**FishTaxa** (2021) 20: 1-13
Journal homepage: www.fishtaxa.com


# Notes on the ichthyofauna of inland streams of the Whiteman Range, New Britain Island, Papua New Guinea

**Pita K. AMICK**[1,2]*, **Pagi S. TOKO**[2,3]
[1]*Amick Environmental Consulting, PO Box 1179 Mt. Hagen, WHP 281, Papua New Guinea.*
[2]*New Guinea Binatang Research Centre, PO Box 604 Madang, Papua New Guinea.*
[3]*University of South Bohemia, Faculty of Science, Branisovska 1760, 370 05 Ceske Budejovice, Czech Republic.*
**Corresponding author: amick.peter@gmail.com*

**Abstract**
Due to the rugged terrains and general inaccessibility to the mountainous parts of New Britain via proper road systems, the inland rivers and streams remain unprospected of its ichthyofauna. By using underwater visual census, we documented freshwater fish covering 16 rivers and creeks. A total of 22 species were recorded of which most were gobies (Gobiidae) and freshwater eels (Anguillidae). We documented the lobed river mullet (*Cestraeus plicatilis*), Kolobangara goby (*Lentipes kolobangara*) and the Ségura gudgeon (*Belobranchus segura*) for the first time in Papua New Guinea outside of their known ranges. Our record on spine-finned fishes (*Kuhlia* spp. and *Mesopristes cancellatus*) far inland (c.a. 40 km from the coastline and at >600 m a.s.l) further increased our knowledge on how far these fishes are able to traverse inland given that there are no natural barriers such as waterfall. We provide an account of each species recorded and recommended for no introduction of exotic fish in the freshwaters of New Britain, Papua New Guinea.

**Keywords:** Freshwater fish, Species account, Insular streams, Lake Lilimo, Bismarck Archipelago.

**Citation:** Amick, P.K.; Toko, P.S. 2021. Notes on the ichthyofauna of inland streams of the Whiteman Range, New Britain Island, Papua New Guinea. FishTaxa 20: 1-13.

## Introduction

The New Britain Island is Papua New Guinea's (PNG) largest volcanic island covering a total land area of 35, 742 km$^2$ (CEPF 2012). Its central cordillera is rugged and mountainous and is made up of two distinct mountain ranges (*viz*. the Nakanai Mountains towards the east, and the Whiteman Range to the south-west). Due to the ruggedness of the mountainous terrains, general accessibility to these montane areas via vehicle-road is difficult as there is no proper road that leads up to the mountain tops, except those previously built and poorly maintained by logging and mineral exploration companies, or by locals themselves. Locals mostly live by the coast where they can travel by sea, or by exceptionally good roads, to nearby government stations and town centres to access basic services. Ironically, this is particularly benefiting for the natural environment where human impacts are minimal and recovery from past logging operation at the foothills takes shape. Whiteman Range is among the 95 Key Biodiversity Areas in the East Melanesian Islands Hotspot identified by the Critical Ecosystem Partnership Fund (CEPF 2012).

Although knowledge on the terrestrial flora and fauna of the interiors of New Britain has received attention over the past two decades (e.g. Anthony et al. 2001; Richards and Gamui 2011), the freshwaters remain unknown, except for few collections in the Kimbe Bay area (e.g. Watson 1991). Ichthyological studies of the neighbouring islands include the Bougainville Island (Powell and Powell 1999), Solomon Islands (Boseto et al. 2007; Boseto et al. 2010), Vanuatu (Keith et al. 2010), Fiji (Boseto and Jenkins 2006), New Caledonia (Marquet et al. 2003) and the Marquesas and the Society Islands (Fowler 1932), Guam, Hawaii (Fowler 1925), Samoa (Keith et al. 2013), and Palau (Nelson et al. 1995). Therefore, we conducted the first ichthyological surveys in the headwaters of the Whiteman Range. This report presents an account of fish occurring in inland freshwaters of the Whiteman Range, New Britain Island, PNG.

## Material and Methods

We documented fish during the months of October to December 2015, and again in 2017, in inland streams on the north-western slope of the Whiteman Range at latitudes between 5°51'S and 6°00'S and longitudes between

*Accepted: 4 May 2021; Published: 15 June 2021*

150°29'E and 150°32'E, and altitudinal range between 164-899 m (Fig. 1). The survey covered 38 sampling spots in 16 creeks (see specific GPS coordinates in Table 1).

**Site descriptions:** There was no sign of human activities close to the area covered in this survey. The nearest human settlement area is Bereme Village, c.a. 10 km north-east of the nearest sampling spot. The forests along the ridges have been logged several decades ago and have since recovered. The waterways are currently unaffected and dominated by native fishes and prawns. This shows how pristine the inland rivers and creeks of the Whiteman Range are. The rivers and streams sampled are very clear even after heavy rains. This clearly infer intact riparian vegetation cover. The sampled river sections were characterized by silty-sandy banks to boulder-strewn watercourses. The creeks are usually narrow (3-4 m wide in pools, 2-3 m in ripples) with much vegetation cover (80-95% canopy cover). Depths vary from knee to waist at ripples and pools, respectively.

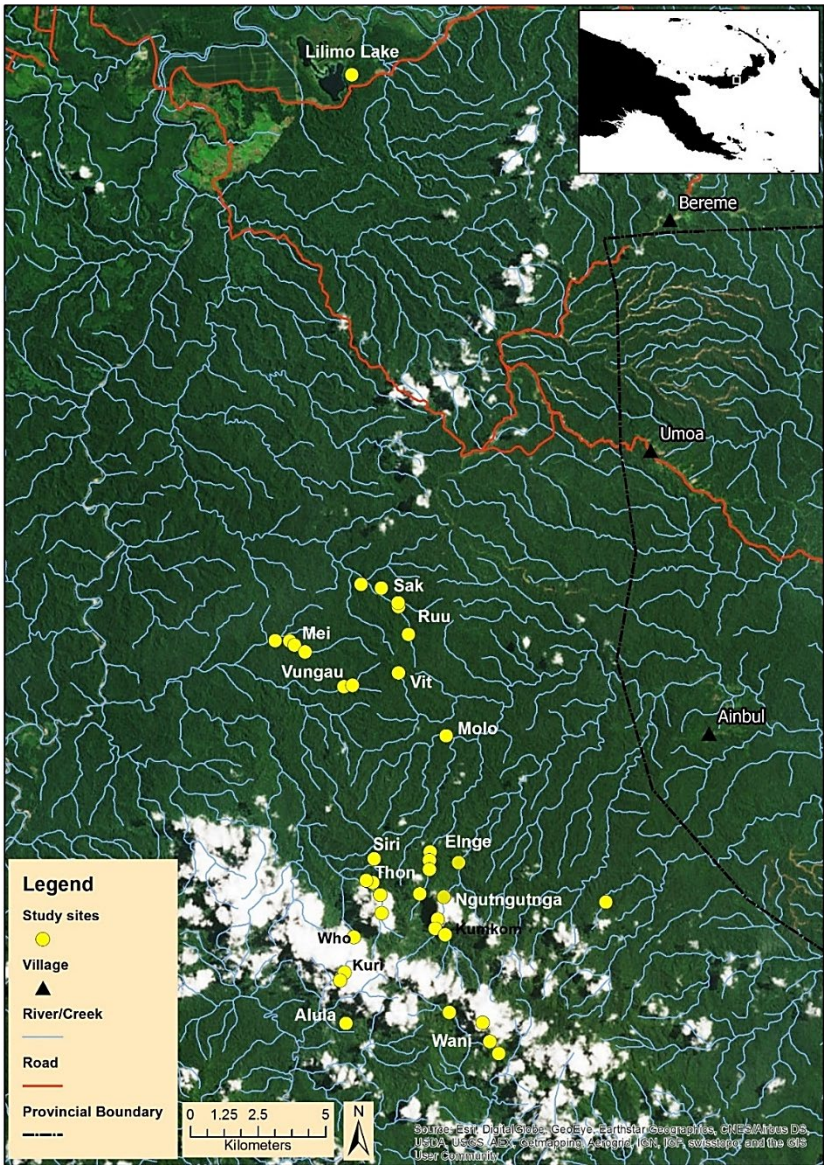


**Figure 1.** Map of the sampling area indicating sampling spots; (insert) map of Papua New Guine.

**Table 1.** GPS coordinates of sampling spots.

| Date | Site ID | Creek | Coordinates |
|---|---|---|---|
| 30-Oct-15 | VIT_01. | Vit Creek | 05º53'55.9"S, 150º32'27.9"E; Alt. 388 |
| 31-Oct-15 | VIT_02. | Vit Creek | 05º53'02.1"S, 150º31'30.1"E; Alt. 444 |
| 1-Nov-15 | MOL_01 | Molo Creek | 05º54'17.1"S, 150º32'27.5"E; Alt. 395 |
| 3-Nov-15 | RUU_01 | Ruu Creek | 05º52'16.2"S, 150º31'42.2"E; Alt. 289 |
| 3-Nov-15 | RUU_02 | Ruu Creek | 05º51'43.1"S, 150º31'30.0"E; Alt. 292 |
| 3-Nov-15 | RUU_03 | Ruu Creek | 05º51'28.7"S, 150º31'09.8"E; Alt. 268 |
| 3-Nov-15 | SAK_04 | Sak Creek | 05º51'38.3"S, 150º31'29.6"E; Alt. 291 |
| 4-Nov-15 | VUN_01 | Vungou Creek | 05º53'18.8"S, 150º30'43.2"E; Alt. 329 |
| 4-Nov-15 | VUN_02 | Vungou Creek | 05º53'18.8"S, 150º30'25.0"E; Alt. 372 |
| 4-Nov-15 | VUN_03 | Vungou Creek | 05º53'16.9"S, 150º30'35.2"E; Alt. 362 |
| 4-Nov-15 | VUN_04 | Vungou Creek | 05º53'02.2"S, 150º30'45.4"E; Alt. 356 |
| 6-Nov-15 | MEI_01 | Mei Creek | 05º52'23.5"S, 150º29'02.8"E; Alt. 172 |
| 6-Nov-15 | MEI_02 | Mei Creek | 05º52'24.1"S, 150º29'19.9"E; Alt. 170 |
| 6-Nov-15 | MEI_03 | Mei Creek | 05º52'28.6"S, 150º29'25.5"E; Alt. 178 |
| 6-Nov-15 | MEI_04 | Mei Creek | 05º52'36.0"S, 150º29'38.4"E; Alt. 248 |
| 6-Nov-15 | MUM_01 | Mumov Creek | 05º52'16.3"S, 150º29'10.0"E; Alt. 164 |
| 11-Nov-15 | THO_01 | Thon Creek | 05º57'11.4"S, 150º30'53.6"E; Alt. 539 |
| 11-Nov-15 | THO_02 | Thon Creek | 05º57'19.3"S, 150º30'59.5"E; Alt. 573 |
| 11-Nov-15 | THO_03 | Thon Creek | 05º57'27.6"S, 150º31'08.3"E; Alt. 603 |
| 11-Nov-15 | THO_04 | Thon Creek | 05º57'49.4"S, 150º31'10.0"E; Alt. 630 |
| 12-Nov-15 | ELN_01 | Elnge Creek | 05º56'36.4"S, 150º32'08.1"E; Alt. 528 |
| 12-Nov-15 | ELN_02 | Elnge Creek | 05º56'46.3"S, 150º32'07.3"E; Alt. 559 |
| 12-Nov-15 | ELN_03 | Elnge Creek | 05º56'57.4"S, 150º32'05.4"E; Alt. 627 |
| 12-Nov-15 | ELN_04 | Elnge Creek | 05º57'26.5"S, 150º31'55.7"E; Alt. 689 |
| 12-Nov-15 | SIR_01 | Siri Creek | 05º56'44.7"S, 150º32'01.2"E; Alt. 571 |
| 13-Nov-15 | NGU_01 | Ngutngutnga Creek | 05º57'57.0"S, 150º32'17.4"E; Alt. 573 |
| 13-Nov-15 | NGU_02 | Ngutngutnga Creek | 05º58'06.9"S, 150º32'14.3"E; Alt. 608 |
| 13-Nov-15 | KUM_01 | Kumkom Creek | 05º58'11.8"S, 150º32'26.2"E; Alt. 619 |
| 15-Nov-15 | KUM_02 | Kumkom Creek | 05º57'30.2"S, 150º32'24.6"E; Alt. 508 |
| 15-Nov-15 | KUM_03 | Kumkom Creek | 05º57'32.1"S, 150º32'23.3"E; Alt. 514 |
| 17-Nov-15 | KUM_04 | Kumkom Creek | 05º56'43.8"S, 150º32'42.0"E; Alt. 469 |
| 23-Nov-15 | ALU_01 | Alula Creek | 05º59'613"S, 150º29'875"E; Alt. 631 |
| 23-Nov-15 | ALU_02 | Alula Creek | 05º59'005"S, 150º30'257"E; Alt. 712 |
| 25-Nov-15 | KUR_01 | Kuri Creek | 05º56'911"S, 150º30'232"E; Alt. 502 |
| 25-Nov-15 | KUR_02 | Kuri Creek | 05º57'107"S, 150º30'515"E; Alt. 537 |
| 25-Nov-15 | WHO_01 | Who Creek | 05º57'782"S, 150º30'368"E; Alt. 610 |
| 2-Dec-15 | WAN_01 | Wani Creek | 06º00'234"S, 150º32'794"E; Alt. 796 |
| 2-Dec-15 | WAN_02 | Wani Creek | 06º00'008"S, 150º32'707"E; Alt. 840 |
| 3-Dec-15 | WAN_03 | Wani Creek | 05º59'484"S, 150º32'311"E; Alt. 899 |
| 5-Dec-15 | WAN_04 | Wani Creek | 06º00'374"S, 150º32'902"E; Alt. 788 |

**Field methods:** By using mask and snorkel, fish were recorded using underwater visual census technique. This technique included three to four hours of underwater observation and recording of species encountered at each creek by three observers. Although we kept a tally of uncommon species and estimated counts of the very common ones, the abundance data is not presented here. The observers covered distances of ca. 500 m each sampling day per creek. We used waterproof notebook and pencil to record species data as soon as an observation was made in the field. Unconfirmed individuals were captured by carefully chasing them into modified scoop nets of mesh size 1.3 mm. Some individuals were speared and collected. Photographs of

representative individuals were taken when fishes were freshly caught. All specimens were preserved in ethanol and later shipped to Muséum national d'Histoire Naturelle, France, for verification of species identifications, and also for storage and long term preservation. Fish data was also augmented from lending of speared fish by local fishermen, especially in the Lake Lilimo area. Fish were identified in the field to genus or species level based on Keith et al. (2010, 2015) and Allen (1991).

**Results and Discussions**

A total of 22 species of freshwater fishes belonging to seven families were recorded (Table 2). As expected, gobies (Gobiidae) were the dominant group (11 spp.) although their rate of encounter varied considerably within each species from 6.25% (recorded only at one creek) to 100%. As sampling spots increased, number of new records eventually flattened out inferring that we recorded most of the species in the rivers sampled (Fig. 2). Our record for flagtails (*Kuhlia* spp.), and a grunter (*Mesopristes cancellatus*) and mullet (*Cestraeus plicatilis*) in the headwaters, 619 m a.s.l. and >40 km river distance from the shoreline, increased our perception about how far these fishes can travel upstream. These spine-finned fishes were recorded only in Kumkom River, and its branch, Ngutngutnga (see Table 1 for the maximum altitudinal record for fishes in Kumkom River). We reason that the absence of spine-finned fish in other rivers sampled was due to waterfalls at lower sections of the creeks, forming natural barriers thus limiting the upstream movement of active-swimming fish migrating further inland. Gobies and freshwater eels were recorded in all creeks because they are known to climb waterfalls (Schoenfuss et al. 2011; Lord et al. 2019; Matsushige et al. 2020). Although we recorded *Anguilla marmorata*, *Sicyopus discordipinnis*, *Smilosicyopus fehlmanni*, *Sicyopterus elomionearum* and *Belobranchus belobranchus* only once at selected creeks (Table 2), their absence from other sampling spots could be related to lack of sampling efforts or behaviour of individual species. Interestingly, our study revealed that the inland rivers and streams of the Whiteman Range show higher species richness when compared to other rivers in PNG (Table 3). The occurrence and dominance of sicydiine gobies and recent discovery of two new species also resulting from this work (Keith et al. 2019; Lord et al. 2020), the abundance of freshwater eels in almost every pool sampled (e.g. *A. bicolor* 62.5% encounter rate), and the occurrence of spine-finned fishes far inland and at shallow depths (<1 m) infer pristine and undisturbed waterways.

Due to the lack of knowledge about freshwater fishes in the inland streams of the Whiteman Range, it is imperative that we provided some information about each species recorded. This is particularly important because of the mining and logging concessions in the forest lands, including the rivers we surveyed and the attempts by local landowners to establish portions of the forest lands, including the river systems, as a conservation area.

**Species Account**

The arrangement of names does not follow a phylogenetic or taxonomic order. The common names are mostly English names and we acknowledge variations in other literature.

**Anguillidae: *Anguilla bicolor* McClelland 1844 (Indian short-finned eel)**

This eel is generally dark brown on the back with no spots (as it appears in *A. marmorata* and *A. megastoma*) and whitish on the ventral parts, especially between the anus and lower parts of the head (Fig. 3A–B). The pectoral fins are whitish on the base and brown to yellowish towards the tips. This eel can grow up to <100 cm in total length. *Anguilla bicolor* can be distinguished from the similar looking *A. megastoma* by its almost equal origin of dorsal and anal fins, uniformly dark color of dorsal parts of the body, and almost equal lengths and widths of the irregularly arranged teeth rows of the upper jaw. This eel is common in the headwaters of the

**Table 2.** Summary of the 2015 and 2017 fish surveys in the inland rivers of the Whiteman Range. Family names of gobioid fishes follow Thacker and Roje (2011). Details of sites sampled is found in Table 1 including the full names of the rivers. Frequency of encounter (% freq.) is calculated as occurrence/number of creeks sampled (i.e. n/16 creeks*100). This calculation is not done for the spine-finned fishes (*Kuhlia* spp., *Mesopristes cancellatus*, and *Cestraeus plicatilis*) because they only occur in one River, Kumkom (Kum) and its branch, Ngutngutnga (Ngu). Further, these spine-finned fishes could not climb waterfalls and man-made barriers such as hydro-electricity dam walls (Ruu Creek Dam, in this case); their absence in other creeks sampled is likely due to waterfalls and/or Ruu Creek Dam. Thus, we did not consider these fishes in our calculations for frequency of encounter rate. All other gobies, gudgeons, and eels are considered in the calculations because they are known to climb walls (Schoenfuss et al. 2011; Lord et al. 2019; Matsushige et al. 2020) and their absence in other creeks could be related to sampling efforts.

| | **Rivers†** | | | | | | | | | | | | | | | | **%** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Latin name** | Vit | Mol | Ruu | Sak | Vun | Mei | Mum | Tho | Eln | Sir | Ngu | Kum | Alu | Kur | Who | Wan | **freq.** |
| **Anguillidae** | | | | | | | | | | | | | | | | | |
| *Anguilla bicolor* | x | x | | | | x | | x | x | | x | x | x | | x | x | 62.5 |
| *Anguilla marmorata* | | | | | | | | x | | | | | | | | | 6.25 |
| *Anguilla megastoma* | | | | | | | | | | | | | | x | x | x | 18.75 |
| *Anguilla reinhardti* | | | x | | x | x | | | | | | | | | | | 18.75 |
| **Rhyacichthyidae** | | | | | | | | | | | | | | | | | |
| *Rhyacichthys guilberti* | x | x | x | x | x | x | x | x | x | | x | x | x | x | x | x | 93.5 |
| **Gobiidae** | | | | | | | | | | | | | | | | | |
| *Sicyopus discordipinnis* | | | | | | | | | | | | | x | | | | 6.25 |
| *Sicyopus beremeensis* | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 100 |
| *Smilosicyopus felhmanni* | | | | | | | | | | | | | | | | x | 6.25 |
| *Stiphodon semoni* | | | | | | x | x | x | | | | | | | | | 18.75 |
| *Stiphodon surrufus* | | x | | x | x | | | | | | | | | | | | 18.75 |
| *Sicyopterus lagocephalus* | | | | | | | | | x | x | x | | x | x | x | x | 43.75 |
| *Sicyopterus cynocephalus* | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 100 |
| *Sicyopterus longifilis* | x | | | | x | | | | | | | | | | | | 12.5 |
| *Sicyopterus stiphodonoides* | x | x | x | | x | x | x | | | | | | x | x | | | 50 |
| *Sicyopterus elomionearum* | | | | | | | | | x | | | | | | | | 6.25 |
| *Lentipes kolobangara* | | | | | | | | | | | | | x | | | x | 12.5 |
| **Eleotridae** | | | | | | | | | | | | | | | | | |
| *Belobranchus belobranchus* | | | | | | | | | | | | x | | | | | 6.25 |
| *Belobranchus segura* | | | x | x | | x | x | | | | x | | | | | | 31.25 |
| **Kuhliidae** | | | | | | | | | | | | | | | | | |
| *Kuhlia rupestris* | | | | | | | | | | | x | x | | | | | n/a |
| *Kuhlia marginata* | | | | | | | | | | | x | x | | | | | n/a |
| **Terapontidae** | | | | | | | | | | | | | | | | | |
| *Mesopristes cancellatus* | | | | | | | | | | | x | x | | | | | n/a |
| **Mugilidae** | | | | | | | | | | | | | | | | | |
| *Cestraeus plicatilis* | | | | | | | | | | | x | x | | | | | n/a |

† River and stream names: Vit –Vit; Mol – Molu; Ruu – Ruu; Sak – Sak; Vun – Vungou; Mei – Mei; Mum – Mumov; Tho – Thou; Eln – El'Nge; Sir – Siri; Ngu – Ngutngutnga; Kum – Kumkom; Alu – Alula; Kur – Kuri; Who – Who; Wan – Wani

Whiteman Range. *Anguilla bicolor* is widespread in the east coast of the African continent and Madagascar to Southeast Asia and the Pacific Islands (Allen et al. 2008).

**Anguillidae: *Anguilla marmorata* Quoy and Gaimard 1824 (Giant long-finned eel)**

*Anguilla marmorata* is difficult to distinguish, in the field, from the similar looking long-finned *A. megastoma* because adults of both species grow up to ~110 cm in maximum size and are dark on the dorsal parts (Fig. 3C–D). *Anguilla marmorata* is mottled and extremely spotty in much of the body except the ventral part between the head and anus which is whitish. It can also be distinguished by the thick, olive-green, upper lip and the shape of the upper jaw dentition where the maxillary teeth band is narrow with three longitudinal rows of teeth with

**Table 3.** Number of fish species recorded at higher elevations (>160 m) of inland streams in New Guinea and Bougainville Island as compared with results of this study. This study shows higher diversity, in terms of species richness, of fish species in the headwaters of the Whiteman Range.

| River system | # fish spp. rec. | Source |
|---|---|---|
| Fly River | <10 | Allen et al. (2008) |
| Purari | <5 | [Amick unpubl. dat.] |
| Laloki | <10 | Berra et al. (1976) |
| Bougainville Is. | <10 | Powell and Powell (1999) |
| Whiteman Range (New Britain) | 22 | [this study] |

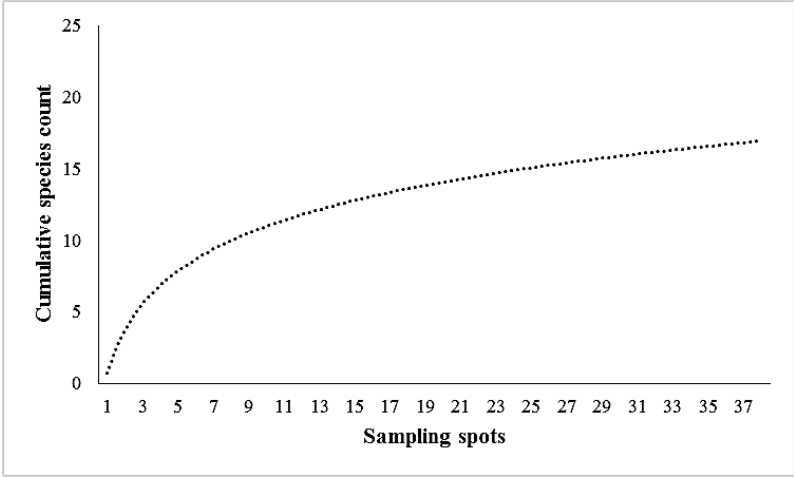


**Figure 2.** Cumulative species count reached an asymptote as sampling spots increased. This infer that most of the fish species occurring in the area have been sampled and the chances of adding a new species is narrow.

toothless groove between them (Fig. 3C). This eel is very common in the Whiteman Range and was recorded in most the creeks sampled. We observed them feed on freshwater prawns and were never intimidated by our presence. *Anguilla marmorata* is widespread in the Indo-Pacific region (Keith et al. 2010).

**Anguillidae: *Anguilla megastoma* Kaup 1856 (Pacific long-finned eel)**

This eel looks very similar to *A. marmorata* in size and colour but is less spotty (Fig. 3E–F). The dorsal and upper parts of the sides are yellowish with dark shades of brown. The ventral part is creamy white. Although the mouth gape is relatively wider, it is difficult to tell from the field unless one has another *Anguilla* species to compare against. The maxillary teeth band is relatively dense with no toothless grove between them (Fig. 3E). It can grow up to 100 cm in maximum length. *Anguilla megastoma* is widespread in the western and central Pacific region from Sulawesi to the Society Islands (Allen 1991).

**Anguillidae: *Anguilla reinhardti* Steindachner 1867 (Marbled eel)**

This is a small eel in the genus (max. 40 cm in total length). Most areas of the body, except the ventral part, is yellowish/brownish with dark spots (Fig. 3G). It is often mistaken as a young *A. marmorata* because of the dark spots and mottling. We encountered this species on only three occasions during the survey. *Anguilla reinhardti* has been recorded in New Guinea, Vanuatu, New Caledonia, New Zealand, and Australia (Allen 1991; Keith et al. 2010).

**Rhyacichthyidae: *Rhyacichthys guilberti* Dingerkus and Seret 1992 (Loach goby)**

The genus has two species, *R. aspro* and *R. guilberti*, both of which occur in the freshwaters. The fish is characterised by very large fan-like pectoral fins, a large but ventrally flattened head and an inferior mouth. Adult fish may grow up to 30 cm. They lie motionless on solid surfaces where there is plenty of current. This fish was plentiful and was recorded in all creeks surveyed. *Rhyacichthys gulberti* was previously recorded only

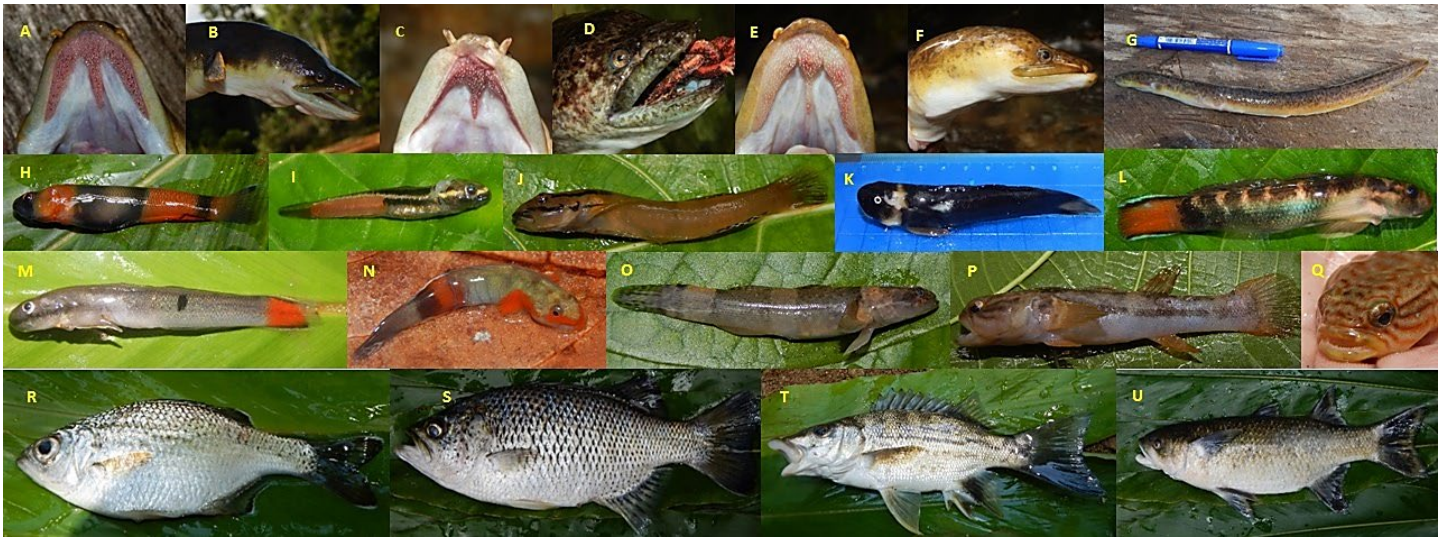


**Figure 2. A**-**B**: *Anguilla bicolor*; **C**-**D**: *A. marmorata*; **E**-**F**: *A. megastoma*; **G**: *A. reinhardti*; **H**: *Sicyopus beremeensis*; **I**: *S. discordipinnis*; **J**: *Smilosicyopus fehlmanni*; **K**: *Sicyopterus elomionearum*; **L**: *S. lagocephalus*; **M**: *S. stiphodonoides*; **N**: *Lentipes kolobangara*; **O**: *Belobranchus belobranchus*; **P**-**Q**: *B. segura*; **R**: *Kuhlia marginata*; **S**: *K. rupestris*; **T**: *Mesopristes cancellatus*; **U**: *Cestraeus plicatilis*.

in New Caledonia and Vanuatu (Keith et al. 2010).

**Gobiidae: *Sicyopus beremeensis* Keith, Amick, Toko & Lord 2019 (Bereme goby)**

A moderate sized sicydiine goby (to ~5.5 cm total length). The fish shows sexual dimorphism where males are slightly larger than females (Fig. 3H). Males are bright red with anterior portion of the head towards the eye areas is very dark or dark grey and a similar dark bar starting at the anterior base of the pectoral fin and a similar, narrow bar at the end of the dorsal fin that does not reach the base of the caudal fin. Dorsal parts of the caudal fin is sometimes tipped light blue and similarly for the anal fin where it is tipped black. The females are greyish with the head area slightly darker. There is a dark band of mid-lateral line that extends just below the eye region to the end of the caudal peduncle. The belly region is usually creamy white in gravid females. The iris is brown in both male and female. This fish prefer shallow pools where the bottom is mixed with fine sands and boulders. This fish is probably a New Britain endemic (Keith et al. 2019).

**Gobiidae: *Sicyopus discordipinnis* Watson 1995**

This is a small size *Sicyopus* (~3.5 cm total length) with a bright red sides between the beginning of the 2$^{nd}$ dorsal fin and end of the caudal peduncle (Fig. 3I). A creamy white or silver white streak runs dorsoventrally in the sides continuing right under the pupil area and around the snout. Two dark lines, also running dorsoventrally, enclose the white streak, with one dark line ending at the start of the red band and the other run parallel and continue with the white streak. The dark bands are sometimes broken or not continuing as is the white streak. The dorsal and ventral parts of the fish are somewhat transparent. The red streak is absent in females. We recorded very few individuals throughout the survey. This fish seem to prefer smaller, sun-lit pools with silty or sandy bottoms. *Sicyopus discordipinnis* has only been recorded in New Guinea, northern Australia, and the Bismarck and Solomon Archipelagos (Keith et al. 2015).

**Gobiidae: *Smilosicyopus fehlmanni* (Parenti and Maciolek 1993) (Fehlmann's sicyopus)**

This fish was rarely encountered. It preferred pools with silty or sandy bottoms. Some even hid under leaf litter only with their heads exposed and would retrieve back into the leaves when we moved closer to them. The body is grey or somewhat brown and transparent (Fig. 3J). A dark streak runs around the snout to the opercle, sometimes broken, or extends but tapers into the mid-section of the pectoral fin. Dark vertical bars may be present extending from the back and downward. The nape, between the eyes and the 1$^{st}$ dorsal fin has small,

black dots of various sizes. Gravid females usually have red-orange belly. This fish was recorded in Palau, New Guinea (Bird's Head), Australia (Cairns area), Solomon Islands, Vanuatu, and New Caledonia (Keith et al. 2015).

**Gobiidae: *Sicyopterus cynocephalus* (Valenciennes 1837) (Cleft-lipped goby)**

This species has a wider regional range that extends between the Philippines to south of Borneo and northern Australia and Solomon Islands (Keith et al. 2015). We recorded this species in all the creeks sampled. It was the most dominant species encountered together with *S. lagocephalus*. This species is among the largest (>12 cm in total length) of the sicydiine gobies we encountered in the Whiteman Range. The color is slightly variable but usually brown or darker on the back and whitish on the ventral parts. There are 5-6 vertical bars on the sides between the caudal peduncle and base of the pectoral fin. These vertical bars are sometimes paired. There is a dark bar extending downward from the eye. The nape is brownish to greenish with broken lines and dots between them. The snout is rounded and an inferior mouth with thick lips adapted for scraping algae. The anal fin may vary in color from grey to bright yellow or grey tipped black. The base of the caudal fin is dull yellow. The paired vertical bars is distinct in young adults. Young adults also have their dorsal fins reddish and a dark spot on the end of the 1$^{st}$ dorsal fin.

**Gobiidae: *Sicyopterus elomionearum* Lord, Keith, Causse & Amick 2020 (Elomione goby)**

This is a moderate sized goby (8.2 cm). It has only been recorded in the El'Nge and Kumkom Creeks in the Whiteman Range. The body is dusky grey with 2 to 4 Y-shaped lighter grey markings on the sides and the belly is whitish to greyish (Fig. 3K). Sexually active males are coal black throughout the body including their fins, which are usually tipped brownish on the edges (Lord et al. 2020). The fish is probably endemic to the headwaters of New Britain (Lord et al. 2020). Specimens have been collected in fast flowing sections of the Creeks where they singly cling on to rocks to scrape algae. Unlike other *Sicyopterus* spp. we encountered, there were one or two individuals seen during underwater surveys but the fish dashed off quickly and was difficult to capture.

**Gobiidae: *Sicyopterus lagocephalus* (Pallas 1770) (Red-tailed goby)**

This is only *Sicyopterus* that has the widest regional distribution (Keith et al. 2015). This species, together with *S. cynocephalus*, were recorded throughout the survey at all creeks. There were too many (~20 individuals per m$^2$) and dominated the creeks. Sexually active males are dark blue-green throughout the body (these blue-green spots may become bright blue), a red caudal fin tipped with blue hue and sometimes two oblique dark lines (Fig. 3L). A bright brown mid-lateral line with 6-8 irregular bars extending from it upwards. The females are light brown tan with up to eight dark bars extending upwards on the sides. The belly is creamy white in females.

**Gobiidae: *Sicyopterus longifilis* de Beaufort 1912 (Threadfin goby)**

Although this fish is common in sections of the rivers close to the coastline, it is rarely seen in the inland creeks at elevations beyond 200 m. This fish looks similar to *S. lagocephalus* and is distinguished by the presence and display of an extremely filamentous first dorsal fin that results from the extensions of the 2$^{nd}$ to 4$^{th}$ fin spines. *Sicyopterus longifilis* also differs from *S. lagocephalus* by having two clefts in the upper lips that are crenulated (as opposed to smooth upper lip that has three clefts in *S. lagocephalus*). Females have slightly shorter filamentous fins. *Sicyopterus longifilis* has been recorded from the Philippines to Sulawesi and New Guinea and parts of the Solomon Archipelago (Keith et al. 2015).

**Gobiidae: *Sicyopterus stiphodonoides* Keith, Allen & Lord 2012**

This fish is moderately smaller than the other *Sicyopterus* spp. we encountered in this study. It has been recorded in small pools usually with a single male and a female lying motionless in the substrate no far from each other. The males are usually blue-greenish on the sides and dark on the back (Fig. 3M). The tail is bright red with transparent tips and two thin lines of light blue bands that run almost parallel to each other (when tail is stretched

out) from the base of the caudal fin to the tip. Both male and female have a dark mid-lateral band that is usually prominent starting at the anterior base of the pectoral fin through to the upper lip and diminishing at the opposite end. The dark bars extending upwards from the mid lateral band is not usually visible except for the band at the sides just below the second dorsal fin, sometimes showing only as a dark spot. It is usually distinct in males. The ventral part of the head and chest areas are usually white but it can be olive blue especially in males. *Sicyopterus stiphodonoides* has only been recorded in the northern parts of New Guinea and the Solomon Archipelago (Keith et al. 2015).

**Gobiidae: *Lentipes kolobangara* Keith, Lord, Boseto & Ebner 2016 (Kolombangara goby)**

This fish was first collected in Kolombangara Island, Solomon Islands, and subsequently described by Keith et al. (2016). It occurs in the headwaters of New Britain and probably occurs in the neighboring Admiralty Archipelago. The male is multi-colored having an irregularly red-painted, nape and upper lip and between the opercle and the upper parts of the pectoral fins (Fig. 3N). The rest of the body is transparent grey with 3-4 thin, vertical bars on the belly and a similar but much thicker brown (or red and brown) bar along the entire portion of the 2nd dorsal fin. The 2nd dorsal fin is sometimes tipped white. The belly is sometimes colored olive blue.

**Gobiidae: *Stiphodon semoni* Weber 1895 (Semon's goby)**

The males are easily spotted in the water because of their prominent blue-green band that extends dorsoventrally to and through the upper lip where the white streak that runs parallel and above it becomes prominent on the snout areas, below the eyes and towards the upper parts of the pectoral fins and diminishes beyond. The dorsal part is dark. Females have a translucent body with two dark bands that run dorsoventrally. Very few individuals have been recorded at elevations beyond 200 m. We recorded this fish at the headwaters of Ru Creek where they were seen lying motionless on the silty bottom and rock faces where the river current was slow. *Stiphodon semoni* has been recorded from Sumatra to Vanuatu, including New Guinea and northern tips of Australia (Keith et al. 2015).

**Gobiidae: *Stiphodon surrufus* Watson and Kottelat 1995 (Persimmon goby)**

This is one of the smallest gobies easily spotted because of the bright red colour. The males are bright red with cycloid scales tipped black. The females are translucent with two dark bands running dorsoventrally. This fish has been recorded at Bereme Creek. It was absent in the creeks beyond 200 m a.s.l. It probably occurs in well oxygenated creeks below 200 m a.s.l. The individuals recorded preferred very shallow ripples and small pools where there was plenty of sands on the bottom. *Stiphodon surrufus* has a distribution that extends from the southern tip of Japan to Taiwan and northern Australia, including New Guinea and the Bismarck and Solomon Archipelago (Keith et al. 2015).

**Eleotridae: *Belobranchus belobranchus* (Valenciennes, 1837) (Throat-spine gudgeon)**

This fish has a widespread distribution in the Indo-Pacific region. We recorded this species 14 km (river distance) from the coastline at 514 m a.s.l. (Table 2, Table 1). There are only two species known to this genus (*B. belobranchus* and *B. segura*) (Keith et al. 2012). Adults may have 4 bars of light and dark brown bands alternating vertically throughout the cylindrical body (Fig. 3O). Adults may not exceed 10 cm in total length.

**Eleotridae: *Belobranchus segura* Keith, Hadiaty & Lord 2012 (Ségura gudgeon)**

*Belobranchus segura* has previously been recorded in Indonesia (Keith et al. 2012). We recorded this species only in the lower sections of the rivers at the foothills of the Whiteman Range. It has a short snout, a cylindrical body, and an upturned superior mouth (Fig. 3P–Q). This fish is brownish and has 2-5 irregular lines on the nape and between the eyes, and 4-5 lines of papillae emerging from the eye area and end at the opercle. A mid-lateral bar running dorsoventrally may become obvious in young adults. The fins are light brown and may have white


**Figure 4. A**: Lake Lilimo; **B**: roasted tilapia (*Oreochromis niloticus*), sold at a roadside markets close to the Lake area; **C**: local fishers with their catches, all happened to be individuals of (**D**) *Giuris aporocephalus*, *G. margaritaceus*, and the recently described New Britain endemic, *G. caussei* (Keith and Mennesson 2020). Unfortunately, these gudgeons are competing with the introduced tilapia (*O. niloticus*) in Lake Lilimo.

margins.

**Kuhliidae: *Kuhlia marginata* (Cuvier1829) (Dark-margined flagtail)**

The dark-margined flagtail occurs in the Indo-Pacific (Keith et al. 2010). It is vertically compressed and brownish or with brown dots on the dorsal part, especially towards the caudal peduncle. The nape and snout areas have zigzag markings of dark brown (Fig. 3R). Ventral parts and most of the sides is whitish or silvery. Both ends of the caudal fin and the soft parts of the dorsal and anal fins form a hue of maroon to black and are usually tipped white. Sometimes the soft dorsal and anal fins are tipped black. This fish form small groups of up to five and actively swim in pools. The school may grow bigger depending on the size of the pool. This fish has a marine ancestry and migrates to the sea to spawn. Adult females may migrate between the freshwaters and seas several times to spawn whereas the males move once in their live to the seas and may never return to the freshwaters (Oka and Tachihara 2008). We recorded this fish at c.a. 40 km river distance from the coastline, around 600 m a.s.l.

**Kuhliidae: *Kuhlia rupestris* (Lacepede 1802) (Rock flagtail)**

The rock flagtail has a wider distribution in the Indo-Pacific (Allen 1991; Keith et al. 2010). It is vertically compressed but slightly deep-bodied and much larger in body size than *K. marginata*. *Kuhlia rupestris* is greenish on the back and upper parts of the sides, and whitish on the belly (Fig. 3S). The fins are somewhat transparent and become dark when fish are taken out of the water. The soft part of the dorsal fin and also the caudal fin may have dark spots towards both ends of the fork. This fish stays singly under rock crevices or snags in deep pools.

**Terapontidae: *Mesopristes cancellatus* Cuvier 1829 (Tapiroid grunter)**

The only *Mesoprestes* we recorded c.a. 40 km from the sea. This fish has thick lips and a pointy snout. Smaller fish were seen in groups of not more than two individuals. Larger individuals were seen actively swimming alone in deep pools where rivers were cascading. This vertically compressed fish is recognised by six dark, vertical bars extending upwards from two to three dorsoventral stripes on the sides (Fig. 3T). The fish is silvery to dark on the back and whitish on the ventral parts. The largest individual we recorded was >20 cm in total length. *Mesopristes cancellatus* has a distribution that extends from southern tip of Japan to New Caledonia.

**Mugilidae: *Cestraeus plicatilis* Valenciennes 1836 (Lobed river mullet)**

There are three species of mullets in the genus *Cestraeus*, all of which occur in the Indo-Pacific (Harrison and Senou 2002). *Cestraeus goldiei* and *C. oxyrhynchus* have been recorded in PNG except for *C. plicatilis* (Hyslop 1996; Harrison and Senou 2002). We recorded the first *C. plicatilis* in PNG. Details of this report is presented elsewhere (Amick et al. in press). The lobed river mullet is dark olive to green on the back and whitish ventrally (Fig. 3U). The largest fish we recorded is >20 cm in total length. We spotted groups of up to four swimming freely in the pools and hid in shelters of snags or rock crevices underwater where it was dimly lit. This mullet penetrated well inland c.a. 40 km from the coastline and was recorded at 600 m a.s.l.

**Danger of pond fishery and exotic fish species**

All of the species recorded in this survey have a diadromous life cycle where the adults spawn at sea and or the eggs are hatched in freshwaters and the hatchlings are transported to the sea by river currents where they mature only to return to the freshwaters and continue the cycle (Mcdowall 2004). During this seaward migration or upstream migration, the young fish are prone to attacks, especially by introduced fishes.

Historically, there have been 27 species of freshwater fish introduced in the river systems in mainland PNG (Allen 1991; Tappin 2007). Most of these fishes were intentionally introduced for aquaculture and inland pond fishery or for biological control of malaria-borne insect larvae (Coates 1987; Coates 1997) but some are already showing characteristics of invasive species (Storey et al. 2002; Amick 2019; Thresher et al. 2020). The omnivorous Nile tilapia (*Oeochromis niloticus*) has been introduced in the Lake Lilimo (05º41'654"S, 150º30'265"E, 26 m a.s.l.), ca. 30 km north of the survey areas (Figs. 1 and 4). Although it is now becoming an important source of food and financial income for the local people, this fish could potentially be harmful as a predator or competing with native fish for food and habitat space once the population has become established (Martin et al. 2010). Bad experiences with introduced fishes in the inland rivers of mainland PNG (Amick 2019; Thresher et al. 2020), and also in other parts of the world, should warn us not to have introduced fish in the freshwaters of New Britain (Cucherousset and Olden 2011). Most of the people of New Britain live by the coast and have access to the marine fishery products. The last thing these coastal people need is inland pond fishery of the noxious common carp (*Cyprinus carpio*) and tilapia.

In conclusion, we sampled only a smaller portion of the streams in the Whiteman Range; much of the rivers in New Britain and neighbouring islands (or the Bismarck Archipelago) and the Admiralty Group of Islands remain to be prospected of its ichthyofauna. Our study showed exceptional species richness in the headwaters of the New Britain island, documented extralimital ranges of *C. plicatilis*, *L. kolobangara*, and *B. segura* and points to the need for further field inventories (see also CEPF 2012; Pippard 2012). As pristine as the inland river systems are, we strongly recommended that no exotic freshwater fish or crustacean should be introduced in the freshwaters, including lakes, of New Britain.

**Acknowledgements**

We thank the local landowners of the Whiteman Range, Fr. Patrick Pose, and our field assistants, Joe Penny and

Brendan Kilme. Ahulo Otio hosted us in Kimbe. Emily Fajardo from CEPA was very instrumental in project advice. The New Guinea Binatang Research Centre provided logistical support during field work and hosted PKA during the period of write up of this paper. Philippe Keith (Muséum national d'Histoire naturelle, France) carefully read the manuscript, commented, and corrected the species names. Comments by two anonymous reviewers greatly improved this paper. This study was funded by the UNDP-CEPA partnership grant CbFCCRM-2014 under GEF Phase #4.

## Literature cited

Allen G.R. 1991. Field guide to the freshwater fishes of New Guinea. Christensen Research Institute. Madang, Papua New Guinea.

Allen G.R., Storey A.W., Yarrao M. 2008. Freshwater Fishes of the Fly River, Papua New Guinea. Tropical Reef Research and Ok Tedi Mining Limited. Tabubil, Papua New Guinea.

Amick P.K. 2019. The Himalayan Snow Trout (*Schizothorax richardsonii* Gray) is doing the unintended in Papua New Guinean rivers. Fishes of Sahul 33: 1501-1508.

Amick P.K., Toko P.S, Causse R. 2021. First, field-based record of the lobed river mullet, *Cestraeus plicatilis* (Pisces: Mugilidae) from Papua New Guinea. Cybium 45: (In Press).

Anthony N., Byrnes D., Foufopoulos J., Putnam M. 2001. Biological survey of New Britain Island, Papua New Guinea. Falcon Art Media. Wisconsin, USA.

Berra T.M., Moore R., Reynolds L.F. 1976. Freshwater fishes of the Laloki River system of New Guinea. Copeia 2: 316-326.

Boseto D., Jenkins A.P. 2006. A checklist of freshwater and brackish water fishes of the Fiji Islands. University of the South Pacific and Wetlands International. Suva, Fiji.

Boseto D., Morrison C., Pikacha P., Pitakia T. 2007. Biodiversity and conservation of freshwater fishes in selected rivers on Choiseul Island, Solomon Islands. The South Pacific Journal of Natural Science 3: 16- 21

Boseto D., Sirikolo M., Boseto H. 2010. Freshwater fishes of the Upper Vila River recorded for World Wildlife for Nature Baseline Survey of Crater of Kolobangara Island (19–23 July 2010). Ecological Solutions (Solomon Islands). Solomon Islands.

CEPF. 2012. East Melanesian Islands biodiversity hotspots ecosystem profile. Critical Ecosystem Parthnership Fund (CEPF). Suva, Fiji.

Coates D. 1987. Consideration of fish introductions into the Sepik River, Papua New Guinea. Aquaculture and Fisheries Management 18: 231-241.

Coates D. 1997. Fish stocking activities undertaken by the Sepik River Fish Stock Enhancement Project (1987–1993) and the FISHAID Project (1993-1997). In: FAO (Ed.). Food and Agriculture Organisation. Rome.

Cucherousset J., Olden J.D. 2011. Ecological impacts of nonnative freshwater fishes. Fisheries 36: 215-230.

Fowler H.W. 1925. Fishes of Guam, Hawaii, Samoa, and Tahiti. Bernice P. Bishop Museum - Bulletin 22: 1-38.

Fowler H.W. 1932. Freshwater fishes from the Marquesas & Society Islands. Bernice P. Bishop Museum - Occasional Papers IX: 1-11.

Harrison I.J., Senou H. 2002. Mugiliformes: Mugilidae. In: K. Carpenter (Ed.). FAO species identification guide for fisheries purposes: the living marine resources of the Western Central Atlantic. Rome, FAO. pp: 2069-2083.

Hyslop E.J. 1996. Observations on the diets of *Oreochromis mossambicus*, *Trichogaster pectoralis*, *Crenimugil heterocheilus* and *Cestraeus goldiei* from the lower Angabanga River, Papua New Guinea. Science in New Guinea 22: 69-76.

Keith P., Amick P.K., Toko P. S., Lord C. 2019. A new species of *Sicyopus* (Teleostei: Gobiidae) from New Britain (Papua New Guinea). Cybium 43: 163-167.

Keith P., Hadiaty R.K., Lord C. 2012. A new species of *Belobranchus* (Teleostei: Gobioidei: Eleotridae) from Indonesia Cybium 36: 479-484.

Keith P., Lord C., Boseto D., Ebner B.C. 2016. A new species of *Lentipes* (Gobiidae) from the Solomon Islands. Cybium 40: 139-146.

Keith P., Lord C., Maeda K. 2015. Indo-Pacific sicydiine gobies: biodiversity, life traits and conservation. Societe

Francaise d'Ichtyologie. Paris, France.
Keith P., Marquet G., Gerbeaux P., Lord C., Vigneux E. 2013. Polynesian freshwater fish and crustaceans: taxonomy, ecology, biology and management. Société Française d'Ichtyologie and CEPF. Paris, Franec.
Keith P., Marquet G., Lord C., Kalfatak D., Vigneux E. 2010. Vanuatu freshwater fish and crustaceans. Soociete Francaise d'Ichyologie. Paris, France.
Keith P., Mennesson M. 2020. Review of *Giuris* (Teleostei: Eleotridae) from Indo-Pacific islands, with description of three new species. Cybium 44: 331-349.
Lord C., Bellec L., Dettaï A., Bonillo C., Keith P. 2019. Does your lip stick? Evolutionary aspects of the mouth morphology of the Indo-Pacific clinging goby of the *Sicyopterus* genus (Teleostei: Gobioidei: Sicydiinae) based on mitogenome phylogeny. Journal of Zoological Systematics and Evolutionary Research 57: 910-925.
Lord C., Keith P., Causse R., Amick P.K. 2020. A new species of *Sicyopterus* (Teleostei: Gobioidei: Sicydiinae) from Papua New Guinea. Cybium 44: 127-136.
Marquet G., Keith P., Vigneux E. 2003. Atlas des Poissons et Crustacés d'eau douce de Nouvelle-Calédonie. Patrimoines Naturels 58: 1-282.
Martin C.W., Valentine M.M., Valentine J.F. 2010. Competitive interactions between invasive Nile tilapia and native fish: the potential for altered trophic exchange and modification of food webs. PloS one 5: e14395.
Matsushige K., Hibino Y., Yasutake Y., Mochioka N. 2020. Japanese eels, *Anguilla japonica*, can surmount a 46-m-high natural waterfall of the Amikake River system of Kyushu Island, Japan. Ichthyological Research. DOI: 10.1007/s10228-020-00759-1.
Mcdowall R.M. 2004. Ancestry and amphidromy in island freshwater fish faunas. Fish and Fisheries 5: 75-85.
Nelson S.G., Smith B.D., Parham J.E., Tibbatts B., Camacho F.A. 1995. A survey of streamfish of the upper reaches of the Ngermeskang River, Palau, with recommendations for conservation and monitoring. University of Guam Marine Laboratory. Guam.
Oka S.-I., Tachihara K. 2008. Migratory history of the spotted flagtail, *Kuhlia marginata*. Environmental Biology of Fish 81: 321-327.
Pippard H. 2012. The current status and distribution of freshwater fishes, land snails and reptiles in the Pacific Islands of Oceania. IUCN. Gland, Switzerland.
Powell J. H., Powell R. E. 1999. The freshwater ichthyofauna of Bougainville Island, Papua New Guinea. Pacific Science 55: 346-356.
Richards S.J., Gamui B. 2011. Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments. Conservation International. Arlington, USA.
Schoenfuss H.L., Maie T., Kawano S.M., Blob R.W. 2011. Performance across extreme environments: comparing waterfall climbing among amphidromous gobioid fishes from Caribbean and Pacific Islands. Cybium 35: 361-369.
Storey A., Roderick I., Smith R., Maie A. 2002. Spread of the introduced climbing perch (*Anabus testudineus*) in the Fly River system, Papua New Guinea, with comments on possible ecological effects. International Journal of Ecology and Environmental Sciences 28: 103-114.
Tappin A.R. 2007. Freshwater biodiversity of New Guinea. In-Stream Publication.
Thacker C.E., Roje D.M. 2011. Phylogeny of Gobiidae and identification of gobiid lineages. Systematics and Biodiversity 9: 329-347.
Thresher R.E., Smith R., Cutajar J. 2020. Optimizing the impacts of an invasive species on the threatened endemic biota of a remote RAMSAR site: Tilapia (*Oreochromis niloticus*) in Lake Kutubu, Papua New Guinea. Biological Invasions 22: 2661-2670.
Watson R.E. 1991. A provisional review of the genus *Stenogobius* with descriptions of a new subgenus and thirteen new species. (Pisces: Teleostei: Gobiidae). Records of the Western Australian Museum 15: 627-710.