PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 2: ENVIRONMENTAL AND SOCIAL BASELINE STUDIES

Part 6: Upstream Terrestrial Biodiversity Baseline Report
Annex 5: Upstream Herpetofauna Baseline Report

TOTAL E&P PNG LIMITED

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Upstream Herpetofauna Baseline Report

Papua LNG Project

Total E&P PNG Limited

The treefrog *Litoria pronimia* from Survey Site

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EXECUTIVE SUMMARY

An intensive survey of frogs and reptiles was conducted at 12 sites in the Purari basin to 1) determine their diversity, and 2) identify significant species, habitats and ecosystems. The fauna is broadly consistent with that previously known from the southern foothills and lowlands of New Guinea, and there is high species overlap with the Kikori basin to the west and the Lakekamu basin to the east.

A total of 98 species of native herpetofauna was documented, including 41 species of frogs and 57 species of reptiles. The family Scincidae (skinks) dominated the reptile fauna, representing more than one third (38.5%) of the reptiles encountered, while the frog family Microhylidae dominated the frog fauna with 22 species out of 41 (54%).

The survey documented 15 species of frogs and three species of reptiles that are undescribed (previously known but unnamed) or new-to-science (discovered for the first time during this survey). However, 10 of these frogs and one of the reptiles have been previously documented from sites outside the study area. One of the new reptiles is a distinctive new species of snake discovered for the first time during this survey and currently known only from alluvial forest within the study area. Diversity at the eight principal survey sites ranged from 12–31 species/site for frogs and 15–22 species/site for reptiles. Site 9 in the Southeast Coast ecological zone had the lowest diversity of both frogs and reptiles.

No frogs or reptiles protected under PNG law or listed as Endangered or Critically Endangered by the IUCN were encountered during the study but nesting sites of the large IUCN Vulnerable freshwater turtles (Pig-nosed Turtle *Carettochelys insculpta* and Striped New Guinea Soft-Shell Turtle *Pelochelys bibroni*) were documented and mapped in the southern portion of PRL-15. The survey documented two frog species listed as Data Deficient by the IUCN: the ground-dwelling microhylid *Callulops marmoratus*, a species previously known only from the Crater Mountain Wildlife Management Area; and the canopy-dwelling treefrog *Litoria sauroni*, previously known only from the Kikori River basin.

An extremely high proportion of frog species documented during the survey (49%) have restricted ranges, and this pattern is evident across all ecological zones with the proportion of restricted-range species ranging from 33-59% across sites. The lowest proportion of restricted-range species was encountered in the extensively modified coastal habitats at Site 9. In contrast only 16.4% of reptiles have restricted ranges and no site had more than 25% of the fauna qualifying for restricted-range status.

The invasive Cane Toad (*Rhinella marina*) occurred at high densities around the Antelope 3 accommodation block, along forestry roads at Site 3 and in villages and gardens at both sites in the Southeast Coast ecological zone. The Antelope 3 toads appear to be an isolated population and a management program should be developed to exterminate this pest species at this site.

The Purari River and its tributaries comprise a near-unmodified river system that supports populations of freshwater turtles and crocodiles that are resources for local communities (turtles, New Guinea Freshwater and Estuarine Crocodiles) and are species of conservation concern (Pig-nosed Turtle, Striped New Guinea Soft-shell Turtle). Adjacent off-river waterbodies are important habitats for breeding by both New Guinea Freshwater and Estuarine Crocodiles.

Clear streams and small rivers in hill forest and alluvial forest support a small but distinct assemblage of frogs including two restricted-range, undescribed frogs of the genus *Hylarana* and the restricted-range treefrog *Litoria exophthalmia*. These species rely on permanent, clear-flowing streams and the humid, dense riparian vegetation along their banks. Small forest pools and seepages in foothill forest

support several species of treefrogs including two undescribed species (*Litoria* sp. 1 and *Litoria* 2), that are reliant on this particular microhabitat for reproduction.

Alluvial forest in the Delta Swamps and Plains and Southeast Coast ecological zones provide the only known habitat for a new species of snake (*Stegonotus* sp. 1) that is currently known only from the study area.

Many species encountered during this survey were restricted to the cool, moist interior of closed-canopy forest and microhylid frogs, a group comprising a high proportion of restricted-range species, rely on high levels of moisture and humidity for the successful development of their terrestrial embryos. Intact forest habitats are therefore important for maintaining the diversity of herpetofauna in the study area.

ACRONYMS AND ABBREVIATIONS

asl	Above sea level
CEPA	Conservation and Environment Protection Authority
CPF	Central Processing Facility
DD	Data Deficient (IUCN threat category)
EN	Endangered (IUCN threat category)
ERIAS Group	ERIAS Group Pty Ltd
ESHIA	Environmental, Social and Health Impact Assessment
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)
LNG	Liquefied Natural Gas
m	meters
mm	millimeters
NT	Near Threatened (IUCN threat category)
PNG	Papua New Guinea
PRL-15	Petroleum Retention License 15
Project	Papua LNG Project
sp.	abbrev. ‘species’ (singular)
spp.	abbrev. ‘species’ (plural)
study area	Upstream terrestrial biodiversity study area
SVL	snout to vent length
TEP PNG	Total E&P PNG Limited
Upstream PAOI	Upstream project area of influence
WMA	Wildlife Management Area

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 characterized by a specific geographical distribution of plants and/or animals.
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.
Community structure	The taxonomic composition of a community; species assemblage.
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*; (3) species listed under CITES Appendix I or II.
Endemic	Belonging exclusively or confined to a particular place.
Endemism	Describes the percentage or ratio of endemic taxa occurring in a place; e.g. a high level of endemism.
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.

1. INTRODUCTION

1.1. BACKGROUND

The following Project description is focused on the upstream components of the Papua LNG Project and aims at providing minimal but appropriate context for the baseline reports.

Joint venture partners are currently planning the development of the Elk-Antelope gas field, which is located within Petroleum Retention License 15 (PRL-15) in the Gulf Province, Papua New Guinea. Total E&P PNG Limited (TEP PNG), a wholly owned subsidiary of TOTAL S.A (TOTAL) has the largest interest in the Elk-Antelope gas field and is the operator of the Papua LNG Project (the Project) on behalf of the other joint venture partners.

The Elk-Antelope gas field is a significant gas discovery in Papua New Guinea consisting of a gas reservoir with several trillion cubic feet of gas reserves located approximately 120 km inland from the township of Kerema, and 340 km northwest of Port Moresby.

The Project will comprise upstream production well development and associated infrastructure at the gas field within PRL-15, construction of an upstream central processing facility (CPF) and delivery of gas and condensate via onshore and offshore export pipelines to a LNG Plant site at Caution Bay, Central Province, 20 km northwest of Port Moresby. The design life for the Project will be 25 years.

The Project area comprises the physical footprint of the various Project components and associated infrastructure as detailed below.

- Production, processing and related facilities (within PRL-15 and the export pipeline corridor):
  - Wellpads and the associated gathering system (including flowlines and trunkline).
  - Central Processing Facility (CPF).
  - Logistics base and river offloading facilities, accommodation camps, airstrip, roads and bridges.
  - Quarries, communications infrastructure.
  - Initial section of the onshore export pipeline.
- Onshore pipeline (outside PRL-15):
  - Remainder of the onshore export pipeline to landfall on the Gulf coast including valve stations.
  - Temporary laydown areas and camps.
  - Quarries, communications infrastructure.
- Transport (river) corridors:
  - River transport routes—the Purari, Urika-Ivo and Wame-Varoi rivers.
- Offshore pipeline:
  - Offshore section of the export pipeline to a LNG Plant site, Caution Bay.

As part of the Project environmental, social and health impact assessment (ESHIA), a Terrestrial Biodiversity Study has been commissioned to provide a baseline characterization of terrestrial biodiversity and conservation values present in the vicinity of the upstream Project area. This report

presents the results of the technical study on herpetofauna conducted as part of the Upstream Terrestrial Biodiversity Study.

1.2 UPSTREAM TERRESTRIAL BIODIVERSITY STUDY AREA AND ECOLOGICAL ZONES

The upstream terrestrial biodiversity study area (hereafter 'study area') covers approximately 7,290 km^2 of the Gulf Province lowlands (to c. 600 m above sea level (asl)). The study area is divided into five ecological zones (Middle Purari Hills, Southeast Hills, Southeast Coast, Delta Swamps and Plains and Mangroves), each of which is expected to support a distinct assemblage of terrestrial biota.

The study area encompasses the upstream Project area of influence (upstream PAOI), the area within which the Project may potentially and measurably impact biodiversity. The terrestrial biodiversity field surveys were focused at representative sites within the upstream PAOI, hereafter referred to in this report as survey sites. Further description of the PAOI is provided in the main Upstream ESBS report and is no longer referred to in this report.[1]

The study area and its component ecological zones are shown in Figure 1. They are described in more detail in the Upstream Terrestrial Biodiversity Baseline Report.

[1] The boundary of the PAOI is shown in figures for context only.

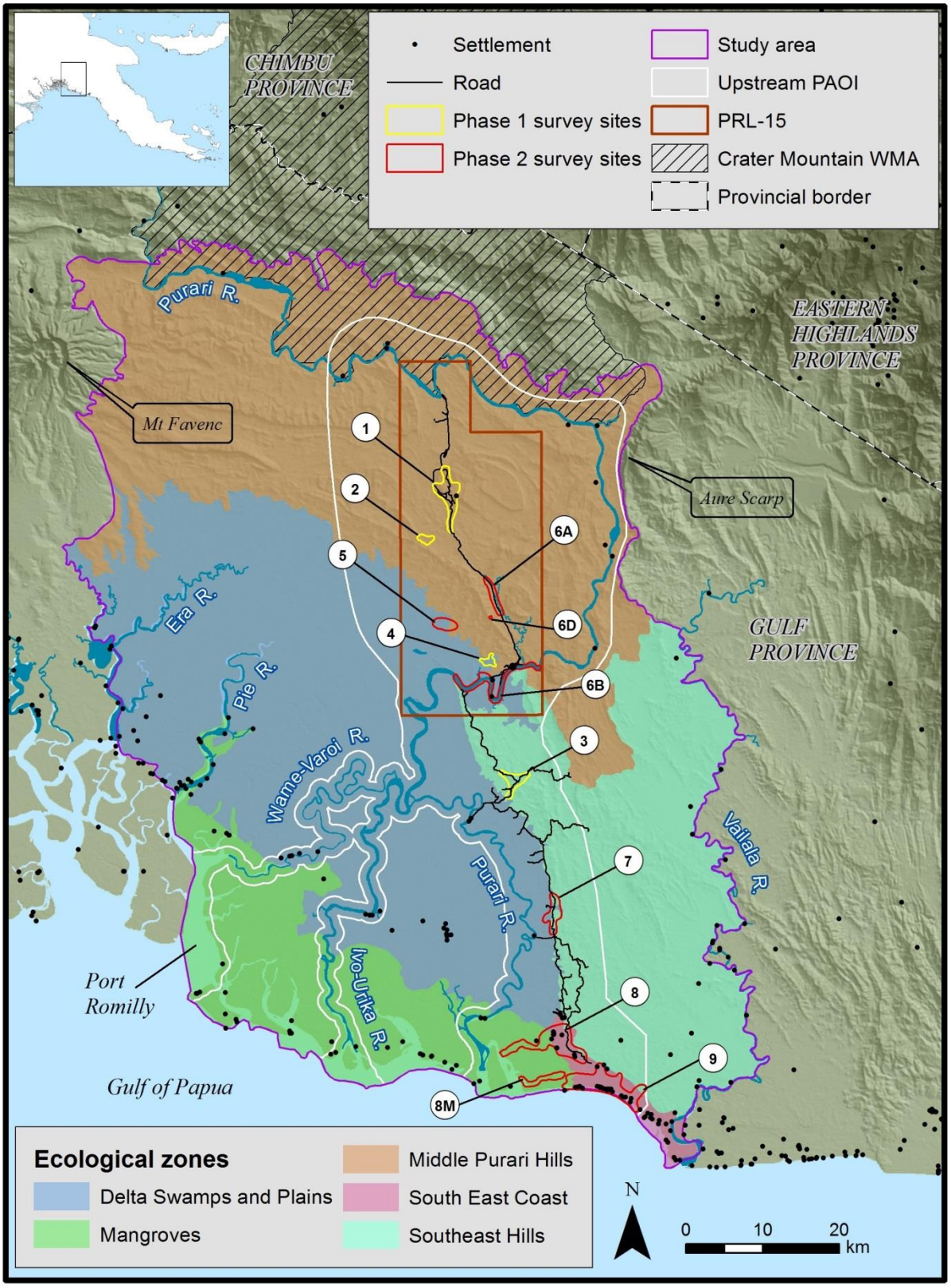

Figure 1. The study area and its component ecological zones, the upstream PAOI and the location of Phase 1 and 2 upstream terrestrial biodiversity study survey sites (i.e. labelled as 1 – 5; 6A, B & D; 7; 8 & *M; and 9). Not all sites were surveyed under the herpetofauna technical study. Information on the sites surveyed is presented in Section 3.2.

1.3. TECHNICAL STUDY OBJECTIVES

The objectives of this technical study are:

- To collate and assess existing information relevant to herpetofauna communities in the vicinity of the study area.
- To survey herpetofauna communities present in the study area.
- To describe and discuss the composition, condition and conservation significance of herpetofauna 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 herpetofauna communities.
  - The presence of non-native herpetofauna species.
- To summarize knowledge gaps in relation to herpetofauna communities present within the study area.

2. EXISTING INFORMATION

The herpetofauna of New Guinea is exceptionally diverse, with the 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. 2016).

Few collections of herpetofauna have been made in the Purari basin. Liem and Haines (1977) listed the reptile and frog species known to that date from the Purari-Kikori mangrove areas and, although their study was limited to the lower deltaic area it provides valuable observations on the importance of several larger herpetofauna species, particularly turtles, as a resource for local communities. In 1979 Pernetta and Burgin (1980) surveyed crocodiles in aquatic habitats between the Purari Delta and a proposed reservoir near Wabo for the Wabo Hydroelectric Scheme project, and during these surveys they observed a nest of the Pig-nosed turtle (*Carettochelys insculpta*), a conservation-priority (IUCN Vulnerable) species. They also prepared a checklist of herpetofauna known from the Purari River area based on the results reported by Liem and Haines (1977), their own opportunistic encounters with other reptiles during the crocodile surveys, and records of additional herpetofauna species from the Purari area (many by J. I. Menzies) that are held in the Natural Sciences Collection at the University of PNG. Although it is now substantially out of date, both in content and in the nomenclature used, that list remains the only attempt to summarize the herpetofauna of the Purari catchment and it also provides valuable data on crocodile populations and their exploitation in the Purari River at that time.

Little herpetological work has since been undertaken within the study area. Dr Christopher Austin from the Louisiana State University surveyed herpetofauna in the vicinity of Wabo during 2009 but no schedule or species lists have been published. A series of studies commissioned for the development of the Elk-Antelope gas field produced limited information about the herpetofauna of the region. Previous studies within PRL-15 (DES 2008, 2010) two unpublished, undertook a series of herpetofauna surveys in the lower Purari River catchment. Although survey effort during those studies was low, and the lack of taxonomic expertise resulted in many species remaining unidentified, they did provide new distributional records for a number of frog and reptile species. Between 2011 and 2012 a series of three herpetofauna surveys was undertaken at 11 sites across the northern

study area in support of a proposed hydro-electric dam baseline study. That study produced the most detailed and accurate assessment of herpetofauna that has been conducted within the study area to date, but unfortunately the data are not available for use and no further reference can be made to the locations or results of those surveys.

A number of herpetofauna surveys to the east and west of the Purari River are relevant to the present study. They include a two month survey of the Lakekamu basin approximately 150 km to the east of the Purari catchment (Allison et al. 1998) that documented 30 species of frogs and 44 species of reptiles, up to 14 of them new-to-science (e.g. Oliver et al. 2008); and a series of surveys between 1999 and 2003 (Richards 2000, 2002a and b; Richards & Allison 2003) conducted in the Kikori basin about 100 km to the west of the Purari River. Some of the results of those surveys were summarized by Richards (2002b) but the total number of frogs known from the Kikori basin has nearly doubled since that publication (Richards, unpubl. data). Recent studies on the ecology of, and harvesting pressure on, the large freshwater turtle *Carettochelys insculpta* in the Kikori River catchment (Eisemberg et al. 2015) are also relevant to the Purari population of this conservation-priority species.

To the north of the study area, researchers associated with the Wildlife Conservation Society conducted intensive studies on frogs in the Crater Mountain Wildlife Management Area (WMA) during the 1990s that led to the discovery of a number of species new-to-science (e.g. Kraus & Allison 2003). These studies highlight the potential for additional undescribed taxa to be found in the hill zone in the north of the study area.

Despite these efforts, overall coverage of the study area remains incomplete, with herpetofaunal communities of swamp forest and littoral habitats particularly poorly known.

3. METHODS

3.1. SURVEY SITES AND TIMING

The study area is centered on the Purari River catchment in Gulf Province, PNG. It covers an extensive area of intact forest ecosystems, and human population density remains low in most areas. The geographical extent and ecological zonation of the study area and a detailed summary of the physical environment, including climatic regimes within the catchment, is presented in the Upstream Terrestrial Biodiversity Baseline Report.

Intensive herpetofauna surveys were conducted from eight camps in the study area (i.e. principal sites being Sites 1–5, and Sites 7, 8 and 9) and four additional ‘minor’ sites (i.e. Sites 6A, 6B, 6D and 8M) were accessed briefly (1–2 days) from site 5 camp. Surveys were conducted in two phases separated by a period of approximately five months. The coordinates, elevations, survey schedule, and search effort at each of the sites surveyed are presented in Table 1 and survey trails at each site are presented in Figures 2–7. Coordinates were recorded using the datum PNG94.

Table 1. Locations, schedule and search effort at each of the survey sites.

Location	UTM PNG94-55S		Alt (m asl)	Arrival	Departure	Trails (m asl)		Search Effort (Man hours)		
						Min	Max			
Phase 1	**Easting**	**Northing**						**Day**	**Night**	**Total**
Site 1	294689	9209644	100	19 Jan, 15:30	27 Jan, 09:00	50	170	140.4	73.3	213.7
Site 2	291894	9202769	95	27 Jan, 09:15	2 Feb, 10:00	55	120	93	52.1	145.1
Site 3	303459	9171560	130	2 Feb, 10:15	9 Feb, 10:45	80	170	102.5	61.7	164.2
Site 4	300251	9186944	30	9 Feb, 11:00	16 Feb, 10:45	15	30	103.8	53	156.8
Phase 2	**Easting**	**Northing**						**Day**	**Night**	**Total**
Site 5	294432	9191260	20	21 Jun, 17:00	2 Jul, 09:20	20	20	132.5	51.5	184
Site 6A	300655	9195465	n/a	27 Jun, 10:15	27 Jun, 16:10	30	50	11.75	0	11.75
				28 Jun, 08:20	28 Jun, 15:00			12.7	0	12.7
Site 6B	299876	9184880	n/a	25 Jun, 10:00	25 Jun, 15:00	5	30	10	0	10
Site 6D	300280	9192765	n/a	26 Jun, 10:15	26 Jun, 16:00	185	250	11.5	0	11.5
Site 7	308305	9153930	15	2 Jul, 09:30	9 Jul, 12:25	5	30	118.7	51.5	170.2
Site 8	308835	9138610	5	9 Jul, 12:40	15 Jul, 09:20	0	15	75.5	32.75	108.25
Site 8M	M1 309575 M2 309180 M3 308595	9133025 9132980 9132770	n/a	11 Jul, 08:45	11 Jul, 12:00	0	5	3.25	0	3.25
Site 9	315970	9131180	0	15 Jul, 09:30	19 Jul, 13:45	0	5	75	26	101
Total man hours										**1,243.25**

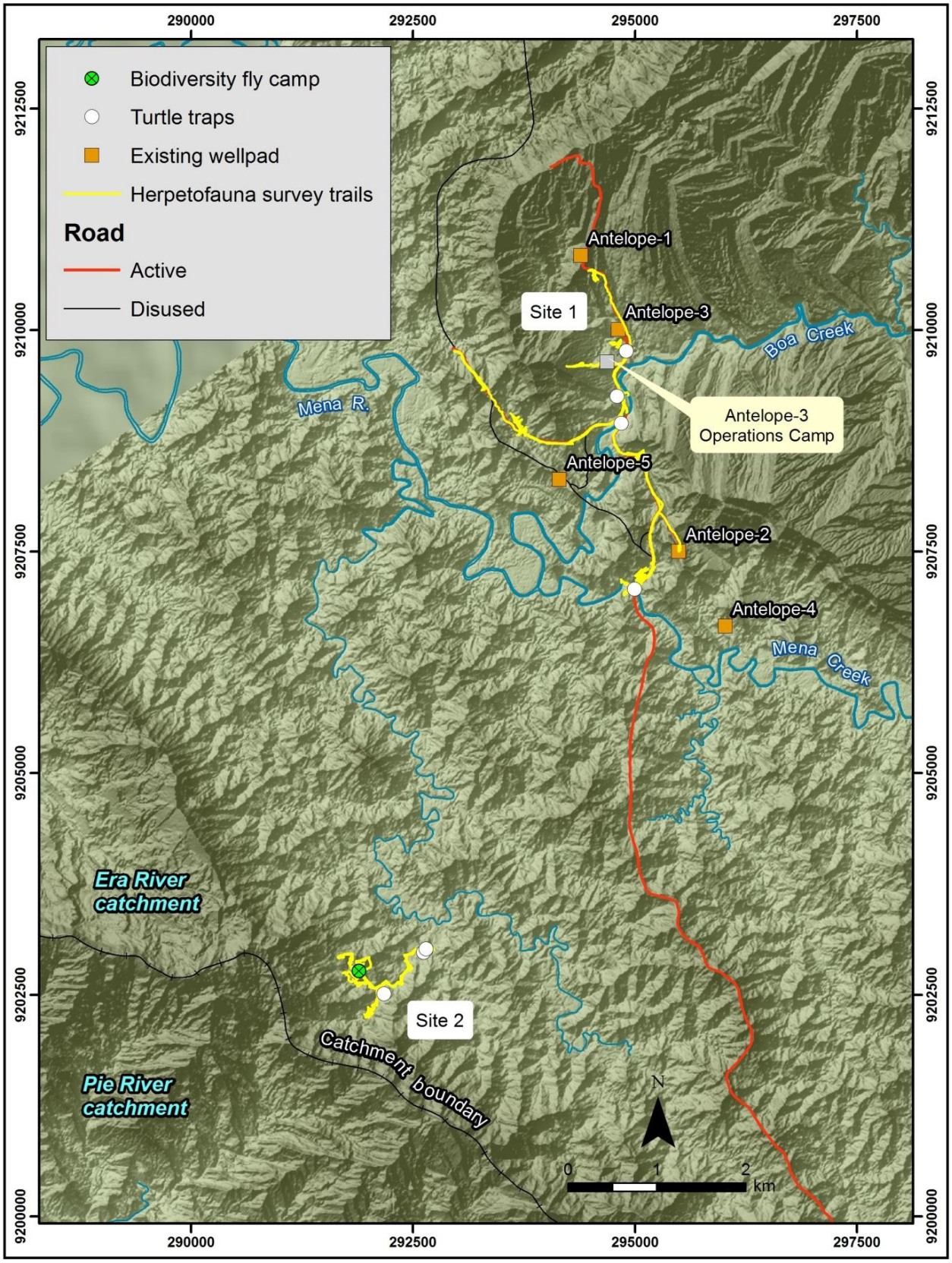

Figure 2. Herpetofauna survey trail coverage and location of turtle traps at Sites 1 (above) and 2 (below).

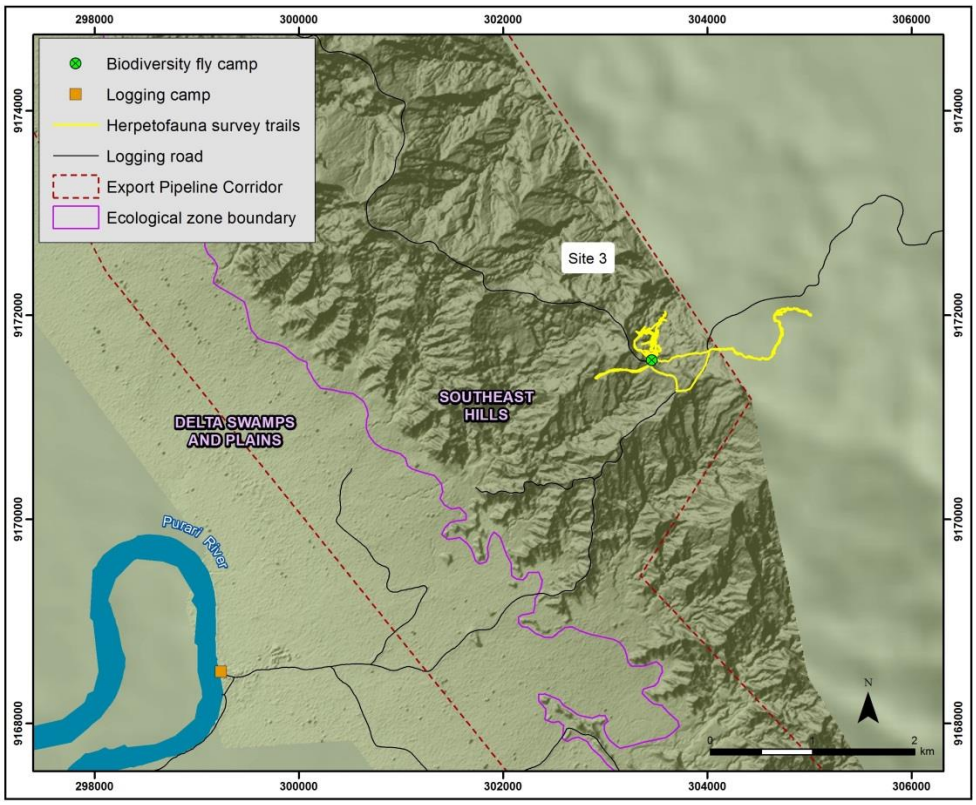

Figure 3. Herpetofauna survey trail coverage at Site 3.

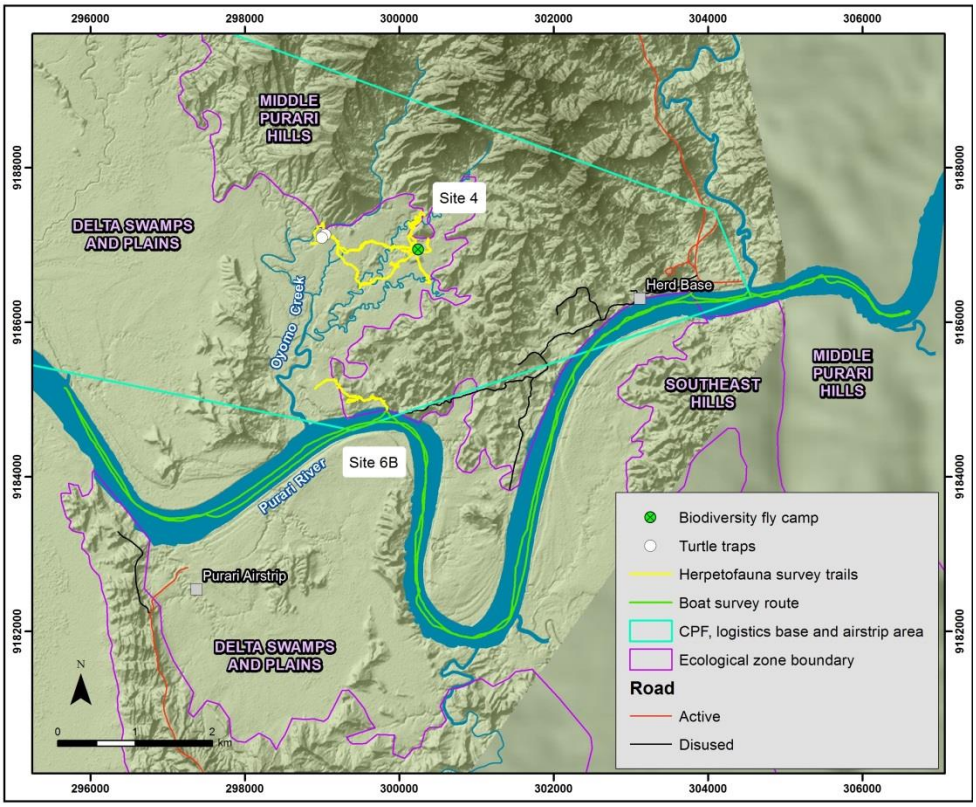

Figure 4. Herpetofauna survey trail coverage and turtle trap locations at Sites 4 and 6B and boat survey route taken to document nesting sites of crocodiles and IUCN Vulnerable turtles.

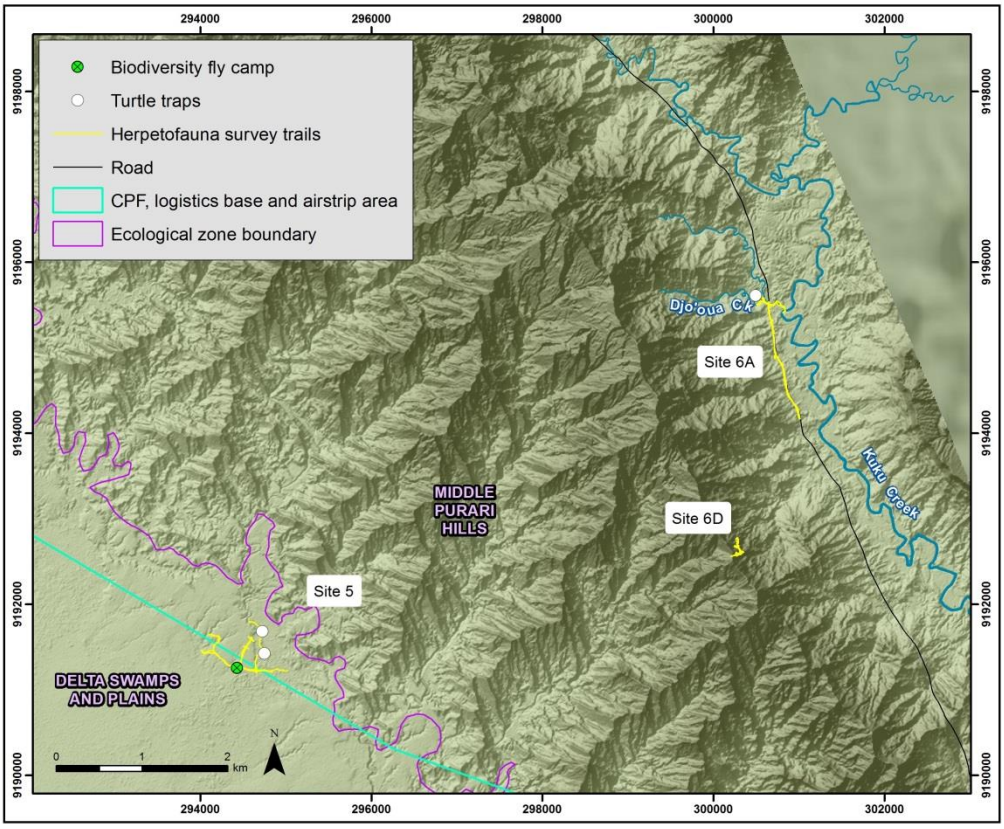

Figure 5. Herpetofauna survey trail coverage and location of turtle traps at Sites 5,6A and 6D.

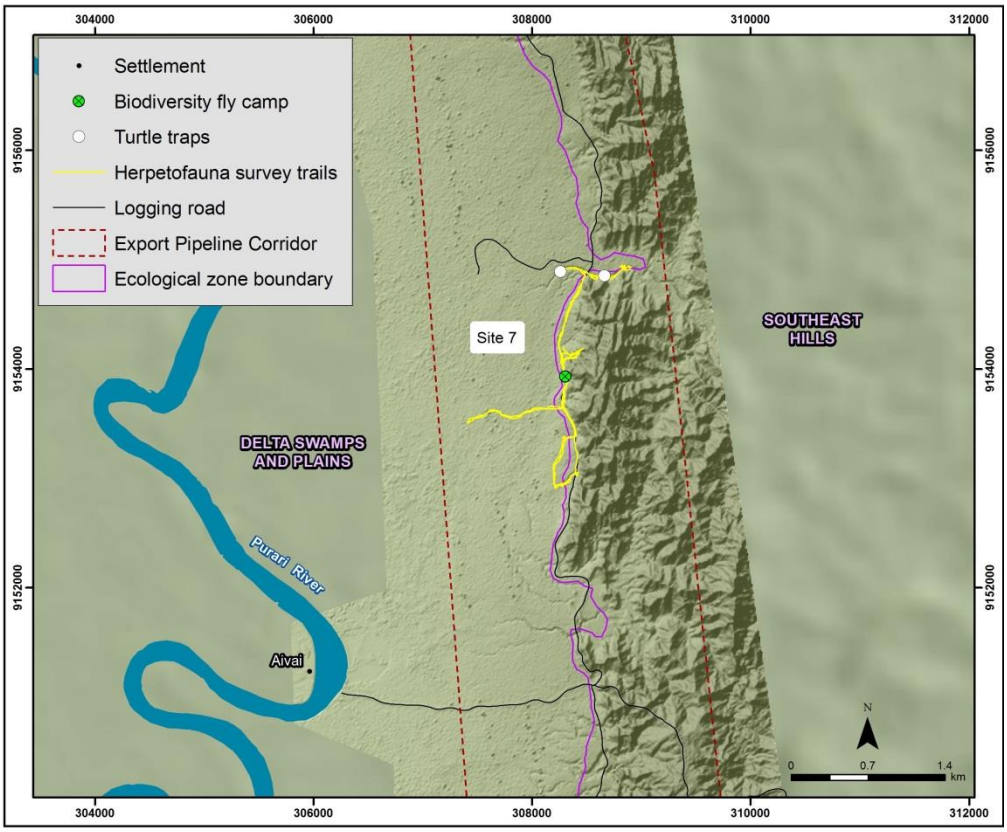

Figure 6. Herpetofauna survey trail coverage and location of turtle traps at Site 7.

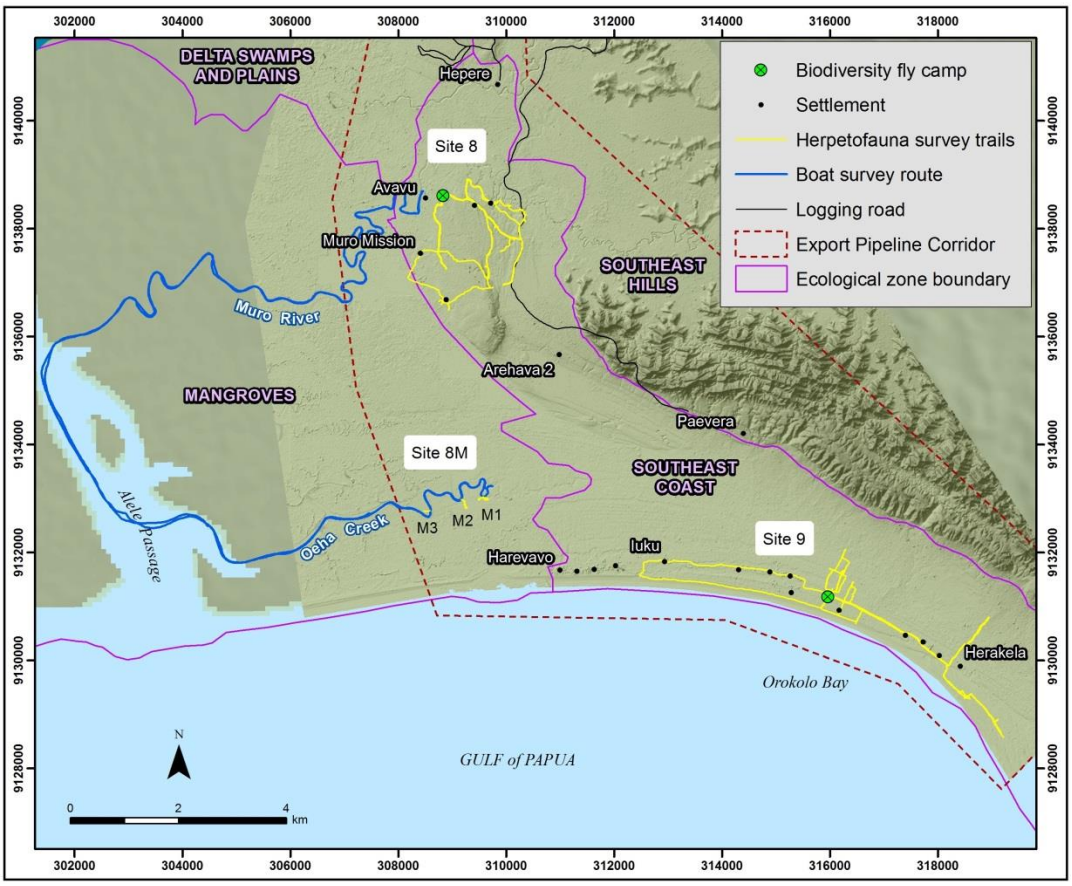

Figure 7. Herpetofauna survey trail coverage at Sites 8, 8M and 9.

3.2. VEGETATION AND HABITAT FEATURES PERTINENT TO HERPETOFAUNA AT EACH SITE

Detailed vegetation characteristics for each site are presented by Venter et al. (2016) and only specific habitat issues relevant to the herpetofauna are discussed further here.

Vegetation types are referred to in the text using a set of FIMS-equivalent terms developed specifically for the Upstream Terrestrial Biodiversity Study. These follow closely the formal FIMS descriptors; they are based on the founding vegetation descriptions (Paijmans 1976; Hammermaster & Saunders 1995) but are generally less cumbersome.

Where a specific vegetation type is referred to in the text it is capitalized and followed in brackets by its FIMS code, for example ‘Hill forest (Hm)’ and ‘Open alluvial forest (Po)’. Specific vegetation types surveyed at each site are listed below. In most cases, however, more general terms are used that apply to multiple possible variants within the study area (and more widely in PNG). These appear without capitals or a FIMS code, for example ‘hill forest’ and ‘alluvial forest’. These generic descriptors follow the various basal FIMS vegetation types, in these examples coded ‘H’ and ‘P’ respectively.

A full list of FIMS vegetation types present within the study area, and equivalent terms used in the Terrestrial Biodiversity Study, is presented in the Upstream Terrestrial Biodiversity Baseline Report.

Site 1 was located in Hill forest (Hm) in the upper Era River catchment in the Middle Purari Hills ecological zone (Figures 1, 2). Road transport at this site provided access to a broader geographical area than was available at most other sites (Figure 2) and the main focus at Site 1 was to survey the Elk-Antelope gas field. This site provided access to large water courses at Boa Creek and Mena Creek, and numerous small, clear tributary streams drain into these larger water bodies within the surveyed area. A number of temporary ponds that had formed as a result of road construction and other infrastructure development provided additional aquatic habitats for a number of frog species.

Site 2 was in Hill forest (Hm) in the Mena basin headwaters of the upper Era River catchment in the Middle Purari Hills ecological zone (Figures 1, 2). Located near the divide between the Era and Pie River catchments this site gave access to the proposed trunkline west route option. Aquatic habitats at this site were restricted to a shallow stream adjacent to the camp, and numerous very small (<2 m wide) seepages and creek-lines that flowed mainly after rain.

Site 3 was in Hill forest (Hm) in the Southeast Hills ecological zone, about 2.5 km from the border with the Delta Swamps and Plains (Figures 1, 3). Located about 8 km northeast of Evara village on the Purari River, it provided access to habitats in the northern section of the proposed export pipeline corridor. The forest in this area had been extensively logged and water was scarce, being restricted to several small (~2–5 m wide), clear and shallow (<30 cm deep) streams among deeply dissected ridges. A number of creek-lines were nearly dry, with water restricted to isolated rock-pools in the creek-bed.

Site 4 was in Open alluvial forest/Swamp forest with isolated patches of Hill forest (Po/Fsw/Hm) in the Delta Swamps and Plains ecological zone, near the border with the Middle Purari Hills (Figures 1, 4). This eastern 'CPF, logistics base and airstrip area' includes the area proposed for development of the CPF as evidenced by the series of geotechnical test pads east of the Site 4 fly camp. The area is dominated by alluvial forest and a variety of shallow, freshwater swamp habitats. Numerous shallow streams traverse the alluvial forest and a larger stream to the west of camp was sufficiently deep to be a potential habitat for freshwater turtles.

Site 5 was also in Open alluvial forest/Swamp forest with isolated patches of Hill forest (Po/Fsw/Hm) in the Delta Swamps and Plains ecological zone. The extensive areas of Hill forest (Hm) to the east of camp in the Middle Purari Hills were accessed only briefly during herpetofauna surveys (Figure 5). A complex of shallow, inter-connected freshwater swamp habitats to the west of camp provided habitat for a suite of swamp-dwelling frogs, and a large stream to the east of camp was sufficiently deep to provide habitat for freshwater crocodiles.

Site 6A was in Hill forest (Hm) in the Middle Purari Hills and sampling was restricted to moderately disturbed forest in the vicinity of a Project road that runs parallel to Kuku Creek; to several small, clear tributaries of Kuku Creek with sandy and rocky substrates that intersect the road; and to the banks of the main channel of Kuku Creek (Figure 5).

Site 6B straddled two ecological zones, the Middle Purari Hills in the east and the Delta Swamps and Plains in the west. The Hill forest (Hm) at the eastern edge of the site was characterized by a series of steep slopes near the Purari River that were drained by small, clear-flowing streams and this habitat graded into Open alluvial forest/Swamp forest with isolated patches of Hill forest (Po/Fsw/Hm) where the terrain was flatter and streams were more sluggish. A boat-based survey to document and map nesting sites of crocodiles and the IUCN Vulnerable Pig-Nosed Turtle and Striped New Guinea Soft-Shell Turtle was conducted along the main channel of the Purari River upstream and downstream of Site 6B in the southern portion of PRL-15 (Figure 4).

Site 6D was on a steep ridge in Hill forest (Hm) in the Middle Purari Hills (Figure 5). Much of the forest at this site was heavily disturbed from slumping of terrain. Important habitats for herpetofauna included several small, shallow seepages and a larger (>5m wide) steep but shallow stream with reduced canopy cover due to a major land slip.

Site 7 was in Small crowned hill forest (Hs) and Open Alluvial forest (Po) on the border of the Southeast Hills and the Delta Swamps and Plains ecological zones (Figure 6). The forest in this area had been extensively logged. Several small (~2–5 m wide), clear and shallow (<30 cm deep) streams with rocky and sandy substrates drained the deeply dissected ridges to the east of camp. A larger creek approximately 1 km north of the camp was sufficiently deep to provide habitat for freshwater crocodiles. All streams draining the Southeast Hills became slow-flowing and muddier within 1–200 m of entering the Delta Swamps and Plains, and aquatic habitats in this zone were dominated by sluggish streams, isolated forest pools and shallow swampy habitats.

Site 8 was in the Southeast Coast ecological zone. Although classified as Alluvial forest (Pl) the areas surveyed had been extensively modified for village houses, for village gardens, and by extensive logging. A small area of Hill Forest (Hm) in the Southeast Hills ecological zone south of the fly camp (Figure 7) was visited only briefly. Aquatic habitats included the large, navigable Muro River, and a number of smaller tributary streams, the flow rates of which were influenced by tidal movements. The riparian vegetation along most streams in this area had been severely modified, or substantially or entirely removed, for construction of gardens. A series of swamps adjacent to the fly camp that were dominated by sago palms (*Metroxylon sagu*) provided habitat for a suite of swamp-dwelling frog species.

Site 8M comprised three sites in the Mangroves ecological zone that were accessed briefly by boat from Site 8. Located on Oeha Creek, mangrove sites M1–3 were within the proposed pipeline route corridor, 1.3–1.5 km from the coast (Figure 7).

Site 9 was also in the Southeast Coast ecological zone (Figures 1, 7). Most of the area is classified as Land use (O). The fly camp was located adjacent to the foreshore in Orokolo Bay. Coconut Palms dominate the foreshore vegetation and provide habitat for a number of arboreal reptile species. A series of drainage channels running parallel to the coast north of the camp provided aquatic habitats for a number of frog species, and these overflowed and flooded the forest floor after heavy rain. A series of freshwater wetlands was present within the beach dune system at the eastern edge of the bay, and these pools and swamps provided additional aquatic habitat for frogs. Mangrove vegetation (M) was accessed briefly at both the eastern and western end of the bay.

3.3. SURVEY METHODS

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 site intensive searches for frogs and reptiles were conducted along the trails illustrated in Figures 2–7 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 whenever possible the advertisement calls of frogs were recorded with an Edirol R05 Solid-state Recorder and a Marantz PMD-661 Recorder and Sennheiser ME66 microphone.

Most species were photographed alive before preparation of representative samples as voucher specimens.

Baited turtle traps were utilized at all sites where water bodies were 1) deep enough to provide suitable habitat for freshwater turtles, and 2) were small enough to be safe from large Estuarine Crocodiles (*Crocodylus porosus*) (Figures 2, 4–6). Conditions were unsuitable for turtle trapping only at Sites 3, 8, 6B, 6D, 8M and 9.

Nesting sites of conservation-significant freshwater turtles along the Purari River in the southern portion of PRL-15 were mapped from a boat on 25th June 2016 using information from two local Pawaian residents who have hunted turtles and collected eggs from these sites. Although it cannot be discounted that other nesting sites occur, our approach in using knowledgeable local nest-harvesters was to maximize the chances that most if not all nesting sites in that area were documented.

3.4. SURVEY EFFORT

Herpetofauna surveys at the eight principal sites totalled 1,243.25 man-hours of survey effort, comprising 841.4 man-hours during daylight hours and 401.85 man-hours at night (Table 1). Survey effort varied from 101.0–213.7 man-hours per site, with Site 1 having the highest, and Site 9 the lowest survey effort. This variation reflected differences in total days available for sampling at each site. Sites 6A, 6B, 6D and 8M were visited only briefly and sampled for less than 25 man-hours each.

3.5. INTERVIEWS

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

3.6. VOUCHER MATERIAL

Specimens required for vouchers to permit accurate identification were euthanized using internationally recommended techniques; by submersion in chlorotone for frogs (McDiarmid 1994), or with lethal injection of chlorotone for reptiles (Barry 2012). Specimens were fixed in 10% formalin solution, and then stored in 70% ethanol. Voucher specimens were exported under permit numbers 016026 and 016115 from 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. Measurements (in mm) are snout-to-vent length (SVL) except turtles for which carapace lengths are reported.

3.7. PROTOCOLS USED

3.7.1. 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 *Hylophorbus* (e.g. Günther 2001, Richards & Oliver 2007) and *Oreophryne* (e.g. Zweifel et al. 2005) which both 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: *Carlia* cf. *luctuosa*. 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, *Cophixalus* sp. 1, *Cophixalus* sp. 2. The numeric system is used where taxonomic identity is confidently resolved and the species is scientifically undescribed. Distinction is made between: (a) species newly discovered during the Papua LNG surveys ('new-to-science') and therefore presently known only from within the study 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 'new-to-science' where they were discovered for the first time during the Papua LNG Project survey, and 'undescribed' if they remain scientifically unnamed but were previously known from either within, or outside of, the study area.

Microhylid frogs previously included in the genus *Albericus* are here included in the genus *Choerophryne* following Peloso et al. (2015) and Hylidae is used instead of Pelodryadidae for consistency with IUCN (2016).

Taxonomic and ecological statements presented without supporting documentation are based on the specialist's extensive expertise of the New Guinean herpetofauna.

3.7.2. Conservation status

The conservation status of each species encountered was determined using the internationally recognized IUCN Red List of Threatened Species (IUCN 2016), the PNG *Fauna (Protection and Control) Act 1966* and the Convention on International Trade in Endangered Species (CITES).

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). Three additional categories used in this report are Near Threatened (NT), Least Concern (LC) and, for those species for which data are insufficient to reach a conclusion, Data Deficient (DD). The definitions of Red List categories relevant for this study are presented in the Baseline Characterization Report. 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, Near Threatened or Data Deficient, to those species listed as Protected under PNG law and to those species listed under Appendices I and II of the Convention on International Trade in Endangered Species (CITES).

3.8. ANALYSIS

3.8.1. Accumulation curves

Species accumulation curves were constructed for frogs and reptiles separately, for each complete day and night of sampling at each site.

3.8.2. Calculating endemism

Each species was given an endemism code of 1–5 based on their known extents of distribution. The scoring system employed to produce these codes was developed for the Terrestrial Biodiversity Study by the biodiversity team based on their extensive experience conducting biodiversity studies throughout PNG and is presented in Table 2. Each site was then assessed for its significance as an area of high endemism based on the percentage of species at the site with codes of 1–5.

Geographic range estimates are provided for potential restricted-range species, defined as those with an area of occupancy of less than 50,000 km^2. Conservative maximum ranges were estimated in

ArcGIS using digital elevation models (DEM; provided by TEP PNG), landform (Bryan & Shearman 2008) and vegetation mapping (PNG FIMS) and based on information about distribution and habitat preferences, including terrain, vegetation types and elevations of prior available records.

Table 2. Endemism codes used to assess levels of endemism of herpetofauna species

Code	Definition
1	Occurs more widely in the Indo-Pacific
2	Endemic to New Guinea, its satellite islands, the Bismarcks and Maluku
3	Endemic to New Guinea and its satellite islands (Waigeo, Misool, Yapen, Biak, Aru, d'Entrecasteaux and Louisiades)
4	Endemic to mainland New Guinea
5	Endemic to southern mainland New Guinea, south of the central cordillera, and the southeast peninsula but not occurring west of Huon Gulf.

4. RESULTS/DISCUSSION

4.1. SPECIES DIVERSITY

A total of 98 species of native herpetofauna was documented during the Project surveys, including 41 species of native frogs and 57 species of reptiles. A further 21 species including 8 frogs and 13 reptiles were previously known from the study area (Appendix 1) bringing the total number of species known from the study area to 119. One introduced frog, the Cane Toad (*Rhinella marina*), was also encountered at four sites. It is not considered in the analyses of frog diversity below. During the present surveys, the family Microhylidae dominated the frog fauna with 22 species out of 41 (53.7%) while the family Scincidae (skinks) dominated the reptile fauna, representing 21 (38.5%) of the reptiles encountered.

Additional restricted range or other significant species that are known to, or might occur in the project area were also identified and each of them is treated in detail. Additional common, widespread species known to occur but not encountered during the Project surveys are listed in Appendix 1 but not treated further.

4.1.1. Frogs

Frog diversity varied across the eight principal sites with the highest diversity encountered at Site 1 (31 species) and the lowest total at Site 9 (12 species: Table 3). Site 1 also had the highest (213.7 man-hours), and Site 9 the lowest (101 man-hours), search effort among these sites. Total frog diversity reported from all sites (41) is higher than that known from other areas in the southern lowlands of PNG (Allison et al. 1998), and this probably reflects the access to multiple sites and habitats across a broad section of the basin during this study.

The frog fauna encountered during this project is dominated by species known to have distributions that extend outside the Purari basin, and this includes at least 10 of the 15 undescribed species documented during the survey (Section 4.3). For example, at least 13 of the 41 species documented during this survey (31.7%) are shared with the Lakekamu basin about 140 km to the east of the study area, and 23 species (56.1%) are shared with the lowlands of the Kikori basin around Kopi, about 100 km to the west. Given that the Lakekamu and Kopi studies were conducted over much smaller areas and so documented fewer species (Allison et al. 1998; Richards 2002a) the overlap in species among these three areas is probably much higher. For example, the proportion of species found at Lakekamu and Kopi that were also found in the study area is 43% and 79% respectively and these percentages are likely to increase when the taxonomic status of a number of species from Lakekamu

and the Kikori basin are reassessed. This broad similarity with adjoining regions is further reflected in the similar compositions of the fauna at the family level at these three locations (Table 4).

Species accumulation curves for five of the eight principal survey sites (Figure 8) do not reach an asymptote, but the majority of species had been detected at each site after 4–5 days of sampling. More sampling at sites 1, 3, 4 and 7 is likely to document additional species, and this is particularly true for Sites 3, 4 and 7 where the accumulation curves remain steeper than at Site 1. However, rates of species accumulation had slowed sufficiently at these sites to suggest that the majority of species had been detected under the weather conditions experienced. Furthermore, similar environments were sampled again after the El Nino during Phase 2 and so any potential gaps are covered.

Failure to reach an asymptote is not unexpected in a large tropical forest area expected to support a diverse frog assemblage. Furthermore, surveys at sites 1–4 were conducted at the end of a major El Nino event when rainfall, and associated frog vocal activity, were uncharacteristically low. Although there were also multiple survey nights without rain during surveys at sites 5–9, these were conducted during the slightly wetter 'southeast (trade winds) season' and three factors indicate that a large proportion of the frog fauna was documented: 1) most species had been documented at each site after 4–5 days of sampling (Figure 8); 2) the total number of species documented is 25% higher than that documented in the Lakekamu basin to the east and the Kikori lowlands to the west (Table 4); and 3) after excluding reports of species that require expert verification, the studies of Liem and Haines (1977), Pernetta and Burgin (1980), Douglas Environmental Services (DES 2008, 2010), and data from two unpublished studies add just eight frog species (equivalent to 19.5% of the species encountered during the present study) to the total known frog fauna of the study area.

Table 3. Frogs documented at 10 sites in the study area, their IUCN status, endemicity codes and restricted-range status. No frogs were detected during daytime surveys at Sites 6B or 8M.

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6A	Site 6D	Site 7	Site 8	Site 9	IUCN Status	Endemism*	RR**
Frogs													
Hylidae													
Litoria auae	X	X	X	X	X			X	X		LC	5	No
Litoria caerulea			X	X					X	X	LC	1	No
Litoria chloristona	X		X		X			X	X		NE	5	Yes
Litoria congenita										X	LC	3	Yes
Litoria exophthalmia	X	X						X			LC	5	Yes
Litoria infrafrenata	X	X	X		X			X	X	X	LC	1	No
Litoria pronimia	X	X									LC	5	No
Litoria prora				X							LC	5	No
Litoria pygmaea				X							LC	3	No

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6A	Site 6D	Site 7	Site 8	Site 9	IUCN Status	Endemism*	RR**
Litoria sauroni	X	X	X	X				X			NE	5	Yes
Litoria thesaurensis			X	X	X			X		X	LC	1	No
Litoria sp. 1		X	X								NE	5	Yes
Litoria sp. 2	X	X									NE	5	No
Limnodynastidae													
Lechriodus melanopyga			X	X	X			X			LC	3	No
Microhylidae													
Austrochaperina derongo	X	X	X	X				X			LC	4	No
Austrochaperina palmipes	X	X	X								LC	3	No
Austrochaperina sp. 1	X										NE	5	Yes
Callulops doriae	X	X	X		X			X			LC	3	No
Callulops marmoratus	X	X	X	X				X			DD	5	Yes
Choerophryne sp. 1	X										NE	5	Yes
Cophixalus cheesmanae	X										LC	5	No
Cophixalus sp. 1	X	X	X								NE	5	Yes
Cophixalus sp. 2	X	X			X			X	X		NE	5	Yes
Cophixalus sp. 3	X	X	X	X		X	X	X			NE	5	Yes
Copiula guttata	X	X	X	X	X			X	X	X	LC	5	Yes
Copiula sp. 1	X	X	X	X	X			X	X		NE	5	Yes
Hylophorbus rufescens	X	X	X	X	X						LC	5	No
Hylophorbus sp. 1	X							X	X	X	NE	5	Yes
Mantophryne lateralis	X	X	X	X				X	X	X	LC	3	No
Metamagnusia slateri	X	X	X	X	X	X	X	X	X	X	LC	5	Yes
Oreophryne oviprotector	X	X		X	X						NE	5	No

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6A	Site 6D	Site 7	Site 8	Site 9	IUCN Status	Endemism*	RR**
Oreophryne pseudunicolor	X	X	X	X	X			X	X	X	NE	5	Yes
Oreophryne sp. 1				X				X	X		NE	5	Yes
Oreophryne sp. 2	X												Yes
Sphenophryne cornuta	X	X	X	X	X			X	X	X	LC	4	No
Xenorhina sp. 1	X	X	X	X	X		X	X	X		NE	5	Yes
Ranidae													
Hylarana daemeli	X	X	X	X	X	X		X	X	X	LC	1	No
Hylarana novaeguineae			X	X	X						LC	5	No
Hylarana sp. 1	X	X		X							NE	5	Yes
Hylarana sp. 2	X	X	X	X				X			NE	5	Yes
Hylarana sp. 3			X	X	X			X	X	X	NE	5	No
Bufonidae													
*Rhinella marina****	X		X						X	X	LC	1	No
TOTAL NATIVE SPECIES: 41	**31**	**26**	**26**	**25**	**18**	**3**	**3**	**24**	**16**	**12**			

*Descriptions of Endemism Codes are provided in Table 2.
**RR = restricted-range; known from an area <50,000km^2.
***Non-native.

Table 4. Numbers and percentages of frog species in each major family documented during this study, and at Lakekamu and Kopi (see text for details).

Frogs	Purari #	Purari %	Lakekamu #	Lakekamu %	Kopi #	Kopi %
Hylidae	13	31.7	10	33.33	6	20.69
Limnodynastidae	1	2.4	1	3.33	1	3.45
Microhylidae	22	53.7	15	50	18	62.07
Ranidae	5	12.2	4	13.3	4	13.79
TOTAL	**41**	**100**	**30**	**100**	**29**	**100**

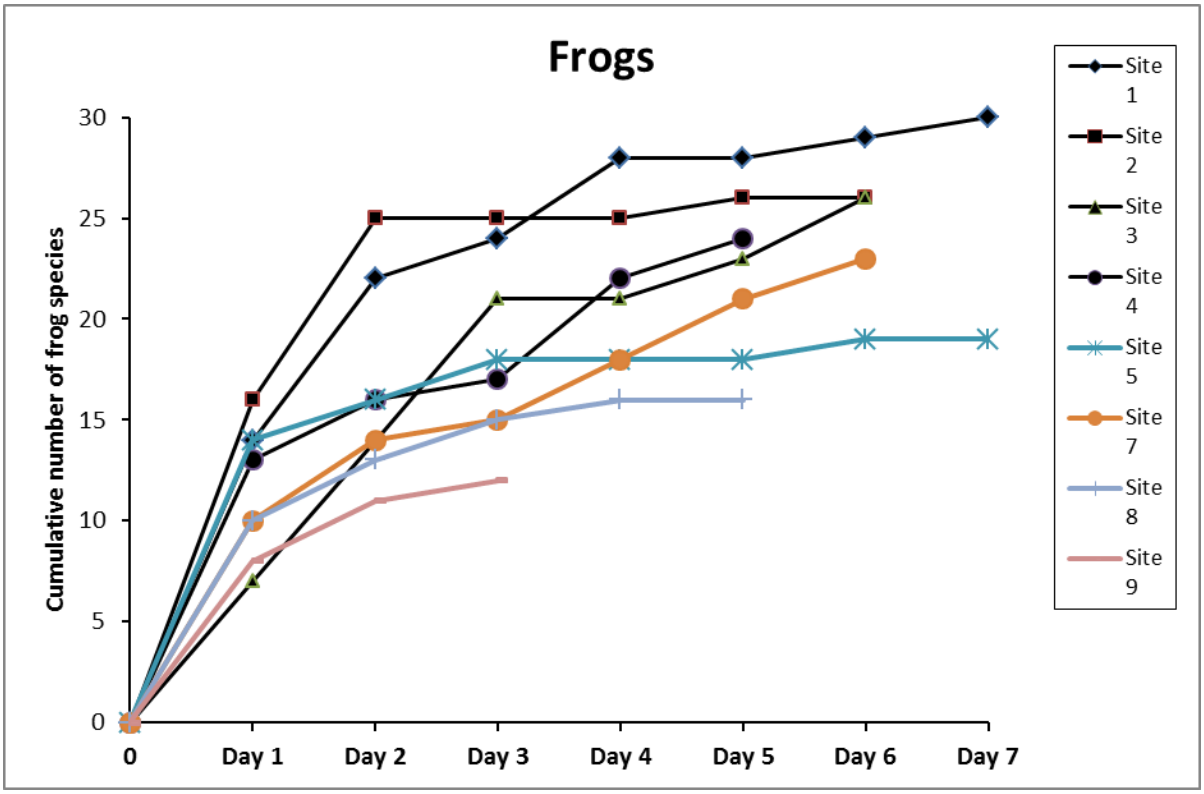

Figure 8. Accumulation curves for frogs at eight principal survey sites in the Purari basin.

4.1.2. Reptiles

The reptile fauna documented during this survey totaled 57 species and diversity among the eight principal sites was similar, ranging from 15 (Site 9) to 22 (Sites 2 and 3) species (Table 5). The fauna is dominated by species with wide known distributions (Table 5) and overall is very similar to that reported from the Lakekamu basin about 140 km east of the study area (Allison et al. 1998) with at least 29 species (51%) documented during this survey shared with the Lakekamu basin. This represents a 66% overlap of the less diverse and geographically more constrained Lakekamu reptile assemblage within the Purari basin. Because reptiles were not sampled intensively at Kopi comparison with the Kikori basin lowlands is not possible. Table 6 illustrates the percentages of reptile species in each of twelve reptile families documented during this survey and in the Lakekamu basin. This table illustrates the strong similarity in a broader taxonomic (family)-level community composition between these basins.

Numerically the fauna at the Purari sites was dominated by the widespread and abundant skinks *Carlia aenigma*, *Emoia caeruleocauda, E. physicae, Sphenomorphus simus* and *Lygisaurus* sp., all of which occurred in large numbers at most of the survey sites (Table 5). The study area population of *E. physicae* is recognized as a distinct subspecies, *E. physicae purari* that is endemic to the gulf lowlands (Brown 1991). One large species of the genus *Emoia* was observed at Sites 5 and 7 but was not captured and so remains unidentified. Given its size and general appearance it may be *E. tropidolepis*, an IUCN Least Concern species, but it is treated conservatively as *Emoia* sp. here. Although snake diversity was generally rather low, a number of notable species were encountered including two dangerously venomous species—the Death Adder (*Acanthophis laevis*) at Sites 3, 5 and 7 and the New Guinea Small-eyed Snake (*Micropechis ikaheka*) at Site 4. Both of these species are highly likely to occur throughout the study area. Three python species were found; the southern D'Albertis Python (*Bothrochilus meridionalis*) at Sites 1, 4 and 5, the Amethystine Python (*Morelia amethistina*) at Sites 2, 3 and 8, and the Green Python (*Morelia viridis*) at Sites 3 and 8. All of these

species are captured and eaten when encountered by local villagers. The most significant snake species encountered was a large and strikingly-colored species of the colubrid genus *Stegonotus* that is new-to-science and, to date, is known only from sites 4, 5, 8 and 9 in the study area (Plate 4; Section 4.3).

No turtles were captured in turtle traps. It is not possible to determine whether this reflects genuine rarity of the turtles or inappropriate bait selection. One specimen of the common and widespread species *Emydura subglobosa* was observed at Site 8, and a photographic record of an unidentified *Chelodina* species from the Purari River in PRL-15 is included in the species list but excluded from calculations of accumulation rates and species diversity among sites because its precise location of origin within PRL-15 is uncertain. It is most likely *C. novaeguineae*, a species listed as Least Concern by the IUCN. Evidence for the presence of two species of IUCN Vulnerable freshwater turtles, the Pig-nosed Turtle (*Carettochelys insculpta*) and the Striped New Guinea Soft-shelled Turtle (*Pelochelys bibroni*) was documented in the southern portion of PRL-15. Accounts for these two species are presented in section 4.2.2.1.

Juvenile Freshwater Crocodiles (*Crocodylus novaeguineae*) were abundant along a small stream at Site 5 and are likely to be common throughout the study area. Tracks possibly belonging to this species were observed at Site 6A adjacent to Kuku Creek, and a significant nesting habitat for this species was identified adjacent to the Purari River in the southern portion of PRL-15 (Figure 10). One young Estuarine Crocodile was observed in coastal mangroves during a boat trip at Site 8M. Brief accounts for the two locally occurring crocodile species are presented in section 4.5.

Species accumulation curves (Figure 9) for five of the eight sites do not approach an asymptote after 6 or 7 days of survey effort, indicating that with additional search effort more species are likely to be documented at these sites. Sites 1, 7 and 9 were the only sites where the accumulation curve reached an asymptote.

Detection of additional reptile species occurs more gradually than detection of frogs, particularly after the first day of sampling (Figures 8, 9). This reflects the fact that frogs 1) vocalize, 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 vocalize 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.

The more gradual accumulation rate for the reptile fauna, particularly at Sites 2–5, suggests that this component of the herpetofauna may be less comprehensively sampled than the frogs, and that additional species would be found with increased search effort. This interpretation is supported by the fact that previous surveys in the study area identified a higher proportion of additional species of terrestrial reptiles (12, equivalent to 21% of the total identified during this survey) than frogs (seven species, 17.5% of total; see above) (Liem & Haines 1977, Pernetta & Burgin 1980, DES 2008, 2010, and unpublished data). Despite this, rates of species accumulation had slowed sufficiently at all sites to suggest that the reptile fauna can be characterized confidently for the purposes of this study. A list of all herpetofauna species known from the study area is presented in Appendix 1.

Table 5. Reptiles documented at 12 sites in the study area, their IUCN and CITES status, endemicity codes* and restricted-range status (Y=Yes/N=No).

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6A	Site 6B	Site 6D	Site 7	Site 8	Site 8M	Site 9	IUCN Status	Endemism	CITES I or II	RR
Reptiles																
Lizards																
Agamidae																
Hypsilurus magnus	X	X		X	X								LC	4		N
Hypsilurus modestus	X								X				LC	2		N
Lophosaurus dilophus		X		X	X			X	X	X			LC	2		N
Gekkonidae																
Cyrtodactylus novaeguineae				X									LC	5		N
Cyrtodactylus serratus					X								LC	5		Y
Gehyra baliola			X							X		X	NE	1		N
Gehyra membranacruralis										X			LC	5		Y
Gehyra sp. 1			X										NE	5		Y
Gekko vittatus												X	NE	1		N
Hemidactylus frenatus	X									X			LC	1		N
Lepidodactylus cf. *orientalis*		X											NE	5		Y
Nactus sp.	X	X	X	X					X	X			NE	1		N
Scincidae																
Carlia aenigma	X	X	X		X	X			X	X		X	LC	5		Y
Carlia cf. *luctuosa*		X	X	X				X					NE	5		Y
Cryptoblepharus litoralis vicinus												X	NE	5		Y
Emoia caeruleocauda	X	X	X	X	X	X		X	X	X		X	LC	1		N
Emoia kordoana				X	X				X				NE	2		N
Emoia longicauda	X	X	X	X	X				X	X		X	NE	3		N
Emoia pallidiceps			X	X					X			X	LC	3		N
Emoia physicae purari	X	X	X	X	X	X	X	X	X				LC	5		Y
Emoia sp. ***					X				X				NE	?		?
Glaphyromorphus nigricaudis												X	NE	5		N
Lipinia longiceps		X											LC	3		N
Lipinia nototaenia		X											LC	5		N
Lygisaurus sp.	X	X	X	X	X	X	X		X	X		X	NE	5		N
Sphenomorphus aruensis			X										LC	3		N
Sphenomorphus meyeri	X	X	X										LC	3		N

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6A	Site 6B	Site 6D	Site 7	Site 8	Site 8M	Site 9	IUCN Status	Endemism	CITES I or II	RR
Sphenomorphus muelleri				X									NE	3		N
Sphenomorphus simus	X	X	X	X	X			X	X				LC	2		N
Sphenomorphus undulatus		X	X						X				LC	3		N
Sphenomorphus solomonis	X												NE	1		N
Sphenomorphus sp. 1		X											NE	5		N
Tiliqua gigas										X		X	NE	2		N
Varanidae																
Varanus indicus	X	X	X	X	X				X	X		X	LC	1	II	N
Varanus prasinus										X		X	LC	1	II	N
Snakes																
Boidae																
Candoia aspera	X												NE	2	II	N
Colubridae																
Boiga irregularis	X	X	X	X	X				X	X			NE	1		N
Dendrelaphis calligaster		X							X			X	LC	1		N
Dendrelaphis macrops			X							X			NE	3		N
Stegonotus cucullatus	X	X		X						X			NE	1		N
Stegonotus diehli	X		X	X						X			NE	4		N
Stegonotus sp. 1				X	X					X		X	NE	5		Y
Tropidonophis doriae	X											X	NE	3		N
Tropidonophis picturatus			X	X	X				X				LC	3		N
Elapidae																
Acanthophis laevis			X		X				X				LC	3		N
Micropechis ikaheka				X									NE	3		N
Toxicocalamus preussi		X											LC	4		N
Pythonidae																
Bothrochilus meridionalis	X			X	X								NE	5	II	N
Morelia amethistina		X	X							X			LC	1	II	N
Morelia viridis			X							X			LC	1	II	N
Typhlopidae																
Ramphotyphlops multilineatus									X				LC	4		N
Crocodiles																
Crocodylus novaeguineae					X								LC	4	II	N

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6A	Site 6B	Site 6D	Site 7	Site 8	Site 8M	Site 9	IUCN Status	Endemism	CITES I or II	RR
Crocodylus porosus										X	X		LC	1	II	N
Turtles																
Carettochelyidae																
Carettochelys insculpta							X						VU		II	N
Chelidae																
Chelodina sp.**													NE	5		?
Emydura subglobosa										X			LC	1		N
Trionychidae																
Pelochelys bibroni							X						VU		II	N
TOTAL: 57	**19**	**22**	**22**	**21**	**18**	**4**	**4**	**5**	**18**	**21**	1	**15**				

*Refer to Table 2 for explanation of abbreviations and codes.
**Based on photographs provided to the team.
***Unknown due to uncertain species identification.

Table 6. Numbers and percentages of reptile species in each major family documented during this study, and at Lakekamu, (see text for details).

Reptiles	Purari #	Purari %	Lakekamu #	Lakekamu %
Agamidae	3	5.26	3	6.81
Gekkonidae	9	15.78	5	11.36
Scincidae	21	36.84	21	47.72
Varanidae	2	3.51	1	2.27
Boidae	1	1.75	1	2.27
Colubridae	8	14.03	5	11.36
Elapidae	3	5.26	4	9.09
Pythonidae	3	5.26	2	4.54
Typhlopidae	1	1.75	0	0
Carettochelyidae	1	1.75	0	0
Chelidae	2	3.51	1	2.27
Trionychidae	1	1.75	1	2.27
Crocodylidae	2	3.51	0	0
TOTAL	**57**	**100**	**44**	**100**

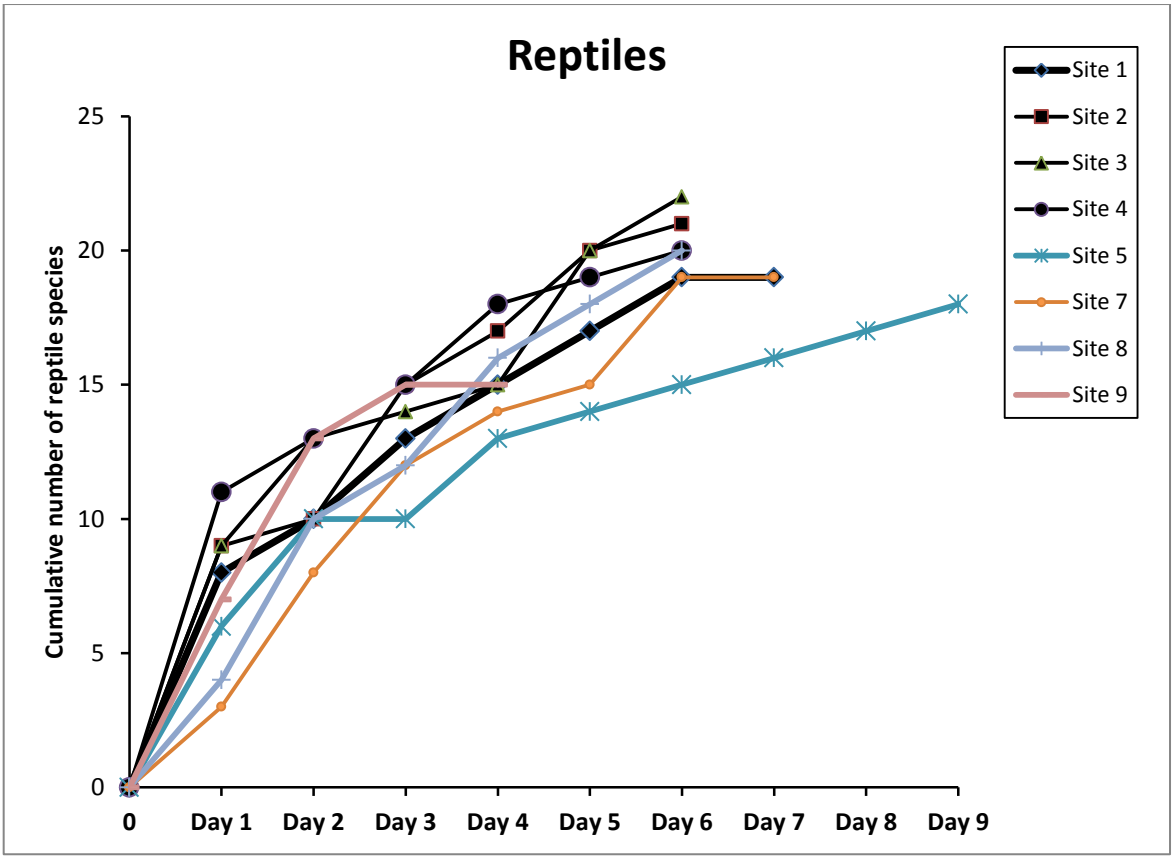

Figure 9. Accumulation curves for reptiles at eight principal survey sites in the Purari basin.

4.2. CONSERVATION LISTED SPECIES KNOWN OR EXPECTED TO OCCUR

Detailed accounts of conservation listed species recorded in the study area are provided in the following sections. No species encountered during this study are Protected under PNG law.

4.2.1. Frogs

The conservation status of most frog species known from PNG has been assessed by the IUCN for inclusion in the IUCN Red List. Two species of frogs encountered during the survey, *Callulops marmoratus*, and *Litoria sauroni* are listed as Data Deficient by the IUCN. No species listed by the IUCN as Critically Endangered, Endangered, Vulnerable or Near Threatened were documented during this project, and no additional conservation listed species are likely to occur based on current knowledge of distribution and habitat preferences. No frog species in PNG is listed under CITES.

Callulops marmoratus (Plate 1) is a moderately large (~55 mm) and robust ground-dwelling microhylid frog. It was described from near Haia in the upper Purari catchment at an elevation of 850 m asl by Kraus & Allison (2003) and until it was documented during this Project was known with certainty only from the Crater Mountain WMA. A population of *Callulops* frogs resembling this species is known from the upper Fly River catchment near Tabubil to the west of the study area but further studies are required to confirm its taxonomic status. This species was heard calling after rain at sites 1–4 and 7. It is listed as Data Deficient 'since it has only recently been described, and there is still very little information on its extent of occurrence, status and ecological requirements' (Allison & Kraus 2004). Most known localities for this species are in hill forest where animals live in holes on steep slopes, including near-vertical stream-banks. In the study area, it was found in both the Middle Purari Hills and Southeast Hills ecological zones, where there appears to be extensive suitable habitat. The extent of its occurrence in alluvial forest is unclear – it was uncommon in alluvial forest at Site 4

where it called from low but steep drier ridges. It was not encountered in flat, wetter, swampy areas. Disturbance to steep stream banks in hill forest may impact local populations of this species. *Callulops marmoratus* has an extremely limited known distribution and, even if the Fly River catchment population is demonstrated to be conspecific, currently available information indicates that this species qualifies as restricted-range with a distribution not exceeding 50,000 km^2.

Litoria sauroni is a very large (to 70 mm SVL), bright green treefrog with a rounded snout, prominent white folds on the arms and legs, and extensively webbed hands. This species was previously known with certainty only from two sites in foothill forest in the Kikori River Basin to the west of the study area. It appears to live exclusively in the forest canopy. *Litoria sauroni* was heard calling after rain at sites 1–4 and 7. It is listed as Data Deficient by the IUCN since it has only recently been described, and there is still very little known about its extent of occurrence, area of occupancy, status and ecological requirements (Richards 2008). This is a forest-dwelling species that lives high in the forest canopy so habitat loss, degradation and fragmentation are major threats. Opening of the forest canopy will increase the insolation that penetrates into the canopy, resulting in increased temperatures and reduced humidity in the habitats occupied by this species. This species qualifies as restricted-range with a distribution not exceeding 50,000 km^2.

4.2.2. Reptiles

No reptile species listed by the IUCN as Critically Endangered, Endangered, Near Threatened or Data Deficient was documented during this project. However, two IUCN Vulnerable freshwater turtles nest in the study area, two marine species have been reported previously from the study area, and an additional four conservation listed marine turtles may occur in the study area's coastal marine environments. Each of these is treated below.

4.2.2.1. IUCN Vulnerable freshwater turtles

Carettochelys insculpta (Pig-nosed Turtle; Plate 4) is a large (to >55 cm carapace length and 22 kg) freshwater turtle known only from the southern lowlands of New Guinea and several drainages in the Northern Territory of Australia. In New Guinea, it appears to occupy most of the major drainages south of the central cordillera although its eastern and western distributional limits are poorly understood. The Pig-nosed Turtle inhabits a wide variety of water bodies including rivers, swamps and lagoons, and estuarine reaches of the river deltas. Within the study area the Pig-nosed Turtle may occur in any of the major waterways in any ecological zone. In the Purari and Kikori catchments hatchlings move to the lower delta to feed on mangrove fruit and other vegetation. Adults are omnivorous, and in the Gulf Province lowlands feed primarily on the unripe fruit, leaves and stems of the mangrove *Sonneratia* spp. (Rose et al. 1982), on other mangrove fruits and vegetation, and on various molluscs and crustaceans (Georges et al. 2008a,b).

The Pig-nosed Turtle nests in sandy banks along the main channel of the Purari River (Pernetta & Burgin 1980), and it is also known to nest adjacent to water in the mouths of major rivers, on islands in river deltas, and even on coastal beaches. In New Guinea nesting occurs at night between September and February. Further information on the location of nesting sites within the study area is presented below.

Adults and eggs of this species are widely consumed in the Purari catchment (Pernetta & Burgin 1980). Other sources of mortality include predation by varanid lizards and inundation of nests during river flooding. Georges et al. (2008b) considered the harvest of *Carettochelys* for local consumption in PNG to be unsustainable, and a significant threat to the survival of these populations. Eisemberg et al. (2015) described current harvesting practices in the Kikori basin and presented a series of recommendations to reduce impacts on this species. *Carettochelys* is listed as Vulnerable by the IUCN in part because it is 'heavily exploited and locally consumed in Papua New Guinea'.

Pelochelys bibroni (Striped New Guinea Soft-shelled Turtle; Plate 4) is a very large (carapace to >100 cm) freshwater turtle endemic to the southern river drainages of New Guinea. It occurs primarily

in rivers and streams, although some coastal records do exist. Information about this species' distribution and natural history were presented by Rhodin et al. (1993) who confirmed the species' presence in the Purari River system. Georges et al (2008a) reported that this species was the least-common turtle in the Kikori drainage and that it is probably locally endangered. No data are available on the status of this species in the Purari basin.

Unlike the Pig-nosed Turtle this species feeds primarily on crustaceans, molluscs and fish and some aquatic plants may also be eaten. Nesting occurs in muddy banks between June and August or September, and between 20 and 45 eggs are normally laid per clutch. Due to its large size humans and crocodiles are the only predators of adults.

This species is listed as Vulnerable by the IUCN because 'There is significant trade in this species for local consumption in Papua New Guinea'.

Purari River turtle nesting sites

The two large freshwater turtle species of conservation significance—the Pig-nosed Turtle (*Carettochelys insculpta*) and the Striped New Guinea Soft-shelled Turtle (*Pelochelys bibroni*) nest on the banks of larger watercourses in the southern half of PRL-15. Information on nesting sites of both species, and on hunting and egg harvesting, was collected during a boat trip in June 2016 from two local Pawaian residents who have hunted turtles and collected eggs from these sites within the last two years (therefore considered current). From these discussions, it is evident that current harvesting rates are high and may be unsustainable.

Figure 10 shows the location of nesting sites of the Pig-nosed Turtle on the banks of the Purari River and of tributary watercourses that harbour nesting sites of the Pig-nosed Turtle and/or the Striped New Guinea Soft-shelled Turtle in the southern portion of PRL-15. Due to the size of the vessel used for survey it was not possible to navigate the tributaries to obtain site-specific coordinates for nesting sites in these smaller watercourses.

Of the two IUCN Vulnerable turtle species nesting in PRL-15, only the Pig-nosed Turtle nests on the banks of the main Purari channel (information from local informants). The mapping is based on the latest LIDAR and photographic data and is therefore considered current and suitable for use in project planning.

It should be noted that these nesting areas are dynamic, changing as sediments shift and banks degrade/prograde under the influence of river flow. However, local informants reported that turtles nest at the same locations each year, and that nesting of both species occurs predominantly during the months of October and November. This is a shorter nesting season than has been reported for the Kikori basin and may reflect periods of peak nesting rather than the entire nesting season. This may also explain the discrepancy between breeding periods of the Striped New Guinea Soft-shelled Turtle reported by Rhodin et al. (1993) for the Fly River basin and that reported by locals for populations nesting in the Purari River tributaries of PRL-15.

Both IUCN Vulnerable turtle species nest on the banks of tributary streams. Six tributary watercourses were identified that harbor nesting sites of one or more of these species (Figure 10). Among the identified tributaries, both Djo'boh Creek and Oyomo Creek were said to harbor nest sites for both turtle species. Both of these creeks drain the 'CPF, logistics base and airstrip area', and parts of two tributaries of the Oyomo Creek system are located within the broad development footprint.

The Striped New Guinea Soft-shelled Turtle is of higher conservation concern than the Pig-nosed Turtle. Both species are harvested locally and both are listed as globally Threatened by the IUCN. However, the Striped New Guinea Soft-shelled Turtle has a more restricted distribution (limited to

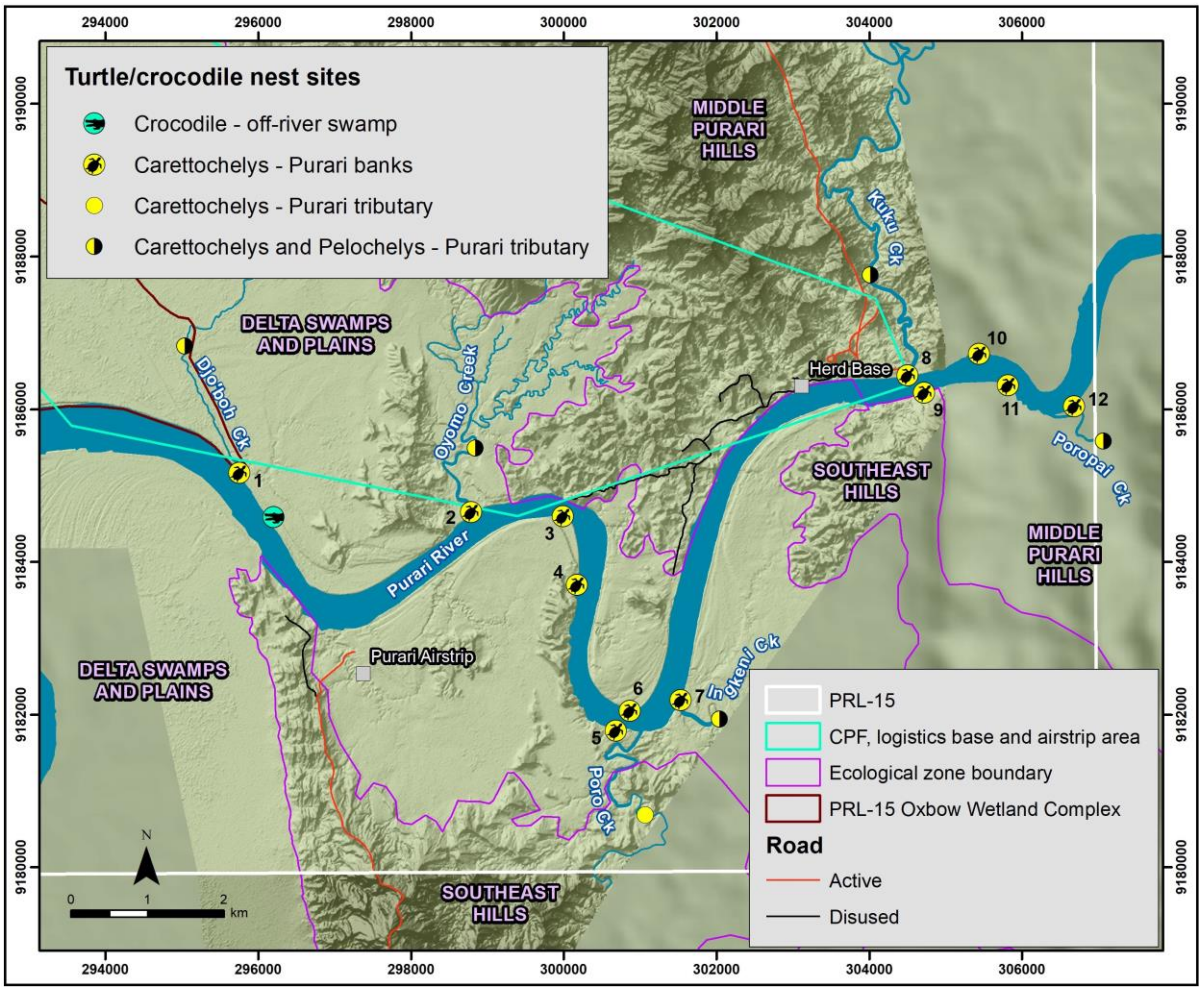

Figure 10. Nesting site of the New Guinea Freshwater Crocodile, and nesting sites of the Pig-nosed Turtle on the banks of the Purari River and of tributary watercourses that harbor nesting sites of the Pig-nosed Turtle and/or the Striped New Guinea Soft-shelled Turtle in the southern portion of PRL-15.

southern New Guinea), is considerably rarer than the Pig-nosed Turtle, there are fewer suitable nesting sites and they nest less frequently. In a study of turtles in the nearby Kikori drainage, Georges et al. (2008a) noted that the Striped New Guinea Soft-shelled Turtle is “probably critically endangered locally”.

Consequently, while Djo’boh Creek and Oyomo Creek are considered to harbor important nesting areas for both species, their importance is notably higher for the Striped New Guinea Soft-shelled Turtle.

The Phase 1 terrestrial biodiversity survey covered those parts of the two Oyomo Creek tributary streams that lie within the CPF fence line. During that survey, local residents reported that: (1) neither of these turtle species nest that high up the stream system; and (2) juvenile turtles are sometimes seen in that area, but they are not common and they have only seen the Pig-nosed Turtle there (not Soft-shelled). Thus, the limited available evidence suggests that these smaller mid-reach stream areas are not of ecological importance for any life-history stage of these Threatened turtles.

4.2.2.2. Conservation significant marine turtles

Liem and Haines (1977) reported two species of marine turtles, the Loggerhead Turtle (*Caretta caretta*: IUCN Vulnerable, CITES Appendix I) and the Green Turtle (*Chelonia mydas*: IUCN Endangered, CITES Appendix I), from the mangrove and estuarine areas of Gulf Province. Four additional marine species, the Hawksbill Turtle (*Eretmochelys imbricata*: IUCN Critically Endangered), Olive Ridley (*Lepidochelys olivacea*) and Leatherback (*Dermochelys coriacea*) Turtles (both IUCN Vulnerable; Leatherback Turtle also Protected in PNG) and Flatback Turtle (*Natator depressus*: IUCN Data Deficient) are also listed on Appendix I of CITES and are known to occur in the Gulf of Papua (e.g. Spring 1982) so they possibly pass through the coastal waters of the study area during foraging.

With the exception of the Flatback Turtle, which is restricted to waters over the Australian continental shelf and extending northward to the Gulf of Papua, all of these species have global distributions in tropical waters. Based on questionnaires circulated to coastal villages, Lockhart (1989) reported that marine turtles nest at several sites along the Gulf of Papua coastline, both east and west of the study area, and A. Pym (unpubl. obs.) observed plundered nest sites and adult turtle tracks indicating nesting activity of turtle species at beaches to the east of Orokolo Bay. Identification of species nesting at these sites relied on descriptions from local informants and there appear to be no beaches used for nesting by marine turtles in the Gulf of Papua where the species involved has been confirmed (Spring 1995; Limpus 2007, 2008a, b, c, d, 2009). Local informants from Kavava and Miha Kavava villages in Orokolo Bay reported that, while marine turtles are consumed when captured in fishing nets, they rarely nest at any beaches in the bay. Harvest rates of adults encountered at sea are poorly known for all species, as are mortality rates from gillnets.

Threats and susceptibilities of marine turtles known or possibly occurring in the study area are described below.

Loggerhead Turtle (*Caretta caretta*)

This species is not known to breed in Papua New Guinea (Limpus 2008a), and few threats have been documented throughout the country. Limpus (2008a) reports that "Human consumption of *C. caretta* in the south Pacific basin appears to be uncommon except in the Trobriand-Woodlark Islands area of Papua New Guinea".

Green Turtle (*Chelonia mydas*)

This species is known to breed in northern and eastern Papua New Guinea (Spring 1982) but there are no confirmed breeding sites in the Gulf of Papua (Spring 1982; Limpus 2008b). Adults are harvested throughout coastal PNG, and many animals are sold in coastal markets but harvest rates are poorly known for most of PNG (Limpus 2008b). Unsustainable harvesting of adults is the major threat to this species in Gulf Province.

Hawksbill Turtle (*Eretmochelys imbricata*)

This species is known to breed in southern, northern and eastern Papua New Guinea (Spring 1982; Limpus 2008c) but there are no confirmed breeding sites in the Gulf of Papua. Migrating adults are, however, known to forage in the Gulf of Papua (Limpus 2008c) so unsustainable harvesting of adults is the major threat to this species in Gulf Province.

Olive Ridley Turtle (*Lepidochelys olivacea*)

This species breeds only very rarely in Papua New Guinea (Limpus 2008d) and there are no confirmed breeding sites in the Gulf of Papua. However, adults are known to forage in the Gulf of Papua (Limpus 2008d) where they are sometimes caught in trawlers (Spring 1982). Unsustainable harvesting of adults is likely to be the major threat to this species in Gulf Province.

Leatherback Turtle (*Dermochelys coriacea*)

In Papua New Guinea this species is known to breed predominantly in northern and eastern regions (Limpus (2009), but Spring (1982) records occasional nesting in Central Province west of Port Moresby. There are no confirmed breeding sites in the Gulf of Papua. Limpus (2009) reports that driftnet/gillnet fisheries within Papua New Guinea national waters may be significantly affecting the survival of *D. coriacea* populations. Adults are also normally harvested when encountered so unsustainable harvesting of adults may also be a major threat to this species in Gulf Province. The Leatherback Turtle is protected by PNG law.

Flatback Turtle (*Natator depressus*)

This species has not been reported from the study area and is not known to breed anywhere in Papua New Guinea. However, adults are known to forage in the Gulf of Papua (Limpus 2007) where they are sometimes captured in trawls and gill nets (Spring 1982; Limpus 2007). Mortality rates have not been quantified (Limpus 2007).

Further information on harvesting of marine turtles is presented in the Land and Natural Resources Report.

4.3. NEW TO SCIENCE AND UNDESCRIBED TAXA

4.3.1. Frogs

At least 15 species of frogs (37% of total) documented in the study area are scientifically undescribed (unnamed). Three of these, *Cophixalus* sp. 1 and *Oreophryne* sp. 1 and 2, are completely new-to-science, being discovered for the first time during Project surveys. Two additional species, *Litoria* sp.1 and *Hylarana* sp. 2, were previously discovered but at present are known only from within the study area. The remaining 10 undescribed species had been previously documented outside of the Purari basin (e.g. Allison et al. 1998; Richards 2002b) but a number of these have sufficiently small known distributions to qualify as restricted-range species (see *Section 4.4*). Most of the undescribed species (10/15; 67%) are in the family Microhylidae, including both new-to-science species. Two species of the family Hylidae and three species of the family Ranidae are also undescribed. Most of these species are illustrated in Plates 1–2.

Species accounts

Hylidae

Litoria sp. 1 – UNDESCRIBED – known only from the study area

A small, (males ~ 33 mm) slender treefrog with a distinct white bar beneath the eye and purple/blue color in the hidden surfaces of the thighs. A forest-dwelling species that was usually encountered in cool, moist gullies with extensive canopy cover. Breeds in small pools on the forest floor, where the species' tadpoles develop. Numerous individuals were seen and heard in hill forest at Sites 2 and 3 in the Purari Middle Hills ecological zone where males congregated to call from leaves above small swamps and seepage-lines along gullies at night. This species is most similar to *Litoria majikthise*, a foothill species currently known from sites further to the west in south-central New Guinea. It is replaced by another morphologically similar but genetically distinct species on the Darai Plateau to the west, and was not encountered at Lakekamu to the east or in the higher elevation hill forest in the Crater Mountain WMA to the north. This species was collected in the Wabo area in 2009 (C. Austin, Louisiana State University; pers. comm., 2011) and remains known only from the study area. Given its extremely small known distribution, currently available information indicates that this species qualifies as restricted-range. A forest-dwelling species, the major threats are forest loss and degradation.

Litoria sp. 2 – UNDESCRIBED – known previously from sites across southern PNG

A small (males ~ 27 mm), slender brown frog with tiny green spots on the dorsum and pale yellow coloration on the hidden surfaces of the thighs. This forest-dwelling species was always encountered in cool, moist habitats with extensive canopy cover where it breeds in small isolated pools along narrow, often steep-sided, gullies. It lays its eggs hanging on leaves up to two meters high over forest pools, where embryos hatch and drop into the water below to complete their development. This species was common along narrow channels draining the steep ridges in hill forest at Sites 1 and 2 in the Middle Purari Hills ecological zone. Suitable habitat is widespread across the Middle Purari Hills, and *Litoria* sp. 2 is also known from similar habitats at numerous locations as far west as Timika at the base of the Snow Mountains in western New Guinea (Richards et al. 2015). A forest-dwelling species, the major threats are forest loss and degradation. This species does not qualify as restricted-range.

Microhylidae

Austrochaperina sp. 1 – UNDESCRIBED – known previously from the Kikori basin

A moderately small (males 26–29 mm), short-legged microhylid frog that was found infrequently at Site 1 in the Middle Purari Hills ecological zone. Although calls of this frog were not heard, it is morphologically similar to a species previously known from the Kikori basin and it is tentatively associated with that species here.

Austrochaperina sp. 1 is a forest-dwelling frog that lives in moist litter on the forest floor, where it presumably lays its eggs in moist terrestrial nests. It was not found in open, disturbed habitats. The apparent rarity of this species probably reflects the dry conditions encountered during the Project surveys rather than low population density because in the Kikori basin this species was encountered, and heard calling, almost exclusively during and after heavy rain. Suitable hill forest habitats occur across the Middle Purari Hills ecological zone and the species is probably widespread there.

This species was not encountered in the Lakekamu basin despite apparently suitable habitat there (Allison et al. 1998), or in higher elevation hill forest in the Crater Mountain WMA, but it is known from hill forests in the Kikori basin to the west. This species qualifies as restricted-range because currently available data suggest that it may occupy a very restricted geographic range, at altitudes between about 100 and 900 m asl, that is in the order of less than 20,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Choerophryne sp. 1 – UNDESCRIBED – known previously from the Kikori basin

A small (<20 mm) brown frog with long front legs, large finger and toe discs, and distinct pale patches on the dorsum. This is an arboreal, forest-dwelling species that calls from ~2–>10 m high in trees with a series of sharp clicking notes. In the study area, it was heard calling at night only at Site 1. Suitable hill forest habitats occur across the Middle Purari Hills ecological zone and the species is probably widespread there.

This species was previously known from the lowlands and foothills of the Kikori basin to the west of the study area. It was not encountered in the Lakekamu basin despite apparently suitable habitat there (Allison et al. 1998), or in higher elevation hill forest in the Crater Mountain WMA, but it is known from altitudes up to at least 800 m asl in the Kikori basin to the west. This species qualifies as restricted-range, with currently available data suggesting that it occupies a geographic range in the

order of less than 20,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Cophixalus sp. 1 – UNDESCRIBED – known previously from the Kikori basin

A moderately small (males ~ 30 mm) brown frog with large finger discs, long legs, and usually having distinct dark spotting on the back. This is a forest-dwelling species that is most common in moist gullies or near streams where there is extensive canopy cover. Males call from leaves up to ~2 m above the ground with a series of harsh buzzing notes. Breeding sites are unknown but eggs are probably deposited in moist terrestrial nests. *Cophixalus* sp. 1 was found at Sites 1–3 in the Middle Purari Hills and Southeast Hills ecological zones, and extensive suitable habitat occurs across these zones.

This species was not encountered in the Lakekamu basin despite apparently suitable habitat there (Allison et al. 1998), or in higher elevation hill forest in the Crater Mountain WMA, but it is known from the lowlands and hills of the Kikori basin to the west of the study area and at altitudes up to about 1,000 m asl at a number of additional sites reaching nearly as far west as Tabubil. This species qualifies as restricted-range, with currently available data suggesting that it occupies a geographic range in the order of less than 50,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Cophixalus sp. 2 – UNDESCRIBED – known previously from the Kikori basin

A small (males ~ 25 mm) grey-brown frog with large finger discs and a distinctly angular snout. This is a forest-dwelling species that is most common on the slopes of steep, moist gullies where there is extensive canopy cover. Males call from leaves up to ~2 m above the ground with a series of rapidly but irregularly repeated peeping notes. Breeding sites are unknown but eggs are probably deposited in moist terrestrial nests. *Cophixalus* sp. 2 was found at Sites 1 and 2 in the Middle Purari Hills ecological zone, in alluvial forest at Sites 5 and 8 in the Delta Swamps and Plains and Southeast Coast ecological zones respectively, and in small crowned hill forest at Site 7 in the Southeast Hills ecological zone. Extensive suitable habitat occurs throughout these zones within the study area.

This species was not encountered in the Lakekamu basin despite apparently suitable habitat there (Allison et al. 1998), or in higher elevation hill forest in the Crater Mountain WMA, but it is known from the lowlands and foothills of the Kikori basin to the west of the study area, up to at least 1,000 m asl (Richards 2002b). This species qualifies as restricted-range, with currently available data suggesting that it occupies a geographic range in the order of less than 20,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Cophixalus sp. 3 – NEW-TO-SCIENCE – known only from the study area

A tiny (males 12–14.5 mm) mottled-brown microhylid frog with small finger discs that was discovered for the first time during this survey. It was found in hill forest at Sites 1-3, 6A, 6D and 7. The only site outside of hill forest where this species was found was Site 4, where it was found in alluvial forest but only on steep stream banks in terrain reminiscent of hill forest habitats. Males called from beneath litter on the steep banks of small forest streams after rain. The call is a long series of musical peeping notes. Unlike most other frogs in the study area this species called predominantly during the day, and was rarely heard at night. *Cophixalus* sp. 3 appears to be restricted to the steep banks of small clear streams. It is one of four frog species currently known only from the study area and appears to be a habitat specialist requiring riparian habitats alongside small streams. Extensive suitable habitat appears to be available in the Middle Purari Hills and Southeast Hills ecological zones but due to its extremely limited geographic distribution this species qualifies as restricted-range. A forest-dwelling species, the major threats are forest loss and degradation, particularly in riparian habitats.

Copiula sp. 1 – UNDESCRIBED – known previously from the Kikori basin

A moderately large (to ~ 34 mm) member of the genus having a narrow snout with a slightly translucent tip, and a dark bar along the side of the head. This is a forest-dwelling species that lives in moist litter on the forest floor, where males produce a rapid 'chattering' call. Breeding sites are unknown but eggs are probably deposited in moist terrestrial nests. *Copiula* sp. 1 was found at Sites 1–5, 7 and 8, and extensive suitable habitat occurs throughout the hill and alluvial forests in the study area.

This species may be the same as that encountered in the Lakekamu basin by Allison et al. (1998), but further studies of the Lakekamu material are required to confirm this. Elsewhere it is known only from the lowlands and foothills of the Kikori basin to the west of the study area, below 500 m asl (Richards 2002b). This species is replaced by a morphologically similar but acoustically distinct species to the west of the Kikori basin (S.J. Richards, unpublished data), and was not encountered in higher elevation hill forest in the Crater Mountain WMA. This species qualifies as restricted-range with currently available data suggesting that, even if it does occur at Lakekamu it may occupy a restricted geographic range in the order of less than 20,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Hylophorbus sp. 1 – UNDESCRIBED – known previously from the Kikori basin

A moderately large (~33 mm), pale brown member of the genus with long limbs and a relatively narrow snout. This is a forest-dwelling species that lives in moist litter on the forest floor, where males called from positions on or slightly above the litter at night. Breeding sites are unknown but eggs are probably deposited in moist terrestrial nests. *Hylophorbus* sp. 1 was found in hill forest in the Middle Purari Hills ecological zone at Site 1, and in the Southeast Hills ecological zone at Site 7. It also occurred in better drained alluvial forest in the Delta Swamps and Plains and Southeast Coast ecological zones at Sites 7, 8 and 9 but was encountered less frequently in wetter swamp habitats, such as mixed swamp forest (Fsw) and sago dominated swamp woodland (Wsw). Extensive suitable habitat occurs throughout the hill and alluvial forests in the study area. This species was found in both primary forest habitats, and in severely degraded patches of remnant forest at Sites 8 and 9 suggesting that this species is resilient to habitat modification. It has been reported from the Kikori basin lowlands to the west of the study area (Richards 2002b).

Populations of *Hylophorbus* resembling this species are known from the upper Strickland River catchment to the west of the Kikori basin but it is unclear whether they represent the same species. This species qualifies as restricted-range, with currently available data suggesting that it occupies a geographic range in the order of less than 20,000 km^2.

Oreophryne sp. 1 – NEW-TO-SCIENCE – known only from the study area

A small member of the genus (a male 24 mm), with large finger discs and a mottled brown dorsum. A forest-dwelling frog, this species was seen and heard only at Sites 4, 7 and 8 where males called from high (usually >10 m) in trees at night in alluvial forest, and at site 7 in small-crowned hill forest immediately adjacent to alluvial forest. It was also heard calling in sago swamps within alluvial forest at Site 8 suggesting that it might occur more widely in sago dominated swamps within alluvial forest woodland (Wsw). The call is a series of short rasping notes, and eggs are probably deposited in moist arboreal nests. This species appears to be restricted to the forest canopy, and is currently known only from the study area. Habitat suitable for this species occurs throughout the alluvial forests of the Delta Swamps and Plains and Southeast Coast ecological zones. This species qualifies as restricted-range, with currently available data suggesting that it occupies a very restricted geographic range in the order of less than 10,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation although several individuals were heard calling in severely degraded habitats suggesting an ability to persist in such habitats.

Oreophryne sp. 2 – NEW-TO-SCIENCE – known only from the study area

A very small member of the genus (< 20 mm), with large finger discs and prominent tubercles on the dorsum. A forest-dwelling frog, one animal was found at Site 1 where it was perched on low foliage beside a small stream adjacent to Mena Creek in hill forest in the Middle Purari Hills ecological zone. This appears to be a newly discovered species not known from any other location. Although habitat requirements are poorly known, small streams in hill forest occur throughout the Middle Purari Hills and the Southeast Hills ecological zones. This species qualifies as restricted-range, with currently available data suggesting that it occupies a very restricted geographic range in the order of much less than 50,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Xenorhina sp. 1 – UNDESCRIBED – known previously from the Kikori basin

A moderate-sized frog (to ~45 mm) with a robust body, narrow snout and very small eyes. This is a forest-dwelling frog that was heard calling at seven of the eight principal survey sites, but was rarely encountered because males called from beneath the litter or within the humus layer of the forest floor only during heavy rain. It occurred predominantly in better drained hill and alluvial forest and was not encountered in wetter, swampy habitats. The call is a single soft hooting sound, repeated in series with each successive note increasing slightly in volume and pitch.

Extensive suitable habitat occurs in the hill forests and alluvial forests throughout the study area. It was absent from only one of the eight principal sites surveyed, the coastal habitats at Site 9. It was not detected in the mangroves at Site 8M or at Sites 6A and B which were only sampled during the day. This species possibly occurs in the Lakekamu basin to the east of the study area (Allison et al. 1998), and was previously known from several sites in the Kikori basin (Richards 2002b). It also occurs at additional locations extending westward almost to the Indonesian border near Tabubil at altitudes up to 1,000 m asl (S.J. Richards, unpublished data). This species qualifies as restricted-range, with currently available data suggesting that it occupies a geographic range in the order of less than 50,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Ranidae

Hylarana sp. 1 – UNDESCRIBED – known previously from the Kikori basin

A very large (females to 143 mm), heavy-bodied frog with long and muscular legs. This frog was previously included in *H. arfaki* but is genetically distinct from that species (S.J. Richards, unpublished data). It is a stream-dwelling species that was found at Sites 1, 2 and 4 where it perched on steep stream-banks in hill and alluvial forest. Breeding occurs only in streams and its call is unknown.

Forested stream habitats suitable for this species occur extensively in the Middle Purari Hills and Delta Swamps and Plains ecological zones, and it probably occurs widely there. *Hylarana* sp. 1 is also known from the Darai Plateau and Moro areas in the Kikori basin, occurring at locations up to 900 m asl (S.J. Richards, unpublished data). The taxonomic status of frogs to the east of the study area (Lakekamu) and west of the Kikori basin that resemble this species requires further genetic studies. This species qualifies as restricted-range, with currently available data suggesting that it occupies a geographic range in the order of less than 20,000 km^2. A forest stream-dwelling species, the major threats are forest loss and degradation and contamination of waterways.

Hylarana sp. 2 – UNDESCRIBED – known previously only from the study area

A moderately large (females to 85 mm), slender *Hylarana* with long and muscular legs and a dark mask on the side of the face. Adults have a distinct row of tubercles between the eyes and males change from brown to yellow during breeding activity. The call is unknown.

This stream-dwelling frog was encountered at Sites 1–4 and 7 in the study area, where it was found along clear, flowing streams with rocky or sandy substrates. Forested stream habitats suitable for this species occur extensively in the Middle Purari Hills, Southeast Hills and the Delta Swamps and Plains ecological zones and it probably occurs widely there. *Hylarana* sp. 2 was previously known only from the Wabo area (C. Austin, Louisiana State University; pers. comm., 2011) and remains known only from the study area. This species was not encountered at Lakekamu to the east, and is replaced by a morphologically similar species in the Kikori basin to the west (S.J. Richards, unpublished data). This species qualifies as restricted-range, with currently available data suggesting that it occupies a geographic range in the order of less than 10,000 km^2. A forest stream-dwelling species, the major threats are forest loss and degradation and contamination of waterways.

Hylarana sp. 3 – UNDESCRIBED – known widely outside the study area

A very small (males <40 mm) *Hylarana* with long legs and a pale glandular fold on the side of the face. It was found at Sites 3–5, 7, 8 and 9 in the Southeast Hills, Delta Swamps and Plains and Southeast Coast ecological zones, where males called from hidden or semi-hidden positions adjacent to slow-flowing and swampy sections of shallow streams.

Habitats suitable for this species occur extensively in the Delta Swamps and Plains and Southeast Coast ecological zones, and less so in the Southeast Hills ecological zone, and the species probably occurs widely in alluvial and swamp forests on flat terrain throughout the study area. This species was not encountered in the Lakekamu basin to the east (Allison et al. 1998) but was previously known from the lowlands of the Kikori basin (Richards 2002b) and the Mimika area of Papua Province, Indonesian New Guinea (Richards et al. 2015) to the west of the study area. It does not qualify as restricted-range. A forest stream-dwelling species, the major threats are forest loss and degradation and contamination of waterways.

4.3.2. Reptiles

Three undescribed and new-to-science reptiles were detected. One species of arboreal gecko of the genus *Gehyra* and one snake of the genus *Stegonotus* were discovered for the first time during this survey. One additional undescribed lizard was encountered; the skink *Sphenomorphus* sp. 1, which was found only at Site 2 during this survey but is known to have a broad distribution in southern New Guinea that extends into Papua Province of neighboring Indonesian New Guinea (S.J. Richards, unpublished data). These species are illustrated in Plate 4.

Species accounts

Gekkonidae

Gehyra sp. 1 – NEW-TO-SCIENCE – known only from the study area

A small (to ~ 55 mm snout-vent length moderately slender gecko of the genus *Gehyra* with large adhesive pads on the fingers and toes. This species was found only in logged hill forest at Site 3 in the Southeast Hills ecological zone. Although its habitat requirements are poorly known it appears to live high in forest trees - two individuals were observed several meters high on tree trunks and one was captured when it glided to the forest floor from a branch >10 m above the ground. The taxonomy of this group is exceptionally difficult but *Gehyra* sp. 1 appears to be new-to-science. The species is currently known with certainty only from the study area where it is known from Site 3. However, it may also occur in the Lakekamu basin (S.J. Richards, unpublished data). Even if this is confirmed the species will qualify as restricted-range having a range of substantially <50,000 km^2**.** A forest-dwelling species, the major threats are forest loss and degradation.

Scincidae

Sphenomorphus sp. 1 – UNDESCRIBED – known widely outside the study area

A small (to ~50 mm), moderately slender forest-dwelling skink with short legs and pale spots across the dorsum and head. It was encountered only at Site 2 in the Middle Purari Hills ecological zone where a single individual was active in moist litter during the day. Extensive habitat suitable for this species occurs throughout the Middle Purari Hills, and it probably occurs in similar habitats in the Southeast Hills ecological zone.

Sphenomorphus sp. 1 has a broad distribution outside the study area, extending west as far as the Star Mountains in Papua Province, Indonesian New Guinea, and also extends onto the northern slopes of PNG's central cordillera (S.J. Richards, unpublished data). It does not qualify as restricted-range. A forest-dwelling species, the major threats are forest loss and degradation.

Colubridae

Stegonotus sp. 1 – NEW-TO-SCIENCE – known only from the study area

A moderately large (~1.2 m) and robust snake with a striking pattern of white and brown coloration dorsally (Plate 4). This new species was encountered at Sites 4, 5, 8 and 9 in alluvial forest in the Delta Swamps and Plains and Southeast Coast ecological zones where it was active at night on the forest floor. Although its habitat requirements are poorly known all records of the species are from drier habitats within alluvial forest. The extent to which it occupies more frequently flooded areas such as swamp forest or sago swamp woodland remains unclear, but other members of the genus have broad habitat tolerances. This species was not encountered in the Lakekamu basin to the east (Allison et al. 1998) and is not known from the Kikori basin to the west (S.J. Richards, unpublished, O'Shea 1996) or from any other location.

This species qualifies as restricted-range. It is currently known only from the study area; within this area the extent of suitable habitat is calculated to be less than 7,500 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

4.4. ENDEMIC AND RESTRICTED-RANGE SPECIES

4.4.1. Frogs

Examination of the broad patterns of endemism of frogs encountered during this survey demonstrates that an extremely high proportion of the fauna (68.3%) is in the highest endemism category (Category 5, being endemic to southern mainland New Guinea; Table 2). Figure 11 illustrates the percent of species in each endemism category at each site. This demonstrates that species endemic to southern New Guinea dominate the frog fauna at all sites, irrespective of the ecological zone or major vegetation types present. The only site where Category 5 endemics represented less than 60% of the fauna was Site 9 in the Southeast Coast ecological zone (42% of the fauna) where frog diversity was low and a number of species shared with Australia increased the weight of endemism Category 1.

Given the large proportion of species in the highest endemism category at all sites, the proportion of species qualifying as restricted-range (having known ranges <50,000 km^2) was assessed. Twenty-one of the 41 native frog species (51.2%) encountered during the survey qualify for restricted-range status. Proportions of restricted-range species among the major frog families ranged from 38.5% for Hylidae to 40% for Ranidae and 68% for Microhylidae. The higher proportion of restricted-range species in the family Microhylidae reflects the large number of undescribed species with poorly-known distributions in that family. Proportions of restricted-range species at all sites were high and

relatively similar, ranging from 33–59% but, reflecting patterns of endemism, were lowest at Site 9 suggesting that the heavily modified habitats of the Southeast coast ecological zone provide few important habitats for endemic and restricted-range species. The percentage of frog species at each site that are restricted-range is illustrated in Figure 12 and short species accounts for each restricted-range species are presented below. Most species are illustrated in Plate 3.

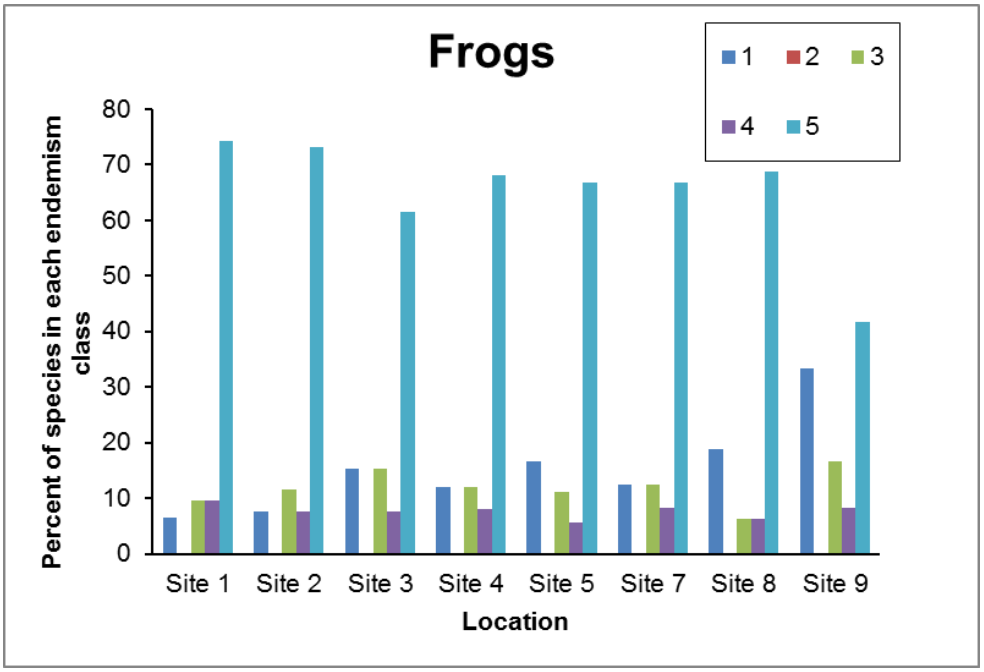

Figure 11. Percent of frog species in each endemism category at each principal site (1–5 = lowest to highest category; see Table 2 for explanation of endemism codes).

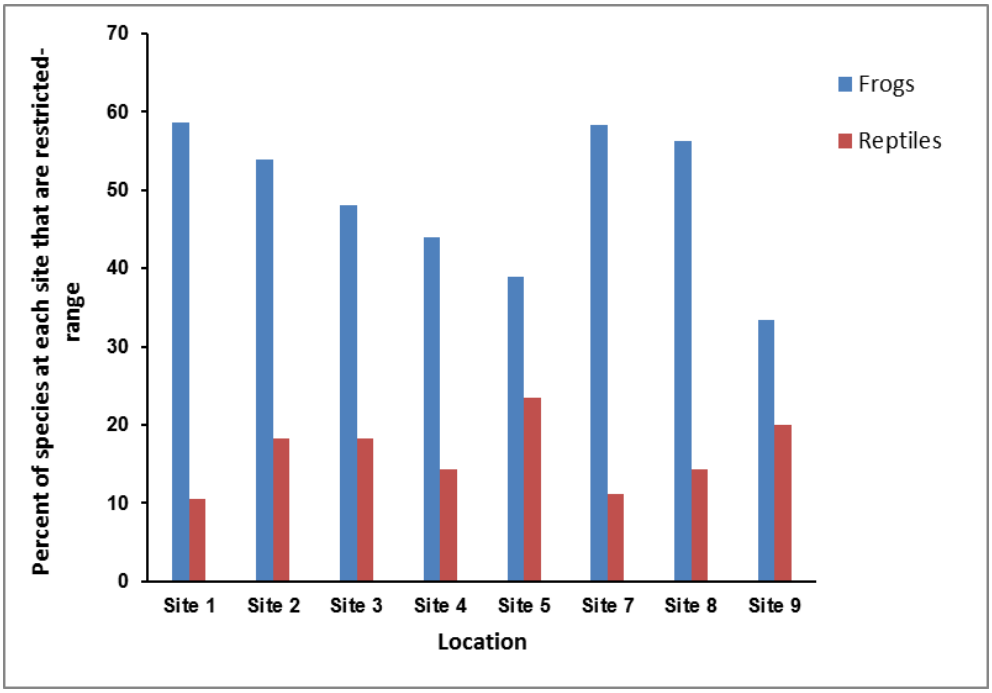

Figure 12. Percent of total herpetofauna species at each principal survey site that are classified as restricted-range.

Species accounts

Restricted-range species known only from the study area

Five frog species documented during this survey are currently known only from the study area. Three of them, *Cophixalus* sp. 3, *Oreophryne* sp. 1 and *Oreophryne* sp. 2, are new-to-science species discovered for the first time during Project surveys. The remaining two species, *Litoria* sp. 1 and *Hylarana* sp. 2, are undescribed and previously known only from the vicinity of Wabo in the study area. Accounts for each of these species are presented in Section 4.3.1. Given that these species were not detected during past surveys in suitable lowland habitat in other parts of Gulf Province to the east and west of the study area (Lakekamu and Kikori basins respectively), or in higher elevation hill forest in the Crater Mountain WMA, currently available data suggest that they may occupy a very restricted geographic range in the order of less than 10,000–15,000 km^2.

Undescribed restricted-range species previously known from outside the study area

Eight frog species documented during this survey are undescribed and have restricted ranges that extend outside of the study area: *Austrochaperina* sp. 1, *Choerophryne* sp. 1, *Cophixalus* sp. 1 & 2, *Copiula* sp. 1, *Hylophorbus* sp. 1, *Xenorhina* sp. 1 and *Hylarana* sp. 1. All of these have narrow distributions in the wet lowland and foothill forests fringing the southern slopes of PNG's central cordillera and have geographic ranges in the order of less than 50,000 km^2. Accounts for each of these species are presented in Section 4.3.1.

IUCN listed restricted-range species previously known from outside the study area

One IUCN Data Deficient species, the ground-dwelling microhylid *Callulops marmoratus*, is here considered to be restricted-range. *Callulops marmoratus* is restricted to a narrow band of wet forest habitats in the Purari basin and possibly extending to the upper Fly River area. An account for this species is presented in Section 4.2.1.

Other restricted-range species documented during this survey

Six additional frog species with known ranges of less than 50,000 km^2 were documented during this survey. Accounts for each of these species are presented below.

Hylidae

Litoria chloristona

A small (to 28 mm), slender green treefrog with a white stripe under the eye and orange-red color in the thighs. Males produce a series of 'zeeeps' and 'clicks' from low vegetation in swamps, ditches and flooded grassland where frogs often occur in great abundance after rain. Within the study area this species was found at Sites 1, 3, 5, 7 and 8; it was particularly abundant around artificial pools and wet grassy road verges on and adjacent to abandoned wellpads and other infrastructure in the vicinity of Antelope 3 accommodation base. It is currently known from a narrow elevational band (0–500 m asl) between Port Moresby in the east and the Kikori River in the west. Extensive suitable habitat occurs throughout the Middle Purari Hills, Southeast Hills, the Delta Swamps and Plains and the Southeast Coast ecological zones. The species' distribution is poorly defined and is close to, but as currently recognized is probably less than 50,000 km^2.

Litoria congenita

Litoria congenita is a small, short-legged treefrog with a variable back pattern. It is predominantly a species of seasonal woodland habitats (Menzies 2006), and is currently known from isolated populations on the Aru Islands, the southern Trans-Fly and around Port Moresby. Two animals encountered at Site 9 represent the first records of this species for Gulf Province and fill a major gap

in distribution between the southern Trans-Fly and Port Moresby populations. At Site 9 one of the animals was captured in a flooded dune system less than 100 m from the ocean; the other was captured in the fly camp. It is unlikely that extensive areas of suitable habitat for this species occur within the study area, where it is probably restricted to the Southeast Coast ecological zone. It is unclear whether the distribution of this species is genuinely fragmented but, as currently recognized, its range is probably less than 50,000 km^2.

Litoria exophthalmia

This is a medium-sized (males to ~40 mm), predominantly brown treefrog with prominent eyes, a variable back pattern often shaped like an hour-glass, and a small spike on the heel. It is a poorly-known species that was originally described from the vicinity of Haia in the Crater Mountain WMA. During this survey, *L. exophthalmia* was found at Sites 1, 2 and 7, where males called from low vegetation along small forest streams. The species' distribution is poorly documented, and no confirmed localities outside of the Crater Mountain WMA have been published with the exception of a possible record from Bobole in Southern Highlands Province (Richards et al. 2010). Extensive suitable habitat within the study area occurs in hill forests in the Middle Purari Hills and Southeast Hills ecological zones. The IUCN Red List assessment for this species estimates its extent of occurrence as less than 20,000 km^2 (IUCN 2004).

Microhylidae

Copiula guttata

A moderately large microhylid frog (males to ~45 mm) having a grey-brown dorsum with numerous darker flecks. This species was abundant at Sites 1–5, 7, 8 and 9 in the Middle Purari Hills, Southeast hills, Delta Swamps and Plains and Southeast Coast ecological zones where males called from the forest floor with a rapidly-repeated series of very loud, harsh 'yapping' notes. *A. guttata* is known only from the lowlands and foothills of the Gulf of Papua, from Lakekamu in the east to Kikori in the west. In the study area, this species was found in hill forest and alluvial forest and was not encountered in wetter swamp forest habitats. Suitable habitat within the reported region of occurrence amounts to approximately 20,000 km^2. A forest-dwelling species that also occurs in open grassland and around artificial waterbodies, this species appears to be resilient to forest loss and degradation.

Metamagnusia slateri

A moderately large (to ~60 mm) and robust frog with irregular dark spots on the dorsum and extremely large finger and toe discs. This species was common in all ecological zones except the Mangrove ecological zone and was encountered at all sites except Sites 6B and 8M (which were sampled only during the day). It occurred in hill, alluvial and swamp forest, and was present in moderately disturbed forest retaining large trees, but not in gardens or plantations including coastal coconut groves. Males called from high in the forest canopy with a series of loud, melodious notes. *M. slateri* is known from the lowlands and foothills of southern PNG at altitudes between sea level and about 1,500 m asl between the Lakekamu basin in the east and the Ok Tedi Headwaters in the west. Suitable habitat within the reported region of occurrence amounts to between 45-50,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Oreophryne pseudunicolor

A moderately small (to ~ 30 mm) tree-dwelling microhylid frog with large toe pads. This species was seen or heard at all eight principal survey sites. Males called from trees, often from high in the canopy but occasionally from less than 3 m above the ground, with a series of loud peeping notes. It was found predominantly in hill and alluvial forest, but males were also heard calling in trees in wet,

swampy habitats within the Delta Swamps and Plains and Southeast Coast ecological zones. It can persist in moderately disturbed habitats where forest cover remains relatively intact. Extensive suitable habitat for this forest-dwelling species occurs throughout the hill and alluvial forests of the study area. This species was previously known from the Kikori basin to the west, and its distribution appears to extend at least as far westward as the border with Indonesian New Guinea. The species' distribution is poorly defined and is close to, but as currently recognized is probably less than, 50,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Additional restricted-range species not documented during this survey

The following taxa not recorded but known or expected to occur in the study area are restricted-range species.

Litoria dorsalis

A small (to ~25 mm) slender brown frog with a long, projecting snout and basal webbing between the toes. This is a poorly-known species that is recorded with certainty only from swampy lowland forest in the Trans-Fly area of Western Province, and Lakekamu in Gulf Province (Menzies 2006). Based on their known distributions it is likely that the record of *Litoria timida* (a similar species not known from the Purari basin) from the study area by Pernetta and Burgin (1980) refers to *Litoria dorsalis* but examination of that material is required to confirm this. In the Trans-Fly *Litoria dorsalis* was found in flooded open woodland habitat while at Lakekamu it occurred adjacent to flooded forest pools under extensive canopy cover. Given that this species was not encountered in the Kikori basin during surveys there it probably has a discontinuous distribution. A forest- and swamp-dwelling species, the major threats are forest loss and degradation of swamp habitats.

Litoria vocivincens

A small (to ~27 mm) slender frog with two distinct color phases – one being green with black spots and the other dull olive with yellow stripes (Menzies 2006). Breeding occurs in shallow, often temporary, waterbodies where males call with a series of 'unmelodious buzzes' (Menzies 2006). The species has a range extending from Milne Bay in the east to the Purari River in the west, but its distribution is restricted to the narrow coastal strip between sea level and 1,000 m asl and so the species qualifies for restricted-range status with an estimated range of less than 40,000 km^2. A forest- and swamp-dwelling species, the major threats are forest loss and degradation of swamp habitats.

4.4.2. Reptiles

In contrast to the frogs, which are dominated by species in the narrowest endemism class (Figure 11), examination of Figure 13 illustrates that at all sites except 4 and 5, reptiles in Category 1 (species widespread in the Indo-Pacific) contributed the greatest proportion of species. Category 3 species (those widespread across mainland New Guinea and satellite islands) also represented a high proportion of the fauna. Only at Sites 4 and 5 was there a higher proportion of Category 5 species than species in Category 1. However the number of Category 5 species at Sites 4 and 5 was similar to other sites (6 vs 3–7) and only one Category 5 species found at each of these sites (the geckos *Cyrtodactylus novaeguineae* at Site 4 and *C. serratus* at Site 5) was not found at other sites so this result appears to be attributable, at least at Site 5, to the relatively depauperate fauna detected at this site (18 species) in combination with the presence of a suite of small category 5 skinks that persist at most sites (Table 5).

Of more interest is the clear pattern for Category 1 (most widespread) species to dominate the heavily disturbed coastal habitats in the Southeast Coast ecological zone (Sites 8 and 9). This reflects the removal or severe degradation of most alluvial forest habitats in this zone and their colonization by widespread, disturbance tolerant species.

These patterns of endemism are reflected in the small number of reptiles encountered that have restricted ranges. Only eight taxa (14% of the reptile fauna) qualify for restricted-range status and two of these involve subspecies. Numbers are too low for meaningful comparisons to be made across taxonomic groups within reptiles but, in contrast to the pattern seen for frogs, there is a much lower proportion of Category 5 species and this pattern is consistent across the study area (Figure 13) and Site 1 has the lowest proportion of restricted-range species (Figure 12). Species accounts for each restricted-range reptile species encountered during the survey are presented below and most species are illustrated in Plate 5.

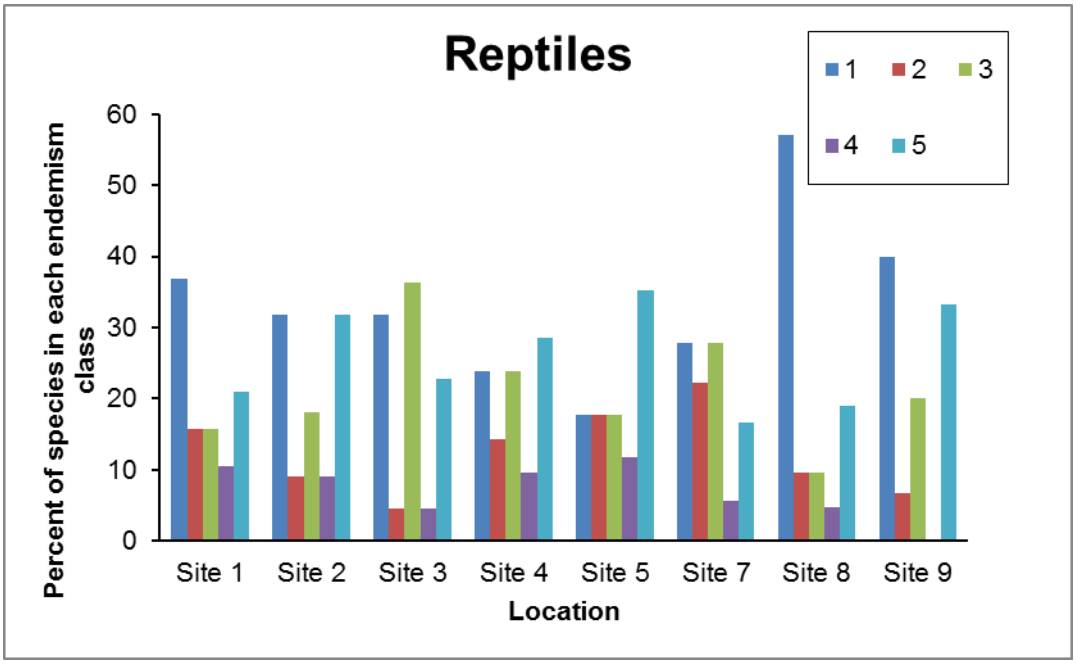

Figure 13. Percent of reptile species in each endemism category at each principal survey site (1–5 = lowest to highest category; see Table 2 for explanation of endemism codes).

Species accounts

Restricted-range species known only from the study area

One new species of snake of the genus *Stegonotus* is currently known only from the study area. A brief account for this species is presented in Section 4.3.2.

One species of gecko, *Gehyra* sp. 1, that was found only at Site 3 appears to be new-to-science and is currently known only from the study area. A brief account for this species is presented in Section 4.3.2.

Restricted-range species previously known from outside the study area

Gekkonidae

Cyrtodactylus serratus

Cyrtodactylus serratus is a large (~140 mm) robust gecko with claws on the fingers and toes. It is an arboreal species that was previously known from scattered sites along the southern fringe of New Guinea's central cordillera extending from the Purari basin in the east to the Ok Tedi headwaters in the west. This species was encountered only in alluvial forest at Site 5. It is known from elevations up to at least 500 m asl and there is extensive suitable habitat for this species in hill forests in the Middle Purari Hills and Southeast Hills ecological zones, and in alluvial forests in the Delta Swamps and

Plains ecological zone. If the distribution of this species extends westwards into the wet hill forests fringing the southern slopes of the central cordillera in Papua Province then it will have a distribution exceeding 50,000 km^2. However, currently available data suggest that this species may occupy a restricted geographic range in the order of less than 50,000 km^2. A forest-dwelling species, the major threats are forest loss and degradation.

Lepidodactylus cf. *orientalis*

Lepidodactylus cf. *orientalis* is a small (to ~45 mm), slender gecko that is endemic to PNG where it is known from two isolated populations on the north and south of the main island between sea level and 665 m asl; one on the Sogeri Plateau near Port Moresby in Central Province, and the other in the Kamiali WMA in Morobe Province (Tallowin & Oliver 2015). A single specimen resembling *L. orientalis* was encountered in Hill forest (Hm) at Site 2 in the Middle Purari Hills ecological zone where it was collected from vegetation at the edge of the fly camp at night. Whether it represents a third, isolated population of *L. orientalis* or a species new-to-science, the Site 2 population is likely to retain its status as a restricted-range species. Because only one individual was encountered its habitat requirements remain poorly-known and threats poorly understood. The Site 2 animal was perched on low vegetation in naturally disturbed hill forest. Other members of the genus are also capable of persisting in severely modified habitats. It probably also occurs in less disturbed hill forest which is widespread in the Middle Purari Hills and Southeast Hills ecological zones.

Gehyra membranacruralis

Gehyra membranacruralis is a large (~ 120 mm) and robust gecko with large adhesive pads on the fingers and toes and distinct flaps along the hind legs. It was previously known from rainforest and savanna habitats, including both primary and secondary habitats, between Port Moresby and the Lakekamu basin. The record from Site 8 in the study area represents a westerly range extension of about 150 km. Failure to detect this large species at other sites suggest that, within the study area it may be restricted to the Southeast Coast ecological zone, where it probably occurs extensively in remnant alluvial forest and gardens, secondary forest and other disturbed habitats. There are no known threats to this species. Despite discovery of this new population *G. membranacruralis* is calculated to occupy a restricted geographic range in the order of substantially less than 50,000 km^2.

Scincidae

Skinks of the genus *Carlia* in New Guinea are a taxonomically difficult group and the identifications of both species encountered during this survey are tentative. One of these species, found at all principal sites except Site 4, was abundant in sunny patches on the forest floor and closely resembles both *C. aenigma* and *C. aramia*, which can themselves only be distinguished by subtle patterns of juvenile coloration (Zug 2004). Neither species is known from the study area but the material obtained during this survey is tentatively identified as *C. aenigma*. *Carlia aenigma* is currently known only from the Papuan Gulf coast between the Kikori River in the east and the Aramia river in the west at altitudes below 500 m. It was particularly abundant in hill and alluvial forest habitats and was also common in open habitats, including gardens and forest regrowth. Extensive suitable habitat for this species occurs throughout all ecological zones in the study area. However, based on the currently known distribution of *C. aenigma* this species is calculated to occupy a restricted geographic range in the order of substantially less than 50,000 km^2.

Carlia cf. *luctuosa*

The second *Carlia* species encountered is a large, robust skink that closely resembles *C. luctuosa*. Unfortunately, insufficient material is available to assess the taxonomic status of the Purari population. *Carlia luctuosa* is currently known only from Kapakapa westward to Angabunga River area and Kone village in Central Province, PNG (Zug 2004), where it is common in forest, plantations

and disturbed areas such as gardens at altitudes below 600 m asl. If the Purari population, which was found predominantly in well drained hill forest in the Purari Hills and Southeast Hills ecological zones (and less commonly in alluvial forest represents *luctuosa* then it will be a major range extension but nevertheless it will represent an additional restricted-range species from the study area; and if it is a new species then it will represent a restricted-range species known only from the study area. A forest-dwelling species, the major threats are forest loss and degradation

Cryptoblepharus litoralis vicinus

Cryptoblepharus litoralis is a small, slender skink that has a broad distribution along the coastal fringe of northern Australia. Horner (2007) recognized three subspecies of *C. litoralis*, two from Australia and one that is currently known only from Ela Beach in Port Moresby, Central Province, PNG. This subspecies, *C. litoralis vicinus*, was found in large numbers on the sand, driftwood, and bases of coconut trees along the beach at Site 9. It was not detected at any other site, nor was it encountered more than 20 m from the beach-front. The Orokolo Bay population represents only the second known location for this subspecies, which has an extremely restricted distribution that is unlikely to exceed 1,000 km^2. A beach-dwelling species, the major threats are loss and degradation of littoral habitats

Emoia physicae purari

A small, brown, litter-dwelling skink, *Emoia physicae* is a widespread species occurring across much of southern and north-eastern PNG. Brown (1991) described the Purari basin population as a new subspecies, *E. physicae purari*, restricted predominantly to the Purari basin and extending west to the Kikori River (Brown 1991). This lizard was abundant in the forest litter and in small sunny clearings at all sites except Sites 8, 8M and 9 in the Southeast Coast and Mangroves ecological zones. This subspecies, but not the species, has a range restricted to the Purari catchment in Gulf, Chimbu, and Eastern Highlands Provinces in southern PNG, and west to the Kikori basin, up to an altitude of 1,000 m asl. *Emoia physicae purari* was the most abundant reptile species at most sites, occurring in hill, alluvial and swamp forest habitat including forest clearings, logged forest and other disturbed habitats. Suitable habitat within the study area amounts to less than 25,000 km^2. A highly adaptable species, no threats are known.

4.5. OTHER SIGNIFICANT SPECIES - CROCODILES

Two species of crocodiles, the Estuarine Crocodile (*Crocodylus porosus*) and the New Guinea Freshwater Crocodile (*Crocodylus novaeguineae*) occur in the Purari River and its major tributaries. During this survey, numerous young *C. novaeguineae* were observed in a stream at Site 5, a young *C. porosus* was observed at Site 8M, and photos of a large adult *C. porosus* that died in a fishing net at Site 8 were provided by local informants.

Pernetta and Burgin (1980; 1983) summarized knowledge about the status and ecology of crocodiles in the Purari River to that date. Both species are mound nesters that mate at the start of the wet season (~October) and nest and lay eggs predominantly through November and December (Pernetta and Burgin 1983).

Pernetta and Burgin were unable to distinguish between the two crocodile species in the wild but noted from interviews with hunters and skin buyers that while the Freshwater Crocodile is widespread throughout the Purari catchment the Estuarine Crocodile has a distribution limited predominantly to the southern portions of the catchment including the main channels of the delta area. Interviews with local informants during the 2016 surveys support this view, with a general consensus that Estuarine Crocodiles do not penetrate in large numbers into the smaller tributaries of the upper Purari catchment.

Small-scale crocodile farms were not observed during the survey but local informants reported that crocodiles are a valuable resource; the meat is used for local consumption, and the skins are sold to

dealers who occasionally come up the river. The skin of Estuarine Crocodiles is more valuable than that of Freshwater Crocodiles and an adult specimen that had drowned in a fishing net at Site 8 approximately one month before the survey was skinned and the skin retained for sale while the remaining carcass was butchered for its meat (photos provided to SJ Richards).

4.6. INVASIVE ALIEN SPECIES

Cane Toad (*Rhinella marina*)

The Cane Toad (*Rhinella marina*) is an exotic amphibian introduced to Australia and New Guinea from South America as a biological control agent. It is a rapidly spreading and highly toxic amphibian and attempts to control it in Australia have failed. *Rhinella marina* has a patchy distribution in PNG, particularly in coastal areas (Lever 2001), and it was encountered during this survey only at Sites 1 and 3 and at Herd Base. The species was accidentally introduced to Staging Camp on the Purari River after it was opened in 2004 (DES 2008) but it is unclear whether the Staging Camp population is the source for the toads now established at Antelope 3 (Site 1). At Site 3 toads were observed along the logging road, but were not found within the forest.

Although the impacts of the Cane Toad on native amphibian populations are poorly understood, this species is considered a serious pest and it has decimated populations of some predators in Australia (e.g. Taylor & Edwards 2005). Cane Toads are restricted predominantly to open savanna habitats, urban areas, and to disturbed forest environments that have been substantially modified by human activities. They are less common in, and appear to disperse slowly through, dense closed-canopy forests. Development of an eradication plan for the population at Antelope 3, and strategies to reduce the likelihood of the Project assisting the spread of this species in future should be a high priority.

4.7. IMPORTANT HABITATS AND LANDSCAPE FEATURES

The hill and alluvial forests of the study area provide a wide variety of microhabitats that support a rich herpetofauna including several PNG-endemic and restricted-range species. Some of these habitats are illustrated in Plates 6 and 7. To maintain this diversity it is important that as much of this mosaic of lowland and foothill forest habitats is retained as possible. However, within this matrix are several features that appear to be focal habitats for a number of taxa.

1) The Purari River and its tributaries comprise a near-unmodified river system that supports populations of freshwater turtles and crocodiles that are resources for local communities (turtles, New Guinea Freshwater and Estuarine Crocodiles) and are species of conservation concern (Pig-nosed Turtle, Striped New Guinea Soft-shell Turtle). These species use these rivers and their banks for feeding and nesting respectively. Sandy and muddy river banks are essential for breeding by the IUCN Vulnerable Pig-nosed Turtle, and Striped New Guinea Soft-shell Turtle and represent an important habitat for these species.

2) Off-river waterbodies are important habitats for breeding by both New Guinea Freshwater and Estuarine Crocodiles throughout their range. Pernetta and Burgin (1983) reported that New Guinea Freshwater Crocodiles construct their nests 6–9 m from adjacent lagoons and sluggish channels, and Cox (1984) reported that while there is some overlap in nesting habitat of the two species in PNG the Estuarine Crocodile is more likely to nest adjacent to larger waterbodies than those selected by the Freshwater Crocodile. Information from local informants, and aerial reconnaissance of a major off-river oxbow wetland system adjacent to the Purari River during the Phase 1 survey, both indicate that nesting crocodiles reach high densities in these habitats and that they are therefore important for maintaining local populations of these species. A swamp adjacent to the main Purari River channel in the southern portion of PRL-15 (Figure 10) was identified as an important breeding habitat for Freshwater Crocodiles and small freshwater turtles (*Emydura subglobosa*).

3) Clear streams and small rivers in both hill forest and alluvial forest support a small but distinct assemblage of frogs including two restricted-range, undescribed frogs of the genus *Hylarana* and the restricted-range treefrog *Litoria exophthalmia*. These species rely on permanent clear-flowing streams for reproduction and are most frequently encountered in the humid, dense riparian vegetation along their banks.

4) Small forest pools and seepages in foothill forest support several species of treefrogs including two undescribed species (*Litoria* sp. 1 and *Litoria* sp. 2), that are reliant on this particular microhabitat for reproduction. *Litoria* sp. 1 is currently known only from the study area.

5) Alluvial forest in the Delta Swamps and Plains and Southeast Coast ecological zones provide the only known habitat for a striking new species of snake (*Stegonotus* sp. 1) that is currently known only from the study area.

6) Intact forest habitats are important for maintaining the diversity of herpetofauna in the study area. Many species encountered during this survey were restricted to the cool, moist interior of closed-canopy forest. Microhylid frogs, a group comprising a high proportion of restricted-range species, rely on high levels of moisture and humidity for the successful development of their terrestrial embryos and are likely to be particularly reliant on the persistence of extensive areas of undisturbed forest canopy.

4.8. CONSERVATION VALUE

Given the high levels of overlap of both frog and reptile species with the Lakekamu basin, and of frogs with the Kikori basin, the major biodiversity values of the herpetofauna in the study area are:

1) That it represents a diverse faunal assemblage typical of and contiguous with adjacent areas along the southern foothills of mainland New Guinea.

2) That it contains five frogs and two reptiles that are undescribed or new-to-science that are so far not known outside of the study area.

3) That it contains a number of large reptile species that are resources for local communities including two large turtle species listed as Vulnerable by the IUCN.

4.9. KNOWLEDGE GAPS AND SEASONALITY ISSUES

The herpetofauna appears to have been well documented based on accumulation curves, and on broad levels of overlap with sites to the east and west. Frogs and reptiles have been well documented in neighboring regions: Kikori, Lakekamu and adjacent uplands in the CMWMA. Although additional species no doubt remain undetected, including potentially additional new-to-science taxa, based on experience in neighboring regions these are not expected to have such different ecological traits as to demand management considerations not already considered as a result of the documented community.

Sites 1–4 were conducted at the end of a major El Nino event when rainfall, and associated frog vocal activity, were uncharacteristically low while surveys at sites 5–9, were conducted during the slightly wetter southeast (trade winds) season. Despite these differences in rainfall, examination of accumulation curves for both frogs and reptiles indicate similar patterns of species discovery over time during the different seasons. These data suggest that in both survey periods a large proportion of the frog fauna was documented and that, overall, seasonality played a limited role in determining rates of species detection.

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APPENDIX 1. CHECKLIST OF HERPETOFAUNA KNOWN FROM THE STUDY AREA

Species	IUCN status	Source*
Frogs		
Hylidae		
Litoria amboinensis	LC	DES (2008)
Litoria auae	LC	This Study
Litoria caerulea	LC	This Study
Litoria chloristona	NE	This Study
Litoria congenita	LC	This Study
Litoria dorsalis	LC	P&B (1980) [probably as *L. timida*]
Litoria exophthalmia	LC	This Study
Litoria infrafrenata	LC	This Study
Litoria nasuta	LC	L&H (1977)
Litoria pronimia	LC	This Study
Litoria prora	LC	This Study
Litoria pygmaea	LC	This Study
Litoria sauroni	NE	This Study
Litoria thesaurensis	LC	This Study
Litoria vocivincens	LC	P&B (1980)
Litoria sp. 1	NE	This Study
Litoria sp. 2	NE	This Study
Nyctimystes pulcher	LC	DES (2008)
Limnodynastidae		
Lechriodus melanopyga	LC	This Study
Microhylidae		
Austrochaperina derongo	LC	This Study
Austrochaperina palmipes	LC	This Study
Austrochaperina sp. 1	NE	This Study
Callulops doriae	LC	This Study
Callulops marmoratus	DD	This Study
Choerophryne sp. 1	NE	This Study
Cophixalus cheesmanae	LC	This Study
Cophixalus sp. 1	NE	This Study
Cophixalus sp. 2	NE	This Study
Cophixalus sp. 3	NE	This Study
Copiula guttata	LC	This Study
Copiula sp. 1	NE	This Study
Hylophorbus rufescens	LC	This Study
Hylophorbus sp. 1	NE	This Study
Liophryne schlaginhaufeni	LC	DES (2008)

Species	IUCN status	Source*
Mantophryne lateralis	LC	This Study
Metamagnusia slateri	LC	This Study
Oreophryne oviprotector	NE	This Study
Oreophryne pseudunicolor	NE	This Study
Oreophryne sp. 1	NE	This Study
Oreophryne sp. 2	NE	This Study
Sphenophryne cornuta	LC	This Study
Xenorhina sp. 1	NE	This Study
Ranidae		
Hylarana daemeli	LC	This Study
Hylarana novaeguineae	LC	This Study
Hylarana papua	LC	P&B (1980)
Hylarana sp. 1	LC	This Study
Hylarana sp. 2	NE	This Study
Hylarana sp. 3	NE	This Study
Bufonidae		
Rhinella marina, Cane Toad	LC	This Study
TOTAL: 49		
Reptiles		
Lizards		
Agamidae		
Hypsilurus magnus	LC	This Study
Hypsilurus modestus	LC	This Study
Lophosaurus dilophus	LC	This Study
Gekkonidae		
Cyrtodactylus novaeguineae	LC	This Study
Cyrtodactylus serratus	LC	This Study
Gehyra baliola	NE	This Study
Gehyra membranacruralis	LC	This Study
Gehyra mutilata	NE	P&B (1980)
Gehyra sp. 1	NE	This Study
Gekko vittatus	NE	P&B (1980)
Hemidactylus frenatus, House Gecko	LC	This Study
Lepidodactylus lugubris, Mourning Gecko	NE	P&B (1980)
Lepidodactylus cf. *orientalis*	NE	This Study
Nactus sp.	NE	This Study
Scincidae		
Carlia aenigma/aramia	LC	This Study

Species	IUCN status	Source*
Carlia cf. *luctuosa*	NE	This Study
Cryptoblepharus litoralis vicinus	NE	This Study
Emoia caeruleocauda	LC	This Study
Emoia kordoana	NE	This Study
Emoia longicauda	NE	This Study
Emoia pallidiceps	LC	This Study
Emoia physicae purari	LC	This Study
Emoia sp. (*tropidolepis*?)	NE	This Study
Eugongylus rufescens	NE	WP (2009)
Glaphyromorphus nigricaudis	NE	This Study
Lipinia longiceps	LC	This Study
Lipinia nototaenia	LC	This Study
Lygisaurus sp.	NE	This Study
Prasinohaema semoni	NE	DES (2008)
Sphenomorphus aruensis	LC	This Study
Sphenomorphus meyeri	LC	This Study
Sphenomorphus muelleri	NE	This Study
Sphenomorphus pratti	NE	P&B (1980)
Sphenomorphus simus	LC	This Study
Sphenomorphus undulatus	NE	This Study
Sphenomorphus solomonis	NE	This Study
Sphenomorphus sp. 1	NE	This Study
Tiliqua gigas	NE	This Study
Varanidae		
Varanus indicus, Mangrove Monitor	LC	This Study
Varanus prasinus, Emerald Monitor	NE	P&B (1980)
Varanus salvadori, Salvadori's Monitor	NE	P&B (1980)
Snakes		
Acrochordidae		
Acrochordus granulatus, File Snake	LC	L&H (1977)
Boidae		
Candoia aspera, Ground Boa	NE	This Study
Elapidae		
Acanthophis laevis, Death Adder	LC	This Study
Aspidomorphus muelleri	LC	WP (2009)
Micropechis ikaheka	NE	This Study
Toxicocalamus preussi	NE	This Study
Toxicocalamus stanleyanus	NE	WP (2009)
Colubridae		

Species	IUCN status	Source*
Boiga irregularis, Brown Tree Snake	NE	This Study
Dendrelaphis calligaster, Green Tree Snake	LC	This Study
Dendrelaphis macrops	NE	This Study
Stegonotus cucullatus, Slaty-grey Snake	NE	This Study
Stegonotus diehli	NE	This Study
Stegonotus sp. 1	NE	This Study
Tropidonophis doriae	NE	This Study
Tropidonophus novaeguineae	LC	WP (2009)
Tropidonophis picturatus	LC	This Study
Pythonidae		
Bothrochilus meridionalis	NE	This Study
Morelia amethistina, Amethistine Python	LC	This Study
Morelia viridis, Green Tree Python	LC	This Study
Typhlopidae		
Ramphotyphlops multilineatus	LC	This Study
Crocodylidae		
Crocodylus novaeguineae, New Guinea Freshwater Crocodile	LC	This Study
Crocodylus porosus, Estuarine Crocodile	LC	This Study
Turtles		
Carettochelydae		
Carettochelys insculpta, Pig-nosed Turtle	VU	This Study
Chelidae		
Chelodina sp.	NE	This Study
Elseya rhodini	LC	L&H (1977)
Emydura subglobosa, New Guinea Painted Turtle	LC	This Study
Trionychidae		
Pelochelys bibroni, Striped New Guinea Softshell Turtle	VU	This Study
Cheloniidae		
Caretta caretta, Loggerhead Sea Turtle	VU	L&H (1977)
Chelonia mydas, Green Sea Turtle	EN	L&H (1977)
TOTAL: 70		

*DES = Douglas Environmental Services (2008); L&H = Liem & Haines (1977); P&B = Pernetta & Burgin (1980); and unpublished data.

Plate 1. Conservation significant, undescribed and new-to-science frog species

Family Microhylidae. *Callulops marmoratus*.
IUCN Data Deficient

Family Hylidae. *Litoria* sp. 1. Undescribed

Family Hylidae. *Litoria* sp. 2. Undescribed

Family Microhylidae. *Cophixalus* sp 1. Undescribed

Family Microhylidae. *Cophixalus* sp 2. Undescribed

Family Microhylidae. *Cophixalus* sp 3. New-to-science

Plate 2. Undescribed and new-to-science frog species

Family Hylidae. *Litoria chloristona*. Restricted-range

Family Hylidae. *Litoria congenita*. Restricted-range

Family Hylidae. *Litoria exophthalmia*. Restricted-range

Family Microhylidae. *Copiula guttata*. Restricted-range

Family Microhylidae. *Metamagnusia slateri*. Restricted-range

Family Microhylidae. *Oreophryne pseudunicolor*. Restricted-range

Plate 3. Restricted range frog species

Family Microhylidae. *Copiula* sp 1. Undescribed

Family Microhylidae. *Oreophryne* sp 1. New-to-science

Family Microhylidae. *Oreophryne* sp 1. New-to-science

Family Microhylidae. *Xenorhina* sp 1. Undescribed

Family Ranidae. *Hylarana* sp. 1. Undescribed

Family Ranidae. *Hylarana* sp. 2. Undescribed

Plate 4. Conservation significant, undescribed and new-to-science reptiles

Family Carettochelyidae. *Carettochelys insculpta*.
IUCN Vulnerable. © S. J. Richards

Family Colubridae. *Stegonotus* sp 1. New-to-science

Family Trionychidae. *Pelochelys bibroni*.
IUCN Vulnerable. © S. J. Richards

Family Gekkonidae. *Gehyra* sp. 1. New-to-science

Family Scincidae. *Sphenomorphus* sp. 1. Undescribed

Plate 5. Restricted range reptiles

Family Gekkonidae. *Cyrtodactylus serratus*. Restricted-range

Family Gekkonidae. *Lepidodactylus* cf *orientalis*. Restricted-range

Family Scincidae. *Carlia aenigma*. Restricted-range

Family Scincidae. *Cryptoblepharus litoralis vicinus*. Restricted-range

Family Scincidae. *Emoia physicae purari*. Restricted-range

Plate 6. Habitat examples

Forest interior at Site 1

Turtle nesting beach on Purari River

Plate 7. Habitat examples

Forest Stream at Site 7

Habitat for the Estuarine Crocodile at Site 8