Soasoa Intergrated Watershed Management

RAPID ASSESSMENT REPORT

Prepared for The Pacific Community (SPC)

Eco-Pasifika Consulting

February, 20210

JBP
scientists
and engineers

Cover photos: Mid Soasoa Watershed system, Labasa, Fiji

Evaluation Team

- Patrick Sakiusa Fong
- Bindiya Rashni
- Lekima Copeland
- Alifereti Naikatini

Citation

Please cite as:

Fong, P. S., Rashni, B., Nand, Y and Rodger, D. 2021. Socio-ecological rapid assessment of the Soasoa watershed area. Prepared for the Fiji Global Climate Change Alliance Plus Scaling up Pacific Adaptation (GCCA+ SUPA) project, The Pacific Community (SPC), Suva, Fiji.

Eco-Pasifika Consulting
Dilkusha Road, Nausori, Fiji
PO Box 19335, Suva

Contents

1. Executive Summary

This report presents the findings of a rapid assessment that was conducted within the Soasoa watershed area, Labasa, Vanua Levu, Fiji. The rapid assessment included biodiversity, socio-economic and river cross section survey and is part of a list of activities to prepare an integrated watershed management plan for the Soasoa watershed area, and is part of the Global Climate Change Alliance Plus Scaling up Pacific Adaptation (GCCA+ SUPA) project. The Soasoa watershed area was identified through the project due to the frequent flooding that usually occur in the area during heavy rainfall, which usually affects the livelihood of communities in the watershed area. The goal of the Fiji GCCA SUPA project is to increase the resilience of vulnerable communities of Soasoa, Macuata province, in Fiji through comprehensive planning, and an integrated scaled up infrastructure and ecosystem-based adaption.

Freshwater fish

The estuarine reaches of the Soasoa River are characterized by indigenous fish assemblages, primarily marine migrants, estuarine migrants, and freshwater stragglers. These estuarine reaches meet the definition of natural habitats. Upstream of Site 1, the habitats are freshwater, and exotic fish species are the most abundant. Fish assemblages of the lower freshwater reaches include freshwater residents and catadromous species, and meet the definition of modified habitats due to habitat changes caused by invasive species and anthropogenic activities. An assessment of aquatic habitats determined that no legally protected areas, endemic species, or globally significant populations of congregatory species have been confirmed as being present in the Soasoa catchment area.

Freshwater macroinvertebrate

Freshwater macroinvertebrate biota were recorded from upper, mid and lower Soasoa catchment. Benthic macroinvertebrate (BMI) samples were collected across a total of five sites using kick-netting technique across multiple micro-habitat types to compile a list of suitable taxa present. A total of 48 unique taxa out of 850 individuals were recorded from the five sampling stations. Average taxon per site was calculated to be 17 individuals. BMI community structure comprised of insects representing 63% of the total taxa recorded while decapod crustaceans represented 19%, molluscs represented 17% and worms represented the minority; 2%.

A total of 20 macroinvertebrate taxa recorded were Unconfirmed Fiji Endemics (UFE) and represented 42% of the total taxa recorded while a total of six taxa (13%) were endemic to Fiji. Fijian endemics included the two caddisflies (Abacaria fijiana and Anisocentropus fijianus) and the endemic damselfly, Nesobasis spp. (genus endemic to Fiji), a water strider (Limnogonus buxtoni fijiensis), a water cricket (Hydropedecticus vitiensis) and the endemic spring snails Fluviopupa spp. The reason for such low endemic representatives is due to lack of morpho-molecular fusion oriented research on aerial adults and their associated aquatic larva/nymph/naiad and therefore majority taxa have been placed into the UFE category. Species of conservation significance were represented by two endemics; damselfly genus Nesobasis spp. (Family: Coenagrionidae) and the minute (3-5mm shell) freshwater spring snails (Fluviopupa spp.) of the family Tateidae. Both are bioindicator of good water quality and good forest and stream health. Both were recorded at the control sites in the headwater systems (Natobe stream, FW1 and FW2).

Invasives

There were 21 invasive plant species and thirteen invasive animal species recorded throughout the survey area. Invasive plants were readily observed in all areas surveyed, most abundantly in disturbed habitats such as roads, tracks, waterways, agricultural areas and near human habitation. The invasive animals recorded included birds, mammals and amphibians. The mammalian invasives were generally domesticated animals, such as pigs, cats and dogs which have become feral, as well as several species of invasive rodents.

Archaeology

The Greater Delaikoro Area is rich in historical and cultural material remains many of which were documented for the first time as part of this survey. Eleven sites were documented including house mounds, burial grounds (including skeletal remains), and fortification ditches.

Socioeconomic assessment

A socioeconomic assessment of eight villages was carried out using secondary data and reports together with key informant interviews. It was evident from this survey that the there is a lot of economic development in the area. Commercial agriculture is prevalent in the area and is a major thret to the sustainability of the watershed. The survey also reported community views on watershed management with the majority of stakeholders supporting the development of watershed management measures in the area.

Conclusion and reccomendation

The results of bioindicator-based ecological assessment of the five sites showed that 40% of the sites were categorized as ‘Moderate-degraded’ status and 60% of them as ‘Degraded’ status. From the site specific observations and quick discussion with the field guide, human pressures leading to ecological instability of the freshwater systems include, unsustainable logging occurring in the area closer to the headwater system, highly modified riparian vegetation, bank instability, soil erosion due to eroded banks, siltation, bank sugarcane farming, bank livestock grazing, use of weedicides and pesticides, grey water discharge and rubbish dumping in the waterways adjacent to households. The key socio-ecological issue was the lack of awareness on human pressures on the catchment utilization and mitigation measures.

Overall the survey findings support a recommendation for protection of the area. It is recommended that a capacity building workshop on community based biomonitoring and river resource mapping be conducted across targeted communities for production of a localized riverine community resource management and Soasoa catchment management plan as a whole. Also, ongoing community awareness programs are recommended to discuss the value of and the mechanisms for protecting the watershed area. Demarcating and managing management interventions should take into account ecological connectivity of habitats and the threats posed by agriculture and invasive species.

2. Introduction

The Soasoa watershed area has been identified as the project site for the Fiji's compoenent of the Global Climate Change Alliance Plus - Scaling up Pacific Adaptation (GCCA+ SUPA) project at the Pacific Community (SPC). The project is funded by the European Union with Euros 14.89 million and is implemented over the period 2019-2022, by the Pacific Community (SPC) in partnership with the Secretariat of the Pacific Regional Environment Programme (SPREP) and The University of the South Pacific (USP) and the government and people of Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Tonga and Tuvalu.

The overall objective of the Fiji component of the project is resilience of vulnerable coastal communities of Macuata province enhanced through comprehensive planning and scaled up infrastructure. The specific objective is the implementation of prioritised climate resilient flood control measures in the Soasoa watershed area. The three key result areas are:

- Development of a Soasoa watershed management plan (2020-2050);
- Preparation of a survey and detailed engineering design for the prioritised scaling up measures for the Soasoa drainage system;
- Implementation of the prioritised scaling up measures for the Soasoa drainage system.

The project is implemented by the Ministry of Waterways and Environment, in collaboration with the Ministry of Economy and coordination from SPC. The project is consistent with Fiji's National Adaptation Plan 2018, National Climate Change Policy 2018-2030 and 5-Year & 20-Year National Development Plan.

For the period 2- 6 November, 2020 a team from Eco-Pasifika Consulting carried out a rapid socioecological assessment in communities within the Soasoawatershed area to produce a baseline assessment of the biodiversity and socioeconomic settings. This biodiversity component of the assessment comprised the following taxonomic groups: freshwater fishes and macroinvertebrates. Invasive flora and fauna were also documented. As part of this baseline survey, parataxonomic training was also carried out to build capacity of two community members who were recruited as field guides and assistants. Additionally, a team carried out a study of the socioeconomic status of communities living in the Soasoa watershed area.

The information that were gathered from the rapid socioecological assessment will contribute to the achievement of the first key result area of the GCCA+SUPA project, which is the development of the Soasoa watershed management plan (2020-2050). The plan will guide the future management of the Soasoa catchment and drainage area over the time frame to 2050. Using this plan as a guide, the project aims to build resilience especially to coastal inundation and flooding through upgrading of coastal protection measures. Management interventions that will be developed by the plan likely include activities such as sustainable landuse practices, restoration of riparian buffer zones, proper waste disposal and management and riverbanks stabilization.

This report is a compilation of the rapid socioecological assessment and the various assessment components in the report will detail the methodologies used and respective findings.

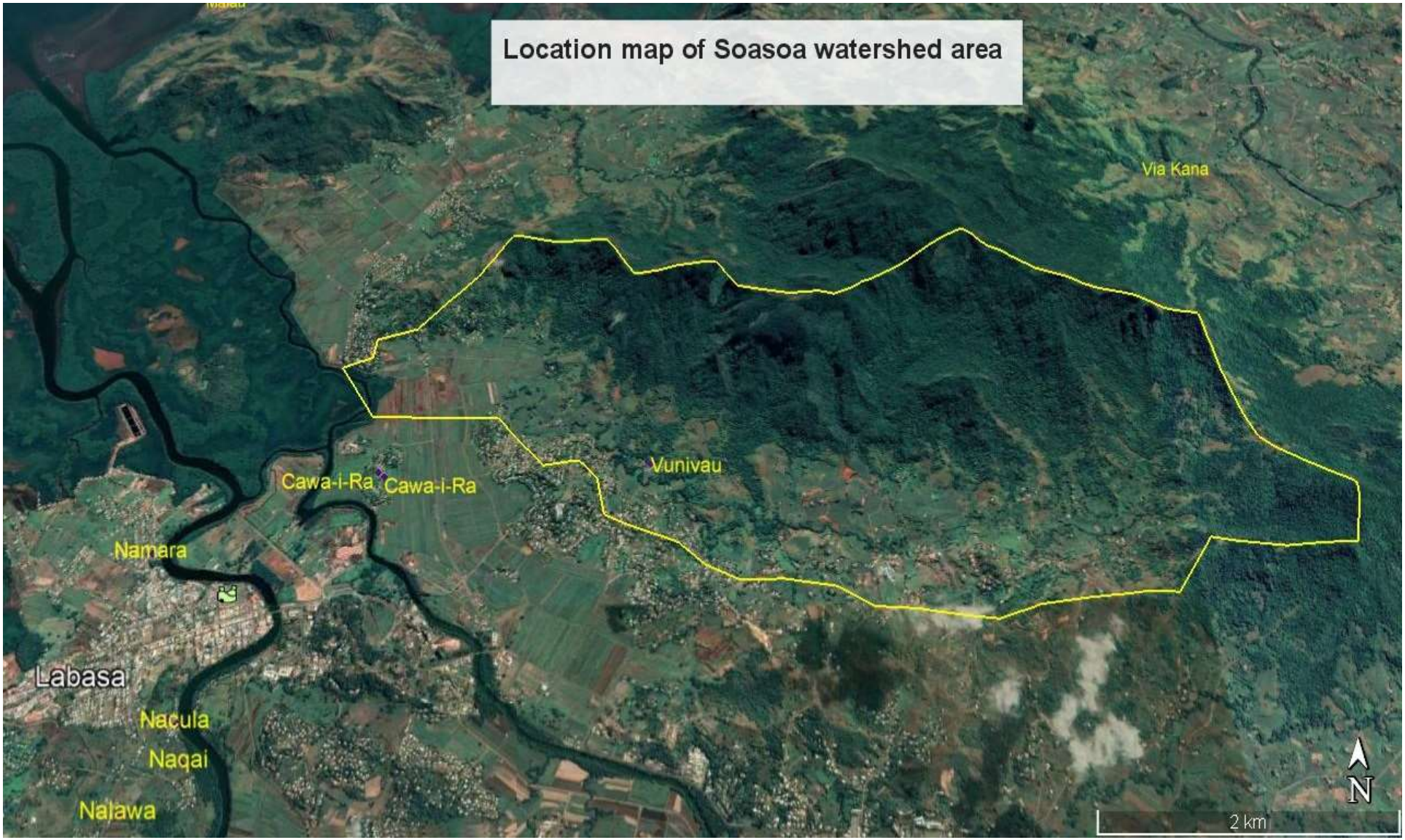


Figure 1: Location map of the Soasoa watershed area, Labasa, in Vanua Levu

3. Rapid Assessment Parameters

3.1 Freshwater fish

1. Introduction

Eco-Pacifica Consulting carried out a rapid baseline survey of aquatic fauna and habitat for the proposed Soasoa catchment flood mitigation project. The information gathered is intended to be incorporated into the overall Soasoa watershed management plan. The Soasoa Drainage Scheme was developed in 1978 by the then Labasa Drainage Board under the Land and Water Resources Management Division of the Ministry of Agriculture. It was designed to protect reclaimed land for sugarcane production through a levee (commonly referred to as seawall), outfall structures including floodgates, flap-gates and a drainage network.

The scheme has been maintained by government, as part of the average FJD 2-3 million national allocation each year for maintenance efforts. It scheme continues to perform its function however, it was designed for a maximum rainfall of 100 mm in 24 hours. The increased rainfall variability and rise in average sea level over recent decades has had profound impact on the infrastructure. The rising sea level has shortened the opening time for the flood and flap gates from 3 hours in 1980s to less than an hour in 2019. Moreover, there is a need to widen the current main drainage systems in the scheme to cater for higher peak flows during flood events. The current drainage dimensions are not able to cater for peak flows, often flooding homes, farms and the road, disrupting connection between Labasa Town and immediate areas past Soasoa.

2. Background and literature review

2.1 Important biodiversity areas

No legally protected areas occur within the Labasa River catchment. However, the lower tidal reaches of the Labasa and Qawa River include extensive areas of estuarine habitats dominated by mangroves. This area is natural habitat and is recognized for its high biodiversity values.

2.2 Fish

The freshwater fish of Fiji are not well-known; the taxonomy of several species remains in question, and new discoveries are likely in estuarine and headwater habitats. Of the 180 species currently recognized, 10 are introduced species and 151 species are indigenous, of which 5 are currently recognized as endemic (Copeland et al., 2015).

The freshwater fauna of tropical Pacific islands is characterized by the dominance of species that have widespread distributions across the Indo-Australian archipelago and the Pacific Ocean, are derived from marine species which have retained some tolerance of seawater, and species which have part of their life cycle in the sea (Jenkins et al 2011).

The majority of Fijian freshwater fish are amphidromous or catadromous. For amphidromous species, adults spawn in freshwater habitats, larvae are carried to marine habitats by river currents, and juveniles return to freshwater habitats. For catadromous species (e.g. *Anguilla* spp., eels), adults migrate to marine habitats and spawn, and juveniles return to freshwater habitats where they grow to maturity. Boseto (2006) lists 14 species that are restricted to freshwater habitats; thus of 89 freshwater fish species, 75 (84%) are obligatory migrants, and are reliant on access, in both upstream and downstream directions, between marine and freshwater habitats to complete their life cycles.

None of the indigenous freshwater fish recorded in Fiji are classified as threatened in the International Union for Conservation (IUCN) Red List. However, Fijian rivers, including the Labasa and Qawa River, are utilised by several shark species, including bull shark (*Carcharhinus leucas*) and one or more species of hammerhead shark (Sphyrna species), including the scalloped hammerhead (*Sphyrna lewini*), which is Critically Endangered.

3. Methodology

3.1 Water Quality Sampling

Water quality sampling was undertaken on Monday 2 November, 2020 by freshwater invertebrate specialist (Bindiya Rashni). Water physicochemistry was measured in-situ at each site using a calibrated Aqua-Read (AP 2000) multi-water quality meter (Figure 1). Parameters measured included temperature, dissolved oxygen (DO), conductivity, pH, and Total Dissolved Solids. At each sampling station the Aqua-Read probe was placed in the water for approximately three minutes to allow for stabilization before readings were taken. In-situ reading were recorded onsite and also stored in the Aqua-Read meter. These readings were later retrieved using the Aqualink AquaMeter Utility software.

3.2 Vertebrates

3.2.1 Fauna surveys – Estuarine reaches of the Soasoa River

In the lower reaches, where channel width, channel depth, and salinity are highest, the primary methods were the use of seine nets and creel survey. Drag-netting was also undertaken using an 8-metre seine net (4 × 4 millimetre mesh size) wherever the river was wadeable. As per Jenkins (2009), an 8-metre seine net was used for the first pass of each surveyed reach where channel depth and width allowed. This was dragged through the water by two people to capture fish in the main water column. Fish and other aquatic fauna were identified and released. Data derived from the field surveys was supplemented, whenever possible, by local knowledge and surveys of fish catch by local people.

3.2.2 Fauna surveys - Middle and upper reaches of the Soasoa River

Upstream of Soasoa floodgate, the Soasoa River and smaller inflowing waters were mostly wadeable and were surveyed using a 10-metre seine net, as described above, and “kick netting”, using a medium seine net (2 m × 1 m, 1.5 mm mesh). For this method, the net was set across the channel, one surveyor held the net, and the second surveyor disturbed the bed of the stream or river upstream of the net. Disturbed fish and invertebrates were carried by the current into the net. On vegetated banks, the medium seine net was also thrust under and through submerged vegetation, dislodging fauna into the net. At sites in the headwaters where water clarity was high, survey methods included visual observation surveys undertaken by mask and snorkel or by observation from the stream-bank.

Table 1 Water quality sampling coordinates in Soasoa catchment

Water Quality Sampling Station	Latitude	Longitude
Station 1	S 16°25.1351'	E 179°23.8211'
Station 2	S 16°25.4196'	E 179°24.1921'
Station 3	S 16°25.1309'	E 179°25.2136'
Station 4	S 16°24.8729'	E 179°26.4650'

Table 2 Sampling Coordinates for riverine fish in Soasoa Catchment

Fish Sampling Station	Latitude	Longitude
Station 1	-16.409938°	179.383446°
Station 2	-16.418776°	179.403123°
Station 3	-16.423561°	179.419980°
Station 4	-16.420981°	179.440188°

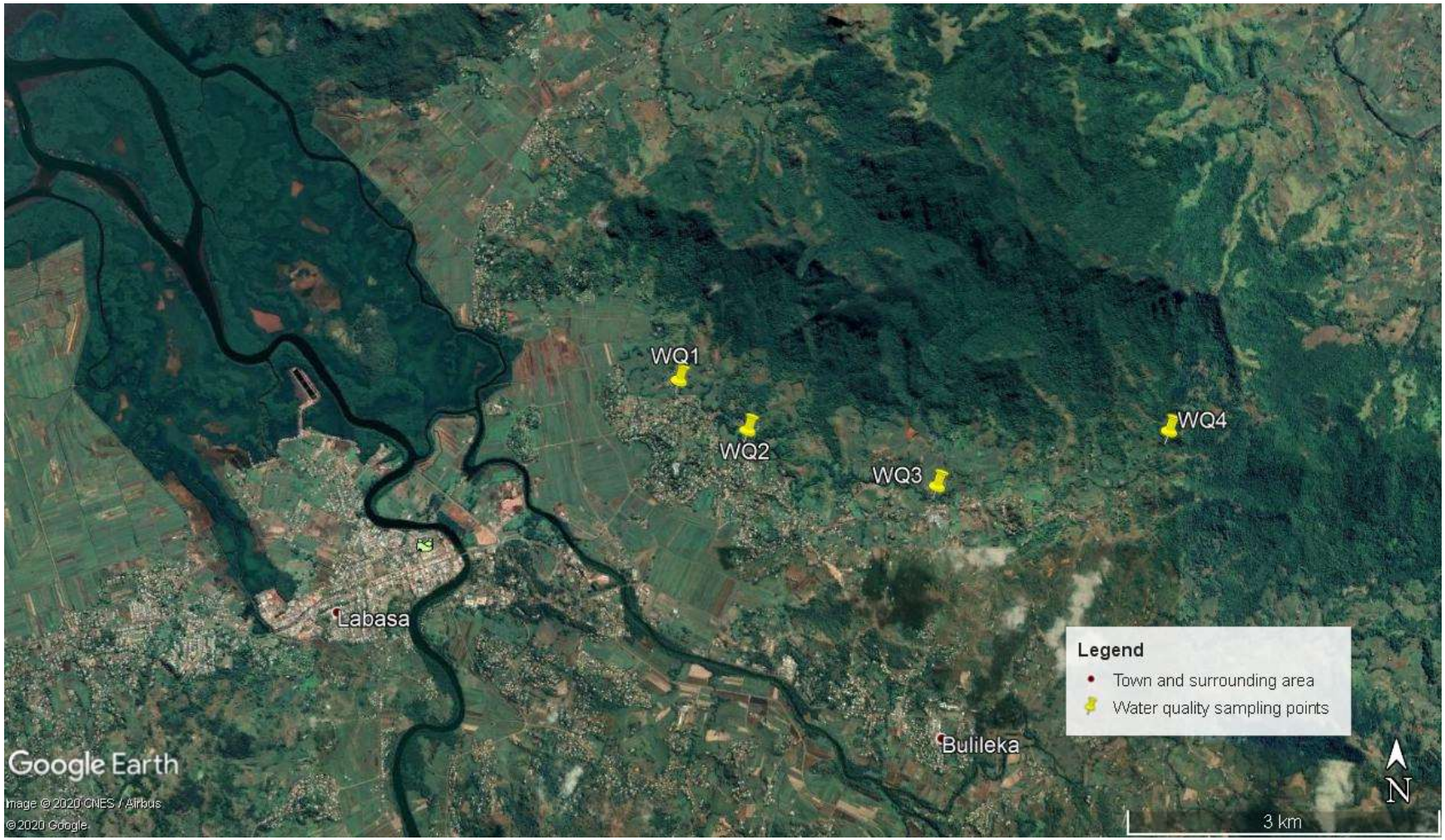


Figure 1 Water sampling locations in Soasoa catchment

Figure 2 Freshwater vertebrate sampling locations.

4. Results and Discussion

4.1 Water Quality

The physiochemistry of water fluctuates with the season and the time of the day at which measurements are taken. Water quality measurements were taken between 11 a.m. and 3 p.m. across the four sites, during the month of November. River temperature ranged from 25.9 °C to 27.3 °C across the four sites. Lower reach sites WQ1 and WQ2 recorded the highest temperatures (>27 °C) which is likely due to the time of the day and the low canopy cover at both sites.

pH readings at the four sites were relatively neutral. The highest pH value was recorded at WQ1 and the lowest was recorded at WQ2 (**Error! Reference source not found.**). D issolved oxygen concentrations were fairly high across the four sites and ranged from 8.07 – 8.96 mg/l. Conductivity reading (measure of total ions in water) was relatively low across the four sites. All four sites recorded reading of less than or equal to 0.02 uS/cm Total Dissolved Solids (TDS) was relatively low at all sites, with an average of 0.01 mg/L for all four sites combined.

Table 3 Water quality results at the four sites sampled in Soasoa

Station	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Electrical Conductivity (uS/cm)	Total Dissolved Solids (mg/L)
WQ1	27.1	7.37	8.07	0.0206	0.0133
WQ2	27.3	6.93	8.56	0.0216	0.014
WQ3	25.9	6.98	8.96	0.0208	0.0132
WQ4	26.1	6.96	8.78	0.0207	0.0134

4.2 Aquatic fauna

A total of ten species (nine families) were observed from the four sites (Table 4**Error! Reference source not found.**). No endemic fish was recorded in the catchment. The most abundant fish was the introduced mosquito fish (*Gambussa affinis*). Well over 100 mosquito fish was observed at Site 3. The remaining families were represented by one species each (Plate 1 to Plate 6). The introduced mosquito fish was nearly ubiquitous and was found in Sites 2, 3 and 4.The remaining ten species were represented by less than six individuals each.

Table 4 Checklist of aquatic fauna observed in Soasoa catchment

Family and Species	S1	S2	S3	S4
Anguillidae				
Anguilla marmorata		x	x	
Cichilidae				
Oreochromis niloticus	x	x	x	
Gobiidae				
Periopthalmus argetimaculatus	X			
Poecillidae				
Gambussa affinis		x	x	x
Lutjanidae				
Lutjanus argentimaculatus	x			
Lutjanus ruselli	x			
Mugilidae				
Mugil cephalus	x			
Terapontidae				
Terapon jarbua	x			
Portunidae				
Scylla serrata	x			
Palaemonidae				
Macrobrachium lar			x	X

Plate 1 Macrobrachium lar

Plate 2 Anguilla marmorata

Plate 3 Lutjanus argentimaculatus

Plate 4 Oreochromis niloticus

Plate 5 Terapon jarbua

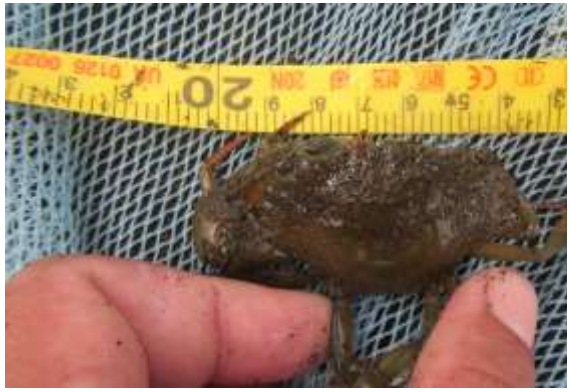


Plate 6 Scylla serata

4.3 Aquatic habitats

4.3.1 Lower tidal reaches and river mouth (Site 1)

The Soasoa River empties into the Qawa River, about 6 km from the mouth of the Qawa River. Together with the Wailevu and Labasa River, these three form a delta on which the town of Labasa stands. The Qawa and the Labasa River are connected by an 8 kilometer canal which helps drain the fertile Labasa plains and adjacent foothills (Gray, 1989). The Qawa River has a catchment area of approximately 126 km^2 and is about 33.5 km long (Yeo, 2001). Together with the Labasa River, they are host to one of the five largest stands of mangroves in Fiji (Gray, 1989). Site 1 is mostly a deep shallow run of 0.5 to 1 meter with an average wetted width of 4 meters.

Plate 7 Lower tidal reaches and flood plain of the Soasoa River.

4.3.2 Lower freshwater reaches of the Soasoa River (Site 2 and 3)

The lower freshwater reaches of the Soasoa River flow predominantly through agricultural land, with extensive sugar cane plantations. The area is mostly used for residential and agricultural purposes. However, we do note that is an active hard rock quarry occurring around Site 3.

In the lower freshwater reaches (from Site 2 to Site 1), the river again has a more meandering path. The wetted width of the river averages about 3 metres, with a range of 1 to 4 metres. Water depth averages 0.2-0.3 metres in riffles and 0.2-0.4 metres in run (Plate 8). Narrow sand and gravel bars are frequently found on inside bends, and, along with mid-channel deposits of sands and gravels, cause restrictions for the water flow,

creating riffle sections and pools. Occasional outcrops of soft bedrock occur midstream, with associated riffles. The river bed mainly consists of gravels and cobbles, with deposits of finer sands and silts in slower runs and backwaters. The banks along this section are, for the most part, have been heavily cleared, with localised areas of active bank erosion.

Plate 8 Soasoa river upstream of flood gate

4.3.3 Upper Catchment

At the upmost site of the sampling on the Soasao River (Site 4), the width of the channel is approximately 4 meters, with a wetted width of 1 meter in the dry season (Plate 9). Most of the river habitat comprised runs (60%), along with riffles (35%) and pools (5%). The average water depth was 0.2 meters, and the substrate is mostly bedrock, boulders, with smaller proportions of sands, and silts.

Plate 9 Site four upper Soasoa catchment

3.2 Freshwater macroinvertebrates

1. Introduction

This section of the report documents the benthic freshwater macroinvertebrate community composition, their status and distribution within the waterways and bioindicator taxa of the waterways draining the proposed systems of the Soasoa catchment within the Macuata province of the Vanua Levu island of Fiji.

The Fijian freshwater benthic macroinvertebrate fauna is represented by seven Phyla and approximately 62 Families (Mangubhai *et al.* 2019), that include Insecta (40 families), Crustacea (4 families), Mollusca (9 families), Nemotoda (2 families), Annelida (3 families), Platyhelminthes (1 family), Nematomorpha (1 family) and Porifera (2 families) (Rashni 2018). Many taxa are yet to be fully described to genus and species level and many aquatic insect larvae have not been matched with their described terrestrial aerial adults. Prior to this study, little was known about the composition of macroinvertebrate communities within the waterways of interest to this study.

The current baseline study was conducted to provide a comprehensive checklist of freshwater macroinvertebrate biota, their status and distribution within the waterways draining the upper, mid and lower Soasoa catchment areas.

2. Methodology

2.1 Habitat and faunal sampling

Figure 1 shows the five (FW1-FW5) sampling sites covered for biological assessment of inland lotic freshwater systems of the proposed Soasoa catchment.

Figure 3: Sampling sites for freshwater macroinvertebrate biota assessment

2.2 Freshwater macroinvertebrate Fauna

2.2.1 Macroinvertebrates

Macroinvertebrate samples were collected across a total of five sites (Table 1) using kick-netting technique to allow an assessment of macroinvertebrate community composition across multiple micro-habitat types within varying freshwater bodies to compile a list of suitable taxa representative of waterways draining the Soasoa catchment.

Sorting and identification

Macroinvertebrate samples were sorted and identified. The guides used in the process included; Choy (1983;1984; 1991), Haynes and Rashni (2016; *Unpublished*), Haynes (2009), Williams (1980) Polhemus *et al*. (2006) and Winterbourn *et al*. (2006). Freshwater crustaceans were identified by Laura Williams-Chan (Crustacean specialist)[1]. Site survey map and eco-status map was produced by Manoa Maiwaqa (GIS programme student at USP).

2.3 Data analysis and presentation of data

(i) *BMI taxa summary* – the contribution that each taxon made to the higher taxonomic groups was calculated and presented as counts and percentage.

(ii) *Taxa richness* – the total number of taxa recorded for each site was calculated and presented in a table.

(iii) *Status & distribution of taxa* – presents a summary of origin of taxa, i.e. whether they were endemic to Fiji, native to other regions (e.g., Pacific, South Pacific, Indo-Pacific, Fiji-Australia, South East Asia), introduced tropical species or unknown.

(iv) *BMI Taxa checklist*- presents a site level tabulated data on taxa, status, common name, abundance and color-coded bioindicator taxa.

3. Results

3.1 Sampling stations

Table 1 provides a general description of the five sampling stations (Figure 2) sampled across targeted Soasoa catchment waterways.

Table 5: Sites surveyed and sampling techniques used across the Soasoa catchment

Area	Stream	Freshwater body type	Site Code	Description	Survey type
Soasoa	Natobe tributary 1	Lotic	FW1	Control site	MK
Soasoa	Natobe tributary 2	Lotic	FW2	Control site	MK
Soasoa	Nasavu	Lotic	FW3	Stream receiving water from a quarry site amidst human settlement	MK
Vunivau	Nasavu	Lotic	FW4	Below bridge amidst sugarcane farm	MK
Vunivau	Nasavu	Lotic	FW5	Amidst human settlement with sugarcane bank farming & bank livestock grazing	MK

Key: MK= Multiple habitat Kick-netting

[1] School of Marine Studies, University of the South Pacific

Figure 4: Sampling stations showing aquatic and riparian habitat characteristics

FW1

FW2

FW3

FW4

FW5

3.2 Macroinvertebrates

3.2.1 Benthic Macroinvertebrate taxa summary

A total of 48 benthic macroinvertebrate taxa out of 850 individuals were recorded from the five sampling stations (Table 2). Insects represented 63% of the total taxa recorded while decapod crustaceans represented 19% followed molluscs (17%) and worms represented the minority (2%).

Table 6: Number of macroinvertebrate taxa recorded per group across sites

Higher taxonomic group	Order / Class	Common name	Number	Count	%
Insecta	Trichoptera	caddisfly	11		
	Ephemeroptera	mayfly	3		
	Lepidoptera	moth	3		
	Diptera	true-fly	2		
	Zygoptera	damselfly	2		
	Anisoptera	dragonfly	1		
	Coleoptera	beetle	2		
	Hemiptera	water bug	5		
	Orthoptera	water cricket	1	30	63
	Caridea	shrimp	7		
	Palaemonid	prawn	1		
	Varunid	crab	1	9	19
Mollusca	Gastropoda	snails	8	8	17
Annelida	Oligochaeta	worms	1	1	2
			Total	48	100

3.2.2 BMI Taxa richness

A total of 48 taxa were recorded across five sampling stations. Average taxon per site was calculated to be 17 individuals. Taxa richness ranged from a total of 11 taxa at sites FW4 and FW5 (Nasavu stream stations in Vunivau area) to 25 taxa at the Nasavu stream station in Soasoa area (FW3) (Figure 4). The ‘angler's curse’ mayflies (*Caenis* sp.) represented the most number of taxa (38% of total number of taxa, i.e. 75 out of 200 individuals) at FW3 (Table 5).

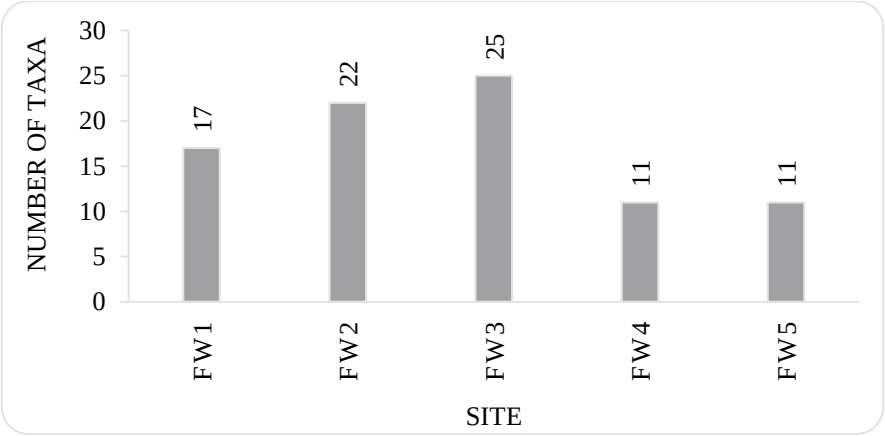


Figure 5: Taxa richness across sites surveyed

Total abundance of BMI taxa ranged from 69 individuals (FW5) to 278 individuals (FW4) (Table 5). Abundance data across sites are not directly comparable in the case of the current survey as a semi-qualitative sampling technique across the available micro-habitats per site was applied. However, abundance of the bioindicator species hold high importance as their presence/absence depends on the availability of micro-habitat type. For example, in the control site (FW2), the endemic spring snail (*fluviopupa* spp.) were present due to the bedrock system supported by excellent water quality, intact riparian vegetation, highly stable banks, leaf litter and absence of eroded banks or silted streambed. They were completely absent in the agriculturally impacted sites (FW3-FW5) supported by physical habitat characteristics such as highly modified riparian zone, eroded bank, algal covered and silted streambed substrates, bank livestock grazing and household rubbish clogs (Figure 3 a-d).

3.2.3 Status & distribution

A total of 20 macroinvertebrate taxa recorded were Unconfirmed Fiji Endemics (UFE) and represented 42% of the total taxa recorded (Figure 5). The next most common group were those Native to Pacific (i.e. 31%). A total of 6 macroinvertebrate taxa (i.e. 13%) identified to lowest taxonomic level possible were endemic to the Fijian Islands. These include the two caddisflies (*Abacaria fijiana* and *Anisocentropus fijianus*) and the endemic damselfly, *Nesobasis* spp. (genus endemic to Fiji), a water strider (*Limnogonus buxtoni fijiensis*), a water cricket (*Hydropedecticus vitiensis*) and the endemic spring snails *Fluviopupa* spp.

The reason for low endemic representatives is due to lack of scientific research on Fijian freshwater invertebrates, preventing the official confirmation of the status of many freshwater macroinvertebrates that has only been identified to genus level and yet to be matched with their respective adults (morpho-molecular fusion) to confirm their species name. Hence many macroinvertebrates identified to family/genus level only (eg. Odontoceridae, Hydrophilidae, *Baetis* sp. *Caenis* sp., and *Nymphicula* sp.) are unofficially known to be endemic to Fiji but has been placed in the UFE status as of present; which in this survey represented the highest (42%) of the total taxa recorded.

The dragonfly naiads of families (Lestidae and Libeluliidae), gastropods (*Melanoides arthurii*, *Thiara Terpsichore, Physastra nasuta*, *Ferrissia noumeensis* and *Physastra nasuta*) and the remaining crustaceans (caridean shrimps) and a crab (*Varuna litterata*) were native to the Pacific region (31%). One thiarid gastropod, the Malaysian trumpet snail/red-rimmed melania (*Melanoides tuberculata*) was an introduced tropical species (2%). Unknowns (2%) comprised a prawn (*Macrobrachium* sp.).

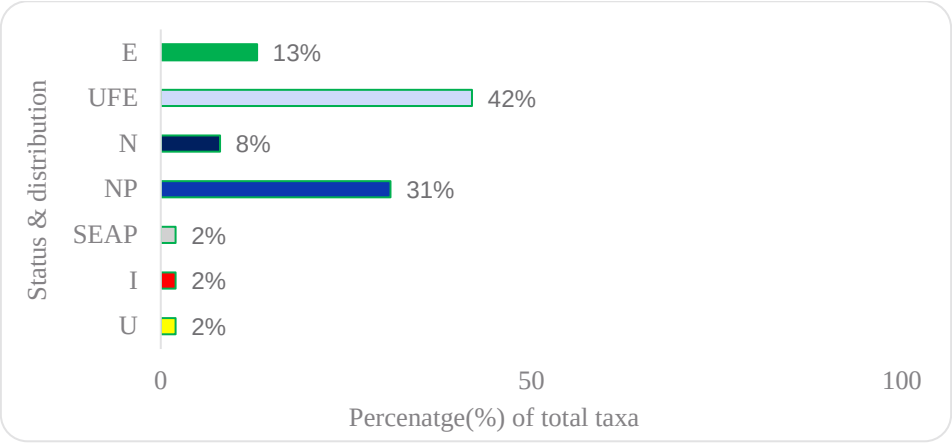


Figure 6: Status and distribution of taxa recorded across all sites

The endemic spring snails (Fluviopupa spp.) were only recorded from the control site, Natobe stream (FW2:26 individuals). The presence of the endemic spring snails indicated excellent water quality and good forest system supporting the headwaters (Figure 7).

3.3 Taxa of conservation significance

Two taxa of conservation significance were identified from the macroinvertebrate community composition recorded across the five lotic systems draining the Soasoa catchment systems. These taxa as per dissecting microscopy view are discussed in Figure 6.

Figure 7: Taxa of ecological significance

Freshwater Macroinvertebrate Taxa of Interest	Picture	Taxa	Brief details
		*Nesobasis* spp. size:12mm long	Coenagrionidae is a family of damselflies widely distributed in the Melanesia and Fiji has its endemic genus, *Nesobasis* with 21 described aerial adult species. The naiad example presented here cannot be placed into a species level as only the adults have been described so far from Fiji. *Nesobasis* species radiation is yet to be explored for Fijian archipelago including Vanua Levu at an island level. Natobe stream system has not previously been sampled for this group especially the terrains supporting FW1 & FW2) system which are the control sites for the Soasoa catchment. Many naiads collected and observed during the survey cannot be placed into species level without morpho-molecular fusion with the aerial adult community composition.
		*Fluviopupa* spp. size: 3-5mm long	Freshwater Spring snails or rissoodean snails belong to the family Tateidae (former family Hydrobiidae) with a single genus, *Fluviopupa*, present in the Melanesian archipelago (Haase *et al.* 2006). Fiji holds a record of 28 endemic *Fluviopupa* species, majorly area endemics (Zilke and Haase, 2017). The *Fluviopupa* spp. collected from the control site (FW2), Natobe stream system headwaters are potentially new species as the spring snails are known to evolve in the headwaters of catchments and usually catchment endemic. Freshwater spring snails are bioindicators of excellent water quality.

3.3 Invasive Species

1. Introduction

Invasive alien species are described in the context of the Convention on Biological Diversity as "alien species whose introduction and/or spread threaten biological diversity" (CBD, 2002). The Millennium Ecosystem Assessment (UNEP, 2005) confirms that invasive alien species have been a significant driver of biodiversity loss over the last century, and forecasts that this trend will continue or increase in all biomes across the globe. Island ecosystems like those in the Pacific are particular vulnerable to the impact of invasive alien species (CBD, 2003).

The list of plant invasives in Fiji (Meyer, 2000) is currently composed of 52 species, classified under three groups according to their degree of invasiveness, namely: 13 dominant invaders, 17 medium invaders and 22 potential invaders).

Pernetta and Watling (1978) compiled a list of introduced vertebrates in Fiji which includes most of the globally common invasive species such as rats, mongooses and the Indian mynah. Fiji has, however, successfully prevented the entry of the giant African snail and the brown tree snake, which have had devastating impacts on other islands in the Pacific (Sherley, 2000).

Invasive species management in Fiji has focused for the most part on control methods; physical, biological and chemical. A few eradication programmes have been implemented on small islands, for example Vatu-i-Ra, where the Pacific rat (*Rattus exulans*) was successfully eradicated to protect seabirds (Seniloli *et al.*, 2011). Whilst eradication programmes are feasible for small isolated islands, it is not a realistic approach for widespread plant and animal invasives in larger areas on the bigger islands.

This invasive species survey was conducted as part of a rapid biodiversity assessment of sites within the Soasoa watershed area, as part of the development of the Soasoa Intergrated Watershed Management Plan.

2. Methodology

A checklist of invasive plant species was compiled based on observations at five areas surveyed, which included the upper, mid and lower sections of the Soasoa watershed area. The survey team started from the Soasoa levee area and move inland towards the upper Soasoa watershed, making records of invasive plant species encountered in the five stations that were visible from the road. Both direct sightings as well as indirect observations (scat, chewing marks etc.) were recorded. Where reports were based on indirect observations identification to species level could not be reliably made, the list indicates the possible species (“cf.”). Invertebrate invasive species (such as agricultural insect pests) were not recorded.

3. Results

Invasive plant species were readily observed in all areas surveyed, and as anticipated were most abundant in disturbed habitats such as roads, tracks, waterways, agricultural areas and near human habitation. The checklist comprised 21 species (Appendix 18), including most of the dominant and moderate invaders listed by Meyer (2000).

The distribution of some of the most common invasive species along the altitudinal gradient on the upper Soasoa watershed area is shown in Figure 31. A greater variety of invasive species were observed in the lower and mid-section of the watershed, nearer to human habitation and agricultural land.

The giant reed, *Arundo donax*, was very common sight, not only along the main Soasoa river system (Figure 32), but also along other tibutires. In areas where there was still or slow-moving water, such as ponds and ditches, the presence of water hyacinth (*Eichornia crassipes*) was noted (Figure 33).

Merremia peltata was one of the most highly visible invasive species and dominated, not just as a blanketing climber over shrubs and trees, but also spreading out over the feeder roads itself (Figure 34). *Clidemia hirta*, a very common shrub species, was less noticeable at the lower altitudes but became more visible as *Merremia* became less dominant at higher altitudes (Figure 35).

Dissotis rotundifolia, classified as potentially invasive (Meyer, 2000), was recorded in great abundance along most of the track, even at higher altitudes. Since it was flowering, the African tulip was visible at long distances, and was observed not just near the roadside but also penetrating into forest in the upper Soasoa watershed.

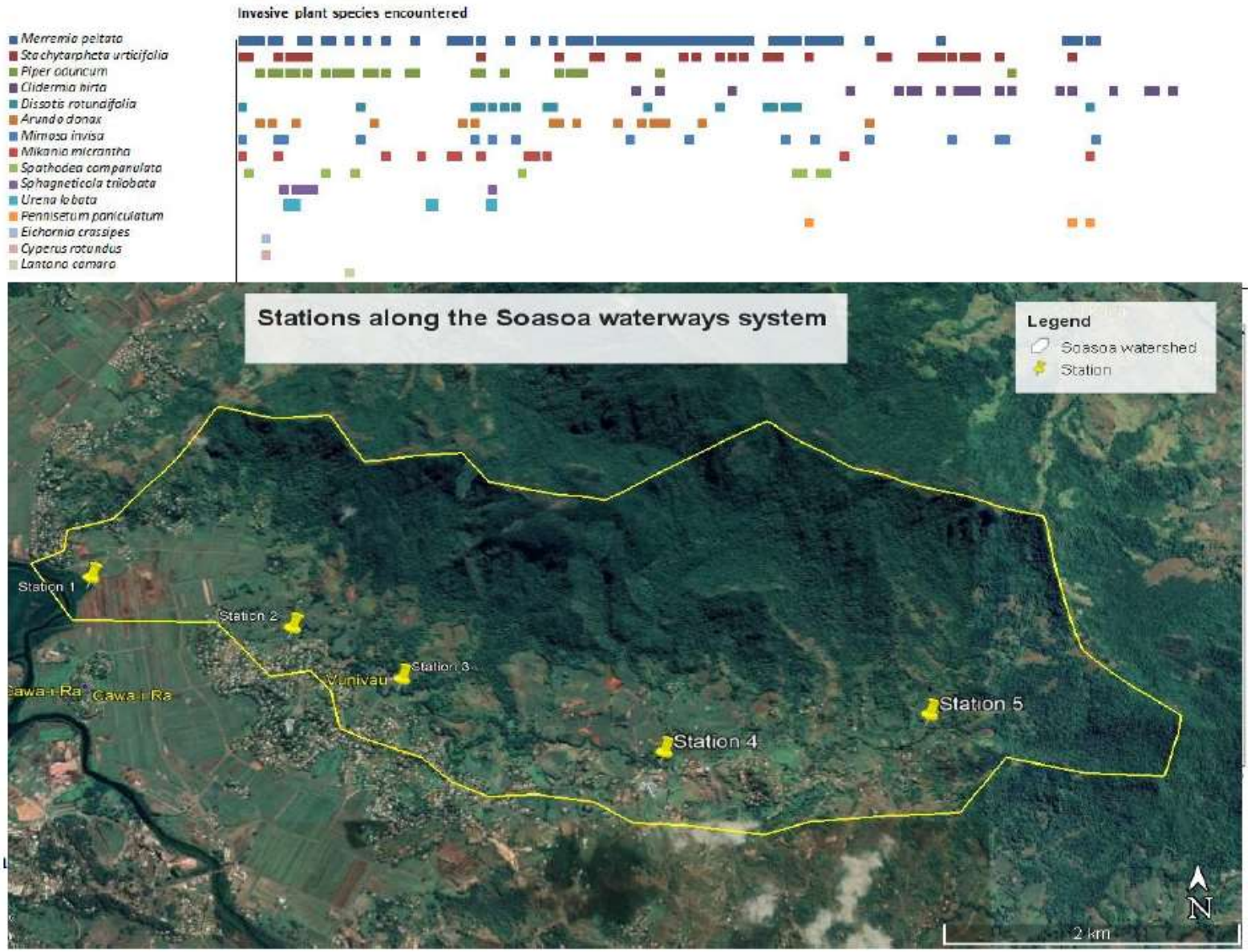


Figure 3: Observation stations along the Soasoa river system

Figure 32: The giant reed, *Arundo donax*, was found along waterways

Figure 33: Water hyacinth, *Eichornia crassipes*, was found in areas of still or slow-moving water.

Figure 34: Catchment is dominated by *Merremia peltata*

Figure 36: *Merremia peltata* growing with an African tulip tree, *Spathodea campanulata*, growing in the upper Soasoa area

Figure 37: Tooth marks made by rats indicated by the arrow on this guava fruit, located in the upper Soasoa watershed area.

The checklist of invasive animal species is given in Appendix 19, and comprises birds, mammals and an amphibian. The mammalian invasives are generally domesticated animals, such as pigs, cats and dogs which have become feral, as well as several species of invasive rodents (mice, rats and mongooses). Evidence of the presence of rats was found in the upper Soasoa watershed area. Here, pandanus fruits were found with tooth markings characteristic of rats (Figure 37).

The invasive bird species, the bulbul and the mynah, were observed throughout the Soasoa watershed system.

3.4 Socioeconomic baseline study

Introduction

The Soasoa watershed has been identified through the GCCA project at SPC to be critical for climate resilience due to the frequent flooding that usually occur in the area. Located approximately 2 kilometers on the northeastern part of Labasa town, Soasoa consists of the following communities; Vunivau village, Namako Settlement, Nubunivonu Settlement, Soasoa Settlement, Valebasoga Settlement, Vuiva Settlement and Vanuavou settlement. The importance of the Soasoa watershed has resulted in the provincial governance of Macuata Province recognising it as an area that is very susceptible to natural disasters, especially flooding.

To protect Fiji's watershed, especially in areas of close to urban centers with high risk of flooding, the creation of watershed management measures is of critical importance. However, natural and physical science perspectives on watershed sustainability need to incorporate social science, especially human behaviours and aspirations. This is important given that human behaviour and aspirations in watershed sustainability context are the main threats and have proven to be the drivers of watershed degradation and natural resource overexploitation. Also, understanding the socioeconomic baseline of the Soasoa watershed, together with the interplays of socio-political system in the area are important information be incorporated into the quest to develop the Soasoa Watershed Management Plan. Unless this Plan incorporates socioeconomic parameters and be tailor-made to align with community livelihood needs and socio-political system, the Soasoa Watershed Management Plan is most likely to fail or be unsustainable in the long term.

This section of the report provides an overview of the socioeconomic baseline of Soasoa watershed area and it discusses in detail information such as the demographic setup, landuse practices, governance and policy analysis, livelihood and economic development.

Objectives

The main objective of the rapid assessment was to obtain basic information for better understanding the current socio-economic status of communities in the Soasoa watershed, landuse systems, perception on flood risks and watershed management as a basis to identify the entry points for the introduction of sustainable watershed management strategies and to enhance the livelihood and climate resilience in the target communities.

The general socioeconomic parameters that the survey aimed to collect include:

- Socioeconomic characteristics of household
- Livelihood sources and income generating activities
- Landuse and resource use pattern
- Land tenure system
- Governance and policy analysis
- Development programs and infrastructure facilities
- Gender and social inclusion issues

Methodology

The socio-economic baseline report draws information from a number of key sources. Data were collected via desktop research and by conducting interviews with key informants and community consultations. The secondary data are from from the Fiji Bureau of Statistics 2017 National Census and previous reports.

The primary data were gathered through one-on-one interview with key community representatives in the Soasoa watershed area and through the community consultations that was conducted for the period 26- 30 October, 2020. conducted from 2011 to 2013.

Data Limitation

The key limitations to this socioeconomic assessment relate to the quality and extent of available information. This socioeconomic assessment relies on the most recent reports and statistical information available at the time of writing. For some indicators, the analysis has relied on information from the Fiji Bureau of Statistics 2017 National Census, which may not accurately reflect more recent social and economic conditions. However, this information remains the best available source at the time of writing. Interviews with key informants supplemented the available statistical data, helped confirm understandings of existing conditions, and provided insight into local issues and trends. Reasonable efforts were made to cross-check and triangulate information from different sources to confirm accuracy. Deficiencies in the existing information are noted where they may influence the conclusions of the analysis

Results

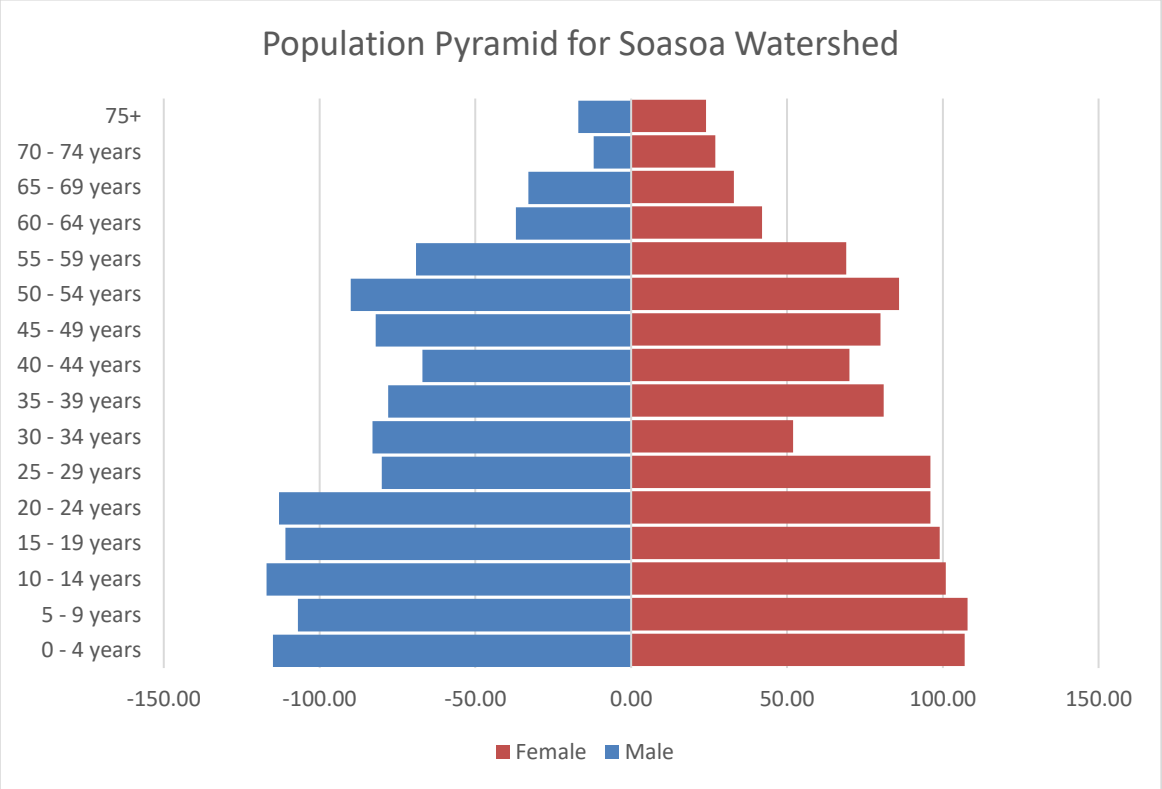
Demographic

The total population in the Soasoa watershed area is 2382. Given that the total household is 543, the average household size is 4. This shows that the majority of the households are small, implying a trend of mostly nuclear family.

The table below details the breakdown of the population in the Soasoa watershed area by communities and sex.

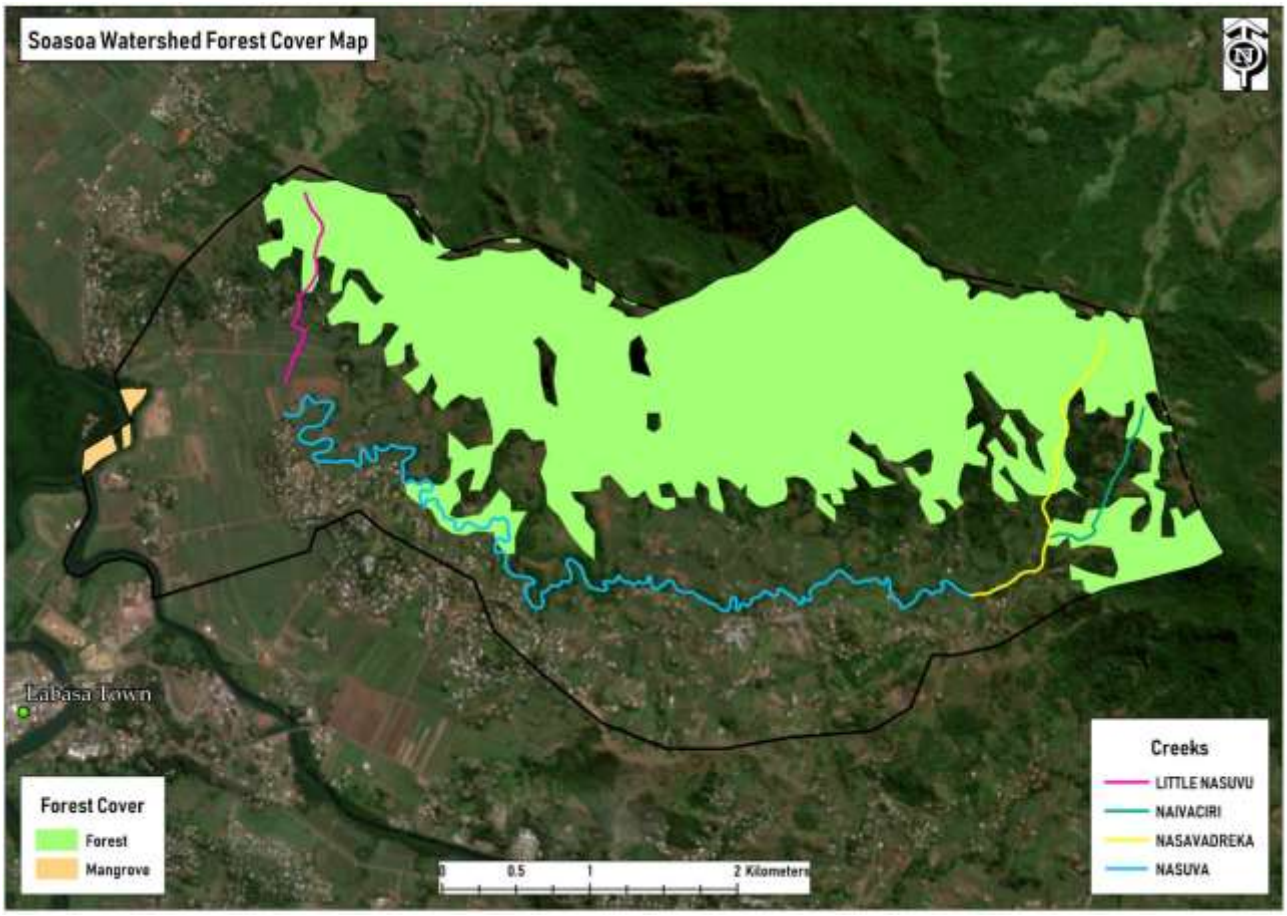
Communities	**Total Household**	**Population Breakdown**		
		Total	**Male**	**Female**
Namako Settlement	17	69	35	34
Nubunivonu Settlement	5	27	15	12
Soasoa Settlement	163	729	364	365
Valebasoga Settlement	349	1504	769	735
Vuiva Settlement	2	11	6	5
Vunivau Village	7	42	22	20
TOTAL				

The age-sex population structure of the study area in the figure below, shows a predominantly young population, with the largest age groups being 0-4 and 10-14 years old. The lowest age category (0-4 years old) is mostly similar with all the other age group above it till the age group 20- 24 years, which implies a consistent birth rate. The pyramid also clearly shows that women in the Soasoa watershed area live longer than men. Women are however fewer in number, comprising only 46% of the population. The median age of the sampled population is 25, closely matching the national average of 24.6 years.

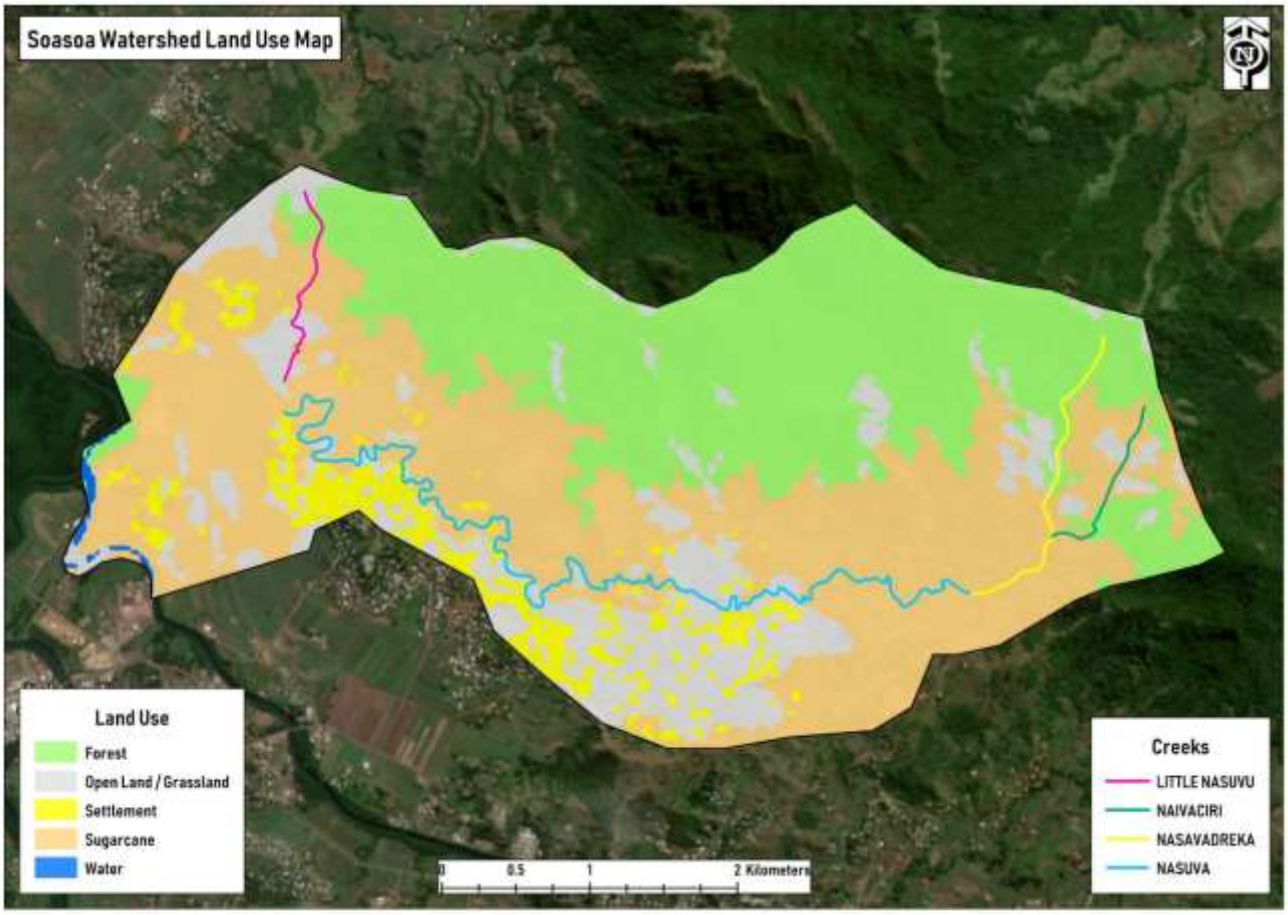


Landuse

Forest cover



Landuse map



Landuse/threats observed across Soasoa waterways

a) FW3: Algal laden & silted streambed

b) FW5: Highly modified riparian vegetation, bank farming & bank livestock grazing2382

c) FW4: Eroded bank, highly modified riparian zone, silted streambed

d) Rubbish clogging the floodgate

Governance

Fiji has both a contemporary and traditional system of governance.

Central government is housed in Suva the capital city. The country is divided into four Divisions; Central (which includes Suva and all areas that are subsequently discussed in more detail in later sections of this report), Western, Eastern and Northern. Each of these divisions is headed by a Commissioner. Whilst the administrative importance of these divisions has historically waxed and waned, recent efforts by government have promoted planning, budgeting and resourcing at the divisional level. Within each division there are then a number of provinces. There are 14 Provinces in total in Fiji. Areas described in more detail later in this report lie within one of three provinces; Namosi, Naitasiri and Rewa. Rotuma, an island that lies off the north coast of Fiji, is governed semi-autonomously by the Rotuma Council established by the 1927 Rotuma Act.

The functions of central government are decentralised at the provincial level. Each province has a Provincial Office which is staffed by a number of largely government employees who have oversight of the functions of service provision to the population that reside in that province. The Provincial Office is headed by the Roko Tui . Most government functions are controlled at provincial level; though there are notable exceptions such as health care and educational provision which is decentralised to the divisional scale in the first instance.

In addition, there are twelve city (2) and municipal (10) councils that oversee the governance of urban areas. These councils comprise elected officials and are headed by a government appointed Special Administrator. Through the Ministry of Regional Development, rural areas are divided into Local Authorities that have advisory powers and provide a voice to all Fijians irrespective of racial background at the provincial scale. The local authorities also have mandate over the issuance of development licences in the areas they control.

In parallel to the state run-government there is also a governance system linked to the indigenous iTaukei. The indigenous population exist through family-units in a number of villages; with a number of villages comprising an iTaukei Tikina (district); and with a number of tikina comprising a province. Note however, there is a discrepancy between the iTaukei tikina district and the colonial definition of district which is used as an administrative unit for

purposes including, in particular, the conduct of national census. Within each tikina there exists the Tikina Council which is comprised of village chief and village headman from the villages within that tikina.

At the top of the iTaukei administrative system within the province sits the Provincial Council which is comprised of indigenous leaders with the paramount chief of the province as the head and the Roko Tui as secretary; providing the link between the Provincial Council and the Provincial Office. The Provincial Council works with the Provincial Office to implement development programmes and address development issues within the Province. Finally, until March 2012 when it was disbanded, members of the iTaukei hierarchy sat on the Great Council of Chiefs.

Typically, each rural iTaukei village will have a number of development committees comprised of community members and leaders. Each committee oversees a specific component of the development of that community. Committees typically include education, church, health, environment and village development. Depending on the communal ownership of assets there may also be, for example, a village carrier (vehicle) committee. In addition, women and youth normally have a committee. Committees report to the wider village meetings. Village meetings are held at least monthly; often every fortnight or weekly. Village meetings are chaired by the village chief with the village headman normally acting as secretary. The village headman is now paid by government to perform their role and acts as a conduit from village to Tikina meetings which in turn pass to the Provincial Council and Provincial Office. Similar governance processes to those in iTaukei villages exist in Indo-Fijian settlements- in which Advisory Councils convene meetings and oversee matters pertaining to development initiatives in the settlement.

4.0 Discussion

This section intends to assist with Yaubula management plan for Soasoa catchment with a specific focus on the status of riverine systems and recommendations on maintenance of ecological integrity of these systems for continued harnessing of ecosystem services. Ecological status of the targeted waterways was based on established bioindicators of riverine ecological health for Fijian systems (Rashni 2014a,b) with concept adopted from Chessman (2003). The eco-status map (Figure 7) shows the ecological status of the freshwater sites surveyed with respective colored keys (Good, Moderately-good, Moderately-degraded and Degraded) as indicators of ecological status type per site.

Native forest cover associated sites (FW1 & FW2) appear to have good (green circles) waterways while systems amongst highly reduced catchment cover or less vegetated areas, with concentrated agriculture and highly modified riparian zones appear to have moderately degraded to degraded waterways. The sites in Vunivau area drained by the Nasavu stream systems (FW4 & FW5) are impacted by intensive adjacent agricultural activities/bank farming which lead to removal of riparian cover and siltation across streambed which are known to contribute to algal bloom and siltation across riverbed (Figure 3), degraded micro-habitats favouring more resilient bioindicator taxa (Table 4) and thus a degraded system indicated via a red circle on the map (Figure 7). The area endemic spring snails (*Fluviopupa* spp.) were present at the control site FW2, well above agriculturally impacted zone

supported by native forest cover indicating an ecologically healthy ecosystem and excellent water quality.

Figure 8: Bioindicator based eco-status for Soasoa catchment waterways

Table 7: Summary of ecological status of sites surveyed

Site	Associated bioindicator taxa	Ecological status	Percentage (%) of sites
FW1 & FW2 (Control sites)	*Fluviopupa* spp., *Chimarra* sp., *Nesobasis* spp., *Apsilochorema* sp. & *Baetis* spp.	Good	40
FW3	*Barbronia sp., Nymphicula* sp., *Nesobasis* spp. & *Apsilochorema* sp.	Moderately Degraded	20
FW4 & FW5	*Chironomus* sp., *Paroxyethira* sp. 2 & *Barbronia* sp.	Degraded	40

Benthic freshwater macroinvertebrate families/genera recorded across the five lotic systems/sites draining the Soasoa catchment are similar to the previously investigated modified catchments in Viti Levu and Vanua Levu (Haynes 1994, 1999; Rashni 2014b, c). However, species level identification is a challenge as those placed as sp. and spp. require morpho-molecular fusion analysis. Overall, the invertebrate groups recorded at stations FW1 & FW2 were more typical of those found in secondary rainforest to slightly disturbed systems while those recorded at stations FW3-FW5 were typical of modified to highly modified lowland agriculturally impacted systems of Fiji.

Multi-habitat (riffle, run, pool, edges, submerged vegetation and submerged fine root mass) sampling via kick-netting revealed a higher diversity of insect larvae, nymphs and naiads at the control sites in upstream systems (FW1& FW2) compared to the sites closer to the river mouth (FW4 & FW5) where gastropods and crustaceans diversity was higher. This is because crustaceans and gastropods are higher in diversity in lowland systems close to river mouth due to their larval distribution via sea currents and successful settling at sluggish

flow habitats while with increasing elevation are added barriers such as waterfalls and high flows which limit the distribution of thiarid and neritids snails and many large crustaceans. Crustacean and gastropod diversity and abundance increased with a decrease in distance from sea, that is, in lower Soasoa catchment sites (FW4 & FW5).

Damselfly naiads and rissodean spring snails were categorized as taxa of conservation significance. Damselfly naiads with majority specimen belonging to the endemic genus *Nesobasis* is of high ecological interest. Currently Fiji records a total of 21 described endemic species of this genus (with 10 species in the process of description, Milen Marinov[2] Pers. Comm.) with no previous records for the headwater tributary system (FW2, Natobe stream). Due to lack of a guide to Odonata naiads of Fiji, many naiads cannot be identified to species level. However, due to the fact the Odonata (aerial and naiad form) community composition has not been previously explored in the waterways and riparian forest system of currently targeted waterways of interest and quite a few area endemic records of *Nesobasis* from Fijian archipelago, it is important to conserve and maintain the ecological niche (waterways and riparian zone) supporting this genera to ensure a healthy breeding population especially in the headwater systems/control sites (Natobe streams, FW1 & FW2).

The minute (3-5mm shell) freshwater spring snails (*Fluviopupa* spp.) of the family Tateidae were also categorized as taxa of conservation significance. These micro-snails were recorded at the headwater systems/control site (FW2). This/these species is/are the only gastropod recorded that is endemic to Fiji during the survey, more specifically they are crenobionts and known to be area endemics and therefore of very high conservation significance. Currently Fiji records a total of 28 *Fluviopupa* species, all of which are endemic and area endemics (Zielke and Haase 2014). A high abundance (FW2:26 individuals) for such a minute snail species suggested that larger populations are thriving well above the sampling site; undisturbed forest system. The *Fluviopupa* spp. collected from site FW2 are potentially new species as the spring snails are known to evolve in the headwaters of catchments and usually catchment endemic. Hence, a very high possibility of a total of at least two new records to science and an increase in the diversity and biogeographical distribution of the area endemic headwater system rissoodean gastropods for Vanua Levu and Fijian highlands at a country level.

The five sites rapid assessment for freshwater macroinvertebrate community structure across upper, mid and lower Soasoa catchment recorded a total of nine bioindicator taxa indicating 40% degraded systems, 20% moderately degraded, 40% good systems. From the site specific observations and quick discussion with the field guide, pressures probably leading to ecological instability of the freshwater systems include, unsustainable logging occurring in the area closer to the headwater system, highly modified riparian vegetation, bank instability, soil erosion due to eroded banks, siltation, bank sugarcane farming, bank livestock grazing, use of weedicides and pesticides, grey water discharge and rubbish dumping in the waterways adjacent to households.

These land use practices would probably have had major impact on ecological stability of the freshwater systems including frequent sediment deposition on river bed over the years affecting water quality, invertebrate colonization, decline in food provision (smothering of

[2] Dr. Milen Marinov- Odonatologist, Chair-IUCN Pacific Dragonfly Specialist Group.

biofilms on submerged rocks) and loss of stable aquatic micro-habitats. Removal of native host plant species (now a weedy/grassy zone) on stream banks in the mid and lower Soasoa areas might have impacted breeding of host plant specific invertebrates upon emergence from river and thus hindering natural colonization of species. The continued catchment cover disturbance over the years most probably resulted in micro-habitat alteration and gradual disappearance of breeding niches (homogenous substrates and deeper water channel) leading to loss of sensitive species which are bioindicators of good to excellent water quality; rarely present at site FW3 and absent from sites FW4 and FW5. Freshwater algal mats evident on sites FW4 & FW5 in Vunivau areas are most probably due to a combination of sedimentation and agriculturally utilized fertilizer leachates.

Additionally, the complete removal of the native riparian vegetation for agriculture purposes has now resulted in bank instability leading to soil erosion. This is of very high concern because bank erosion contributes to rapid sediment discharge in waterways which leads to shallowing of water depth and thus rapid mixing of salt water at high tides and eventually quick floods. A commonly observed scenario in Soasoa. Also the existing highly modified/weedy-grassy riparian vegetation coupled with continued bank livestock grazing leads to bank instability and thus rapid sediment and agricultural nutrient discharges directly to waterways which could otherwise have been used up by the initial riparian vegetation comprising of a mixture of plants serving specific functions.

Improper waste disposal (direct into waterways at some sites) have led to clogging of flood gates and hindrance in water flow and threat to aquatic community which serve specific ecological functions to maintain ecosystem stability. Perhaps strict measures on rubbish disposal strategy for lease agreement tenancy should help mitigate the issue.

As expected, the areas surveyed along the Soasoa watershed were home to a wide variety of the invasive plant and animal species known to be present in Fiji. Whilst for the most part these species were restricted to the disturbed areas associated with roads, plantations, tracks and settlements, there was evidence of incursion into primary forest areas by some species, in particular *Clidemia hirta,* a highly successful understory shrub.

The impacts of invasive species can be both direct and indirect, and some effects are immediate whereas others are more long-term. Rodents such as mongooses and rats, for example can have immediate and devastating effects on native birdlife by killing adults and juveniles and feeding on eggs. They can also have a long-term effect on the regenerative capacity of certain plant species by feeding on their seeds or fruit. Invasive plant species can impact on the native flora generally through the process of outcompeting them, since invasive plants tend to have very rapid growth, high dispersal capabilities and high reproductive success.

5. Conclusion

Key principles to maintain migration pathways for aquatic fauna, where structures interact with waterways, are:

(i) Avoid alteration of the existing gradient and alignment of the stream or river bed within the structure.

(ii) Ensure that the structure allows for the stream or river bed to pass through it at a similar width to the existing bed to avoid any constriction in flow that would cause a localised increase in velocity.

(iii) Install self-regulating “fish-friendly” especially for the Soasao flood gates. These maximizes the time for which the gate remains open, thereby increasing the ability for fauna to migrate upstream. Details of flood- or tide-operated floodgates are provided on the website for the New South Wales Department of Primary Industries (https://www.dpi.nsw.gov.au/fishing/habitat/rehabilitating/floodgate).

Any proposal for an Intergrated Watershed Management Plan will have to take into account how to protect the biodiversity in the area from the negative impacts of invasive species. Invasive species are an inevitable threat to protected areas not just from surrounding or marginal localities, but also from disturbed habitats within the protected area itself.

Invasive species control and/or monitoring should be a component of any proposal for the designation and long-term management of a proposed Soasoa IWMP. Without management to prevent and address invasive alien species, watershed values, including ecosystem services and biodiversity, will inevitably be eroded (Poorter *et al.*, 2007).

A major socio-ecological issue is the lack of awareness on human pressures on the catchment utilization and mitigation measures. For mitigation of anthropogenic pressures on the Soasoa freshwater systems, improvement of water quality and for gradual restoration/recovery of aquatic habitats, a decline in sedimentation and nutrient leachates and possibly allow 50% recovery of native/area endemic freshwater macroinvertebrate species (possibly the existing gene pool population in headwater systems), it is highly recommended to conduct a workshop and in field training with the respective riverine resource user communities in the view of the bioindicator based eco-status.

To be able to upskill and empower a climate resilience community, the training should be aimed to increase the understanding on riverine ecosystem functioning and associated catchment activities responsible for currently faced environmental issues, aquatic biota community, as well as to explore the rooted traditional knowledge on community based riverine resource management; river resource mapping. The workshop and field work should be designed to introduce the participants to basic stream structure and biological communities, stream health monitoring using bioindicators and catchment activities that pose threats to their watercourses.

A resulting community based matrix should be developed in association with the eco-status map to reflect the bioindicator community recorded per site, observed threats, mitigation and enhancement measures for site associated villages. It is highly recommended that upstream and downstream communities work collaboratively to observe the recommendation as per matrix for an effective catchment management planning, riverine resource rehabilitation and

ecosystem service maintenance. This matrix should then be included in the Soasoa catchment management plan and proposed rehabilitation activities per site should be strictly observed and monitored for long term freshwater ecosystem services benefits.

6. Reference

1. Chessman, B., 2003. SIGNAL 2 – A Scoring System for Macro-invertebrate ('Water Bugs') in Australian Rivers, Monitoring River Heath Initiative Technical Report no 31, Commonwealth of Australia, Canberra.
2. Choy, S. 1983. Caridina fijiana n. sp.(Decapoda: Atyidae) from Nadarivatu, Fiji. New Zealand journal of zoology, 10, 147-150.
3. Choy, S. 1991. The atyid shrimps of Fiji with description of a new species. Zoologische Mededelingen, 65, 343-362.
4. Choy, S.C. 1984. A new atyid shrimp, Caridina nudirostris sp. nov.(Decapoda, Natantia, Atyidae) from the Nadrau Plateau, Fiji. Crustaceana, 288-294.
5. Copeland L. K. F., Boseto David T., Jenkins Aaron P. (2016) Freshwater ichthyofauna of the Pacific-Asia Biodiversity Transect (PABITRA) Gateway in Viti Levu, Fiji. Pacific Conservation Biology 22, 236-241.
6. Gray, A. J. (1989). A Directory of Wetlands in Ocenia. Wetlands International, Suva. (pp 1-41) Fiji.
7. Hasse, M., Ponder, W.F and Bouchet, P. 2006. The Genus Fluviopupa Pilsbry, 1911 from Fiji (Caenogastropoda, Rissooidea). Journal of Molluscan studies 72:119-136.
8. Haynes, A. 1994. "The effects of development on Fijian island freshwater invertebrates." Memoirs of the Queensland Museum no. 36: 87-91.
9. Haynes, A. 1999. "The long term effect of forest logging on the macroinvertebrates in a Fijian stream." Hydrobiologia no. 405:79-87.
10. Haynes, A. 2009. Snails in Fiji's rivers and streams. Institute of Applied Sciences, Suva. Fiji. 28 pages.
11. Haynes, A. 2001. Freshwater Snails of the Tropical Pacific Islands. Institute of Applied Sciences, Suva. Fiji. 115 pages.
12. Haynes, A and Rashni, B.2016. Guide to Aquatic Insects of Fiji (Unpublished). 84 pages.
13. Jenkins, A.P., Jupiter, S.D. (2011). Spatial and seasonal patterns in freshwater ichthyofaunal communities of a tropical high island in Fiji. Environ Biol Fish 91, 261–274
14. Mangubhai, S., H. Sykes, E. Lovell, G. Brodie, S. Jupiter, C. Morris, S. Lee, E. M. Loganimoce, B. Rashni, R. Lal, Y. Nand & I. Qauqau, 2019. Chapter 35 - Fiji: Coastal and Marine Ecosystems. In Sheppard, C. (ed) World Seas: an Environmental Evaluation (Second Edition). Academic Press, 765-792.
15. T Polhemus, John & Polhemus, Dan & Ò Ïîëõåìóñ, Äae & À Ïîëõåìóñ, Ä. 2006. A new genus and two new species of Microveliinae from Fiji (Heteroptera: Veliidae) Íîâûé ðîä è äâà íîâûõ âèäà Microveliinae ñ Ôèäæè (Heteroptera: Veliidae). Russian Entomol. J. 15. 181-186.
16. Poorter, M. D., Pagad, S. & Ullah, M. I. (2007). Invasive alien species and protected areas: a scoping report. Part I. Global Invasive Species Programme.

17. Rashni, B. 2014a. Effect of catchment forest cover on macroinvertebrate community structure in streams of Fiji. Masters in Marine Science: School of Marine Studies. University of the South Pacific. Suva.
18. Rashni, B. 2014b. Piloting stream health assessment in rural & remote communities of Fiji. A case study of Drawa block villages. IAS Environmental Report No. 316.
19. Rashni, B. 2014c. Chapter 6 Freshwater Macroinvertebrates. In: Pene, S and Tuiwawa, M (ed.). FPAM (2014) Biological and Socio-Economical Baseline Report for the Establishment of the Greater Delaikoro Protected Area, Vanua Levu, Fiji Islands. A Rapid Biodiversity Assessment, Socioeconomic Study and Archaeological Survey of the Greater Delaikoro Area. FPAM-2014- Biodiversity-01.Report. FAO/GEF-PAS.
20. Rashni, B., 2018. Freshwater Macroinvertebrates. In Tuiwawa, M., H. Waqa-Sakiti, S. Tuiwawa, A. Naikatini, L. Copeland & B. Rashni (eds) Colo-i-Suva forest park wildlife. University of the South Pacific Press, Suva, Fiji, Suva, Fiji.
21. Williams, W. D. 1980. Australian Freshwater Life: the Invertebrates of Australian inland waters. Macmillan Company of Australia Pty Ltd. Melbourne. 321p.
22. Winterbourn, M.J.,Gregson,K.L.D and Dolphin, C. H. 2006. Guide to the Aquatic Insects of New Zealand (4th Ed.). The Entomological Society of New Zealand. 108p.
23. Yeo, S. (2001). A Review of Flooding in Macuata Province, Fiji Islands. SOPAC (pp. 1154) Suva.
24. Zielske, S and Haase, M. 2017. New insights into tateid gastropods and their radiation on Fiji based on anatomical and molecular methods (Caenogastropoda: Truncatelloidea). Zoological Journal of the Linnean Society 172, 71–102.


JBP
scientists
and engineers