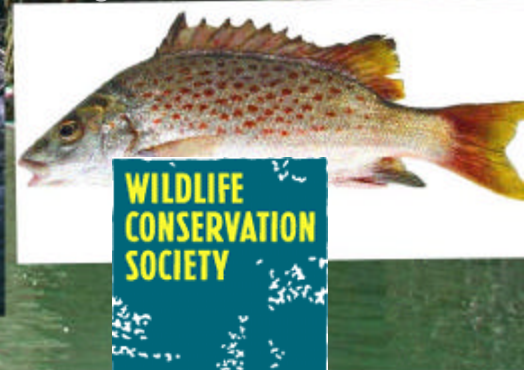


*A preliminary investigation of*  
**Priority Ichthyofaunal Areas**  
**for Assessing Representation in**  
**Fiji's Network of Forest Reserves**



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**Wetlands International-Oceania (Fiji Office)**



Technical Report to the Wildlife Conservation Society  
October 2003

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## Executive Summary

In an attempt to address some of the major gaps in knowledge on Fiji's freshwater ichthyofauna and to better inform the design of a network of forest reserves, this study was undertaken using prior literature and collections, a series of strategic surveys and alpha taxonomic work. This report presents the current state of knowledge for Fiji's freshwater ichthyofauna, a framework for ichthyofaunal representation and priority taxa and freshwater areas for conservation. The work carried out during this study, combined with survey and taxonomic work carried out during the previous nine months, has resulted in the discovery of seven potential new species and 15 new records for the Fiji Islands (Jenkins and Boseto, *in preparation*). The current study resulted in 1839 fishes being collected from 78 sites around the Fiji islands including all major catchments of the largest islands of Viti Levu, Vanua Levu and Taveuni. All but one of the suspected nine Fijian freshwater endemic fishes were collected. Eleven species of conservation significance are discussed in detail and seven priority areas for ichthyofaunal conservation are proposed. Discussions are included on ichthyofaunal diversity, zoogeographic affinities, ubiquity and rarity before proposing a set of rules for representing Fijian freshwater ichthyofauna in the proposed forest network.



## **Introduction**

Freshwater resources are under serious threat on all corners of the globe from anthropogenic influences. The island nations of Melanesia are particularly vulnerable due to their limited freshwater resources, burgeoning populations and increasing extractive activities from mining and logging companies. Available data suggest that between 20-35 percent of freshwater fishes are vulnerable, endangered or extinct, mostly because of habitat alteration. This fauna is nutritionally and economically important, easily surveyed and certain species provide good indication of water quality and ecosystem well-being. However, there are serious gaps in knowledge on the biodiversity and taxonomy of freshwater fishes in the region with major on-the-ground implications in terms of freshwater and integrated multi-system management.

The freshwater ichthyofauna of the Fiji Islands is also poorly understood and very poorly studied in comparison to the marine and estuarine faunas. Whitley provided an initial checklist in 1927 with mainly marine fauna. Fowler (1959) provided the first major overview of fishes from Fiji including some freshwater fauna collected in the lower reaches of Fiji freshwaters, drawing on almost entirely marine and estuarine collections dating back to 1838. Ryan (1980) was the first to summarize the state of knowledge for brackish and freshwater ichthyofauna where he listed 75 native and 11 introduced species. This fauna, in addition to freshwater mollusca and crustacea, was then later re-examined by Lewis and Pring (1986) in a report by Division of Fisheries.

The Wildlife Conservation Society commissioned the current study as part of a two year USAID funded initiative to assess representation in a forest reserve network and promote the role of forestry certification at landscape scales in forest conservation. In an attempt to address some of the major gaps in knowledge on Fiji's freshwater ichthyofauna and to assess the efficacy of Fiji's

network of forest reserves, this study was undertaken using prior literature and collections, a series of strategic surveys and alpha taxonomic work. This report presents the current state of knowledge for Fiji's freshwater ichthyofauna, a framework for ichthyofaunal representation, priority taxa and areas for conservation and a preliminary ranking of Fijian watersheds in terms of providing ecosystem services.

## **Methods**

Data used for this study are from the Fiji Freshwater Fishes Database housed with the collections at the Marine Studies Program of the University of the South Pacific and administered by Wetlands International-Oceania at the Fiji Office. This database is populated by information from existing published literature, data from the current Masters work of University of South Pacific student, David Boseto and data collected at 78 sites as part of the study. This database is the most comprehensive assemblage of data on the freshwater ichthyofauna of Fiji. This database will be further refined, updated and used by the Fiji Department of Environment and the IUCN Oceania Freshwater Fishes Specialist Group.

## **Sampling Strategy**

Given the short time frame (9 months) in which to carry out this study, field and laboratory work was highly strategic using a set of samples taken for determining representation. Firstly, all of the major catchments of the four largest islands of Fiji were targeted (Viti Levu, Vanua Levu, Taveuni and Kadavu) for surveys. Due to time constraints, Kadavu was not surveyed during the course of this study. Secondly, mid -upper reaches of every catchment were targeted for survey work to maximize chances of detecting unique assemblages or taxa, in particular locally endemic, waterfall -climbing gobies of the sub-family Sicydiine. Lower reaches were only targeted where literature suggested that interesting taxa or assemblages existed in these areas. In addition, two stream systems

(Tavoro, Taveuni and Savura, Viti Levu) were intensively sampled every 50 meters from mouth to above the first major waterfall. These findings were used to help extrapolate our findings to the less intensively sampled, similar habitat water bodies.

### **Taxonomic Work**

Taxonomic work during this study was dedicated to accurate identification of specimens to the species level and rapid description of suspected new taxa. This work has assisted greatly in the development of USP and FIT student capacity to correctly identify freshwater taxa. The most systematically problematic taxa were fishes of the Family Gobiidae which is the most speciose vertebrate family. The majority of laboratory time was spent in the descriptive work on several species of goby suspected to be new taxa and curation of collected specimens. During this project, one new species paper describing *Schismatogobius chrysonotus* n.sp. has been completed and submitted (Jenkins & Boseto, 2003, in press) and another describing two new Sicydiine gobies (*Lentipes bellameyae* n.sp. and *Sicyopus merielae* n.sp.) is nearing completion. Other new taxa collected are *Sicyopterus* n.sp., being described by David Boseto (USP), *Glossogobius* n.sp., being described by Doug Hoese (Australian Museum) and *Redigobius* n.sp., being described by Helen Larson (Northern Territory Museum). The remaining suspected new taxa is a species of *Stiphodon*, which we have yet to dedicate any time to, but is planned to be studied by the author and D. Boseto.

### **Fish Sampling**

A variety of techniques were used to collect fish from each water body, depending upon the characteristics of the site and availability of equipment. The apparatus and techniques used were as follows:

*Electrofisher* (Smith-Root; 500V, 50% duty cycle) – This was used intensively in shallow streams and banks of deeper areas. Generally the user would have a fine mesh net attached to the wand and someone positioned down stream with hand nets to dip out stunned fishes. This is a very comprehensive method when the apparatus working. However, it is heavy and unwieldy in dense forest.

*Large seine net* (2 m x 7 m, 0.4 cm<sup>2</sup> mesh) – This net was pulled in a rough circle, with the bottom edge down as close as possible to the substrate and forward of the top floating edge of the net. This technique was executed before anyone could set foot in the water body to minimize the number of fleeing fishes. This was generally used only in minor tributaries and slow moving or still waters.

*Medium pole seine net* (1.2 m x 0.8 m, 1mm<sup>2</sup> mesh) – This was used in a variety of ways. Firstly, it was held firmly downstream as people kick and dislodge rubble upstream. This was a useful method for collecting small, bottom dwelling fish. On vegetated banks the net was thrust under submerged vegetation and the vegetation was disturbed on the bank dislodging fishes into the net. Also, this net was used to “scoop” (bottom edge held forward, run along substrate for a few seconds then lifted) from any accessible shallow body of water. This net was particularly useful for narrow streams.

*Small hand nets* (15cm x 10cm + 10 cm x 8 cm, 1 mm<sup>2</sup> mesh) – These were used to “scoop” the underside of overhanging rocks and in small crevices in the smaller streams and also to collect fishes when using the electrofisher.

*Gill net* (6 m x 1.5 m, 2 cm<sup>2</sup> monofilament mesh) – This was used at the mouths of streams and rivers. It was erected with two poles and stretched to its full length then allowed a 2hr “soak” time before it was checked.

*Hook and line* (8 lb test line, 3.5 cm hook) – The hooks were baited predominantly with insects and were thrown from the bank into larger water bodies that could not be fished effectively by any of the other methods. A small weight was attached to the line to aid in the casting process.

*Spear* – A small multi-prong spear was effective for collecting elusive fishes such as lutjanids, kuhliids, gobies, etc. It was used while swimming underwater with mask and snorkel equipment.

*Local villagers* – One should never underestimate the skill and knowledge of local inhabitants. You can always be assured that they will know how to catch just about anything that swims. If you have trouble collecting certain fishes (for example large species that are best caught with a gill net, but you don't have one) offering local kids or adults a small reward often yields big dividends.

### **Collections**

Voucher specimens were collected, fixed in a 10% formalin solution and transferred to 70% ethanol solution after 5 days of fixation. Some specimens were stored directly in 70% ethanol for DNA analysis. As color loss is rapid, accurate preservation of color patterns was recorded by photography. Fresh specimens were placed in a portable aquarium with some local aquatic vegetation and benthos to enhance the photography. Voucher specimens were deposited at the collections of the University of South Pacific and duplicates have been deposited in the Australian Museum, Sydney. Some specimens have been also deposited in the reference collections of the Western Australian Museum, Northern Territory Museum, California Academy of Sciences and the Smithsonian Institution.



## **Descriptive Site Data**

Current speed was measured by floating a plastic lid a measured distance, timing it with a stopwatch and dividing distance (m) by time(s). Biophysical variables, specifically pH, temperature, dissolved oxygen and conductivity, were measured using a multi-meter. Location and altitude were taken with a Garmin 8 hand held GPS. Maximum depth, width, and reach sampled measures were taken using a fiberglass, waterproof measuring tape.

## **Selection of Priority Ichthyofaunal Areas (PIA's)**

Several analyses were carried out using the Fiji Freshwater Fishes database, existing literature and personal expertise to make a preliminary assessment of the priority sites within Fiji for the conservation of freshwater fishes. Based on the current level of knowledge, the following aspects of the Fijian freshwater ichthyofauna were examined:

- 1) Sites containing fauna of conservation importance; ie. foci of endemic species (sites with three or more endemics), IUCN listed species, extremely rare or zoogeographically restricted species or communities.
- 2) sites of high overall species diversity; 12 or greater species per site
- 3) sites of high goby diversity (water quality indicator); 5 or greater species per site
- 4) Altitudinal or reach restriction; how restricted are individual species to headwater, middle, terminal, reaches of streams or rivers (as defined in Polhemus et.al. 1992).
- 5) Zoogeographic affinities; how restricted are individual species to zoogeographic regions
- 6) Ubiquity; % of all sites sampled that species occurs; examines most widespread species
- 7) Rarity; % of all sites sampled that species occurs; examines most apparently restricted species

8) Special elements; unusual communities, habitats, known sites for rare or endangered populations of fish species (including Red List, CITES species even though not collected)

## **Results and Discussion**

### **Collections**

The work carried out during this study, combined with survey and taxonomic work carried out during the previous nine months by the author and David Boseto, has resulted in the discovery of seven potential new species and 15 new records for the Fiji Islands (Jenkins and Boseto, *in preparation*). The current study resulted in 1839 fishes being collected from 78 sites in all the major catchments in Viti Levu, Vanua Levu and Taveuni. Eighty-seven species were collected representing around 70% of the total fauna of 127 species known to inhabit Fiji's freshwaters. 83 of 112 (74%) of the indigenous fishes and four of 15 (27%) of the introduced fishes were collected. All but one of the suspected nine Fijian freshwater endemic fishes were collected (see Appendix 1). Material from recent surveys of Kadavu has yet to be studied.

### **Fijian Freshwater Fishes of Conservation Significance**

This section presents details for each known species of conservation significance and includes a series of annotations, each separated by a semicolon. These annotations pertain to general habitat, detailed habitat, known altitudinal range, general activity mode, social behavior, major feeding type, food items, reproductive mode, maximum size, general distributional range, conservation status and additional comments pertinent to the present survey including sites where collected. The length is given as standard length (SL) for most species, which is the distance from the tip of the snout to the base of the caudal fin. Total length (TL) is given for a few fishes that do not have a clearly defined caudal fin (eels for example). The phylogenetic sequence of the families appearing in this list follow the system that is used by the major Australian museums and approximates proposed in Nelson's *Fishes of the World* (1984).

## Ophichthyidae – Snake Eels

### ***Yirkala gjellerupi* (Weber & de Beaufort 1916) – Short-jawed Snake Eel**

Fresh water; creeks and rivers; below 50 m; cryptic; usually buried in sand, solitary; carnivore; fishes, crustaceans; spawns pelagic eggs; 22 cm TL; *known previously only from a single specimen* (holotype) from Irian Jaya; several collected in this study by electrofisher in the Savura Creek catchment, Viti Levu; likely to have an Indo-West Pacific range but unknown. This is a new record for Fiji, and was collected from sites 13 and 14.

## Terapontidae – Grunters

### ***Mesopristes kneri* (Bleeker 1876) – Orange-spotted grunter**

Marine, estuarine and freshwaters; harbours, river mouths, estuaries and the lower reaches of streams below about 5-10 m; roving predator; solitary or in groups; carnivore; insects, crustaceans molluscs and fishes; demersal eggs with no parental care; 30 cm SL; *b*, collected in Viti Levu, Vanua Levu and Taveuni, presumed to be widespread in the lower streams and river mouths of the large islands. Collected from sites 4, 23 and lower Dreketi River.



Figure 1. *Mesopristes kneri*, male, 22 cm SL, mouth of Rewa River

## Mugilidae – Mullet

### *Liza melinoptera* (Valenciennes, 1836) – Otomebora Mullet

Fresh and marine waters; lowland creeks and rivers; to at least 100 m elevation; forms benthic grazing schools; forms aggregations; omnivore; algae and organic detritus; spawns pelagic eggs; to 30 cm SL: Indo Pacific; East Africa to Samoa, north to the Philippines and the South China Sea, south to Tonga and tropical Australia; Palau in Micronesia, to Marquesas Islands; *listed as Endangered on IUCN Red List; none collected in present survey; presumably very rare; cited in Lewis and Pring (1986).*

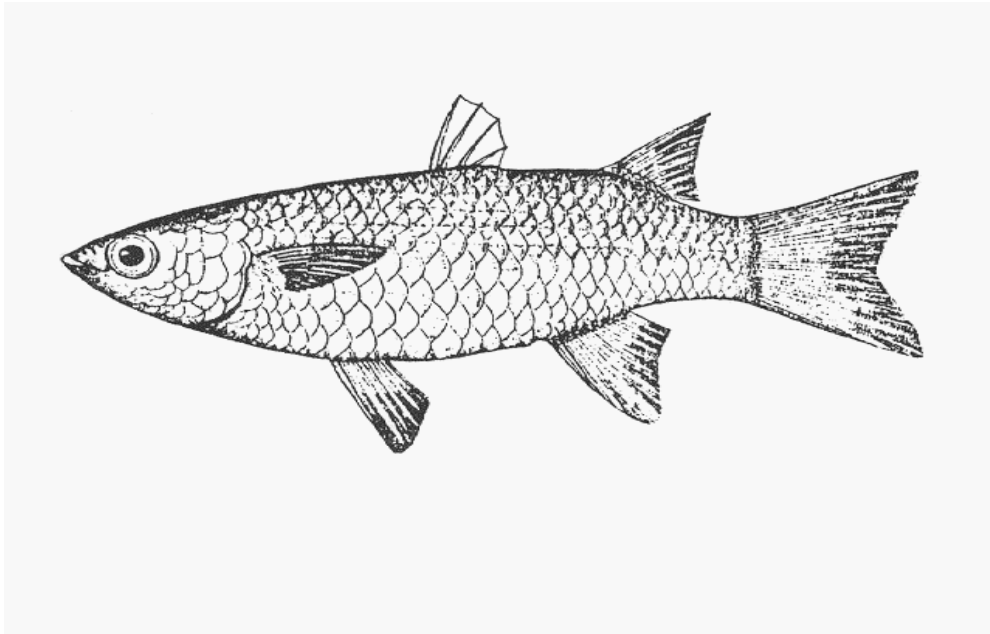


Figure 2. *Liza melinoptera*, from Fishbase (2000).

## Eleotridae – Gudgeons

### *Lairdina hopletupus* (Fowler, 1953) – Hoofprint goby

Fresh water and estuaries; lower creeks and rivers; below about 5-10 m elevation; bottom dweller; solitary or in groups; presumed omnivore; algae, crustaceans, insects and their larvae; presumed parental care of demersal eggs; 33 mm SL; known only from two badly damaged specimens collected from hoof print puddles in the lower Sigatoka River; a presumed Fijian endemic genus; none collected in the present survey.

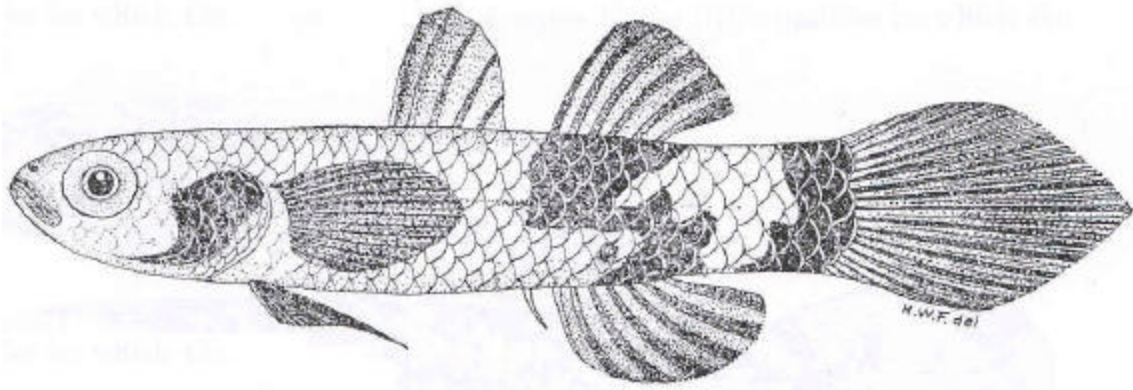


Figure 3. *Lairdina hopletupus*, drawing of holotype by Henry Fowler from Fowler (1953), male, 32 mm, lower Sigatoka River.

**Gobiidae – Gobies**

***Glossogobius n. sp.* (Hoese and Allen, in preparation)**

Fresh water; creeks and rivers; below about 50 m elevation; rests on bottom; solitary or in groups; carnivore; small crustaceans and fishes; parental care of demersal eggs; 12 cm SL; undetermined distribution; likely widespread in lower to middle freshwaters throughout Fiji and Indo-west Pacific but *may be restricted to Fiji*; collected at sites 7, 12, 13, 28, 31, 33, 50, and 51. This species is most similar to *G. celebius*. This is a new record for Fiji.



Figure 4. *Glossogobius n. sp.*, male, 10 cm SL, Tavoro Creek, Taveuni.  
Photo by D. Boseto.



***Lentipes "bellameyae" n. sp.* (Jenkins & Boseto, in preparation) – Bella's Goby**

Fresh water; creeks and rivers; below about 20 m elevation; rests on bottom; solitary or in groups; carnivore; small crustaceans and fishes; presumably amphidromous; 4.5 cm SL; *Fiji Islands endemic; likely Taveuni Island endemic restricted to fused rock wall streams*; known only from specimens collected in Sites 41, 42 Waitavala Creek, Taveuni; has peculiar and distinctive ancillary reproductive organs. *This is a new species to science.*



Figure 5. *Lentipes "bellameyae" n. sp.*, male, 4 cm SL, Waitavala Creek., Taveuni

***Redigobius leveri* (Fowler 1943) – Lever's Goby**

Freshwaters; creeks and rivers; below about 100 m elevation; rests on bottom; solitary or in groups; carnivore; benthic invertebrates; parental care of demersal eggs; 4.5 cm SL; *Fiji islands endemic*. Previously reported as *Gobius leveri* (Ryan 1980); quite common (approx. 20% of sites) in less disturbed freshwater areas throughout survey; likely widespread in less disturbed freshwaters of larger islands; curiously none collected on Vanua Levu.



Figure 6. *Redigobius leveri* , male, 38 mm SL, Savura Creek, Viti Levu

***Redigobius n. sp. (Larson, in preparation)***

Freshwaters; creeks and rivers; below about 150 m elevation; rest on bottom or mid-water schooling; solitary or in groups; carnivore; benthic invertebrates; parental care of demersal eggs; 3.5 cm SL; *Fiji islands endemic, presumed Vanua Levu endemic*; known only from the upper Lekutu River system in Vanua Levu. This was collected at site 56 and is a new species to science.



Figure 7. *Redigobius n. sp.* male, 31 mm SL, upper Lekutu River.

Photo by J. Pogonoski.

***Schismatogobius chrysonotus* (Jenkins and Boseto, 2003 *in press*) –  
Orange-spotted Scaleless Goby**

Fresh water; lowland creeks and rivers; below about 50 m elevation; rests on bottom; often buried in sand and pebbles, solitary or in small groups; carnivore; insects, larvae; presumed amphidromous; 41 mm SL; *Fiji Islands endemic*; collected in Viti Levu, Vanua Levu, and Taveuni, presumed to be widespread in clear freshwater streams of the larger islands. Collected from sites 11, 13, 31, 43, 50, 51 and 57. *This is a new species to science.*



Figure 8. *Schismatogobius chrysonotus* n. sp. male, 3.5 cm SL, Nasekawa River, Vanua Levu. Photo by J. Pogonowski



***Sicyopterus n. sp. (Boseto, in preparation) – Tavoro Goby***

Fresh water; lowland creeks and rivers; below about 40 m elevation; rests on bottom; solitary or in groups; herbivore; filamentous algae growing on rock surfaces; hatching and larval stage presumably occurs at sea, postlarval stage to adult in freshwater; 85 mm SL; *an undescribed species likely to be a Fiji endemic, most closely resembles *S. lagocephalus* (Pallas 1770) but with several meristic differences including much lower transverse scale counts. This is a new species to science.*



Figure 9. *Sicyopterus n. sp.* male, 8.5 cm SL, Tavoro Creek, Taveuni

***Sicyopus "merielae" n. sp.* (Jenkins & Boseto, in preparation) – Meriel's Goby**

Fresh water; creeks and rivers; below about 20 m elevation; rests on bottom; solitary or in groups; carnivore; small crustaceans and fishes; presumably amphidromous; 4.5 cm SL; *Fiji Islands endemic; highly likely to be a Taveuni Island endemic restricted to fused rock wall streams*; known only from specimens collected in Waitavala Creek, Taveuni; has peculiar distinctive ancillary reproductive organs. *This is a new species to science.*

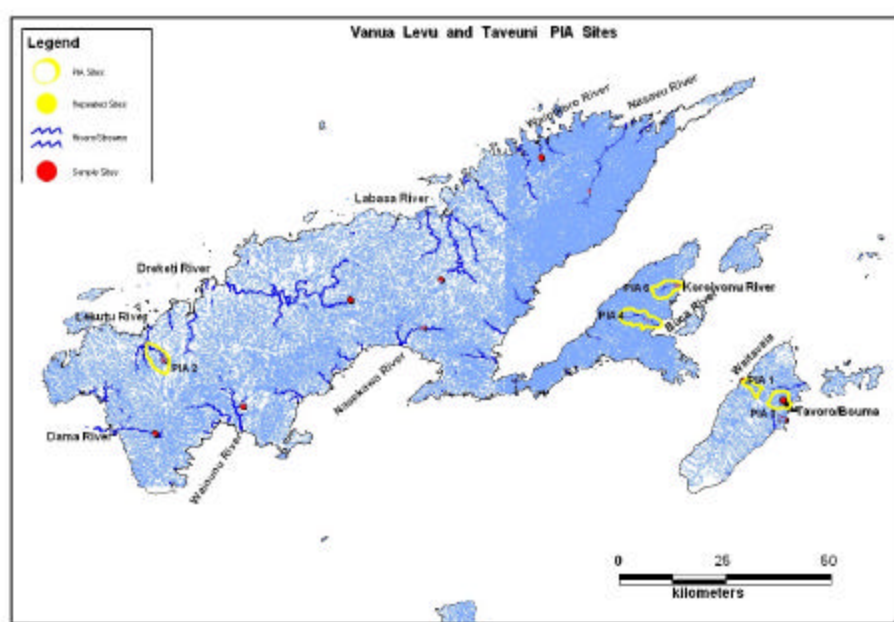
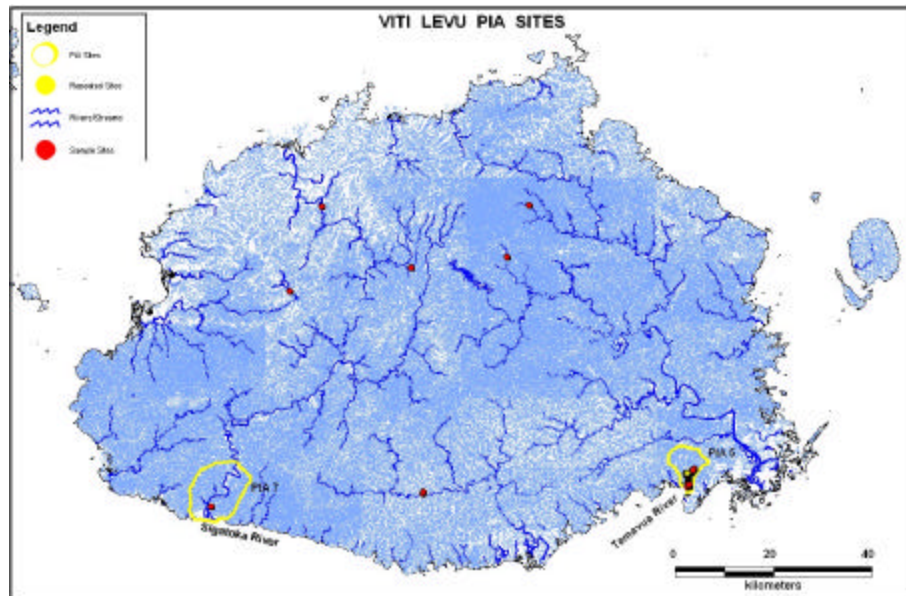


Figure 10. *Sicyopus merielae n. sp.* female, 4 cm SL, Waitavala Creek, Taveuni



## Priority Ichthyofaunal Areas

The following seven areas, called Priority Ichthyofaunal Areas (PIAs) are listed in order of conservation importance and are based on the current level of knowledge on freshwater fish fauna within Fiji using the criteria described in the methods section. *All areas should be considered for inclusion in the design of a representative forest reserve network for Fiji.* Boundaries and locations are shown below for Viti Levu, Vanua Levu, and Taveuni.



**PIA 1. Fused rock streams of Northwestern Taveuni.** Sites 41 and 42 (Waitavala Creek) in particular should be afforded some protection (Figure 11). Other similar habitats in this area of Taveuni have been reported (Soqulu, D. Olson, pers. comm.) and should also be examined. The boundaries of this PIA are the entire stream catchment as the important ichthyofauna are amphidromous species. This area is particularly important for healthy, breeding populations of the locally endemic and unusual *Lentipes n.sp.* and *Sicyopus n.sp.* It is also apparently a relatively unusual habitat type in Fiji. Some element of co-management with the tourism industry should be considered for the site as the “rock slides” are an important destination for tourists in Taveuni and also locally important for water supply and recreation.



Figure 11. PIA 1, Waitavala Creek on Taveuni island.

**PIA 2. Upper Lekutu conglomerate streams and pools, Vanua Levu.** Site 56 a stream near Kavula River, upper Lekutu catchment, Vanua Levu should be given some protection (Figure 12) as this is the only known site of the endemic *Redigobius n.sp.* This species is likely to exhibit parental care of demersal eggs, like others in the genus, and is not an amphidromous or migratory fish and is therefore likely site restricted. This stream habitat is also characterized by fused rock but not nearly as smoothly worn as PIA 1. This is a rough fused rock that appears almost as a conglomerate and also forms pools in the upper Lekutu catchment.



Figure 12. PIA 2. Upper Lekutu conglomerate stream and rock pool, Site 56, Vanua Levu. Photo by J. Pogonoski.



**PIA 3. Tavoro/Bouma National Park stream system, Taveuni.** Sites 22–34. The entire Tavoro catchment system on northeastern Taveuni Island within the Bouma National Park is important as the only known system containing the waterfall-climbing endemic *Sicyopterus n.sp.*, as well as containing high overall diversity (48 species) (D. Boseto, Masters thesis) and high levels of endemism (contains at least third of the endemics). The catchment system is relatively intact and water quality is relatively high, though susceptible to cyclone damage. Lower reaches of the system lost over a meter in depth due to large scale erosion following Cyclone Ami in 2002 translating to loss in habitat for fishes and declining water quality for consumption. This site is apparently under some level of protection within the national park system.



Figure 13. PIA 3. Tavoro Ck, Bouma National Park, Taveuni. Photo by D. Boseto.

**PIA 4. Buca River system, Natewa Peninsula, Vanua Levu.** Site 51. This system is particularly notable for high goby diversity (6 species netted in a 50 m reach), an indicator of high water quality, high endemism (at least a third of the endemic species) and has by far the largest sampled breeding populations of the endemic species *Schismatogobius chrysonotus*. It is among the most pristine and undisturbed sites sampled during the survey. As many of the species including several endemics are amphidromous, the whole system has been highlighted as a PIA.

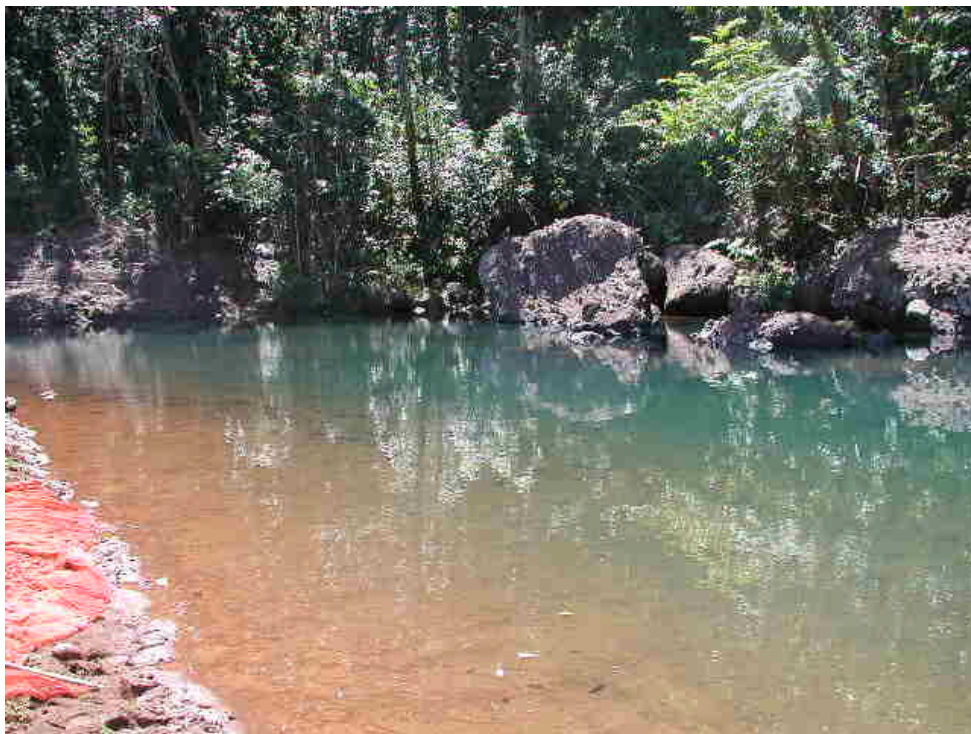


Figure 14. PIA 4. Upper Buca river system, Natewa Peninsula, Vanua Levu. Site 51. Photo by J. Pogonoski.

**PIA 5. *Tamavua River system, Viti Levu.*** Sites 1-22. The entire catchment area of this river system is marked as a PIA because it is a system of relatively high overall diversity (53 species) (D. Boseto, Masters thesis) containing some highly unusual fauna (e.g. *Yirkalla gjellerupi*) and high levels of endemism (approximately half of all country endemics). It is also likely to periodically contain the IUCN listed endangered *Liza melinoptera* although not found in this study. It is also nationally important as a water supply source for the capital city of Suva and is an existing national forest reserve area within the Savura catchment.

**PIA 6. *Nala river system, Natewa Peninsula, Vanua Levu.*** Sites 49, 50. Particularly notable as a system with relatively high goby diversity (7 species) and potentially a focus of endemism (4 out of existing seven species i.e. 57% are potentially endemic species). It is also notable as one of the least disturbed sites seen during the survey. While only the Lower Nala was sampled the whole system has been highlighted as a PIA.



Figure 15. PIA 6. Nala River system, Natewa Peninsula, Vanua Levu Sites 49, 50.

Photo by J. Pogonoski.



**PIA 7. Lower Sigatoka River** – Site 45. This site is being included only to be precautionary in that it is the only known site that the potentially endemic genus of gudgeon *Lairdina hopletopus* is found. None were caught during this survey.



Figure 15. PIA 7. Lower Sigatoka , Viti Levu , Site 45. Photo by J. Pogonoski.

### **Diversity**

Comparisons of diversity estimates within the study are contentious as the sites ranked with the highest diversity are those that were intensively sampled by the latest electrofishing apparatus. Much of the duration of the survey, the electrofishing apparatus was not working rendering much comparison between sites meaningless. This method of sampling allows the collection of several species that otherwise generally escape detection using nets and other traditional methods. As such, even comparisons to other past similar studies in PNG are arguable because of the disparity of sampling methods. However, on the positive side, without this apparatus, many of the new taxa probably would not have been collected and the true level of diversity would not be known for these sites.

The intensively sampled systems recorded a diversity of 53 species from the Tamavua and the 48 species from the Tavoro (Boseto, Masters thesis), which is quite a bit higher than anticipated based on surveys from similar river systems in Papua New Guinea. Only 35 species are known from the Laloki/Brown system (Beehler 1993) and 28 from the Biges River (Parenti and Allen 1991), which are similar but larger rivers in PNG. Even the huge Sepik River in PNG has only 57 species recorded from within its waters (Allen and Coates 1990). If we were to take these results at face value one might say the river systems of Fiji were highly diverse, however, this is more likely the result of intensive sampling with the latest equipment.

However, if we are to compare the two comparably intensively sampled areas, sites 8-13 in the mid-Savura catchment stand out as being exceptionally diverse with 13-18 species per 50 m stretch. This is the highest consistently high diverse stretch of river known from this study. This has been included as a PIA as a precautionary measure. Also notably diverse is the lower Nala site 50 which has 13 species only sampling with the net. This has also been included as a PIA as a precautionary measure.

### **Altitudinal or Reach Restriction**

Figure 16 illustrates the percentages of the ichthyofauna collected that are restricted by life history characteristics to headwater, middle or terminal stream habitats (as defined in Polhemus *et. al.* 1992).

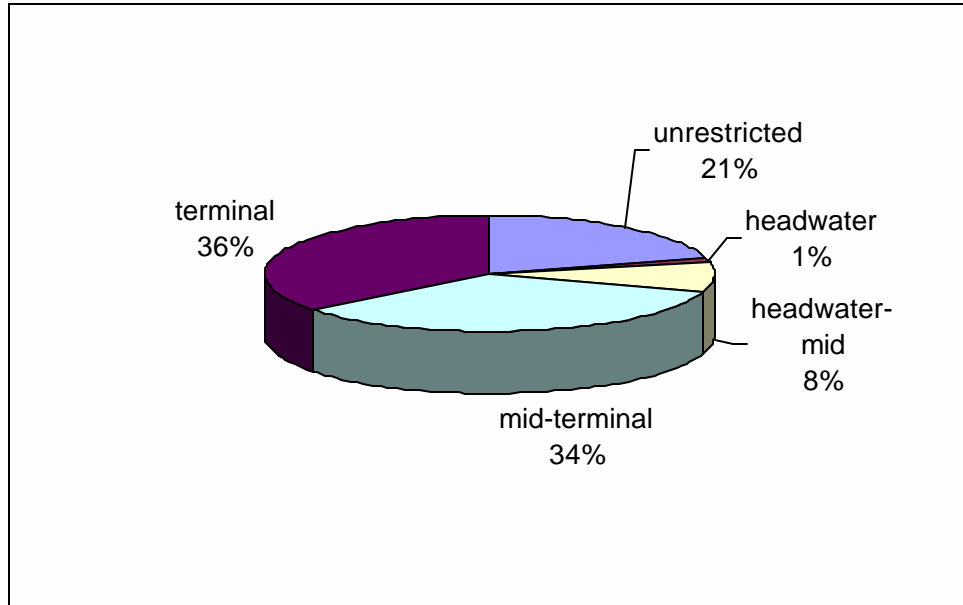


Figure 16. Percentages of the ichthyofauna collected restricted by life history characteristics to headwater, middle, terminal stream habitats.

Over 21% of the fauna is unrestricted to habitat type and an additional 70%, at least, of the fauna is only unrestricted to the upper reaches. The remaining nine percent, the fauna either restricted to the headwaters or headwaters and middle reaches, are the interesting component of the fauna for our purposes of representation as these tend to have a propensity for very local distributions. Based on our collections, this fauna is comprised of several species from the genus *Redigobius* including *R. leverii*, *R. leptochilus* and *R. n.sp.* I have included *R. n.sp.* as restricted to headwaters as it has only been found in this habitat. However, this may change with further sampling. This analysis shows that at least 90% of the fauna is found in the middle to terminal reaches of Fijian freshwaters.

## Zoogeographic Affinities and Endemism

Table 1 gives an idea of the known geographic ranges of the collected fauna illustrating some of the zoogeographic affinities and indicating levels of endemism among the fauna collected. The table is arranged in declining range sizes.

Table 1. Known geographic ranges of collected ichthyofauna

<b>Geographic range</b>	<b>Number of species</b>
Global Tropics	2
Africa, Asia, Oceania	5
Asia, Oceania	9
Indo-Pacific	16
Indo- west Pacific	30
Western Pacific	1
West-central Pacific	2
Fiji Islands	3
Single island	3
unknown	6

For our purposes of designating priority ichthyofaunal areas we are interested in the restricted range species. A large portion of fauna is wide ranging with 16% ranging throughout the global tropics and widespread throughout Africa, Asia and Oceania and another 46% ranging widely throughout the broader Indo-Pacific region. The eel, *Anguilla megastoma*, and the flagtail, *Kuhlia munda*, range only within the West and Central Pacific. The Short jawed snake eel *Yirrlaka gjellerupi* is known only from Irian Jaya and Fiji but is tentatively placed in the West-Central Pacific range category. The terapon *Mesopristes kneri* and the gobies *Redigobius leveri* and *Schismatogobius chrysonotus* are only known from the Fiji Islands. *Lentipes sp.* and *Sicyopus sp.* are only known from the fused rock wall streams of north-western Taveuni and *Redigobius sp.* is only known from a single pool in the upper Lekutu River in Vanua Levu. The ranges of an additional six species are unknown.

## Ubiquity

Table 2 presents a good approximation of the top ten most widespread/most commonly seen freshwater fishes in Fiji.

Table 2. Top ten most widespread/commonly seen freshwater fishes in Fiji showing % of sites sampled that species occur, presented in phylogenetic order.

Genus	species	% sites
<i>Anguilla</i>	<i>marmorata</i>	42.31
<i>Kuhlia</i>	<i>marginata</i>	42.31
<i>Kuhlia</i>	<i>rupestris</i>	35.90
<i>Kuhlia</i>	<i>munda</i>	16.67
<i>Eleotris</i>	<i>melanosoma</i>	41.03
<i>Eleotris</i>	<i>fuscus</i>	26.92
<i>Hypseleotris</i>	<i>guentheri</i>	30.77
<i>Redigobius</i>	<i>leverii</i>	17.95
<i>Stenogobius</i>	<i>genivittatus</i>	25.64
<i>Stiphodon</i>	<i>rutilaureus</i>	17.95

Overall this result is not surprising, similar insular freshwater habitats throughout the Indo-West Pacific would generally yield the same list at the generic level with the top five or six species remaining constant while the bottom three or four would likely change at the species level. The three important results of this analysis are; 1) the Fijian endemic *Redigobius leverii* is apparently quite ubiquitous and as such should be considered less critical in terms of conservation status compared to other more restricted fauna; 2) a new record for Fiji, *Stiphodon rutilaureus*, is actually among the top ten most commonly encountered fishes in Fiji (this helps to illustrate the poor level of knowledge regarding Fiji's freshwater ichthyofauna; and, 3) giant freshwater eels continue to be collected in abundance at approximately half of the sites in Fiji. Freshwater eel populations worldwide are declining rapidly and Fiji has a rapidly diminishing chance to maintain healthy eel populations within several watersheds. This could not only be developed as a good indicator of water quality but a lucrative fishery for the country.

## Rarity

Table 3 is a best estimation of the top five rarest freshwater fish in Fiji as a result of analyzing the number of all sites sampled that the species occur, using knowledge of their life history traits and local abundance estimates.

Table 3. Top five rarest freshwater ichthyofauna in Fiji

Rank	Genus	species
1	<i>Redigobius</i>	<i>sp.</i>
2	<i>Lentipes</i>	<i>sp.</i>
3	<i>Sicyopus</i>	<i>sp.</i>
4	<i>Yirkala</i>	<i>gjellerupi</i>
5	<i>Liza</i>	<i>melinoptera</i>

*Redigobius n.sp.* is probably the rarest freshwater fish in Fiji. This is based on the fact that it has only been encountered in a single small pool in the upper Lekutu River in Vanua Levu. It was present in abundance with no other species present in this isolated pool. This species is likely to exhibit parental care of demersal eggs, like others in the genus, and is not an amphidromous or migratory fish and is therefore likely site restricted. It looks unlike any other known *Redigobius* (Helen Larson, pers. comm.). *Lentipes n.sp.* and *Sicyopus n. sp.* are also likely to be habitat restricted to the fused rock wall streams of north western Taveuni but because they are likely amphidromous species and their populations can exist in upper, middle or lower reaches of these types of streams they are therefore ranked lower in terms of rarity. *Lentipes* is ranked above *Sicyopus* because the genus *Lentipes* is known to have a greater number of endemic species restricted to single sites. *Yirkala gjellerupi* is an extremely poorly known animal previously known from a single specimen collected in the early 1800's in Dutch Northern New Guinea, presently Irian Jaya. We only collected this eel from the middle Savura Creek catchment in Viti Levu and this is the only other location on Earth that this fish is known from. While it is probably more widespread than collections



suggest it is nonetheless a very rarely encountered animal (John McCoscker, pers. comm.). *Liza melinoptera* is listed as endangered on the IUCN Red List. While the range of this species is known to be quite large, none were encountered in the present survey. Lewis and Pring (1986) last reported the species from around the Rewa Delta area. However, we sampled only a few lower river reaches where this species is likely to occur and did not collect any.

### **Ichthyofaunal Representativeness for a Forest Reserve Network**

The following recommendations would strengthen the ability of a forest reserve network to help conserve Fiji's freshwater biodiversity:

- All major islands and island groups should be individually represented, specifically; Viti Levu, Vanua Levu, Taveuni, Kadavu, Mamanucas, Lomaiviti. This is substantiated with data for Viti Levu, Vanua Levu, and Taveuni where island level endemism is documented and presumed for the other major islands and island groups (Fig. 17).
- Taveuni Island should be represented by two provinces, roughly divided as NW and SE provinces which are characterized by distinct subsets of endemic ichthyofauna. The unique components of these provinces are described under PIA 1 and PIA 3.
- Vanua Levu should be represented by two provinces, roughly divided as Natewa Peninsula in the SE and the rest of Vanua Levu. Distinct ichthyofaunal characteristics are discussed under PIA 2, PIA 4, and PIA 6.
- Wherever possible, entire catchment areas including headwater, middle and terminal reaches (unobstructed by dams, wiers, etc.) should be included. For maximal conservation of biodiversity, choose the most densely forested middle-terminal reaches of the river system. The exception is when a PIA extends to the headwater reaches. Then, densely forested upper-middle reaches of the catchment should be selected.

- All Priority Ichthyofaunal Areas (PIAs) should be included in the network. PIAs are numbered in decreasing priority if decisions have to be made about non-inclusion of a PIA.
- When choosing between catchments on an island or between catchments on different islands, select the catchment or catchments that provide the higher level of ecosystem service.

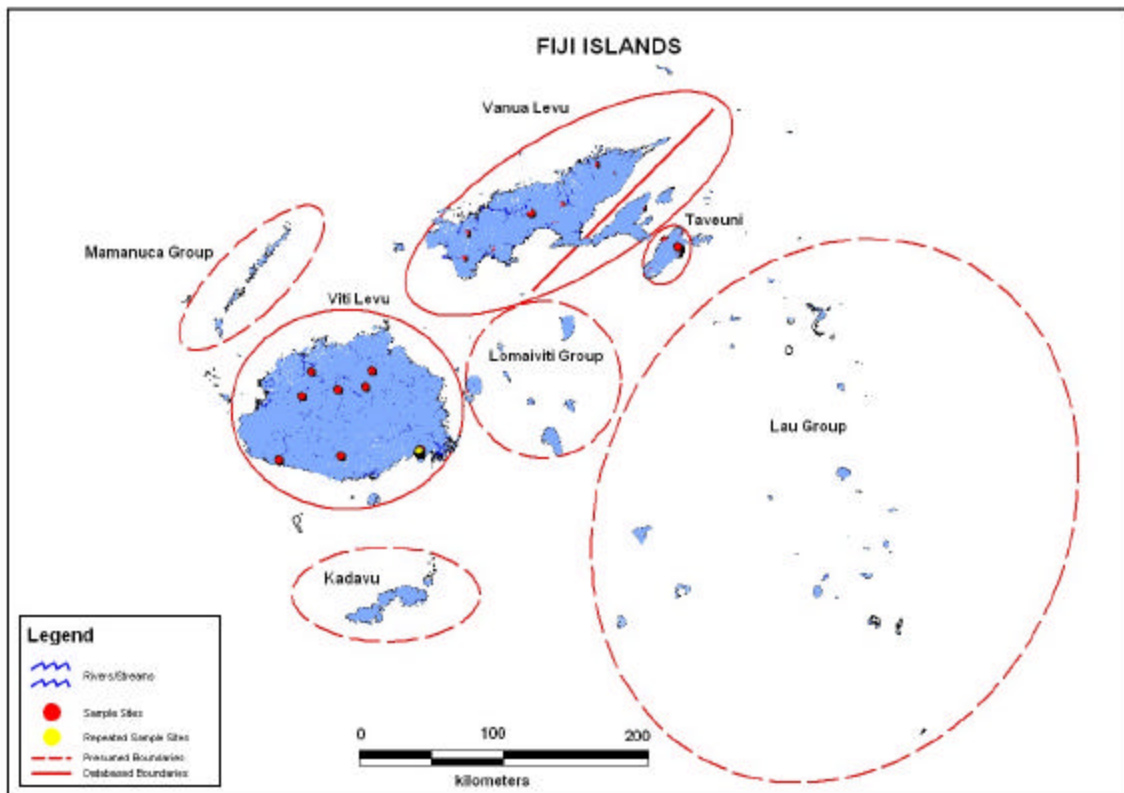


Figure 17. Proposed Ichthyofaunal Provinces for Fiji

## Study Limitations

One of the major limitations of this study was the short timeframe in which to build a broad picture of a virtually unstudied fauna. All of the headwater, middle and terminal reaches of the major catchments should certainly have been sampled more intensively. This sampling intensity was limited by time and equipment failure. The electrofishing apparatus was not working for much of the survey causing a few areas to be intensively sampled (Tamavua River system, Tavoro system) and many areas only to be only sampled by net. A number of large, obvious areas remain unknown for freshwater ichthyofauna such as the island of Kadavu (Appendix 5). With operational electrofishing equipment for the whole survey and a several years of systematic survey work our results may be different. This ichthyofaunal component of this study should be considered as a preliminary investigation using the available data and information to date. Our understanding of distributions and taxonomy will likely change as further investigations continue. None of Fiji's lakes or swamps has been adequately sampled. Southern *et al.* (1986) did a preliminary survey of Lake Tagimaucia but didn't collect any fishes. Several species are likely to exist in the swamps (e.g. Melimeli, lower Sigatoka) that have yet to be collected including the elusive presumed endemic genus *Lairdina*. A major determinant of accuracy in such a study is a good understanding of taxonomy for the target group. While we achieved a fair amount of taxonomic work and description, lifetimes of taxonomy work remains to be done that will certainly shift the lines of conservation priorities.

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## Appendix 1. List of Fishes Collected/Observed

\* endemic

+ new country record

# undescribed species

~ synonymized

Family	Genus	Species
<b>Carcharhinidae</b>	<i>Carcharhinus</i>	<i>leucas</i>
<b>Anguillidae</b>	<i>Anguilla</i>	<i>megastoma</i>
	<i>Anguilla</i>	<i>marmorata</i>
	<i>Anguilla</i>	<i>bicolor</i> +
<b>Moringuidae</b>	<i>Moringua</i>	<i>abbreviata</i>
<b>Muraenidae</b>	<i>Gymnothorax</i>	<i>polyuranodon</i>
<b>Ophichthidae</b>	<i>Lamnostoma</i>	<i>kampeni</i> -
	<i>Yirkala</i>	<i>gjellerupi</i> +
<b>Engraulidae</b>	<i>gen</i>	<i>sp</i>
<b>Hemiramphidae</b>	<i>Zenarchopterus</i>	<i>dispar</i>
<b>Belonidae</b>	<i>Strongylura</i>	<i>sp</i>
	<i>Microphis</i>	<i>argulus</i>
	<i>Microphis</i>	<i>liaspis</i>
	<i>Microphis</i>	<i>brachyurus</i>
	<i>Microphis</i>	<i>retzi</i>
	<i>Microphis</i>	<i>breviodorsalis</i>
<b>Tetrarogidae</b>	<i>Tetraroge</i>	<i>barbata</i> +
<b>Chandidae</b>	<i>Ambassis</i>	<i>vaivasensis</i> ~
	<i>Ambassis</i>	<i>urotaenia</i>
<b>Terapontidae</b>	<i>Terapon</i>	<i>jarbua</i>
	<i>Mesopristes</i>	<i>kneri</i> +
<b>Kuhliidae</b>	<i>Kuhlia</i>	<i>marginata</i>
	<i>Kuhlia</i>	<i>rupestris</i>
	<i>Kuhlia</i>	<i>munda</i>
<b>Apogonidae</b>	<i>Apogon</i>	<i>amboinensis</i>
	<i>Apogon</i>	<i>lateralis</i>
<b>Carangidae</b>	<i>Caranx</i>	<i>sexfasciatus</i>
	<i>Carangoides</i>	<i>sp.</i>
<b>Leiognathidae</b>	<i>Leiognathus</i>	<i>dussumieri</i>
	<i>Leiognathus</i>	<i>equulus</i>
	<i>Leiognathus</i>	<i>fasciatus</i>
<b>Gerriidae</b>	<i>Gerres</i>	<i>sp.</i>
<b>Haemulidae</b>	<i>Plectrorhincus</i>	<i>gibbosus</i>
<b>Lethrinidae</b>	<i>Lethrinis</i>	<i>harak</i>
<b>Mullidae</b>	<i>Upeneus</i>	<i>vittatus</i>
	<i>Parapeneus</i>	<i>indicus</i>
<b>Lutjanidae</b>	<i>Lutjanus</i>	<i>argentimaculatus</i>
	<i>Lutjanus</i>	<i>sp.</i>
	<i>Lutjanus</i>	<i>russelli</i>
	<i>Lutjanus</i>	<i>fulvus</i>
<b>Monodactylidae</b>	<i>Monodactylus</i>	<i>argenteus</i>

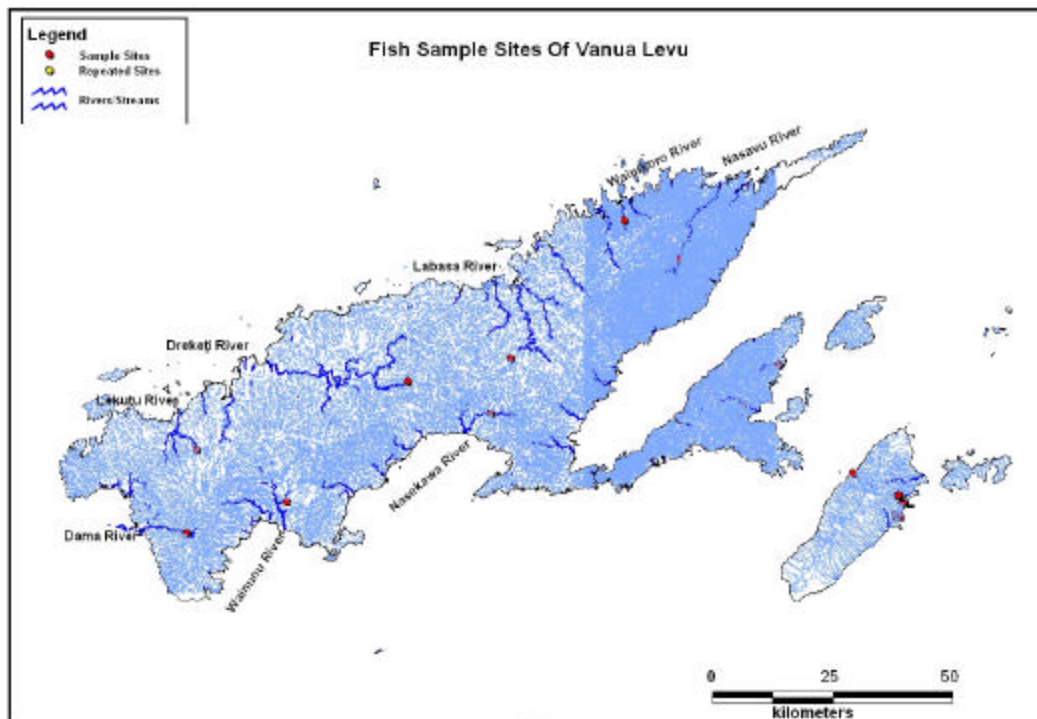
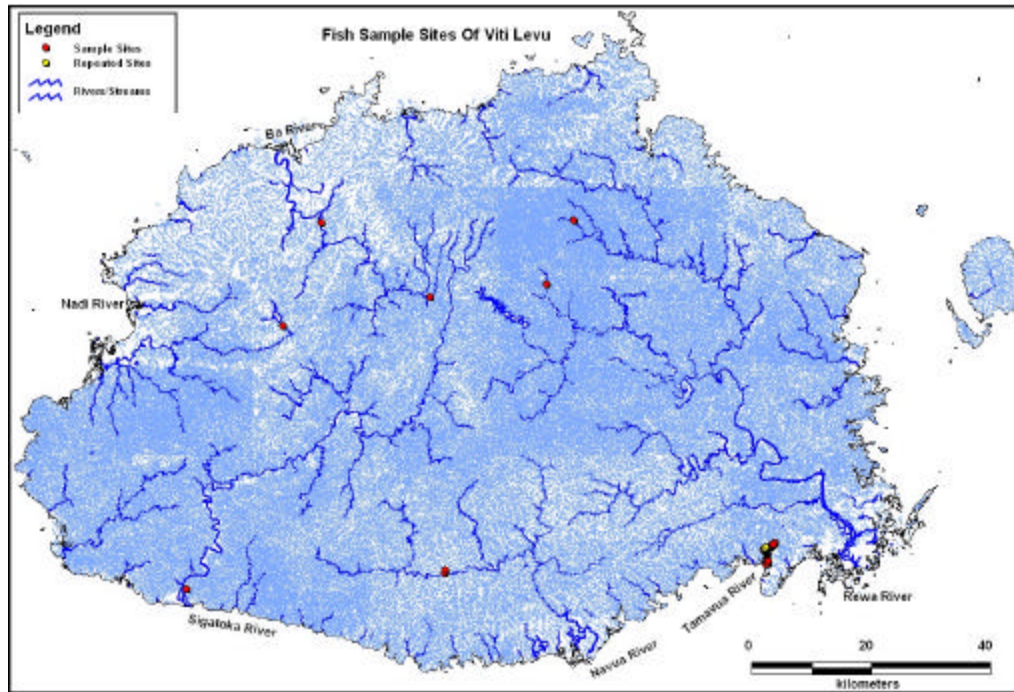


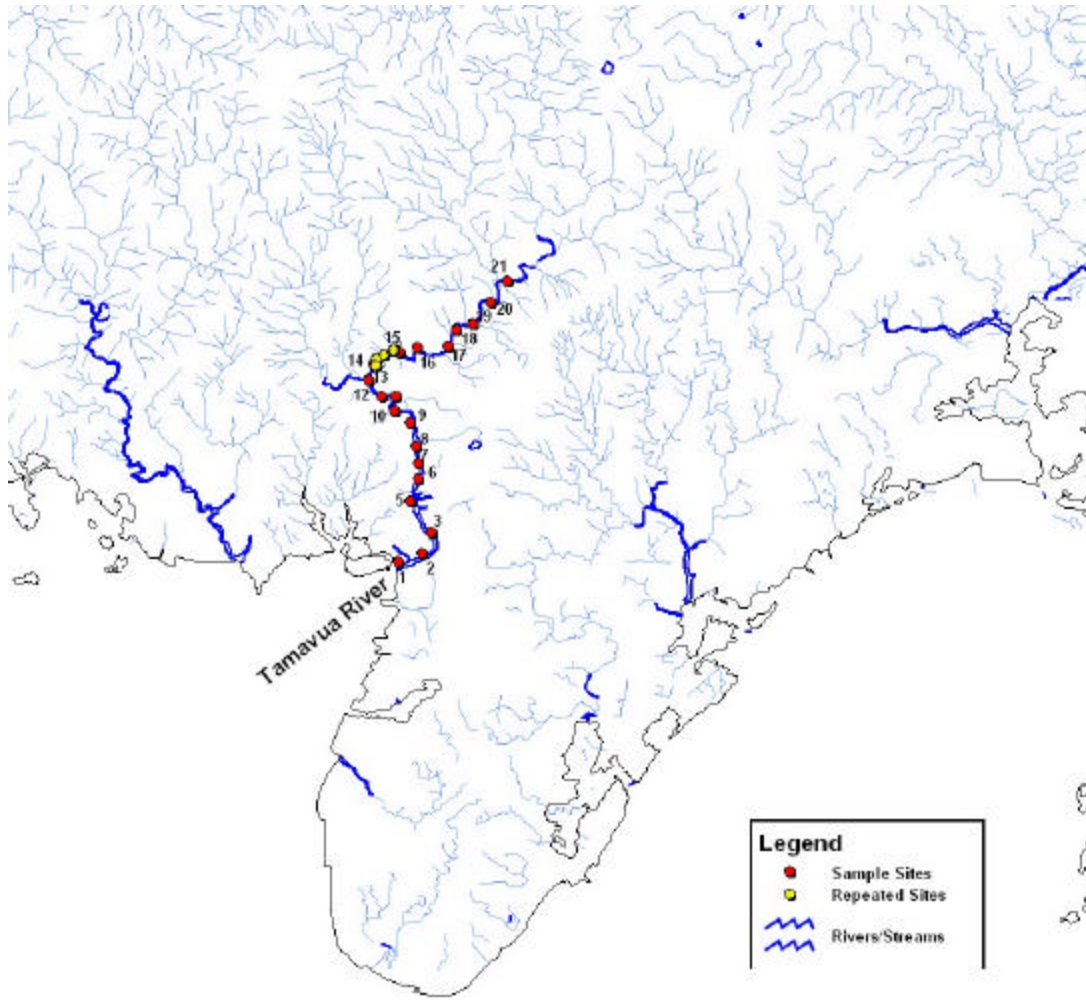
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<b>Scatophagidae</b>	<i>Scatophagus</i>	<i>argus</i>
<b>Mullidae</b>	<i>Liza</i>	<i>subviridis</i>
	<i>Mugil</i>	<i>cephalus</i>
<b>Sphyraenidae</b>	<i>Sphyraena</i>	<i>barracuda</i>
<b>Eleotridae</b>	<i>Bostrychus</i>	<i>sinensis</i>
	<i>Belobranchus</i>	<i>belobranchus+</i>
	<i>Eleotris</i>	<i>fuscus</i>
	<i>Eleotris</i>	<i>melanosoma</i>
	<i>Hypseleotris</i>	<i>guentheri</i>
	<i>Giurus</i>	<i>margaritaceus~</i>
	<i>Giurus</i>	<i>hoedti+</i>
	<i>Ophiocara</i>	<i>porocephala</i>
	<i>Bunaka</i>	<i>gyrinoides+</i>
<b>Gobiidae</b>	<i>Awaucos</i>	<i>ocellaris</i>
	<i>Stenogobius</i>	<i>genivittatus</i>
	<i>Glossogobius</i>	<i>n.sp+#</i>
	<i>Glossogobius</i>	<i>celebius</i>
	<i>Psammogobius</i>	<i>biocellatus+</i>
	<i>Schismatogobius</i>	<i>chrysonotus+*</i>
	<i>Periophthalmus</i>	<i>argentilineatus</i>
	<i>Stiphodon</i>	<i>rutilaureus+</i>
	<i>Stiphodon</i>	<i>semoni+</i>
	<i>Stiphodon</i>	<i>"birdsong" n.sp</i>
	<i>Sicyopterus</i>	<i>lagocephalus +</i>
	<i>Sicyopterus</i>	<i>micrurus</i>
	<i>Sicyopterus</i>	<i>n.sp#*+</i>
	<i>Lentipes</i>	<i>bellameyae n.sp*+#</i>
	<i>Sicyopus</i>	<i>zosterphorum</i>
	<i>Sicyopus</i>	<i>merielae n.sp*+#</i>
	<i>Redigobius</i>	<i>leptochilus+</i>
	<i>Redigobius</i>	<i>bikolanus+</i>
	<i>Redigobius</i>	<i>leveri* ~</i>
	<i>Redigobius</i>	<i>n.sp*+#</i>
<b>Siganidae</b>	<i>Siganus</i>	<i>vermiculatus</i>
<b>Tetraodontidae</b>	<i>Arothron</i>	<i>reticularis</i>
<b>Diodontidae</b>	<i>Diodon</i>	<i>liturosus</i>
<b>Poecilliidae</b>	<i>Gambusia</i>	<i>affinis</i>
	<i>Gambusia</i>	<i>holbrooki+</i>
<b>Cichlidae</b>	<i>Oreochromis</i>	<i>mossambicus</i>
	<i>Oreochromis</i>	<i>niloticus</i>
<b>Centrarchidae</b>	<i>Micropterus</i>	<i>salmoides</i>

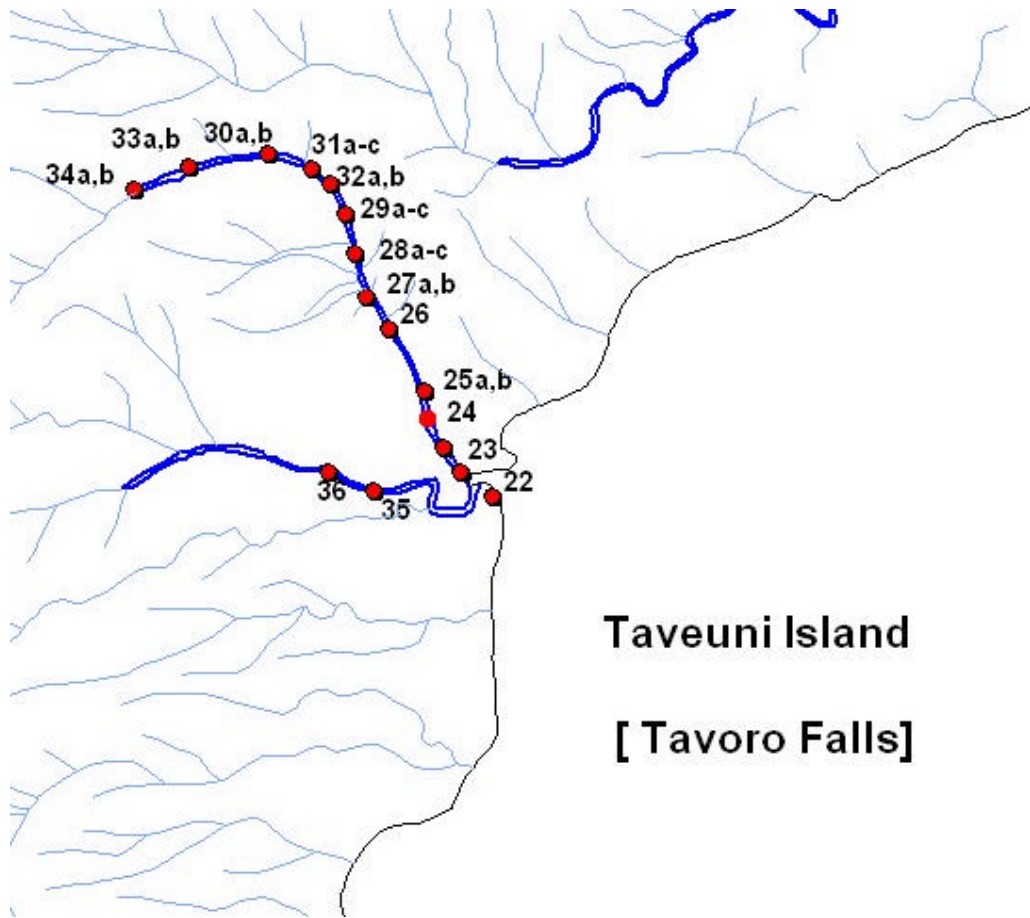
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## Appendix 2. Sample Sites for Freshwater Fishes in Fiji





Tamavua River, Savura Creek, Viti Levu



**Taveuni Island**  
**[ Tavoro Falls ]**