsis *Dorcopsulus vanheurni* (NT) used to be a common species but is now uncommon and in decline due to hunting by local people and dogs. It occurs in the upper hill to upper-montane forests throughout the central mountain chain of the island of New Guinea, from 800 to 3,200 m AMSL, but has been extirpated from some areas, such as the Torricelli ranges (Leary et al. 2016f). There is a small possibility of its occurrence in the Project area. Interviews with local hunters at both study sites suggested they had no knowledge of *D. vanheurni*.

6.3.6. New Guinea Pademelon Thylogale browni (VU)

The New Guinea Pademelon *Thylogale browni* is listed as Vulnerable because of an ongoing population decline due to hunting pressures of local people with dogs. The species is a preferred target for hunting because of its large size relative to other prey, and numbers typically decrease closer to villages. It is widespread throughout northern and north-eastern New Guinea, occurring in primary and secondary tropical moist forest in elevations from sea level up to 3,200 m AMSL, but seems to prefer disturbed areas (Leary et al. 2016g). There is a small possibility of its occurrence in the Project area but hunters interviewed appeared to be unfamiliar with its occurrence at both study sites.

6.3.7. Bulmer's Fruit Bat Aproteles bulmerae (CR)

The likelihood of the presence of Bulmer's Fruit Bat *Aproteles bulmerae* (CR) (also listed as P under the *Papua New Guinea Fauna (Protection and Control) Act 1966*) is low given that this species prefers large, relatively inaccessible sinkholes at higher elevations that are subject to low hunting pressure (Aplin et al. 2016). The documented elevational range of c. 500–2,400 m spans the habitat categories of Hill Forest, Lower Montane and Upper Montane Forests. On the last survey, sinkholes deemed as suitable roost habitat were observed, but there was no unambiguous evidence of its presence (Aplin and Armstrong 2011).

6.3.8. Thomas's Big-eared Bat Pharotis imogene (CR)

There is also a low likelihood of the presence of Thomas's Big-eared Bat *Pharotis imogene* (CR) (also listed as P under the *Papua New Guinea Fauna (Protection and Control) Act 1966*). While it has only ever been recorded from lowland habitats, which are present in the Project area, it has only been encountered in the south-eastern part of the island, and not north of the central cordillera of New Guinea (Bonaccorso et al. 2008; Hughes et al. 2014).

6.3.9. Data Deficient bats

The New Guinea Sheath-tailed Bat *Emballonura furax*, Telefomin Leaf-nosed Bat *Hipposideros corynophyllus* and Fly River Leaf-nosed Bat *Hipposideros muscinus* were previously listed as Data Deficient, but have recently been reassessed as Least Concern (Armstrong and Aplin 2017b,c,d), mostly because of new records generated on environmental impact assessment surveys.

6.4. Species of significance to local communities

The interviews conducted with local hunters and the examination of their hunting trophies was a valuable source of information about many species of mammals present in the study area. In addition to revealing part of the local diversity of the mammal assemblage, the results demonstrate that local people have a reliance on bush meat in addition to their domesticated pigs. A total of 10 species were identified amongst the hunting trophies examined. These were mostly medium-sized marsupials such as bandicoots (Peroryctidae: 3 species amongst the trophies) and cuscus (Phalangeridae: 4 species amongst the trophies).

Small wallabies such as the White-striped Dorcopsis *Dorcopsis hageni* and species of large flying-fox (Moluccan Naked-backed Fruit Bat *Dobsonia moluccensis* and an unidentified species of *Pteropus*) are also valued hunting quarries. Some of the larger rodents are also hunted and eaten (Mottled-tailed Giant Rat *Uromys caudimaculatus*; Rock-dwelling Giant Rat

Xenuromys barbatus). None of these species are listed as threatened or Protected, but increased and sustained hunting pressure can significantly reduce population sizes and cause local extirpations. This is of particular concern for the Black-spotted Cuscus *Spilocuscus rufoniger* (CR). If they were present, the larger species such as tree kangaroos and long-beaked echidnas would be prized hunting items when encountered. It appears from hunter interviews that although larger-sized mammals are preferred; any mammal species encountered during hunting can be collected regardless of its body size.

Mammals contribute most meat to rural subsistence hunters in PNG (Mack and West 2005), and the targets of hunting need close attention from wildlife managers. In the study by Mack and West (2005) that was conducted in two remote locations in Papua New Guinea (in the Telefomin area of Sandaun Province), they recorded a remarkable 1.2 tons of wild meat (in a study period of 225 days) derived from mainly from 37 large-bodied mammal genera, including species of *Dendrolagus, Zaglossus* and *Phalanger*. This trend is likely to be happening in most remote locations where hunting for wild meat is the norm for a large segment of the PNG population that live at the fringes of the cash economy, have poor access to cash, and who have a lack of options for obtaining protein from farm-sourced animals. This scenario is present in the local communities who live along the project corridor assessed in this study.

7 IMPORTANT HABITATS

7.1. Lowland forest

The development of the proposed infrastructure corridor from Vanimo to Frieda River will run mostly in tropical lowland forest. Large areas of lowland forest in Sandaun Province close to the coast have been logged to various degrees, with large areas present as secondary forest that has been logged several times (Shearman and Bryan 2015). In the past two decades, there has been an acceleration of forest loss (Shearman et al. 2008). Large-bodied mammal species such as tree kangaroos prefer undisturbed habitats with intact large-crowned forest and are sensitive to operations that open the canopy of closed forests. Generally, maximum diversity of mammal species is supported by the maintenance of the intactness of primary forest.

The most significant mammal that relies on lowland forests in the Project area is the Critically Endangered Black-spotted Cuscus *Spilocuscus rufoniger*. This rare species occurs from sea level up to 1200 m AMSL, and is restricted to northern New Guinea, including Sandaun Province. The few available specimens in museums have come from Sandaun Province and West Papua (Flannery 1995).

Some bat species are sensitive to changes in the structure of forest habitats, with some disappearing and others becoming more common when habitats are opened up (Kalko 1998; Jones et al. 2003). Opening of forest has the potential to reduce habitat quality for some species that do not venture far from closed forest canopies. This includes species producing call types *sCF* (hipposiderids bats), *ICF* (rhinolophid bats), *bFM* (species of *Kerivoula, Murina, Nyctophilus*) and probably *i.fFM.d* (*Emballonura* spp.).

Intact mammal communities on a regional scale have high conservation value, whether or not they include taxa that are listed as threatened. It is widely acknowledged that bats perform a variety of roles within the forest ecosystem, with the most important being the keystone roles of flower pollination, seed dispersal of fruiting plants, and regulation of insect populations

(Fujita and Tuttle 1991; McConkey and Drake 2006; Kalka et al. 2008; Williams-Guillén et al. 2008; Lobova et al. 2009). In many habitats across New Guinea bats are probably the most abundant group of mammals, and they seem to be disproportionately so in any areas that are naturally resource poor. Accordingly, they underpin many aspects of ecosystem functionality and thus warrant conservation effort.

7.2. Caves and rock shelters as roosts for bats

Significantly, 15 of the 19 echolocating bat species, and two of the seven Pteropodidae use caves for roosts, either occasionally, or because of an obligate requirement (**Table 6**). Those species reliant on caves are therefore vulnerable to disturbance of colonies that have aggregated for daily refuge, and for seasonal breeding activity. They will be present in colonies of various size in areas of limestone karst that provide roosting opportunity in caves of various depths. Little is known of the requirements of PNG bats for breeding, but the daily requirement for underground roost sites makes them vulnerable to disturbance of caves. All bat species recorded are probably capable of ranging several kilometres during their nightly foraging activities, and their detection within sites planned for development will be a result of this rather than roosting if caves are not present within development footprints.

Several bat species are generally regarded as 'obligate' cave-roosting species (**Table 6**; Bonaccorso 1998), including hipposiderids (such as Temminck's Leaf-nosed Bat *Aselliscus tricuspidatus,* Fawn-coloured Leaf-nosed Bat *Hipposideros cervinus,* Diadem Leaf-nosed Bat *H. diadema,* Maggie Taylor's Leaf-nosed Bat *H. maggietaylorae,* Fly River Leaf-nosed Bat *H. muscinus,* Wollaston's Leaf-nosed Bat *H. wollastoni*), one rhinolophid (Large-eared Horseshoe Bat *Rhinolophus philippinensis*), emballonurids (species of *Emballonura*, and possibly the Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus*), miniopterids (*Miniopterus* cf. *australis*, *Miniopterus* cf. *macrocneme* and *Miniopterus* cf. *tristis*), and two large-bodied pteropodids (Lesser Bare-backed Fruit Bat *Dobsonia minor,* Moluccan Naked-backed Fruit Bat *D. moluccensis*). All of these species are thought to roost typically in caves, with shallow rocky overhangs and fissures sometimes mentioned as secondary roost sites (Flannery 1995; Bonaccorso 1998).

The status of the various hipposiderid bats as 'local residents' rather than nightly immigrants from roosts in areas further afield is supported by the regularity of their acoustic detection, and their flight morphology that is inconsistent with regular long-distance flights. These observations point to the regular use of local roosts and, for some species, the use of these sites not only as a base for foraging but also for breeding. By contrast, the species of bent-winged bat *Miniopterus* spp. are capable of nightly long-distance flight and may roost either nearby their site of detection or much further afield.

An important implication of the relatively high abundance of cave-roosting species is that small fissures or rock overhangs suitable for use by cave-roosting bats must be dispersed through the study area. However, without intensive surveys it is not possible to state whether these are numerous, or whether the calls detected in the ultrasonic recordings had their origin from colonies in relatively rare and isolated underground structures. It is possible that bats congregating in a single roost could be responsible for many of the calls on the anonymous recordings.

7.3. Mature trees as roosts for hollow-dwelling mammals

Large and/or senescent trees are likely to play a major role in maintaining the diversity of local wildlife. Such trees are more common in primary, intact forest, and tree hollows provide daytime shelter for many species of mammal are larger and more numerous in large, old trees. Epiphyte load also tends to be larger and more diverse in such trees, which also provides refuge for various mammal species. Large and/or senescent trees are essential for maintaining local populations of a wide variety of mammal species that use hollows for shelter and reproduction, especially the possums in the families Pseudocheiridae, Phalangeridae and Acrobatidae, and including species of conservation significance such as the Common Spotted Cuscus *Spilocuscus maculatus*. Bats that are known to congregate for breeding purposes in tree hollows include some *Hipposideros* spp., all *Nyctophilus* spp., and *Pipistrellus* spp. (Flannery 1995; Bonaccorso 1998).

8 CONCLUSIONS

1. The mammal faunas in the survey sites of the Terrestrial Biodiversity Study Area are diverse, but large-bodied species of marsupial such as tree kangaroos are presumably in low number or absent because of hunting pressure from nearby villages.

2. The sites surveyed in this study are a potential habitat for eight non-volant mammal families and over 40 species occurring in New Guinea, representing 30 percent of the New Guinea terrestrial mammal fauna. In the current study, five non-volant mammal families were actually sampled from the eight expected to occur in the project area, which is relatively high given the limited field time. A total of 16 non-volant mammal species was actually detected by the methods employed on the survey.

3. There is a diverse community of bats present, with at least 19 echolocating insectivorous species detected from their calls, and with a further seven species detected through capture and examination of hunting trophies. Significant taxonomic issues remain in some groups, but no species of bat detected is listed as Threatened or Protected.

4. Sampling of terrestrial mammals was aided greatly by the access to hunting trophies examined at the communities, which also provided important information on the protein source for the local communities. Based on the information collected, local bush meat is sourced mainly from two mammal families, the Phalangeridae and Peroryctidae.

5. The habitats surveyed are potentially important for the rare and Critically Endangered *Spilocuscus rufoniger*, which was only noted from a hunter testimony. It is possible that the Vulnerable Goodfellow's Tree Kangaroo *Dendrolagus goodfellowi* may also be present, especially at higher elevations in the Sepik Development Project.

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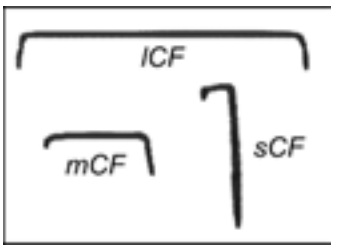
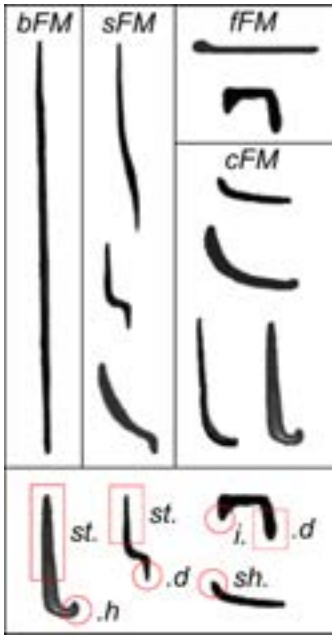
10 ATTACHMENTS

Attachment 1. Summary of mist net placements (nocturnal trapping began 18:30, concluded 06:30; 12 hours).

Site	Net No.	Position No.	Net length	IW wpt	Open	Closed	Nocturnal hours	Nocturnal net-m-hrs	Habitat
Camp 1	1	1	9	17	29/11, 18:00	30/11, 08:00	12	108	Open alluvial forest/garden regrowth
Camp 1	2	1	12	17	29/11, 18:00	30/11, 08:00	12	144	Open alluvial forest/garden regrowth
Camp 1	3	2	12	19	29/11, 18:30	30/11, 08:00	12	144	Open alluvial forest/garden regrowth
Camp 1	4	2	12	19	29/11, 18:30	30/11, 08:00	12	144	Open alluvial forest/garden regrowth
Camp 1	5	3	12	23	30/11, 18:00	2/12, 11:30	24	288	Primary medium crowned hill forest ridge
Camp 1	6	3	12	23	30/11, 18:00	2/12, 11:30	24	288	Primary medium-crowned hill forest ridge
Camp 1	7	4	9	22	30/11, 18:00	2/12, 11:30	24	216	Primary medium-crowned hill forest ridge
Camp 1	8	4	9	22	01/12, 18:30	2/12, 11:30	12	108	Primary medium-crowned hill forest ridge
Camp 1	9	4	9	22	01/12, 18:30	2/12, 11:30	12	108	Primary medium-crowned hill forest ridge
Camp 1	10	5	12	28	2/12, 18:30	3/12, 08:00	12	144	Primary small-crowned hill forest
Camp 1	11	6	9	27	2/12, 18:30	3/12, 08:00	12	108	Primary small-crowned hill forest
Camp 1	12	6	9	27	2/12, 18:30	3/12, 08:00	12	108	Primary small-crowned hill forest
Camp 1	13	7	12	25	2/12, 18:30	3/12, 08:00	12	144	Primary small-crowned hill forest
Camp 1	14	7	9	25	2/12, 18:30	3/12, 08:00	12	108	Primary small-crowned hill forest
Total Camp 1							**204**	**2160**	
Camp 2	1	1	12	37	5/12, 16:30	7/12, 09:30	24	288	Alluvial forest
Camp 2	2	1	12	37	5/12, 16:30	7/12, 09:30	24	288	Alluvial forest
Camp 2	3	1	9	37	5/12, 16:30	7/12, 09:30	24	216	Alluvial forest
Camp 2	4	1	9	37	5/12, 16:30	7/12, 09:30	24	216	Alluvial forest
Camp 2	5	1	9	37	5/12, 16:30	7/12, 09:30	24	216	Alluvial forest
Camp 2	6	2	12	42	6/12, 15:00	6/12, 20:30	2	24	Alluvial forest next to camp
Camp 2	6	2	12	42	7/12, 18:30	8/12, 10:30	12	144	Alluvial forest next to camp
Camp 2	7	2	12	42	6/12, 15:00	6/12, 20:30	2	24	Alluvial forest next to camp
Camp 2	8	2	12	42	6/12, 15:00	6/12, 20:30	2	24	Alluvial forest next to camp
Camp 2	9	2	9	42	6/12, 15:00	6/12, 20:30	2	18	Alluvial forest next to camp
Camp 2	10	3	12	53	8/12, 16:30	9/12, 08:30	12	144	Alluvial forest
Camp 2	11	3	12	53	8/12, 16:30	9/12, 08:30	12	144	Alluvial forest
Camp 2	12	3	12	53	8/12, 16:30	9/12, 08:30	12	144	Alluvial forest
Camp 2	13	3	12	53	8/12, 16:30	9/12, 08:30	12	144	Alluvial forest

Site	Net No.	Position No.	Net length	IW wpt	Open	Closed	Nocturnal hours	Nocturnal net-m-hrs	Habitat
Camp 2	14	3	12	53	8/12, 16:30	9/12, 08:30	12	144	Alluvial forest
Camp 2	15	3	9	53	8/12, 16:30	9/12, 08:30	12	108	Alluvial forest
Total Camp 2							**212**	**2286**	
Grand Total							**416**	**4446**	

Attachment 2. 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, 2014a), Armstrong et al. (2015a,b); Armstrong 2017; examples are not scaled equally). Pulses generally consist of three main sections: an initial frequency sweep (IFS), followed by the main body (BST: Body Sub Type), and ending in a terminating frequency sweep (TFS). The shape of the pulse is represented by the codes in the form 'IFS.BST.TFS', prefixed by a value representing the mean characteristic frequency in kHz. Note that most CF pulses have a recognisable initial upward frequency sweep, and all have a terminating frequency sweep, so the IFS and TFS descriptors are not used for this Body Sub Type.

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

Attachment 3. Summary of all detections from acoustic recordings.

			EMBALLONURIDAE	*Emballonura dianae*	*Emballonura furax*	*Mosia nigrescens*	*Saccolaimus saccolaimus*	HIPPOSIDERIDAE	*Aselliscus tricuspidatus*	*Hipposideros cervinus*	*Hipposideros diadema*	*Hipposideros maggietaylorae*	*Hipposideros wollastoni*	*Hipposideros* sp.	*Hipposideros muscinus*	RHINOLOPHIDAE	*Rhinolophus* cf. *philippinensis*	VESPERTILIONIDAE	*Murina florium*	*Myotis moluccarum*	*Nyctophilus microtis*	*Pipistrellus* sp.	MINIOPTERIDAE	*Miniopterus* cf. *australis*	*Miniopterus* cf. *medius*	*Miniopterus* cf. *tristis*
Rec unit	**Night of**	**Locality**		*35 i.fFM.d*	*52 i.fFM.d*	*65 i.fFM.d*	*25 sFM*		*115 sCF*	*140 sCF*	*58 mCF*	*128 sCF*	*82 mCF*	*75 mCF*	*92 mCF*		*42 ICF*		*100 bFM*	*40 bFM*	*50 bFM*	*42 st.cFM*		*55 st.cFM*	*48 st.cFM*	*38 st.cFM*
449995	28/11/2017	Camp 1			X	X			X		X						X			X		X			X	X
449995	29/11/2017	Camp 1				X			X				X		X		X									
449995	30/11/2017	Camp 1		X																						
449995	1/12/2017	Camp 1		X					X								X									
449995	2/12/2017	Camp 1				X			X		X		X	X	X							X				X
449995	3/12/2017	Camp 1		X		X			X	X			X	X			X									
449995	5/12/2017	Camp 2		X	X	X			X						X							X			X	X
449995	6/12/2017	Camp 2				X									X						X	X			X	
449995	7/12/2017	Idam R				X			X		X				X							X			X	
449995	8/12/2017	Camp 2				X			X													X		X		X
449995	9/12/2017	Camp 2				X			X		X				X										X	
450008	1/12/2017	Camp 1		X	X				X		X															X
450008	2/12/2017	Camp 1		X		X			X		X		X		X							X				
450008	3/12/2017	Camp 1				X			X				X	X			X									
450008	5/12/2017	Camp 2							X		X				X						X					

Rec unit	Night of	Locality	EMBALLONURIDAE	*Emballonura dianae*	*Emballonura furax*	*Mosia nigrescens*	*Saccolaimus saccolaimus*	HIPPOSIDERIDAE	*Aselliscus tricuspidatus*	*Hipposideros cervinus*	*Hipposideros diadema*	*Hipposideros maggietaylorae*	*Hipposideros wollastoni*	*Hipposideros* sp.	*Hipposideros muscinus*	RHINOLOPHIDAE	*Rhinolophus* cf. *philippinensis*	VESPERTILIONIDAE	*Murina florium*	*Myotis moluccarum*	*Nyctophilus microtis*	*Pipistrellus* sp.	MINIOPTERIDAE	*Miniopterus* cf. *australis*	*Miniopterus* cf. *medius*	*Miniopterus* cf. *tristis*
				35 i.fFM.d	*52 i.fFM.d*	*65 i.fFM.d*	*25 sFM*		*115 sCF*	*140 sCF*	*58 mCF*	*128 sCF*	*82 mCF*	*75 mCF*	*92 mCF*		*42 ICF*		*100 bFM*	*40 bFM*	*50 bFM*	*42 st.cFM*		*55 st.cFM*	*48 st.cFM*	*38 st.cFM*
450008	7/12/2017	Idam R				X	X		X												X	X				X
450008	8/12/2017	Camp 2				X			X										X		X	X		X	X	
450008	9/12/2017	Camp 2				X			X		X				X							X				
450057	29/11/2017	Camp 1		X		X			X	X	X		X		X					X		X			X	
450057	30/11/2017	Camp 1		X	X	X			X		X						X								X	
450057	1/12/2017	Camp 1		X	X	X			X	X	X						X								X	
450057	2/12/2017	Camp 1		X	X	X			X	X	X		X	X								X				
450057	3/12/2017	Camp 1		X		X			X				X						X							
450057	5/12/2017	Camp 2			X	X			X		X				X						X	X				X
450057	7/12/2017	Idam R			X	X			X		X				X						X			X	X	X
450057	8/12/2017	Camp 2							X						X											
450057	9/12/2017	Camp 2		X		X						X			X						X					

Attachment 4. Notes accompanying identifications from echolocation calls.

EMBALLONURIDAE
Large-eared Sheath-tailed Bat *Emballonura dianae* **Call type *35 i.fFM.d***
Call shape typical of *Emballonura*, and identification based on the recording of reference calls made elsewhere (K.P. Aplin and K.N. Armstrong, unpublished data).
New Guinea Sheath-tailed Bat *Emballonura furax* **Call type *52 i.fFM.d***
Call shape typical of *Emballonura*, and identification based on the recording of reference calls made elsewhere (K.P. Aplin and K.N. Armstrong, unpublished data).
Lesser Sheath-tailed Bat *Mosia nigrescens* **Call type *65 i.fFM.d***
Attributable based on reference calls collected elsewhere in Papua New Guinea (Leary and Pennay 2011; K.P. Aplin and K.N. Armstrong, unpublished data), as well as reference calls recorded on the survey. Characteristic frequency recorded from bats in flight ranged from c. 58 kHz to over 70 kHz, which appears to be the normal range for this species, but it may also conceal the presence of Beccari's Sheath-tailed Bat *Emballonura beccarii* whose illustrated distribution almost reaches the study area (Bonaccorso and Leary 2008).
Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus* **Call type *25 sFM***
Attributed to *Saccolaimus saccolaimus* based on several features: characteristic frequency around 25 kHz, the 'serpentine' pulse shape, characteristic shapes of pulses in examples of the feeding buzz, alternating low-high characteristic frequency of successive calls (Milne et al. 2009), and the harmonic profile (most energy in the second harmonic, faint fundamentals at c. 12 kHz could be seen in some examples). Capture or spotlighting is required to support an attribution of calls to this species.
HIPPOSIDERIDAE
Temminck's Leaf-nosed Bat *Aselliscus tricuspidatus novaguinea* **Call type *115 sCF***
Attributable to this species based on information in Leary and Pennay (2011), and also on reference calls recorded in the Project area (Aplin and Armstrong 2011).
Fawn-coloured Leaf-nosed Bat *Hipposideros cervinus* **Call type *140 sCF***
Attributable to this species based on information in Leary and Pennay (2011), and also on reference calls recorded in the Project area (Aplin and Armstrong 2011).
Diadem Leaf-nosed Bat *Hipposideros diadema griseus* **Call type *58 mCF***
Attributable to this species based on information in Leary and Pennay (2011), and also on reference calls recorded elsewhere in Papua New Guinea (K.P. Aplin and K.N. Armstrong, unpublished data).
Maggie Taylor's Leaf-nosed Bat *Hipposideros maggietaylorae* **Call type *125 sCF***
Attributable to this species based on information in Leary and Pennay (2011), and also on reference calls recorded in the Project area (Aplin and Armstrong 2011). Slightly higher characteristic frequency and long terminal sweeps relative to those of *Aselliscus tricuspidatus* are diagnostic of this species.

Fly River Leaf-nosed Bat *Hipposideros muscinus*
Call type *92 mCF*

Attributed based on reference calls recorded southern PNG (K.P. Aplin and K.N. Armstrong, unpublished data), however this is a significant range extension, and may also derive from related species whose calls have not yet been characterised (e.g. *Hipposideros edwardshilli*).

Wollaston's Leaf-nosed Bat *Hipposideros wollastoni*
Call type *82 mCF*

Attributed based on reference calls recorded in the Project area (Aplin and Armstrong 2011). The calls are a few kHz lower than *H. wollastoni* recorded on the south side of the central cordillera and may reflect call differences between the subspecies.

Unidentified leaf-nosed bat *Hipposideros* cf. *corynophyllus*
Call type *75 mCF*

Pulses of medium duration (15–30 ms), and with a tonal characteristic frequency below that of *H. wollastoni* were recorded on the survey, but no captures were made of bats emitting these frequencies. Potential candidates for this call are *H. corynophyllus* and *H. edwardshilli*, which are known to occur at higher elevations around Telefomin (*H. corynophyllus*) or further north in West Sepik Province (*H. edwardshilli*), and may range much further than their distributions as shown by the IUCN.

RHINOLOPHIDAE

Large-eared Horseshoe Bat *Rhinolophus philippinensis*
Call type *42 ICF*

Attributable with high confidence to one of the incipient Australasian taxa in the *Rhinolophus philippinensis* complex. The characteristic frequency (of the second harmonic) is most similar to that of the 'intermediate' form (as yet unnamed) in northern Australia and is presumably the same or a closely related species (K.N. Armstrong unpublished data). This detection represents a significant range extension but it is unlikely that the call type is mis-attributed.

MINIOPTERIDAE

Unidentified bent-winged bat *Miniopterus* cf. *tristis*
Call type *38 st.cFM*

Attributable to one of several medium–large candidate species of *Miniopterus* (all except *M. australis*; the name *tristis* is assigned for convenience only, and *M. magnater* is also a candidate given the field identifications from Aplin and Armstrong 2011). Feeding buzzes that dropped significantly in frequency below search phase pulses—typical of *Miniopterus*—were observed in the recordings. This call type is known from elsewhere in Papua New Guinea, and was also encountered by Aplin and Armstrong (2011).

Unidentified bent-winged bat *Miniopterus* cf. *macrocneme*
Call type *48 st.cFM*

Most likely one of several candidate species in the Miniopteridae (the name *M. macrocneme* is assigned for convenience only). Species of *Pipistrellus* overlap in characteristic frequency but this call type was sometimes associated with feeding buzzes that dropped significantly in frequency below search phase pulses—typical of *Miniopterus*. No captures of this taxon were made, but this call type was attributed *to Pipistrellus angulatus* by Aplin and Armstrong (2011) because they also captured it. In reality, any call with a characteristic frequency between 40–50 kHz could have derived from any one of several medium-sized *Miniopterus* or one of three *Pipistrelle* species that occur in the study area of the present survey (P*. angulatus, P. collinus* or *P. papuanus*).

Unidentified bent-winged bat *Miniopterus* cf. *australis*
Call type *55 st.cFM*

This call type is most likely attributable to the small-bodied *Miniopterus* cf. *australis* or an allied undescribed taxon, but a species of *Pipistrellus* is also possible, since the calls of several Papua New Guinean *Pipistrellus* (Vespertilionidae) overlap in characteristic frequency. Feeding buzzes that dropped significantly in frequency below search phase pulses—typical of *Miniopterus*—were present. No captures of this taxon were made, but this call type is known from elsewhere in southern Papua New Guinea.

VESPERTILIONIDAE

Maluku Myotis *Myotis moluccarum*
Call type *40 bFM*

Attributable to this genus based on reference calls from elsewhere in Papua New Guinea, and examples of *Myotis macropus* from Australia (K.N. Armstrong unpublished data). The name *M. moluccarum* is applied by Simmons (2005) and Reardon and Bonaccorso (2008) to a taxon thought to be distributed widely across Papua New Guinea, but there is a possibility that the call recordings from the study area derive from a second species of *Myotis* that is thought to be present in Papua New Guinea (Cooper et al. 2001).

Flute-nosed Bat *Murina florium*
Call type *100 bFM*

Attributable to *Murina* cf. *florium* based on reference calls recorded elsewhere in Papua New Guinea (K.P. Aplin and K.N. Armstrong, unpublished data). This call type is also very similar to those of both *Kerivoula muscina* and *Phoniscus papuensis* so the identification is ambiguous and requires confirmation from a capture.

Papuan Long-eared Bat *Nyctophilus microtis*
Call type *50 bFM*

Attributable to *N. microtis* and/or an affiliated undescribed taxon based on reference calls recorded by Aplin and Armstrong (2011). This taxon is thought to contain at least three species in PNG (K.P. Aplin and K.N. Armstrong, unpublished data).

Unidentified Pipistrelle *Pipistrellus* sp.
Call type *42 st.cFM*

Reference calls were recorded from captured individuals of two species of *Pipistrellus* (thought to be *P. angulatus* and *P. papuanus*) captured on the survey conducted by Aplin and Armstrong (2011) that are similar to this call type. The variation in characteristic call frequency seen in the anonymous recordings overlapped with call types *38 st.cFM* and *48 st.cFM*, making call type recognition difficult for some examples. Further work needs to be undertaken to resolve the call differences between the various species of *Pipistrellus* and *Miniopterus* in Papua New Guinea.

Attachment 5. List of all mammal captures and trophies.

Rec#	Date	Site	Survey method	Family	Species	Voucher No.	Sex	Habitat
1	2017-11-30	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Alluvial secondary regrowth
2	2017-11-30	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Alluvial secondary regrowth
3	2017-11-30	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Alluvial secondary regrowth
4	2017-11-30	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		F	Alluvial secondary regrowth
5	2017-11-30	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Alluvial secondary regrowth
6	2017-11-30	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Alluvial secondary regrowth
7	2017-11-30	Camp 1	Hand net	Emballonuridae	*Mosia nigrescens*		F	Open habitat in old garden regrowth
8	2017-11-30	Camp 1	Hand net	Emballonuridae	*Mosia nigrescens*		F	Open habitat in old garden regrowth
9	2017-11-30	Camp 1	Hand capture	Phalangeridae	*Spilocuscus maculatus*			Disturbed regrowth forest
10	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Disturbed primary forest, West/Ridge transect
11	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Disturbed primary forest, West/Ridge transect
12	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Disturbed primary forest, West/Ridge transect
13	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		A	Disturbed primary forest, West/Ridge transect
14	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		A	Disturbed primary forest, West/Ridge transect
15	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		F	Disturbed primary forest, West/Ridge transect
16	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		F	Disturbed primary forest, West/Ridge transect
17	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*	SJR15208	M	Disturbed primary forest, West/Ridge transect
18	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
19	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
20	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect

Rec#	Date	Site	Survey method	Family	Species	Voucher No.	Sex	Habitat
21	2017-12-01	Camp 1	Mist net	Hipposideridae	*Hipposideros* sp.	SJR15209	F	Disturbed primary forest, West/Ridge transect
22	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
23	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		?	Disturbed primary forest, West/Ridge transect
24	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Disturbed primary forest, West/Ridge transect
25	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
26	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
27	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
28	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
29	2017-12-01	Camp 1	Snap trap	Muridae	*Paramelomys platyops*	SJR15210	F	Disturbed primary forest, along Dibini River
30	2017-12-01	Camp 1	Hunting trophy	Peroryctidae	*Echymipera clara*			Trophies collected at Usaremin 2 village
31	2017-12-01	Camp 1	Hunting trophy	Peroryctidae	*Echymipera kalubu*			Trophies collected at Usaremin 2 village
32	2017-12-01	Camp 1	Hunting trophy	Peroryctidae	*Peroryctes raffrayana*			Trophies collected at Usaremin 2 village
33	2017-12-01	Camp 1	Hunting trophy	Phalangeridae	*Phalanger gymnotis*			Trophies collected at Usaremin 2 village
34	2017-12-01	Camp 1	Hunting trophy	Macropodidae	*Dorcopsis hageni*			Trophies collected at Usaremin 2 village
35	2017-12-01	Camp 1	Hunting trophy	Pteropodidae	*Dobsonia moluccensis*			Trophies collected at Usaremin 2 village
36	2017-12-01	Camp 1	Hunting trophy	Phalangeridae	*Spilocuscus maculatus*			Trophies collected at Usaremin 2 village
37	2017-12-01	Camp 1	Hunting trophy	Muridae	*Xenuromys barbatus*			Trophies collected at Usaremin 2 village
38	2017-12-01	Camp 1	Hunting trophy	Muridae	*Uromys caudimaculatus*			Trophies collected at Usaremin 2 village

Rec#	Date	Site	Survey method	Family	Species	Voucher No.	Sex	Habitat
39	2017-12-01	Camp 1	Mist net	Pteropodidae	*Macroglossus minimus*		F	Disturbed primary forest, West/Ridge transect
40	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		F	Disturbed primary forest, West/Ridge transect
41	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Disturbed primary forest, West/Ridge transect
42	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Disturbed primary forest, West/Ridge transect
43	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Disturbed primary forest, West/Ridge transect
44	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Disturbed primary forest, West/Ridge transect
45	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Disturbed primary forest, West/Ridge transect
46	2017-12-01	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Disturbed primary forest, West/Ridge transect
47	2017-12-01	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Disturbed primary forest, West/Ridge transect
48	2017-12-02	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
49	2017-12-02	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
50	2017-12-02	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		F	Disturbed primary forest, West/Ridge transect
51	2017-12-02	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Disturbed primary forest, West/Ridge transect
52	2017-12-02	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
53	2017-12-02	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		?	Disturbed primary forest, West/Ridge transect
54	2017-12-02	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Disturbed primary forest, West/Ridge transect
55	2017-12-02	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Disturbed primary forest, West/Ridge transect
56	2017-12-02	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Disturbed primary forest, West/Ridge transect

Rec#	Date	Site	Survey method	Family	Species	Voucher No.	Sex	Habitat
57	2017-12-02	Camp 1	Mist net	Pteropodidae	*Macroglossus minimus*		M	Disturbed primary forest, West/Ridge transect
58	2017-12-02	Camp 1	Snap trap	Muridae	*Rattus praetor*	SJR15201	F	Trapped with snap trap set in Usaremin 2 village
59	2017-12-03	Camp 1	Snap trap	Muridae	*Paramelomys platyops*		F	Trapped in swamp primary forest, South transect
60	2017-12-03	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Primary swamp forest, south transect
61	2017-12-03	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Primary swamp forest, south transect
62	2017-12-03	Camp 1	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Primary swamp forest, south transect
63	2017-12-03	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		F	Primary swamp forest, south transect
64	2017-12-03	Camp 1	Mist net	Pteropodidae	*Syconycteris australis*		M	Primary swamp forest, south transect
65	2017-12-05	Camp 2	Mist net	Pteropodidae	*Macroglossus minimus*		M	Lowland primary forest
66	2017-12-06	Camp 2	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Lowland primary forest
67	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
68	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
69	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
70	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
71	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
72	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland primary forest
73	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
74	2017-12-06	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
75	2017-12-06	Camp 2	Mist net	Pteropodidae	*Dobsonia minor*		M	Lowland primary forest
76	2017-12-06	Camp 2	Mist net	Pteropodidae	*Paranyctimene raptor*		M	Lowland primary forest
77	2017-12-06	Camp 2	Mist net	Pteropodidae	*Macroglossus minimus*		F	Lowland primary forest
78	2017-12-07	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland primary forest
79	2017-12-07	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland primary forest
80	2017-12-07	Camp 2	Hunting trophy	Peroryctidae	*Echymipera clara*		M	Trophy collected from bush camp near Camp 2
81	2017-12-07	Camp 2	Hunting trophy	Peroryctidae	*Echymipera rufescens*			Trophy collected from bush camp near Camp 2
82	2017-12-08	Camp 2	Mist net	Pteropodidae	*Macroglossus minimus*		M	Lowland tropical forest
83	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
84	2017-12-08	Camp 2	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Lowland tropical forest

Rec#	Date	Site	Survey method	Family	Species	Voucher No.	Sex	Habitat
85	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
86	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
87	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
88	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
89	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
90	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
91	2017-12-08	Camp 2	Hunted	Peroryctidae	*Echymipera kalubu*	SJR15207	M	Lowland primary forest
92	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
93	2017-12-08	Camp 2	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Lowland tropical forest
95	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
96	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
97	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
98	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
99	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
100	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
101	2017-12-08	Camp 2	Mist net	Pteropodidae	*Nyctimene albiventer*		M	Lowland tropical forest
102	2017-12-08	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
103	2017-12-09	Camp 2	Mist net	Pteropodidae	*Macroglossus minimus*		F	Lowland tropical forest
104	2017-12-09	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
105	2017-12-09	Camp 2	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Lowland tropical forest
106	2017-12-09	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
107	2017-12-09	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
108	2017-12-09	Camp 2	Mist net	Pteropodidae	*Macroglossus minimus*		F	Lowland tropical forest
109	2017-12-09	Camp 2	Mist net	Pteropodidae	*Nyctimene albiventer*		F	Lowland tropical forest;
110	2017-12-09	Camp 2	Hunting trophy	Phalangeridae	*Phalanger vestitus*			Lowland tropical forest
111	2017-12-09	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		M	Lowland tropical forest
112	2017-12-09	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
113	2017-12-09	Camp 2	Mist net	Pteropodidae	*Syconycteris australis*		F	Lowland tropical forest
114	2017-12-10	Camp 2	Interview	Phalangeridae	*Spilocuscus rufoniger*			Lowland tropical forest
115	2017-12-10	Camp 2	Hunting trophy	Phalangeridae	*Phalanger* sp.			Lowland tropical forest
116	2017-12-10	Camp 2	Hunting trophy	Pteropodidae	*Pteropus* sp.			Lowland tropical forest
117	2017-12-10	Camp 2	Hunting trophy	Peroryctidae	*Echymipera rufescens*			Lowland tropical forest

Rec#	Date	Site	Survey method	Family	Species	Voucher No.	Sex	Habitat
118	2017-12-10	Camp 2	Photographed live	Macropodidae	*Dorcopsis hageni*			Lowland tropical forest
119	2017-12-10	Camp 2	Hunted	Peroryctidae	*Echymipera kalubu*		F	Lowland tropical forest
120	2017-12-10	Camp 2	Hand capture	Muridae	*Rattus* sp.			Lowland tropical forest

Attachment 6. Position and habitats of AnaBat Swift bat detector deployments.

Swift unit	Night of	Latitude	Longitude	Brief habitat description
449995	28/11/2017	-4.5742	141.53193	Dibini Creek stream bed, edge of secondary regrowth and disturbed primary forest
449995	29/11/2017	-4.5753	141.53096	Disturbed primary forest habitat along Dibini Creek
449995	30/11/2017	-4.57429	141.53187	Disturbed primary forest on ridge transect
449995	1/12/2017	-4.57429	141.53187	Disturbed primary forest on ridge transect
449995	2/12/2017	-4.57397	141.53292	Primary forest in tree fall gap
449995	3/12/2017	-4.57719	141.53204	Swamp forest
449995	5/12/2017	-4.17089	141.30761	Stream bank in moderately disturbed lowland primary forest
449995	6/12/2017	-4.16871	141.31118	Moderately disturbed primary forest along a hunting bush track
449995	7/12/2017	-4.1699	141.30926	Near camp under disturbed primary forest
449995	8/12/2017	—	—	—
449995	9/12/2017	—	—	—
450008	1/12/2017	-4.57428	141.53213	Disturbed primary forest on Ridge transect, overlooking treefall gap
450008	2/12/2017	-4.57398	141.53277	Primary swamp forest along small stream
450008	3/12/2017	—	—	Swamp forest
450008	5/12/2017	-4.17069	141.30789	Stream bank in moderately disturbed lowland primary forest
450008	7/12/2017	-4.14142	141.25435	Edge of Idam 1 village, directed over Idam River
450008	8/12/2017	—	—	—
450008	9/12/2017	—	—	—
450057	29/11/2017	-4.57583	141.5306	Disturbed primary forest habitat along Dibini Creek
450057	30/11/2017	—	—	Disturbed primary forest on Ridge transect
450057	1/12/2017	-4.57372	141.53073	—
450057	2/12/2017	-4.5738	141.53277	Edge of primary and secondary forest overlooking treefall gap
450057	3/12/2017	—	—	Swamp forest
450057	5/12/2017	-4.17005	141.30947	Open habitat cleared for Camp 2
450057	7/12/2017	-4.07513	141.25081	Gardens along tributary of Idam River, facing tributary creek and forest opposite
450057	8/12/2017	—	—	—
450057	9/12/2017	—	—	—

Attachment 7. Reconciliation of species name and call type usage between the present 2017 survey and Aplin and Armstrong (2011).

Genus species	Common name	2017 survey	Aplin and Armstrong 2011
EMBALLONURIDAE			
Mosia nigrescens	Lesser Sheath-tailed Bat	*65 i.fFM.d*	*64 sCF / i.cvFM Mosia nigrescens*
Emballonura dianae	Greater Sheath-tailed Bat	*35 i.fFM.d*	*34 i.fFM.d / sCF Emballonura* sp.
Emballonura furax	New Guinea Sheath-tailed Bat	*52 i.fFM.d*	not recorded
Emballonura raffrayana	Raffray's Sheath-tailed Bat	not recorded	*42 i.fFM.d Emballonura* sp.; 47 sCF / i.fFM.d Emballonura sp.
Saccolaimus saccolaimus	Bare-rumped Sheath-tailed Bat	*25 sFM*	*24 cFM Saccolaimus* sp.; *27 sh.cFM.d Emballonura* sp.
	Unidentified bat	not recorded	*17 sh.cFM Saccolaimus* sp. or molossid?
	Unidentified bat	not recorded	*20 cFM Saccolaimus* sp. or molossid?
HIPPOSIDERIDAE			
Aselliscus tricuspidatus	Temminck's Leaf-nosed Bat	*115 sCF*	*112 sCF Aselliscus tricuspidatus*
Hipposideros ater	Dusky Leaf-nosed Bat	not recorded	*144 sCF Hipposideros ater*
Hipposideros cervinus	Fawn-coloured Leaf-nosed Bat	*140 sCF*	*137 sCF Hipposideros cervinus*
Hipposideros diadema	Diadem Leaf-nosed Bat	*58 mCF*	*58 mCF Hipposideros diadema*
Hipposideros muscinus	Fly River Leaf-nosed Bat	*92 mCF*	*90 mCF Hipposideros semoni* or *H. muscinus*?
Hipposideros maggietaylorae	Maggie Taylor's Leaf-nosed bat	*128 sCF*	*124 sCF Hipposideros maggietaylorae*
Hipposideros wollastoni	Wollaston's Leaf-nosed Bat	*82 mCF*	*82 mCF Hipposideros wollastoni*
Hipposideros sp.	Unidentified leaf-nosed Bat	*75 mCF*	*75 mCF Hipposideros semoni* or *H. muscinus*?
RHINOLOPHIDAE			
Rhinolophus cf. *philippinensis*	Large-eared Horseshoe Bat	*42 lCF*	*42 lCF Rhinolophus philippinensis*
MINIOPTERIDAE			
Miniopterus cf. *australis*	Little Bent-winged Bat	*55 st.cFM*	*55 st.cFM.d / cFM* vespertilionid?
Miniopterus cf. *macrocneme*	Small Melanesian Bent-winged Bat	*48 st.cFM*	*47 st.cFM.h Pipistrellus angulatus*
Miniopterus cf. *tristis*	Greater Bent-winged Bat	*38 st.cFM*	*37 st.cFM Miniopterus magnater*

Genus species	Common name	2017 survey	Aplin and Armstrong 2011
VESPERTILIONIDAE			
Murina florium	Flute-nosed Bat	*100 bFM*	not recorded
Myotis moluccarum	Maluku Myotis	*40 bFM*	*40 st.bFM / st.sFM.d Myotis moluccarum*
Nyctophilus microdon	Small-toothed Long-eared Bat	not recorded	*53 st.fFM*; *55 st.bFM Nyctophilus* aff. *microdon*
Nyctophilus microtis	Papuan Long-eared Bat	*50 bFM*	not recorded
Philetor brachypterus	Short-winged Pipistrelle	not recorded	*30 st.cFM Mormopterus* or *Emballonura* sp.
Pipistrellus sp.	Unidentified Pipistrelle	*42 st.cFM*	*42 cFM* possibly a vespertilionid

Avifauna of the Sepik Development Project infrastructure corridor study area

Dr Iain A. Woxvold

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Acronyms and Abbreviations

asl	above sea level
ca.	abbrev. ‘circa’; approximately
CEPA	Conservation and Environment Protection Authority
cm	centimetres
dbh	diameter at breast height
DD	Data Deficient (IUCN threat category)
EBA	Endemic Bird Area (BirdLife International zoning)
DEM	Digital elevation model
EIA	environmental impact assessment
EN	Endangered (IUCN threat category)
FIMS	PNG Forest Inventory Mapping System
Fsw	Mixed swamp forest (FIMS vegetation type)
GPS	Global Positioning System
Hm	Hill forest (FIMS vegetation type)
IFC	International Finance Corporation
IOC	International Ornithological Congress
IUCN	International Union for the Conservation of Nature
km	kilometers
km^2	square kilometers
LC	Least Concern (IUCN threat category)
LIDAR	Light Detection and Ranging
m	metres
NT	Near Threatened (IUCN threat category)
pers. comm.	abbrev. ‘personal communication’
Pl	Large crowned alluvial forest (FIMS vegetation type)
PNG	Papua New Guinea
Po	Open alluvial forest (FIMS vegetation type)
Project	Sepik Development Project
Ps	Small crowned alluvial forest (FIMS vegetation type)
RAI	relative abundance index
sp.	abbrev. ‘species’ (singular)
spp.	abbrev. ‘species’ (plural)
study area	infrastructure corridor study area
Wsw	Swamp woodland (FIMS vegetation type)

Glossary of Technical Terms

Anthropogenic	Originating from human activity.
Asymptote	A straight line approached but never crossed by a curve (species recorded versus survey effort in the context of this report).
Biogeographic zone	An area that is characterised by a specific geographical distribution of plants and/or animals.
Central range	Refers to the central mountainous spine of New Guinea that runs from the eastern edge of the Vogelkop Peninsula in Indonesian New Guinea to the eastern tip of mainland Papua New Guinea.
Conservation listed species	Includes: (1) species listed under the IUCN Red List as threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened or Data Deficient; (2) species listed as Protected under the PNG *Fauna (Protection and Control) Act 1966*.
Endemic	Belonging exclusively or confined to a particular place.
Endemism	Describes the proportion of endemic taxa occurring in a place; e.g. a high level of endemism.
Frugivore	A species that includes fruit as a significant component of its diet.
Protected	Species listed as Protected under the Papua New Guinea *Fauna (Protection and Control) Act 1966.*
Raptor	A bird of prey. Includes diurnal (eagles, hawks, falcons, etc.) and nocturnal species (owls).
Restricted-range	Species which have a total historical breeding range of less than 50,000 km^2.
Taxa	Plural of taxon; a systematic division (i.e. more than one species, genera, etc.).
Taxonomic	Taxonomy is the science of identifying, naming and classifying living organisms.

Executive Summary

Birds were surveyed at three sites south of the Sepik River within the Sepik Development Project (the Project) infrastructure corridor study area (hereafter 'study area'). Surveys were conducted during 28 November–11 December 2017. The main survey program was based on sampling over multiple days (range: 4−5 days, excluding transfers) at two principal survey sites (Camps 1 and 2) provided with field-based accommodation. A shorter expeditionary visit was made to Idam 1 village (one night overstay) to facilitate boat survey of the lower reaches of the Idam River. Data from prior surveys conducted (1) by this author immediately east of the study area in 2009–2011 and (2) by other ornithologists north of the Sepik River are drawn upon to help characterise the study area's avifauna.

A total of 129 bird species was recorded during the 2017 surveys using a combination of field observations, camera trapping, mist netting, automated sound recording and discussions with local Papua New Guinea (PNG) residents. Species richness was highest at Camp 1 (105 species) which provided access to areas of hill and alluvial forest as well as extensive riverine and riparian habitats surveyed by boat.

Thirteen (13) conservation listed species are confirmed present. All are Protected under PNG law, and three resident bird species recorded in hill forest and/or alluvial forest environments are listed as Threatened or Near Threatened by the International Union for the Conservation of Nature (IUCN)—Papuan Eagle (*Harpyopsis novaeguineae*) (Vulnerable—VU), Pesquet's Parrot (*Psittrichas fulgidus*) (VU) and Victoria Crowned Pigeon (*Goura victoria*) (Near Threatened).

Based on current knowledge of avian distributions and habitat preferences, an additional 21 conservation listed species may occur within the study area, including a further 17 IUCN listed species (two Threatened, 13 Near Threatened and two Data Deficient).

For all conservation listed species recorded or potentially occurring in the study area, summary accounts are provided of their distribution, habitat preferences, occurrence in the study area (recorded and potential) and known threats/susceptibilities.

The study area's diverse and integrated forest environments are recognised for their importance to maintaining a species-rich tropical avifaunal community that includes a high proportion of New Guinea endemics and a suite of IUCN Threatened and Near Threatened taxa. Within this ecosystem complex: (1) alluvial forest is singled out for its regionally limited extent (compared to hill forest), for its vulnerability to current logging practices, and for its importance to a high proportion of locally resident avifauna, and; (2) foothill forest is recognised for its importance to a high proportion of resident bird species, including the IUCN threatened Pesquet's Parrot. Rivers, streams and off-river waterbodies provide habitat for a variety of resident and migratory waterbird species but are not expected to support any large breeding colonies. At the northern end of the infrastructure corridor, intertidal wetlands in the Vanimo area provide habitat for Palaearctic shorebirds but are not expected to support large congregations of these migratory species. Local landscape features that provide important bird habitat include caves and rock overhangs, large trees in low nutrient or disturbed environments, and large fig trees.

1 Introduction

1.1 Background

Frieda River Limited (FRL) is proposing to develop the Sepik Development Project (the Project) to commercialise the copper and gold resource present in the Frieda River (upper Sepik) catchment of northwest mainland Papua New Guinea (PNG).

During 2009–2011, extensive terrestrial biodiversity field studies were conducted for the Project across a ca. 3,500 km^2 study area extending south from the Sepik River and east from the Saniap, Usake and Upper May rivers. A subsequent revision to the Project design includes the proposed ca. 325 km access road, pipeline and northern transmission line corridor (the 'infrastructure corridor') linking the mine area with Vanimo on the Sandaun Province coast. Most of the proposed infrastructure corridor lies outside (west and north) of the previously assessed biodiversity study area.

As part of the Project Environmental Impact Statement (EIS), a terrestrial biodiversity study has been commissioned to provide a baseline characterisation of the terrestrial biodiversity and conservation values present within, and in the vicinity of, the infrastructure corridor. This report presents the results of the technical study on avifauna (birds) conducted as part of the terrestrial biodiversity study.

1.2 Technical study objectives

The objectives of this technical study are:

- To collate and assess existing information relevant to bird communities in the study area.
- To survey bird communities present in relatively intact forest environments south of the Sepik River.
- To describe the conservation significance of bird communities present within the study area, including:
    - The presence and status of species of conservation significance recorded or potentially present.
    - Habitats and other landscape features important to bird communities.
    - The presence of non-native bird species.
- To summarise knowledge gaps in relation to bird communities present within the study area.

2 Study Area

The proposed infrastructure corridor includes (tracking north from the mine area):

- South of the Sepik River—areas along the Right May (Abei) River in East Sepik Province; a crossing of the West Range into Sandaun Province; areas along the Idam River and its upper reach tributaries, including part of the Tawa River; back swamps and floodplains along the Sepik River from the Idam River mouth downstream to near the mouth of the Simaia River.
- North of the Sepik River—northwest from the Sepik River to Green River township; then north along an existing road towards Vanimo, along the transition zone between the Horden River floodplain and the eastern foothills of the Border Mountains; across the Bewani Mountains and onto the north coastal plains.

Elevation ranges from sea level to approximately 600 m above mean sea level (asl) on the Bewani Mountains. The highest point along the infrastructure corridor south of the Sepik River is at approximately 450 m asl on the West Range.

Natural vegetation along the infrastructure corridor comprises mostly structural variants of hill and alluvial forest communities, assigned mapping codes Hm, Po, Ps and Pl under the PNG Forest Inventory Mapping System (FIMS) (Hammermaster and Saunders 1995). Wooded freshwater swamps, including swamp woodland (Wsw) with sago (*Metroxylon sagu*) and pandanus (*Pandanus* spp.) and mixed swamp forest (Fsw), occur mostly on the meander floodplains and back swamps flanking the Sepik River.

Vegetation south of the Sepik River is largely intact and shows little sign of human disturbance. There are no existing roads in this sector of the study area, and anthropogenic forest conversion and degradation is limited predominantly to village and garden areas (current and former) along navigable waterways. Additional relatively minor disturbances occur away from the larger watercourses, for example at hunting camps.

Extensive forest loss and degradation has taken place along the proposed infrastructure corridor north of the Sepik River. Loggers have harvested most of the forest along the existing road to a distance of approximately 100 km south of the coast as far as the Yagroner Hills area, with the harvesting extending for tens of kilometres east and west of the road across the plains north and south of the Bewani Mountains (Hansen et al. 2013; Bryan and Shearman 2015). Forest conversion has been most intensive on the north coastal plains, where extensive areas of large crowned alluvial forest (Pl), a favoured source of commercial timber, have been logged and converted to Oil Palm (*Elaeis guineensis*) plantations. South of the Yagroner hills most of the forest lining the road has been disturbed to some degree, though extensive areas of medium crowned hill forest (Hm) and small crowned alluvial forest (Ps) remain unharvested.

The current study focussed on two principal survey locations located adjacent to the southern portion of the infrastructure corridor.

3 Existing Information

3.1 Avian diversity and endemism in New Guinea

New Guinea and its satellite islands support the world's highest concentration of endemic birds (Gregory 2013). The region is exclusively home to most species of bird-of-paradise (Paradisaeidae), bowerbirds (Ptilonorhynchidae), Australasian robins (Petroicidae), cassowaries (Casuariidae) and owlet-nightjars (Aegothelidae), and is the only place in which berrypeckers and longbills (Melanocharitidae, Paramythiidae), satinbirds (Cnemophilidae) and melampittas (Melampittidae) are found. Of nearly 800 bird species recorded in the New Guinea region, nearly 60% are endemic (365 species: Pratt and Beehler 2015).

BirdLife International has defined a series of Endemic Bird Areas (EBAs) across the globe to identify geographic centres of bird endemism. EBAs comprise distinct geographical regions that support populations of at least two 'restricted-range' bird species (total global breeding range less than 50,000 km^2; Stattersfield et al. 1998). The infrastructure corridor traverses the centre of the North Papuan Lowlands EBA. This EBA covers 180,000 km^2 of predominantly forested habitats below 1,000 m asl from the southeast of Geelvink Bay in Papua Province, Indonesia, east to the Huon Gulf in northeast mainland PNG. It includes all of the hill and lowland areas of the Sepik River basin and the north coastal plains.

While New Guinea's north coastal ranges, including the Bewani Mountains, separately form the 4,700 km^2 North Papuan Mountains EBA, that EBA is restricted to areas above 1,000 m asl and for the purposes of this assessment is not considered to overlap with the study area.

3.2 Prior surveys in the study area and surrounds

3.2.1 Upper Sepik lowlands

South of the Sepik River, Joseph Bürgers first collected birds from east of the study area along the May, Frieda, Wario and April Rivers during the German Augusta Fluss Expedition of 1912–13. The results were later written up by Erwin Stresemann (e.g. 1921, 1923). Half a century later, in 1963 P. Temple (Bishop Museum) collected birds from the upper Sepik basin including along the May River (and from upland sites near Telefomin). While collecting mammals from Sandaun Province, Tim Flannery and Lester Seri made some incidental bird collections from relevant elevations west of the study area, most notably along the August (Yapsiei) River and tributaries (100–700 m asl) (summarised in Rowland 1995).

The most recent detailed studies are those conducted by the present author immediately east of the study area during the 2009–2011 Project biodiversity studies. More than 20 sites were visited covering a variety of vegetation types and substrates from the lowlands to above 1,350 m asl (Woxvold 2011).

Many additional birders have worked along the Sepik River, some of whom have collected birds and/or published their records. Most (e.g. Crome and Swainson 1974; Pearson 1975; Lister 1977; Stringer 1977; Gregory 1996) did not travel upstream of Ambunti, the unofficial border separating the 'middle' and 'upper' sectors of the Sepik River. Under German administration, Carl Hunstein worked along the lower and middle Sepik River in the late 1880s. Thomas Gilliard and Mary LeCroy surveyed birds along the Sepik River from its mouth to Ambunti and in the Wewak area during the American Museum of Natural History (AMNH) expedition of 1953–54 (Gilliard and LeCroy 1966). Relatively few recreational birders have published lists from the upper Sepik basin, and these typically only after short stays (e.g. May River area, Tolhurst 1993).

In low elevation hill forest east of the study area, collections from the Lordberg and Hunstein Ranges were made by Dr Bürgers (reported by Stresemann (1921, 1923), Lyn Craven (*in litt.* 2009) and Andrew Mack, Allen Allison and D. Wright (in 1989 for Bishop Museum). Research at the nearby Mekil Biological Research Station on Mount Stolle (e.g. Scholes 2005, 2006) was conducted at elevations too high (above 1,700 m asl) to be relevant to current purposes.

3.2.2 North coastal ranges and plains

North of the Sepik River, birds have been surveyed on the Bewani Mountains by Jared Diamond (1969; Diamond and Terborgh 1968) and on neighbouring north coastal ranges—the Toricelli and Prince Alexander Mountains—by Diamond (1967, 1969; Diamond and Terborgh 1968) and Hulme (1977). More recently, members of the Tenkile Conservation Alliance have published camera trap records of birds from the Torricelli Mountains (Thomas 2014).

In lowland forest a number of ornithologists have worked on the north coastal plains around Vanimo, publishing either general observations (including species lists) (Diamond et al. 1977; Palliser 1989; Richards and Rowland 1995; Shany 1995) or detailed notes on the restricted-range bird-of-paradise the Pale-billed Sicklebill (*Epimachus bruijnii*) (Whitney 1987; Beehler and Beehler 1986). Much of this habitat has since been logged or replaced with oil palm.

3.2.3 Summary of existing knowledge

Published information on bird communities of the upper Sepik lowlands (below 500 m asl) and the north coastal ranges and plains is limited. Accordingly, parts of the study area lie within regions defined in 1993 under the PNG Conservation Needs Assessment (CNA) as 'major terrestrial unknowns'; that is—within a set of "16 major geographic areas within Papua New Guinea for which the present lack of scientific information is particularly serious" (Swartzendruber 1993, p. 10). The overlapping 'major terrestrial unknown' regions are:

1. **Bewani Mountains**—"The low coastal range that reaches westward to the Irian border, and the humid lowlands south of this range, are little studied and apparently biologically rich. Recent discoveries include montane endemic mammals and a lowland bird of paradise formerly known only from Irian Jaya." Much of this habitat has recently been logged.

2. **Central Range**—The high range that rises south of the Sepik basin is little studied and largely forested.

Few local studies have been conducted since the PNG CNA to improve this state of knowledge, the most notable being those of the 2009–2011 Project biodiversity studies conducted immediately east of the study area.

4 Methods

Information on the study area's avifauna was collected through a combination of literature review and field surveys. Reviewed material includes the results of local surveys described above (Section 3), broader regional summaries of New Guinea's birdlife (e.g. Coates 1985, 1990; Pratt and Beehler 2015; Beehler and Pratt 2016) and international conservation assessments (IUCN 2017). Field survey locations and methods are described below.

4.1 Survey sites and timing

Ground surveys were conducted in areas south of the Sepik River during 28 November–11 December 2017, at the start of the 'northwest (monsoon) season' of December–March. Table 1 lists the location, timing and elevations covered at each survey site.

The main survey program was based on sampling over multiple days (range: 4−5 days, excluding transfer days) at two principal survey sites (Camps 1 and 2) provided with field-based accommodation. Accommodation at these sites was provided at temporary 'fly camps' constructed specifically for the purpose of the present study. A shorter expeditionary visit was made to Idam 1 village (one night overstay) to facilitate boat survey of the lower reaches of the Idam River.

A brief description of each survey site (chronological order) and the habitats surveyed for birds is given below (Sections 4.1.1–4.1.3). A detailed description of the vegetation (types, structure and floristics) present at each survey site is presented in the flora technical report (Takeuchi 2018).

In addition to the detailed surveys conducted south of the Sepik River, on 12 December the ca. 190 km-long road between Green River and Vanimo was driven. Roadside habitats were viewed from the vehicle, though birds were not surveyed *en route*.

Table 1 The location and time spent at each fly camp/accommodation base during bird surveys. All dates are for the year 2017.

Site	Base location[A]	Elevations covered[B]	Arrival	Departure
Camp 1	559085 9494427	65–175	28/11, 09:30	4/12, 13:00
Camp 2	534344 9539086	85–180	4/12, 13:15	7/12, 9:30
			8/12, 14:45	11/12, 10:30
Idam River	Idam 1 village	50–65	7/12, 09:45	8/12, 14:30

[A] Camp/insertion points: PNGMG94 Zone 54.

[B] All elevations in m asl from LIDAR digital elevation model (DEM) to the nearest 5 m.

4.1.1 Camp 1

Camp 1 was positioned in an area of post-garden regrowth on the banks of Dibiri Creek near its confluence with the Right May (Abei) River and about ten minutes' walk upstream from Usaremin 2 village (labelled 'Uriaka' on the 1:100,000 topographic map sheet), a small settlement of 38 households located on the Right May River approximately five river kilometres upstream from Hotmin village (Figure 1). Birds were surveyed over five complete days and on parts of two days. Foot

surveys were conducted on trails through forest, gardens (current and former) and along tributary watercourses (Dibiri Creek and Uriake River). A boat survey was undertaken on 1 December to reconnoitre riverine and riparian habitats both upstream and downstream of the camp along the Right May and May rivers.

Natural vegetation is mapped as open alluvial forest (FIMS code Po) on the floodplains and flanking terraces of the Right May and May rivers, and medium crowned hill forest (FIMS code Hm) on adjacent hill slopes. Most of the alluvial forest accessible on foot from the camp had been converted to gardens, was in various stages of post-conversion regrowth or had been otherwise heavily disturbed. Less disturbed examples were observed by boat further away from camp. Natural vegetation was more prevalent as hill forest on the spurs and ridges west of camp and on the terraces flanking Dibiri Creek, though these were also subject to regular visitation by local residents for hunting and small-scale resource extraction.

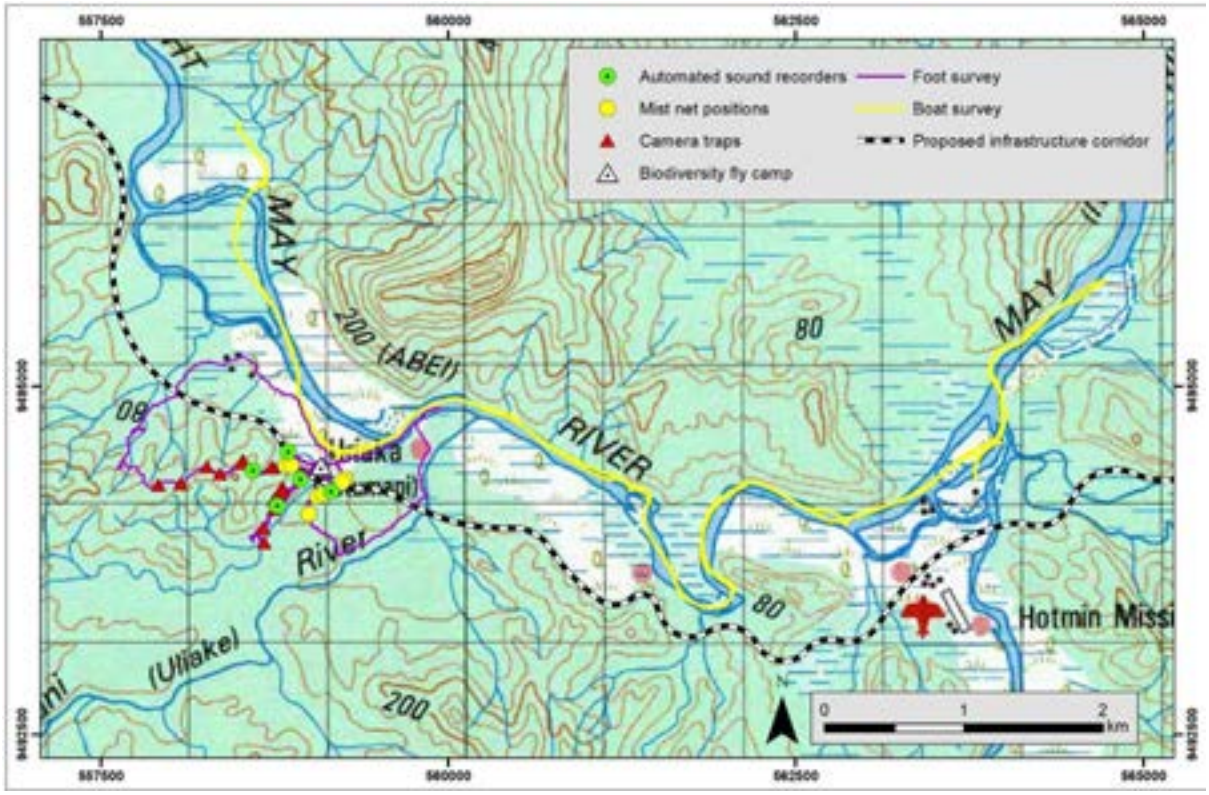

Figure 1 Bird survey coverage at Camp 1.

4.1.2 Camp 2

Camp 2 was located in a garden area adjacent to a hunting hut on the '*Wara Kep*', a small creek that flows west and north across alluvial plains to meet the Idam River near Idam 1 village approximately 6.3 km northwest of the camp (Figure 2). Birds were surveyed on foot over four entire days and on parts of four days (Table 1) in small crowned alluvial forest (FIMS code Ps) and in medium crowned hill forest on the foothill spurs and ridges present to the north of camp (Figure 2). The camp was situated approximately three hours walk from the large (>1,000 people) Idam 1 village. Aside from a few hunting huts and small adjacent gardens observed along the *Wara Kep*, and numerous walking trails through the forest, there was little sign of anthropogenic disturbance to forest habitats. Nevertheless, the area is evidently frequently visited by hunters; local residents stated that some hunting-sensitive species, for example *Dorcopsis* wallabies, were formerly present in good numbers but are now scarce.

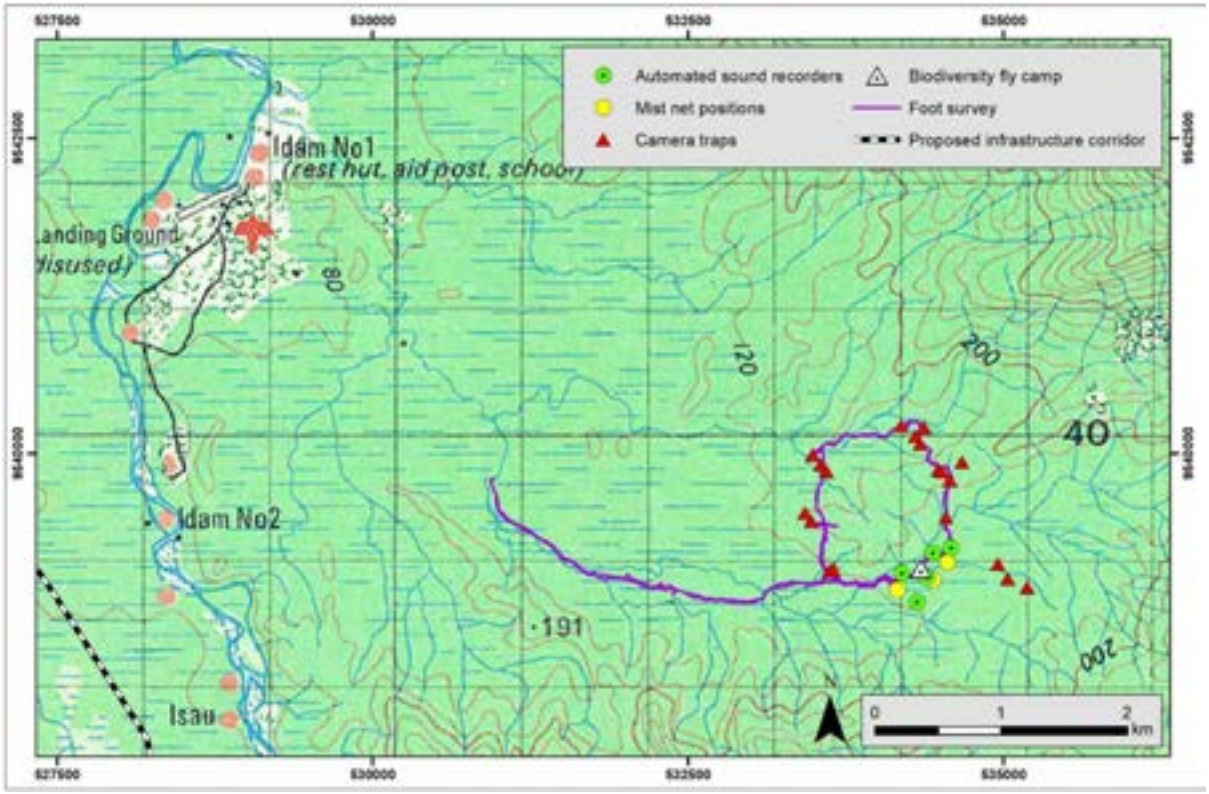

Figure 2 Bird survey coverage at Camp 2.

4.1.3 Idam River

Two boat trips were made during 7–8 December along the lower reaches of the Idam River and parts of the Sepik River (Figure 3). This short-term visit was designed to survey waterbirds and to visit riparian vegetation types not easily accessible from land-based camps. Aside from waterfowl observed during these surveys, the avifauna recorded in adjacent forest habitats was a subset of that observed at Camps 1 and 2. Stops were made at a hunting hut to view hunting trophy material, and two automated sound recorders were deployed at the edge of garden–hill forest–sago swamp woodland along a small tributary creek to record birds overnight and during the peak period of birdsong activity the following dawn. Natural vegetation along the river is mapped as various forms of alluvial forest (FIMS codes Ps and Po) with medium crowned hill forest (Hm) present on the few foothill spurs and isolated hills that abut the river course—at Bisiabru village and on Sunday Hill near the Sepik River (Figure 3). Much of the vegetation observed along the river had been converted to villages or gardens or was otherwise heavily disturbed by local residents. Remaining areas of natural habitat along the meander floodplains were subject to frequent inundation.

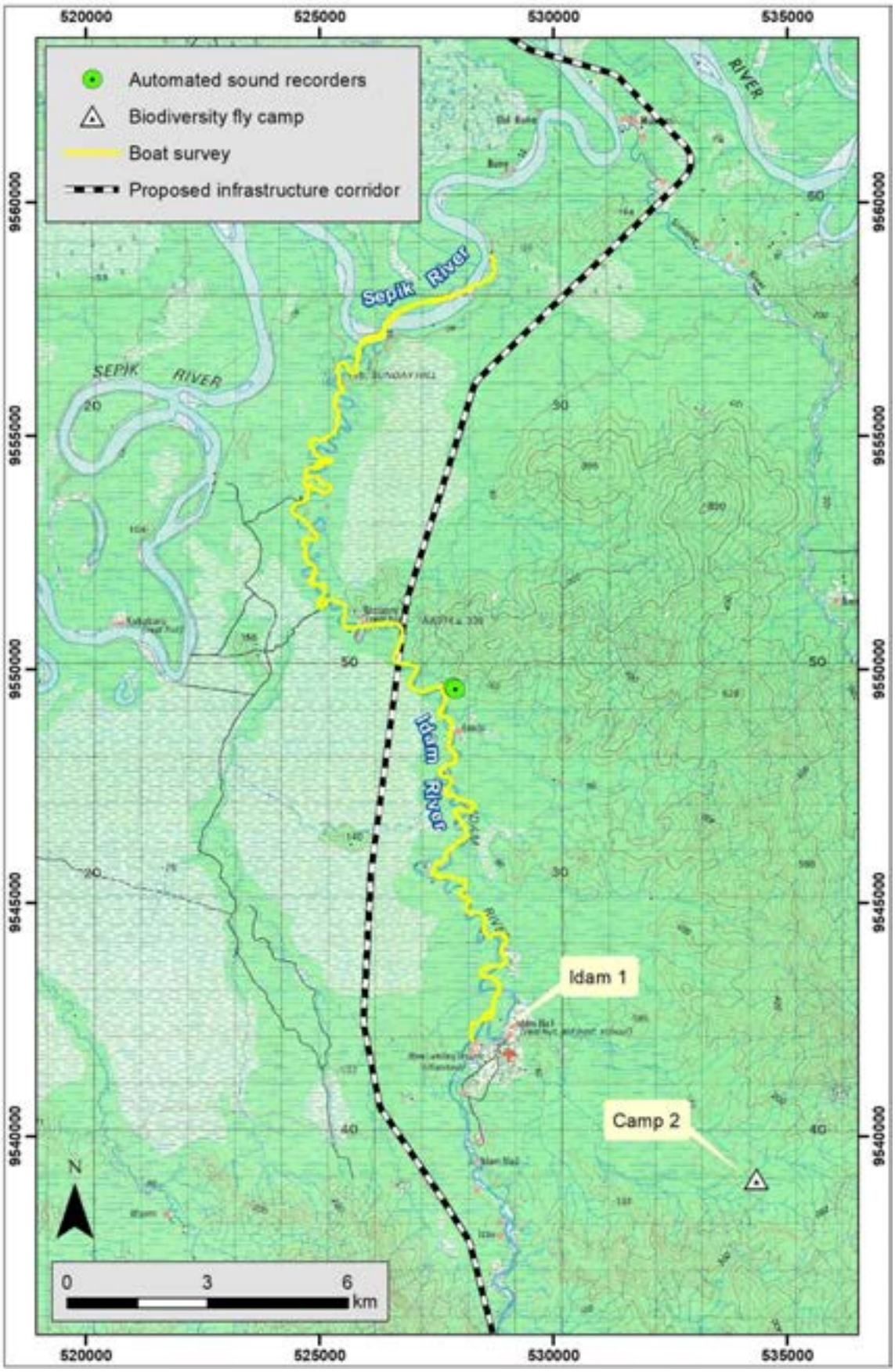

Figure 3 Bird survey coverage along the Idam River.

4.2 Field techniques and survey effort

Survey methods included 'active' searches, mist netting, camera trapping, automated sound recording and discussions about birds with local resident field assistants. These techniques were combined to maximise completeness of the bird species inventory and the likelihood of locating species of conservation significance in the time available at each site. Survey efforts for each method are summarised in Table 2.

Bird surveys were conducted in accordance with the permitting procedures of the PNG Conservation and Environment Protection Authority (CEPA).

Table 2 Per-site survey effort summaries.

Site	Active search hrs[A]	Mist nets			Camera traps		Automated sound recorders	
		No. nets	No. positions	Diurnal net-m-hrs[B]	No.	Hrs	No. positions	Hrs
Camp 1	35.25	14	7	396.00	16	1,543.25	5	158.00
Camp 2	24.75	15	3	1,458.00	19	2,073.25	5	136.18
Idam River	6.25	–	–	–	–	–	2	33.10
Total	66.25	29	10	1,854.00	35	3,616.50	12	327.28

[A] Excluding informal survey periods (e.g. incidental observations from camp).

[B] Diurnal period taken from 06:30 to 18:30.

4.2.1 Active searches

Active searches included walks along trails, rivers and creeks through forest and gardens, boat surveys, and static surveys from helipads or other sites that afforded good views of surrounding habitat. Survey trails are shown in Figures 1−3.

Surveys were conducted throughout daylight hours and included time before dawn and after dusk to cover active periods of both diurnal and nocturnal birds. Effort was weighted to periods of peak bird activity during the early morning and late afternoon.

Hourly counts were made of all birds seen or heard during active searches. To avoid double counting within search periods, only species previously unrecorded within the search period were recorded during the return journey along survey trails.

4.2.2 Mist nets

Up to 15 mist nets (range 14–15; Table 2) ranging in size from 9 to 12 m (31 mm mesh) were deployed at Camps 1 and 2. Nets were deployed in a variety of habitats, including hill and alluvial forest and in areas of secondary growth. Nets were mounted on poles close to the ground (top not higher than 4 m), either singly or in linear series (up to six nets) in multi-net 'positions' (Figures 1–2). All nets were checked regularly during daylight hours and at least once within 1.5 hours after nightfall.

Mist nets were deployed for a total of more than 1,850 diurnal net-metre hours (Table 2). Most captured birds were brought back to camp and stored in the shade in calico bags for subsequent processing including photography, biometric measurement and plumage marking prior to release. Recaptures were released at the net site at time of capture.

4.2.3 Camera traps

Up to 19 digital camera traps (Reconyx HC550/PC850/XP9) were deployed at Camps 1 and 2 along animal trails and at apparent feeding stations in an effort to photograph terrestrial birds and mammals.

All camera traps were programmed to maximum detection sensitivity and to take three photographs on each 'trigger event' with the minimum amount of rest time between triggers (<2 seconds). Most cameras were baited with cooked rice, banana, pawpaw and/or cassava to increase the detection probability of terrestrial fauna during short-term deployments. Units were deployed for a total of more than 3,600 camera trap-hours (Table 2). Camera trap locations are shown in Figures 1–2.

4.2.4 Automated sound recorders

Automated sound recorders (Bioacoustic Audio Recorder (BAR); Frontier Labs) were deployed in forest environments at Camps 1 and 2 and along the Idam River. The BARs recorded audible sounds, including bird calls, continuously for periods of up to 48 hours. More than 327 hours of recordings (Table 2) were screened for the presence of birds not detected during active survey periods and other notable species. Deployment along the Idam River provided opportunity to screen bird vocalisations from the peak periods of bird activity (early morning and late afternoon) that would otherwise have been missed.

4.2.5 Community knowledge

Direct observations were supplemented with data gathered opportunistically during conversations with local Papua New Guinean residents. Most information came from conversations with local residents who had been assigned to assist with the terrestrial biodiversity surveys. Conversations about birds were held with Min speakers from Hotmin and Usaremin 2 villages at Camp 1, and with Abau speakers of Idam 1 village at Camp 2 and at Idam 1. Discussions focused on the distribution and status of recognisable species of conservation significance (e.g. cassowaries, crowned pigeons) and on the use and importance of bird species to local communities.

4.3 Analysis

Species accumulation curves were generated for each site in Excel by matching accumulated species richness against survey time (hours).

Relative abundance indices (RAIs) were calculated for individual species detected by camera trap (camera trap RAI), from the rate of independent photographic capture 'events' (per hour x 100), summed across cameras within sites. Events were considered independent where consecutive pictures of the same species were taken more than 30 minutes apart. Multiple events were scored within 30-minute periods only where more than one individual was seen in a single photograph and/or where plumage differences permitted identification of separate individuals in successive photographs.

The following abundance rankings and their abbreviations appear in text, tables and appendices:

- Occasional (O)—Species encountered only once or twice despite sufficient time spent in suitable habitat.
- Fairly common (FC)—Species encountered with some regularity given sufficient time in suitable habitat.
- Common (C)—Species found on at least two-thirds of days given sufficient time in suitable habitat.
- Very common (VC)—Species with multiple individuals encountered daily.
- Present (X)—recorded but abundance not ranked.

These rankings have been developed specifically for this report to communicate the relative abundance of various species both within and between sites. For reasons well documented (e.g. Bibby et al. 2000; O'Brien 2011) they are not intended to provide an accurate estimate of population density. Relative abundance estimates reflect encounter rates, and behavioural differences between species influence their detection probabilities. For example, some vagile and/or conspicuously vocal species (e.g. some large parrots) may be over-represented where single individuals are repeatedly

encountered. Conversely, other species may be under-recorded as detectability through vocalisations varies seasonally and/or with resource availability (e.g. terrestrial columbids, cuckoos, pittas). Thus a direct comparison of the number of encounters between species will in many cases not provide an accurate estimate of relative population densities. However, by categorising recorded frequencies into a limited number of broad-scale classes, relative abundance rankings are expected to provide a more reliable inter-species comparison.

Accurate abundance rankings rely on a reasonable probability of detection. Accordingly, abundance rankings were not applied in cases where the detection probability was low—for example, where insufficient time was spent at a survey site (Idam River) or in suitable habitat, and for shy/cryptic species.

4.4 Conventions used

4.4.1 Taxonomy and nomenclature

Nomenclature (common and scientific names) and family arrangements follow the International Ornithological Congress (IOC) World Bird List (version 8.1) (Gill and Donsker 2018) for most species. Where species are mentioned in the text the scientific name appears with the common name on first mention and only the common name is used thereafter. Species appearing in square brackets (in text, tables and appendices) were only provisionally identified to species level. Though not definitively identified, encounters are considered most likely to have involved the species named.

4.4.2 Conservation listed species

Conservation listed species referred to in this report are of two general kinds:

- Species listed by the International Union for the Conservation of Nature (IUCN) in The IUCN Red List of Threatened Species (IUCN 2017) as:
    - Threatened—IUCN threatened categories include (in descending order of conservation significance): Critically Endangered (CR), Endangered (EN) and Vulnerable (VU).
    - Near Threatened (NT).
    - Data Deficient (DD).

  These species are hereafter collectively referred to as 'IUCN listed' species. Most species appearing in this report are classified as 'Least Concern' by the IUCN and thus are not presently considered to be at risk. This IUCN category does not appear subsequently in the text but is included in the taxonomic appendices.

- Species listed as Protected under the PNG *Fauna (Protection & Control) Act 1966* (Fauna Act), hereafter referred to as 'nationally Protected' species and denoted by the abbreviation (P). The list of nationally Protected species was obtained from Kula and George (1996).

4.4.3 Restricted-range species

Restricted-range species are those with a distribution covering less than 50,000 km^2 (Stattersfield et al. 1998; IFC 2012). Restricted-range bird species considered in this report include those defined by BirdLife International (Stattersfield et al. 1998; http://www.birdlife.org/datazone/eba) plus any additional species whose range is considered to be less than the threshold size based on more recent data.

4.4.4 Mapping and coordinates

A Garmin 60CSx GPS unit was used to record tracks and coordinates of individual locations in the field. All maps and coordinates appearing in this report use the PNG94 (Zone 54) geographic coordinate system (datum). All elevations are given as metres above mean sea level (m asl).

5 Results and Discussion

5.1 Diversity summaries

A total of 129 bird species[1] from 44 families was recorded within the study area. Site records for all species are presented in Appendix 1 together with their conservation status. Table 3 lists the number of bird species recorded at each site.

Table 3 The number of bird species recorded at each survey site (all methods combined).

Site	No. species
Camp 1	105
Camp 2	91
Idam River	69
All sites	**129**

Twenty-two (22) birds from 13 species were mist netted and eight bird species were photographed by camera trap (Appendix 1). Camera trap rates for photographed species are displayed in Figure 4. Camera trap rates were highest for the two locally occurring mound-nesting megapodes (Megapodiidae)—the Collared Brushturkey (*Talegalla jobiensis*) (Plate 2A) and New Guinea Scrubfowl (*Megapodius decollatus*) (Plate 2B). A selection of species mist netted and camera trapped is included in Plates 1–8.

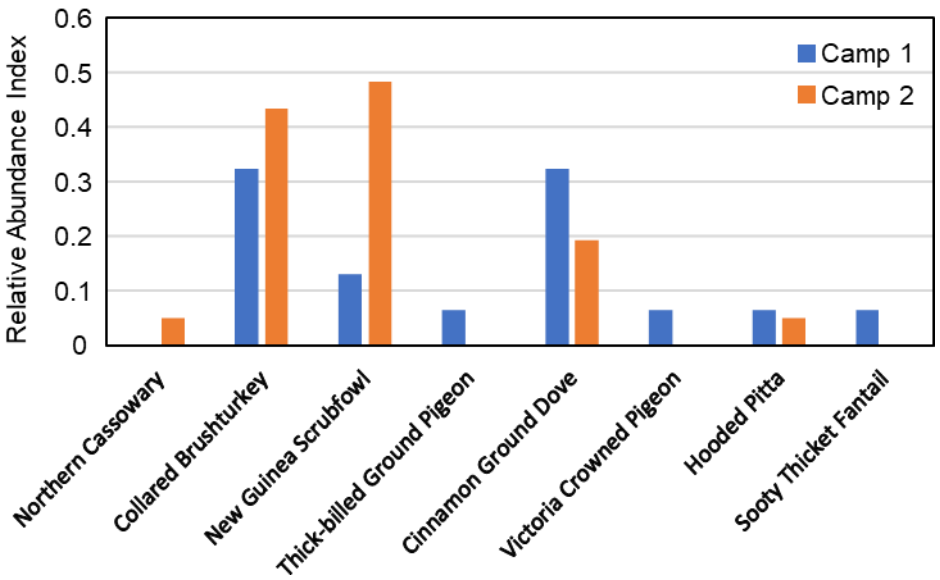

Figure 4 Camera trap rates (RAIs) for individual species photographed at Camps 1 and 2.

Figure 5 shows bird species discovery curves for surveys at Camps 1 and 2 (insufficient time was spent at Idam River to plot a meaningful curve). While a final asymptote was not reached at either

[1] Including provisional identifications where there is no confusion with species already recorded.

site, the rate of species accumulation had slowed markedly towards the end of each survey period, indicating that most locally occurring species had already been detected.

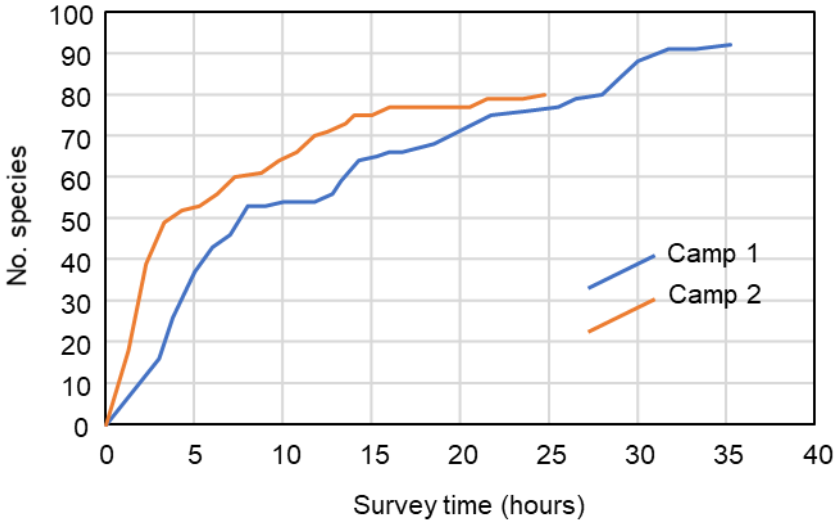

Figure 5 Bird species discovery curves at Camps 1 and 2. Data from active search periods (trapping data excluded).

Counts of 90–100+ species are consistent with tallies recorded by this author over similar periods at comparable elevations in southern mainland PNG (I. Woxvold, unpublished data), but are generally higher than per-site tallies recorded immediately east of the study area during the 2009–2011 Project surveys. Twelve (12) sites surveyed in 2009–2011 covered lowland elevations overlapping those surveyed in 2017 (50–180 m asl) (see Appendix 2). Survey effort at six of these sites—Frieda Bend, Ok Isai, Kaugumi, East Sepik, Iniok and Wario—was comparable to that expended at Camps 1 and 2 in 2017 (4–5 complete days). The total of 105 species from Camp 1 is higher than the tallies from all 2009–2011 sites, and only the previous tally from Iniok (on the Sepik River, 93 species) is higher than the 2017 Camp 2 total. Higher tallies from the 2017 surveys are in part attributable to the variety of habitats accessed from each of the Camp 1 and 2 fly camps, including hill and alluvial forest and gardens and regrowth. Waterbirds observed from Camp 1 along the Right May and May rivers—Great-billed Heron (*Ardea sumatrana*), Great Egret (*A. alba*), Little Egret (*Egretta garzetta*), Little Pied Cormorant (*Microcarbo melanoleucos*), Great Cormorant (*Phalacrocorax carbo*) (Plate 3A), Australasian Darter (*Anhinga novaehollandiae*) and White-bellied Sea Eagle (*Haliaeetus leucogaster*)—further contributed to the highest total there.

Nine species recorded in 2017 were not previously recorded from the 12 comparable lowland sites surveyed in 2009–2011 (Table 4). All are resident New Guinean species of forest or, in the case of the Moustached Treeswift (*Hemiprocne mystacea*), open terrestrial environments. Although not recorded previously at lowland sites, most were recorded at upland localities during the 2009–2011 Project surveys; four species were not recorded at any site during the 2009–2011 surveys—Grey-headed Goshawk (*Accipiter poliocephalus*), Thick-billed Ground Pigeon (*Trugon terrestris*) (Plate 4B), Papuan Hawk-Owl (*Urglaux dimorpha*) and [Barred Owlet-nightjar (*Aegotheles bennetti*)] (Table 4).

Table 4 Bird species recorded in 2017 and not previously recorded at lowland sites in 2009–2011. Birds marked with an asterisk (*) were not recorded at any site during the 2009–2011 Project surveys.

Scientific name	English name	Status	Camp 1	Camp 2	Idam River
Accipiter poliocephalus	Grey-headed Goshawk*				X
Trugon terrestris	Thick-billed Ground Pigeon*		X	X	
Uroglaux dimorpha	Papuan Hawk-Owl*		X	X	X
Aegotheles bennettii	Barred Owlet-nightjar*		[X]		
Hemiprocne mystacea	Moustached Treeswift			O	
Machaerirhynchus flaviventer	Yellow-breasted Boatbill			O	
Coracina melas	Black Cicadabird			O	
Ptiloris magnificus	Magnificent Riflebird	P	O	C	
Microeca flavovirescens	Olive Flyrobin			FC	

Fifty (50) bird species recorded at lowland sites during the 2009–2011 Project surveys were not recorded in 2017. They are listed in Appendix 2 along with their conservation status. They include one resident IUCN Near Threatened species – Blue-black Kingfisher (*Todirhamphus nigrocyaneus*) – and one migrant nationally Protected species – Intermediate Egret (*Egretta intermedia*). The birds listed in Appendix 2 are among the most likely additional species to occur in the area.

5.2 Conservation listed species

5.2.1 Conservation listed species recorded in the study area

Thirteen (13) conservation listed species have been recorded within the study area (Table 5)[2]. All are nationally Protected, and three are IUCN listed—the Vulnerable Papuan Eagle (*Harpyopsis novaeguineae*) and Pesquet's Parrot (*Psittrichas fulgidus*) and the Near Threatened Victoria Crowned Pigeon (*Goura victoria*).

Detailed accounts for conservation listed bird species recorded in the study area are presented in the following sections. Accounts for each species include a summary of the distribution, status and availability of suitable habitat within the study area.

[2] The conservation status of New Guinean birds has recently been reassessed under the IUCN Red List, resulting in the downgrade to Least Concern of a number of previously listed locally recorded or potentially occurring bird species, including Northern Cassowary (*Casuarius unappendiculatus*), New Guinea Flightless Rail (*Megacrex inepta*), Papuan Hawk-Owl (*Uroglaux dimorpha*).

Table 5 Conservation listed species recorded in the study area in 2017 and east of the study area during the 2009–2011 Project surveys.

Scientific name	English name	Status[A]	Camp 1	Camp 2	Idam River	2009–2011 sites[B]
Ardea alba	Great Egret	P	X		X	13,18,19,21
Egretta garzetta	Little Egret	P	X			19
Harpyopsis novaeguineae	Papuan Eagle	VU,P	[X]			3,4,14
Goura victoria	Victoria Crowned Pigeon	NT,P	X	X	X	6,13–16,18–23
Rhyticeros plicatus	Blyth's Hornbill	P	X	X	X	1–7,11–23
Probosciger aterrimus	Palm Cockatoo	P	X	X	X	5–8,11–16,19–23
Psittrichas fulgidus	Pesquet's Parrot	VU,P		X		1,2,4–11,13–15,20
Manucodia ater	Glossy-mantled Manucode	P	[X]			(19)
Manucodia jobiensis	Jobi Manucode	P	X			(2,7,9,17,19)
Ptiloris magnificus	Magnificent Riflebird	P	X	X		3,4,6,11
Cicinnurus regius	King Bird-of-paradise	P	X	X		6,7,11–14,16,17,20–22
Seleucidis melanoleucus	Twelve-wired Bird-of-paradise	P	X			16,19,22
Paradisaea minor	Lesser Bird-of-paradise	P	X	X	X	1–8,11–14,16,19

[A] Abbreviations for conservation listing categories are explained in Section 4.4.2.

[B] Site codes for the 2009–2011 Project surveys: 1—Nena Base; 2—Nena D2; 3—Nena D1; 4—Nena Limestone; 5—Nena-Usage; 6—Malia; 7—Koki; 8—Frieda Base; 9—HI Site; 10—Ubiame; 11—Upper Ok Binai; 12—Ok Binai 1; 13—Frieda Bend; 14—Ok Isai; 15—Frieda Strip; 16—Kaugumi; 17—East Sepik; 18—Hauna (& lakes); 19—Iniok; 20—Warangai South; 21—Wario; 22—Wogamush; 23—Kubkain. Parentheses indicate this or another manucode species was recorded.

5.2.1.1 IUCN threatened species

Papuan Eagle (*Harpyopsis novaeguineae*) (VU, P)

The Papuan Eagle is New Guinea's largest bird of prey, reaching up to 90 cm in length (Coates 1985). Not a soaring raptor, it flies through or low over the canopy to hunt mammals and birds on the ground and in trees (Coates 1985; Watson and Asoyama 2001). Visually inconspicuous, it is most readily detected by its distinctive call (Watson and Asoyama 2001).

The Papuan Eagle is endemic to New Guinea where it occurs throughout the island in forested habitats from sea-level to over 3,000 m asl (Coates 1985). It occurs at low population densities with breeding pairs occupying extensive territories (estimated at 13.0 ± 3.9 km^2 at Crater Mountain WMA: Watson and Asoyama 2001). While most records are from undisturbed forest, it also persists in logged forest (I. Woxvold, unpublished data), presumably where suitable prey remains.

Occurrence in the study area

A Papuan Eagle was provisionally heard at Camp 1 on 4 December; the call is distinctive but was too distant to be confirmed. It was reported previously from the Nena D1, Nena Limestone and Ok Isai sites during the 2009–2011 Project surveys.

Suitable habitat is widespread in the study area, with the highest densities likely to occur in primary hill and alluvial forest where prey items likely remain at highest local densities.

Pesquet's Parrot (*Psittrichas fulgidus*) (VU, P) (Plate 5B)

This unusual, large black-and-red parrot is a nomadic and specialist frugivore feeding on a select variety of figs (Mack and Wright 1998). It is endemic to New Guinea where it inhabits hill and lower montane forest up to 1,200 m asl (occasionally to 2,000 m) (Coates 1985). It nests in tree hollows, the only nest reported in the literature being found in a tall dead tree (Mack 1994).

Occurrence in the study area

Pesquet's Parrot was commonly encountered at Camp 2 with singles and groups of up to five birds seen daily. As estimates of abundance reflect encounter rates, they should be interpreted with caution when considering vagile and vocally conspicuous species such as Pesquet's Parrot. Although encountered regularly, this is an easily detected species and multiple records at Camp 2 may have involved repeat encounters with the same individuals. As a nomadic frugivore, numbers present in any one area are also likely to change with seasonal patterns in food availability.

During the 2009–2011 Project surveys Pesquet's Parrot was among the most widely encountered species in hill forest environments and was at least fairly common at most hill forest sites. It was also recorded on the lowland plains near the hill-foot boundary.

Pesquet's Parrot is likely to be widespread in small numbers in hill forest throughout the study area, including in the hills of the central range, Border Mountains and Bewani Mountains.

5.2.1.2 IUCN Near Threatened species

Victoria Crowned Pigeon (*Goura victoria*) (NT, P) (Plate 5A)

The world's largest pigeons, crowned pigeons (*Goura* spp.) are a terrestrial-foraging species endemic to the lowlands of PNG (Beehler and Pratt 2016). The Victoria Crowned Pigeon is endemic to northern New Guinea from eastern Geelvink Bay, Papua Province (Indonesia) east to Astrolabe Bay, PNG, with isolated populations on Biak and Yapen Islands (Geelvink Bay) and the northern lowlands of the southeast peninsula. It occurs in closed-canopy forest, preferring areas of gentle alluvial terrain including seasonally flooded and swamp forest habitats (Coates 1985; Gibbs et al. 2001). Although normally found in primary forest, some evidence suggests that it persists in structurally damaged forest where hunting levels remain low (Mack et al. 2000; F. Crome, pers. obs.).

Occurrence in the study area

Victoria Crowned Pigeon was confirmed present at all survey sites. At Camp 1 a single was camera trapped in hill forest on a ridgeline west of camp at ca. 160 m asl (Plate 5A). At Camp 2 one was seen in hill forest north of the fly camp on 5 December, another was seen in alluvial forest west of camp on 9 December, and S. Richards heard the species in forest near camp on 6 December. Along the lower Idam River this species' call was detected via automated sound recorder at the edge of sago swamp woodland, hill forest and gardens on the morning of 8 December. Surveyed areas are regularly hunted by local residents and the observed densities are likely to be lower than those naturally occurring in more remote areas of similar habitat.

During the 2009–2011 Project surveys Victoria Crowned Pigeon was widespread in forest environments on the lowland plains and in the foothills, and was also recorded in an area of gardens and disturbed riparian forest near Iniok village. Suitable habitat is widespread in the study area as alluvial forest, nearby swamp forest and in foothill forest below ca. 500 m asl.

5.2.1.3 Nationally Protected species

Great Egret (*Ardea alba*), Little Egret (*Egretta garzetta*) (P)

Two egret species—large white herons of rivers and wetlands—have been recorded in the study area, both of which are Protected under PNG law. They are conspicuous, easily recognised and well known to local residents. Both occur widely from Africa through Eurasia to Australasia, with the Great

Egret also present in North and South America. Local subspecies occur from India (Great Egret) or Indonesia (Little Egret) to Australasia.

Both species occurs throughout New Guinea in a variety of wetland habitats, predominantly in the lowlands but occasionally up to montane elevations (Coates 1985). Their breeding status in New Guinea is poorly understood; some birds are present in all months, but each year there is a significant exchange of waterbirds between Australia and New Guinea with many birds occurring locally as non-breeding visitors (Coates 1985; Dingle 2004). Breeding at specific locations has been confirmed for the Great Egret (Aroa River, Trans-Fly) but not for the Little Egret (Bishop 2005; Beehler and Pratt 2016).

Occurrence in the study area

Two Great Egrets and one Little Egret were seen along the Right May and May rivers on 1 December during the boat survey from Camp 1, and one Great Egret was observed from the boat along the Idam River on 7 December.

During the 2009–2011 Project surveys, both species were observed along rivers and lakes on the Sepik plains.

Suitable habitat within the study area occurs as freshwater wetlands, rivers, wet grasslands and coastal and estuary margins. They are likely to be most common along lakes and rivers of the Sepik drainage, with the Great Egret typically more numerous than the Little Egret (Gregory 1996).

Blyth's Hornbill (*Rhyticeros plicatus*) (P)

Blyth's Hornbill occurs throughout New Guinea in a variety of forest types up to 1,500+ m asl, but is most common in the lowlands and hills (Coates 1985; Kemp 2001). As New Guinea's only hornbill species, and one of the region's largest and most mobile frugivores, Blyth's Hornbill plays a critical role in forest ecosystem dynamics (Mack and Wright 2005; Kinnaird and O'Brien 2007); in the Crater Mountain WMA, Blyth's Hornbill was ranked as the second most important keystone frugivore (behind Dwarf Cassowary) in terms of dispersing the seeds of a high proportion of local plant species (Mack and Wright 2005). Nesting takes place in the hollow of a large tree, normally at least 18 m above the ground (Coastes 1985).

Occurrence in the study area

Blyth's Hornbill was present at all sites and listed as common at Camps 1 and 2 (Appendix 1).

It was one of the most widely recorded bird species during the 2009–2011 Project surveys with dozens of birds occasionally seen at favoured roost sites.

Suitable habitat is widespread in the study area, predominantly as hill forest, alluvial forest and swamp forest, and including logged and fragmented forest habitats. They are likely to be absent from densely populated coastal areas.

Palm Cockatoo (*Probosciger aterrimus*) (P)

This is a large and conspicuous species occurring throughout the New Guinea lowlands and hills (to 1,300 m asl) in rainforest, secondary forest and tropical savannah where birds feed on a variety of seeds and fruit. Their population biology in New Guinea has not been investigated, though on Cape York Peninsula (Australia) they reproduce slowly, breeding infrequently and typically laying only one egg at a time (Murphy et al. 2003), thereby making them vulnerable to population decline. In Australia their population density also depends on the availability of hollow-bearing trees, with birds visiting and maintaining more nest hollows than they require for breeding (Murphy et al. 2003).

Occurrence in the study area

Palm Cockatoos were present at all three survey sites. One or two birds were heard on most days at Camps 1 and 2, their calls were detected via automated sound recorder along the lower reaches of

the Idam River. Palm Cockatoos were widespread during the 2009–2011 Project surveys, though in smaller numbers than most other medium-large parrots and cockatoos.

Suitable habitat is widespread in the study area, predominantly as hill forest, alluvial forest and swamp forest. Multiple records within sites likely involved repeat encounters with the same individuals, and population densities are expected to be low.

Glossy-mantled Manucode (*Manucodia ater*) (P)

The manucodes are a group of glossy black, rather crow-like birds-of-paradise (Coates 1990; Frith and Beehler 1998). Unlike most birds-of-paradise, they are monogamous pair-forming and sexually monomorphic (males and females appear the same). Manucodes present the most difficult problem of field identification among all birds-of-paradise. Vocalisations are often the most reliable diagnostic feature, though the calls of the locally occurring Jobi Manucode (*Manucodia jobiensis*) are still poorly documented, leaving potential for confusion with other locally occurring species.

The Glossy-mantled Manucode is endemic to New Guinea and satellite islands where it inhabits forest, forest edge, secondary growth, swamp forest, woodlands and scrub in the lowlands and foothills, locally up to ca. 900 m asl (Coates 1990; Frith and Beehler 1998). It is the most common manucode in open and disturbed habitats.

Occurrence in the study area

Glossy-mantled Manucode was provisionally heard at Camp 1; the call is distinctive but was heard only faintly on two occasions. This species or Jobi Manucode was seen in gardens along the lower Idam River on 8 December, and in gardens near Iniok village during the 2009–2011 Project surveys. Elsewhere nearby it has been recorded on the April River and at Maeanderberg (Stresemann 1923).

Suitable habitat is widespread in the study area in hill forest, alluvial forest, swamp forest and disturbed/cultivated areas.

Jobi Manucode (*Manucodia jobiensis*) (P) (Plate 8A)

The Jobi Manucode is endemic to the northern lowlands and a restricted part of the western southern lowlands of New Guinea where it inhabits various types of forest, swampy forest and forest edges normally up to 500 m asl but occasionally as high as 750 m (Frith and Beehler 1998). Its voice is poorly known, and field views are normally insufficient to separate this shy bird from the similar looking Glossy-mantled Manucode and Crinkle-collared Manucode.

Occurrence in the study area

A Jobi Manucode was mist netted on a ridge in low elevation hill forest at Camp 1 (identification based on measurements, plumage patterning and bill morphology) (Plate 8A). A second manucode that remained near the net while the bird was extracted was possibly also a Jobi Manucode. This species or Glossy-mantled Manucode was seen in gardens along the lower Idam River on 8 December. During the 2009–2011 Project surveys, this species or Glossy-mantled was seen in gardens near Iniok village, and this species or Crinkle-collared Manucode was seen or heard at sites in peat forest and hill forest. This species is known from elsewhere in the upper Sepik basin at Maeanderberg and along the April River (Stresemann 1923).

Suitable habitat is widespread in the study area in hill forest, alluvial forest and swamp forest.

Magnificent Riflebird (*Ptiloris magnificus*) (P)

The Magnificent Riflebird inhabits lowland and hill forests across most of New Guinea, east in the north as far as the Ramu River, and Cape York Peninsula (Australia) (Coates 1990; Frith and Beehler 1998). A shy species, its presence is usually revealed by the male's distinctive call.

Occurrence in the study area

One heard singing in hill forest at Camp 1, and up to four birds heard in hill forest on most days at Camp 2. Immediately east of the study area it was patchily distributed in hill forest during the 2009–2011 Project surveys.

Suitable habitat is widespread in the study area as hill forest, alluvial forest and less commonly swamp forest.

King Bird-of-paradise (*Cicinnurus regius*) (P) (Plate 8B)

The King Bird-of-paradise is a common resident of lowland and foothill forests (to ca. 300 m asl, less common higher), including swamp forest, of New Guinea and nearby islands. Its diet consists of fruit and invertebrates (Frith and Beehler 1998).

Occurrence in the study area

Fairly common at Camp 1, with one or two birds heard in better quality hill forest on two days and a hen-plumed bird mist netted. Common at Camp 2 with up to four birds heard in hill and alluvial forest on most days and a hen-plumed bird mist netted. It was widely distributed at lower elevation sites during the 2009–2011 Project surveys.

Suitable habitat is widespread as hill forest, alluvial forest and swamp forest (Coates 1990; Frith and Beehler 1998).

Twelve-wired Bird-of-paradise (*Seleucidis melanoleucus*) (P)

The Twelve-wired Bird-of-paradise is endemic to New Guinea and Salawati Island where it inhabits lowland forest, especially swamp forest with sago (*Metroxylon sagu*) and pandanus (*Pandanus* spp.), mostly near sea level but in places up to 180 m asl (Coates 1990; Frith and Beehler 1998). Males occupy dispersed display areas that include multiple advertising posts (emergent, bare, near-vertical branches).

Occurrence in the study area

Uncommon at surveyed sites, with one heard in swamp forest south of the Camp 1 fly camp. In 2009–2011 it was recorded only at three lowland sites with sago present (Kaugumi, Iniok and Wogamush).

Suitable habitat occurs as alluvial forest, swamp forest and swamp woodland, especially where sago or pandanus is present.

Lesser Bird-of-paradise (*Paradisaea minor*) (P)

The Lesser Bird-of-paradise is endemic to northern New Guinea from the Huon Peninsula west to the Vogelkop Peninsula and nearby Misool and Yapen Islands, where it inhabits primary and disturbed forest from the lowlands to ca. 1,550 m asl (Frith and Beehler 1998). It belongs to a well-known group (genus *Paradisaea*) whose members engage in elaborate and conspicuous group-male displays. Up to 10 or more males may perform at a ‘lek’ which may be temporary or used continuously for many years. Leks may be formed in any habitat type, but usually in the upper portion or top branches of a canopy tree, often in a prominent position in the local topography (e.g. ridge crest) (Coates 1990; Frith and Beehler 1998).

Occurrence in the study area

Lesser Bird-of-paradise was recorded at all survey sites—it was common at Camp 1, with up to five birds heard on most days; fairly common at Camp 2, with one or two birds heard most days; and their calls were detected via automated sound recorder along the lower reaches of the Idam River. East of the study area it was one of the most conspicuous and widespread birds of the 2009–2011 surveys.

Suitable habitat is widespread as hill, alluvial and swamp forest as well as forest edge and secondary growth.

5.2.2 Possible additional conservation listed species

Based on current knowledge of avian distributions and habitat preferences, an additional 21 conservation listed species may occur within the study area (Table 6), including a further 17 IUCN listed species (two Threatened, 13 Near Threatened and two Data Deficient). No Critically Endangered bird species are expected to occur in the study area.

Brief accounts of each possible additional conservation listed species are provided below.

Table 6 Possible additional conservation listed species and prior records from the mine terrestrial biodiversity study area during the 2009–2011 Project surveys.

Scientific name	English name	Status[A]	2009–2011 sites[B]
Zonerodius heliosylus	Forest Bittern	NT	6
Ardea intermedia	Intermediate Egret	P	18,19,21
Aquila gurneyi	Gurney's Eagle	NT	
Erythrotriorchis buergersi	Chestnut-shouldered Goshawk	DD	
Megatriorchis doriae	Doria's Goshawk	NT	3
Esacus magnirostris	Beach Stone-curlew	NT	
Numenius madagascariensis	Far Eastern Curlew	EN	
Limosa lapponica	Bar-tailed Godwit	NT	
Limosa limosa	Black-tailed Godwit	NT	
Calidris tenuirostris	Great Knot	EN	
Calidris canutus	Red Knot	NT	
Calidris ferruginea	Curlew Sandpiper	NT	
Calidris ruficollis	Red-necked Stint	NT	
Limnodromus semipalmatus	Asian Dowitcher	NT	
Tringa brevipes	Grey-tailed Tattler	NT	
Aerodramus papuensis	Three-toed Swiftlet	DD	
Todirhamphus nigrocyaneus	Blue-black Kingfisher	NT	16
Manucodia chalybatus	Crinkle-collared Manucode	P	(2,7,9,17)
Phonygammus keraudrenii	Trumpet Manucode	P	
Drepanornis bruijnii	Pale-billed Sicklebill	NT,P	
Diphyllodes magnificus	Magnificent Bird-of-paradise	P	1,3–7,9–11

[A] Abbreviations for conservation listing categories are explained in Section 4.4.2.

[B] Parentheses indicate this or another manucode species was recorded.

5.2.2.1 IUCN Threatened species

Far Eastern Curlew (*Numenius madagascariensis*) (EN), Great Knot (*Calidris tenuirostris*) (EN)—Two IUCN Endangered migratory shorebird species breeding in the northern hemisphere and seasonally present in New Guinea throughout the austral winter or *en route* to wintering grounds in Australia. The conservation of migratory shorebirds and their habitats is the focus of elevated international concern, since a large proportion of species is in decline and continues to be threatened by a wide range of environmental changes, notably the destruction of tidal foraging habitat and associated roosting sites along migratory routes and at wintering grounds (Gosbell and Clemens 2006; Wilson et al. 2011; Szabo et al. 2016). Predominantly near-coastal species, they forage for invertebrates on tidal mudflats on the shoreline and in sheltered bays, estuaries and lagoons (Coates 1985; Higgins and Davies 1996). Potentially seasonally present in coastal environments at the northern end of the infrastructure corridor. However, there are no extensive inter-tidal systems in the Vanimo area, and if present they are expected to occur in low numbers.

5.2.2.2 IUCN Near Threatened species

Forest Bittern (*Zonerodius heliosylus*)—A rare heron endemic to New Guinea in forest swamps, streams and pools from the lowlands to 1,430 m asl. Not recorded in 2017, but recorded east of the study area at the Malia site during the 2009–2011 surveys. Likely to be present in small numbers

within the study area, occurring in freshwater pools and streams in hill forest, alluvial forest and swamp forest, preferring little-disturbed environments.

Gurney's Eagle (*Aquila gurneyi*)—A very large bird of prey (wingspan to 1.85 m) present throughout New Guinea and in the Moluccas, in a variety of forest habitats to at least 1,300 m asl. Suitable forest habitat is widespread in the study area wherever suitable prey (including flying fox colonies) may be found—hill forest, alluvial forest and swamp vegetation.

Doria's Goshawk (*Megatriorchis doriae*)—A rarely encountered bird of prey endemic to lowland and hill forest throughout New Guinea, from sea level to at least 1,650 m asl. Not recorded in 2017, but recorded east of the study area at the Nena D1 site during the 2009–2011 surveys. Suitable hill and alluvial forest forest is widespread across the study area, though as a species that hunts below the canopy it is likely to be relatively scarce in logged forest.

Beach Stone-curlew (*Esacus magnirostris*)—A large, resident shorebird of beaches, tidal flats, reefs and mangroves. May occur on shores and subcoastal habitats at the northern end of the infrastructure corridor, but likely to be scarce as much of the Vanimo coast is frequently visited by humans.

Bar-tailed Godwit (*Limosa lapponica*), Black-tailed Godwit (*L. limosa*), Red Knot (*Calidris canutus*), Curlew Sandpiper (*C. ferruginea*), Red-necked Stint (*C. ruficollis*), Asian Dowitcher (*Limnodromus semipalmatus*), Grey-tailed Tattler (*Tringa brevipes*)—Seven migratory shorebird species breeding in the northern hemisphere and seasonally present in New Guinea throughout the austral winter or *en route* to wintering grounds in Australia. Potentially seasonally present and most likely to occur in coastal environments at the northern end of the infrastructure corridor. The Black-tailed Godwit, Red-necked Stint and Curlew Sandpiper also occur on the margins of freshwater wetlands and thus may also occur in suitable habitat in the Sepik basin. Where present these species are likely to occur in small numbers as no wetland habitats of significance to migratory waterbirds have been identified within the study area.

Blue-black Kingfisher (*Todirhamphus nigrocyaneus*)—A rare and poorly known New Guinea endemic occupying lowland forest to ca. 600 m asl (Beehler and Pratt 2016). The distinctive subspecies occupying northern mainland PNG, *Todirhamphus nigrocyaneus quadricolor*, is known from a handful of sites from Yapen Island and the lowlands of north Papua Province (Indonesia) east to Astrolabe Bay and an isolated population recently discovered in the lower Markham River (I. Woxvold, unpublished data; Beehler and Pratt 2016). Not recorded in 2017, but provisionally recorded (considered very likely this species) east of the study area at the Kaugumi site during the 2009–2011 surveys. Suitable habitat within the study area occurs as alluvial forest and tall swamp vegetation, including swamp forest and sago swamp woodland. Potentially absent from logged forest areas in the northern sector of the study area.

Pale-billed Sicklebill (*Drepanornis bruijnii*)—This bird-of-paradise is a restricted-range species (Stattersfield et al. 1998), occupying lowland forest (to 175 m asl) from east Geelvink Bay, Papua Province, east to a very small known area of occurrence within PNG—at four sites on the north coastal plains near Vanimo and in the footslopes of the northern and southern flanks of the Bewani Mountains (Beehler and Beehler 1986; Whitney 1987; Beehler and Pratt 2016). The known PNG locations have now been logged (Hansen et al. 2013; Bryan and Shearman 2015). Reports of its occurrence further south along the upper Sepik River (e.g. BirdLife International 2018) appear to be unconfirmed, though potentially suitable habitat extends there unbroken from known locations to the north. It is tolerant of some habitat disturbance (Beehler and Beehler 1986; Whitney 1987), though recent intensive logging and conversion to oil palm has no doubt reduced its range within PNG. The infrastructure corridor traverses areas of lowland forest potentially occupied by this species; most likely in areas of intact alluvial and foothill forest north of Green River.

5.2.2.3 IUCN Data Deficient species

Chestnut-shouldered Goshawk (*Erythrotriorchis buergersi*)—A large bird of prey. One of New Guinea's rarest birds (Beehler 1993). Known from hill and lower montane forest at ca. 450–1,600 m asl. Recorded previously from near the study area at Maeanderberg, ca. 45 km east of Green River

(Stresemann 1923). Suitable hill forest within the study area occurs on the Bewani Mountains and West Range crossings.

Three-toed Swiftlet (*Aerodramus papuensis*)—Very difficult to distinguish in the field from other all-dark New Guinea swiftlets. Endemic to New Guinea where recorded with certainty from only four localities between sea level and 2,400 m asl. Ecology poorly known. May occur anywhere in the study area.

5.2.2.4 Nationally Protected species

Intermediate Egret (*Ardea intermedia*)—Occurs widely from Africa through Eurasia to Australasia, the local subspecies present northwest to Indonesia. Present throughout New Guinea in a variety of wetland habitats, predominantly in the lowlands. Recorded breeding in New Guinea only in the Trans-Fly (Bishop 2005; Beehler and Pratt 2016). Not recorded in 2017, but expected to occur and commonly encountered in wetland habitats east of the study area during the 2009–2011 surveys.

Crinkle-collared Manucode (*Manucodia chalybatus*)—Endemic to mainland New Guinea and Misool Island (Indonesia), in forest and forest edge from the lowlands to 1,700 m asl, though predominantly in hill forest above 500 m. This shy bird is similar in appearance to the Glossy-mantled and Jobi Manucodes and is not easily distinguished based on vocalizations alone. This species or Jobi Manucode was seen or heard at sites in peat forest and hill forest during the 2009–2011 surveys. Within the study area it may occur in hill forest at the base of the central range and in the foothills of the Bewani and Border Mountains.

Trumpet Manucode (*Phonygammus keraudrenii*)—Occurs predominantly in primary forest in New Guinea and Cape York Peninsula (Australia) from the lowlands to 2,000 m asl where it feeds mainly on figs (Coates 1990; Frith and Beehler 1998). The locally occurring northern subspecies (*P. k. neumanni*) is predominantly a bird of upper hill and lower montane environments with only two suspected lowland records (Frith and Beehler 1998). Within the study area it is most likely to occur in hill forest at the base of the central range and in the foothills of the Bewani and Border Mountains.

Magnificent Bird-of-paradise (*Diphyllodes magnificus*)—Endemic to New Guinea and satellite islands where common and widespread in forest from the lowlands to 1,780 m asl (Frith and Frith 2009). Not recorded in 2017, but widespread in the hill zone east of the study area during the 2009–2011 surveys. Suitable habitat within the study area includes at the base of the central range and in the foothills of the Bewani and Border Mountains.

5.3 Endemic and restricted-range species

The New Guinea region is rich in avian endemics (Section 3.1). More than one half of the bird species recorded during the 2017 surveys (67/129; 51.9%) are found only on New Guinea and its satellite islands[3]. Of these, 16.4% (11/67) occur only on mainland New Guinea, and two species – Northern Cassowary (*Casuarius unappendiculatus*) and Edwards's Fig Parrot (*Psittaculirostris edwardsii*) – are found only in the northern watershed.

Edwards's Fig Parrot is the only putative restricted-range bird species (breeding range <50,000 km^2) recorded during the 2017 surveys. However, while it is listed by Stattersfield et al. (1998) as a restricted-range species its area of occupancy is likely to be closer to 100,000 km^2 (estimated from GIS mapping of known distribution), and it is currently described by BirdLife International (2018) as occupying an area of 165,000 km^2. It thus does not qualify for restricted-range status.

One restricted-range bird species may occur in the study area. The IUCN Near Threatened Pale-billed Sicklebill is listed by Stattersfield et al. (1998) as a restricted-range species, and while BirdLife International (2018) currently estimate its extent of occurrence at 111,000 km^2, its known range is here conservatively estimated (based on GIS mapping and including areas of potentially suitable

[3] Including Waigeo, Misool, Yapen, Biak, Aru, d'Entrecasteaux and Louisiades.

habitat extending from known locations) to cover less than 50,000 km^2. Its potential distribution within the study area is described in Section 5.2.2.2.

The Brown Lory (*Chalcopsitta duivenbodei*), not recorded in 2017 but expected to occur, is also listed by Stattersfield et al. (1998) as a restricted-range species, but as is the case with Edwards's Fig Parrot its actual range is estimated to be well above 50,000 km^2.

5.4 Migratory species

New Guinea's avifauna includes some 60 migratory species that breed in the northern hemisphere[4] (Eurasia) and around 30 species that breed to the south in Australia and New Zealand.

Most bird species recorded in the study area are present in New Guinea only as breeding residents (Project and prior surveys combined: 118/129; 91.8%). The remaining 11 species, listed in Table 7, occur in New Guinea at least partly as non-breeding visitors. They include eight species of freshwater wetland environments and three species of forest and open terrestrial habitats.

5.4.1 Migrants to wetland environments

Most birds migrating to New Guinea visit coastal and freshwater wetland environments.

Most migratory species recorded in wetland environments within the study area (7/8) breed in Australia (Table 7). Each year there is a significant exchange of waterbirds between Australia and New Guinea, though for many species the patterns of movement and breeding are still poorly known (Dingle 2004; Beehler and Pratt 2016). At least four of the recorded species—Pacific Black Duck (*Anas superciliosa*), Little Pied Cormorant, Little Black Cormorant (*Phalacrocorax sulcirostris*) (Plate 3B) and Australasian Darter—may breed within the study area and/or elsewhere regionally within the upper Sepik basin lowlands. Records of Great Egret and Little Egret likely involved Australian breeding birds, though the presence of previously unreported breeding colonies within the local region cannot be ruled out. Three additional Australian breeding waterbirds were recorded during the 2009–2011 surveys—Intermediate Egret (*Egretta intermedia*), Pied Heron (*E. picata*) and Whiskered Tern (*Chlidonias hybrida*). As with the egrets already recorded, these are considered unlikely to breed locally (Beehler and Pratt 2016).

The Common Sandpiper (*Actitis hypoleucos*) was the only northern hemisphere migrant recorded in the study area, with at least three birds seen along the Idam River. This species belongs to a diverse group of more than 30 Palaearctic shorebirds (Scolopacidae, Charadriidae) that are seasonally present in New Guinea throughout the austral winter or *en route* to wintering grounds in Australia (excluding vagrants: Bishop 2006; Pratt and Beehler 2015). They include nine IUCN listed species that are listed in Table 6 and described above (Sections 5.2.2.1 and 5.2.2.2)[5]. The conservation of migratory shorebirds and their habitats is the focus of elevated international concern, since a large proportion of species is in decline due to (*inter alia*) the ongoing destruction of tidal foraging habitat and associated roosting sites along migratory routes and at wintering grounds (Gosbell and Clemens 2006; Wilson et al. 2011; Szabo et al. 2016). In additional to the 2017 records, small groups of migratory shorebirds, almost certainly including and probably exclusively comprised of Sharp-tailed Sandpiper (*Calidris acuminata*), were seen during aerial reconnaissance of larger lakes south of the Sepik River and east of the present study area in October 2009. However, in contrast to Australian breeding waterbirds, most Palaearctic shorebirds are predominantly near-coastal species, and are

[4] Published estimates vary; Dingle (2004) conservatively listed some 40 species as migrating to the Australo-Papuan region from breeding grounds in Eurasia, while Mack and Dumbacher (2007) noted that 75 species are listed under treaties designed to protect birds migrating between Australia and Japan (Japan-Australia Migratory Bird Agreement) and Australia and China (China-Australia Migratory Bird Agreement), all of which have been recorded or may be expected to occur in New Guinea (as a destination or *en route* to Australia).

[5] Asian Dowitcher (*Limnodromus semipalmatus*), Black-tailed Godwit (*Limosa limosa*), Bar-tailed Godwit (*L. lapponica*), Far Eastern Curlew (*Numenius madagascariensis*), Grey-tailed Tattler (*Tringa brevipes*), Great Knot (*Calidris tenuirostris*), Red Knot (*C. canutus*), Red-necked Stint (*C. ruficollis*), Curlew Sandpiper (*C. ferruginea*).

expected to congregate in largest numbers on tidal mudflats along the coast and in sheltered bays, estuaries and lagoons. However, there are no extensive inter-tidal systems in the Vanimo area, and the study area's freshwater wetlands likely provide habitat for a limited number of species and in small numbers.

Table 7 Migratory species (not breeding on mainland New Guinea) recorded in the study area.

Scientific name	English name	Migratory status[A]	Habitat[B]	Source[C]
Anas superciliosa	Pacific Black Duck	BR/M	W	A
Ardea alba	Great Egret	M(+BR)	W	A
Egretta garzetta	Little Egret	M(+BR)	W	A
Microcarbo melanoleucos	Little Pied Cormorant	BR/M	W	A
Phalacrocorax sulcirostris	Little Black Cormorant	BR/M	W	A
Phalacrocorax carbo	Great Cormorant	M	W	A
Anhinga novaehollandiae	Australasian Darter	BR/M	W	A
Actitis hypoleucos	Common Sandpiper	M	W	N
Eudynamys orientalis	Pacific Koel	BR/M	F,O	A
Scythrops novaehollandiae	Channel-billed Cuckoo	M(+BR)	F,O	A
Cacomantis variolosus	Brush Cuckoo	BR/M	F,O	A

[A] M—species that occur in New Guinea only as non-breeding migrants; M(+BR)—non-breeding migrants with possible (unknown) local breeding populations in New Guinea, or with known New Guinea breeding populations localised and not known within the study area; BR/M—breeding residents with populations seasonally augmented by non-breeding visitors. Data from Coates (1985, 1990), Beehler and Pratt (2016).

[B] F—forest; O—open and disturbed areas; W—freshwater wetlands.

[C] Breeding grounds outside of New Guinea: A—Australia; N—northern hemisphere.

5.4.2 Migrants to terrestrial environments

Most migrants to terrestrial environments breed in Australia and visit New Guinea during the austral winter (May–October). Three such species were recorded in 2017 (Table 7). At least two of these—Pacific Koel (*Eudynamys orientalis*) and Brush Cuckoo (*Cacomantis variolosus*)—have local breeding populations seasonally augmented by non-breeding visitors from Australia, and birds encountered during the survey were thus likely to be local resident breeders. The Channel-billed Cuckoo (*Scythrops novaehollandiae*) is not known to breed in New Guinea, though birds are regularly recorded during the austral summer (present study; Beehler and Pratt 2016) and breeding may occur but remain undetected. Channel-billed Cuckoos were present at all sites surveyed in 2017 (and at the Frieda River airstrip). Based on current knowledge they are assumed to have included some non-breeding migrants, though the presence of a local breeding population cannot be ruled out.

The 2017 surveys were poorly timed to encounter southern terrestrial migrants, and a number of additional species may occur, including five species recorded previously during the 2009–2011 surveys—Dollarbird (*Eurystomus orientalis*), Buff-breasted Paradise-Kingfisher (*Tanysiptera Sylvia*), Sacred Kingfisher (*Todirhamphus sanctus*), Rainbow Bee-eater (*Merops ornatus*) and Satin Flycatcher (*Myiagra cyanoleuca*). All migrants to terrestrial habitats occur widely across New Guinea and most either predominantly occupy or are tolerant of open and disturbed environments. The study area does not include habitat for these species requiring specific conservation action.

5.5 Alien invasive species

One non-native bird species was recorded—the Eurasian Tree Sparrow (*Passer montanus*) at Vanimo. Eurasian Tree Sparrow was first recorded in mainland PNG at Port Moresby in April 2009

(Gregory 2009a, b), and later that year at Frieda Base (Woxvold 2011). An accomplished colonist, its recent arrival has been followed by a rapid expansion into settled areas across much of mainland PNG (Woxvold et al. 2015; Beehler and Pratt 2016).

Two other invasive bird species may occur (Pratt and Beehler 2015)—the Rock Dove (*Columba livia*) and the House Sparrow (*Passer domesticus*). These are most likely to inhabit densely populated areas around Vanimo.

All invasive bird species occurring in New Guinea are closely associated with areas of human settlement and almost exclusively occupy open and disturbed habitats (Pratt and Beehler 2015). Should they become established within the study area none is expected to pose a serious threat to native bird populations.

5.6 Species important to local communities

Birds have long played an important role in the livelihood and culture of New Guinea's indigenous peoples (Coates 1985; Pangau-Adam and Noske 2010), and in most (or all) rural societies subsistence strategies include the harvesting of uncultivated plants and the hunting of wildlife (Bourke et al. 2000). In many New Guinea societies nearly all types of birds are eaten, with even the smallest species hunted opportunistically (e.g. Kocher Schmid 1993; Woxvold et al. 2015). However, for most people a subset of taxa consistently provides the most valuable resources, including cassowaries, megapodes, large columbids such as crowned pigeons (*Goura* spp.) and imperial pigeons (*Ducula* spp.), hornbills, waterfowl and, particularly in societies where '*bilas*' (ceremonial finery) is an important commodity, elaborately plumed birds-of-paradise, large parrots and raptors (Beehler 1993).

The Min and Abau people encountered during the 2017 surveys hunt birds for food and trade. As in many cultures, cassowaries are economically and nutritionally the most important birds; they are hunted and eaten and their young are raised to be consumed or sold on for 1,000–1,500 PNG Kina (Usaremin 2 informant). Two sub-adult Northern Cassowaries were held in pens at Usaremin 2 village, and Northern Cassowary chicks were kept at both Usaremin 2 and Idam 1 villages (Plate 1).

A hunter's bird hide seen on a hill forest ridge was reported to be used for catching megapodes and crowned pigeons which were then consumed.

5.7 Important bird habitats

The study area includes a variety of habitats that support multiple resident and/or migratory bird species of conservation significance.

5.7.1 Important forest environments

Forest habitats support the vast majority of bird species residing or regularly occurring in the study area—of the bird species recorded, more than 82% (106/129) occur in forest environments, most of which are forest-dependent (cannot persist in converted or secondary habitats alone). All resident (non-migratory) conservation listed and restricted-range species confirmed present or potentially occurring in the study area are dependent on forest habitats. Within the study area landscape, alluvial forest and foothill forest are identified as being of particular importance to locally occurring bird communities.

5.7.1.1 Alluvial forest

Within the study area, lowland alluvial forest (FIMS code P) occurs in its various forms:

- In discrete areas south of the Sepik River, along meander floodplains, back swamps and alluvial terraces lining the major watercourses (May and Idam rivers) amid hill terrain at the base of the central range (small crowned (Ps) and open alluvial forest (Po)).
- On the meander floodplains along the Sepik River (open alluvial forest (Po)).
- Most extensively north of the Sepik River, on alluvial plains east of the Border Range and south of the Bewani Range (mostly small crowned alluvial forest (Ps) with a small mapping unit of large crowned alluvial forest (Pl) along the Faringi River), and, at least formerly, on the north coastal plains between the Bewani Range and Vanimo (large crowned alluvial forest (Pl)).

Alluvial forest has a much more restricted distribution than hill forest (FIMS code H) across mainland PNG, and as a favoured source of commercial timber is under pressure from industrial logging activities, including locally within the study area between Vanimo and the Yagroner Hills and more broadly across Sandaun Province (Hansen et al. 2013; Bryan and Shearman 2015).

Lowland alluvial forest supports the richest bird communities in the Asia-Pacific realm. Non-swamp forest on gentle (such as alluvial) terrain is the favoured habitat of many terrestrial species, including cassowaries (*Casuarius* spp.), New Guinea Scrubfowl, pittas (*Pitta* spp.) (Plate 6A) and a variety of terrestrial pigeons (I. Woxvold; unpublished camera trap data) including the crowned pigeons (*Goura* spp.; King and Nijboer 1994). Terrestrial birds are especially vulnerable to forest disturbance (Munks and Watling 2013), and remaining areas of intact alluvial forest thus provide important habitat for terrestrial species, notably including the Northern Cassowary, a species of economic value to local residents, and the IUCN Near Threatened Victoria Crowned Pigeon. Alluvial forest also provides suitable habitat for all other resident IUCN listed species and most nationally Protected species confirmed present within the study area. Other forest birds recorded in the study area that are likely to be restricted to or more abundant in alluvial forest include White-bellied Thicket Fantail (*Rhipidura leucothorax*), Shining Flycatcher (*Myiagra Alecto*), Twelve-wired Bird-of-paradise (*Seleucidis melanoleuca*) and Black-sided Robin (*Poecilodryas hypoleuca*). Alluvial forest north of the Sepik River also supports the Pale-billed Sicklebill, a bird-of-paradise with a very restricted distribution in PNG whose habitat is under threat from logging.

Elsewhere in the Asia-Pacific region, the relative importance of hill and alluvial forest has been well studied in Sundaic Southeast Asia. Following detailed studies on birds in Malaysia, Wells (1985) confirmed that bird species richness is highest in lowland alluvial forests, and further noted that (Wells 1985, p. 221):

> "it cannot be over-emphasized that for the lowland forest bird fauna the extreme lowlands, below the hill-foot boundary, is the key zone".

Much of the alluvial forest mapped present in the northern half of the infrastructure corridor has been logged. The influence of logging on forest bird communities in New Guinea has been little studied (reviewed in Munks and Watling 2013). In general, results indicate that bird species richness and abundance is lower in logged secondary forest than in unlogged forest (Driscoll 1984, summarised in Lamb 1990; Marsden and Symes 2008; Tvardikova 2010; Dawson et al. 2011). However, studies have also found (1) that species assemblages change with time as the forest regenerates, (2) that species richness is highest in sites with intermediate disturbance, and (3) that species richness is higher in disturbed sites that are near primary forest habitats (Marsden and Symes 2008; Munks and Watling 2013). While a good deal of the forest near Vanimo has been converted outright to oil palm plantation, the conservation value of remnant areas of logged-over alluvial forest will vary *inter alia* with the above-listed parameters.

5.7.1.2 Foothill forest

Within the study area, medium crowned hill forest (FIMS code Hm) occurs:

- South of the Sepik River, on the West Range between the headwater reaches of the Idam and Right May rivers.
- North of the Sepik River, on the eastern foothill flank of the Border Range, on the Bewani Range and at the northern base of coastal foothills near Vanimo.

Compared to alluvial forest, hill forest is more widespread across PNG. It is a favoured source of commercial timber, especially in the relatively accessible foothill zone in areas with gentle terrain. Most of the hill forest near Vanimo and on the Bewani Range near the infrastructure corridor has been logged.

Low elevation foothill forests (below 500 m asl) support among the richest bird communities present in New Guinea (Pratt and Beehler 2015). Detailed comparisons of bird diversity among alluvial and adjacent foothill forest communities are lacking for PNG, though most species that occupy alluvial forest also occur in the foothill zone. Foothill forest provides suitable habitat for almost all resident IUCN listed and nationally Protected bird species recorded or potentially occurring in the study area. Notably, hill forest is the preferred habitat of the IUCN Vulnerable Pesquet's Parrot (Beehler and Pratt 2016; Section 5.2.1.1). At elevations below 200 m asl they also support the Pale-billed Sicklebill, a bird-of-paradise with a very restricted distribution in PNG whose habitat is under threat from logging.

5.7.2 Freshwater environments

5.7.2.1 Rivers and streams

Rivers and streams provide focal habitat for a variety of waterbirds and other stream-specialist species.

Minor forest streams that flow beneath a closed forest canopy are widespread in the hill and alluvial zones. Birds associated with these watercourses are sometimes classified as forest-dwelling species, and include the elusive Forest Bittern (*Zonerodius heliosylus*) (not yet recorded though potential to occur) and some small, predominantly piscivorous kingfisher species such as the Azure Kingfisher (*Ceyx azureus*). These watercourses and their associated biota are well represented elsewhere in the local region and wherever lowland hill forest persists across New Guinea's northern watershed.

Larger watercourses too wide for canopy closure vary in width from ca.10 m across to more than 300 m wide in places along the Sepik River. These provide foraging habitat for a suite of additional waterbirds that do not regularly occur along the more minor watercourses. Those recorded within the study area include herons and egrets (three species), cormorants and darters (four species), Pacific Black Duck, Great-billed Heron, White-bellied Sea Eagle and Common Sandpiper.

Watercourses comparable in size and character to the Right May, Idam, Faringi, Bapi-Horden and similar rivers are well represented regionally in PNG's northern watershed. By contrast, as PNG's second largest river, the Sepik is less well replicated in a regional context. However, despite its size, surveys conducted thus far (2017 and 2009–2011) indicate that this section of the Sepik River in itself (excluding off-river waterbodies) does not directly provide important habitat for resident or migratory waterbird species—relevant records from along flowing watercourses have to date involved scattered occurrences with no large congregations or breeding colonies reported. It does, however, provide the main source of water for potentially important off-river water bodies.

5.7.2.2 Off-river water bodies

Off-river standing-water or slow-flowing freshwater wetlands provide focal habitat for a variety of bird species that congregate in these environments including a suite of locally breeding and migratory taxa. Off-river water bodies were not observed directly during the 2017 surveys, but examination of the 1:100,000 Idam (sheet no. 7189) and Amanab (sheet no. 7190) topographic map sheets indicates they may occur as oxbow wetlands associated with former channels of the Idam and Sepik rivers.

Where present, these may support among the largest aggregations of freshwater wetland birds within the study area, and potentially provide breeding habitat for some resident wetland species.

Compared to the features mapped within the study area, wetlands of greater significance to waterbirds are abundantly present elsewhere within the local region. More than a dozen oxbow lakes are mapped present along the meander floodplain of the Sepik River within 50 km downstream of the infrastructure corridor, with some lakes reaching more than 5 km in length (the actual number of oxbow lakes may be higher as the Sepik River has changed course significantly since the 1970s when topographic maps were prepared). Further downstream, a number of large basin lakes are present in poorly drained back swamps beyond the meander floodplain zone. Within 80–100 km of the study area, lakes Warangai and Warui were surveyed in 2009–2011, with almost 20 species of waterbird observed, some in large numbers (Whiskered tern and egret spp.).

Little information is available regarding the numbers of waterbirds that breed in the Sepik River basin. Large rookeries have been reported for some species (e.g. Intermediate Egret, Spotted Whistling Duck (*Dendrocygna guttata*): Gilliard and LeCroy 1966), and the 21,000 ha Chambri Lake (PNG's second largest behind Lake Murray) hosts large numbers of waterbirds, many of which breed there. The number of species and individuals that breed in wetlands within the study area remains unknown, though by virtue of their size alone, these wetlands are expected to be less important to waterbirds than others present more widely in the local region

5.7.3 Important local landscape features

Local landscape features important to avifauna include various terrain and habitat features upon which multiple species and/or multiple individuals of one or more species are ecologically dependent.

5.7.3.1 Caves and rock overhangs

Caves and rock overhangs provide important habitat for a variety of swiftlets (*Collocalia*, *Aerodramus* spp.) that shelter there to roost and breed in colonies. Two such swiftlet species have been recorded in the study area, the Glossy Swiftlet (*Collocalia esculenta*) and Uniform Swiftlet (*Aerodramus vanikorensis*)[6], and others may occur, including the rare and poorly known Three-toed Swiftlet (DD).

Large caves are most likely to occur in areas of surface limestone. Geological mapping shows that surface limestone is present in the study area in limited areas of the north coastal hills between Vanimo and the Bewani Range, and on the southern slopes of the Bewani Range crossing (Bryan and Shearman 2008). No surface limestone is present within the infrastructure corridor south of the Bewani Range.

Smaller caves and rock overhangs may occur more widely, for example in areas with escarpments and other steep terrain features on the West Range.

5.7.3.2 Large trees in low-nutrient or disturbed environments

Large trees provide a concentrated source of natural resources that are important for maintaining the diversity of local wildlife. Tree hollows, for example, are larger and more numerous in large, old trees. Large trees are therefore essential for maintaining local populations of a wide variety of mammals, birds, reptiles and amphibians that use hollows for shelter and reproduction, and those bird species (e.g. owls, diurnal raptors) that prey upon them. A number of species of conservation significance recorded in the study area, including Palm Cockatoo (P), Pesquet's Parrot (VU, P) and Blyth's Hornbill (P), require tree hollows for reproduction. Large trees also provide preferred nesting sites for large diurnal raptors (eagles, kites, goshawks, etc.).

[6] The small, all-dark *Aerodramus* swiftlets seen regularly during the surveys are confidently considered to have included, and probably exclusively comprised, Uniform Swiftlet (*Aerodramus vanikorensis*). Though essentially indistinguishable from Mountain Swiftlet (*A. hirundinaceus*) in flight, the latter is considered absent from flat lowland terrain and rare below 500 m asl (Beehler and Pratt 2016).

Tree size is dependent on a variety of environmental factors including soil type, drainage, terrain and disturbance history. In general, 'large' trees are expected to be relatively common in many parts of the study area where large-statured forest types occur, including certain areas of undisturbed hill and alluvial forest. In contrast, landforms (1) deficient in nutrients, (2) with steep, unstable terrain, and/or (3) that experience regular prolonged flooding, often naturally support a lower density of large boled trees. Large tree densities are also much lower in heavily logged forest.

Within the study area, large trees will be of greatest importance in a local landscape context in:

- Logged forest, including hill forest and alluvial forest, in the northern half of the infrastructure corridor.
- Naturally small statured vegetation types on periodically or permanently inundated landforms, including freshwater swamp habitats.

In these environments, large trees may be defined as those with >75 cm diameter at breast height (dbh).

5.7.3.3 Large fig trees

Large fig trees (*Ficus* spp.) are among the most important food source for tropical frugivores the world over (O'Brien et al. 1998; Shanahan et al. 2001), a fact attributed to their nutrient-rich, unprotected fruits, their production of large crops that ripen synchronously within a tree, consistent production between years, and asynchronous fruiting between trees resulting in a year-round 'local' supply of fruit. New Guinea's wildlife includes a high proportion of frugivorous birds (Pearson 1977; Mack and Dumbacher 2007), many of which rely heavily on figs. Fig-parrots (*Cyclopsitta*/*Psittaculirostris* spp.), Pesquet's Parrot (VU), the manucode birds-of-paradise (P) and some cuckooshrikes (*Coracina* spp.) have all evolved to become fig specialists. Among other frugivores, a number of keystone species that play an important ecological role in dispersing the seeds of rainforest trees (e.g. cassowaries, Blyth's Hornbill, pigeons; Mack and Wright 2005) and a number of birds-of-paradise (Paradisaeidae, in addition to the manucodes; Frith and Beehler 1988) include figs as a major component of their diet.

A productive fig tree need not attain the size of other 'large trees' for it to play an important ecological role in the local landscape. They are here defined as those with >50 cm dbh.

5.8 Conclusion

The survey documented as many of those bird species present as possible in the time available at each site, with a special focus on determining the presence and status of high conservation value species, including IUCN listed, nationally Protected and restricted-range species. Survey design was based on the coverage of multiple distinct ecosystems/vegetation types present within the infrastructure corridor in the relatively undisturbed environments south of the Sepik River. A variety of survey techniques were combined in order to maximise taxonomic coverage, including aural and visual detection, mist netting, camera trapping, automated sound recording and discussions with local residents. The results of the 2017 surveys provide the most detailed dataset currently available on bird communities present within this sector of the study area. These were supplemented with data from (1) more extensive surveys conducted immediately east of the study area in 2009–2011, and (2) publicly available information on birds present north of the Sepik River, including in the Bewani Range and on the north coastal plains.

Multiple additional conservation listed species may occur within the study area (Section 5.2.2; Table 6), including 17 IUCN listed species (two Threatened, 13 Near Threatened, two Data Deficient). Information on the ecology, status and threats of these species is provided (Section 5.2.2); in all cases where an occurrence in the study area is considered a possibility, other sensitive species with similar ecological requirements have already been recorded and/or relevant priority habitats have been identified, providing for the development of a comprehensive set of relevant avoidance, mitigation and management strategies.

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Plates

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Plate 1 Northern Cassowary (*Casuarius unappendiculatus*) (A) sub-adult and (B) chick, captive at Usaremin 2 village.

Plate 2 (A) Collared Brushturkey (*Talegalla jobiensis*) and (B) New Guinea Scrubfowl (*Megapodius decollatus*) camera trapped at Camp 2.

Plate 3 (A) Juvenile (lower left) and adult Great Cormorant (*Phalacrocorax carbo*) and (B) Little Black Cormorant (*P. sulcirostris*) on the lower Idam River.

Plate 4 (A) Cinnamon Ground Dove (*Gallicolumba rufigula*) and (B) Thick-billed Ground Pigeon (*Trugon terrestris*) camera trapped at Camp 1.

Plate 5 (A) Victoria Crowned Pigeon (*Goura victoria*) camera trapped at Camp 1. (B) Pesquet's Parrot (*Psittrichas fulgidus*).

Plate 6 (A) Hooded Pitta (*Pitta sordida*) camera trapped at Camp 1. (B) Tan-capped Catbird (*Ailuroedus geislerorum*).

Plate 7 (A) Puff-backed Honeyeater (*Meliphaga aruensis*). (B) Northern Variable Pitohui (*Pitohui kirhocephalus*).

Plate 8 (A) Jobi Manucode (*Manucodia jobiensis*). (B) King Bird-of-paradise (*Cicinnurus regius*).

Appendix 1

Project survey records

Birds recorded in the study area during the 2017 Frieda River Project bird surveys and their conservation status. Provisional (uncertain) records appear in square brackets. 'Status' indicates species listed by the IUCN as Vulnerable (VU) or Near Threatened (NT) or Data Deficient (DD) and species listed as Protected (P) under the PNG *Fauna (Protection & Control) Act 1966*. Abbreviation codes for records at individual sites: VC—Very Common (species with multiple individuals encountered daily); C—Common (species found on at least two-thirds of days with significant time in suitable habitat); FC—Fairly Common (species encountered with some regularity given significant time in suitable habitat); O—Occasional (species encountered only once or twice despite significant time spent in suitable habitat); X—Present but abundance not assessed*; L—species deduced present based on information from local residents. Records from the two principal survey sites (Camp 1 and Camp 2) include in brackets the number of individuals camera trapped (e.g. c1) or mist netted (e.g. n1).

Scientific name	English name	Status	Camp 1	Camp 2	Idam River
CASUARIIDAE					
Casuarius unappendiculatus	Northern Cassowary		X	X(c1)	L
ANATIDAE					
Anas superciliosa	Pacific Black Duck				X
MEGAPODIIDAE					
Talegalla jobiensis	Collared Brushturkey		C(c5)	C(c9)	X
Megapodius decollatus	New Guinea Scrubfowl		FC(c2)	FC(c10)	X
ARDEIDAE					
Ardea sumatrana	Great-billed Heron		X		
Ardea alba	Great Egret	P	X		X
Egretta garzetta	Little Egret	P	X		
PHALACROCORACIDAE					
Microcarbo melanoleucos	Little Pied Cormorant		X		X
Phalacrocorax sulcirostris	Little Black Cormorant				X
Phalacrocorax carbo	Great Cormorant		X		X
ANHINGIDAE					
Anhinga novaehollandiae	Australasian Darter		X		
ACCIPTRIDAE					
Aviceda subcristata	Pacific Baza		X		
Harpyopsis novaeguineae	Papuan Eagle	VU,P	[X]		
Hieraaetus weiskei	Pygmy Eagle		X		

Scientific name	English name	Status	Camp 1	Camp 2	Idam River
Accipiter hiogaster	Variable Goshawk		X		
Accipiter poliocephalus	Grey-headed Goshawk				X
Haliastur sphenurus	Whistling Kite		X		X
Haliastur indus	Brahminy Kite		FC		X
Haliaeetus leucogaster	White-bellied Sea Eagle		X		
RALLIDAE					
Rallina tricolor	Red-necked Crake		X		X
Amaurornis moluccana	Pale-vented Bush-hen		X		X
SCOLOPACIDAE					
Actitis hypoleucos	Common Sandpiper				X
COLUMBIDAE					
Macropygia amboinensis	Amboyna Cuckoo-Dove		FC	C	X
Macropygia nigrirostris	Bar-tailed Cuckoo-Dove		O		
Reinwardtoena reinwardti	Great Cuckoo-Dove		FC	O	
Chalcophaps stephani	Stephan's Emerald Dove			O	
Trugon terrestris	Thick-billed Ground Pigeon		X(c1)	X	
Gallicolumba rufigula	Cinnamon Ground Dove		FC(c5)	FC(c4,n1)	
Goura victoria	Victoria Crowned Pigeon	NT,P	O(c1)	FC	X
Ptilinopus magnificus	Wompoo Fruit Dove		FC	C	X
Ptilinopus perlatus	Pink-spotted Fruit Dove		FC	FC	
Ptilinopus superbus	Superb Fruit Dove		C	C	X
Ptilinopus coronulatus	Coroneted Fruit Dove		VC	VC	X
Ptilinopus iozonus	Orange-bellied Fruit Dove		FC	C	X
Ptilinopus nainus	Dwarf Fruit Dove		O	O	
Ducula rufigaster	Purple-tailed Imperial Pigeon		FC	C	
Ducula pinon	Pinon's Imperial Pigeon		C	FC	X
Ducula zoeae	Zoe's Imperial Pigeon		VC	VC	X
Gymnophaps albertisii	Papuan Mountain Pigeon			O	
CUCULIDAE					
Centropus menbeki	Ivory-billed Coucal		C	C	X
Centropus bernsteini	Black-billed Coucal		FC		X
Microdynamis parva	Dwarf Koel		O	O	
Eudynamys orientalis	Pacific Koel				X

Scientific name	English name	Status	Camp 1	Camp 2	Idam River
Scythrops novaehollandiae	Channel-billed Cuckoo		O	O	X
Chrysococcyx megarhynchus	Long-billed Cuckoo		O	O	
Chrysococcyx minutillus	Little Bronze Cuckoo				X
Cacomantis variolosus	Brush Cuckoo		C	FC	X
STRIGIDAE					
Ninox theomacha	Papuan Boobook		X	X	X
Uroglaux dimorpha	Papuan Hawk-Owl		X	X	X
PODARGIDAE					
Podargus ocellatus	Marbled Frogmouth		X	X	
Podargus papuensis	Papuan Frogmouth		X	X	X
AEGOTHELIDAE					
Aegotheles bennettii	Barred Owlet-nightjar		[X]		
HEMIPROCNIDAE					
Hemiprocne mystacea	Moustached Treeswift			O	
APODIDAE					
Collocalia esculenta	Glossy Swiftlet		FC		
Aerodramus vanikorensis	Uniform Swiftlet		FC	FC	X
Mearnsia novaeguineae	Papuan Spine-tailed Swift		FC	O	X
ALCEDINIDAE					
Melidora macrorrhina	Hook-billed Kingfisher		C	C	X
Dacelo gaudichaud	Rufous-bellied Kookaburra		C	FC	X
Syma torotoro	Yellow-billed Kingfisher		FC	C	
Ceyx solitarius	Papuan Dwarf Kingfisher		FC	C(n3)	
BUCEROTIDAE					
Rhyticeros plicatus	Blyth's Hornbill	P	C	C	X
CACATUIDAE					
Probosciger aterrimus	Palm Cockatoo	P	C	FC	X
Cacatua galerita	Sulphur-crested Cockatoo		C	C	X
PSITTACULIDAE					
Psittrichas fulgidus	Pesquet's Parrot	VU		C	
Eclectus roratus	Eclectus Parrot		VC	C	X
Geoffroyus geoffroyi	Red-cheeked Parrot		C	C	X
Geoffroyus simplex	Blue-collared Parrot		[O]	[O]	

Scientific name	English name	Status	Camp 1	Camp 2	Idam River
Charmosyna/placentis rubronotata	Red-fronted/Red-flanked Lorikeet		O	O	
Lorius lory	Black-capped Lory		VC	C	X
Trichoglossus haematodus	Coconut Lorikeet		C	C	X
Psittaculirostris edwardsii	Edwards's Fig Parrot		O	FC	
PITTIDAE					
Erythropitta macklotii	Papuan Pitta				X
Pitta sordida	Hooded Pitta		FC(c1)	FC(c1)	
PTILONORHYNCHIDAE					
Ailuroedus geislerorum	Tan-capped Catbird		O	FC(n1)	
MALURIDAE					
Malurus cyanocephalus	Emperor Fairywren			X	
MELIPHAGIDAE					
Pycnopygius stictocephalus	Streak-headed Honeyeater		FC	O	X
Xanthotis flaviventer	Tawny-breasted Honeyeater		C	FC	X
Philemon meyeri	Meyer's Friarbird			O	
Philemon novaeguineae	New Guinea Friarbird		VC	C	X
Melilestes megarhynchus	Long-billed Honeyeater		FC(n3)		X
Caligavis obscura	Obscure Honeyeater		FC	FC	
Meliphaga aruensis	Puff-backed Honeyeater			X(n1)	
Meliphaga sp.	Honeyeater sp.		VC	C	X
ACANTHIZIDAE					
Crateroscelis murina	Rusty Mouse-warbler		FC	C(n2)	X
Sericornis spilodera	Pale-billed Scrubwren		O		
Gerygone magnirostris	Large-billed Gerygone				X
Gerygone chrysogaster	Yellow-bellied Gerygone		C	C	
POMATOSTOMIDAE					
Garritornis isidorei	Papuan Babbler		O	O	
MELANOCHARITIDAE					
Melanocharis nigra	Black Berrypecker		FC	FC	
Toxorhamphus novaeguineae	Yellow-bellied Longbill		C(n1)	FC	X
PSOPHODIDAE					
Ptilorrhoa caerulescens	Blue Jewel-babbler		FC	FC	
MACHAERIRHYNCHIDAE					

Scientific name	English name	Status	Camp 1	Camp 2	Idam River
Machaerirhynchus flaviventer	Yellow-breasted Boatbill			O	
ARTAMIDAE					
Artamus leucorynchus	White-breasted Woodswallow				X
Peltops blainvillii	Lowland Peltops			O	
Melloria quoyi	Black Butcherbird		C	O	X
Cracticus cassicus	Hooded Butcherbird		C	FC	X
CAMPEPHAGIDAE					
Coracina boyeri	Boyer's Cuckooshrike		FC	C	X
Coracina schisticeps	Grey-headed Cuckooshrike		FC	VC	
Coracina melas	Black Cicadabird			O	
Campochaera sloetii	Golden Cuckooshrike		FC	FC	X
Lalage atrovirens	Black-browed Triller		C	C	X
PACHYCEPHALIDAE					
Pseudorectes ferrugineus	Rusty Pitohui		O	FC	
Colluricincla megarhyncha	Little Shrikethrush		O	O	
ORIOLIDAE					
Pitohui kirhocephalus	Northern Variable Pitohui		VC(n1)	VC(n1)	X
Oriolus szalayi	Brown Oriole				X
DICRURIDAE					
Dicrurus bracteatus carbonarius	(Papuan) Spangled Drongo		C	C	X
RHIPIDURIDAE					
Rhipidura leucophrys	Willie Wagtail		X		X
Rhipidura threnothorax	Sooty Thicket Fantail		O(c1)		
Rhipidura leucothorax	White-bellied Thicket Fantail		FC	FC	X
Rhipidura rufidorsa	Rufous-backed Fantail		FC	FC	
MONARCHIDAE					
Symposiachrus guttula	Spot-winged Monarch		O(n1)	FC	
Symposiachrus manadensis	Hooded Monarch			O(n1)	
Carterornis chrysomela	Golden Monarch			O	
Arses insularis	Ochre-collared Monarch		O	FC	
Myiagra alecto	Shining Flycatcher		O	O	X
CORVIDAE					
Corvus tristis	Grey Crow		FC	FC	

Scientific name	English name	Status	Camp 1	Camp 2	Idam River
PARADISAEIDAE					
Manucodia ater	Glossy-mantled Manucode	P	[X]		
Manucodia jobiensis	Jobi Manucode	P	X(n1)		
Manucodia ater/jobiensis	Glossy-mantled/Jobi Manucode	P			X
Ptiloris magnificus	Magnificent Riflebird	P	O	C	
Cicinnurus regius	King Bird-of-paradise	P	FC(n1)	C(n1)	
Seleucidis melanoleucus	Twelve-wired Bird-of-paradise	P	O		
Paradisaea minor	Lesser Bird-of-paradise	P	C	FC	X
PETROICIDAE					
Poecilodryas hypoleuca	Black-sided Robin		VC(n1)	C(n2)	
Microeca flavovirescens	Olive Flyrobin			FC	
HIRUNDINIDAE					
Hirundo tahitica	Pacific Swallow		X		X
STURNIDAE					
Mino dumontii	Yellow-faced Myna		FC	FC	X
Mino anais	Golden Myna			O	
DICAEIDAE					
Dicaeum geelvinkianum	Red-capped Flowerpecker		FC	C	
NECTARINIIDAE					
Leptocoma aspasia	Black Sunbird		FC	FC	X
ESTRILDIDAE					
Lonchura/grandis spectabilis	Hooded/Great-billed Mannikin				X

* Includes uncommon species, species restricted to habitat subject to limited survey time (e.g. large watercourses) and shy/cryptic species that may be more abundant but are not easily detected.

Appendix 2

Bird species not recorded in 2017 but recorded previously at lowland sites immediately east of the study during the 2009–2011 Project surveys. Provisional (uncertain) records appear in square brackets. 'Status' indicates species listed by the IUCN as Vulnerable (VU) or Near Threatened (NT) or Data Deficient (DD) and species listed as Protected (P) under the PNG *Fauna (Protection & Control) Act 1966*. Abbreviation codes for records at individual sites: VC—Very Common (species with multiple individuals encountered daily); C—Common (species found on at least two-thirds of days with significant time in suitable habitat); FC—Fairly Common (species encountered with some regularity given significant time in suitable habitat); O—Occasional (species encountered only once or twice despite significant time spent in suitable habitat); X—Present but abundance not assessed (see Section 4.3); L—species deduced present based on information from local residents.

Scientific Name	English Name	Status	Ok Binai 1	Frieda Bend	Ok Isai	Frieda Strip	Kaugumi	East Sepik	Hauna (& lakes)	Iniok	Warangai South	Wario	Wogamush	Kubkain
ANATIDAE														
Dendrocygna guttata	Spotted Whistling Duck									O				
Ixobrychus sinensis(/dubius)	Yellow(/Black-backed) Bittern									O				
Dupetor flavicollis	Black Bittern									FC				
Nycticorax caledonicus	Nankeen Night Heron								FC	FC				
Egretta intermedia	Intermediate Egret	P							FC	C		X		
Egretta picata	Pied Heron								C	O				
ACCIPTRIDAE														
Henicopernis longicauda	Long-tailed Honey Buzzard					X	O							
Circus spilothorax	Papuan Harrier								X					
Milvus migrans	Black Kite								C	FC				
RALLIDAE														
Megacrex inepta	New Guinea Flightless Rail											L		
Porphyrio melanotus	Australasian Swamphen								X					
RECURVIROSTRIDAE														
Himantopus leucocephalus	Pied Stilt								FC	FC				

Scientific Name	English Name	Status	Ok Binai 1	Frieda Bend	Ok Isai	Frieda Strip	Kaugumi	East Sepik	Hauna (& lakes)	Iniok	Warangai South	Wario	Wogamush	Kubkain
CHARADRIIDAE														
Vanellus miles	Masked Lapwing								C	FC		X		
Charadrius dubius	Little Ringed Plover			X										
SCOLOPACIDAE														
	wader sp(p).								FC					
LARIDAE														
Chlidonias hybrida	Whiskered Tern								C	C				
COLUMBIDAE														
Chalcophaps longirostris	Pacific Emerald Dove									[X]				
Ptilinopus aurantiifrons	Orange-fronted Fruit Dove									FC		O		
Ducula mullerii	Collared Imperial Pigeon								X					
CUCULIDAE														
Centropus phasianinus	Pheasant Coucal									[X]				
STRIGIDAE														
Ninox rufa	Rufous Owl							X						
CAPRIMULGIDAE														
Eurostopodus papuensis	Papuan Nightjar									X				
Caprimulgus macrurus	Large-tailed Nightjar								X					
APODIDAE														
Hirundapus caudacutus	White-throated Needletail		X											
CORACIIDAE														
Eurystomus orientalis	Oriental Dollarbird			O	FC		FC	FC	C	C				
ALCEDINIDAE														
Tanysiptera galatea	Common Paradise Kingfisher			O						O				

Scientific Name	English Name	Status	Ok Binai 1	Frieda Bend	Ok Isai	Frieda Strip	Kaugumi	East Sepik	Hauna (& lakes)	Iniok	Warangai South	Wario	Wogamush	Kubkain
Tanysiptera sylvia	Buff-breasted Paradise Kingfisher						O							
Todirhamphus nigrocyaneus	Blue-black Kingfisher	NT					[X]							
Todirhamphus sanctus	Sacred Kingfisher								X	FC				
Ceyx azureus	Azure Kingfisher						X		X			[X]		
MEROPIDAE														
Merops ornatus	Rainbow Bee-eater				O		O	O	C	C				
PSITTACULIDAE														
Micropsitta pusio	Buff-faced Pygmy Parrot				X		[X]					X	X	
Charmosyna rubronotata	Red-fronted Lorikeet			O										
Chalcopsitta duivenbodei	Brown Lory						C			[X]				
Pseudeos fuscata	Dusky Lory						O	O			X			
Loriculus aurantiifrons	Orange-fronted Hanging Parrot											X		
MALURIDAE														
Malurus alboscapulatus	White-shouldered Fairywren								X	O				
MELIPHAGIDAE														
Glycichaera fallax	Green-backed Honeyeater						X							
Lichmera alboauricularis	Silver-eared Honeyeater			[X]						O				
Conopophila albogularis	Rufous-banded Honeyeater									C				
Meliphaga analoga	Mimic Honeyeater				X		X	FC						
ACANTHIZIDAE														
Gerygone chloronota	Green-backed Gerygone											FC		
CAMPEPHAGIDAE														
Coracina papuensis	White-bellied Cuckooshrike								FC	FC				
PACHYCEPHALIDAE														

Scientific Name	English Name	Status	Ok Binai 1	Frieda Bend	Ok Isai	Frieda Strip	Kaugumi	East Sepik	Hauna (& lakes)	Iniok	Warangai South	Wario	Wogamush	Kubkain
Colluricincla harmonica	Grey Shrikethrush								[X]	FC				
MONARCHIDAE														
Myiagra cyanoleuca	Satin Flycatcher									O				
CISTICOLIDAE														
Cisticola exilis	Golden-headed Cisticola								X	C				
STURNIDAE														
Aplonis metallica	Metallic Starling								C	C				
Aplonis cantoroides	Singing Starling								X	X				
NECTARINIIDAE														
Cinnyris jugularis	Olive-backed Sunbird								X					
PASSERIDAE														
Lonchura tristissima	Streak-headed Mannikin									O				

Amphibians and Reptiles

A report prepared for Coffey Services Australia Pty Ltd and Frieda River Limited

By Stephen J. Richards

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Cover images

Top: The IUCN Data Deficient treefrog, *Litoria purpureolata*;
Bottom: The IUCN Vulnerable Variegated Giant Softshell Turtle, *Pelochelys signifera*.

1 EXECUTIVE SUMMARY

- This study characterises the herpetofauna of the proposed infrastructure corridor for the Sepik Development Project, an open-pit copper-gold mine in Sandaun and East Sepik Provinces, northern Papua New Guinea.

- A total of 45 species of herpetofauna, including 22 frogs and 23 reptiles, were documented from three sites. The fauna is dominated by species with broad known distributions in the northern lowlands of New Guinea but four frogs and two lizards appear to be undescribed.

- Each of the undescribed species had been previously recorded from at least one other site during the 2009–2011 Frieda River Project Terrestrial Biodiversity Assessment surveys.

- Four poorly-known frog species documented during the survey are conservation listed. *Litoria hunti, L. purpureolata*, *L. richardsi and Papurana volkerjane* are listed as Data Deficient by the IUCN. The record of *Litoria richardsi* at Camp 2 represents only the second known location for this species north of the central cordillera.

- One reptile, the Variegated Giant Softshell Turtle, *Pelochelys signifera,* that occurs in the Idam River is conservation listed. It is listed as Vulnerable by the IUCN. No frogs or reptiles listed as Endangered or Critically Endangered by the IUCN were encountered during the study.

- The Variegated Giant Softshell Turtle, the Northern Snapping Turtle *Elseya schultzei*, and other large frogs and lizards including the monitor lizard *Varanus jobiensis*, the forest dragon *Hypsilurus magnus* and the frog *Papurana volkerjane* are regularly hunted for food by local landowners.

- Important habitats identified during the surveys include 1) small clear streams, including those in the Bewani Mountains, which are known to or likely harbour specialist stream-dwelling frogs, 2) lowland forests in the southern section of the corridor that provide a mosaic of terrestrial and freshwater habitats that support a rich herpetofauna assemblage, and 3) turtle nesting banks on the Idam River that are vital for the successful reproduction of the IUCN Vulnerable Variegated Giant Softshell Turtle, *Pelochelys signifera*.

ACRONYMS AND ABBREVIATIONS

AMSL	Above mean sea level
CEPA	Conservation and Environment Protection Authority
DD	Data Deficient (IUCN threat category)
EN	Endangered (IUCN threat category)
FIMS	PNG Forest Inventory Mapping System
Hm	Hill forest (FIMS vegetation type)
IUCN	International Union for the Conservation of Nature
km	Kilometres
km^2	Square kilometres
LC	Least Concern (IUCN threat category)
LIDAR	Light detection and ranging (remote sensing method)
m	metres
mm	millimetres
PNG	Papua New Guinea
Project	Sepik Development Project
sp.	Abbrev. 'species' (singular)
spp.	Abbrev. 'species' (plural)
study area	Infrastructure Corridor Terrestrial Biodiversity Study Area
SVL	Snout to vent length

GLOSSARY OF TECHNICAL TERMS

Anthropogenic	Originating from human activity.
Asymptote	A straight line approached but never crossed by a curve (species recorded versus survey effort in the context of this report).
Carapace	The upper shell of a tortoise
Central cordillera	Refers to the central mountainous spine of New Guinea that runs from the eastern edge of the Vogelkop Peninsula in Indonesian New Guinea to the eastern tip of mainland PNG.
Conservation listed species	Includes: (1) species listed under the IUCN Red List as threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened or Data Deficient; (2) species listed as Protected under the PNG *Fauna (Protection and Control) Act 1966*;
Endemic	Belonging exclusively or confined to a particular place.
Herpetofauna	Refers to both amphibians and reptiles
Protected	Species listed as Protected under the Papua New Guinea *Fauna (Protection and Control) Act 1966.*
Restricted-range	Species which have a total historical breeding range of less than 50,000 km^2.
Taxa	Plural of taxon; a systematic division (e.g. more than one species, genera, etc.).
Taxonomic	Taxonomy is the science of identifying, naming and classifying living organisms.

2 INTRODUCTION

2.1. Background

Frieda River Limited (FRL) is assessing the feasibility of developing the Sepik Development Project (the Project), an open-pit copper-gold mine and supporting infrastructure in Sandaun and East Sepik Provinces, northern Papua New Guinea (PNG). The mine will be accessed by a 325 km infrastructure corridor, which consists of an existing road from Vanimo to Green River and a new road through to Hotmin and to the mine site. A concentrate pipeline and transmission line will also be located within the corridor. Terrestrial biodiversity studies were completed between 2009–2011 for the mine area for a previous design of the Frieda River Project.

This study forms part of the terrestrial biodiversity characterisation required for the EIS, specifically for the proposed infrastructure corridor (the study area).

2.2. Study objectives

The objectives of the herpetofauna baseline characterisation are to:

- Characterise the existing herpetofauna and provide context at the local, national and international scale noting any sensitive environmental areas or habitats.
- Document any rare, threatened, undescribed or otherwise noteworthy reptile and amphibian species (i.e., International Union for Conservation of Nature (IUCN)-listed or community significance), communities and habitats present within the study area.
- Document any exotic and invasive herpetofauna species.

3 EXISTING INFORMATION

The herpetofauna of New Guinea is exceptionally diverse, with the total number of frog and reptile species known from the region currently exceeding 750 (Menzies 2006; Allison 2007; Papuan Herpetofauna Website 2013). This number is increasing rapidly as taxonomic revisions of the fauna and exploration of remote regions reveals numerous new species, particularly in the frog families Hylidae and Microhylidae (e.g. Günther et al. 2014; Menzies 2014; Günther & Richards 2016) and the gecko genus *Cyrtodactylus* (Oliver & Richards 2012; Oliver et al. 2008, 2016).

Significant contributions to knowledge about the diversity and distributions of herpetofauna in the northern lowlands of Papua New Guinea include a comprehensive summary of the distribution of scincid lizards across the region by Mys (1988), summaries of the herpetofauna of Kau Wildlife Management Area in Madang Province by Read (1998) and Austin (2006), and a series of surveys by the Bishop Museum that visited the isolated Bewani, Hunstein and Torricelli Ranges with some attention to the Sepik lowlands (Kraus & Allison 2006a). Two more recent studies reported by Austin et al. (2008) and Dahl et al. (2009, 2013) also documented herpetofauna at a number of sites in the lowlands of the Sepik Basin.

The herpetofauna of the Mamberamo Basin in adjacent Papua Province, Indonesia, was visited by the 1938–1939 Archbold expedition (Archbold et al. 1942). Although valuable herpetological material was collected during that survey a dedicated herpetologist was not present and a synthesis of the herpetological results was never published. The Archbold material was subsequently examined by R.G. Zweifel of the American Museum of Natural History who described a number of new taxa from that expedition (e.g. Zweifel 1958, 2000). More recently a Conservation International sponsored Rapid Biodiversity Assessment Program (RAP) survey to the Mamberamo Basin (Richards & Suryadi 2002) documented herpetofauna at two sites resulting in the discovery and description of several new frog species (Oliver et al. 2007; Günther et al. 2009). Given the continuity of habitats and lack of major biogeographic barriers between the Mamberamo and Sepik basins, many of the taxa documented from the Mamberamo lowlands may reasonably be expected to also occur in the Sepik catchment of northern Papua New Guinea; a number of species previously known from the Mamberamo Basin have now been documented in the Sepik Basin (Kraus 2010).

The most comprehensive herpetofauna studies undertaken to date in the upper Sepik River basin were those conducted during the extensive terrestrial biodiversity field surveys for the 2009–2011 Frieda River Project. That study documented 58 frogs and 41 reptiles, including numerous new-to-science species, at 17 sites across the lowlands and foothills of the upper Sepik River basin. This report presents an assessment of herpetofaunal diversity and conservation significance at two additional sites in the newly proposed infrastructure corridor in the lowlands of north-west mainland Papua New Guinea.

4 METHODS

4.1 Survey sites and timing

Surveys were conducted during 28 November – 11 December 2017, at the start of the 'northwest (monsoon) season'. Table 1 lists the location, timing and elevations covered at each survey site.

Two principal survey sites (Camps 1 and 2) were sampled over multiple days (range: 4−5 days, excluding transfer days; Table 1) from temporary 'fly camps' constructed specifically for the purpose. An overnight visit was also made to Idam 1 village to facilitate a boat-based survey of the lower reaches of the Idam River. Frog surveys at Idam 1 village were restricted to remote recording using bioacoustics recorders (Section 4.2.2).

A single-day (6-hour) traverse of the road between Green River and Vanimo was also conducted to assess the overall quality of forest habitat and to identify any significant habitats for herpetofauna along the northern sectors of the infrastructure corridor. Herpetofauna species were not surveyed during this journey.

A brief description of each survey site and the habitats surveyed is given below (Sections 4.1.1–4.1.3). A detailed description of vegetation types, structure and floristics at Camps 1 and 2 is presented in the flora technical report (Takeuchi 2018).

Table 1. The location and time spent at each survey site. All dates are for the year 2017.

Site	Base location[A]	Elevations covered[B]	Arrival	Departure
Camp 1	559085 9494427	65–150	28/11, 09:30	4/12, 13:00
Camp 2	534344 9539086	85–180	4/12, 13:15	7/12, 9:30
			8/12, 14:45	11/12, 10:30
Idam River	Idam 1 village	50–65	7/12, 09:45	8/12, 14:30

[A] Camp/insertion points: PNGMG94 Zone 54.

[B] All elevations in m AMSL from LIDAR digital elevation model (DEM) to the nearest 5 m.

4.1.1 Camp 1

Camp 1 was positioned in an area of post-garden regrowth on the banks of Dibiri Creek near its confluence with the Right May (Abei) River and about ten minutes' walk upstream from Usaremin 2 village (labelled 'Uriaka' on the 1:100,000 topographic map sheet), a small settlement of 38 households located on the Right May River approximately five river kilometres upstream from Hotmin village. Frogs and reptiles were surveyed over five 'complete' days and nights, and on parts of two days. Foot surveys were conducted on trails through hill and swamp forest, gardens (current and former) and along tributary watercourses (Dibiri Creek and Uriake River; Plate 1A). A boat survey was undertaken on

1 December to reconnoitre riverine and riparian habitats both upstream and downstream of the camp along the Right May and May rivers (Plate 1B).

Natural vegetation is mapped as open alluvial forest (FIMS code Po) on the floodplains and flanking terraces of the Right May and May rivers, and medium crowned hill forest (FIMS code Hm) on the adjacent hill slopes. Most of the alluvial forest accessible on foot from the camp had been converted to gardens, was in various stages of post-conversion regrowth or had been otherwise heavily disturbed. Less disturbed examples were observed by boat further away from camp. Natural vegetation was more prevalent as hill forest on the spurs and ridges west of camp (Plate 1C) and on the terraces flanking Dibiri Creek, though these were also subject to regular visitation by local residents for hunting and small-scale resource extraction.

4.1.2 Camp 2

Camp 2 was located in a small garden area adjacent to a hunting hut on the 'Wara Kep' (Plate 1D), a small creek that flows west and north across alluvial plains to meet the Idam River near Idam 1 village approximately 6.3 km northwest of the camp. In addition to a range of small streams, other accessible aquatic habitats relevant for herpetofauna included small temporary forest pools and a large, possibly permanent, forest pool (Plate 1E). Herpetofauna were surveyed on foot over five entire days and four nights, and on parts of three days (Table 1) in small crowned alluvial forest (FIMS code Ps) and in medium crowned hill forest on the foothill spurs and ridges present to the north and south of camp (Figure 2). The camp was situated approximately three hours walk from the large (>1,000 people) Idam 1 village. Aside from a few hunting huts and small adjacent gardens observed along the Wara Kep, and numerous walking trails through the forest, there was little sign of anthropogenic disturbance to forest habitats.

4.1.3 Idam River

Two boat trips were made during 7–8 December along the lower reaches of the Idam River (Plate 1F) and parts of the Sepik River. Stops were made at a hunting hut to view hunting trophy material (Plate 1G, H), and two automated sound recorders were deployed at the edge of garden–hill and forest–sago swamp woodland along a small tributary creek to record frogs overnight (Table 2). Natural vegetation along the river is mapped as various forms of alluvial forest (FIMS codes Ps and Po) with medium crowned hill forest (Hm) present on the few foothill spurs and isolated hills that abut the river course—at Bisiabru village and on Sunday Hill near the Sepik River. Much of the vegetation observed along the river had been converted to villages or gardens or was otherwise heavily disturbed by local residents. Remaining areas of natural habitat along the meander floodplains were subject to frequent inundation.

4.2 Herpetofauna sampling

A minimum of two searchers were involved in every survey. Field methods followed standard protocols established and accepted for Rapid Biological Assessments in New Guinea (e.g. Richards & Dahl 2011; Catenazzi et al. 2016). Records from opportunistic collections by other team members, local assistants and villagers are also incorporated. At each principal survey site intensive searches for frogs and reptiles were conducted along trails that were established for this purpose. Start time, finish time, number and identity of

searchers and weather conditions were noted. During the day searches focused on heliothermic (basking) reptiles along trails through forest, clearings, and along stream and river banks where small lizards were collected by hand or were stunned with a large rubber band. Large lizards and snakes were collected by hand. Non-basking reptiles were sampled by searching in deeply shaded forest, during rain, or at dusk. Nocturnal reptiles, including geckos, were detected by walking along forest trails at night with a headlamp.

Frogs were sampled at night by conducting visual-encounter and aural surveys along the same forest trails and at all accessible aquatic habitats. Water-bodies examined included seepages, small closed-canopy streams, larger streams and forest pools. Because a large proportion of New Guinean frogs have life cycles that are independent of free-standing water (Anstis et al. 2011), extensive visual and aural searches along trails in forest away from water were also conducted. Identification of frogs and reptiles observed but not captured was enhanced by using binoculars (lizards, snakes) and recording of calls (frogs). Frog calls are an important diagnostic character that assists greatly with species identification and, in addition to the bioacoustics recorders (Section 4.2.2), whenever possible the advertisement calls of frogs were recorded with an Edirol R05 Solid-state Recorder and a Sennheiser ME66 microphone.

4.2.1 Interviews

Informal interviews with local field assistants were conducted to obtain information about the presence, use and significance of reptile and amphibian species.

4.2.2 Bioacoustic recorders

To detect frog calls remotely bioacoustic recorders (BARs) were deployed in forest and adjacent to watercourses and waterbodies (Plate 2A). Each unit recorded all audible sounds, including frog calls, continuously and were shifted after 1–2 days. Details of BAR placement, dates and habitat are presented in Table 2. Recordings made between 1900 and 2400 hr each night were screened for the calls of frogs not detected during active survey periods, using Adobe Audition software.

Table 2. Date, location and habitat of BARs deployed at three survey sites.

Site	Unit no.	Deployment date	Location	Habitat
Camp 1	2	30/11/2017	54 M 558851 9494531	Small seepage in swampy forest
Camp 1	3	30/11/2017	54 M 558937 9494330	Small stream draining into Dibini Creek
Camp 1	4	1/12/2017	54 M 558594 9494391	Hill forest on ridge above camp
Camp 1	3	2/12/2017	54 M 558771 9494142	Small, steep, clear rocky stream
Camp 1	2	2/12/2017	54 M 559159 9494244	Small stream in lowland forest
Camp 2	2	5/12/2017	54 M 534390 9539016	Small seepage stream in forest
Camp 2	3	5/12/2017	54 M 534439 9539212	Over large forest pool in good forest
Camp 2	4	5/12/2017	54 M 534581 9539250	Large stream (Wara Kep) near camp
Camp 2	2	9/12/2017	54 M 534312 9538823	In Pandanus swamp
Camp 2	3	9/12/2017	54 M 534193 9539051	Lowland rainforest, not near water
Idam River	3	7/12/2017	54 M 527854 9549610	Edge of hill forest and garden
Idam River	4	7/12/2017	54 M 527906 9549580	Edge of sago swamp and garden

4.2.3 Voucher material

Few voucher specimens were collected. Several frogs vouchered to permit accurate identification were euthanized using the internationally recommended technique of submersion in chlorotone (McDiarmid 1994). Specimens were fixed in 10% formalin solution, and then stored in 70% ethanol. Voucher specimens were exported under a permit issued by the PNG Conservation and Environment Protection Authority (CEPA) to confirm identifications, and will subsequently be deposited in the PNG National Museum and the South Australian Museum, Australia.

4.3 Protocols used

4.3.1 Taxonomic issues and nomenclature

The herpetofauna of New Guinea remains poorly known. Many groups of frogs and reptiles are currently undergoing revision and new techniques including DNA and acoustic analyses are revealing widespread species to be complexes of closely related but distinct taxa. Particularly problematic groups include lizards of the genera *Carlia* (e.g. Zug 2004), *Emoia* (e.g. Brown 1991) *Sphenomorphus* and *Gehyra*, and most microhylid frog genera but particularly *Copiula*, *Hylophorbus* (e.g. Gunther 2001; Richards & Oliver 2007) and *Oreophryne* (e.g. Zweifel et al. 2005) which contain numerous morphologically similar but acoustically and genetically distinct undescribed species. In some cases it is therefore not possible to assign an established name to a species encountered during the surveys. The following system of abbreviations is applied in this report to account for various levels of uncertainty.

- **'sp.'** (singular) or **'spp.'** (plural)—used in cases where one or more taxa could not be identified to species level, or where reference is made to multiple species within a genus without the need for more specific information.

- **'cf.'**—for example: *Gehyra* cf. *brevipalmata*. This abbreviation is used to refer to species that are clearly allied to a named taxon, but for which insufficient data are available to confidently assign specimens to any particular species. The taxon may be part of a known species complex, and/or may be scientifically undescribed (=unnamed), though further work is required to determine its identity.

- **'sp. 1', 'sp. 2', etc.**—for example: *Litoria* sp. 1. The numeric system is used where taxonomic identity is confidently resolved and the species is scientifically undescribed. Where relevant distinction is made between: (a) species newly discovered during the 2017 survey ('new-to-science') and therefore presently known only from within the Project area; (b) other undescribed species known only from within the study area, and; (c) undescribed species known to occur more widely across New Guinea.

Species are described in this report as 'undescribed' if they remain scientifically unnamed but were previously known from either within, or outside of, the study area.

4.3.2 Conservation status

The conservation status of each species encountered was determined using the internationally recognised IUCN Red List of Threatened Species (IUCN 2017), and the

PNG *Fauna (Protection and Control) Act 1966*. The IUCN Red List provides taxonomic, conservation status and distribution information on plants and animals. The IUCN Red List criteria identify three categories of threatened species which are considered to be facing a heightened risk of extinction: Critically Endangered (CR), Endangered (EN) and Vulnerable (VU). Two additional categories used in this report are Least Concern (LC) and, for those species for which data are insufficient to reach a conclusion, Data Deficient (DD) (Table 3). Species that have not been assessed by the IUCN are listed as Not Evaluated (NE). This includes a number of reptile species that were evaluated in 2015 but for which the evaluations have not yet been formally adopted by the IUCN (P. Bowles, pers. comm.).

In this report the term 'conservation listed' is collectively applied to all species listed by the IUCN as threatened, or Data Deficient; none of the species encountered is Protected under PNG law.

Table 3. Conservation classifications for non-extinct species used by the IUCN

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

5 RESULTS & DISCUSSION

5.1 Species diversity

A total of 22 frog and 23 reptile species were documented from three sites during this survey (Tables 4–5). Forty-three of the total 45 herpetofauna species were found at Camps 1 and 2, each with 35 species. Ten of the total 45 species were encountered during the brief survey around Idam 1 village, of which just two reptiles were not also found at either Camp 1 or 2. A selection of species is illustrated in Plates 2–3.

5.1.1 Frogs

The frog fauna encountered during this survey is dominated by species known to have distributions that extend far outside the infrastructure corridor (Austin et al. 2008; Dahl et al. 2009; Kraus 2010) and it is, with the exception of one species (*Litoria richardsi*) at Camp 2, a subset of the fauna documented during the 2009–2011 Frieda River Project surveys.

A total of 18 frog species were documented at each of the two principal survey sites (Camps 1 & 2). This is slightly lower than the 20–27 species reported by Dahl et al. (2009) for each of five sites in the northern lowlands of Papua New Guinea, but is within the range of 13–20 species documented at three sites of similar elevation during the 2009–2011 Frieda River Project surveys. Overlap between the fauna at Camps 1 and 2 was moderately high with 14 of 22 species shared (63.6%); all of the species documented at Idam River were also found at both Camps 1 and 2.

The broad similarity of the fauna with adjoining regions is reflected in the similar compositions of the fauna at the family level. It is dominated by the families Microhylidae (egg-brooding frogs) and Pelodryadidae (treefrogs). For example frogs in the family Microhylidae dominated the fauna comprising 45.5% of the fauna during this study, 53% of the fauna in the 2009–2011 Frieda River Project study area, 58% at Utai (Austin et al. 2008) and 52% among the 5 sites documented by Dahl et al. (2009) across the northern lowlands of Papua New Guinea. The proportion of treefrogs in the family Pelodryadidae encountered during this study (31.8%) is also similar to that reported from the 2009–2011 Frieda River Project study area (36%) and the sites documented by Dahl et al. (2009) across the northern lowlands of Papua New Guinea (30%) but is higher than that reported from Utai by Austin et al. (2008; 18%). The families Ceratobatrachidae (4.5%), Dicroglossidae (4.5%) and Ranidae (13.6%) are minor contributors to the fauna and are represented by species with broad distributions beyond the study area.

Species accumulation curves for Camp 1 and Camp 2 are presented in Figure 1. The curve for Camp 1 has reached an asymptote after four days, but at four days the accumulation curve for Camp 2 is still climbing steadily. This suggests that the majority of species had been detected at Camp 1 after four days of sampling, but that more sampling at Camp 2 would have documented additional species. Failure to reach an asymptote is not unexpected in a large tropical forest area expected to support a diverse frog assemblage, and given the documentation of >20 species at five lowland sites in northern PNG by Dahl et al (2009) it is reasonable to conclude that the total frog fauna at Camps 1 and 2 will also exceed that number. However it should be noted that much of the forest environment surrounding Camp 1 was old garden regrowth, and it is possible that this

forest conversion has reduced the fauna there such that it is genuinely less diverse than that occurring at Camp 2.

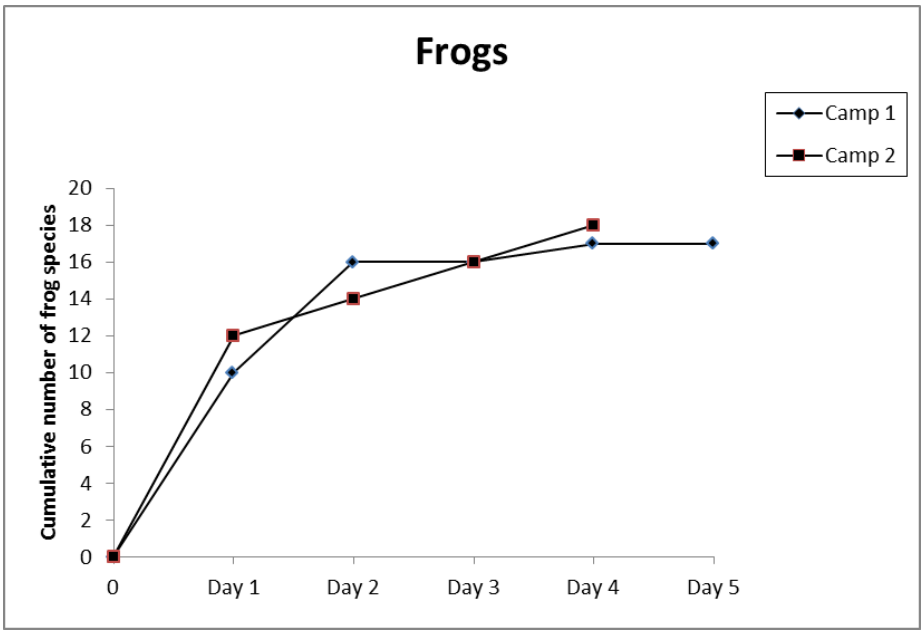

Figure 1. Species accumulation curves for frogs at camps 1 and 2.

Overall the frog fauna documented at Camps 1, 2 and Idam River was unremarkable. With the exception of four species listed as Data Deficient by the IUCN but known to occur widely outside the survey area, and four undescribed species that were also documented during the 2009–2011 Frieda River Project surveys, it was dominated by common, widespread species (Table 4). The scarcity of cool, clear fish-free streams flowing over rocky substrates has precluded colonisation of these lowland habitats by torrent-dwelling habitat-specialist frogs, which represented a significant component of the Hill Zone frog fauna during the 2009–2011 Frieda River Project surveys and included numerous new-to-science species known only from that surveyed area. In contrast just three species, *Limnonectes grunniens*, *Papurana arfaki/jimiensis* and *P. volkerjane* were found to occupy stream habitats during this study. All have wide distributions extending beyond the Sepik River basin. One additional species, the undescribed treefrog *Litoria* sp. 1, that occurred on the ridges behind Camp 1 during this study, was previously known only from five sites surveyed during the 2009–2011 Frieda River Project surveys. It is restricted to small, clear-flowing seepage streams draining steep ridges.

Species accounts for each conservation listed and undescribed species are presented in Sections 6.1 and 6.2.

Frogs of the family Microhylidae have a reproductive strategy that is independent of free-standing water. They deposit large, yolk-filled eggs in moist terrestrial, arboreal or subterranean nests where males guard them until they hatch directly into small frogs, avoiding an aquatic tadpole stage. This group dominates the frog fauna at most sites in New Guinea, particularly where free-standing or flowing water is absent, and their high diversity (>45% of the fauna during this study) reflects the constantly wet terrestrial environment where their terrestrial embryos do not face desiccation. The distribution of

these species within the study area is independent of the distribution of waterbodies, so retention of forest habitats will be required to maintain this diversity.

Table 4. Frog species encountered at three sites in the study area

Family	Scientific Name	IUCN Status	Camp 1	Camp 2	Idam River*
Altitude (m)			**100**	**123**	**50–65**
Ceratobatrachidae	*Cornufer papuensis*	LC	+	+	+
Dicroglossidae	*Limnonectes grunniens*	LC	+	+	+
Microhylidae	*Choerophryne proboscidea*	LC	+	+	+
Microhylidae	*Copiula* sp. 1	NE	+	+	
Microhylidae	*Hylophorbus atrifasciatus*?	NE		+	
Microhylidae	*Hylophorbus proekes*	NE	+	+	+
Microhylidae	*Hylophorbus* sp. 1	NE	+	+	+
Microhylidae	*Oreophryne biroi*	LC	+	+	+
Microhylidae	*Oreophryne hypsiops*	LC	+	+	+
Microhylidae	*Sphenophryne cornuta*	LC	+	+	
Microhylidae	*Xenorhina oxycephala*	LC	+	+	
Microhylidae	*Xenorhina* sp. 1	NE	+		
Pelodryadidae	*Litoria humboldtorum*	LC		+	
Pelodryadidae	*Litoria hunti*	DD	+		
Pelodryadidae	*Litoria infrafrenata*	LC	+	+	
Pelodryadidae	*Litoria purpureolata*	DD	+	+	
Pelodryadidae	*Litoria richardsi*	DD		+	
Pelodryadidae	*Litoria thesaurensis*	LC	+		
Pelodryadidae	*Litoria* sp. 1	NE	+		
Ranidae	*Papurana arfaki/jimiensis*	LC	+	+	
Ranidae	*Papurana papua*	LC	+	+	
Ranidae	*Papurana volkerjane*	DD		+	
TOTAL	**Grand Total = 22**		**18**	**18**	**7**

*based on one night of BAR data only.

5.1.2 Reptiles

The reptile fauna documented during this survey totalled 23 species, and diversity at both major sites was 17 species (Table 5). This exceeds the diversity encountered at all 17 sites surveyed during the 2009–2011 Frieda River Project surveys (3–15 species). Just three species were encountered during the short visit along the Idam River. The fauna is dominated by species with wide known distributions and overall is very similar to, and almost entirely a subset of, the terrestrial reptile fauna reported from the vicinity of Utai village at the base of the Bewani Mountains by Austin et al. (2008). The only exception appears to be *Stegonotus cucullatus*, a large, common and widespread snake encountered at Camp 1 that was not reported from Utai. Numerically the fauna was dominated by the widespread and abundant skinks *Emoia caeruleocada*, *E. jakati* and *E. kordoana*, the agamid (dragon) lizard *Hypsilurus modestus*, the gecko *Cyrtodactylus sermowaiensis* and the Brown Tree Snake *Boiga irregularis*. With the exception of an unidentified gecko of the genus *Gehyra*, and documentation of the widespread but IUCN

Vulnerable Variegated Giant Softshell Turtle *Pelochelys signifera* in the Idam River, the reptile fauna was dominated by common, widespread species known from other sites outside the Project area.

Species accumulation curves (Figure 2) for the two principal survey sites are approaching, but have not reached, an asymptote after five days of survey effort, indicating that with additional search effort more species are likely to be documented at these sites. Detection of additional reptile species generally occurs more gradually than detection of frogs, particularly after the first day of sampling (Figures 1, 2). This reflects the fact that frogs 1) vocalise, making rapid detection at the start of a survey possible, and 2) some groups aggregate in suitable aquatic breeding habitats so they can be targeted at those sites. Unlike frogs, reptiles do not vocalise and most terrestrial species do not aggregate; it is therefore difficult to target priority habitats and, for some groups (particularly snakes), densities and therefore encounter rates are low. This probably explains the failure to detect any of the large, conspicuous pythons known to occur in the area during this study. Three species (*Leiopython albertisii*, *Morelia amethistina* and *M. viridis*) were documented at low density (found at no more than 3 of 17 sites/species during the 2009–2011 Frieda River Project surveys) and they would almost certainly occur at low densities throughout the infrastructure corridor.

Despite this, rates of species accumulation had slowed sufficiently at both sites to suggest that the reptile fauna can be characterised confidently for the purposes of this study. A list of all reptile species documented during this study is presented in Table 5.

No dangerously venomous snakes were documented during these surveys and, although Small-eyed Snakes (*Micropechis ikaheka*) were described by local landowners and are highly likely to occur throughout the infrastructure corridor, local informants at all three sites consistently reported that Death Adders (*Acanthophis* sp) do not occur in the region surveyed.

Trophies of two freshwater turtles, *Elseya schultzei* and *Pelochelys signifera* were found in a hunting hut along the Idam River (Plate 1G, H), and *E. novaeguinea* was also encountered in streams at both Camps 1 and 2 (Plate 2B) where they are hunted for food. Local informants also reported that neither Freshwater (*Crocodylus novaeguineae*) nor Saltwater Crocodiles (*C. porosus*) occur in the vicinities of Camps 1 and 2 because the waterways are too high in the catchment; at Idam 1 village crocodiles are said to be largely absent, and Freshwater Crocodiles encountered only occasionally in the lower reaches of the Idam River.

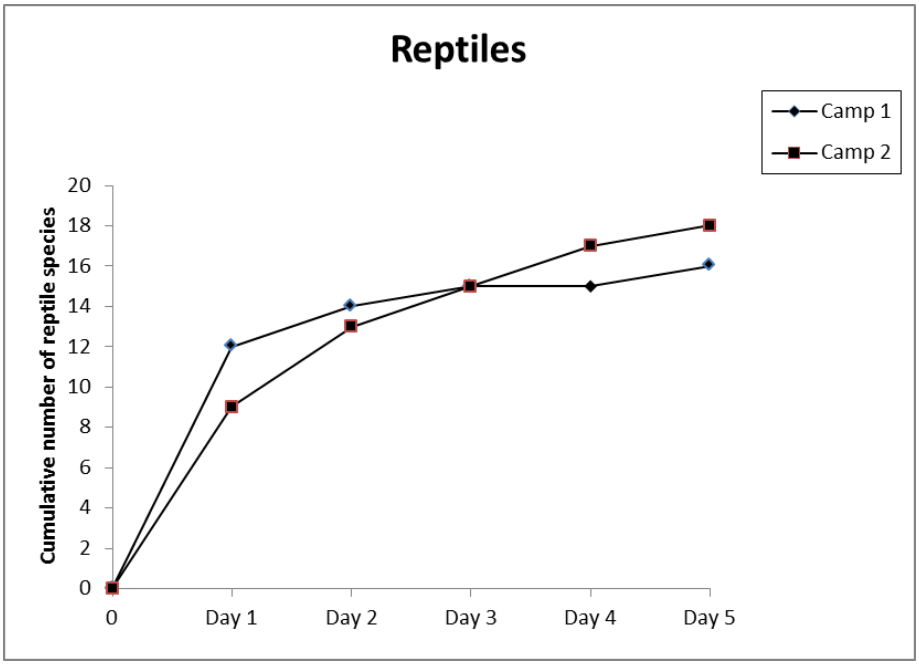

Figure 2. Species accumulation curves for reptiles at Camps 1 and 2.

5.3 Exotic and invasive species

No exotic or invasive herpetofauna species were encountered but the Cane Toad, *Rhinella marina*, is abundant at Vanimo (Austin et al. 2008).

6 SPECIES OF CONSERVATION SIGNIFICANCE

6.1 Species listed by IUCN or protected under Papua New Guinea legislation

Four of the described frog species documented during this survey are listed as Data Deficient by the IUCN (Tables 4, 6) due to their small known geographic ranges and poorly understood population status. (www.iucnredlist.org. Downloaded on 01 February 2018). Only one species of reptile that was documented during this study has been assessed by the IUCN in a category above Least Concern: The Variegated Giant Softshell Turtle, *Pelochelys signifera*, was previously included in the species *P. bibroni* or *P. cantorii* and had not been independently assessed by the IUCN. In March 2018 a draft red list assessment classified this species as Vulnerable (Tables 5, 6), and that classification is adopted here

None of the species documented during this survey are protected by Papua New Guinea law.

Table 5. Reptile species encountered at three sites in the infrastructure corridor

Group	Family	Scientific Name	IUCN Status	Camp 1	Camp 2	Idam River
	Altitude (m)			**100**	**123**	**50–65**
LIZARDS	Agamidae	*Hypsilurus magnus*	LC	+	+	
	Agamidae	*Hypsilurus modestus*	LC	+	+	
	Gekkonidae	*Cyrtodactylus sermowaiensis*	LC	+	+	
	Gekkonidae	*Gehyra* cf. *brevipalmata*	NE	+		
	Gekkonidae	*Gekko vittatus*	NE			+
	Gekkonidae	*Nactus* cf. *multicarinatus*	NE	+	+	
	Scincidae	*Emoia caeruleocauda*	LC	+	+	
	Scincidae	*Emoia jakati*	LC	+	+	
	Scincidae	*Emoia kordoana*	NE	+	+	
	Scincidae	*Emoia longicauda*	NE	+	+	
	Scincidae	*Emoia pallidiceps*	LC	+	+	
	Scincidae	*Emoia* sp.	NE	+	+	
	Scincidae	*Sphenomorphus minutus*	LC	+	+	
	Scincidae	*Sphenomorphus simus*	LC		+	
	Scincidae	*Sphenomorphus solomonis*	NE	+		
	Varanidae	*Varanus jobiensis*	LC		+	
SNAKES	Boidae	*Candoia aspera*	NE		+	
	Colubridae	*Boiga irregularis*	NE	+	+	
	Colubridae	*Stegonotus cucullatus*	NE	+		
	Colubridae	*Stegonotus diehli*	NE		+	
	Elapidae	*Aspidomorphus muelleri*	LC	+		
TURTLES	Chelidae	*Elseya schultzei*	LC	+	+	+
	Trionychidae	*Pelochelys signifera*	Vu			+
	TOTAL	**Grand Total = 23**		**17**	**17**	**3**

Table 6. Herpetofauna species documented during this study that are listed by IUCN in a category other than least Concern

Species	IUCN category*
Litoria hunti	Data Deficient ver 3.1
Litoria purpureolata	Data Deficient ver 3.1
Litoria richardsi	Data Deficient ver 3.1
Papurana volkerjane	Data Deficient ver 3.1
Pelochelys signifera	Vulnerable A4cde ver 3.1

*IUCN data taken from: IUCN Red List of Threatened Species. Version 2017-3. <www.iucnredlist.org>. Downloaded on 01 February 2018, except *P. signifera*, draft assessment dated 29 March 2018.

6.1.1 Frogs

6.1.1.1 *Litoria hunti* (IUCN Data Deficient)

(Plate 2C; image from 2009–2011 Frieda River Project surveys**)**

Litoria hunti is a large, green arboreal treefrog. Richards et al. (2006) encountered it calling from at least 5–8m above ground in forest trees in lowland forest, and one specimen was found calling from vegetation 1.5 m high in a swamp. This suggests that *L. hunti* may breed in pools on the forest floor and it does not appear to rely on stream or riparian habitats for reproduction or foraging. (Richards *et al*. 2006).

Prior to the 2009–2011 Frieda River Project surveys this species was known with certainly only from the vicinity of Utai Village in Sandaun Province (Richards et al. 2006). During the 2009–2011 surveys it was common at two sites around Nena Base, although recent genetic studies indicate that the Nena specimens may be sufficiently distinct genetically to warrant recognition as a new species. During this survey several *L. hunti* individuals were heard calling from the canopy at Camp 1. Specimens collected in the foothills of the Foya Mountains, Papua Province, Indonesia might also refer to this species (Richards et al. 2006) and it almost certainly occurs widely across the Sepik Basin and into neighbouring Papua Province, Indonesia.

Because adults live in the forest canopy they would be susceptible to habitat clearing, disturbance and fragmentation. The species is unlikely to be specifically hunted.

6.1.1.2 *Litoria purpureolata* (IUCN Data Deficient)

(Plate 2D)

Litoria purpureolata is a moderately large, green treefrog. It appears to be a strictly arboreal species that lives in the forest canopy, and probably comes to the ground only to breed. This species was described from the Tiri River, a small tributary of the Mamberamo River in Papua Province, Indonesia. The original type series were calling from a shallow swamp in lowland forest and this species probably breeds in pools or swamps on the forest floor in the wet season (Oliver et al. 2007; Richards 2008).

This species was first documented from northern PNG during the 2009–2011 Frieda River Project surveys, and at the same time by Kraus (2010). It was abundant in swamp forest at both principal sites where males called from between ~2–20 m above the forest floor. It therefore appears to have a moderately broad distribution across the lowlands of northern New Guinea.

Adults live in the forest canopy and would be susceptible to habitat clearing, disturbance and fragmentation. Their breeding areas, swamps in forest, would be susceptible to changes in hydrology and contamination. The species is unlikely to be specifically hunted.

6.1.1.3 *Litoria richardsi* (IUCN Data Deficient)

(Plate 2E)

Litoria richardsi is a moderately small (30 mm SVL), strikingly coloured treefrog with extensive, thick black webbing between the fingers and bold black and yellow markings ventrally (Dennis & Cunningham 2006).

This species was described from two sites; one near Tabubil, Western Province, and one in the Mamberamo Basin of Papua Province, Indonesian New Guinea. It has also been documented at a number of sites in the lowlands of south-central PNG including the Darai Plateau in the Kikori Basin (as *Litoria* sp. nov. 5; Richards & Allison 2003). In the original description of the species Dennis & Cunningham (2006) noted that they expected it to occur more widely in suitable habitat in intervening areas between the Star Mountains and the Mamberamo Basin. The population discovered at Camp 2 is only the second known from north of the central cordillera and indicates that *L. richardsi* does indeed have a broad distribution in central New Guinea.

It has been suggested that this species may breed in tree-holes (Dennis & Cunningham 2006) and remain in the canopy for most of its life. Adults live in the forest canopy and would be susceptible to habitat clearing, disturbance and fragmentation.

6.1.1.4 *Papurana volkerjane* (IUCN Data Deficient)

(Plate 2F)

Papurana volkerjane is a large member of the genus, with females growing to 105 mm and males to nearly 80 mm SVL (Günther 2003). It was described from the Bird's-neck region of Papua Province, Indonesian New Guinea and it was subsequently documented from north-western PNG by Kraus & Allison (2006). This species was common at Camp 2 where males were frequently observed on the banks, and in nearby riparian vegetation, along the main channel of the Wara Kep. This is a forest-dwelling species so habitat loss, degradation and fragmentation are major threats. It is closely associated with clear-flowing streams so removal of riparian vegetation could impact adults by removing shelter and calling sites along streams, while disturbance of the stream banks and stream beds could increase sediment loads through increased erosion potentially impacting survivorship of the species' aquatic larvae.

6.1.2 Reptiles

6.1.2.1 *Pelochelys signifera* (IUCN Vulnerable)

(Plate 1H, 2G, H)

This is a very large (carapace to >60 cm; Cann & Sadlier 2017), soft-shelled turtle found only in northern New Guinea (Webb 2003). The populations there have a complicated taxonomic history, the result of which is that the Sepik River population is currently considered to be a species distinct from the population in southern Papua New Guinea (*P. bibroni*) and also distinct from the species in SE Asia (*P. cantorii*). *Pelochelys signifera* is covered by a new IUCN red-list assessment that was submitted on 29 March 2018 and is currently being processed by the IUCN. It will be published within the next three months.

This species is harvested whenever encountered and has been classified as Vulnerable by the IUCN in the new assessment. During our survey we observed one carapace in a hunting hut on the Idam River (Plate 1H) and a juvenile was brought to Camp 2 from Idam

1 village (Plate 2G, H). Local informants report that the species is rare, restricted to larger waterways (including the Idam River), and that eggs, juveniles and adults are consumed.

Unsustainable harvesting of nests, juveniles and adults, and destruction of, or disturbance to, sandy nesting banks along larger watercourses are the major threats to this species. Additional information on this species is presented in Appendix 1.

6.2 Undescribed species

Four species of frogs (18% of total) and two species of reptiles (9%) documented at the two principal sites appear to be undescribed. All of them were previously documented during the 2009–2011 Frieda River Project surveys and it is extremely likely, given the extensive areas of apparently suitable habitat available, that they have broad distributions in the northern lowlands of western PNG.

6.2.1 Frogs

6.2.1.1 *Copiula* sp. 1

(Plate 3A)

A small (~25 mm SVL) mottled-brown frog with a plump body, a pale stripe between the snout and the eye, and moderately large discs on the toes. This species was previously identified as *C. pipiens*, which it closely resembles. However its call is much longer than that described for *pipiens* and it probably represents an undescribed species. It is a terrestrial species occurring in closed-canopy rainforest where males call from hidden positions in the litter during and after rain at night. It was encountered widely in the lowlands and foothills during the Frieda River Project surveys. Additional studies are required to confirm its status.

6.2.1.2 *Hylophorbus* sp. 1

Microhylid frogs of the genus *Hylophorbus* are the taxonomically most difficult group encountered during this survey. Advertisement calls of at least three species were heard, but only one species was observed. It is tentatively identified as *H. proekes*, a species recently described by Kraus & Allison (2009), although some morphological characters differ subtly from that species. A second call-type is tentatively assigned to the recently described *H. atrifasciatus*. That species was described from northern PNG by Kraus (2013) without a description of its call – but several specimens resembling *atrifasciatus* were obtained during the 2009–2011 Frieda River Project surveys, and calls associated with this species at that time resemble those heard at Camp 2. Finally, a *Hylophorbus* species with a very long call sequence (>30 notes) was heard at both Camps 1 and 2. It represents an undescribed species that was also detected during the 2009–2011 Frieda River Project surveys and is referred to here as *Hylophorbus* sp. 1.

Hylophorbus species are terrestrial, forest-dwelling frogs that call at night from hidden positions in the litter both during and after rain, and often during dry weather.

6.2.1.3 *Xenorhina* sp. 1

Frogs of the genus *Xenorhina* are plump, short-legged fossorial species with narrow snouts and tiny eyes that live in, and call from under, the litter on the forest floor or within

the humus layer. The call of one species heard at Camp 1 resembles that of an undescribed species encountered during the 2009–2011 Frieda River Project surveys. No specimen was found, but the species is tentatively considered to belong to the same, undescribed species documented at 4 foothill and lowlands sites during the 2009–2011 Frieda River Project surveys.

6.2.1.4 *Litoria* sp. 1

(Plate 3B)

A small (males ~ 32 mm) brown treefrog found only along narrow, slow-flowing but clear streams and clear seepages. During the 2009–2011 Frieda River Project surveys this species was found at several sites in the Study Area Hill Zone. During the current study it was found only on small seepages on the steep ridge behind Camp 1. It probably has a broad distribution along the northern foothills of the central cordillera and likely does not extend far into the lowlands except where elevated ridge systems occur.

6.2.2 Reptiles

6.2.2.1 *Gehyra* cf *brevipalmata*

(Plate 3C)

A single small, slender gecko of the genus *Gehyra* was collected in forest adjacent to Camp 1. It appears to represent an undescribed, but previously known species related to *G. brevipalmata*. It was also found at one site in lowland forest during the 2009–2011 Frieda River Project surveys.

6.2.2.2 *Nactus* cf *multicarinatus*

An undescribed species with a wide distribution across the lowlands of New Guinea that belongs to an unresolved complex of closely-related species. This small, predominantly terrestrial gecko was detected at five lowland sites during the 2009–2011 Frieda River Project surveys and was documented at Camp 2 during this study.

6.2.3 Additional, conservation significant restricted range species that may occur

Cophixalus balbus (IUCN: DD) is a small brown microhylid frog that was originally described from northern Papua Province, Indonesia. It has subsequently been documented from several localities in the Sepik Basin (Dahl et al. 2009) and probably has a wide distribution across the northern lowlands of western Papua New Guinea. This species has a known range of <50,000 km^2 and probably occurs within the infrastructure corridor.

Cophixalus pipiens (IUCN: DD) is a small purplish-brown microhylid frog that was originally described from near Wewak, in East Sepik Province. It is now known to have a broad distribution in the northern lowlands and foothills of New Guinea between Wewak and the Adelbert Mountains, and on Japen Island (Menzies 2006) but its known range is <50,000 km^2. It probably occurs within the northern reaches of the infrastructure corridor.

A number of additional microhylid frog species with restricted ranges are known to occur at altitudes above 900 m AMSL in the Bewani Mountains (Menzies 2006), which are considered to have an extremely diverse frog fauna (Tallowin et al. 2017). However unless their altitudinal ranges are shown to extend much lower than currently documented, their distributions are unlikely to overlap the infrastructure corridor.

6.3 Species significant to local communities

Our local assistants reported that the large River Frogs (*Papurana arfaki/jimiensis and P. volkerjane*) and reptiles including the semi-aquatic Forest Dragon (*Hypsilurus magnus*), monitor lizards (*Varanus* spp), large pythons (*Leiopython albertisii*, *Morelia amethistina* and *M. viridis*), and the New Guinea freshwater turtles *Elseya novaeguinea* and *Pelochelys signifera*, are captured for food when encountered. Local hunters brought examples of *Papurana volkerjane*, *Hypsilurus magnus, Varanus jobiensis and Elseya schultzei* to camp following a night's hunting along the Wara Kep at Camp 2 (Plate 3D). Consumption of frogs is unlikely to have a major impact on any populations in the study area due to their high abundance, but large reptiles including monitor lizards, freshwater turtles and pythons are still consumed when encountered and due to their lower abundance would be sensitive to an increase in local human population. Additional information on crocodiles and turtles is presented in Appendix 1.

7 IMPORTANT HABITATS

This survey identified four habitats that are important for the maintenance of herpetofaunal diversity or species of conservation significance in the project area.

7.1 Lowland forest

The forests of the study area provide a wide variety of microhabitats that support a rich herpetofauna assemblage. Although no individual microhabitats within the lowland forest are identified as being of particular significance in generating or supporting this richness, the diversity of habitats available, including well-drained ridges, damp gullies, small and large streams and seepages, and temporary and permanent forest pools, provide the terrestrial and aquatic structural complexity to support a moderately rich terrestrial and aquatic herpetofauna.

7.2 Rivers, streams and their riparian zones

Clear-flowing streams and their associated riparian vegetation are crucial for the survival of conservation listed and undescribed species. Although the diversity of stream-dwelling herpetofauna species at Camps 1 and 2 was lower than that documented in the Hill Zone during the 2009–2011 Frieda River Project surveys, streams supported a Data Deficient frog (*Papurana volkerjanae*) and an undescribed treefrog (*Litoria* sp. 1). These streams are characterised by rapid changes in volume following intense rainfall events, and increased sediment loads through disturbance to riparian vegetation and stream substrates can negatively impact these habitat-specific species.

Although the lowland rainforests of northern PNG harbour relatively few stream-dwelling specialist frogs, there are two areas where the infrastructure corridor reaches altitudes above 400 m; the crossing of the West Range (~450 m AMSL) and in the Bewani

Mountains (~600 m AMSL). During the reconnaissance of the Green River to Vanimo section of the infrastructure corridor, a number of clear-flowing streams were traversed while crossing the Bewani Mountains. Like most of the forest in the northern sectors of the corridor, forest at these crossings was severely degraded. However, based on the diversity of stream-specialist frogs encountered at similar altitudes during the 2009–2011 Frieda River Project surveys, it is possible that these streams support a unique assemblage of frogs and they are identified as a potentially noteworthy habitat requiring careful management during construction activities.

7.3 Turtle nesting banks

Although turtle nesting sites were not specifically documented during this survey, sandy banks along the Idam River below Idam 1 village were reported by local informants to be nesting sites for the IUCN Vulnerable turtle, *Pelochelys signifera*. Little is known about the nesting ecology of this species but known nesting sites should be considered significant habitats and their damage or degradation avoided to minimise impacts on this conservation significant species.

7.4 Bewani Mountains

The eastern Bewani Mountains were identified as a major 'Unknown Area' and a major 'Wilderness Area', and Mount Menawa in the Bewani Mountains as a 'Biologically Important Area' for reptiles and amphibians by the Papua New Guinea Conservation Needs Assessment (CNA) (Allison 1993). Since the CNA assessment, surveys in the eastern Bewani Mountains have documented a number of new frog species there (Allison & Kraus 2003; Kraus & Allison 2006b), and Tallowin et al. (2017) reported that the north-western Bewani Mountains are one of the three most species rich areas of New Guinea for frogs, the others being the central highlands and the Torricelli Mountains. Although most species known from the Bewani mountains occur more widely, and several species previously considered to be endemic have been documented from other north-coast ranges (Kraus & Allison 2006a), the Bewani Mountains are considered to be a significant habitat due to the known high diversity of species occurring there.

8 OVERALL CONCLUSION

Overall the fauna documented during this study was unremarkable. With the exception of four species listed as Data Deficient by the IUCN but known to occur widely outside the survey area, and four undescribed species that were also documented during the 2009–2011 Frieda River Project surveys, the frog fauna was dominated by common, widespread species. Similarly, with the exception of an unidentified gecko of the genus *Gehyra*, and documentation of the widespread but IUCN Vulnerable Variegated Giant Softshell Turtle *Pelochelys signifera* in the Idam River, the reptile fauna was dominated by common, widespread species known from other sites outside the study area.

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10 APPENDIX 1. ADDITIONAL INFORMATION ON FRESHWATER TURTLES AND CROCODILES

Turtles

***Elseya schultzei* (IUCN N/E)**

Elseya schultzei is a moderately small (to 30 cm carapace length) freshwater turtle with a broad distribution encompassing all of northern lowland New Guinea east of the Bird's Neck region of Papua Province in the west, and at least to Madang in the east (Thomson et al. 2015). It was classified by the IUCN as Least Concern (under *E. novaeguineae*) (Asian Turtle Trade Working Group 2000) but a new IUCN assessment was in preparation at the time of writing. This species is abundant throughout the Sepik system, and although it occurs in the main river channel, and in swamps, lakes and other off-river waterbodies throughout the region, it is also commonly found and collected in small tributary streams (S. Richards, personal observation). A juvenile specimen was found in a small, clear tributary stream above a steep waterfall at Camp 1 during this project. Locals report that this species is common, and that it is harvested whenever found, particularly during the nesting season which they state is from around May–June (based on interviews during the 2009–2011 surveys); and that nesting occurs in both the main river channel and in off-river waterbodies. Although locals reported that they do not specifically hunt for this species they do look for signs of nesting, and harvest adults and clutches at this time. Adults are also collected and consumed whenever they are encountered, throughout the year. At Camp 2 local hunters captured a live adult turtle from the stream adjacent camp during the survey, and trophy shells of *E. schutzei* were observed in a hunting hut along the Idam River.

Elseya schultzei appears to be abundant throughout its range. It probably occurs in most permanent waterbodies that intersect the infrastructure corridor between Green River and Vanimo, except possibly at the higher elevations where the corridor traverses the Bewani Mountains.

***Pelochelys signifera* (IUCN Vulnerable)**

Pelochelys signifera is a large (to ~100 cm; see Figure 3b in Sheil et al. 2015), highly aquatic softshell turtle with a broad distribution in northern New Guinea that extends from the Nabire region of Papua Province, Indonesia in the west to the Madang region of Papua New Guinea in the east. Its range incorporates all of the major drainage basins in this region including the Ramu, Sepik and Mamberamo basins (Rhodin et al. 1993; Richards et al. 2002; Sheil et al. 2015) where it occupies larger rivers, wetlands, and even estuaries and coastal regions under freshwater influence. Based on observations of *P. bibroni* in southern New Guinea and *P. cantorii* in southeastern Asia (Rhodin et al. 1993; Das 2008), *P. signifera* may also occasionally enter the near-coastal marine environment. The diet of the species is poorly known, but is hypothesized to include fish, prawns, and crabs (Rhodin et al. 2018). According to Cox (1984) and Rhodin et al. (1993) nesting occurs in the dry season (September–October), and the species appears to be a solitary sporadic nester (Rhodin et al. 2018). However, apart from the report of three *P. signifera* nests found in a nesting mound of *Crocodylus novaeguineae* in the Sepik River (Cox 1984), the nesting habits, clutch sizes, and clutch frequency of this species remain unknown. Growth rate and age and size at maturity also remain unknown.

Pelochelys signifera is highly prized as food by local people, and both adults and eggs are harvested throughout its range whenever encountered (Rhodin et al. 1993; Richards et al. 2002; Sheil et al. 2015). It is collected during general fishing activity using nets and traps and on baited lines, and is occasionally speared or caught by hand in shallow waters (Rhodin et al. 1993; Richards et al. 2002; Sheil et al. 2015; Richards, unpubl. data). In the Mamberamo basin it is caught by hand in shallow clear waters where animals burrow into sandy or muddy substrates to avoid detection leaving a distinctive outline of the buried animal (Richards, unpubl. data). Following consumption of the flesh, shells of adults harvested in the Sepik region of Papua New Guinea may be decorated and sold into the tourist trade as ceremonial masks (Rhodin et al. 1993).

Local informants provided different estimates of this species' abundance during the 2009–2011 surveys, ranging from abundant to uncommon, though the species was consistently reported to be less common than *Elseya schultzei*. During the 2017 survey *P. signifera* was reported to be restricted to larger, deeper portions of the Idam River, where (according to local informants) exposed banks are used as nesting sites by this species. A single juvenile specimen captured in the Idam River was brought to Camp 2 by local community members during the 2017 survey.

The lack of information about this species' nesting and foraging habitats makes it difficult to predict its local distribution and to identify potential nesting sites. However construction of river crossings on sandy and muddy river banks along larger waterways may disturb nesting sites of this IUCN Vulnerable species. From the south, based on maps but without ground-truthing, potential sites of intersection between *P. signifera* habitat and infrastructure include:

1. Proposed river crossing ~1 km east of Bisiabru on the Idam River
2. Proposed river crossing ~1 km north of Old Buna on the Sepik River near Mukuasi (and possibly at the crossing of Simaia Creek upstream of Mukuasi)
3. Proposed river crossing ~4 km SW of the Kwomtari Landing Ground below the confluence of Biebiu Creek and Bapi (Keri) River.

Although there are three additional major river crossings between the Bewani Mountains and Vanimo, each is the site of existing infrastructure and appeared to be heavily impacted during observations in 2017.

In summary, with the possible exception of # 3 (above), each of the waterways intersecting the infrastructure corridor between Green River and Vanimo that were observed during the 2017 survey are probably too small to support nesting populations of *P. signifera*, or were already severely impacted by sand extraction or bridge construction activities that were not associated with the Project. However this should not preclude interviews with local communities at each site to identify any possible remaining nesting sites.

Crocodiles

Two species of crocodiles (New Guinea Freshwater Crocodile *Crocodylus novaeguineae* and Saltwater or Estuarine Crocodile *C. porosus*) occur in the Sepik River lowlands and both are of national significance culturally and economically; their export and related activities being controlled under the Crocodile Trade (Protection) Act 1974.

The New Guinea Freshwater Crocodile is the smaller of the two - females grow to 3 m and males to 3.5 m (Hall 1991), although larger animals have been documented (Cox 2010). The Saltwater Crocodile is the largest living crocodile species - males grow to over 6 m and weigh up to a tonne while females grow to 3.5 m. The New Guinea Freshwater Crocodile is restricted to the lowlands of New Guinea and the island of Pulau Kimaam (Cox et al. 2003) and appears to be abundant throughout much of its extensive habitat (Cox 2010), while the Saltwater Crocodile is more widely distributed from Sri Lanka and eastern India through south-east Asia to most of New Guinea's lowlands, northern Australia, and the Solomon and Caroline Islands (Webb et al. 2010). Despite its name it is not restricted to estuarine or saltwater environments, and it occupies most of the freshwater wetlands of lowland New Guinea, including the extensive lagoons and lakes associated with the Sepik River.

Landowners legally harvest crocodiles for food, sale, cultural purposes and export of hides, and sustainable harvesting of saltwater crocodile eggs has become a powerful economic incentive for the conservation of crocodile populations (Cox et al. 2006). In 2005 crocodile products earned an estimated 35 million Kina in export income (Cox et al. 2006) and during the 2009–2011Frieda River study (S Richards *pers. obs*.) income from crocodiles was cited in most villages visited on the Sepik River as a major source of funds. In contrast at Idam Village local informants reported during the 2017 survey that crocodiles are absent from the river locally because it is too shallow, and that Freshwater Crocodiles (but not Saltwater Crocodiles) occurred rarely in the downstream, deeper reaches of the Idam River closer to the confluence with the Sepik River. No crocodile farms were encountered, or reported by local informants, in the Idam River area.

Where they occur, hunting and egg harvesting of New Guinea Freshwater Crocodile is less frequent because of the lower value of its skin and, at least on the Sepik, the major buyer of crocodiles and eggs, Mainland Holdings, was not buying its eggs at the time of the 2009–2011Frieda river study. Although monitoring of egg harvests and nesting of this species has been sporadic and much less intensive than for saltwater crocodiles, Cox (2010) concluded that the potential for sustainable management of this species is high.

There were three major farms and 6–7 small crocodile farms at Kubkain during the 2011 Frieda biodiversity surveys and one or more at Iniok; all supplied live juveniles, raised from wild-caught animals, and wild-killed adult skins of both species to Mainland Holdings. Data gathered from village interviews indicated that there was also a farm at Paru Village, with about 30 of both species being raised for sale to agents of Mainland Holdings from Hauna and Kubkain, but that there were no farms at Nekei, although locals there harvested eggs, juveniles and adults, for their own consumption. The absence of crocodile farms at Idam River presumably reflects the low density and limited distribution of crocodiles there, and the absence of the more valuable Saltwater Crocodile. The current status of crocodile farms documented during the 2009–2011 surveys is not known.

The then PNG Department of Environment and Conservation undertook systematic nest monitoring of the Saltwater Crocodile in the Sepik River Basin from 1982 (e. g. Cox et al. 2006, Solmu and Sine 2009, Solmu no date), and the data indicate that the nesting population has increased significantly since monitoring began (Cox et al. 2006). Informants at Iniok, Nekei, Paru (Wogamush) and Kubkain Villages indicated that both species were extremely abundant in the lowlands of the 2009–2011 study area (S. Richards, March 2011) but that the New Guinea Freshwater Crocodile was commoner in off-river waterbodies than in the main river channels. After 1985 the number of nests documented during nest monitoring for both species increased, particularly in 'secure' sites i. e. those areas protected by a single landowner or village, and not 'in dispute' (Gowep 2009).

In 1998 the Sepik Wetlands Management Initiative (SWMI), a community organization based in the district centre of Ambunti, East Sepik Province, was formed. This organization works with PNG Department of Environment and Conservation (now Conservation and Environment Protection Authority; CEPA) and village communities to promote conservation of crocodile populations and wetlands, sustainable use of wetlands resources, and promotion of rural development (Cox et al. 2006, Gowep 2009). SWMI has undertaken nest censuses for both species in the middle and upper Sepik, and collated data on egg harvesting rates since 1985. Initial egg harvesting was generally less than 2000 eggs/year and conducted by helicopter during DEC's aerial surveys. However, since 2002 when canoe harvesting started the harvest has increased greatly and between 2004 and 2008 the take of saltwater crocodile eggs was between 10,000 and 17,000 eggs/year.

Harvests of adult New Guinea Freshwater Crocodile in the Sepik declined from over 20,000/year between 1977 and 1980 to 12,000-20,000/year between 1981and 1989, then fluctuated between 10,000-20,000/year between 1997 and 2005 (Solmu and Sine 2009). With regards to eggs and hatchlings Cox (2010) reports: "Until the mid-1990s hatchlings and eggs were collected and raised in centralized crocodile farms. Harvests for this purpose ranged from 2,500 to 10,000". Surveys of nests in a representative area of the middle and upper Sepik River suggest the population declined slightly from 1981 to 1999 but Cox (2010) also reported that "After a 4-year halt in nest counts, numbers increased steeply from 2003 to 2007, probably as a synergistic result of strengthened protection measures for breeding crocodiles linked to *C. porosus* egg harvests (Cox et al. 2006)."

Farming does not breed animals and the industry is dependent upon wild production for the harvests so habitat conditions that support breeding is critical. Saltwater crocodiles in the Sepik construct nests in floating mats of vegetation in open areas, predominantly between November and March, with a smaller pulse in March-April (Cox et al. 2006). The

New Guinea Freshwater Crocodile lays eggs in mound nests from August to October, usually on floating mats of vegetation in densely overgrown channels, lake fringes and scroll swales, and occasionally on stream banks or scroll levees. According to local informants interviewed during the 2009–2011 Frieda River study the major threat to both species appears to be dramatic reductions in aquatic plants due to exotic fish, particularly Pacu (*Piaractus brachypomum*) and Java Carp (*Puntius gonionotus*) but we have no way of confirming this.

According to information obtained during interviews at Nekei, Wogamush and Kubkain, damage to nesting habitat of the New Guinea freshwater Crocodile has resulted in females nesting in sub-optimal nesting sites, particularly in cooler, more terrestrial situations throughout the Study Area. Because crocodiles exhibit temperature dependent sex-determination (e. g. Woodward and Murray 1993) a major shift in nesting behaviour from open-water nests to cooler terrestrial sites among trees may change population sex ratios and have consequences for long-term population viability. Cox et al. *(*2006) and Gowep (2009) also reported that anthropogenic burning of grassland habitats prior to 2006 may have had a major impact on nesting habitat of the Saltwater Crocodile in the 1990s, with between 50% and 80% of the nesting habitat reduced at surveyed sites (Cox *et al.* 2006).

Both crocodile species occur predominantly in lagoons and lakes associated with the Sepik River channel, and most breeding activity, and harvesting of eggs, juveniles and adults by local communities, occurs in these off-river waterbodies rather than in the main river channel (e. g. Cox et al. 2006; local informants, March 2011). There are therefore few locations in the proposed infrastructure corridor where these species are likely to occur.

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Odonata

A report prepared for Coffey Services Australia Pty Ltd and Frieda River Limited

By Stephen J. Richards

February 12th 2018

TABLE OF CONTENTS

Cover images

Top: The stream-dwelling damselfly *Palaiargia charmosyna*;

Bottom: The forest-breeding dragonfly *Lyriothemis meyeri*.

1 EXECUTIVE SUMMARY

- This study characterises the odonates of the proposed infrastructure corridor for the Sepik Development Project, an open-pit copper-gold mine in Sandaun and East Sepik Provinces, northern Papua New Guinea.

- A total of 50 species of odonates, including 25 damselflies and 25 dragonflies, was documented from two sites. The fauna is dominated by species with broad known distributions in the northern lowlands of New Guinea.

- Two poorly-known damselfly species documented during the survey, *Nosoticta nigrifrons* and *Papuargia stueberi*, are listed as Data Deficient by the IUCN. Both of them are stream-dwelling species.

- Two species of 'flatwing' damselflies of the genus *Metagrion* appear to be undescribed. They are both stream-dwelling species and were previously known from the 2009–2011 Frieda River Project surveys.

- Important habitats identified during the surveys include 1) lowland closed-canopy swamp forests in the southern section of the corridor that support an odonate assemblage unable to persist in open, disturbed areas, and 2) clear-flowing streams which support a diverse assemblage of more than half of the odonate fauna in the areas surveyed, and are likely to harbour specialist stream-dwelling odonates elsewhere in the infrastructure corridor including the Bewani Mountains.

ACRONYMS AND ABBREVIATIONS

AMSL	Above mean sea level
CEPA	Conservation and Environment Protection Authority
DD	Data Deficient (IUCN threat category)
EN	Endangered (IUCN threat category)
FIMS	PNG Forest Inventory Mapping System
Hm	Hill forest (FIMS vegetation type)
IUCN	International Union for the Conservation of Nature
km	Kilometers
km^2	Square kilometers
LC	Least Concern (IUCN threat category)
LIDAR	Light detection and ranging (remote sensing method)
m	meters
mm	millimeters
PNG	Papua New Guinea
Project	Sepik Development Project
sp.	Abbrev. 'species' (singular)
spp.	Abbrev. 'species' (plural)
study area	Infrastructure Corridor Terrestrial Biodiversity Study Area
SVL	Snout to vent length

GLOSSARY OF TECHNICAL TERMS

Anthropogenic	Originating from human activity.
Asymptote	A straight line approached but never crossed by a curve (species recorded versus survey effort in the context of this report).
Central cordillera	Refers to the central mountainous spine of New Guinea that runs from the eastern edge of the Vogelkop Peninsula in Indonesian New Guinea to the eastern tip of mainland PNG.
Conservation listed species	Includes: (1) species listed under the IUCN Red List as threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened or Data Deficient; (2) species listed as Protected under the PNG *Fauna (Protection and Control) Act 1966*;
Endemic	Belonging exclusively or confined to a particular place.
Odonata	Refers to both damselflies and dragonflies.
Protected	Species listed as Protected under the Papua New Guinea *Fauna (Protection and Control) Act 1966.*
Restricted-range	Species which have a total historical breeding range of less than 50,000 km^2.
Taxa	Plural of taxon; a systematic division (e.g. more than one species, genera, etc.).
Taxonomic	Taxonomy is the science of identifying, naming and classifying living organisms.

2 INTRODUCTION

2.1. Background

Frieda River Limited (FRL) is assessing the feasibility of developing the Sepik Development Project (the Project), an open-pit copper-gold mine and supporting infrastructure in Sandaun and East Sepik Provinces, northern Papua New Guinea (PNG). The mine will be accessed by a 325 km infrastructure corridor (the study area), which consists of an existing road from Vanimo to Green River and a new road through to Hotmin and to the site. A concentrate pipeline and transmission line will also be located within the infrastructure corridor. Terrestrial biodiversity studies were completed for the mine area in 2009–2011 for a previous design of the Project.

This study forms part of the terrestrial biodiversity characterisation required for the EIS, specifically for the proposed infrastructure corridor.

2.2. Study objectives

The objectives of the Odonata baseline characterisation are to:

- Characterise the existing odonates and provide context at the local, national and international scale noting any sensitive environmental areas or habitats.
- Document any rare, threatened, undescribed or otherwise noteworthy odonate species (i.e., International Union for Conservation of Nature (IUCN)-listed or community significance), communities and habitats present within the study area.
- Document any exotic and invasive odonate species.

3 EXISTING INFORMATION

With nearly 500 described species (Orr & Kalkman 2015), the dragonflies and damselflies (Odonata) of New Guinea are a diverse and colourful component of the region's biodiversity. Although the fauna shares many components with Australia (Theischinger & Hawking 2006) there are also striking differences between the faunas, and several groups that are species-rich in New Guinea, such as Idiocnemidine and Platystictid damselflies, are absent from Australia. Given their moderately large size, relative ease of identification, and a complex life cycle that includes an aquatic larva and terrestrial, flying adult stage, odonates are considered to be potentially useful indicators of environmental change (e.g. Clark & Samways 1996; Samways & Simaika 2016). However despite their ease of identification the odonate fauna of New Guinea remains incompletely documented and numerous new species have been described from the region in the last 10 years (e.g. Gassmann & Richards 2008; Kalkman et al. 2010; Orr et al. 2014; Theischinger & Richards 2015, 2016; Theischinger et al. 2017; Orr & Richards 2016, 2017).

More than 200 described species are known to occur in the northern lowlands of New Guinea (Kalkman & Orr 2013; Orr & Kalkman 2015). Until recently much of our knowledge about this fauna was based on material collected in Indonesian (then Dutch) Papua Province, mainly by the 1938–1939 Archbold Expedition (Archbold et. al. 1942) and private collectors including W. Stueber and E. Cheesman (Lieftinck 1949). In contrast, with few exceptions (for a recent example see Gassmann 2015), the fauna of northern Papua

New Guinea has remained poorly documented with recent odonate surveys in the country focused on southern and far-eastern regions (e.g. Richards et. al. 1998).

In their overview and assessment of New Guinea freshwater biotas, Polhemus et al (2004) used damselflies as one of the indicator taxa to delineate areas of freshwater endemism in the region. They recognised the Mamberamo Basin and the Sepik-Ramu-Markham Basin as separate areas of endemism, but only the Mamberamo Basin supported endemic odonates (2 species); recognition of the Sepik-Ramu-Markham Basin area of endemism was based largely on the presence of endemic fishes (Polhemus et al. 2004). However given the continuity of habitats and lack of major biogeographic barriers between the Mamberamo and Sepik basins, it is reasonable to expect that endemic taxa documented from the Mamberamo Basin may also occur in the Sepik River Basin and that the odonate fauna of the Sepik lowlands is likely to closely resemble the better-known faunas of the Jayapura area and the Mamberamo Basin in northern Papua Province. Indeed a number of species previously known only from northern Papua Province have recently been documented in northern PNG (e.g. *Thaumatagrion funereum*; Kalkman & Orr 2013).

The most comprehensive odonate studies undertaken to date in the upper Sepik River basin were those conducted during the extensive terrestrial biodiversity field surveys for the 2009–2011 Frieda River Project. That study documented 107 odonate species, including numerous new-to-science species, at 20 sites across the lowlands and foothills of the upper Sepik River basin. Most of those new species were discovered at sites above 300 m AMSL in the foothills of the central cordillera (e.g. Orr et al. 2012). However a number of new species and an entirely new genus were also discovered in, and subsequently described from, the lowlands of the upper Sepik River basin (Theischinger & Richards 2012).

This report presents an assessment of odonate diversity and conservation significance at two additional sites in the newly proposed infrastructure corridor in the lowlands of north-west mainland Papua New Guinea.

4 METHODS

4.1 Survey sites and timing

Surveys were conducted during 28 November–11 December 2017, at the start of the 'northwest (monsoon) season'. Table 1 lists the location, timing and elevations covered at each survey site.

Two principal survey sites (Camps 1 and 2) were sampled over multiple days (range: 4−5 days, excluding transfer days; Table 1) from temporary 'fly camps' constructed specifically for the purpose. Although an overnight visit was also made to Idam 1 village to facilitate a boat-based survey of the lower reaches of the Idam River, opportunities to survey odonates along the river and around Idam 1 village were limited. Only three common, widespread species, *Neurothemis stigmatizans*, *Orthetrum serapia* and *Pseudagrion civicum*, were observed; each of these also occurred at either or both of Camps 1 and 2 so, given the limited search effort at Idam 1 the odonate fauna at this site is not considered further in this report.

A single-day (6-hour) traverse of the road between Green River and Vanimo was also conducted to assess the overall quality of forest habitat and to identify any significant habitats for odonates along the northern sectors of the infrastructure corridor. Odonate species were not surveyed during this journey.

A brief description of each principal survey site and the habitats surveyed is given below (Sections 4.1.1–4.1.2). A detailed description of vegetation types, structure and floristics at Camps 1 and 2 is presented in the flora technical report (Takeuchi 2018).

Table 1. The location and time spent at each survey site. All dates are for 2017.

Site	Base location[A]	Elevations	Arrival	Departure
Camp 1	559085 9494427	65–150	28/11, 09:30	4/12, 13:00
Camp 2	534344 9539086	85–180	4/12, 13:15	7/12, 9:30
			8/12, 14:45	11/12, 10:30

[A]Camp/insertion points: PNGMG94 Zone 54
[B]All elevations in mAMSL from LIDAR digital elevation model (DEM) to the nearest 5m.

4.1.1 Camp 1

Camp 1 was positioned in an area of post-garden regrowth on the banks of Dibiri Creek near its confluence with the Right May (Abei) River and about ten minutes' walk upstream from Usaremin 2 village (labelled 'Uriaka' on the 1:100,000 topographic map sheet), a small settlement of 38 households located on the Right May River approximately five river kilometres upstream from Hotmin village. Odonates were surveyed over five 'complete' days, and on parts of two days. Foot surveys were conducted on trails through hill and swamp forest (Plate 1A), gardens (current and former) and along Dibiri Creek (Plate 1B).

Natural vegetation is mapped as open alluvial forest (FIMS code Po) on the floodplains and flanking terraces of the Right May and May rivers, and medium crowned hill forest (FIMS code Hm) on the adjacent hill slopes. Most of the alluvial forest accessible on foot from the camp had been converted to gardens, was in various stages of post-conversion regrowth or had been otherwise heavily disturbed. Less disturbed examples were observed by boat further away from camp. Natural vegetation was more prevalent as hill forest on the spurs and ridges west of camp and on the terraces flanking Dibiri Creek, though these were also subject to regular visitation by local residents for hunting and small-scale resource extraction.

4.1.2 Camp 2

Camp 2 was located in a small garden area adjacent to a hunting hut on the 'Wara Kep' (Plate 1C), a small creek that flows west and north across alluvial plains to meet the Idam River near Idam 1 village approximately 6.3 km northwest of the camp. In addition to a range of small streams, other accessible aquatic habitats relevant for odonates included small temporary forest pools and a large, possibly permanent, forest pool (Plate 1D). Odonates were surveyed on foot over five entire days, and on parts of three days (Table 1) in small crowned alluvial forest (FIMS code Ps) and in medium crowned hill forest on the foothill spurs and ridges present to the north and south of camp. The camp was

situated approximately three hours walk from the large (>1,000 people) Idam 1 village. Aside from a few hunting huts and small adjacent gardens observed along the Wara Kep, and numerous walking trails through the forest, there was little sign of anthropogenic disturbance to forest habitats.

4.2 Odonate sampling

At both sites intensive searches were conducted for adult dragonflies and damselflies along and around all available water-bodies, during the morning, on sunny afternoons, and in the evenings. Activity patterns of odonates vary among species, with some taxa preferring to perch in early-morning sun patches in the forest, others defending territories along streams, and others flying in forest gaps predominantly at dusk, and rarely perching. Water-bodies examined included seepages, small closed-canopy streams, larger streams and small forest pools. Additional surveys were conducted along forest trails and in clearings, especially helipads, where large dragonflies often hunt for small flying insect prey. Surveys were conducted by two searchers using long-handled insect nets. Specimens required for identification were stored in glassine envelopes in boxes containing naphthalene and silica gel to prevent mould and deterioration.

Larval odonates were not targeted during this study because the larvae of most New Guinean taxa remain unknown. Larvae are predaceous and providing sufficient prey to rear individuals to metamorphosis for identification in the field would have been labour intensive and, based on studies of other tropical species, development rates of most species encountered would have been too slow to permit successful rearing in the field. As a result identifications based on larval collections would be problematic at best for most species.

4.3 Protocols used

4.3.1 Taxonomic issues and nomenclature

The odonata of New Guinea remains poorly known and many groups of dragonflies and damselflies are currently undergoing revision. Particularly problematic groups include ‘flatwing’ damselflies of the family Argiolestidae (e.g. Kalkman et al. 2010), and coenagrionid damselflies of the genera *Papuagrion* and *Teinobasis*. In some cases it is therefore not possible to assign an established name to a species encountered during the surveys. The following system of abbreviations is applied in this report to account for various levels of uncertainty.

- ‘sp.’ (singular) or ‘spp.’ (plural)—used in cases where one or more taxa could not be identified to species level, or where reference is made to multiple species within a genus without the need for more specific information.

- ‘sp. 1’, ‘sp. 2’, etc.—for example: *Metagrion* sp. 1. The numeric system is used where taxonomic identity is confidently resolved and the species is scientifically undescribed.

This report follows the terminology for damselflies adopted by Kalkman & Orr (2013), and for dragonflies the terminology follows Orr & Kalkman (2015). The term ‘dragonfly’ is commonly used in two different ways in the literature: either to denote the entire order Odonata (including both dragonflies and damselflies), or to denote only the sub-order

Anisoptera, or 'True Dragonflies', excluding the sub-order Zygoptera or 'Damselflies'. The term 'odonate' is used throughout this report to indicate the entire order, including both dragonflies and damselflies. The term 'dragonfly' and 'damselfly' are used in the specific sense to indicate these respective subfamilies.

4.3.2 Conservation status

The conservation status of each species encountered was determined using the internationally recognised IUCN Red List of Threatened Species (IUCN 2017), and the PNG Fauna (Protection and Control) Act 1966. Only a small selection of odonate species from New Guinea have been evaluated by the IUCN as part of a global assessment of the group (Clausnitzer et al. 2009). The IUCN Red List provides taxonomic, conservation status and distribution information on plants and animals. The IUCN Red List criteria identify three categories of threatened species which are considered to be facing a heightened risk of extinction: Critically Endangered (CR), Endangered (EN) and Vulnerable (VU). Two additional categories used in this report are Least Concern (LC) and, for those species for which data are insufficient to reach a conclusion, Data Deficient (DD). A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate (IUCN 2017). Species that have not been assessed by the IUCN are listed as Not Evaluated (NE).

None of the species encountered is Protected under PNG law.

5 RESULTS & DISCUSSION

5.1 Species diversity

A total of 50 species of odonates was documented at the two sites, including 25 species of damselflies and 25 species of dragonflies (Table 2). The families Platycnemididae (including the speciose genus *Nososcticta* that was formerly included in the Protoneuridae or Disparoneuridae) and Coenagrionidae dominated the damselfly fauna with 11 (44%) and 7 (28%) species out of 25 respectively. The family Libellulidae dominated the dragonfly fauna, representing 19 (76%) of the 25 species encountered. Odonate diversity was slightly higher at Camp 2 (43 species) than at Camp 1 (39 species). A selection of species is illustrated in Plates 1–2.

The odonate fauna in the study area is dominated by species known to have broad distributions that extend outside the study area, and with two exceptions is entirely a subset of the species encountered during the 2009–2011 Frieda River Project surveys. The two exceptions are the widespread calopterygid damselfly *Neurobasis australis*, which at Camps 1 and 2 replaced *N. ianthinpennis*, a morphologically and ecologically similar species that was found at most foothill sites during the 2009–2011 surveys; and the libellulid dragonfly *Neurothemis ramburii*, an abundant species which ranges from mainland Asia to New Guinea but was not detected during the 2009–2011 surveys. Two other species, *Papuagrion* sp. and *Teinobasis* sp. could not be identified to species.

The only comparable study of odonate diversity and community structure in the northern lowlands of PNG was that conducted during the 2009–2011 Frieda River Project terrestrial biodiversity surveys. Only three of 17 sites surveyed intensively during that project documented odonate faunas that equalled or exceeded the 39 species documented at Camp 1; and only one site exceeded the total of 43 species documented at Camp 2 (having 46 species). Furthermore, examination of the species accumulation curve constructed for odonate species at both sites demonstrates that the curve is not approaching an asymptote at either site and that additional species would have been detected with further search effort. In combination these results suggest that diversity at both sites is extremely high, and that numerous additional species are likely to occur at both sites. Additional significant species that may occur in the study area are described in Section 6.2.

5.2 Exotic and invasive species

No exotic or invasive odonate species were encountered and none are known to occur in Papua New Guinea.

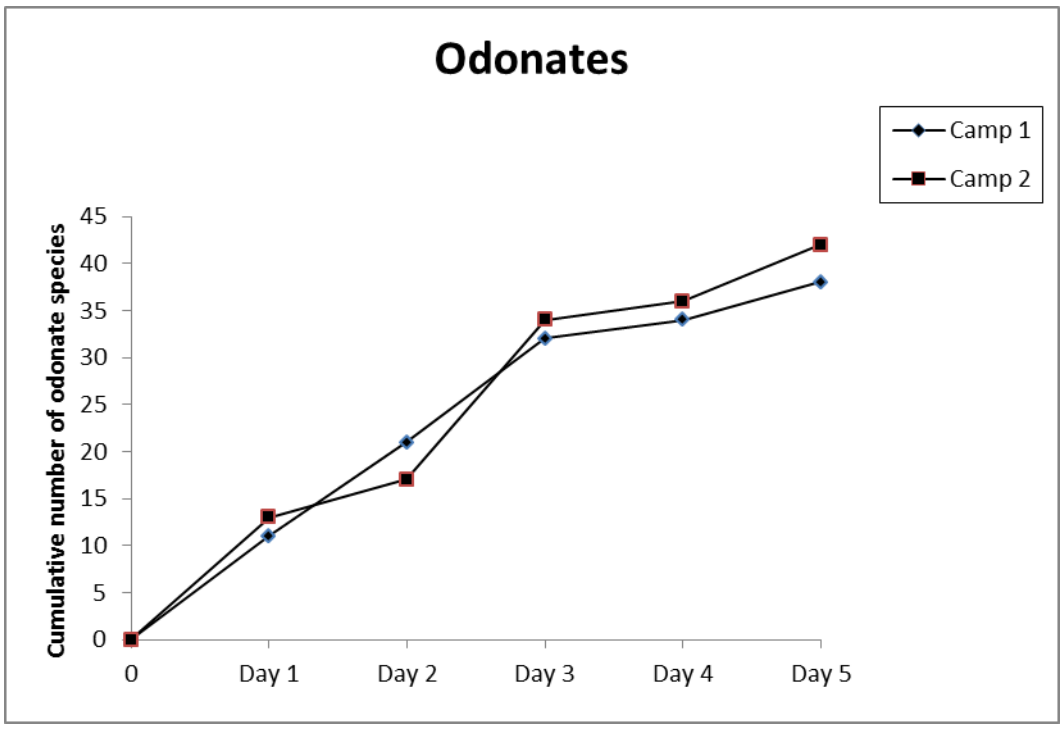

Figure 1. Species accumulation curves for odonates at Camps 1 and 2.

Table 2. List of odonate species encountered and their IUCN status

Family	Species	IUCN Status	Camp 1	Camp 2	Aquatic habitat type[1]
Altitude (mAMSL)			**100**	**123**	
DAMSELFLIES					
Argiolestidae	*Metagrion* sp. 1	NE	x		Str
Argiolestidae	*Metagrion* sp. 2	NE		x	Str
Calopterygidae	*Neurobasis australis*	LC	x	x	Str
Chlorocyphidae	*Rhinocypha tincta*	LC	x	x	Str
Coenagrionidae	*Argiocnemis ensifera*	NE		x	P, O, Sw
Coenagrionidae	*Papuagrion occipitale*	NE	x	x	F
Coenagrionidae	*Papuagrion* sp.	NE	x	x	F
Coenagrionidae	*Pseudagrion civicum*	NE	x	x	R, Str
Coenagrionidae	*Teinobasis macroglossus*	NE	x	x	Sw
Coenagrionidae	*Teinobasis olthofi*	NE	x	x	F
Coenagrionidae	*Teinobasis* sp.	NE		x	F
Isostictidae	*Selysioneura capreola*	NE	x	x	Str
Lestidae	*Indolestes lygisticercus*	NE	x		Sw
Platycnemididae	*Idiocnemis chloropleura*	NE		x	Str
Platycnemididae	*Idiocnemis obliterata*	NE	x	x	Str
Platycnemididae	*Nososticta callisphaena*	NE	x	x	R, Str
Platycnemididae	*Nososticta cyanura*	NE	x	x	Str
Platycnemididae	*Nososticta melanoxantha*	NE	x	x	Str
Platycnemididae	*Nososticta nigrifrons*	DD	x		R, Str
Platycnemididae	*Nososticta nigrofasciata*	NE	x	x	Str
Platycnemididae	*Nososticta rosea cruentata*	NE	x	x	Str
Platycnemididae	*Palaiargia charmosyna*	NE	x	x	Str
Platycnemididae	*Papuargia stueberi*	DD	x		Str
Platycnemididae	*Arrhenocnemis* sp.	NE	x		Str
Platystictidae	*Drepanosticta clavata*	NE	x	x	Str
DRAGONFLIES					
Aeshnidae	*Agyrtacantha dirupta*	LC	x		F, R, Str, Sw
Corduliidae	*Hemicordulia silvarum*	NE	x	x	F, R, Str
Corduliidae	*Metaphya tillyardi*	LC		x	R, Str
Gomphidae	*Ictinogomphus lieftincki*	NE	x	x	R, Str
Libellulidae	*Agrionoptera insignis*	LC	x		P, Sw
Libellulidae	*Agrionoptera longitudinalis*	LC	x	x	P, Sw
Libellulidae	*Diplacina anthaxia*	NE		x	Str
Libellulidae	*Diplacina smaragdina*	NE	x	x	Str
Libellulidae	*Huonia arborophila*	LC	x	x	Str
Libellulidae	*Huonia epinephele*	NE	x	x	Str
Libellulidae	*Lyriothemis meyeri*	LC	x	x	P, Sw
Libellulidae	*Nannophlebia amphicyllis*	NE	x	x	Str

Family	Species	IUCN Status	Camp 1	Camp 2	Aquatic habitat type[1]
Libellulidae	*Nannophya pygmaea*	LC	x	x	P, Sw
Libellulidae	*Nesoxenia mysis*	NE	x	x	P, Sw
Libellulidae	*Neurothemis ramburii*	LC		x	O
Libellulidae	*Neurothemis stigmatizans*	LC	x	x	O
Libellulidae	*Orthetrum serapia*	LC		x	O
Libellulidae	*Orthetrum villosovittatum*	LC	x	x	O
Libellulidae	*Protorthemis coronata*	NE	x	x	O
Libellulidae	*Rhyothemis phyllis*	LC		x	O
Libellulidae	*Rhyothemis resplendens*	LC	x	x	P, Sw
Libellulidae	*Tetrathemis irregularis*	LC	x	x	Sw
Libellulidae	*Tramea aquila*	NE		x	O
Macromiidae	*Macromia terpsichore*	NE	x	x	F, Str
Synthemistidae	*Palaeosynthemis feronia*	NE		x	Str
	Total = 50 species		39	43	

[1]Aquatic habitat type is the set of environments that the species was most frequently associated with, and presumed to be their primary breeding habitat: 'F' = Forest (away from water); 'P' = Pool in forest; 'R' = River (>5 m wide); 'Str' = clear-flowing stream or seepage (<5 m wide); 'Sw' = Swamp forest; 'O' = encountered most frequently in open, including heavily disturbed, habitats including exposed pools.

6 SPECIES OF CONSERVATION SIGNIFICANCE

6.1 Species listed by IUCN or protected under Papua New Guinea legislation

Two damselfly species documented during the survey, *Nososcticta nigrifrons* and *Papuargia stueberi*, are listed as Data Deficient by the IUCN. Both of them are stream-dwelling species.

None of the species documented during this survey are protected by Papua New Guinea law.

6.1.1 *Nososcticta nigrifrons*

(Data Deficient)

Nososcticta nigrifrons is a small, slender, black damselfly with bright blue markings on the thorax, thin blue rings on the abdomen, and a completely black face (Plate 1E). Until recently this species was known only from a single specimen collected over 100 years ago in southern Papua Province of Indonesian New Guinea (Kalkman 2009a). However additional material representing this species has now been obtained from a number of sites across southern PNG since 1996 (Richards et al. 1998; Richards & Theischinger 2013), and the species clearly has a very broad distribution across southern New Guinea in the foothills of the central cordillera below about 500 m AMSL. Theischinger & Richards (2015) recently argued that *N. lorentzi*, a species that is morphologically similar to *nigrifrons* and which was documented during the 2009–2011 Frieda River Project surveys,

is a synonym of *nigrifrons* and should be treated as that species. This hypothesis should be tested with genetic data.

It is clear that this species should no longer be considered Data Deficient. It has a distribution extending widely across the foothills of southern PNG and, if the synonymy of *lorentzi* with *nigrifrons* is confirmed by genetic data, it also occurs at multiple sites north of the central cordillera. However until the species' status is formally reassessed by the IUCN the status of Data Deficient must be retained.

This species is restricted to clear-flowing streams and rivers; it does not occur in swampy habitats, but it does occupy more open-canopy habitats than most *Nososticta* species and is frequently found perched on flood debris, rocks, and riparian vegetation in full sun on the banks of large streams and rivers. Therefore, although removal of forest cover and damage to streams and adjacent riparian habitats would directly impact shelter and feeding sites, the impacts on the survival of adults may be less severe than for *Papuargia stueberi*, which requires cool shady habitats adjacent to streams. However damage to the stream banks' structure and vegetation, and directly to the stream bed, would increase turbidity of the stream water through increased erosion, potentially impacting survivorship of the larvae of this species.

6.1.2 *Papuargia stueberi*

(Data Deficient)

Papuargia stueberi is a large and beautiful green and blue damselfly (Plate 1F). Until recently it was the only member of its genus and known only from two sites near the PNG-West Papua border in the foothills of the Bewani Mountains (Kalkman 2007b). In 2017 a new subspecies of *P. stueberi* was described from the Mul Baiyer region of Western Highlands Province, and a new species (*P. brevistigma*) was described from the Strickland River headwaters south of the central cordillera (Orr & Richards 2017). During the 2009–2011 Frieda River Project surveys the nominate subspecies, *P. s. stueberi*, was documented at three sites in the upper Sepik River basin. The new locality for this species at Camp 1 fills a gap between the type locality in the Bewani Mountains and the 2009–2011 survey sites where this species was encountered, suggesting that it has a moderately broad distribution in suitable habitats in north-western PNG; observations in the field confirm that this species may have a specialised reproductive strategy involving egg deposition on rocks in steep waterfall habitats.

This is a forest-dwelling species that occupies cool, shady habitats adjacent to streams and requires access to clear-flowing rocky streams with waterfall habitats for its survival and reproduction. Therefore, removal of forest cover and damage to streams and adjacent riparian habitats would directly impact its shelter, feeding and breeding sites. In addition to impacts on the survival of adults, damage to the stream banks' structure and vegetation, and directly to the stream bed, would increase turbidity of the stream water through increased erosion, potentially impacting survivorship of the larvae of this species.

6.2 Other significant species that may occur

Two species of odonates that have small known distributions in the lowlands of northern New Guinea, and that have been assessed as Data Deficient by the IUCN were detected

during the 2009–2011 Frieda River Project surveys and may occur in the southern portion of the infrastructure corridor as described further below.

One additional species, *Akrothemis bimaculata*, a new genus and species that was discovered and described from lowland forest during the 2009–2011 Frieda River Project surveys (Theischinger & Richards 2012) may also occur more widely in the southern portion of the infrastructure corridor.

6.2.1 *Cyanocnemis aureofrons*

(Data Deficient)

Cyanocnemis aureofrons is a moderately large blue damselfly with a yellow face which was, prior to the 2009–2011 Frieda River Project surveys known only from a single location on the Idenberg River in Papua Province, Indonesian New Guinea (Kalkman 2009c). During the 2009–2011 surveys this species was common at most of the mid- and lower-elevation sites (150-550 m AMSL.; Table 4) with torrential streams. It probably occurs throughout the foothills and lowlands of central-northern New Guinea and may occur within the infrastructure corridor where elevations exceed ~150 m (for example where it crosses the West Range).

This is a forest-dwelling species restricted to cool, clear-flowing rocky streams and rivers. Therefore, removal of forest cover and damage to streams and adjacent riparian habitats would directly impact shelter and feeding sites of adults. Damage to the stream banks' structure and vegetation, and directly to the stream bed, would increase turbidity of the stream water downstream through increased erosion, potentially impacting survivorship of the larvae of this species.

6.2.2 *Thaumatagrion funereum*

(Data Deficient)

Thaumatagrion funereum is a tiny black damselfly with broad, dark wings that was originally discovered in Pandanus swamps in the vicinity of Jayapura in 1930–1931 Kalkman 2009d). The species was not seen again until it was rediscovered at Kaugumi during the 2009–2011 Frieda River Project surveys. It represents a monotypic genus of uncertain relationships and bizarre appearance, and its documentation in swamp forest at Kaugumi was a significant discovery.

Whether this unusual species occurs more widely in the Sepik Basin lowlands, or has a patchy distribution limited by specific hydrological and vegetative features of the landscape is not known; it was not detected at either of the principal survey sites during this survey but its presence in swamp forest elsewhere in the infrastructure corridor cannot be discounted.

6.2.3 *Akrothemis bimaculata*

This dragonfly genus and species is known only from two specimens collected in lowland rainforest at Kaugumi during the 2009–2011 Frieda River Project surveys (Theischinger & Richards 2012). Both specimens were perched over small pools in swampy forest that appeared to be regularly inundated. No other information about the species' ecology or habitat requirements is available. It is possibly widespread in the northern lowlands of

PNG and may occur in suitable habitat (e.g. small pools in swampy forest subject to regular inundation) within the infrastructure corridor.

6.3 Undescribed species

Two species of damselflies in the genus *Metagrion* that were documented at Camps 1 and 2 appear to be undescribed. Both of these were previously documented during the 2009–2011 Frieda River Project surveys and it is extremely likely, given the extensive areas of apparently suitable habitat available, that they have broad distributions in the northern lowlands of western PNG.

6.3.1 *Metagrion* spp.

The taxonomy of many 'flatwing' damselflies of the family Argiolestidae remains poorly resolved. Some species differ only subtly in morphology, and genetic studies will be required to fully understand the diversity of the group. Despite these difficulties two species of the argiolestid genus *Metagrion* that were encountered during this study appear to be undescribed. They are morphologically similar, and are distinguished from each other predominantly by consistent differences in the shape and extent of pale markings on the thorax (Plate 1G, H). The two species did not co-occur, with *Metagrion* sp. 1 being found only at camp 1 while *Metagrion* sp. 2 was found only at Camp 2.

Like other members of the genus, *Metagrion* sp. 1 and 2 are forest-dwelling species that occupy cool, shady habitats adjacent to small clear-flowing seepages and streams. Therefore, removal of forest cover and damage to streams and adjacent riparian habitats would directly impact their shelter, feeding and breeding sites. In addition to impacts on the survival of adults, damage to the stream banks' structure and vegetation, and directly to the stream bed, would increase turbidity of the stream water downstream through increased erosion, potentially impacting survivorship of the larvae of this species.

6.4 Species significant to local communities

No species of damselflies or dragonflies are hunted or captured, and they are not valued for ceremonial purposes. Local informants reported that no species are considered of significance to local communities.

7 IMPORTANT HABITATS

This survey identified three habitats that are important for the maintenance of odonate diversity or species of conservation significance in the study area.

7.1 Swamp forest

The 'closed canopy' swamp forests at both principal sites provided habitat for a rich odonate assemblage. Although none of the species documented in the swamps is of conservation significance, and many have very wide distributions across lowland New Guinea, most of them (for example *Teinobasis macroglossus*, *Lyriothemis meyeri*, *Nesoxenia mysis*) were not encountered in more open, disturbed areas with extensive sunlight penetration. Furthermore two other significant species, *Thaumatagrion funereum* (IUCN Data Deficient) and *Akrothemis bimaculata* (known only from the Frieda River area) are known only from swampy forest habitats. This habitat therefore not only supports a

diverse forest-dwelling odonate assemblage but potentially also contains a number of poorly-known restricted range species.

7.2 Rivers, streams and their riparian zones

Clear-flowing streams and the dense riparian vegetation along their banks provide habitat for distinct assemblages of odonates at both principal survey sites. More than half of the species encountered were found exclusively, or predominantly, in these habitats (54%; Table 2). The size of the streams, and the structure and density of riparian vegetation associated with each is a crucial factor determining the species of odonates that are able to persist along them. For example, assemblages were often completely different in narrow stretches of stream with dense overhanging riparian vegetation from those in more open sections of the same stream, and some genera, e.g. *Drepanosticta*, *Metagrion*, *Selysioneura*, preferred smaller shaded streams with complex understorey riparian vegetation while other species e.g. *Diplacina smaragdina and Huonia* spp, preferred wider streams with more open understoreys and canopy gaps that allowed large sun patches to penetrate to the creek bed. Furthermore, both species of damselflies listed as Data Deficient by the IUCN, and both undescribed species of *Metagrion*, are forest-dwelling species that rely on clear-flowing streams for their survival.

Although odonates were not documented during the car-based reconnaissance along the infrastructure corridor between Green River and Vanimo, a number of small, clear-flowing streams were noted to intersect the corridor where it traverses the Bewani Mountains. The corridor reaches >500 m AMSL in this section and it is likely that stream-dwelling odonates, including the IUCN data Deficient species *Papuagrion stuberi*, which was originally described from the Bewani Mountains (Kalkman 2009b), occur on these streams.

It should be noted that the streams and their immediately adjacent riparian vegetation cannot be considered in isolation. It was clear during this survey that many stream-dwelling species move into the forest, onto nearby ridges or into nearby moist gullies, presumably to forage.

7.3 The Bewani Mountains

The Bewani Mountains were identified as a biologically important area for conservation of terrestrial invertebrates in Papua New Guinea during the PNG Conservation Needs Assessment (Miller et al. 1993). Although that assessment did not include odonates, the Bewani Mountains are known to have a diverse odonate fauna, based on the collections there by W. Stüber between 1936 and 1939 (Hämäläinen & Orr 2016). This fauna includes numerous species discovered for the first time by Stüber on the lower slopes of the southern Bewani Mountains in what is now Papua Province (e.g. Hämäläinen & Orr 2016 and papers quoted within). At least one species, *Papuagrion corruptum*, is to date known only from lowland forest at the base of the Bewani Mountains and several others are known only from the Bewani's plus one or two additional locations in north-central New Guinea (Kalkman & Orr 2013). The lower slopes of the Bewani Mountains are considered a significant habitat for odonates within the infrastructure corridor given the high known diversity of species there and because the area supports IUCN Data Deficient and restricted range species.

8 OVERALL CONCLUSIONS

The odonate fauna in the study area is extremely diverse, with species totals at Camps 1 and 2 exceeding all but three of the 17 sites surveyed intensively during the 2009–2011 Frieda River Project surveys. However no additional new species were documented and the fauna is dominated by species known to have broad distributions that extend outside the study area. With two exceptions the odonate fauna is a subset of the species encountered during the 2009–2011 Frieda River Project surveys.

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