French Ichthyological Society (SFI)

FILLING GAPS AND IMPROVING KNOWLEDGE OF FRESHWATER FAUNA: A WAY FORWARD FOR IMPROVING MANAGEMENT OF RIVERS OF THE SOLOMON AND VANUATU ISLANDS

Sicyopterus stiphodonoides (regional endemic)

FINAL REPORT OF THE FIELD TRIPS IN CHOISEUL (SOLOMON)

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Freshwater fish & crustaceans of Kolobangara watershed priority site: diversity and conservation (Choiseul, Solomon)

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Abstract

Fish and crustaceans of Kolobangara watershed, Choiseul island's priority site (including the Sirebe Rainforest and Biodiversity Conservation Area (SRBCA) and Vuri Rainforest and Biodiversity Conservation Area (VRBCA) were surveyed over a 3 weeks period in october 2014). Our study shows that the freshwater fauna of Kolobangara watershed is rich and consists of 80 species (52 fishes and 28 decapod crustaceans). Among these species, several are endemic to Solomon Islands, and Choiseul is one of the main Solomon Islands for their conservation. As nothing was known of freshwater crustaceans in the Solomon Islands before this trip, all the species caught are new occurrences for this country and for Choiseul Island, specifically. One new species of freshwater crab was collected, as 3 new species of shrimps. In terms of freshwater fishes we noted 12 new occurrences with two likely undescribed species.

As all species collected were diadromous and specifically amphidromous in their life history, it is important to recognise the potential for human impacts on freshwater habitats and particularly on the migrational pathways between estuarine and freshwater habitats. These species have to undertake two migrations between freshwater and the sea. The success of such a life cycle - *i.e.* production of larvae for downstream migration after hatching and return to rivers with post-larvae and juveniles during the upstream migration – depends on maintaining the mountain/forest-river-ocean corridor to enable movements between both habitats.

I. INTRODUCTION

1- Freshwater fishes of Solomon Islands

Previous collections of freshwater organisms in the Solomon Islands have been very limited. The earliest mention of ichthyofaunal surveys of Solomon Islands is by Macleay (1879) followed by Herre (1931) but their primary taxonomic emphasis was on marine ichthyofauna. Since that time there is rare sporadic mention from a scientific perspective of freshwater fishes in the Solomon Islands and this is confined mostly within the taxonomic literature. Gray (1974), published a relatively superficial account treating 36 mainly brackish water fish species. Although this author provided a section on the methods that were used to catch the fishes, there was no mention of where the specimens were deposited, or even if they were actually preserved. The Fisheries Department in Honiara did maintain a collection of marine fishes through the 1990s, but this was destroyed during the social unrest of the early 2000s. Over the last few years, a few field trips in the Solomon Islands were conducted by Boseto et al. (2007), Jenkins & Boseto (2007), Polhemus et al. (2008), Boseto & Sirikolo (2010) and Boseto et al. (2010).

In 2004 and March 2005, Polhemus et al. (2008) prospected the main islands of the Solomon Islands, including Choiseul Island. In 2005, Boseto et al. (Boseto et al. 2007) conducted a biodiversity project for freshwater fish in the same sites on Choiseul that had been attended by Polhemus et al. (2008) to: (a) complement the fish survey done in March 2005 and (b) provide biological information for a conservation management plan for terrestrial taxa on Choiseul Island. The specific aims of that study were to: (i) produce a more complete freshwater fish species checklist for Choiseul Island and (ii) determine the conservation significance of these taxa.

Then, in 2009, Boseto and Sirikolo (2010) conducted another study in Choiseul as part of a baseline freshwater biodiversity inventory within the Kolobangara watershed. This work also included basic training in field collection and fish identification for local guides. This survey served to make an initial list of the vertebrates of Kolobangara watershed (where the Sirebe Rainforest and Biodiversity Conservation Area (SRBCA) and Vuri Rainforest and Biodiversity Conservation Area (VRBCA) are located).

Nevertheless, the Solomon Islands remain to be comprehensively surveyed for freshwater organisms and especially for crustaceans, and there remain many relevant taxonomic challenges.

2- Freshwater crustaceans of the Solomon Islands

No detailed studies of freshwater crustaceans have been reported for the Solomon Islands. In contrast, nearby Papua New Guinea (Nobili, 1899; Bott, 1974; Holthuis, 1949, 1950, 1968, 1982, 1984; Karge et al., 2010; Lukhaup & Pekny, 2006; Lukhaup & Herbert, 2008; De Man, 1915; Roux, 1911, 1917, 1921, 1927, 1934), the islands of the Bismarck Archipelago (Roux, 1934; Holthuis, 1978) and Vanuatu (Keith et al., 2010) have been surveyed repeatedly and this provides an appreciation of what likely exists in parts of the Solomon Islands and especially the most northerly province of Choiseul.

The objectives of our study in the context of the CEPF 'Melanesia Hotspot' were to: a) provide an inventory of fish and crustaceans in the Kolobangara watershed (a priority site on Choiseul Island), and b) to collect presence/absence data on the species, c) to validate taxonomic identifications, and d) develop a preliminary understanding of relative species rarity and /or endemicity.

II. METHODS

The first field trip was organised on Choiseul Island priority site (the Kolobangara watershed, including the Sirebe Rainforest and Biodiversity Conservation Area (SRBCA) and Vuri Rainforest and Biodiversity Conservation Area (VRBCA), during 3 weeks in October, 2014 (8/10/2014 to 24/10/2014). In order to meet our social assessment plan objectives, this expedition started long before October and needed several months of preparation (nearly 6), over which consultation with the tribes (see Fig. 1 for more details) that were to be associated with this project, took place. A MOU was sign with all of them and additional meetings in their land and in Honiara were organised to communicate the project. This was done by one of our team member, D. Boseto (a native of Choiseul), with the NGO ESSI. When in the field, at each site prospected, meetings were organized with the local members of the community (tribes, villages) before work started and a restitution was also done before departure. During the field trip we trained local staff (from NGOs, protected area agencies and tribes in taxonomy and ecology of freshwater fauna (fishes, crustaceans). A report concerning the Social assessment plan has been written separately (see Part 3).

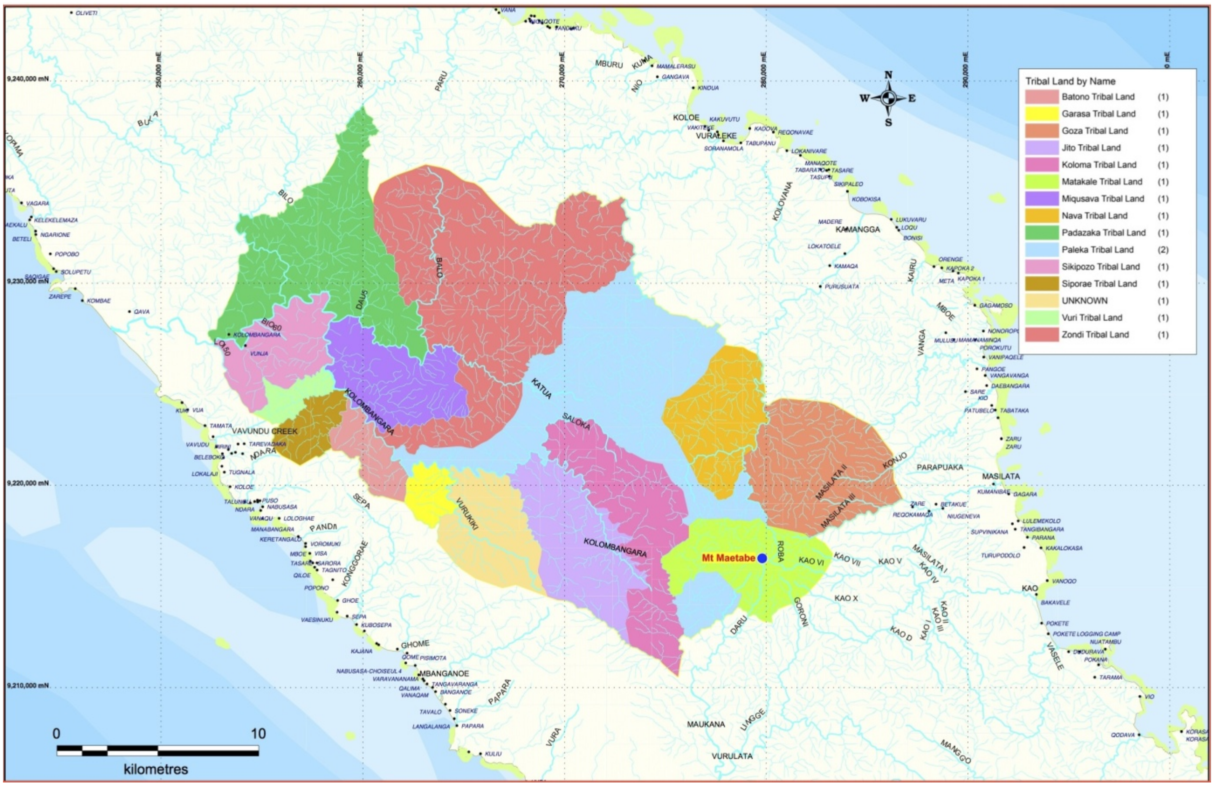

Figure 1: Tribe territories of the Kolobangara watershed

Streams

The streams of Choiseul can be divided into three zones defined according to the slope, the average current velocity and the size of the substrate: *higher course*, *middle course*, and *lower course*. These three zones are specific habitats for different fish and crustacean species. Specific criteria define these three zones (Keith et al., 2010):

*The *higher course* is characterised by a steep slope (generally more than 10%); thus current speed is high. The substrate is usually composed of large boulders and cobbles directly coming from the parent-rock. The delimitation with the middle course often corresponds to a topographical discontinuity, such as a cascade. The distance between this reach and the river mouth is highly variable; it largely depends on the catchment areas geological characteristics.

*The *middle course* has an average slope generally of less than 10%. The riverbed is covered in pebbles and rocks. Sometimes, sandy bottoms can be found in slow current reaches. The length of this zone depends on the geological origins of the catchment area.

* The *lower course* is the part of the stream located in the coastal plain (or the floodplain for tributaries of large rivers); its length is thus generally reduced. For coastal streams, two areas can be distinguished in this zone: the estuary, immediately under marine influence, and the upstream part, where the water's conductivity is very low.

Some estuaries can be very broad, and the intrusion of salt water can go relatively far upstream. The slope and the current speed are low to nil; it is a high accumulation zone. In estuaries, the sediments are composed of sand and silt, but higher upstream the grain size is coarser (gravel, pebbles and boulders). This zone is not present in all streams. For some streams, it is related to the influence of the middle course and the average and peak current speed and sediment grain size. The marine tidal influence is often minimal.

There is a relationship between the stream flow and the species found within each zone. The majority of species occupy moderate flow habitat. On the contrary, populations found in facies where the current is very strong (rapids or steps) are characterised by the presence of species having specific adaptations to this type of environment; this is, for example, the case for gobies of the *Sicyopterus* genus that are capable of resisting very strong currents by sticking to the substrate with their ventral suction cup. In these mountainous streams, one facies can quickly be replaced by another because of the flow variability and the torrential regime. This is particularly so in these mountain areas where rainfall is high. Nevertheless, the distribution of all populations of aquatic species (fish, crustaceans) reflects the altitudinal gradient and their ecological preferences. Indeed, some species favour living exclusively in the lower course, whereas others are found only in the higher course.

A generator (Dekka Lord 2000) was used for the sampling. The portable machine that was used had a battery with an output power of 180 W. It gives rectangular impulses at a fixed frequency of 100 Hz or 400 Hz. The duty cycle is controllable and is of 5 to 25 %. It has three voltage outputs: 150, 200 and 300 V. Electric fishing is performed in wadable streams by progressing in an upstream direction; in that way the water stays clear in front of the operators. The method consists of placing a fishing electrode near habitat shelters in which the animals are found; the electrode creates an electrical field, which has an attraction effect within a radius of a one-metre zone under average conditions. When a fish comes within this field, it is stunned; it can then be caught easily with a hand net.

During our survey 16 sites were prospected (Fig. 2).

Snorkelling with mask and handnets was also used as a complementary method to the electrofishing. Species were caught, photographed or videoed to aid identification. Snorkelling was typically conducted by a single researcher on a different day to electrofishing surveys, so as to minimise effects on the number of species observed by each technique.

Figure 2: Prospection sites in Kolobangara priority site

Habitat facies data (depth, width, substrate, shade, riparian cover etc), although not reported on below, was also, when possible, recorded for all surveyed sites.

III. Results

The fishes and crustaceans of Kolobangara were mainly diadromous as was expected. Diadromous species are migratory and alternate between freshwater and saltwater according to their life cycle. Diadromous species are classified in three sub categories:

1. Anadromous species spend the majority of their life in salt water and migrate to freshwater to reproduce (e.g. Salmonidae) *(not in the area prospected).*
2. Catadromous species spend the majority of their life in freshwater and migrate to saltwater to reproduce (e.g. Anguillidae).
3. Amphidromous species: females spawn many ova in freshwater, which are then fertilised by the males. After hatching the larvae are carried by the current out to sea where they spend a variable amount of time (Lord et al., 2010). The young fry then go back to freshwater to resume their growth (Keith et al., 2003). The migration has no reproductive goal, unlike the two former categories. Amphidromy is a major adaptation to insular environments (Mc Dowall, 2007), and is the main type of life cycle for the Solomon fish and crustaceans.

A total of **80 species**, 28 species of crustaceans and 52 species of fish, were collected at the different sites (Figs 2-5; Table 1; Appendix 1,2). Among them 12 local or regional endemic. According to IUCN status 6 are data deficient and one is vulnerable, but many species have been not evaluated. **No introduced species** were found.

As nothing was known on crustaceans in Solomon before this trip, all the species caught are new occurrences for this country and for Choiseul Island. **Three outright new species of *Caridina* for science were suspected as is one new species of crab**. Many rare species were collected. For **fish** we noted 12 new occurrences with **two potential new species**.

Figure 3: A selection of the freshwater crustaceans from Choisel Island including a) female, and b) male of *Labuanium trapezoideum,* c) *Atyopsis spinipes*, d) *Caridina typus*, e) *Caridina* sp., and f) *Macrobracium lar* (B. Ebner).

Out of the fish caught during the survey, the majority belong to Gobiidae and Eleotridae families. The crustaceans caught are amphidromous and belong mainly to the families Atyidae and Palaemonidae. Table 1 provides a list of the species encountered during the study. Photographic examples of some of the crustacean (Figure 3), goby (Figure 4) and other fish species (Figure 5) are provided in subsequent figures.

Figure 4: A selection of the gobies found in streams from Choisel Island including a) *Stiphodon pelewensis* (male), b) *Stiphodon rutilaureus* (male) c) *Smilosicyopus fehlmanni*, d) *Redigobius tambujon*, e) *Stenogobius* sp., and f) *Awaous ocellaris*

IV. DISCUSSION

1. Comparison between sites

Considering the number of genera and species found in the different rivers of Kolobangara watershed and tributaries of the main stream. We noted that they are all quite similar. The sites surveyed in the current study supported high levels of diversity in terms of fish and crustaceans. Indeed, all sampling sites were situated in pristine forest, with natural rivers and no logging. The differences in composition of the aquatic fauna that were observed seemed to be linked only to the accessibility of the sites for recruiting larvae (distance from sea, velocity, obstacles…) and altitudinal gradient.

These results generally conform with what is commonly found for amphidromous fishes and crustaceans altitudinal distribution in the Pacific Islands elsewhere (Keith, 2003; Keith and Lord., 2011). The fact that the ecological conditions become increasingly constraining with altitude (strong current, unavailability of food) explains why only some species (*Sicyopterus species, Macrobrachium lar, Anguilla marmorata*) can be found from the lower course to the higher course of the river, and that only a few species live only in the higher course *(Anguilla megastoma, Lentipes* spp.*, Macrobrachium latimanus*). The number of freshwater species gradually diminishes from the estuary to the upstream reaches of the streams. Reduced diversity is most pronounced above major barriers (cascades and waterfalls). Only some of the eels (Anguillidae) and specific groups of sicydiine gobies as *Sicyopterus* spp.*, Lentipes* spp., *Sicyopus* spp. or *Smilosicyopus* spp. *etc.,* are able to climb the biggest waterfalls.

Finally, even if most of the indicator species of river quality are found between the middle and the upper courses of streams, there are parts of the Solomon Islands where some regional endemic (table 1) species may require special conservation attention.

Table 1: freshwater species from Kolombangara watershed (Choiseul)

Crustaceans (all species are new occurences; ° local or regional endemic)

Atyidae
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina brevidactyla Roux, 1919
C. brevicarpalis De Man, 1892
C. neglecta Cai & Ng, 2007
C. nsp1 ***novem species***°
C. nsp2 ***novem species***°
C. nsp3 ***novem species***°
C. papuana Nobili, 1905°
C. serratirostris De Man, 1892
C. typus Milne Edwards, 1837

Palaemonidae
Macrobrachium australe (Guérin-Méneville, 1838)
M. bariense (De Man, 1892)
M. cognatus (Roux, 1927)°
M. gracilirostre (Miers, 1875)
M. handshini (Roux, 1933)
M. jaroense (Cowles, 1914)
M. lar (Fabricius, 1798)
M. latidactylus (Thallwitz, 1891)
M. latimanus (Von Martens, 1868)
M. placidulum (De Man, 1892)

Gecarcinucidae
Sendleria cf solomonis ***novem species (?)***°

Sesarmidae
Geosesarma maculatum (De Man, 1892)
Labuanium trapezoideum (H. Milne Edwards, 1837)

Varunidae
Ptychognathus riedelii (A. Milne Edwards, 1868)
Pyxidognathus granulosus A. Milne-Edwards, 1879
Utica gracilipes White, 1847
Varuna litterata (Fabricius, 1798)

Fishes (* new occurences; ° local or regional endemic; DD data deficient; VU Vulnerable)

Ambassidae	*Ambassis interruptus*
	Ambassis miops
Anguillidae	*Anguilla marmorata*
	Anguilla megastoma DD
Eleotridae	*Belobranchus segura**
	Bunaka gyrinoides
	Butis butis
	Eleotris fusca
	*Eleotris acanthopoma**
	Eleotris sp2 ***novem species*** **°*
	Giuris magaritaceus
	Giuris sp.
	Hyseleotris guentheri
	Ophiocara porocephala
Carangidae	*Caranx sexfasciatus*
Gobiidae	*Awaous ocellaris*
	Awaous guamensis
	*Glossogobius clitellus**
	*Glossogobius illimis**
	*Lentipes kaaea**
	Lentipes multiradiatus°*
	Lentipes sp ***novem species*** **°*
	Redigobius bikolanus
	Redigobius oyensi DD*
	*Redigobius tambujon**
	Schismatogobius cf marmoratus
	Sicyopterus lagocephalus
	Sicyopterus longifilis
	Sicyopterus stiphodonoides°
	Sicyopterus cynocephalus DD
	*Smilosicyopus fehlmanni**
	Sicyopus discordipinnis° DD
	Stenogobius cf hoesei
	Stiphodon rutilaureus
	Stiphodon pelewensis DD
	Stiphodon surrufus VU
	Stiphodon semoni
Kuhliidae	*Kuhlia marginata*
	Kuhlia rupestris
Lutjanidae	*Lutjanus argentimaculatus*
	Lutjanus fulvus
Mugilidae	*Cestreus plicatilis*
	Mugil cephalus
Muraenidae	*Gymnothorax polyuranodon*
Ophichthidae	*Lamnostoma kampeni*
Rhyacichthyidae	*Rhyacichthys cf guilberti°*
Scorpaenidae	*Tetraroge niger*
Syngnathidae	*Hippichthys sp**
	Microphis brachyurus
	Microphis retzii
	Microphis leiaspis
Terapontidae	*Mesopristes argenteus*
	Mesopristes cancellatus

Figure 5: A selection of fishes from streams of Choisel Island including a) *Rhyacichthys cf. guilberti*, b) *Giuris* sp., c) *Microphis brachyurus* (male), d) *Lamnostoma kampeni* e) *Tetraroge niger*, and f) *Mesopristes cancellatus.*

2. Comparisons with other sites

From the current survey we conclude that the sites prospected have high species richness compared with others sites that have been prospected in the Solomon Islands. Choiseul Island, and particularly the Kolobangara watershed with its intact landscape including pristine forest, is important for the conservation of many freshwater species (see below).

List of important species

Endemic species

Among the species caught, several endemic fish species from the Solomon or from other restricted regions were found in Kolobangara. The **two new species** of fishes discovered, *Lentipes* nsp and *Eleotris* nsp, are probably **endemic to Solomon** (as *Lentipes solomonensis*) with the main population on Choiseul Island. Others are endemic to the Solomon and nearest islands such as *L. kaaea* (endemic to the middle-eastern Pacific), and *L. multiradiatus* and *Sicyopterus stiphodonoides* endemic to Papua New Guinea/Solomon Islands, and *Sicyopus discordipinnis* endemic to Papua New Guinea/Solomon Islands/Australia. All the Gobiidae **Sicydiinae species are generally considered as key indicators** of good water quality such (e.g. *Smilosicyopus felhmanni*, *Sicyopus discordipinnis* and *S. zosterophorum*, *Sicyopterus* spp. and *Stiphodon* spp.). It is also the case for *Schismatogobius* spp..

In terms of the crustaceans, the **new crab** *Sendleria cf solomonensis nov. sp.* is endemic to the Solomon Islands, and probably confined to Choiseul Island streams. Indeed this genus is represented by four endemic species, all in IUCN Red list of threatened species: *S. gjellerupi* (Roux, 1927) occuring in Papua, *S. genuitei* Guinot, 1987; *S. gloriosa* (Balss, 1923) in New Britain (Bismarck Archipelago); and *S. solomonis* (Roux, 1934) on Bougainville Island.

In terms of the *Caridina* and *Macrobrachium* genera, whereas the majority of constituent species have an Indo-Pacific or Pacific distribution, *Caridina papuana* and *Macrobrachium cognatus* are restricted to Papua New Guinea and the Bismarck Archipelago. The **three new species**, *Caridina* sp 1, sp2 and sp3, as far as we know, have been collected only on Choiseul Island. Prospection in the other Solomon Islands are needed to accurately determine their distribution, but they are, at minimum, **endemic to the Solomon** Islands.

Some of the other species that were caught are also threatened or data deficient (but many are have been not evaluated by IUCN) and/or indicate high water quality streams and healthy catchments. For instance: *Anguilla marmorata* (the Giant Mottled-Eel), *Anguilla megastoma* (Polynesian Longfinned Eel), *Sicyopus* spp., and *Sicyopterus lagocephalus* (Red-tailed Goby) or *Stiphodon surrufus* (Vulnerable under D2) by way of fishes and *Macrobrachium lar* and *Macrobrachium latimanus* in terms of crustaceans. Some key biological and ecological information in regard to these key species is given below.

Biological and ecological information related to some key species

Anguilla marmorata, occurs both in the Indian and Pacific Oceans. It lives in fast flowing water from estuaries to the higher reaches, but it can also be found in stagnant waters. It feeds at night. Young eels feed on prawn larvae (*Macrobrachium*) and fish fry. Glass eels have a little developed caudal spot whereas their medio-lateral line bears many melanophores. Glass eels arrive in estuaries between October and April, with a peak season in January-February. Glass eels measure 47 to 57 mm total length (TL) (Marquet et al., 2003). The species is present in all the Indo-Pacific area and is **heavily fished** in human inhabited areas (Keith et al., 2010) including Choiseul Island (this study).

Anguilla megastoma is found in the Pacific area (Solomon Islands, French Polynesia, Vanuatu, New Caledonia, Pitcairn Island group). It lives in the higher reaches of the rivers and is an indicator of good water quality (Keith et al., 2010). It feeds at night. It eats crustaceans (prawns) and fish. Glass eels have a relatively well-developed caudal spot whereas the medio-lateral line has few melanophores. Glass eels arrive in estuaries between April and July each year. They measure 47 to 49 mm TL (Marquet et al., 2003). Less common than *Anguilla marmorata* and also fished, this eel need to be given the highest level of protection and **should be monitored** in the Solomon Islands to avoid population level collapse.

Anguilla megastoma (E. Vigneux)

Smilosicyopus occurs in clear, fast flowing (40 to 80 cm.s-1 ; Keith et al., 2004) and oxygen rich streams. It prefers rocky substrate. It is found in lower and middle courses of rivers, up to an altitude of 50 to 100 m. It is carnivorous and feeds on small aquatic insects and crustaceans. This species is amphidromous. After the reproduction, larvae are carried to sea where they stay for several months. They recolonise freshwater when they transition to juveniles (Keith et al., 2010).

Lentipes occurs in small, clear and oxygen rich streams. It lives on rocky substrate, in fast flowing currents (30 et 80 cm.s-1) or in counter-currents and up to 200 to 300 m in altitude. It is probably one of the species capable of migrating the furthest upstream. It lives on the bottom or swims freely in its territory, especially during courtship. The species is amphidromous: during reproduction, the female lays the eggs on top of rocks. Larvae go to sea after hatching, and they stay at sea forseveral months. When larvae reach 13 to 16 mm TL, they return to fresh water to resume growth (Keith et al., 2010). *Lentipes* species are one of **the main emblematic indicators of water quality** in tropical islands rivers.

Sicyopus zosterophorum is found from Indonesia, Sumatra in the Indian Ocean, southern Japan to Vanuatu and New Caledonia. This species occurs in clear, fast flowing and oxygen rich streams. It prefers substrate with pebbles and cobbles. It is found in the middle course of the river, up to 200 m in altitude. It is carnivorous and feeds on small aquatic insects and crustaceans. It is an amphidromous species. After the reproduction, larvae are carried to sea where they stay for several months. They recolonise fresh water after a few months at sea. This species is an indicator of good water quality (Keith et al., 2010b).

Sicyopterus lagocephalus adults are extremely rheophilic and they generally live in fast flowing zone where the current velocity is high (130 to 160 cm.s-1), in more or less deep areas (20 to 40 cm deep), adhering to pebbles and cobbles by ventral sucker (Donaldson et al. 2013). It feed by scraping diatoms off the rocky substrate. It is an amphidromous species. It reproduces in rivers. The female lays 50,000 to 70,000 eggs. The embryonic development takes place in freshwater. The larvae are carried to sea after hatching where they will develop into post-larvae. When this competent stage is reached (after nearly 130 to 240 days spent at sea), they regroup near river mouths in order to start migrating upstream. It seems that post-larvae are drawn to freshwater flowing to the sea in the coastal zones. With their sucker, they can climb waterfalls and therefore colonise the streams at high altitude (Lord et al., 2010; Ebner et al. 2011).

This species is widespread in the Indo-Pacific area; it occurs in the Western Indian Ocean, from the Comoros Islands to the Mascarenes, and in the Pacific, in New Caledonia, Vanuatu and Australia, and as far as French Polynesia and Japan. *Sicyopterus lagocephalus* is an indicator of good water quality (Lord et al., 2010).

Finally, **two totemic *Macrobrachium* prawns** were fished in Choiseul Island streams and require protection.

Macrobrachium lar (Giant jungle prawn) is found throughout the Indo-Pacific region. This species is found in the rivers from the lower to the higher courses. It colonises well oxygenated streams as well as river mouths. This species is amphidromous. The reproduction takes place in fresh or brackish waters. Courtship behaviour precedes mating. The eggs are relatively small and a single female can carry more than 40,000. The incubation period lasts about 20 days (Marquet et al., 2003). There are ten larval stages. After hatching the larvae are carried to sea. The juveniles migrate towards freshwaters as they reach 30 to 35 mm in length. The feeding habits of this species are varied and are essentially omnivorous (Keith et al., 2010).

Macrobrachium latimanus (P. Keith)

Macrobrachium latimanus (Mountain river prawn) is found in the Indo-Pacific region. This species is found in the medium course of rivers but mostly in the higher courses, in zone where the current is medium to strong and in water pits and cascades (Keith et al., 2010). It prefers substrates with pebbles, rocks and boulders enabling it to hide easily. In these zones the water temperature rarely is over 20° C and remains well oxygenated. The species is amphidromous. *Macrobrachium latimanus* has an omnivorous feeding mode, and the species is an indicator of high quality water (Keith et al., 2010).

Last, the Noreil *Rhyacichthys cf guilberti* was found during the survey. It prefers clear, well oxygenated waters, both in gently sloping rivers and in wider streams. It inhabits a restricted river stretch, between the estuary and the first impassable cascade. The species is benthic and probably nocturnal. *Rhyacichthys* belongs to the most ancient specialised group of hill-stream fishes characterised by their depressed bodies, by various attachment mechanisms, and by an herbivorous (algal diet) and insectivorous diet of plucked from hard substratum. It is probably the most sensitive species to human impacts on freshwater habitats.

All of these species of freshwater fishes and crustaceans are indicators of good water quality (Keith, 2003), and are vulnerable to a range of human impacts (see recommendations below).

V. CONSERVATION RECOMMENDATIONS

It has been commonly found in studies of tropical Pacific Island streams that the number of species recorded is greater in rivers flowing under natural vegetation cover and where the flow is unmodified than it is in human disturbed streams (Keith, 2003; Keith et al., 2013). This result can be easily explained from current knowledge about amphidromous species and by considering the way the river-forest system works. Indeed, the vegetation cover maintains a certain river flow, cool temperatures, and thus well-oxygenated water; it produces exogenous food inflows for the aquatic species, an important factor as insular river systems are generally low in available nutrients. The vegetation cover thus raises the river's trophic potentialities, while favouring habitat diversity (shelter for crustaceans for example) and water filtration (Keith et al., 2013).

Amphidromous species colonising the rivers are distributed along the river from the estuary to the higher reaches according to their ecology. Some are therefore only found at a certain altitude according to the water temperature, its physical and chemical parameters and its hydrological properties. The majority of the species encountered during the survey are rheophillic (they live in strong currents) that is particularly the case for the endemic and key species caught; in order to maintain a high level of biodiversity, it is therefore necessary to maintain high flow rates. The seasonal variability favours massive freshwater flow in estuaries, thus allowing post-larvae from the sea to colonise the rivers (amphidromous species).

The current state of knowledge on the life cycle of the diadromous species (biology, ecology), the length of the larval phase and the part it plays in the dispersal of larvae, is of direct relevance to management and conservation. The management and the conservation of species must take into account both the dependency of adult populations on the larval pool for replacement, and the contribution of each reproductive population to the larval pool (Murphy and Cowan, 2007). The length of the larval marine phase might increase the probability of finding a river for colonisation, as will the strength and the direction of marine currents. The survival of the species in Solomon Islands depends also on the ability of existing populations to provide enough larvae to maintain appropriate adult numbers. **The Kolobangara watershed area is one of the main population sources for some endemics and needs to be protected, particularly in pristine forest areas.**

Seasonal variables (e.g., rainfall, drought, floods, typhoons, etc.) have a major impact on the survival of populations. Furthermore, biological events such as reproduction, spawning, and the dispersal of larvae are dependent on these events and are synchronised with them. On the islands, because of the restricted available area for urbanisation, the impact of humans on aquatic habitats is highly significant, particularly on estuarine habitats, which are crucial to amphidromous species. Recall that amphidromous species have to undertake two migrations between freshwater and the sea. The success of such a life cycle, is contingent on maintaining the mountain/forest-river-ocean corridor in Kolobangara and maintaining an open channel to allow for movement between both habitats.

In summary, several important facts warrant mention for the management and/or the **conservation of Choiseul freshwater fish and crustaceans**.

1- It is essential to allow species to move freely between the upstream and downstream reaches for trophic or gamic migrations or for the larvae's downstream migration; and between the downstream and upstream reaches for river colonisation by the post-larvae and the juveniles. To ensure the free circulation of these species requires that there be **no barriers** in the river that cannot be crossed both up and downstream (the ecological and biological characteristics of all the species involved need to be studied).

2- The different ecological studies carried out show that a **minimum flow has to be maintained** in order to maintain rheophillic zones (strong current and high water oxygenation) in the river and thus enable the species adapted to such an environment to complete their biological cycle. **The flow rates must be high and must follow seasonal variations**: the freshwater wave discharging at sea "calls" the post-larvae which then colonise the rivers. The disappearance of these rheophile areas would rapidly lead to the extinction of the endemic species.

3- **The vegetation cover must be maintained or restored over rivers**. This forest cover ensures the water remains cool and is well oxygenated; it also ensures regular rainfall thus supplying the catchment area with water. Forest cover provides a high diversity of habitats and therefore of species. It also supplies exogenous elements for the nourishment of certain species. **This is especially noteworthy on Choiseul Island where some parts of Kolobangara watershed are exploited by logging companies**. In these areas we noted a huge modification of the water clarity and quality with the disappearance of the natural filtration and the accumulation of silt. These perturbations have negative consequences for the aquatic communities and the village water supplies.

4- The installation of **structures modifying the flow** rate, degrading habitats or causing pollution **should be avoided**. River eutrophication leads to the disappearance of rare and/or endangered species because of the modification of the physical and chemical parameters of the water; moreover, the proliferation of filamentous algae would restrain the development of amphidromous species, as they are usually grazing species scraping short algae off pebbles and rocks.

5- **Kolobangara estuary must be preserved** as it represents areas where certain species transit, where larvae of amphidromous species exit to sea, and where post-larvae and juveniles enter to colonise the rivers. The Kolobangara lower course must be kept in its natural state to preserve the natural tribes fishing.

6- Finally, **urgent studies on the life cycle of the diadromous species** (biology, ecology) are needed. Man-made developments on these streams can alter larval dispersion and therefore the recruitment success. It is therefore necessary to understand the ecology of this special fauna to the best of our ability, and to develop regional management and restoration strategies in order to preserve amphidromous species.

Conclusion

Freshwater fauna of Kolobangara watershed is rich and consists of 80 species (52 fishes and 28 decapod crustaceans). Our study gives the first exhaustive list of them. Among these species several are endemic to Solomon Islands, and Choiseul is one of the main Island for their conservation. As nothing was known of freshwater crustaceans in the Solomon Islands before this trip, all the species caught are new occurrences. One new species of freshwater crab was collected, as 3 new species of shrimps. In terms of freshwater fishes we noted 12 new occurrences with two new species. All are migratory species (diadromous).

To conserve these species the vegetation cover must be maintained or restored over rivers. This is especially noteworthy on Choiseul Island where some parts of Kolobangara watershed are exploited by logging companies. Kolobangara estuary must be preserved as it represents areas where certain species transit, where larvae of amphidromous species exit to sea, and where post-larvae and juveniles enter to colonise the rivers. It is essential to allow species to move freely between the upstream and downstream reaches (mountain/forest-river-ocean corridor). The Kolobangara lower course must be kept in its natural state to preserve also the natural tribes fishing. This study empowered communities in terms of encouraging traditional leadership and governance, and provided tools for resource managers as part of the human capacity development outcome through training.

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APPENDIX: LIST OF FISH SPECIES PER SITES

10/10/14 Pisuku- S06°58.900; E 156°46.685; alt. 15-66 m.
Anguilla marmorata
Anguilla megastoma
Belobranchus segura
Bunaka gyrinoides
Eleotris fusca
Eleotris sp2
Giuris magaritacea
Sicyopterus lagocephalus
Sicyopterus stiphodonoides
Smilosicyopus fehlmanni
Stiphodon rutilaureus
Stiphodon pelewensis
Stiphodon surrufus
Stiphodon semoni
Kuhlia marginata
Kuhlia rupestris

10/10/14 Pisuku- S06°58.951; E 156°46.582; alt. 15 m.
Giuris magaritacea
Hypseleotris guentheri
Glossogobius illimis

11/10/14 Vorama - S 06°58.687; E 156°46.746; alt. 15m.
Anguilla marmorata
Microphis brachyurus
Belobranchus segura
Eleotris fusca
Giuris magaritacea
Glossogobius illimis
Sicyopterus lagocephalus
Sicyopterus stiphodonoides
Stiphodon rutilaureus
Stiphodon pelewensis
Stiphodon surrufus
Kuhlia marginata

12/10/14 Pisuku(2)- S 06°58.965; E 156°46.718
Belobranchus segura
Sicyopterus lagocephalus
Sicyopterus stiphodonoides
Sicyopus zosterophorus
Smilosicyopus fehlmanni
Stiphodon pelewensis
Stiphodon surrufus
Stiphodon semoni

12/10/14 Pisuku mouth(3)- S 06°58.848; E 156°46.582
Gymnothorax polyuranodon
Hypseleotris guenteri
Eleotris fusca
Giuris magaritacea
Glossogobius illimis
Redigobius bikolanus
Sicyopterus longifilis
Sicyopterus stiphodonoides
Stenogobius hoesei
Stiphodon pelewensis
Kuhlia marginata
Lutjanus argentimaculatus

Loraseke 13/10/14- S 06°58.024; E 156°47.861
Anguilla marmorata
Anguilla megastoma
Belobranchus segura
Bunaka gyrinoides
Eleotris fusca
Eleotris sp2
Giuris magaritacea
Glossogobius illimis
Redigobius tambujon
Sicyopterus lagocephalus
Sicyopterus stiphodonoides
Sicyopterus longifilis
Sicyopus discordipinnis
Smilosicyopus fehlmanni
Stiphodon rutilaureus
Stiphodon pelewensis
Stiphodon surrufus
Stiphodon semoni
Stenogobius hoesei
Kuhlia marginata
Kuhlia rupestris

Vorasiki 13/10/14- S 06°58.520; E 156°47.416
Belobranchus segura
Giuris magaritacea
Glossogobius illimis
Sicyopterus stiphodonoides
Stiphodon pelewensis
Stiphodon surrufus
Stiphodon semoni
Kuhlia marginata
Kuhlia rupestris

Trek creek1- S06°59.085; E 156°47.454' ; alt. 132 m
Sicyopterus stiphodonoides

Stiphodon surrufus
Lentipes kaaea

Trek creek1- S06°59.027'; E 156°47.913" ; alt. 93 m.
Sicyopterus stiphodonoides
Stiphodon surrufus
Sicyopus discordipinnis
Smilosicyopus fehlmanni
Lentipes kaaea

Tereke15/10/14- S 07°00.661'; E 156°49.075
Anguilla marmorata
Bunaka gyrinoides
Eleotris fusca
Awaous guamensis
Glossogobius illimis
Stiphodon pelewensis
Kuhlia marginata
Kuhlia rupestris
Microphis retzii
Microphis leiaspis

Tereke-2 15/10/14- S07°00.857'; E156°49.194'
Anguilla marmorata
Awaous guamensis
Glossogobius illimis
Schismatogobius cf marmoratus
Kuhlia marginata
Kuhlia rupestris
Microphis retzii
Microphis leiaspis

Camp3 17/10/14- S 07°01.758; E 156°50.008
Mugil cephalus
Cestreus plicatilis
Mesopristes argenteus
Lutjanus argentimaculatus

Gu'ma 17/10/14- S 07°01.764; E 156°49.899; Alt. 50m.
Anguilla marmorata
Bunaka gyrinoides
Eleotris fusca
Awaous guamensis
Awaous ocellaris
Glossogobius illimis
Schismatogobius cf marmoratus
Kuhlia marginata
Kuhlia rupestris
Microphis leiaspis

Gu'ma-2 17-18/10/14- S 07°02.328: E 156°49.571 ; Alt. 70m.
Anguilla marmorata
Schismatogobius cf marmoratus
Sicyopterus stiphodonoides
Sicyopterus cynocephalus
Smilosicyopus fehlmanni
Sicyopus discordipinnis
Stiphodon pelewensis
Stiphodon semoni
Rhyacichthys cf guilberti
Kuhlia marginata
Kuhlia rupestris

Lokapare 20/10/14- S 07°01.613'; E 156°46.567'
Anguilla marmorata
Anguilla megastoma
Belobranchus segura
Bunaka gyrinoides
Eleotris fusca
Giuris magaritacea
Glossogobius clitellus
Redigobius oyensi
Lentipes multiradiatus
Lentipes sp
Sicyopterus lagocephalus
Sicyopterus stiphodonoides
Sicyopus discordipinnis
Sicyopus zosterophorum
Smilosicyopus fehlmanni
Stiphodon pelewensis
Stiphodon surrufus
Stiphodon semoni
Schismatogobius cf marmoratus
Rhyacichthys cf guilberti
Kuhlia marginata
Kuhlia rupestris
Microphis retzii

Lokapare 21/10/14- S 07°01.834'; E 156°45.789'
Anguilla marmorata
Gymnothorax polyuranodon
Lamnostoma kampeni
Butis butis
Eleotris fusca
Giuris magaritacea
Glossogobius illimis
Sicyopterus lagocephalus
Stiphodon rutilaureus
Schismatogobius cf marmoratus
Kuhlia marginata

Kuhlia rupestris
Microphis leiaspis
Microphis retzii
Tetraroge niger

<u>LIST OF CRUSTACEAN SPECIES PER SITES</u>

Pisuku stream; 10/10/2014
Secteur 1 S06°58.951; E 156°46.582; altitude 15 m

ATYIDAE
Caridina nsp1
C. papuana Nobili, 1905

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. lar (Fabricius, 1798)
M. placidulum (De Man, 1892)

Secteur 2 S 06°58.900; E 156°46.685; altitude 66m

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina nsp1
C. nsp2

PALAEMONIDAE
M. gracilirostre (Miers, 1875)
M. lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)
M. placidulum (De Man, 1892)

Vorama stream; 11/10/2014
Secteur1 S 06°58.687; E 156°46.746; 15m altitude

ATYIDAE
C. brevidactyla Roux, 1909
C. papuana Nobili, 1905
C. serratirostris De Man, 1892

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. cognatus (Roux, 1927)
M. lar (Fabricius, 1798)

VARUNIDAE
Varuna litterata (Fabricius, 1798)

Secteur2 S 06°58.848; E 156°47.021

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)

PALAEMONIDAE
M. gracilirostre (Miers, 1875)
M. lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)
M. placidulum (De Man, 1892)

Pisuku stream S 06°58.965; E 156°46.718; 12/10/2014

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina nsp2

PALAEMONIDAE
M. gracilirostre (Miers, 1875)
M. lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)
M. placidulum (De Man, 1892)

Pisuku stream S 06°58.848; E 156°46.582 aval

ATYIDAE
Caridina nsp1
C. nsp3

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. gracilirostre (Miers, 1875)
M. latidactylus (Thallwitz, 1891)

Lokasereke river; S 06°58.024; E 156°47.861; 13/10/2014

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina brevidactyla Roux, 1919
C. neglecta Cai & Ng, 2007
C. nsp3
C. papuana Nobili, 1905
C. serratirostris De Man, 1892

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. lar (Fabricius, 1798)
M. placidulum (De Man, 1892)

Vorasiki river; S 06°58.520; E 156°47.416; 13/10/2014

ATYIDAE
Atyoida pilipes (Newport, 1847)

Atyopsis spinipes (Newport, 1847)

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)
M. placidulum (De Man, 1892)

Creeks 14/10/2014

Creek 1 S06°59.085; E 156°47.454' ; 132 m

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina nsp2
C. papuana Nobili, 1905
C. typus Milne Edwards, 1837

PALAEMONIDAE
Macrobrachium lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)

Creek 2 S06°59.027'; E 156°47.913" ; 93 m

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina nsp2
C. papuana Nobili, 1905
C. typus Milne Edwards, 1837

PALAEMONIDAE
Macrobrachium lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)

GECARCINUCIDAE
Sendleria cf solomonis (Roux, 1934)

Tiriki river; 15/10/2014
Secteur 1 S 07°00.661'; E 156°49.075

ATYIDAE
C. brevicarpalis De Man, 1892
C. papuana Nobili, 1905

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. lar (Fabricius, 1798)

SESARMIDAE
Geosesarma maculatum (De Man, 1892)
Labuanium trapezoideum (H. Milne Edwards, 1837)

Secteur2 S07°00.857'; E156°49.194'

ATYIDAE
Atyopsis spinipes (Newport, 1847)
C. brevicarpalis De Man, 1892
C. papuana Nobili, 1905

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. cf jaroense (Cowles, 1914)
M. lar (Fabricius, 1798)
M. placidulum (De Man, 1892)

Gu'ma river 17/10/2014
secteur 1 S 07°01.764; E 156°49.899; Altitude: 50m

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina nsp3
C. brevicarpalis De Man, 1892
C. brevidactyla De man, 1908
C. papuana Nobili, 1905

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. lar (Fabricius, 1798)

secteur 2 S 07°02.328: E 156°49.571 ; Altitude:70m

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. gracilirostre (Miers, 1875)
M. lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)
M. placidulum (De Man, 1892)

Camp 3 S 07°01.758; E 156°50.008

VARUNIDAE
Ptychognathus riedelii (A.Milne-Edwards, 1868)

Utica gracilipes White, 1847

Lopakare river   S 07°01.613'; E 156°46.567'; 20/10/2014 amont

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina brevicarpalis De Man, 1892
Caridina brevidactyla Roux, 1919
C. nsp2
C. papuana Nobili, 1905
C. serratirostris De Man, 1892

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. gracilirostre (Miers, 1875)
M. lar (Fabricius, 1798)
M. latimanus (Von Martens, 1868)
M. placidulum (De Man, 1892)

VARUNIDAE
Geosesarma maculatum (De Man, 1892)
Ptychognathus riedelii (A.Milne-Edwards, 1868)

Lopakare river   S 07°01.834'; E 156°45.789'; 21/10/2014

ATYIDAE
Atyoida pilipes (Newport, 1847)
Atyopsis spinipes (Newport, 1847)
Caridina brevidactyla Roux, 1919
C. brevicarpalis De Man, 1892
C. serratirostris De Man, 1892

PALAEMONIDAE
Macrobrachium australe (Guérin-Méneville, 1838)
M. bariense (De Man, 1892)
M. handschini (Roux, 1933)
M. lar (Fabricius, 1798)

VARUNIDAE
Ptychognathus riedelii (A.Milne-Edwards, 1868)
Pyxidognathus granulosus A.Milne-Edwards, 1879