A Rapid Biodiversity Assessment, Socioeconomic Study and Archaeological Survey of the Rewa River Mangroves, Viti Levu, Fiji.

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ORGANISATIONAL PROFILES AND AUTHORS

Institute of Applied Sciences (University of the South Pacific)

The Institute of Applied Sciences (IAS) was established in 1977 as part of the University of the South Pacific. The Institute operates as a consulting body within the university, applying the professional and academic expertise of its staff as required by government, NGO or private projects in Fiji and the Pacific region. IAS operates through six thematic units: the South Pacific Regional Herbarium, the Environment Unit, the Quality Control Unit, the Drug Discovery Unit, the Analytical Unit and the Food Unit. This survey was coordinated and headed by the South Pacific Regional Herbarium.

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The mission of Conservation International (CI) is to build upon a strong foundation of science, partnership and field demonstration, to empower societies to responsibly and sustainably care for nature for the well-being of humanity. Conservation International operates in Fiji in partnership with The National Trust of Fiji.

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EXECUTIVE SUMMARY

This report presents the findings of an expedition conducted under the Fiji MESCAL programme at the demonstration site: the Rewa River mangroves. The expedition team carried out surveys of the area's biodiversity, cultural and archaeological heritage and its socioeconomic profile.

Flora, vegetation and ecology

A total of 181 plant taxa were recorded in the area. There were 96 native species, five of which are endemic to Fiji. Eight obligatory mangrove tree species were recorded, with an additional four non-tree species classified as mangrove associates. The main plant communities or habitat types identified in the study site were: *Rhizophora* (tiri) forest, mixed mangrove forest, *Bruguiera* (dogo) forest, back of the mangrove forest, *Acrostichum* (borete) habitat, coastal beach forest, anthropogenic secondary forest, peatbog swamp, grassland swamp and woody shrub swamp.

Herpetofauna

A total of ten herpetofauna species were documented on the survey over four man-hours of diurnal survey, 71 hours of sticky trapping and six man-hours of nocturnal surveys. There were two endemic, six native and two invasive species recorded in the area. Overall four species are on the IUCN Red List of Threatened Species.

Avifauna

A total of 36 species of birds and 2 species of bat were recorded in the surveys, four of which are introduced, ten of which are endemic, and the remainder are native to Fiji. One species, *Pteropus samoensis*, is on the IUCN Red List of Threatened Species.

Terrestrial Insects

A total of 14 Coleopteran families were sampled including the rare beetle families; Cerambycidae, Cicindelidae and Passalidae. New records for this area included *Papilio schmeltzi* (Fijian swallowtail butterfly) and the endemic moth *Calliteara fidjiensis*.

Freshwater Fish

A total of 43 species of fish and 5 species of crustaceans were collected. *Plectorhinchus albovittatus*, *Tylosurus crocodilus crocodilus* and *Rastrelliger kanagurta* are new records for the brackish-water fish community in Fiji. The largest endemic insular fish species in

the Pacific, *Mesopristes kneri*, was also recorded. Fish biomass was greatest in downstream zones within the mangrove area.

Invasive Species

Invasive species were recorded throughout all habitat types to some extent. The undisturbed true mangrove habitat dominated by *Rhizophora* and *Bruguiera* was the least invaded. More invasive species were located in the drier areas to the back of the mangroves and in other habitats such as coastal forest, agricultural areas, secondary forest and disturbed areas.

Forestry Timber Inventory

A total of 927 trees in 47 plots were assessed. Tree composition was dominated by four species: dogo, tiri, dabi and selala. A total standing timber volume of 696, 290 m^3 was calculated. Calculating total carbon stocking within the study area is hindered by the lack of wood density values for these species, as well as the lack of allometric equations for calculating tree species biomass in the Rewa River mangroves.

Fisheries Survey

From a total of 761 fish, 121 fin-fish species were recorded, from 47 different fish families. The fish family Gobiidae was the most common. The survey also recorded 35 species of invertebrates, including crabs, prawns, gastropods, bivalves, sea cucumbers and others.

Socio-economic assessment

A questionnaire survey of 185 households highlighted that the main source of household income is the sale of fish, followed by the sale of mangrove invertebrates. 92% of households stated that their primary fuelwood source is from dry mangrove wood. Only 28% respondents stated that they consider sustainable harvesting approaches when cutting down mangroves.

Archaeological Survey

A total of 27 archaeologically and culturally significant sites were documented including sites for the installations of chiefs, fortification sites, old villages, burial grounds and sacred sites. Of these 27 sites, seven had not been previously known, and are new records for the Tailevu and Rewa provinces.

INTRODUCTION

MESCAL programme

The MESCAL (Mangrove Ecosystems for Climate Change Adaptation and Livelihoods) programme is a partnership-based initiative of IUCN that is being implemented in five countries across the Pacific: Fiji, Samoa, Solomon Islands, Tonga and Vanuatu.

The aim of the MESCAL programme is to assist in climate-proofing coastal communities and sustaining livelihoods by promoting investments in mangrove and associated coastal ecosystems.

In Fiji the MESCAL programme is coordinated by the Department of Environment with technical advisory input from the Mangrove Management Committee (MMC). It aims to strengthen mangrove management in Fiji by achieving the following outcomes:

- improved decision-making among stakeholders by making available comprehensive baseline information on the status of mangroves in Fiji,
- strengthened national mangrove management with the development of a National Mangrove Management Plan,
- enhanced technical capacity of government staff in mangrove management through the trialling of practices and research tools at the project demonstration sites,
- improved public awareness of mangrove management and conservation through awareness campaigns and information dissemination.

The Fiji MESCAL demonstration site is the Rewa River mangroves. Based on activities at this site, the programme will demonstrate the implementation of the National Mangrove Management Plan, identify information gaps, gather data and develop appropriate tools and mechanisms needed for sustainable mangrove management at a national level.

Survey Overview

The survey, carried out in September 2012, included the following components:

- a rapid biodiversity assessment (including a timber volume assessment),
- a socioeconomic study,
- an archaeological survey.

Study Area

The MESCAL project demonstration site in the Rewa Delta is Fiji's largest mangrove system. The site covers an area of approximately 35 000 hectares in the adjacent provinces of Rewa and Tailevu. The Rewa River drains approximately a third of the land area of Viti Levu.

The survey was carried out in four main study sites within the Rewa Delta:

Site 1: Natila Settlement, Tailevu Province

Natila settlement lies 1km from the Namara-Naisausau road. There is a bridge-like embankment through an area of mangroves, connecting the road to the settlement. Natila settlement is located on the coast, in sight of Viwa Island which lies 2km offshore. There are several small streams or creeks found along this coastline. Most of the major ecosystems in this area were moderately to heavily impacted by human activities, especially from agricultural development and human habitation.

Site 2: Waicoka Village, Tailevu Province

Waicoka village is accessible by road and is located on the edge of a reclaimed mangrove forest along the Waidamu River. Land reclamation associated with past dredging and river realignment was observed upstream. Mangrove forests downstream from Naisogovau Village and along the Navuloa River are extensive and diverse. Some of the largest mangrove trees and most intact habitats observed during the entire survey were found in this area.

Site 3: Nasilai Village, Tailevu Province

Nasilai Village is located on the edge of a mangrove forest at the mouth of the Nasilai River. Most of the mangrove habitats surveyed showed little evidence of human impact. Some of the largest *Bruguiera* trees were recorded here. Extensive freshwater wetland swamps, coastal strand and beach vegetation were found in this area.

Site 4: Muaicake and Muaira Villages, Vutia, Rewa Province

These adjacent villages are only accessible by boat. Mangroves along the main Rewa River are heavily impacted by logging and dredging activities. Large stands of mangroves have been destroyed by the dumping of dredging spoils, and embankment erosion was observed further downstream. Extensive stands of young mangroves were observed in areas near the heavily populated Suva-Nausori corridor.

1 FLORA, VEGETATION AND ECOLOGY

Senilolia H. Tuiwawa, Hans Wendt and Marika V. Tuiwawa

1.1 Introduction

Fiji has approximately 42, 000 hectares of land that is covered by mangrove forests (Spalding *et al.,* 2010), occurring in the intertidal zones of the volcanic and limestone islands. The largest stands, located around the major rivers of Ba, Nadi and Rewa in Viti Levu and Labasa, Qawa and Dreketi in Vanua Levu, together comprise over 90% of Fiji's mangrove area.

The Rewa River mangroves form the largest, most complex and most intact mangrove system in Fiji. Botanical documentation of the area is restricted to the works of Raj *et al.* (1984). The survey described in this report is thus the most recent botanical account of this important mangrove area.

The objectives of the botanical survey were to:

- identify the principal vegetation types in the MESCAL demonstration site,
- identify and describe the forest/habitat types present,
- identify key mangrove plant species,
- assess the current level of disturbance in different forest/habitat types.

1.2 Methodology

1.2.1 Floral diversity survey

Specimens of native plants that were flowering or fruiting were collected throughout the study area, identified, pressed (Figure 1) and dried and placed in long-term storage in the South Pacific Regional Herbarium. Species names are based on the works of Smith (1979, 1981, 1985, 1988, 1991) for seed plants, and those of Brownlie (1977) and Brownsey and Perrie (2011) for ferns and fern allies.

1.2.2 Forest/habitat type mapping and characterisation

The classification and characterisation of different habitat types was made based on the principal vegetation types described by Mueller-Dombois and Fosberg (1998). Preliminary identification of different habitat/forest types within the study area was made using satellite imagery, with reference to topographic and forest cover maps in order to identify and describe terrain features. Ground truthing of the preliminary

habitat classifications was made during the field survey, covering as much of the study area as was feasible.

The level of disturbance of forested areas was assessed and each site assigned to one of the following three disturbance categories:

- Low—primary forest with little or no evidence of natural or human-induced disturbance;
- Medium—transition or secondary forest either in recovery or in the process of being disturbed, displaying some of the ecological complexity (succession species and/or problematic species) and function associated with secondary forest or transition forest;
- High—secondary forest showing signs that disturbance was recent and ongoing.

1.2.3 Vegetation community structure

A quantitative assessment of vegetation community structure within different forest/habitat types was carried out using 10 x 10 m plots along a 100 m transect. Each plot's location was recorded with a GPS and photographs taken of its representative features.

Every tree in a plot with a diameter at breast height (dbh) greater than 5 cm was enumerated, and its species name, dbh, bole height, crown height and crown width recorded (Figure 2 and Figure 3). Ground cover and epiphytic species within each plot were also identified and recorded (Figure 4). The percentage ground cover and percentage canopy cover for each plot was visually estimated.

Figure 1: Field preparation of plant specimens for research purposes

Figure 2: Field assistant measuring the dbh of the stilt roots of *Rhizophora* × *selala*

Figure 3: Field assistants estimate the bole height, crown height and width of an ivi tree

Figure 4: Collection of epiphytic specimens

The number of transects and plots used to assess these forest/habitat types at the four study sites are summarised in Table 1.

Table 1: Vegetation transects and plots used at study sites

Study site	No. of transects	No. of plots
Site 1 – Natila	6	27
Site 2 – Waicoka	17	77
Site 3 – Nasilai	8	66
Site 4 – Vutia	2	13
Total	33	183

1.3 Results and discussion

1.3.1 Floral diversity survey

The checklist of the 181 vascular plant taxa recorded in the study area is provided in 0. The checklist comprises 163 angiosperms (128 dicotyledons and 35 monocotyledons), and 18 ferns and fern allies. Five of the species are endemic to Fiji, a further 91 are native and 61 are introductions.

All of the eight obligatory mangrove tree species known to occur in Fiji were recorded in the study area, namely, *Bruguiera gymnorhiza* (dogo), *Rhizophora samoensis* and *R. stylosa* (both known as tiri or tiri wai), *R.* × *selala* (selala), *Heritiera littoralis* (kedra ivi na yalewa kalou), *Lumnitzera littorea* (sagale), *Xylocarpus granatum* (dabi) and *Excoecaria agalloch*a (sinu gaga).

Bruguiera gymnorhiza and the three *Rhizophora* taxa were the most common and widespread species at all four study sites. The other obligatory mangrove tree species were not very common and were more localised in their distribution, especially *L. littorea* which appeared to be rare in general.

An additional four native species are deemed mangrove associate species: *Dalbergia candenatensis* (denimana/wa denimana), *Acrostichum aureum* (borete), *Scirpodendron ghaeri* (misimisi/vulu) and *Grammatophyllum elegans* (mangrove orchid/Veisari orchid). The latter two, *S. ghaeri, G. elegan*s, are not exclusively mangrove species, and may be found cultivated or growing naturally outside of a true mangrove system.

As expected, the overall plant diversity of the mangrove was low, relative to other vegetation types in Fiji. None of the species documented are on the IUCN Red List of Threatened Species(IUCN, 2013).

1.3.2 Forest/habitat type mapping and characterisation

Table 2 presents the estimated area of each principal vegetation type, including the different forest/habitat types within them.

Table 2: Forest/habitat types and principal vegetation types in the MESCAL project area

Principal Vegetation Types	Forest/Habitat types	Forest/Habitat Area (ha)	Vegetation Type Area (ha)
Mangrove forest and shrub	*Acrostichum* swamp	203.29	**8, 886.08**
	Back of the mangrove	2, 182.62	
	Bruguiera forest	1, 978.06	
	Human habitation	5.28	
	Mixed mangrove forest	3, 507.37	
	Rhizophora forest	968.42	
	Salt Marsh	41.04	
Coastal strand & beach vegetation	Coastal forest	150.25	**163.97**
	Human habitation	13.66	
Freshwater wetland swamps	Freshwater wetlands	276.03	**277.66**
	Human habitation	1.63	
Lowland rain forest	Anthropogenic secondary forest	916.63	**2, 754.47**
	Lowland secondary forest	1, 837.88	
Non-forest	Agriculture	6, 691.21	**8, 865.84**
	Human habitation	2, 149.87	
	Roads	24.77	
Water body	Coral reefs	3, 321.67	**14, 444.58**
	Deep water	3, 852.19	
	Intertidal mudflats	5, 785.93	
	River	1, 480.13	
	Water bodies	4.65	
Total			**35, 392.57**

The distribution of these vegetation and habitat types across the MESCAL study area are shown in the two maps below.

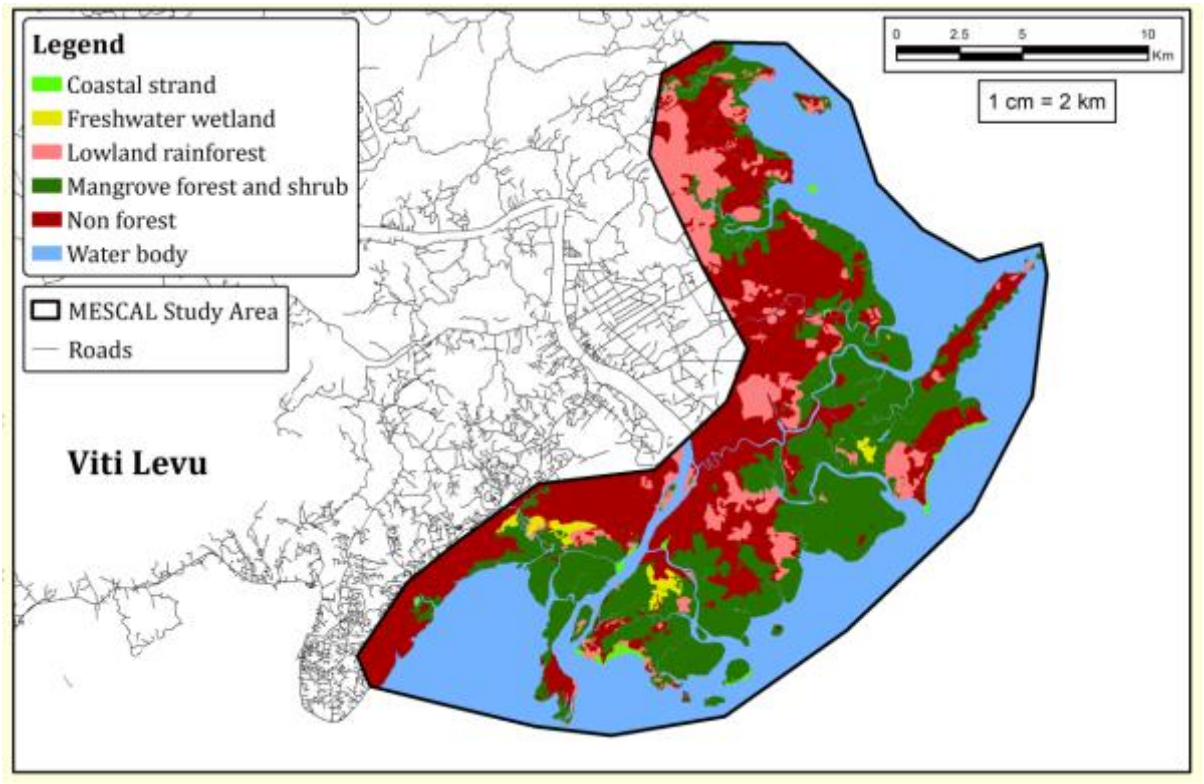

Figure 5: Principal vegetation types of the MESCAL project area

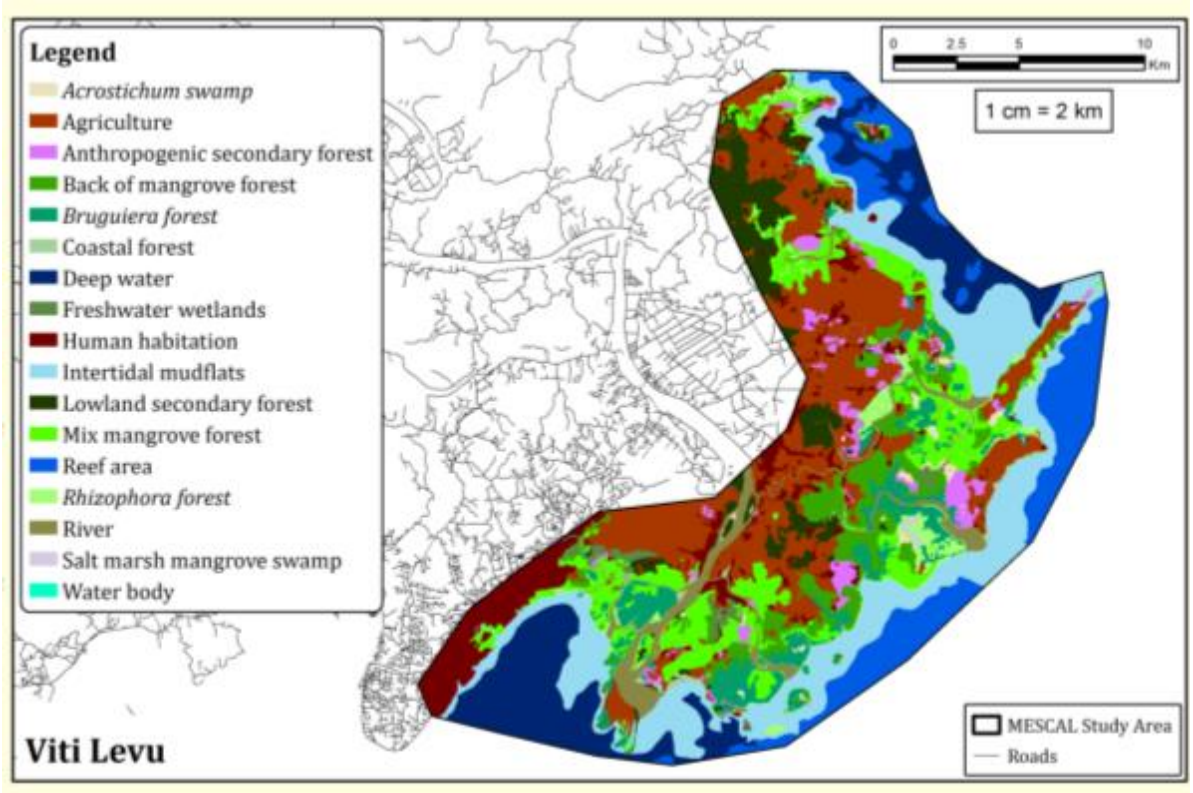

Figure 6: Forest/habitat types of the MESCAL project area

Detailed descriptions of forest/habitat types assessed during the study are presented in Appendix 3.

1.3.3 Vegetation community structure

Of Fiji's nine principal vegetation types (Mueller-Dombois and Fosberg, 1998) the following four were encountered during the MESCAL survey:

- mangrove forest and scrub vegetation,
- coastal strand vegetation,
- lowland rain forest vegetation,
- freshwater wetland vegetation.

The first three principal vegetation types above were quantitatively assessed.

The mangrove forest and scrub vegetation is a system that merges with freshwater wetland swamps in the coastal areas of major river deltas (Sites 3 & 4) and lagoon mangroves (Site 1) where mangroves occupy the mud-covered stream banks and foreshore respectively, of the tidal zones. Four habitat types were assessed as part of this vegetation system: *Rhizophora* forest, *Bruguiera* forest, mixed mangrove forest and back of the mangrove. A fifth habitat, the *Acrostichum* swamp, was observed but not quantitatively assessed.

The coastal strand vegetation observed along the coastline was a fragmented and degraded system and was mostly restricted to Nasilai (Site 2) and Vutia (Site 4) study areas. Mangroves were not part of this system.

Lowland rain forest is vegetation found above the high tide mark and restricted to areas behind the freshwater swampland and the back of the mangrove forest.

The freshwater wetland vegetation was not quantitatively assessed. It was restricted to poorly drained alluvial areas usually behind mangrove forests (in most instances associated with a large river system).

***Rhizophora* forest**

Rhizophora forest is comprised of the three *Rhizophora* taxa, namely, *R. stylosa*, *R. samoensis* and the hybrid *R.* × *selala*. These taxa are difficult to distinguish in the field so a generic classification was used, and the stands referred to collectively as *Rhizophora* forest. *Rhizophora* forest is usually restricted to the seaward edge of any mangrove system and *Rhizophora* species tend to be the first to establish on any newly formed coastal or deltaic mudflats.

Rhizophora forests were quantitatively assessed at Site 1 (one plot) and Site 2 (3 plots).

At Site 1, overall, the *Rhizophora* stands observed in the area were stunted, a growth form usually associated with lagoonal mangroves where there are no large rivers. *Rhizophora* individuals in the plot had an average dbh of 6.41 cm and an average bole to canopy height of 2 m. Some individuals were observed with a dbh less than 5 cm and growing no higher than 50 cm tall yet were already flowering and fruiting. In some stands the bole height was less than 30 cm.

Figure 7: *Rhizophora* forest along the bridge-like embankment leading to Natila Settlement. Note the general stunted growth of trees in this forest system.

At site 2 near Waicoka Village, a lagoon mangrove system was assessed. This system of mangrove differed from that at Site 1 in that a large river system was close to the assessment site.

Three 10 m x 10 m plots were in the *Rhizophora* stand proper and another four along the same transect were in mixed mangrove forest. On average nine individuals were recorded within a plot, with an average dbh of 20 cm (range: 5cm–109 cm).

Figure 8: Measuring the multiple stems of *Rhizophora* × *selala* at Site 2, near Waicoka Village.

There were no logged stumps observed within the plots but a few were seen outside the plot, closer to the road. A hybrid *R.* × *selala* tree with a multi-stem dbh of 109 cm was the largest individual measured (Figure 8). *R.* × *selala* was the dominant species (56% relative dominance).

At Site 3, large stands of this forest type were also observed. At Site 4, large stands of this forest type were generally absent, although a very dense stand of young, apparently recently logged, *Rhizophora* was seen.

Mixed mangrove forest

Mixed mangrove forest is not dominated by a single species, but is composed of two or more of the eight mangrove tree species; *B. gymnorhiza*, the three *Rhizophora* taxa, *X. granatum*, *H. littoralis*, *E. agallocha* and *L. littore*a. Where two or more of these species were found together in one area, with each comprising more than 10% of the relative biomass, the forest type was classified as mixed mangrove.

Mixed mangrove forest generally occurs as a transition zone between *Rhizophora* forest and *Bruguiera* forest. Often difficult to access, because of the density of stilt roots (Figure 9, Figure 10), this forest type was estimated to cover an area of 3, 507 ha in total across the MESCAL project site. Fourteen plots along four transects at Sites 1, 2 and 4 were used to assess this forest type.

Figure 9: Field guide, Kalusi Nokasavu, of Waicoka Village standing amongst the roots of *R* × *selala* and B*. gymnorhiza* in mixed mangrove forest.

Figure 10: A line transect running through mixed mangrove forest.

At Site 1, a total of six plots along two transect and at two different locations were used to assess the mixed mangrove forest. The trees were generally stunted and near Natila Settlement the average dbh was 7 cm (range 5 cm – 20 cm) and the average stocking was nine trees (range: 7 – 11) per plot. Near Nakoroivau Village the average dbh was 10

cm (range: 7 cm – 45 cm) with an average stocking of thirteen trees (range: 12 – 15) per plot. The reason for the difference was that a large river passes closer to this mangrove system. Overall, the average relative dominance was 69% (range 24.1%–88.9%), the dominant species being either *Rhizophora* or *B. gymnorhiza*. Many recently logged tree stumps were noticed outside the plots and in areas where seedlings made up as much as 80% of the ground cover, indicating a high regeneration rate.

At Site 2, between Moala and Waicoka villages, a total of seven plots along a transect were used to quantitatively assess this forest type. The *Rhizophora* trees, especially *R.* × *selala,* encountered on this transect were some of the largest and tallest measured during the entire survey. The average dbh was 20.9 cm (range: 5 cm – 87 cm) with an average stocking of ten trees (range: 2 – 21) per plot. The average relative dominance of the dominant species was 56% (range: 35.0% – 86.7%) and like Site 1, this was either a *Rhizophora* species or *B. gymnorhiza*. Logged stumps were noticed outside the plots and most of these were observed closer to the main road.

At Site 3, no mixed mangrove forests were quantitatively assessed but, as at Site 2, large and equally tall *Rhizophora* species were observed. Access into such stand was near impossible and separating individual trees (especially the three *Rhizophora* taxa) was time consuming and difficult.

At Site 4, two plots along two transects were used to quantitatively assess this forest type. The average dbh was 10.5 cm (range: 5 cm – 36 cm) with an average stocking of 30 trees (range: 24-41) per plot. The average relative dominance of the dominant species, *B. gymnorhiza*, was 70%. The general absence of large *B. gymnorhiza* trees in this section of the study area was indicative of the regular harvesting of mangrove trees for fuel or construction purposes. Also, as observed along the lower reaches of the main Rewa River, large sections of *B. gymnorhiza* stands had been used as dumping sites for dredged sediments.

Bruguiera **forest**

Across the delta, the *Bruguiera* forest was estimated to cover an area of 1, 978 ha across the entire MESCAL site. The *Bruguiera* forest is heavily dominated by *B. gymnorhiza* trees. Other mangrove species that may also be found here contribute less than 10% of the relative biomass of trees in the area. The *Bruguiera* forest was usually located behind the *Rhizophora* forest. In some cases *Bruguiera* stands were observed growing on the edge of a river or foreshore. In such cases, this was most likely the result of

erosion over a very long period. The zone has consistently been used as a nursery for fish and crustaceans, and as a source of firewood and construction materials. Overall a total of 81 plots along 18 transects were used to quantitatively assess this forest type.

At Site 1, within the vicinity of Natila Settlement, three plots along two transects were used. The average dbh was 18.6 cm (range: 5 cm – 50 cm) with an average stocking of fifteen trees (range: 12 – 20) per plot. The relative dominance of *Bruguiera* is 100%. Overall, the *Bruguiera* trees were generally shorter when compared to the other three study sites where the average height was 5.4 m (range: 5.1 m – 7 m). Stumps of recently logged *Bruguiera* trees were noticed outside the plots and these were used almost exclusively as fuel by locals from nearby villagers. It was also noticed that near villages and settlements the mangrove forest was used as a pig rearing area.

At Site 2, a total of 41 plots along nine transects were distributed in the following locations: between Moala and Waicoka villages, on the outskirts of Naisoqovau Village, along the mid-section of the Navuloa River and near Antioki Village.

The average dbh was 26.4 cm (range: 5 cm – 90 cm) with an average stocking of 10 trees (range: 2 – 18) per plot. The average relative dominance of B*. gymnorhiza* was 99.4% (range: 90.5% – 100%). The *B. gymnorhiza* trees overall were taller when compared to those encountered at Site 1, having an average height was 8 m (range: 3.5m – 12.2 m).

Stumps of recently logged *B. gymnorhiza* trees were observed outside the plots, in particular near the banks of the Navuloa River and near farming settlements where large sections of mangroves were removed. The largest tree measured during the entire survey was 118 cm in girth (Figure 11) and was recorded along the Navuloa River.

At Site 3, a total of 32 plots along four transects were used to quantitatively assess this forest type. The average dbh was 38.3 cm (range: 24.2 cm – 60.8 cm) with the largest tree having a dbh of 113 cm. The average stocking of trees within a plot was nine individuals (range: 6 – 16) per plot. The relative dominance of *B. gymnorhiza* was 100% in 31 of the 32 plots (one plot was dominated by *E. agallocha*). The *B. gymnorhiza* trees at this site were generally taller compared to those encountered in the other three study sites, having an average height of 14.7 m (range: of 8.6 m to 15.3 m). Eleven stumps of recently logged *B. gymnorhiza* trees were recorded inside plots along the four transects, and many more were observed outside of the plots, particularly near the banks of larger rivers.

Figure 11: Field assistant Manoa Maiwaqa, measuring the girth of a *B. gymnorhiza* tree on the swampy banks of the Navuloa River

At Site 4, a total of six plots along two transects were used to quantitatively assess this forest type. The average dbh was 9.3 cm (range: 5 cm – 43 cm). The average stocking of trees within a plot was 33 individuals (range: 20 – 57) per plot. The average relative dominance of *B. gymnorhiza* was 96.8%, with other species (*Rhizophora* and *X. granatum*) constituting less than 10% of the total biomass. The average height was 7.5 m (range: 6.6 m – 8.6 m). On average four stumps of logged *B. gymnorhiza* trees were recorded per plot and many more were observed outside the plots (Figure 12).

Figure 12: Pneumatophores of *B. gymnorhiza* on the banks of the Vunidawa River

Overall, the *Bruguiera* forest comprised a highly impacted secondary forest. There had been a history of logging along the banks of the main Rewa River. Also as observed along the lower reaches of the main Rewa River, large sections of once prime *B. gymnorhiza* stands had been killed by the recent dumping of dredging spoils.

Back of the mangrove forest

The back of the mangrove forest is located furthest from the riverbank or coastline, behind the *Rhizophora*, mixed mangrove and *Bruguiera* forests. It was estimated to cover an area of 2, 183 ha across the entire MESCAL site. The low-lying sections of this undulating terrain were generally muddy and filled with brackish water during high tide. In most cases, the *Rhizophora* species were absent, but occasionally one or two of the other mangrove species (*A. aureum*, *H. littoralis*, *X. granatum, E. agallocha* and *B. gymnorhiza*) were found here. On higher ground the substrate was not inundated except during king tides or very heavy rain Secondary succession species were found here, e.g. *Glochidion* spp., *Elattostachys falcata* (marasa), *Morinda citrifolia* (kura), *Pittosporum* spp., *Hibiscus tiliaceus* (vau), *Cocos nucifera* (coconut); as well as some introduced species: *Annona glabra* (uto ni bulumaku), *Mangifera indica* (mango), *Artocarpus altilis* (uto), *Citrus* spp., *Leucaena leucocephala* (vaivai) and *Adenanthera pavonina* (red bead tree).

A total of 68 plots along 14 transect were used to quantitatively asses this forest type for the entire RRM.

At site 1, within the vicinity of Natila Settlement and Nakoroivau Village, eleven plots along two transects were used for the assessment of this forest type. The average dbh for all trees assessed was 29.3 cm (range: 5 cm – 160cm). The average stocking of trees was ten per plot, of at least four different species. The average height was 8.4 m (range: 5.6 m to 11.3 m). The average relative dominance was 56.1% with *Inocarpus fagifer* (ivi) being the dominant species in most plots and occasionally *Barringtonia edulis* (vutu rakaraka), *X. granatum* and *Cerbera manghas* (vasa) in other plots. These species also formed the larger trees found in this forest type with *I. fagifer* recorded as the largest with a dbh of 160 cm. In addition to the above-mentioned species, *A. glabra* and *B. gymnorhiza* were the most common species found in this forest type. Stumps were observed primarily outside the assessment plots, and local guides indicated that trees were harvested for fuel wood and construction materials.

Figure 13: Regularly inundated waterways in the back of the mangrove forest behind Natila Settlement (left) and at Nasilai Village (right).

At site 2, near Waicoka Village, 27 plots along seven transects were used to assess this forest type. The average dbh for all trees assessed was 28.2 cm (range: 5 cm – 149 cm). The average number of trees within a plot was eleven individuals per plot (range: 4 – 20), made up of at least four species. The average height was 8.3 m (range: 5.4 m – 10.6 m). The average relative dominance was 50.2% (range 7.2% – 90.9%). The largest tree recorded was an *I. fagifer* with a dbh of 149 cm. Other large trees recorded from some of the plots included *C. nucifera*, *M. indica* and *C. manghas*. The most common species recorded from the plots included *A. glabra* and *E. agallocha* and those mentioned above. Along sections of the Navuloa River additional common species included *A. pavonina* and *B. racemosa*.

At site 3, vicinity of Nasilai Village, a total of 25 plots along four transects were used to quantitatively assess this forest type. The average dbh for all trees assessed was 21.1cm with an average range from 12.3cm to 50.9cm for trees with sizes ranging from 5cm to 178cm. The average number of trees (with dbh greater than 5cm) within a plot was thirteen individuals with a range of seven to 21 individuals per plot made up of at least five species per plot. The average height was 8.4m with a range of 6m to 11.2m. The average relative dominance was 48.7% (range: 12.0% – 91.9%). The most dominant species were large trees like *I. fagifer* (the largest individual with a dbh of 178 cm), and others such as *Intsia bijuga* (vesi), *Rhizophora* spp., *X. granatum, B. gymnorhiza*, *A. glabra* and *C. nucifera*. The most common species included those previously listed as well as *A. altilis*.

At Site 4, five plots along a transect was used to assess the back of the mangrove forest. The average dbh for all trees assessed was 14 cm (range: 5 cm – 89 cm). The average stocking was 20 trees per plot (range: 14 – 23) made up of at least six species. The

average height was 6.4 m (range: 5.4 m to 7.5 m). The average relative dominance was 26.8% (range: 9.0% – 68.7%) The largest tree was *I. fagifer* with a dbh of 89 cm. Other dominant species were *B. racemosa*, *C. nucifera* and *Pandanus tectorius* (vadra). Overall, the back of the mangrove comprised a secondary forest system that was heavily impacted. There was evidence of high disturbance from natural disasters, human habitation and other activities

Figure 14: Agricultural activities in back of the mangrove forest were common at all sites.

Coastal beach vegetation

Coastal strand and beach vegetation was treated as a single forest/habitat type situated along the foreshore of the beach. There were no mangroves or mangrove associates species found. This vegetation type was estimated to cover a total area of 150 ha across the MESCAL site. A total of nine plots along three transects were used to quantitatively asses this forest type.

The assessment was only carried out at Site 3 at Nasilai beach. A similar forest was observed along Mataisuva beach front (Site 4) but was not assessed due to heavy rain and time constraints.

Figure 15: Coastal beach forest at Nasilai beach, Tailevu.

The average dbh for all trees measured was 22.4 cm (range: 5 cm – 129 cm). The average stocking of trees within a plot was eleven individuals with at least three species per plot. The average height was 7.2 m (range: 4.6 m – 10.3 m). The average relative dominance was 47.5% (range: 23.4% – 84.4%). *C. nucifera* was the dominant species in most plots. Other common species were *Terminalia litoralis, Macaranga* sp.*, Hernandia nymphaeifolia* (evuevu), *Guettarda speciosa* (buabua) and *P. tectorius*.

Figure 16: Stratified forest classification showing the canopy species *Cocos nucifera* and *Pandanus tectorius* (including their saplings) and the ground cover (*Ipomoea pes-caprae*) at Nasilai beach

The most common species found were *C. nucifera* and *P. tectorius* (Figure 16) and the largest tree recorded was *Erythrina variegata* (drala) with a dbh of 129 cm. The ground cover was mostly composed of saplings and seedlings of the trees above, as well as

Calophyllum inophyllum (dilo), *Neisosperma oppositifolium* (vao), *Syzygium richii*, *Canavalia rosea* (drautolu), *Barringtonia asiatica* (vutu gaga), *H. tiliaceus*, *Ipomoea pes-caprae* (wa bula)and the exotic weed *Wedelia biflora* (wedelia)

Lowland rain forest vegetation

In the study area this vegetation was restricted mostly to areas behind the mangrove forest and included agricultural fallow land, plantations and pastures that were situated on ground that was neither regularly inundated nor prone to flooding. In total lowland rain forest was estimated to cover 2, 755 ha across the MESCAL project area. Six plots along three transects at Site 1 were used to quantitatively assess this forest type.

The average dbh for all trees assessed was 40.4 cm (range: 6 cm – 117 cm). The average stocking of trees was nine individuals per plot (range: 5 – 14) and an average of five species per plot. The average height was 11.1 m (range: 7.6 m – 15.9 m). The average relative dominance was 53.7% (range: 31.3% – 93.3%). The dominant species were *Spathodea campanulata* (African tulip), *I. bijuga*, *M. indica*, *I. fagifer* and *L. leucocephala*. The largest tree was *I. bijuga* with a dbh of 117 cm. Another common species was *Dysoxylum richii* (tarawau kei rakaka). The ground cover was mostly composed of saplings and seedlings of the above species.

Overall, lowland rain forest was a secondary forest resulting from years of agricultural development and human habitation, and consisted mostly of traditional fruit and nut trees was well as recently introduced exotic trees e.g. *Pometia pinnata* (dawa), *Spondis dulcis* (wi), *Syzygium malaccense* (kavika), *Dracontomelon vitiense* (tarawau), *B. edulis*, *C. nucifera, Citrus maxima* (moli kana) and *Dioscorea* spp. This forest type was widespread at all four study sites and is economically important sites for the local communities.

Figure 17: Coconut plantation, fallow land, gardens, exotic species and mangrove forest in the background near Natila Settlement, Tailevu.

Acrostichum swampland

This habitat type was not quantitatively assessed, but satellite image analysis and ground truthing estimated that it covers an area of approximately 203 ha across the MESCAL site. These swamps, dominated by the mangrove fern, *Achrostichum aureum*, are regularly inundated with brackish water and are restricted to areas behind mangrove forest. Further inland, the habitat merges with freshwater wetland swamps.

Freshwater wetland vegetation

This habitat type was not quantitatively assessed, but satellite image analysis and ground truthing estimated that it covers an area of approximately 277 ha across the MESCAL site. Most of these wetlands were observed at Sites 2 and 3 and at site 4 where it had been converted to gardens and pasture areas (Figure 18). In some locations around Site 4 wetland areas were being used for human habitation. Three types of wetland swamps were observed: peatbog, grassland and woody shrub swamps.

Peatbog swamps are characterised by stagnant water containing mostly sedges such as *Eleocharis* spp. (kuta), *Dictranopteris* spp. (bracken fern or qato), *Lycopodium cernum* (lewa nini) and occasional individual *P. tectorius* trees. In grassland swamps the dominant species are *Brachiara mutica* (paragrass) and *Paspalum* spp. These areas can be used for cultivation of wetland crops but are prone to flooding. Woody shrub swamps contain woody shrubs like *Premna serrratifolia* (yaro), *P. tectorius, A. glabra* and a variety of sedges and grasses. A few clumps of the mangrove fern *A. aureum* were also observed here.

Figure 18: Wetland dominated by woody shrub land being used for gardening and livestock pasture

1.4 Conclusions and recommendations

One of the most critical problems identified during the survey was the gradual and occasionally extensive degradation of the back of the mangrove and lowland forest habitats. The impact of human activities on the vegetation in these areas is high and it is suggested that a recovery and enrichment intervention program be implemented, that would rehabilitate these degraded habitats through reforestation with selected tree species.

Similarly, the waterways that have undergone dredging activities show evidence of heavy erosion on the foreshores of most villages, causing households to shift housing and farming activities further inland. Replanting the area with appropriate plant species would mitigate the issue.

Any form of large scale logging of mangroves (including clear felling and commercial logging) should be discouraged and instead replaced with selective logging only at designated areas, away from villages and other settlements and also away from river banks and the foreshore. This activity should be closely monitored by a relevant organisation or institution.

It is suggested that each village or settlement living in or near a mangrove area set aside a section of their mangrove forest as a tabu site. These areas are to be carefully selected to assist in protecting and promoting the processes the ecosystem provides.

It is recommended that large sections of mangrove forest at Sites 2 and 4 should be considered for official protection for the genetic resources and ecosystem processes they generate. These areas would be eligible for protection under the Ramsar Convention.

The reclamation of mangroves to make way for agriculture and human habitation should be addressed with greater seriousness and sensitivity. As documented during the survey, large sections of river bank along the main Rewa River outlet have been reclaimed, causing the loss of large stands of prime *Bruguiera* forest. Such reclamation activity needs to be regulated to minimise disturbance to the mangrove ecosystem and the loss of all its associated resources.

2 HERPETOFAUNA

Nunia Thomas and Isaac Rounds

2.1 Introduction

Fiji has the third largest area of mangroves in the Pacific Island region, after Papua New Guinea and the Solomon Islands. Herpetofauna diversity and abundance in Fiji is generally understudied, and particularly so in mangrove ecosystems.

Publications on ecological studies of Fiji's herpetofauna are limited (Zug, 1991, Narayan *et al.*, 2008, Narayan and Hero, 2010, Thomas *et al.*, 2011). Most of the literature is currently limited to field assessments on presence/absence and population change in certain species(Morrison, 2003a, Morrison, 2003b, Morrison, 2004, Fisher *et al.*, 2012b, Harlow and Biciloa, 2001, Harlow *et al.*, 2007, Thomas, 2006, Thomas, 2009),as well as some taxonomic studies (Keogh *et al.*, 2008, Zug and Ineich, 1993).

Herpetofauna, particularly native species, are vulnerable to disturbances because of their small home ranges, sedentary nature and ecological requirements (Benayas *et al.*, 2006). The ecology of Fiji's native species and their responses to disturbance (physical and biological) is data deficient and this alone is cause for concern. Island species like those in Fiji potentially play an important role in pollination or seed dispersal (Olesen and Valido, 2003) or in the control of other types of organisms such as insects, but as yet these factors have not been studied in Fiji.

Herpetofauna surveys in Fiji have generally been based on opportunistic survey methods, but standardised in such a way as to allow for comparison between sites. Because of the cryptic and heliophilic nature of Fiji's reptiles, survey and trap methods for these species are wide-ranging, and limited by weather conditions.

The objectives of this survey were to:

1. Document the herpetofauna diversity in in the MESCAL project area using standardised survey methods;
2. Produce a herpetofauna checklist, with special focus on native, threatened and culturally important species; and
3. Identify actual and potential threats to herpetofauna survival in the area.

2.2 Methodology

2.2.1 Timing and weather conditions

Survey work was conducted at 13 locations in the MESCAL project area. The weather during the survey period (September 18-28, 2013) was not ideal for herpetofauna surveys. The optimal weather for sticky traps and diurnal surveys (i.e. warm and sunny conditions) occurred on only four of the ten days of survey. The average air and water temperatures during the nocturnal surveys were 24.5°C and 23.8°C, respectively.

2.2.2 Habitat assessment

The study area contained several ideal herpetofauna habitats, including agricultural land, true mangrove forest, back of the mangrove forest, mangrove swamps and village areas. In total eight sites (Figure 19) with varying habitat types were intensively surveyed, using standard survey methods described below.

Fiji's native herpetofauna are cryptic in nature, and yield low capture rates during unfavourable weather. For this reason, habitats at which they were collected were recorded, but abundance between habitat types is not analysed. Only presence/absence data is presented in this report. Habitat characteristics and other basic ecological and biological information of herpetofauna found were recorded. Observations on possible threats to herpetofauna species and populations were also noted.

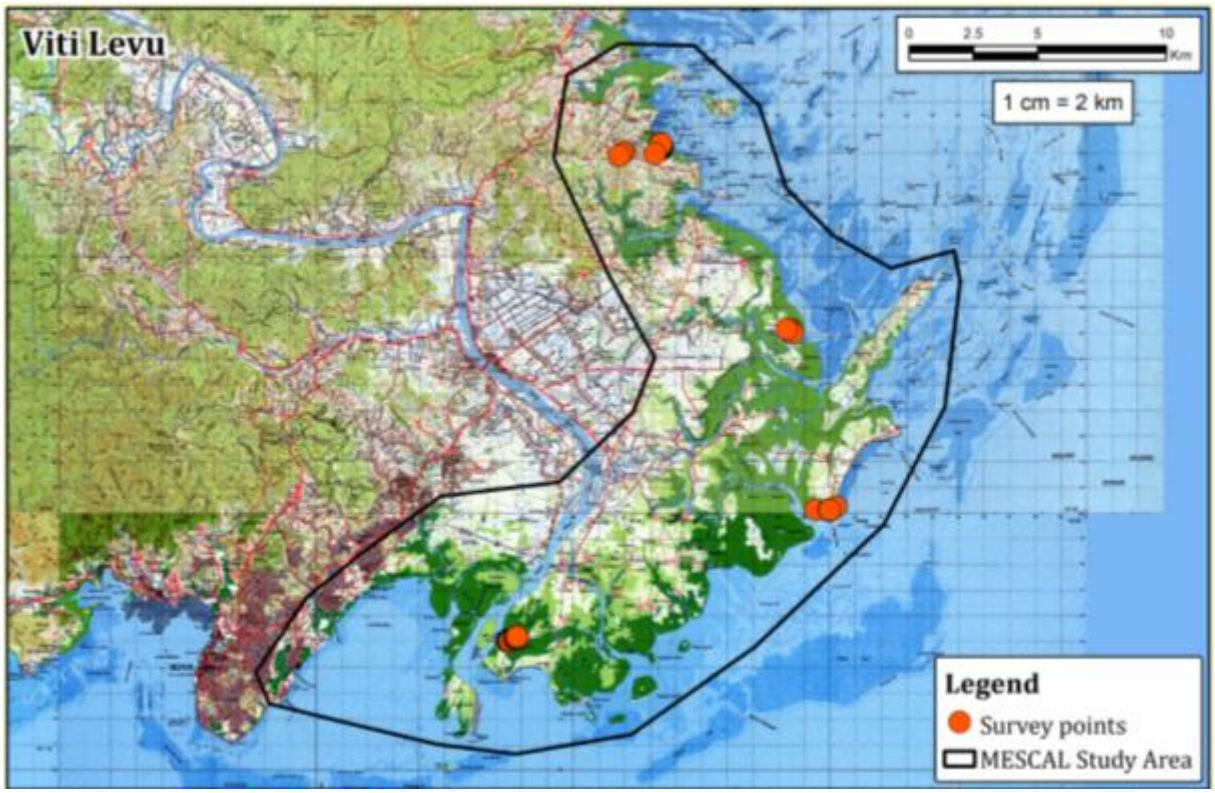

Figure 19: Herpetofauna study sites

2.2.3 Survey Methods

The herpetofauna survey was carried out using the four techniques described below.

Sticky traps

Sticky traps (Masterline®) were laid out at intervals along a transect in habitats idea for herpetofauna e.g. forests, forest margins and agricultural areas. These traps target both terrestrial and arboreal species.

Each interval was designated a station number (1-10) with a cluster of three traps per station, each representing a particular habitat structure (tree, log and ground). Leaf litter cover, canopy cover and undergrowth were all recorded. Traps left overnight were checked regularly for captured specimens.

Standard visual surveys

Frogs and geckoes are more active and visible at night. Standardised (time constrained) nocturnal visual encounter surveys (2 hours) in ideal native frog habitat were carried out (time was reduced to 1 hour if no native frogs were encountered in the first hour of survey). This method gives an encounter rate for comparison with other surveys within Fiji.

Search efforts with a minimum of two observers at any one time targeted potential native frog habitats. Environmental variables such as air temperature, water temperature, weather conditions and percentage cloud cover were taken at the beginning and end of each nocturnal survey.

Opportunistic visual surveys

Opportunistic visual encounter surveys outside of the standardised visual encounter searches allow for a record of presence/absence of herpetofauna. Skinks are more likely to be seen during the day, particularly during hot and sunny conditions.

Opportunistic diurnal surveys were conducted along trails, along the river banks on kayaks, around village gardens, vegetation plots and in forest habitats. Search efforts targeted potential skink habitats and diurnal retreat sites of native frogs and snakes. The diurnal surveys began at 09:00 and ended at 15:00 on each of the survey days. The team had a minimum of two searchers at any one time.

Interviews with local guides

Local guides participating in the field surveys were interviewed during the survey for an indication of presence or absence of target species in the area.

2.2.4 Conservation Value

An assessment of the value of the herpetofauna found in the study area was conducted following Benayas *et al.* (2006), with additional notes from the lead author's perspectives based on previous herpetofauna surveys in Fiji.

Values were assigned to each species based on their conservation status, known ecological role or their listing under the Convention on International Trade in Endangered Species (CITES), Fiji's Endangered and Protected Species Act (EPS) or the UCN Red List of Threatened Species

The points were calculated as follows:

- 1 point was added to a species' score for each of the following attributes: native to Fiji, endemic to Fiji, endemic to Viti Levu, IUCN Red List, CITES Annex 1, CITES Annex 2, EPS Act Schedule 1, EPS Act Schedule 2, food source for other animals, indicator species of environmental status, pet trade, totem animal.
- 1 point was deducted from a species' score for each of the following attributes: introduced species, recognised pest species.
- The final score categories were: No Use/Pest = scores less than 0, Important = scores between 1 and 4, and Very Important = scores over 4.

2.3 Results

Table 3 summarises the survey methods employed at each site and the number of individuals of each species that were captured. Herpetofauna species were captured at three of the four sites i.e. Natila, Waicoka and Nasilai. There were no herpetofauna species captured at the 4th site, Vutia, but this was more likely due to unfavourable weather than to a total absence of herpetofauna.

Three of the four survey methods employed (standard nocturnal and diurnal searches and sticky trapping), on average yielded the same degree of species diversity (2-3 species), but with different species compositions. The guide interviews yielded reports of only two species.

Table 3: Herpetofauna species encountered at all survey sites using different methods

	Date	Survey Locality	Survey method	Species name (no. of individuals captured)
Site 1: Natila Settlement				
1.	17-09-2012	Wailailai. Stream, 1m wide, steep terracing.	Standard 2hr nocturnal survey	*Nactus pelagicus* (2) *Candoia bibroni* (1) *Platymantis vitiensis* (1)
2.	17-09-2012 18-09-2012 19-09-2012	Agricultural area between settlement and mangrove swamp (back of mangrove swamp)	Sticky trap survey	*Gehyra oceanic* (2) *Emoia cyanura (*2) *Hemiphyllodactylus typus* (1)
	18-09-2012		Standard 2hr nocturnal survey	*Bufo marinus* (1)
3.	18-09-2012	Agricultural area between Natila and upper road.	2hropportunistic survey	*Lepidodactylus lugubris* (3) *Gehyra oceanica* (2)
Site 2: Waicoka Village				
4.	19-09-2012	Ivi patch at entrance to village	Standard 1hr nocturnal survey	*Bufo marinus* (1)
5.	20-09-2012	Vunimoli	3hr opportunistic survey	*Gehyra oceanica* (3) *Lipinia noctua* (1)
6.	20-09-2012 21-09-2012	Navola	18hr sticky trap survey	*Emoia cyanura* (1)
7.	21-09-2012	Naitata	3hr opportunistic survey	*Gehyra oceanica* (3) *Nactus pelagicus* (1)
Site 3: Nasilai Village				
8.	24-09-2012	Nukurua-Nasilai	Standard 5hr survey, kayak	*Gehyra oceanica (3)*
9.	25-09-2012	Navaimau, Vunimoli, Vaturua	5hr opportunistic survey, kayak	*Gehyra oceanica* (2) *Candoia bibroni* (1)
10.	25-09-2012	Nukutubu	Standard 1hr nocturnal survey	*Gehyra oceanica* (3) *Bufo marinus* (4)
11.	25-09-2012 26-09-2012	Nukutubu	Sticky trap survey	none
Site 4: Vutia				
12.	27-09-2012 28-09-2012	Kobisi	18hr sticky trap survey	none
13.	27-09-2012 28-09-2012	Kobisi	Opportunistic survey	none

The survey targeted 20 herpetofauna species (Table 4) that could potentially occur in the study area. Of the ten species captured, two were endemic (*Platymantis vitiensis* and *E. concolor*), six were native (*Candoia bibroni, Gehyra oceanica, Nactus pelagicus,*

*Hemiphyllodactylus typus, Lipinia noctua, Emoia cyanu*ra) and two were invasive (*Bufo marinus, Lepidodactylus lugubris*).

These ten species were captured over 14 man-hours of diurnal survey, 71 hours of sticky trapping and 6 man-hours of nocturnal surveys. Two species were not encountered during the survey but were reported to occur by local villagers: *Brachylophus bulabula* (the endemic banded iguana) and *Platymantis vitianus* (the endemic Fiji ground frog). The team surveyed the reported site of the Fiji ground frog at Wailailai, Natila but only encountered the endemic sister species, *P. vitiensis* (the Fiji tree frog).

Table 4: List of species that historically occur on Viti Levu, their conservation status and cultural importance

Common names: English, Fijian	**Scientific name**	**Conservation Status IUCN Red List 2013**	**Cultural status in Fiji**
Iguanas			
*∞banded iguana vokai, saumure	*Brachylophus bulabula*	Viti Levu Endemic Endangered(Fisher *et al.*, 2012a)	Totem
Snakes			
*†Pacific boa gata, gwata, balei	*Candoia bibroni*	Native Least Concern(Allison *et al.*, 2012)	Totem
*Fiji burrowing snake gata, gwata, balei	*Ogmodon vitianus*	Viti Levu endemic Endangered(Allison *et al.*, 2013c)	Totem
Geckoes			
*giant forest gecko moko kabi	*Gehyra vorax*	Native	Totem (not species specific)
*†oceanic gecko moko kabi	*Gehyra oceanica*	Native	Totem (not species specific)
†mourning/Pacific gecko, moko kabi	*Lepidodactylus lugubris*	Introduced	
*Mann's Gecko moko kabi	*Lepidodactylus manni*	Endemic	Totem (not species specific)
*†slender toed gecko moko	*Nactus pelagicus*	Native Least Concern(Zug *et al.*, 2013)	Totem (not species specific)
house gecko moko kabi	*Hemidactylus frenatus*	Introduced	Totem (not species specific)
fox gecko moko kabi	*Hemidactylus garnotti*	Introduced	Totem (not species specific)
†*Indopacific tree gecko moko	*Hemiphyllodactylus typus*	Native	Totem (not species specific)
Skinks			
*Pacific black skink moko loa	*Emoia nigra*	Native, extirpated from Viti Levu	Unknown
*barred tree skink moko sari	*Emoia trossula*	Native, extirpated from Viti Levu. Endangered(Allison *et al.*, 2013b)	Totem (not species specific)
*†moth skink moko sari	*Lipinia noctua*	Native	Totem (not species specific)

Common names: English, Fijian	Scientific name	Conservation Status IUCN Red List 2013	Cultural status in Fiji
*pygmy snake-eyed skink, moko sari	*Cryptoblepharus eximius*	Endemic	Totem (not species specific)
*montane tree skink moko sari	*Emoia campbelli*	Endemic Endangered(Fisher *et al.*, 2013)	Totem (not species specific)
*†green tree skink moko sari	*Emoia concolor*	Endemic Near Threatened(Hamilton *et al.*, 2013)	Totem (not species specific)
	Emoia sp. nov. ? (Watling & Thomas, unpub.)	Viti Levu endemic	Unknown
*blue-tailed copper-striped skink, moko sari	*Emoia impar*	Native Least concern(Hamilton *et al.*, 2012)	Totem (not species specific)
*†brown-tailed copper-striped skink, moko sari	*Emoia cyanura*	Native	Totem (not species specific)
*bronze-headed skink moko sari	*Emoia parkeri*	Endemic Vulnerable(Allison *et al.*, 2013a)	Totem (not species specific)
Amphibians			
†marine/cane toad botokarokaro	*Bufo marinus*	Introduced, Invasive	None
*†Fiji tree frog ula	*Platymantis vitiensis*	Endemic, Near Threatened(Zug *et al.*, 2004b)	Totem
*∞ Fiji ground frog ula, dreli, botoniviti	*Platymantis vitianus*	Endemic Endangered(Zug *et al.*, 2004a)	Totem
* Target species (endemic, native and endangered) of MESCAL survey † Species captured during the survey ∞ Species not captured, but reported to be present by the local guides			

The conservation values attributed to each of the captured species are presented in Table 5. The highest ranked species were *P. vitiensis*, *E. concolor* and *C. bibroni*, with scores of 7, 6 and 5, respectively.

Table 5: Calculated conservation values of herpetofauna species captured in the MESCAL demonstration site

Category	Species	Conservation Value
Very important	*Platymantis vitiensis*	7
	Emoia concolor	6
	Candoia bibroni	5
Important	*Lipinia noctua*	4
	Emoia cyanura	4
	Gehyra oceanica	3
	Nactus pelagicus	3
	Hemiphyllodactylus typus	3
Introduced/Pest	*Lepidodactylus lugubris*	-1
	Bufo marinus	-2

Invasive ants (*Anoplolepis gracilipes*) were also captured on the sticky traps. Interestingly, no rats were captured on the sticky traps despite being observed during nocturnal surveys. Other known herpetofauna threats observed were mongooses, pigs (community owned, free-roaming at village outskirts) and domestic cats.

2.4 Discussion

This expedition confirms the presence of ten species of herpetofauna within the MESCAL project area; of which eight are native; and four listed as threatened under the IUCN Red List of Threatened Species. The current state of knowledge on the distribution of Fiji's native and introduced herpetofauna has been based primarily on opportunistic surveys carried out in different parts of the country. This current survey of the Rewa delta mangrove system will contribute to filling in knowledge gaps on herpetofauna distribution in Fiji.

The low encounter rates and low diversity of herpetofauna in the study sites do not necessarily mean an absence or scarcity of the species. Low encounter rates of heliophilic species (skinks and geckoes) were expected given the location of the study area and its habitat types, and are typical globally in tropical rain forest habitats (Ribeiro-Junior *et al.*, 2006).

The presence of the Fiji tree frog (*Platymantis vitiensis*), and the absence of the Fiji ground frog (*P. vitianus*) in the study area is of exceptional interest, considering that the latter occurs offshore of Natila settlement on Viwa Island. This study confirms the absence of the Fiji ground frog from the study area and raises more questions on the apparent disjunct distribution of the species between the Nakauvadra mountain range in Ra and Viwa Island in Tailevu.

Of particular significance in this expedition was the presence of the native Indo-Pacific tree gecko, *Hemiphyllodactylus typus*, historically common to disturbed areas in Fiji but seemingly displaced by introduced geckoes (Morrison, 2003).

Fiji's terrestrial herpetofauna are significantly impacted by introduced mammalian predators. This is particularly true for Viti Levu which has seen the extirpation of two large terrestrial skinks (*Emoia trossula* and *E. nigra*) in the presence of the mongooses, feral cats, feral pigs and rats, all of which were present in the study area and are known predators of herpetofauna and their nests, eggs and young. The direct impact of invasive ants on Fiji's herpetofauna has not been studied, however they have been observed attacking injured herpetofauna in other study sites in Fiji.

The MESCAL demonstration site is a good location for long term detailed monitoring studies of Fiji's herpetofauna. Intact mangroves and mangrove associate forests will need to be surveyed in greater detail to document and understand herpetofauna diversity in this vegetation type.

3 AVIFAUNA

Alivereti Naikatini

3.1 Introduction

Fiji's avifauna comprises the terrestrial and marine species of birds and bats that either live in Fiji year-round or that migrate through the archipelago at different times. Overall, data on the feeding, roosting and nesting habitats of Fiji's avifauna is limited.

There are 68 species of land birds found in Fiji, 57 of which are native. Mangrove areas in Fiji have not been the focus of many targeted avifauna surveys in the past, since there is a general understanding that bird diversity in this ecosystem is low. It is important to note therefore that none of Fiji's Important Bird Areas or IBAs include mangroves(Masibalavu and Dutson, 2006).

However, the contribution of birds in any ecological system is crucial and there is a need for further in-depth ecological and long term studies of this faunal component of the mangrove ecosystem. Mangroves are often associated with vast areas of mudflats and sandflats which are important foraging areas for shorebirds. Seabirds also feed in the inshore area along mangrove forests.

Bats are the only native terrestrial mammals of Fiji and six species occur here, four of which are native and two of which are endemic(Flannery, 1995, Palmeirim *et al.*, 2007). Four of the six species are listed as threatened(Palmeirim *et al.*, 2007). Like bats, birds are important indicators of forest health. They are also important seed dispersers, pollinators and insect control agents.

The objectives of the avifauna survey were to:

- provide an annotated checklist of all the avifauna species (birds and bats) observed in the study site,
- highlight species that are of conservation importance (focal species),
- provide preliminary data on the abundances of species present,
- determine the importance of each species to humans and as well as its role in the ecosystem.

This study is crucial because it will provide baseline data to monitor mangrove avifauna biodiversity in the future, inform conservation measures, and put value to each focal species recorded.

3.2 Methodology

Four assessment methods were used to identify the avifauna species present in the MESCAL demonstration site: point counts, crepuscular surveys with a bat detector, opportunistic surveys and interviews with the local communities.

3.2.1 Point counts

Point counts were the most commonly used technique during the survey. Ten minute counts were carried out at each station, as this time period has been previously determined to be the most time-effective(Naikatini, 2009). To avoid double counts the point stations were placed 200-400m apart. All birds and bats detected within a 50m radius were recorded at each station. A rangefinder was used to estimate the distance from the observer to the bird. Point counts were done just after dawn and just before dusk, when birds are the most active. Count stations were selected based on accessibility in dense mangrove areas, and kayaks were used to access some areas.

3.2.2 Bat detector aided crepuscular surveys

A bat detector was used in the evenings between 7pm and 10pm when weather conditions were favourable. The observer walked along a pre-determined trail, stopping at various points where an opening or gap appeared in the canopy and aimed the bat detector at the sky. The bat detector was tuned into frequencies at which the two microbat species present in Fiji would be detected if they flew over or were feeding nearby.

3.2.3 Opportunistic surveys

Opportunistic surveys were conducted whilst travelling between point count stations and between survey sites. At mud or sand flats, shorebirds and seabirds in flight or feeding at these sites were recorded. Whilst travelling by boat along the coastline feeding seabirds flying close to the mangroves were also recorded.

3.2.4 Interviews with the local community

Local guides and villagers were interviewed to document what knowledge the local community had of bats in the area (in particular roost locations), as well as information on bird species they may have encountered in the mangroves.

3.2.5 Species ranking

Species that were determined to be present in the area were assigned scores to that reflected how important they were to the ecosystem. The scores were calculated based on the following attributes:

- 1 point was added to a species' score for each of the following attributes: indigenous/regular visitor; Fiji endemic; island endemic; IUCN Red Listed; CITES listed; indicator species; pollinator; seed disperser; food source for humans; food source for other birds and animals, insect controller, carnivore, bird of prey.
- 1 point was deducted from a species' score for each of the following attributes: introduced species, recognised pest.
- The score of each species was used to classify its importance: <1= no use/pest; 1= some use; 2-3= useful; 4=very useful; 5-6= important; >6 = very important.

3.3 Results

3.3.1 Avifauna diversity and distribution

A total of 97 point counts were carried out, covering an area of 76 ha and totalling over 36 man-hours. Figure 20 shows the location of all locations where point counts were conducted in the Rewa river mangroves. Surveys of seabirds and shorebirds were carried out at the points shown in Figure 21. Figure 22 highlights the confirmed locations of roosts of two bat species (*Pteropus samoensis* and *P. tonganus*), as well as some unconfirmed locations of *P. tonganus* roosts.

A total of 36 bird species (two seabirds, six shorebirds, 28 landbirds) and two species of bats were recorded during the survey (the full checklist is provided in Appendix 4). The landbirds recorded comprised a wide range of generalist species that are common to secondary and disturbed habitats in Fiji. A total of ten habitat types were surveyed and the summary of the bird diversity in each habitat is summarised in Table 6.

Butorides striatus (mangrove heron), a shy, secretive bird which is rarely seen in the open, was recorded frequently in the mixed mangrove habitat and the *Bruguiera* zone, an indication of the enormous size of the mangrove forest in the Rewa Delta and that much of the mangrove ecosystem is still intact. Four species of introduced birds, *Pycnonotus cafer* (red vented bulbul), *Acridotheres fuscus* (jungle myna), *Amandava amandava* (red avadavat) and *Streptopelia chinensis* (spotted dove), were observed in the study area.

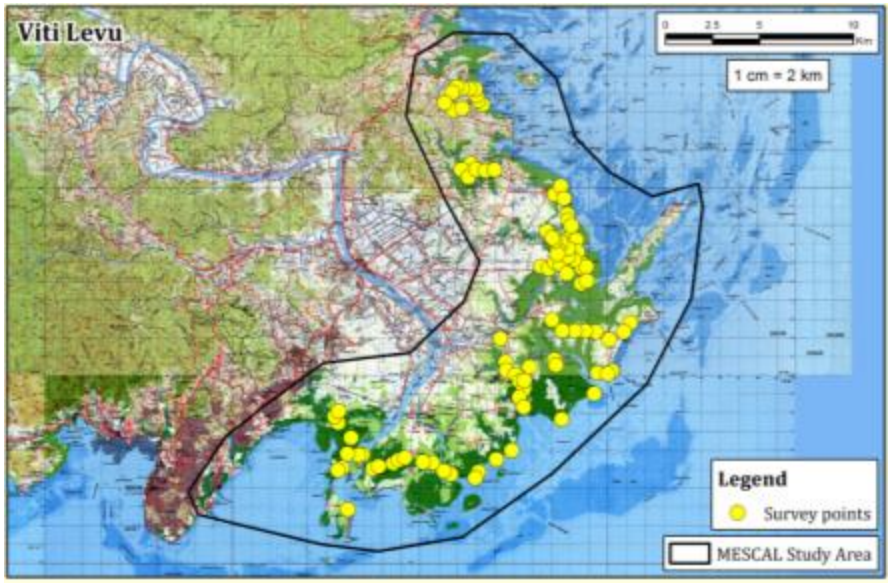

Figure 20: Landbird survey sites

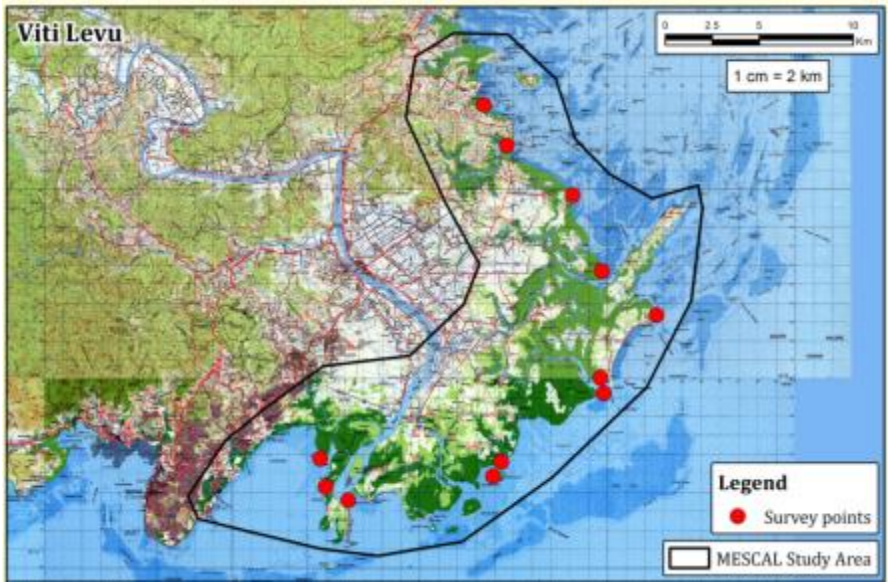

Figure 21: Shore and seabird survey sites

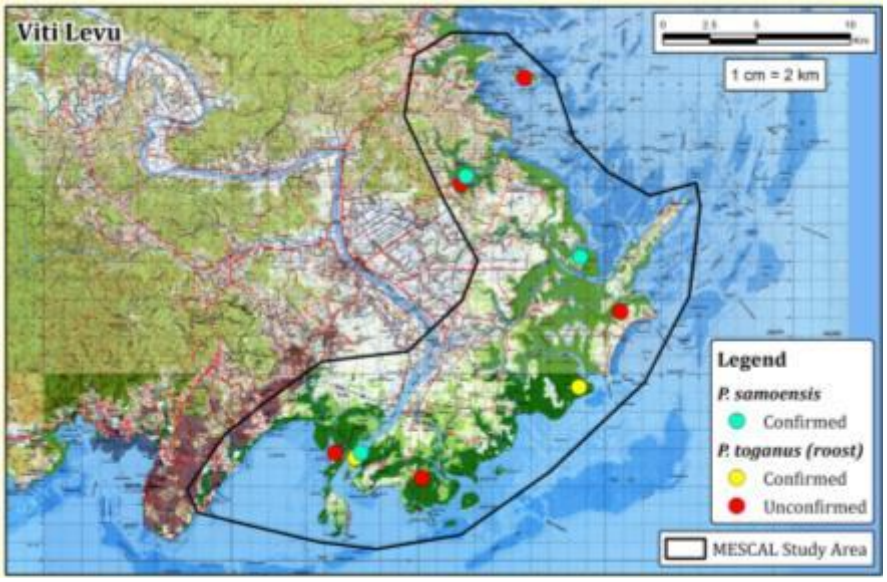

Figure 22: Bat survey sites

Table 6: Avifauna species recorded in the different habitats of the Rewa River mangroves and their ecosystem importance score

	Species	Habitat Types*										Importance score and category
		Rhi	Mix	Bru	Bom	BoP	Coa	HuP	Fru	Sec	Sho	
Land birds	Vanikoro broadbill	x	x	x	x	x	x	x	x	x		3 Useful
	white-collared kingfisher	x	x	x	x	x	x	x	x	x		4 Very useful
	jungle myna	x	x	x	x	x	x	x	x	x		-1 No use/pest
	wattled honeyeater	x	x	x	x	x	x	x	x	x		3 Useful
	orange-breasted myzomela	x	x	x	x	x	x	x	x	x		4 Very useful
	Polynesian triller	x	x	x	x	x		x	x	x		4 Very useful
	slaty monarch	x	x	x	x		x	x	x	x		3 Useful
	white-rumped swiftlet	x	x		x	x	x	x	x	x		2 Useful
	silvereye	x		x	x	x	x	x	x	x		3 Useful
	red-vented bulbul	x		x	x	x		x	x	x		-1 No use/pest
	eastern reef heron	x	x	x	x		x	x				3 Useful
	Fiji bush warbler		x		x	x		x	x	x		3 Useful
	spotted dove			x		x	x	x	x	x		0 No use/pest
	Pacific black duck	x	x		x			x	x			1 Some use
	collared lory			x	x			x		x		4 Very useful
	golden dove			x	x				x	x		3 Useful
	many-coloured fruit dove	x	x		x							2 Useful
	lesser shrikebill				x			x	x			3 Useful
	Fiji woodswallow						x		x	x		3 Useful
	red avadavat						x	x	x			0 No use/pest
	Pacific harrier	x			x							3 Useful
	mangrove heron		x	x								4 Very useful
	streaked fantail					x			x			3 Useful
	scarlet robin					x		x				3 Useful
	Fiji goshawk				x							5 Very useful
	white-faced heron					x						3 Useful
	Fiji parrotfinch							x				3 Useful
	barking pigeon									x		5 Important
Shore birds	Pacific golden plover										x	3 Useful
	ruddy turnstone										x	3 Useful
	far eastern curlew										x	3 Useful
	wandering tattler										x	3 Useful
	bar-tailed godwit										x	3 Useful
	Terek sandpiper										x	3 Useful
Sea birds	lesser frigate										x	2 Useful
	crested tern										x	3 Useful
Bats	Pacific flying fox		x			x		x	x	x		4 Very useful
	Samoan flying fox		x		x							6 Important
Total number of species per habitat		14	13	14	19	14	12	19	18	16	8	

*Habitat types: Rhi=*Rhizophora*, Mix=mixed mangroves, Bru=*Bruguiera*, Bom=back-of-the-mangrove, BoP=borete and *Pandanus* swamp, Coa=coastal, HuP=human habitation and plantation, Fru=fruit trees, Sec=secondary forest, Sho=shoreline (coast, mudflats, sandflats etc.)

Only two species of bats were recorded during the survey, *Pteropus samoensis* (Samoan flying fox) and *P. tonganus* (Pacific flying fox). No microbats were detected over the six nights of surveying with the bat detector. Intact mangrove forest areas are often inaccessible and provide good roosting places for tree dwelling bats; five confirmed roost locations were recorded during the survey (Figure 22). The presence of *P. samoensis* is a good indication of the health and extent of these mangroves, as this species is normally observed in intact primary rain forest systems and rarely in open areas or secondary forest.

The back-of-the-mangrove habitat and areas of human habitation recorded the highest number of species. *Rhizophora*-dominated, *Bruguiera*-dominated and mixed mangrove vegetation only recorded the presence of 13-14 species, which further strengthens anecdotal reports of low bird diversity in mangrove areas. Shoreline, coastline and mud or sand flats areas had the lowest diversity, as only shore and sea birds were recorded in this habitat.

Five of the 28 landbird species were ubiquitous throughout all nine habitats (excluding the shore habitat): *Foulehaio carunculata* (wattled honeyeater), *Todirhamphus chloris* (white collared kingfisher), *Myiagra vanikoroensis* (Vanikoro broadbill), *Myzomela jugularis* (orange-breasted myzomela) and *Acridotheres fuscus* (introduced jungle myna). These five species tend to be the most commonly detected and abundantly encountered bird species in Fiji. The other 23 species were more restricted to other habitats. This could be due to food availability, predators, accessibility and other factors.

3.4 Discussion

Since mangrove areas are known to have generally low bird diversity, it was not surprising that the species recorded in the MESCAL site were mostly generalists, which are commonly observed in any forest system in Fiji.

The only species of conservation concern recorded in this survey was *Pteropus samoensis*, which is classified as Near Threatened on the IUCN Red List (Brooke and Wiles, 2008), and is also listed in the CITES Appendix I. Its presence suggests that the Rewa River mangroves are an important habitat for this species in Fiji. Three other species of conservation significance are listed on the CITES Appendix II: *Phigys solitaries*, (collared lorry), *Circus approximans* (Pacific harrier) and *Accipiter rufitorquoes* (Fiji goshawk).

The rating system developed for this report is a novel methodology, being applied for the first time to a Fiji avifauna survey. The scores for each species provide a rudimentary means of ranking a species contribution to ecosystem functioning, as well as its conservation significance. However, caution must be exercised when interpreting the results of this evaluation as the categories are qualitative. Further studies of this nature would allow for more quantitatively-assigned categories and therefore statistical analyses.

Shorebirds commonly forage for food in mudflat and sand flats areas (adjacent to mangrove forests), which are exposed during low tides. These exposed areas are rich with invertebrate fauna and are ideal foraging grounds for shore and sea birds. There is a large information gap on shorebird abundance in the Rewa delta, during the warmer months of October to May, when these birds migrate to Fiji. During the ten day MESCAL survey, not many shorebirds were recorded as it was not the migratory season. There is a need for a follow-up survey to determine the diversity and abundance of shorebirds in each feeding site in the Rewa River mangroves.

Similarly, for landbirds there is a need for follow-up studies to determine the abundance of each species in the different habitats. The species checklist compiled is a result of a ten day survey period and cannot be used as a stand-alone reference for monitoring of avifauna in this area. Determining the density of each species in each habitat will enable the monitoring bird populations across the ten different habitats of the Rewa River mangroves in the future.

4 INSECTS

Hilda Waqa-Sakiti

4.1 Introduction

This baseline survey, the first entomological survey in the area was carried out with the primary aim of determining the general diversity of insects within the Rewa River mangroves. Entomological surveys were conducted targeting different habitats within this system (e.g. *Bruguiera* forest, mixed mangrove, back of the mangrove and agricultural land) and employing a variety of collection techniques (light traps, leaf litter sampling, active and opportunistic surveys). The general diversity of insects was documented and their significance in terms of the ecosystem services they provide is discussed.

The objectives of the study were to:

- conduct a baseline assessment of insects within selected areas of the Rewa River mangroves,
- document the presence of species that are of national or international significance.

4.2 Methodology

4.2.1 Site selection and habitat considerations

Four representative habitat types within the mangrove ecosystem were selected for this study:

- Bruguiera mangrove forest, comprising pure stands of a single species *Bruguiera gymnorhiza* (dogo)
- A mixed mangrove forest comprising *Bruguiera* sp., *Rhizophora* spp. and other mangrove tree species
- back of the mangrove dominated by *Inocarpus fagifer* (ivi), *Cocos nucifera* (coconut) and *Pandanus tectorius* (vadra),
- agricultural land & grassland comprising *Manihot esculenta* (cassava), *Colocasia esculenta* (taro), *C. nucifera* and *Ipomoea batatas* (sweet potatoes)

4.2.2 Survey methods and sites

Nocturnal surveys were conducted using ultraviolet light traps. These were set at night (weather permitting) and left to run from 6pm to 6am. Insects have been sorted to Order and then to Family level. Specimens were curated, catalogued and placed in long-term storage at the South Pacific Regional Herbarium (SPRH), Suva.

Leaf litter surveys were conducted; using 1 m^2 quadrats which were sampled at 5 m intervals along a 50 m transect within the vegetation plots. Leaf litter was sieved through 12 mm mesh sieves and later transferred into Winkler bags hung for at least 48 hours to dry. Specimens were transferred into ethanol filled, tightly sealed and labelled vials for further sorting and identification in the lab.

Butterflies were also actively sampled using handheld nets on days with fine weather conditions. Voucher specimens were taken for identification. Prasad & Waqa-Sakiti (2007), a guide to the butterflies of Fiji, was used for identification of the butterfly specimens.

Insects were also sampled opportunistically while carrying out surveys for other taxa

4.3 Results

4.3.1 Insect diversity

Specimens from a total of 34 insect families were collected (Table 7). The family Elateridae was commonly encountered during nocturnal surveys using light traps. Rare families such as Cerambycidae, Cicindelidae and Passalidae were also collected within the surveyed sites.

A total of 20 species were recorded for the Order Lepidoptera (i.e. butterflies & moths) of which two are endemic butterfly species: *Papilio schmeltzi* (Fijian swallowtail butterfly) and *Xois sesara*. This survey contributed the first records for *P. schmeltzi* from this area i.e. Natila, Anitioki and Waicoka (in Tailevu) and Nasilai (in Rewa).

The moth collection included a total of three endemic species (*Calliteara fidjiensis, Cleora nausori, Cleora injectalia*), two species that are considered agricultural pests (*Spodoptera litura, Pilotecera melanougus*) and three widespread species (*Rusicada nigritarsis, Striglina navigatorum, Giaura* spp.).

Overall, the insect diversity within the area was not observed to be locally or internationally significant in terms of endemic, rare or threatened species. However, these insects do contribute significantly to ecosystem services.

Table 7: Insects recorded from the Rewa River mangroves survey and their ecosystem functions

Order	Family	Ecosystem Functions (at the family level)	Species (*=endemic)	Collection method			
				LT	LL	BF	OS
Coleoptera	Anthribidae	Herbivory, seed predation			1		
	Cerambycidae	Decomposition		5			3
	Chrysomelidae	Herbivory, pollinators		1			
	Cicindelidae						1
	Curculionidae	Herbivory, decomposition, pollinators, seed predation		1			
	Dytiscidae			1			
	Elateridae	Decomposition, predation, herbivory		9			
	Eucnemidae			1			
	Nitidulidae	Decomposition, pollinators, seed predation, herbivory		3			
	Passalidae	Decomposition		1			
	Scarabaeidae	Herbivory, dung decomposition, pollinators, decomposition		5			
	Scolytidae	Decomposition		1			
	Staphylinidae	Pollinators, fungal feeders		1			
	Tenebrionidae	Decomposition, pollinators, fungal feeders		2			
Diptera	Drosophilidae			1			3
	Muscidae			1			2
	Stratiomyidae			1			
Hemiptera		Herbivory, predation, parasitic		4			
Hymenoptera	Formicidae	Seed dispersal, predation, pests		3	147		4
Orthoptera	Gryllidae	Good indicators of sustainable land use		2			
	Acrididae						1
	Tettigonidae						2
Lepidoptera	Lymantridae	Many forestry & agricultural pests	*Calliteara fidjiensis**	1			
	Noctuidae	Night pollinators, pests	*Spodoptera litura*	1			
	Geometridae	Pollinators, Bio-indicators for climate change (sensitive to temperature), some are pests	*Cleora injectaria**	1			
			*Cleora nausori**	1			
	Thyrididae		*Striglina navigatorum*	1			
	Noctuidae	Herbivory, some are pests	*Rusicada nigritarsis*	1			
			Eudocima fullonia				1
	Pyralidae	Mostly agricultural pests	*Piletocera melanauges*	1			
	Nolidae		*Giaura sp*	1			
	Ctenuchidae	Pollinators	*Euchromia creusa*			1	
	Papilionidae	Herbivory	*Papilio schmeltzi**			8	
	Nymphalidae	Herbivory, pollinators	*Euploea boisduvalii*			7	
			Euploea nemertes			6	
			Eurema sulphurata			6	
			Hypolimnas bolina			4	
			Hypolimnas octocula			1	
			Melanitis leda			1	
			*Xois sesara**			11	
	Hesperiidae	Herbivory	*Oriens augustula*			4	
	Lycaenidae	Herbivory, pests	*Jamides bochus*			2	
Phasmatodea	Phasmatidae	Herbivory, pests					4
Scorpiones							1
Araneae				1			4
Collection methods: LT:=Light Trap, LL:=Leaf Litter sampling, BF:=Butterfly surveys, OS:=Opportunistic surveys							

4.4 Discussion

Although the entomological survey within the Rewa River mangroves did not any record locally or internationally significant (i.e. endemic , rare or threatened) species, the important role insects play in providing vital ecological services such as pollination, decomposition, pest control and wildlife nutrition proves the need for efforts towards their conservation within their ecosystems.

Insects comprise the most diverse and successful group of organisms and they contribute significantly to vital ecological functions such as pollination, pest control, decomposition, and maintenance of wildlife species. These complex interactions result in food production and waste removal, which are vital ecosystem services. These ecosystem services need to be assigned economic values, so that insect conservation can be valued in the same way as other taxa that have more readily calculable economic value due to their direct consumption by humans.

Estimating even a minimum value for a subset of the services that functioning ecosystems provide may help establish a higher priority for their conservation. A study by Losey and Vaughan (2006)estimated the annual value of a subset of ecological services provided by insects (i.e. dung burial, pest control, pollination, and wildlife nutrition) in the United States to be at least USD 57 billion, an amount that justifies greater investment in the conservation of these essential service providers.

4.4.1 Recommendations

- Preserve mangrove ecosystems in the Rewa River and prevent further habitat loss due to fuelwood harvesting (identify an alternative to meet energy needs or implement sustainable firewood management).
- Increase community awareness and develop training for mangrove management with landowners.
- Enhance the conservation status of insects by estimating the economic value of ecosystem services provided by them within the mangrove ecosystem.
- Conduct mangrove seed viability studies focusing on seed predation by insects.
- Conduct long-term mangrove health monitoring.

5 BRACKISH-WATER FISH AND CRUSTACEANS

Lekima Copeland, Fulori Nainoca, Semisi Meo and Rusiate Ratuniata

5.1 Introduction

The natural products and ecological services provided by mangrove ecosystems make them critically important for climate change mitigation and adaptation. Mangrove forests worldwide have been converted into other alternative uses primarily due to the undervaluation of this natural system. The complexity in placing a monetary value on all relevant factors has contributed to this trend in undervaluation (Ronnback, 1999).

There are currently 166 species of brackish and freshwater fish recorded from tidal reaches upwards, 156 of which are native to Fiji (Jenkins, 2009). At least eleven fish species are considered endemic to the insular waters of Fiji. This includes the largest archipelagic endemic riverine fish in the Pacific Islands, *Mesopristes kneri* (Jenkins, 2009).

Few studies have been carried out on Fiji crustaceans and the majority of the research to date has focused on freshwater ecosystems. A total of 25 crustacean species have been recorded in freshwater in Fiji, three of which are endemic (Marquet *et al.*, 2002).

The objectives of this survey were to:

1. Undertake a rapid assessment of fish and crustacean assemblages along four distributaries of the Rewa River (Natila, Waicoka, Nasilai and Vunidawa).
2. Produce baseline information with a preliminary annotated checklist of brackish water fish and crustaceans across the four river systems.

5.2 Methodology

5.2.1 Sampling sites

The Rewa River mangroves are the largest area of mangrove forest in Fiji and also include the largest peat swamp in Fiji (Bonatoa swamp). This large fluvial system is host to an array of brackish and freshwater fauna and flora. Four river systems in the Rewa Delta mangrove system were sampled (Figure 23).

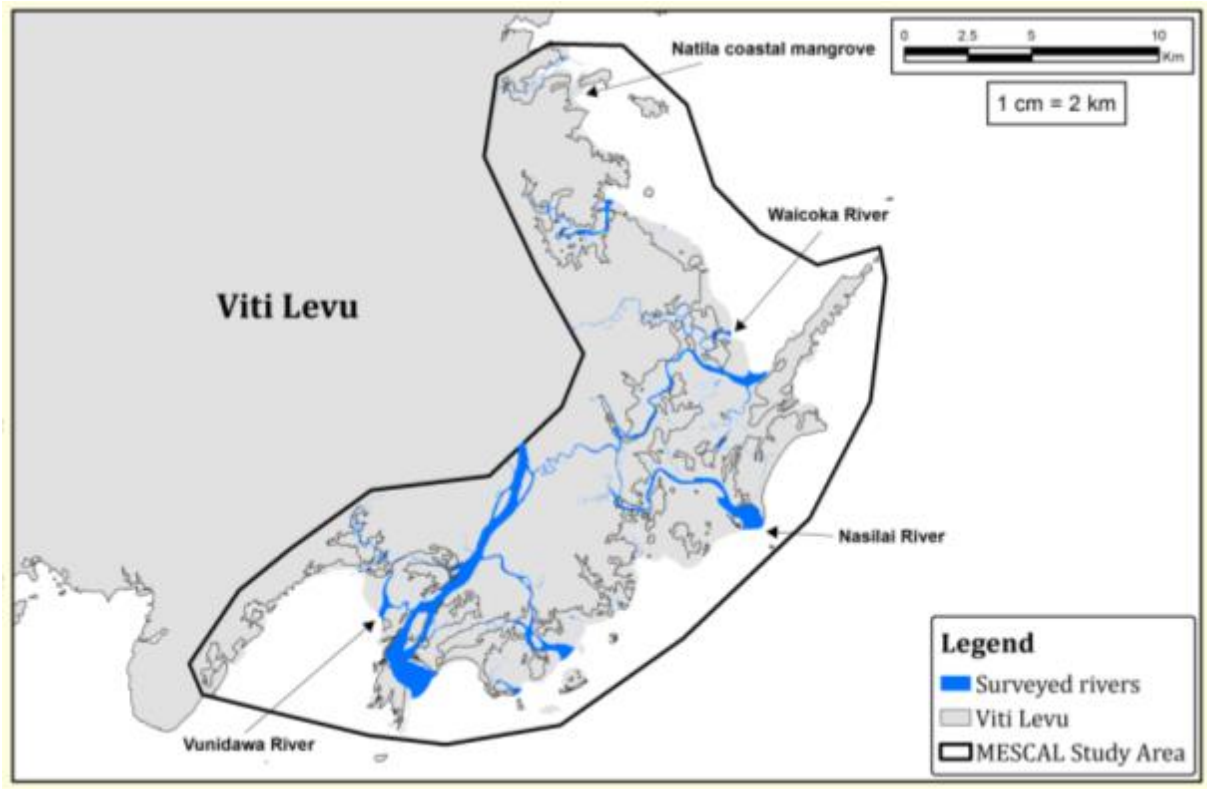

Figure 23: Map of the study area showing rivers systems sampled

Samples sites within these river systems were selected so as to cover the mangrove zones characterised by Sheaves & Johnston (2012). These zones are detailed in Table 8. One of the zones (upstream sedge) was not sampled.

Table 8: Mangrove zone characteristics, adapted from Sheaves and Johnston (2012)

Zone	Characteristics
Coastal mangrove	Mainly *Rhizophora* mangroves growing along island shorelines outside of estuaries. There may be associated sand/mud flats, sometimes with areas of seagrass or macro-algae.
River mouth sand flat	Shallow sandy areas outside of mangrove estuaries, at the interface of the estuary and the coastal zone.
Downstream mangrove	The upper part of the current extent of mangrove forest (approximately the last 3km of current mangrove extent). This area has more constant freshwater influence than the downstream mangrove zone.
Upstream mangrove	The upper part of the current extent of mangrove forest (approximately the last 3km of current mangrove extent). This area has more constant freshwater influence than the downstream mangrove zone.
Upstream sedge (not sampled in this survey)	The zone immediately upstream of the current mangrove forest extent. This zone has eroding banks with little vegetation on the outside of bends and a vegetated margin on depositional banks dominated by sedges on the inside of bends. There are scattered mangroves along the depositional banks but forests have apparently been cleared. This zone has extensive human impacts along its banks.

5.2.2 Sampling methods

A variety of collection techniques were used to gain as comprehensive a sample as possible to determine presence or absence of different species at the survey sites. Appendix 6, Appendix 7, Appendix 8 and Appendix 9 provide details on the precise location, time, habitat and zones in which these methods were deployed.

Gill net

Gill net sampling was conducted in water deeper than 50 cm, using one 25 m x 2 m net (0.1 m mesh size) and two 30 m x 3 m nets (0.05 m mesh size), with a soak time of approximately one hour. This method targeted larger mobile brackish water fauna.

Fyke net

A fyke net was deployed in shallow drainage channels during high tide and was retrieved when all water had drained out at low tide.

Beach seine

Seining was conducted in low angle banks with a relatively firm bottom at the mouth of the river system during low tide.

Cast net

Cast netting (Figure 24) was undertaken in all zones along two major bank habitats; erosional and accreting banks. A single net thrower did all the casting throughout the study. Cast netting was done during low tide when all fish would be in the main channel. This method was used across all zones to provide standardization.

Figure 24: An example of a good cast net being thrown as close as possible to the edge of the water

5.2.3 Water quality

Water quality readings were taken at fish sampling sites before fishing commenced. Dissolved oxygen, temperature, pH, salinity and turbidity were measured using a commercial handheld GPS Aquameter and AP-1000 Aquaprobe. Water clarity was measured using a Secchi disk. Appendix 10 shows the water quality readings for all sites sampled.

5.2.4 Biomass calculations

Biomass was calculated from size class estimates of length and existing published figures from Fishbase (Froese and Pauly, 2011). The standard length-weight (L-W) expression was used:

$$W=aL^b$$

where,

W=weight (g)

L= length (cm)

a and b are coefficients related to body form and growth.

For the a and b parameters, priority was given to sites closest to Fiji or those studies with the greatest number of fish analysed. If no L-W parameters were available for the species, the factors for the species with the most similar morphology in the same genus were used (Jennings and Polunin, 1996). If a suitable similar species could not be determined, the average values for the genus were used. Several of the L-W conversions required total length (TL); a length-length (LL) conversion factor was obtained from Fishbase where necessary to convert from fork length (FL) to TL before calculating the biomass.

5.2.5 Species identification

Species identification was done based on the experience of the authors, with the aid of several field guides (Allen *et al.*, 2003), Fishdex cards (Jenkins and Mailautoka, 2009), and available keys from the literature.

5.3 Results

The survey captured a total of 792 fishes and 125 crustaceans. Table 9, below, contains the checklist of fish recorded from different habitats across the four study sites. Appendix 11 and Appendix 12 provide details on the biomass and inherent values of the fishes caught during the survey.

Table 9: Checklist of fishes and crustaceans caught in different mangrove habitat zones

Family	Species	Sites:	Natila				Waicoka				Nasilai				Vunidawa			
		Zones:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Fish																		
Megalopidae	*Megalops cyprinoides* (Broussonet, 1782)				x													x
Muraenidae	*Gymnothorax* cf. *dorsalis*																x	
Ophichthidae	*Pisodonophis* sp.																x	
Clupeidae	*Sardinella fijiense* (Fowler & Bean, 1923)							x	x			x	x					
Engraulidae	*Stolephorus indicus* (van Hasselt, 1823)						x	x	x			x	x					
Chirocentridae	*Chirocentrus dorab* (Forsskål, 1775)						x											
Belonidae	*Tylosurus crocodilus crocodilus* (Péron & Lesueur, 1821)						x											
Hemiramphidae	*Zenarchopterus dispar* (Valenciennes, 1847)			x	x			x	x				x				x	
Syngnathidae	*Microphis retzi* (Bleeker, 1856)								x									
	cf. *Hippocampus* sp.			x														
Scopaenidae	Unidentified scorpion fish								x				x					
Serrenidae	*Epinephelus* sp.			x														
Terapontidae	*Mesopristes kneri* (Bleeker, 1876)															x		
	Terapon jarbua (Forsskål, 1775)										x							
Kuhliidae	*Kuhlia marginata* (Cuvier, 1829)																	x
Apogonidae	*Apogon* spp.			x					x				x	x			x	
Lactaridae	*Lactarius lactarius* (Bloch & Schneider, 1801)								x									
Carangidae	*Caranx sexfaciatus* Quoy & Gaimard, 1825												x					
	C. papuensis Alleyne & Macleay, 1877				x			x		x			x				x	
	Scomberoides tol(Cuvier, 1832)		x															
Leiognathidae	*Gazza minuta* (Bloch, 1795)							x	x								x	
	Leiognathus equulus (Forsskål, 1775)			x			x	x	x	x		x	x	x			x	
	L. fasciatus (Lacepède, 1803)							x										
	L. splendens (Cuvier, 1829)												x					
Lutjanidae	*Lutjanus argentimaculatus* (Forsskål, 1775)								x								x	
	L. fulviflamma (Forsskål, 1775)								x									
	L. fulvus (Forster, 1801)								x				x					
	L. russellii (Bleeker, 1849)			x														
Gerridae	*Gerres longirostris* (Lacepède, 1801)							x				x						
Heamulidae	*Plectorhinchus albovittatus* (Rüppell, 1838)				x													
Lethrinidae	*Lethrinus amboinensis* Bleeker, 1854											x						
Mullidae	*Upeneus vittatus* (Forsskål, 1775)							x				x						
Mugilidae	*Mugil cephalus* Linnaeus, 1758			x	x			x	x	x		x	x	x		x	x	x
	Moolgarda seheli (Forsskål, 1775)												x					
Eleotridae	*Belobranchus belobranchus* (Valenciennes, 1837)								x									
	Bostrychus sinensis Lacepède, 1801								x								x	
	Butis amboinensis (Bleeker, 1853)								x									
Gobiidae	Unidentified goby								x									
Siganidae	*Siganus vermiculatus* (Valenciennes, 1835)							x	x			x						
Sphyraenidae	*Sphyraena qenie* Klunzinger, 1870																x	
Scombriidae	*Rastrelliger kanagurta* (Cuvier, 1816)								x									
Chanidae	*Chanos chanos* (Forsskål, 1775)							x										
Tetraodontidae	*Arothron manilensis* (Marion de Procé, 1822)				x								x					
Crustaceans																		
Macrophthalmidae	*Macrophthalmus* sp.							x										
Palaemonidae	*Palaemon concinnus* Dana, 1852								x					x		x	x	
Penaeidae	*Penaeus monodon* Fabricius, 1798			x					x					x				
Portunidae	*Portunus sanguinolentus* (Herbst, 1783)						x	x										
	Scylla serrata (Forskål, 1775)											x				x	x	x
1=coastal mangrove, 2=river mouth, 3=downstream mangrove, 4=upstream mangrove																		

The fish catch comprised a total of 43 species of fish from 30 families, mostly in their juvenile stages. Several species caught in this survey are of high value as food to villagers while the remaining species are used as bait fishes and/or play important ecological roles in the system as predator or prey.

A single endemic fish, *Mesopristes kneri* was found during the survey and is of global conservation significance because it is the largest endemic freshwater fish in the Pacific (Jenkins, 2009). There were also five species (four families) of crustaceans caught during the survey.

5.3.1 Natila river system

Being a small and narrow system, sampling was only conducted within three zones (downstream, river mouth and coastal). The upstream zones were inaccessible due to dense impenetrable mangroves. This river system is in close proximity to coral reef systems and therefore, more marine species were found in this region as opposed to the other river systems surveyed. Gill nets and hand lines are the most common methods of fishing in this area. In total there were 106 fish (twelve species) and two tiger prawns (one species) found in this system. Figure 25 shows the biomass of fish species caught in Natila using gill nets.

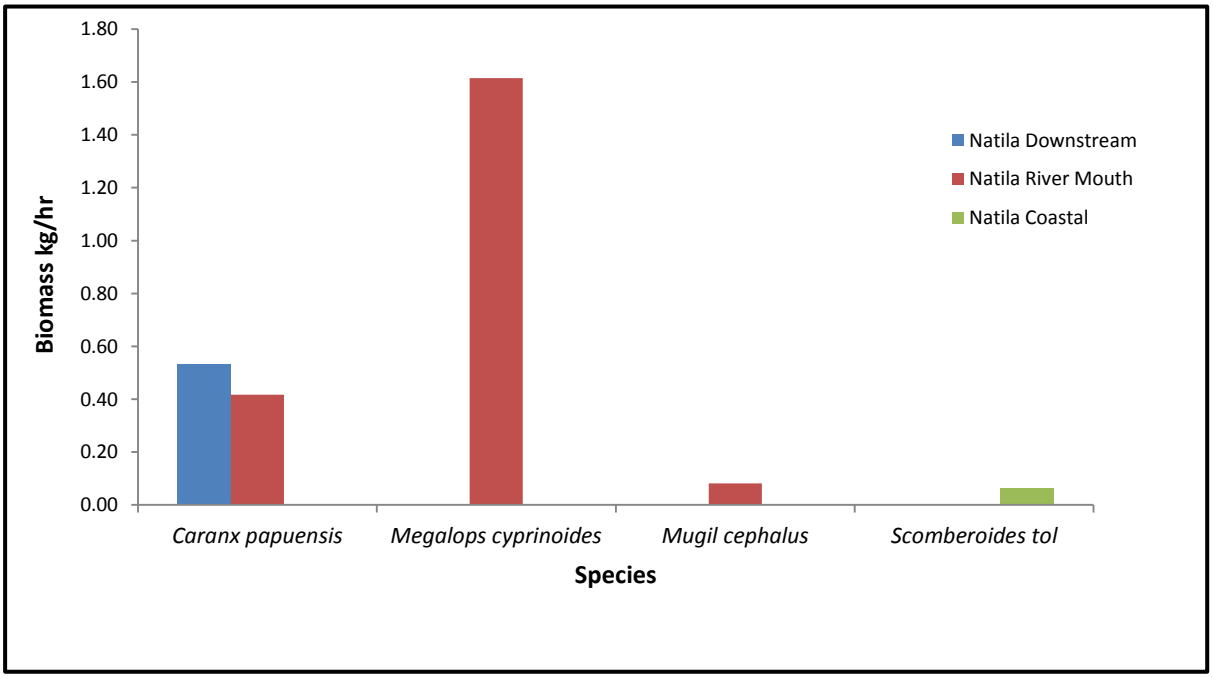

Figure 25: Fish biomass caught with gillnets in different zones in the Natila river system

Downstream mangrove

With a total of three gill nets deployed on this zone, the most abundant species captured were *Caranx papuensis* (saqa). Despite their maximum length of 88 cm documented for

this species (Froese and Pauly, 2011), these individuals were quite small with an average fork length of 21 cm and a total biomass of 0.53 kg/hr.

Eight species of fish and one species of crustacean were collected with cast nets. The most abundant fish species were *Zenarchopterus dispar* and *Mugil cephalus*. Other species include *Stolephorus indicus*, *Leiognathus equulus*, *Apogon* spp. (tina), *Epinephelus* sp. (kavu) and cf. *Hippocampus sp*.

Two juvenile marine species, *Plectorhinchus albovittatus* and *Arothron manilensis* (Figure 26) were collected from the fyke net, demonstrating the importance of mangrove ecosystems as important nursery areas for marine fauna that accommodate part of their life cycle in brackish environments.

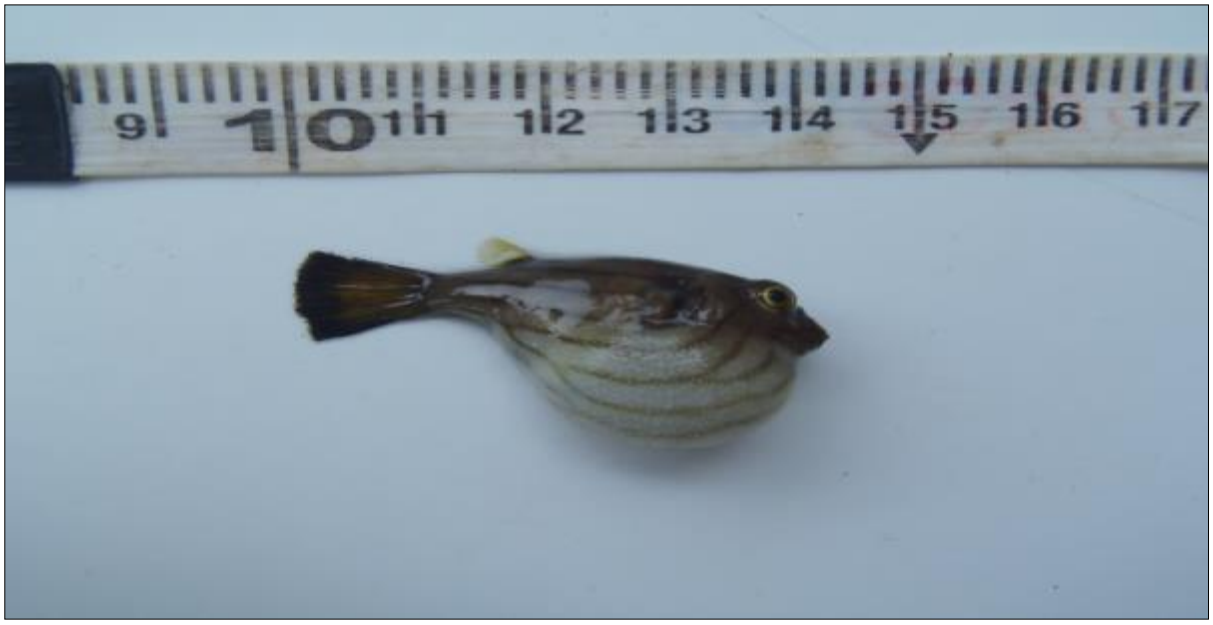

Figure 26: A new record for brackish water in Fiji, the puffer fish, *Arothron manilensis.*

River mouth

Out of three gill nets deployed in this zone, *Megalops cyprinoides* was the most abundant species with a total biomass of 1.61kg/hr and an average fork length of 31 cm (a maximum length of 45 cm is reported by Froese and Pauly, 2011). Least abundant were *C. papuensis* and *M. cephalus* with a total biomass of 0.41kg/hr and 0.08kg/hr, respectively.

The most abundant fish in the beach seine was *M. cephalus* with an average fork length of 11 cm and a total biomass of 0.46 kg. There were also two counts of the prawn, *Penaeus monodon*, which had an average carapace length of 12 cm. Time constraints prevented completion of surveys on these zones.

Coastal mangrove

Only gill nets were used in this zone. The three gill nets deployed captured a single species of fish, *Scomberoides tol* (votonimoli), which had a fork length of 20 cm and a total biomass of 0.065 kg/hr.

5.3.2 Waicoka river system

In this river system, surveys were conducted within four zones (upstream mangrove, downstream mangrove, river mouth; and coastal mangrove). Unfortunately, the upstream sedge zone was not surveyed as access was made impossible by a floodgate (Figure 27). A difference of about 1 m was observed in the water level on either side of the floodgate when the picture below was taken.

Figure 27: Floodgate in the Waicoka river system

This floodgate poses a challenge to migrating fish, restricting the pathway of their natural lifecycle. In addition, at the upstream mangrove zone, the original pathway of the river had been redirected as a result of dredging and increasing developments and vegetation clearing has caused much disturbance and change to the flora and fauna within the area.

However, in comparison to Natila, the Waicoka system is obviously larger and the fish species more diverse and abundant. In total, there were 446 fish (29 species) and 83 crustaceans (four species) recorded here. Figure 28shows the biomass of fish species in Waicoka River caught using gill nets.

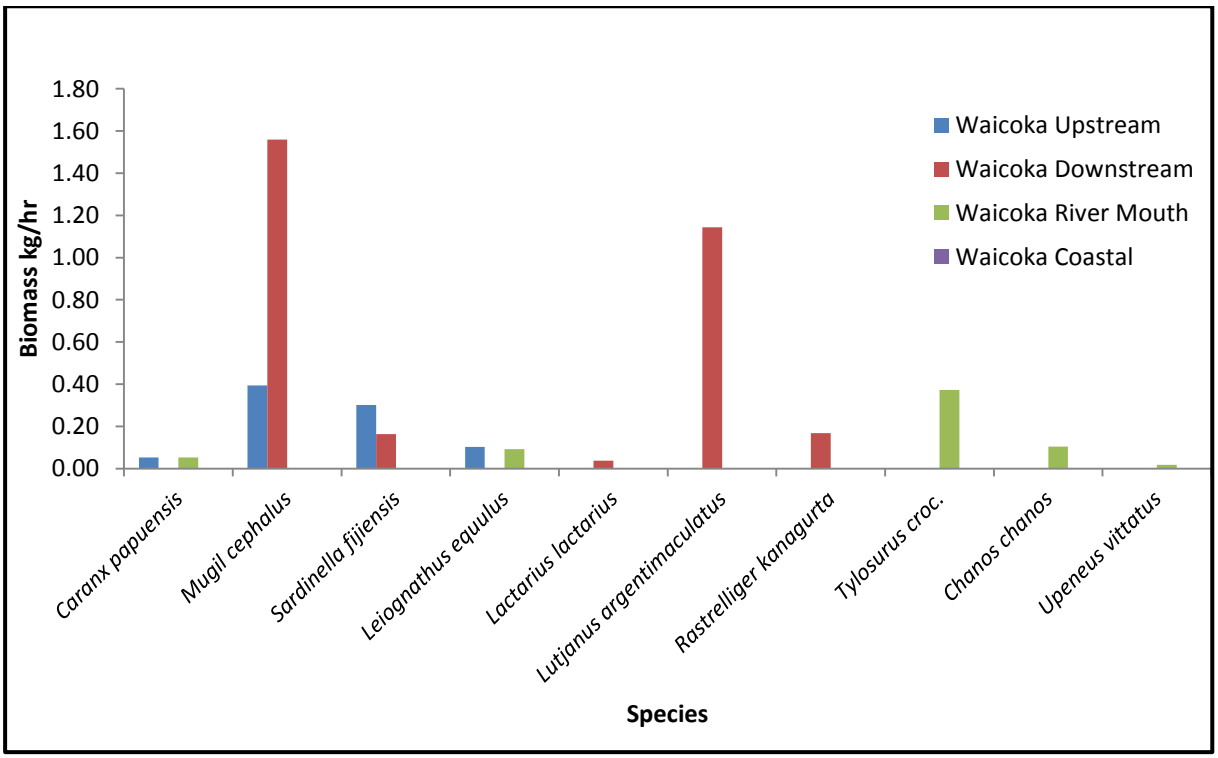

Figure 28: Fish biomass caught with gillnets in different zones in the Waicoka river system

Upstream mangrove

Only two methods were implemented in this zone, gill net and cast net. A total of fourteen fish were caught in the gill nets. *M. cephalus*, *L. equulus* and *Sardinella fijiensis* (daniva) were the most abundant with a total biomass of 0.39kg/hr, 0.30kg/hr and 0.10kg/hr, respectively. These species are not only a subsistence resource but are also an income source for local communities. In the cast nets, only two species of fish were caught, *S. indicus* and *L. equulus* with total biomass of 0.02kg and 0.05kg. Although they do not have any direct economic value, they are often caught to use as baitfish.

Downstream mangrove

Three methods were implemented in this zone, gill nets, cast nets and fyke nets. A total of 20 fish were caught in the gill nets, the most abundant being *M. cephalus* with a total biomass of 1.55kg/hr. The least abundant were *S. fijiensis* and *Rastrelliger kanagurta* each with a total biomass of 0.16 kg/hr and fork lengths of 15 cm and 22 cm, respectively. Moreover, one of the six nets caught a Mangrove jack (*Lutjanus argentimaculatus*) which had a total biomass of 1.14 kg/hr and a fork length of 42 cm, emphasising the importance of these river systems in nurturing fish species of key economic value.

The cast nets caught a total of 48 fish and crustaceans. Most abundant were *S. indicus* and the ponyfishes *L. equulus* and *Gazza minuta*. A total of 26 mangrove prawns

(*Palaemon concinnus*) with an average carapace length of 3cm were also collected. Although mangrove prawns do not have direct commercial value they are often cooked as a local delicacy known as rourou vakautona, which can be sold for cash income for some villagers.

The two fyke nets deployed in this zone collected a diverse range of species of fish and crustaceans. In both nets the most abundant fish were the cardinalfishes (*Apogon spp*.), followed by *Bostrychus sinensis* and *M. cephalus*. The most abundant crustacean caught was *P. concinuus*.

River mouth

Three methods were implemented in this zone: gill nets, cast nets and beach seine. There were a total of seven species caught in the gill nets. Most abundant was *L. equulus* with a total biomass of 0.07kg/hr. Individual fish species including *Tylosurus crocodilus crocodilus*, *Upeneus vittatus* and *Chanos chanos* were also caught. These had a total biomass of 0.37kg, 0.22kg and 0.10 kg respectively, per hour of net deployment. The cast nets caught an abundance *of L. equulus* with a total biomass of 0.97kg; and *S. indicus* with a total biomass of 0.01kg. Furthermore, most abundant in the beach seine was *L. equulus* and *M. cephalus*. Other species caught include *Siganus vermiculatus*, *P. monodon* and two crab species, *Portunus sanguinolentus* and *Macropthalmus sp*.

Coastal Mangrove

Due to time constraints only one set of gill nets was implemented in this zone. Apart from a three spot swimmer crab (*P. sanguinolentus*), all three nets deployed did not collect any fish.

5.3.3 Nasilai river system

Towards the main Rewa River, the river systems become interconnected and therefore, species diversity was expected to be greater in the Nasilai river system compared to the previous two. However, being closer to the urban area, this river also has a larger human population and therefore a higher fishing pressure, than the others. A total of 142 fish (20 species) and seven crustaceans (3 species) were caught in this river system. Figure 29 shows the biomass of fish species in Nasilai caught using gill nets.

Upstream mangrove

A total of four species were collected from six gill nets deployed in this zone. Out of ten individuals caught, the most abundant were *S. fijiensis* and *M. cephalus,* each with a total

biomass of 0.32kg/hr and 0.24kg/hr respectively. In the cast nets the three most abundant species were *S. indicus* and *L. equulus,* both with an average fork length of 5 cm and *Apogon* spp. with an average fork length of 6 cm.

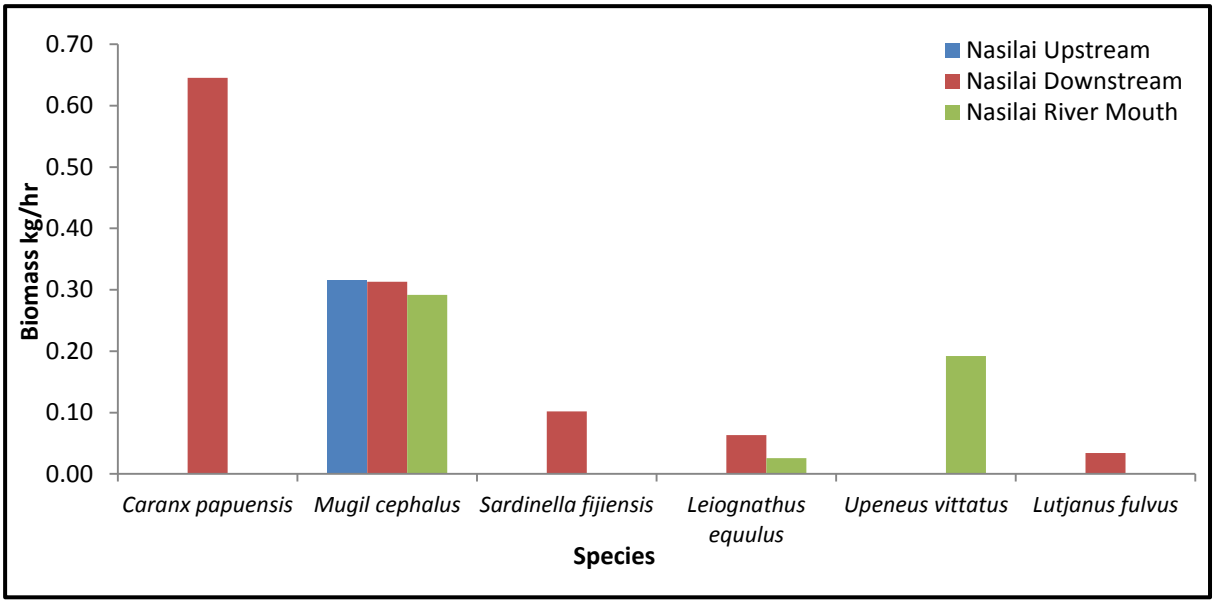

Figure 29: Fish biomass caught with gillnets in different zones in the Nasilai river system

Downstream mangrove

Relative to the other river systems, fish species found on this zone were similar, with *S. fijiensis*, *L. equulus* and *M. cephalus* dominating the catch in the gillnets. Other individuals caught included *C. papuensis* and *L. fulvus*. Two types of ponyfishes were most abundant in the cast nets: *L. equulus* and *L. splendens*.

Dominant in the fyke nets were the cardinalfish (*Apogon spp*.) with an average fork length of 5 cm. The catch also included a striped pufferfish (*A. manilensis*), blacktail snapper (*L. fulvus*) and an unidentified scorpion fish all in their juvenile stage.

River mouth

Of the six gill nets deployed in this zone, a total of five fish species and one crustacean were collected. Most abundant was *M. cephalus* followed by individual counts of *Lethrinus harak*, *Gerres longirostris*, *Upeneus vittatus* and *L. equulus*. Also dominating the collection in the beach seine method was *M. cephalus* with a total biomass of 0.15 kg and an average fork length of 14 cm. Also in the nets were two *Terapon jarbua* (average fork length of 12 cm) and a single juvenile *C. papuensis* (fork length of 10 cm).

5.3.4 Vunidawa river system

Given its location with respect to the main Rewa River, the Vunidawa was a very different system when compared to the previous three. The currents were much

stronger and turbidity was greater. The area is quite populated and therefore a lot more debris was observed. However, the fisheries collection was relatively similar to the other systems, differing slightly in abundance in some zones.

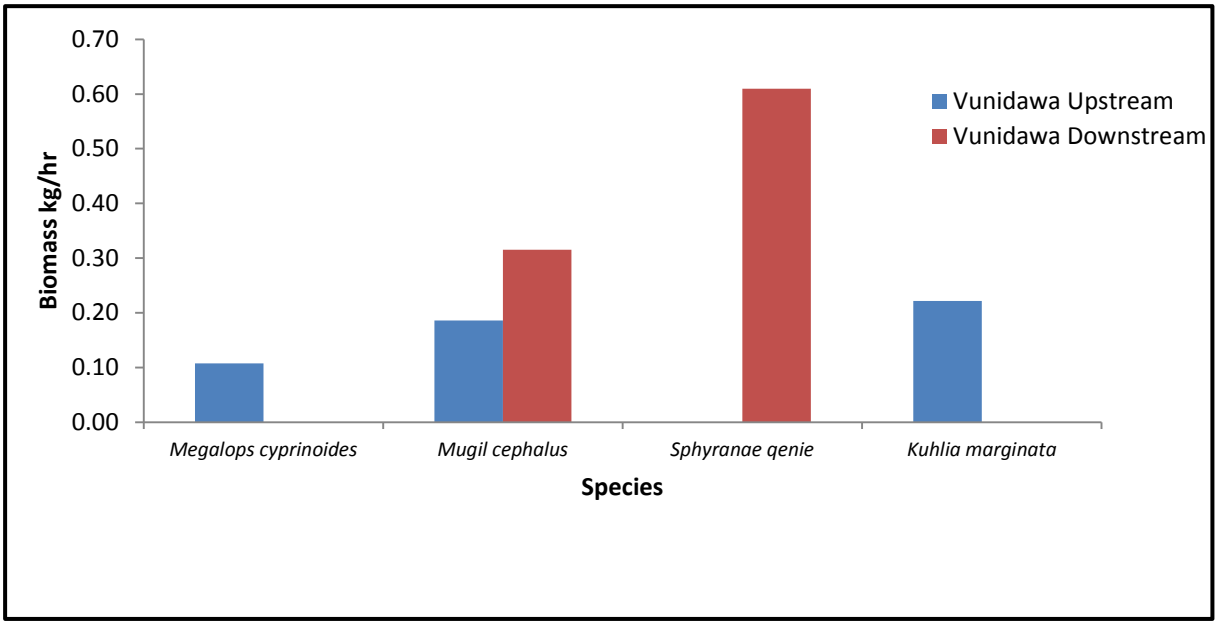

Figure 30: Fish biomass caught with gillnets in different zones in the Vunidawa river system

A total of 102 fish (15 species) and 29 crustaceans (4 species) were recorded. Figure 30 shows the biomass of fish species in the Vunidawa river system caught using gill nets.

Upstream mangrove

Gillnets were the only method implemented in this zone due to time constraints and unfavourable weather conditions. A total of six fish and one crustacean were collected in this zone. Most abundant was *M. cephalus* with total biomass of 0.13 kg/hr. There were also individual counts of *M. cyprinoides* and *Kuhlia marginata* with a total biomass of 0.10 kg/hr and 0.22 kg/hr respectively. The mangrove crab (*Scylla serrata*) had a carapace length of 10 cm.

Downstream mangrove

Two species were caught with the gill nets: *M. cephalus* and *Sphyraena qenie*, with a total biomass of 0.31 kg/hr and 0.61 kg/hr, respectively. The cast nets collected eight species of fish and two species of crustacean. The catch was dominated by *Apogon spp*. that had an average fork length of 4 cm, *L. equulus* with a total biomass of 0.02 kg; and *S. indicus* with a total biomass of 0.0018 kg. Other crustacean species caught in the cast nets were *P. monodon* and *P. concinnus*.

The fyke nets caught four species of fish (*Apogon* spp., *B. sinensis, L. argentimaculatus*, *L. equulus*) and two eels, *Gymnothorax dorsalis* and *Pisodonophis sp*.). The fyke nets also caught two species of crustaceans: *S. serrata* and *P. concinnu*s.

River mouth

Four species of fish and two species of crustaceans were recorded from a total of six beach seine. Amongst them was a juvenile *M. kneri* with a fork length of 3 cm. Given the rarity of this fish species it was encouraging to sight this juvenile in this area.

5.4 Discussion

5.4.1 New additions to the brackish water fishes of Fiji

This survey has resulted in several new additions to the list of brackish water fishes occurring in Fiji (Boseto and Jenkins, 2006). Generally, the two species *T. crocodilus crocodilus* and *R. kanagurta* would not be considered brackish water fish as they are mainly reef-associated fishes. However, since they were caught in brackish water during this survey then due consideration must be taken to adding them to the list of brackish water fishes of Fiji. Other new records for brackish water include cf. *Hippocampus sp*., *S. qenie*, *P. albovittatus* and *A. manilensis*.

The occurrence of the moray eel, *Gymnothorax* cf. *dorsalis*, is a possible range extension of *G. dorsalis* whose current documented distribution is restricted to Hong Kong, the Straits of Malacca, Malaysia and Taiwan (Froese and Pauly, 2011). Moray eels are, however, difficult to key out and this record will need to be verified by experts in the group Muraenidae.

A notable trend is that the distributaries of the Rewa River system in the northern part of the delta (Tailevu) maintain a significant ecological support mechanism in reef fish species recruitment and rearing of their juveniles. This is much less apparent at the mouth of the main Rewa River (around the Vunidawa Creek), since the adjacent reef system is being smothered by alluvial sediment from upland fluvial washouts. Here, the majority of the juvenile catch (mullets, ponyfish and rabbitfish) were found along the edges of low angle banks and mud flats at low tide while deep angle banks had high occurrences of *S. indicus* along the edges of mangroves at low tide.

5.4.2 Fish biomass across the four river systems

In rural areas of the Pacific, fresh fish can account up to 80% of the diet while the remainder comprised of canned fish(Bell *et al.*, 2009). At the national level, the food

resources provided by the Rewa River mangroves cannot be understated. The primary food fishes were mullet (*M. cephalus*), jack (*C. papuensis*), ponyfish (*Leiognathus spp*.), mangrove jack (*L. argentimaculatus*) and tarpons (*M. cyprinoides*). Additionally, marine visitors to the delta such as *T. crocodilus crocodilus¸ R. kanagurta* and *S. qenie* inject important sources of protein for the communities along the delta. The importance of fish for consumption and sale is crucial for the overall wellbeing of the coastal people of the Tailevu and Rewa provinces

In general, the downstream zones and river mouth dominated biomass of fishes across the sites. Waicoka downstream mangrove had the highest total biomass of fishes caught per hour (3.07 kg/hour).

5.4.3 Water quality across sampling sites

Generally, water quality across sites was conducive for fish and crustaceans. The only notable difference was in the turbidity and salinity of the Vunidawa river system. This system is one of major rivers draining the Rewa River and therefore salinity readings were lower compared to the other three sites. This greater influx of freshwater brings with it more suspended sediments which also resulted in higher turbidity and low clarity readings.

5.4.4 Limitations of the study

There were several constraints during the fieldwork that necessitated several adjustments to the methodology. A major problem encountered was engine failure and low fuel which caused problems with logistics and faunal sampling. Species identification may have experienced minor variation. Species such as mullets are hard to distinguish between other members in the same family (Mugilidae) especially with juveniles.

5.4.5 Conclusions and recommendations

The finding of this rapid assessment highlights the importance of the Rewa River mangrove ecosystem and its associated habitats to fish and crustaceans. Over half of the fishes surveyed were in their juvenile stages. Understanding the value of mangrove ecosystems in Fiji is critically important as the majority of the fishes and crustaceans sampled are important commercial species while some are used as baitfish by villagers. This study however, represents a snapshot in time and there is a strong need to do further studies through the year to broaden the temporal understanding of the mangrove faunal community.

The Rewa River mangroves are an important biodiversity area and should be recognised as a national conservation priority for climate change adaptation and food security. The development along the Suva-Nausori corridor threatens to encroach on this mangrove system. The inappropriate deforestation of mangroves for coastal development remains a worrying trend in Fiji. Overall, the Tailevu part of the Rewa River mangroves should be given priority for establishing a mangrove forest reserve, since this area is relatively well intact with large tracts of *Bruguiera* forest remaining, compared to the Rewa part which was dominated mainly by *Rhizophora* along the river banks. This will also entail the need to restore degraded areas that have high survival prospects.

Overfishing along the river is an issue that was highlighted by the community. Discussions with them indicated that the largest archipelagic endemic riverine fish in the Pacific Islands, *Mesopristes kneri*, is fished daily and therefore under tremendous pressure. The communities in the Rewa delta are not the only users, other communities in the extended Rewa Delta and the Nasinu area also fish in this river system. Effective measures need to be implemented to control commercial fishers and illegal users who benefit from the sale of their catch. Issue of licenses to commercial fishers and permits to subsistence fishers needs to be regulated and catch records collected. This data could form the basis of efforts to ensure sustainable fishing in the area.

The implementation of gear restriction in the river system is commended. The ban on gill net use in the delta is a step in the right direction but much more can be done in terms of enforcement. The Fisheries Department needs to improve enforcement and ensure compliance of fishing activities. The current fisheries legislation allows local community members to become certified honorary fish wardens and each village is encouraged to appoint such people. Having these additional enforcers would guarantee a reduction of illegal fishing practices. Anecdotal evidence from villagers suggests that net use continues despite government regulation, and poaching is a major cause of depleted fish stocks.

Crab traps per unit area are not currently controlled and most, if not all, areas have very high numbers of traps. There needs to be regulation of trap placement, and the number of crab traps per fishermen, in order to ensure survival of the crab fisheries. Recently, there have been concerns raised by the public on the need to monitor sales of undersized crabs. Crustaceans such as mud crabs, mud lobsters and prawns have high economic value and therefore, management of this fishery is crucial. Trap reduction and habitat protection can aid in the recovery of crab population, also ensuring survival of

large sized individuals. Illegal fishing techniques needs to be monitored as there were sightings of mass deaths of juvenile mud lobsters in one river system, apparently due to the use of chemicals and/or natural poison. The culprits of illegal and destructive fishing methods need to be dealt hefty penalties as a deterrent. Not only do chemicals degrade natural resources, they also pose a health risk if consumed.

Impoundment in the form of flood gates in most of the delta distributaries impedes the ecological connectivity of the migratory species over the waterway. 98% of Fiji's freshwater fishes must use the marine environment at some phase in their lifecycle (Jenkins, 2009). The floodgate design need to be revised so that is allows the connectedness of the species migrating over the marine and fresh water.

Land use management is vital to the future and sustainability of these mangrove ecosystems and the adjacent reef system. There is a need to strengthen awareness on sustainable land use practices including proper farming techniques, controlled logging, riparian area management for buffer effect, and reforestation along the cleared tributaries of the mid and upper river zones. Introduced upstream flora, sedimentation and siltation prohibit coral and fish larvae settlement in adjacent marine system (Mark Hay, *pers. comm*.). Studies on ecological connectivity and chemical elemental assay in PNG palm oil plantation have proven the impact of non-native tree species deterring coral recruitment and generation. This concern is evident in the Rewa river system with less to no marine fish species recruitment found compared to the Tailevu distributaries. The fore reef community in Rewa could be smothered with alluvial deposits drained from across the river water ways from farther upstream. An integrated ecosystem based management is critical to ensure the sustainable protection and safeguard of resources.

6 INVASIVE SPECIES

Sarah Pene and Isaac Rounds

6.1 Introduction

6.1.1 Defining an 'invasive' species

The scientific community has yet to agree on a universally recognised definition of what an invasive species is, or on the criteria that are needed to assign a particular species to a list of invasive species in a particular country or region (Fox and Gordon, 2004). There are however some common criteria that are widely used to characterise the invasiveness of a species;

- They are non-native; they have been introduced to an area/country where they have never occurred before, either intentionally or accidentally by humans, or other agents such as animals, wind or water.
- They have then become naturalised; they are able to reproduce without human assistance and are capable of building self-sustaining populations
- They are increasing in abundance or spread.
- They have harmful effects on the natural environment.

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).

6.1.2 Invasives as a threat to mangroves and associated habitats

Invasive species are one of the biggest threats to global biodiversity, second only to habitat loss. The management of invasive species is a key focus of Fiji's National Biodiversity Strategy and Action Plan (2003) which has as a specific objective to "*effectively control invasive and potentially invasive species present in Fiji*".

Not all invasive species present in a country will be invasive across all habitats. Whether a habitat is vulnerable to invasion depends on a variety of factors beginning with the abiotic conditions of the habitat, its level of disturbance and the biotic interactions between the species within that habitat (Olyarnik *et al.*, 2008). Habitat shape is also an important determinant of the rate at which a habitat can be invaded (Cumming, 2002).

True mangrove habitats are generally considered difficult to invade, because of their wet and salty conditions and the fact that not many species have the capacity to grow within

these conditions (Lugo, 1998). In the Pacific mangrove habitats contain the least number of invasive species. Far more invasive species are recorded for dry lowland, mesic inland, wet upland and cloud forest habitats (Meyer, 2000: Table 4, p112). Although the mangrove habitat is still considered to be vulnerable to invasion, particularly if disturbed, the threat level from invasive species is considered to be low (Ellison and Fiu, 2010).

6.2 Methodology

6.2.1 Invasive plant species

The diversity and abundance of plant species were measured at several points throughout the study site, within 10 m x10 m plots along transect lines through the various mangrove habitats and associated habitats. For a full description of the vegetation community structure and the locations of these transects, see Appendix 2.

6.2.2 Invasive mammals

In a modified version of the methodology described by Cunningham and Moors (1996), traps were laid in pairs along a 25-30m transect in areas of mangrove, and the back of mangroves, near villages. The number of trap pairs along one transect ranged from seven to ten. Each trap was baited with roasted coconut and left overnight. The next day a record was made for each trap; if the bait was intact or taken, and whether the trap was sprung, or not sprung.

6.3 Results

6.3.1 Invasive plant species

A list of the 52 plant species considered invasive within Fiji was compiled as part of a technical review and regional strategy on Pacific invasive species, coordinated by SPREP (Meyer, 2000). The list grouped these invasive species into dominant invaders (13), moderate invaders (17) and potential invaders (22). This list is shown below in Table 10, as well as an indication of whether each species was quantitatively sampled within the transects at the MESCAL study site, or observed as being present overall.

Table 10: Invasive plants of Fiji (Meyer, 2000) and their presence in the MESCAL project area

Scientific name	Common names	Habit	Habitat	Recorded in plots	Present in study site overall, not recorded in plots
Dominant invaders					
Annona glabra	pond apple	small tree	mangrove	✓	
Clidemia hirta	Koster's curse	shrub	mesic/wet	✓	
Eichhornia crassipes	water hyacinth	aquatic herb	wetlands		✓

Scientific name	Common names	Habit	Habitat	Recorded in plots	Present in study site overall, not recorded in plots
Hydrilla verticillata	water thyme	aquatic herb	wetlands		
Lantana camara	lantana	thorny shrub	dry/mesic		✓
Leucaena leucocephala	wild tamarind	small tree	dry	✓	
Merremia peltata	merremia	vine	dry/mesic		✓
Mikania micrantha	mile-a-minute	vine	dry/mesic	✓	
Pennisetum polystachion	mission grass	grass	0–400 m		✓
Piper aduncum	false kava	shrub	0–1000 m		✓
Rubus moluccanus	wild rasberry	spiny shrub	mesic/wet		✓
Spathodea campanulata	African tulip	large tree	mesic	✓	
Sphagneticola trilobata	Singapore daisy	herb	dry/mesic	✓	
Moderate invaders					
Samanea saman	rain tree	large tree	dry	✓	
Arundo donax	giant reed	tall grass	dry/mesic		✓
Chrysobalanus icaco	coco plum	shrub	mangrove	✓	
Citharexylum spinosum	fiddlewood	tree	-		✓
Clerodendrum chinense	Honolulu rose	shrub	0–900 m		✓
Cyperus rotundus	nutgrass	sedge	-		✓
Hedychium coronarium	white ginger	erect herb	mesic/wet		✓
Hedychium flavescens	yellow ginger	erect herb	mesic/wet		✓
Kyllinga polyphylla	Navua sedge	sedge	mesic/wet		✓
Mimosa invisa	giant sensitive grass	thorny shrub	dry/mesic		✓
Opuntia vulgaris	prickly pear	succulent	dry		
Passiflora foetida	stinking passionflower	vine	mesic	✓	
Psidium guajava	guava	tree	dry/mesic		✓
Solanum torvum	prickly solanum	herb	0–900 m		✓
Stachytarpheta urticifolia	blue rats tail	herb	0–850 m		✓
Urena lobata	hibiscus bur	herb	mesic/wet		✓
Zizyphus mauritiana	Indian jujube	thorny tree	dry		
Potential invaders					
Acacia farnesiana	Ellington's curse	shrub	-		
Agave sisalana	sisal	succulent	-		
Allamanda cathartica	allamanda	vine	-		✓
Antigonon leptotus	chain of love	vine	-		✓
Ardisia crispa	Australian holly	shrub	-		
Calliandra surinamensis	powder puff	tree	-		✓
Clerodendrum paniculatum	pagoda flower	shrub	-		
Coccinia grandis	ivy gourd	vine	-		✓
Costus sericeus	cape ginger	herb	-		✓
Cryptostegia grandiflora	rubber vine	vine	-		
Dissotis rotundifolia	pink lady	herb	-		✓
Hemigraphis alternatus	-	herb	-		✓
Lonicera japonica	Japanese honeysuckle	vine	-		
Melia azedarach	pride of India	tree	-		✓
Merremia tuberosa	word rose	vine	-		
Odontonema tubiforme	fire spike	shrub	-		✓
Pseuderanthemum bicolor	-	shrub	-		✓
Psidium cattleianum	strawberry guava	tree	-		
Thunbergia grandiflora	blue trumpet vine	vine	-		✓
Sanchezia nobilis	sanchezia	shrub	-	✓	
Schefflera actinophylla	umbrella tree	tree	-		✓
Tithonia diversifolia	tree marigold	shrub	-		

Of the above, those species that were quantitatively sampled within the transect or which were most abundant within the study site overall are described in more detail below, grouped according to whether they were found specifically in mangrove ecosystems or in other associated habitats.

The information on each of the species that follow is compiled primarily from the five volumes of Smith's *Flora Vitiensis Nova* (1979, 1981, 1985, 1988, 1991) and the Global Compendium of Weeds (Randall, 2002), unless otherwise stated. All photographs are those of the author unless otherwise indicated.

Invasive plants found within mangrove habitats

The most prominent invasive species in the mangrove forest dominated by *Rhizophora* spp. and *Bruguiera gymnorhiza* was *Annona glabra*. This tree favoured the drier areas within the mangroves, and avoided those areas which were closest to the water's edge and regularly inundated. Per 10 m x 10 m plot the abundance of *A. glabra* ranged from 1 to 9 with a mean of 4 trees per plot. Whilst generally found in mixed associations with native mangrove trees, this species did sometimes occur in monotypic stands i.e. composed solely of *A. glabra* trees.

The shrub *Clidemia hirta*, commonly known as Koster's curse, was also present within the mangrove zone, but restricted to the drier areas. Per 10 m x 10 m plot the percentage ground cover of *C. hirta* ranged from 5 to 25%.

In the waterways of the delta, alongside riverine mangrove habitats there was evidence of water hyacinth, *Eichhornia crassipes*, which is a highly invasive aquatic plant currently under biological control in Fiji. The floating mats of this plant were small (none were seen that were greater than 2 m^2 in area), and were clearly damaged and not thriving.

***Annona glabra* L.**

Family: Annonaceae
Common names: bullock's heart, uto ni bulumakau
Native range: Tropical and subtropical Americas, West Africa
Description, habitat: Small tree 2-8m high, found near sea level, naturalises readily in the drier parts of mangrove swamps.
Biological control: None:

Eichhornia crassipes (Mart.) Solms
Family: Pontederiaceae
Common names: water hyacinth
Native range: Tropical and subtropical South America
Description, habitat Floating herb, found generally near sea level, in stagnant or slow-flowing bodies of water.
Biological control: The mottled water hyacinth weevil, *Neochetina eichhorniae*, was introduced in 1977.

Photo:www.invasive.org

Clidemia hirta (L.) D. Don
Family: Melastomataceae
Common names: Koster's curse
Native range: Tropical Americas
Description, habitat: Shrub 0.5-3m high, occurring in thickets in open areas in forests and forest margins.
Biological control: The *Clidemia* thrips, *Liothrips urichi*, was introduced in 1930.

Invasive plants found in proximity to mangrove habitats

The transects that were sampled further inland towards the back of the mangroves, in drier areas, in coastal forests, scrubland and adjacent to agricultural areas contained a much wider variety of invasive plant species. Many of these were found in very close proximity to mangroves but always on land that was not subject to daily inundation by saltwater.

Towards the back of the mangroves, where conditions were drier, and there was more available light many of the invasive creepers were evident, in particular *Merremia peltata* (merremia) and *Mikania micrantha* (mile-a-minute), as well as *Sphagneticola trilobata* (Singapore daisy).

The African tulip tree, *Spathodea campanulata*, was present throughout the study site, in stands of secondary forest, as well as adjacent to agricultural areas, on roadsides and on the margins of coastal forest areas. In the lowlands behind the back of the mangrove habitat large stands of *S. campanulata* and *A. glabra* were observed. Stocking of *S. campanulata* ranged from 3%-100% relative dominance in some areas.

Spathodea campanulata Beauv.

Family: Bignoniacae
Common names: African tulip
Native range: Tropical Africa
Description, habitat: Tree reaching 35m in height, found in agricultural areas, secondary forest, forest margins and disturbed areas.
Biological control: None

Merremia peltata (L.) Merr.

Family: Convolvulaceae
Common names: *merremia*, *wa bula*, *wa damu*
Native range: Indian Ocean and Indonesia. It is found across the Pacific but whether or not it is native to these islands is yet to be conclusively determined (Paynter *et al.*, 2006)
Description, habitat: Creeper and woody vine, found in forests, forest margins, open hillsides, along roadsides and in disturbed areas
Biological control: None

Photo:www.invasive.org

Mikania micrantha Kunth

Family: Asteraceae
Common names: mile-a-minute, wa bosucu
Native range: Tropical Americas
Description, habitat: Fast-growing climber, found in forest margins, clearings, pastures, roadsides.
Biological control: A rust fungus, *Puccinia spegazini*, was released on Viti Levu, Vanua Levu, Ovalau and Taveuni in 2009 (Tunabuna, *pers. comm.*)

Photo:www.invasive.org

Sphagneticola trilobata (L.) Pruski.

Family: Asteraceae
Common names: wedelia, Singapore daisy
Native range: Tropical Americas
Description, habitat: Shrub 1-3m high, found from sea level to 450m on shorelines, edges of mangroves, roadsides and forest margins.
Biological control: None

Photo:www.issg.org

Piper aduncum L.

Family: Piperaceae
Common names: yaqoyaqona, false kava
Native range: Tropical Americas
Description, habitat: Shrub, or slender tree 1.5-8m high found along roadsides, near cultivation and sometimes in secondary forest.
Biological control: None

Samanea saman (Jacq.) Merr.

Family: Fabaceae
Common names: raintree, vaivai
Native range: Tropical Americas
Description, habitat: Tree 7-25m high, commonly found near sea level along roadside, riverbanks and in secondary forest.
Biological control: None

Photo:www.invasive.org

Lantana camara L.

Family: Verbenaceae
Common names: lantana
Native range: Tropical and subtropical Americas
Description, habitat: Shrub 1-3m high, found from sea level to approximately 900m in thickets on forest margins, roadsides, disturbed areas and agricultural land.
Biological control:16 insect biological control agents have been introduced over the last century (Thomas and Ellison, 1999).

Photo:www.invasive.org

Stachytarpheta urticifolia Sims

Family: Verbenaceae
Common names: blue rat's tail
Native range: Tropical Americas
Description, habitat: Shrub 0.5-3m high, found along roadsides, in cleared areas, plantations and pasture.
Biological control: None

Photo:www.invasive.org

6.3.2 Invasive mammals

Traps were laid at two sites over two nights at each site. Although many baits were taken, and some of the traps were sprung, there were no rats or mice actually captured although three of the traps captured crabs. Table 11, below, summarises the record of all trap activity.

Table 11: Record of rat-trap activity

Site	Date	Trap No.	Trap A	Trap B
Site 1: *Natila*	17 Sept	1	BT – NS	BT – S
		2	BT – NS	BT – NS
		3	BOK – S (c)	BT – NS
		4	BT – NS	BOK – NS
		5	BT – NS	BOK – NS
		6	BOK – NS	BOK – NS
		7	BOK – NS	BT – NS
	18 Sept	1	BT – NS	BT – S (c)
		2	BOK – S	BT – NS
		3	BT – NS	BOK – NS
		4	BT – NS	BT – NS
		5	BOK – NS	BT – S (c)
		6	BT – NS	BOK – NS
		7	BOK – S (c)	BT – NS
Site 2: *Waicoka*	19 Sept	1	BOK – NS	BOK – NS
		2	BOK – NS	BOK – NS
		3	BOK – NS	BOK – NS
		4	BOK – NS	BOK – NS
		5	BOK – NS	BOK – NS
		6	BT – NS	BT – TT
		7	BT – NS	BT – NS
		8	BT – S	BT – NS
		9	BT – NS	BT – NS
		10	BT – NS	BT – NS
	20 Sept	1	BT – S	BT – S
		2	BT – S	BT – NS
		3	BOK – NS	BT – NS
		4	BOK – NS	BOK – NS
		5	BT – NS	BT – S
		6	BOK – NS	BT – S (c)
		7	BOK – NS	BOK – NS
		8	BT – NS	BT – S
		9	BT – S	BOK – NS
		10	BOK – NS	BOK – NS

BOK = Bait left untouched, BT= Bait taken, S=trap sprung, NS=trap not sprung.
Any organism caught in a sprung trap was recorded (c=crab).

Both rats and mongooses were seen by members of the survey team throughout the study site at various times, but no captures were made for identification to species level. Domesticated mammals, which have the potential to become feral, such as pigs, dogs and cats were present within villages and farmland throughout the study site.

6.4 Discussion

Invasive mammals such as rats and mongooses are present in or near mangrove areas but there are no evidence that they are of damage to the mangrove plant communities.

They can however have damaging effects on the native mangrove fauna, such as native birds, amphibians and reptiles and invertebrates that live in the muddy substrate.

In terms of invasive plants, the mangrove habitat most at risk is the back of the mangrove. Stands of *Annona glabra* and *C. hirta* were well established there with an occasional African tulip tree, *S. campanulata* tree*. Passiflora foetida* (stinking passionflower)*, M. micrantha* and *M. peltata* were also relatively well established.

Annona glabra is the one species capable of tolerating both inundated soils (Mielke *et al.*, 2005) and high salinity (Setter *et al.*, 2008). In Australia, *A. glabra* is considered highly invasive to wetland habitats, and has been shown to be capable of invading even relatively undisturbed areas (Agriculture & Resource Management Council of Australia & New Zealand; Australian & New Zealand Environment & Conservation Council and Forestry Ministers, 2001). This species has already established itself in monotypic stands within certain areas of the study site, and is also present in habitats that are in close proximity to the mangroves.

The large number of other invasive plant species present in very close proximity to the mangroves means that this habitat could be vulnerable to invasion in the event of disturbance, especially in the case of disturbances that may alter the physical characteristics of the mangrove habitat in terms of inundation and salinity.

7 TIMBER VOLUME ASSESSMENT

Samuela Lagataki

7.1 Introduction

This assessment and analysis of the tree species composition within the Rewa River mangroves was undertaken as a component of the wider baseline biological, ecological and sociological assessment of the area.

The objective of the study was to economically assess the timber and carbon stock of within the mangroves of the Rewa Delta. In order to do this estimates of the total biomass of the different tree species had to be made, in order to then calculate carbon stocking within the assessment area.

The calculation of biomass in Fiji's mangrove forests is challenging due to the lack of wood density values for certain species (*Bruguiera gymnorhiza*, *Xylocarpus granatum* and *Rhizophora* spp.), as well as the fact that an allometric equation for the calculation of biomass in the Rewa River mangroves has yet to be developed.

7.2 Methodology

Figure 31 shows the locality of the study area in relation to the main urban areas of Suva City and Nausori Town. Data collection was carried out in the vicinity of six villages: Natila, Nakoroivau and Waicoka in the province of Tailevu, and Nasilai, Tavuya and Vutia in the province of Rewa.

7.2.1 Vegetation typing

Four of Fiji's nine principal vegetation types, as described by Mueller-Dombois and Fosberg (1998) made up the majority of the area study: lowland forest; mangrove forest and shrub, coastal strand vegetation and freshwater wetland. The vegetation within the Rewa River mangroves was further classified into 14 different forest and habitat types across these four principal vegetation types (Table 12).

For the purposes of the timber and carbon stocking assessment three of these habitats were selected for sampling: *Bruguiera* forest, mixed mangrove forest and the back of the mangrove.

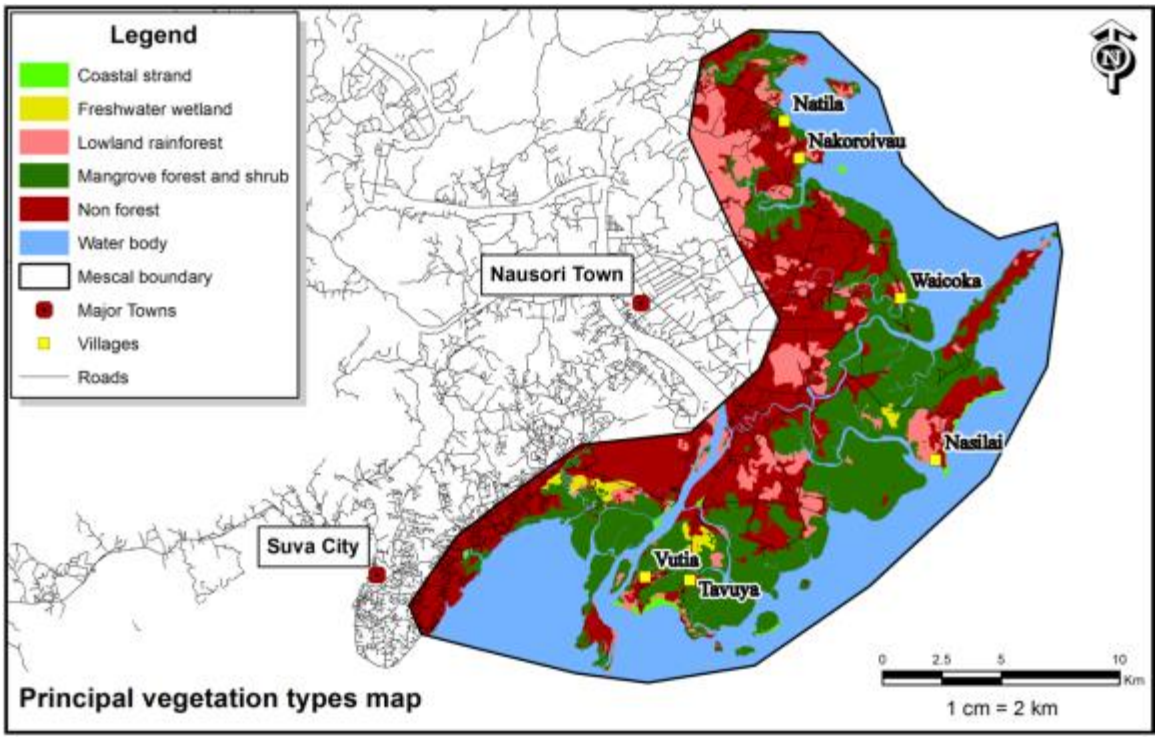

Figure 31: Map of timber volume assessment sites

Table 12: Principal vegetation types and habitats in the MESCAL project area

Forest or habitat types	Principal Vegetation Type				Total area (hectares)	% of total area
	Coastal strand vegetation	Lowland forest	Mangrove forest & shrub	Freshwater wetland		
Bruguiera forest *			1, 978.062		1, 978.1	9.6
Mixed mangrove forest*			3, 507.368		3, 507.4	17.0
Back of mangrove*			2, 182.622		2, 182.6	10.6
Rhizophora forest			968.420		968.4	4.7
Borete swamp			203.287		203.3	1.0
Salt marsh			41.037		41.0	0.2
Coastal forest	150.249				150.3	0.7
Human habitation	3.658	2, 149.865	5.282	1.629	2, 170.4	10.5
Agricultural land		6, 522.421			6, 522.4	31.6
Secondary forest		1, 650.880			1, 650.9	8.0
Anthropogenic secondary forest		916.628			916.6	4.4
Shrubland		186.996			187.0	0.9
Plantation forest		168.788			168.8	0.8
Roads		24.769			24.8	0.1
Total	163.907	11, 620.347	8, 886.079	277.659	20, 671.97	100
*habitats assessed in this study						

7.2.2 Plot location and distribution

Sampling was carried out in 47 plots in the vicinity of six villages in Rewa and Tailevu. The number of plots carried out in each area is given in Table 13. The coordinates of the exact location of each plot can be found in Appendix 13.

Table 13: Plot distribution for timber volume assessment

Province	Village	Number of plots
Tailevu (24 plots)	Natila	5
	Nakoroivau	3
	Waicoka	16
Rewa (23 plots)	Nasilai	8
	Tavuya	2
	Vutia	13
Total		47

7.2.3 Plot sampling

Five different sizes of sample plots and belt transects were used depending on the density of the species of interest.

- 10 m x 10 m
- 20 m x 10 m
- 30 m x 10 m
- 40 m x 10 m
- 50 m x 10 m

For areas of high species density, a plot or shorter transect was used whereas for areas with low species density a longer belt transect was used. The total plot area across the 47 plots was 1.5 hectares. In each plot, every tree was assessed and the following three parameters recorded: species name, tree diameter, and height to the first branch (estimated using a telescopic tree height rod of known length).

7.2.4 Log volume and stocking calculations

All plot data was sorted by species in order to calculate the total log volume for each species. The three dominant species (dogo, tiri, dabi) were analysed individually whilst the remaining species were grouped together under a different category as "others".

The following formula was used for calculating log volume:

$$V=\frac{\pi\left(\frac{D}{2}\right)^2 \times L \times 0.7}{1000}$$

where,

V= log volume (m^3)

D= tree diameter (cm)

L = Log length (m), the height from the ground to the first branch.

0.7 is the approved conversion tree form factor for Fiji(de Vletter, 1995)

Once the total volume for each species in the plot was calculated it was divided by the total plot area (in hectares) in order to get the plot stocking (volume per hectare) of each species.

7.3 Results

7.3.1 Timber species

A total of seventeen tree species were identified during the assessment (Table 14). Notably, there was a strong dominance of *Bruguiera gymnorhiza* (over 78% of the trees assessed in the plots).A further 6% were either *Rhizophora stylosa* or *R. samoense*, 5% were *Xylocarpus granatum* and just over 4% were the hybrid *Rhizophora* × *selala*. These four taxa together constituted 94% of all trees assessed.

Table 14: Timber species recorded from the plot assessments

Scientific name	Local Name	% of total number of trees assessed	Cumulative %
Bruguiera gymnorhiza	dogo	78.63	78.63
R. stylosa and *R. samoense*	tiri	6.45	85.07
Xylocarpus granatum	dabi	5.00	90.08
Rhizophora × *selala*	selala	4.24	94.32
Cocos nucifera	niu	1.36	95.67
Annona glabra	uto ni bulumakau	1.36	97.03
Inocarpus fagifer	vi	1.19	98.22
Excoecaria agallocha	sinu	0.59	98.81
Ficus obliqua	baka	0.17	98.98
Elattostachys falcata	marasa	0.17	99.15
Spathodea campanulata	African tulip, pasi	0.17	99.32
Leucaena leucocephala	vaivai	0.17	99.49
Barringtonia racemosa	vutu wai	0.17	99.66
Alphitonia zizyphoides	doi	0.08	99.75
Morinda citrifolia	kura	0.08	99.83
Lumnitzera littorea	sagale	0.08	99.92
Pandanus tectorius	vadra	0.08	100

7.3.2 Diameter class distribution

Tree diameter distribution is an indicator of which species constitutes the bulk of the volume in a particular population. If a particular species has many trees with large diameters relative to other species, it will have a larger proportion of timber volume. Table shows that *B. gymnorhiza* dominates across the whole range of diameter classes, indicating that it is the clear dominant species in terms of standing timber volume.

Table 15: Diameter class distribution of trees by species

Timber species	Diameter class (cm)									
	<10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**>90**
Bruguiera gymnorhiza	291	199	191	153	61	19	5	5	3	2
R. stylosa and *R. samoense*	55	16	4	1						
Xylocarpus granatum	27	17	3	4	1	2	1		3	1
Rhizophora × selala	6	32	10	2						
Cocos nucifera	5	10	1							
Annona glabra		1	14	1						
Inocarpus fagifer	9	3	1		1					
Excoecaria agallocha		1	3	1	1					
Ficus obliqua	2									
Elattostachys falcata	1	1								
Spathodea campanulata		2								
Leucaena leucocephala				2						
Barringtonia racemosa		1								
Alphitonia zizyphoides	1									
Morinda citrifolia	1									
Lumnitzera littorea		1								
Pandanus tectorius		1								
Total	**398**	**285**	**227**	**164**	**64**	**21**	**6**	**5**	**6**	**3**

7.3.3 Tree species associations

The most abundant species recorded during the tree species analysis were dogo, tiri, dabi and selala. Plots were classified into three categories, coded as D, DTBO and DBO, according to the composition of the four principal species in the plot (Table 16). Each category of species association was allocated to a specific forest type or class (*Bruguiera* forest, mixed mangrove forest or back of the mangrove forest).

- D plots contained either pure dogo stands, or a mix of dogo and tiri associations which were clearly dominated by dogo. Plots that fell in this species association category were classified as *Bruguiera* forest.
- DTBO plots contained a mix of the four principal species of dogo, tiri, dabi, selala as well as other species. Plots that fell in this species association category were classified as mixed mangrove forest.
- DBO plots did not contain any tiri or selala. They were composed of a mix of dogo, dabi and other species. Plots that fell into this species association category were classified as the back of the mangrove forest.

Table 16: Proportion of species standing volume in different plot and forest types

Code	Species Associations (from plot species data)	Proportion of standing volume					Forest type/class (from Table 12)
		Dogo	Tiri	Dabi	Selala	Others	

D	Dogo Tiri	98%	2%				*Bruguiera* forest
DTBO	Dogo Tiri Dabi Selala Others	27%	3%	61%	1%	8%	Mixed mangrove forest
DBO	Dogo Dabi Others	44%	%	14%		42%	Back of the mangrove

7.3.4 Standing timber volumes

Each forest type contains a mixture of the four principal species and any additional species categorised collectively as 'others'. The total log volume of these species within a particular forest type in the study area was calculated by extrapolating the density of the plots to the total study area, for each forest type (Table 17).

Table 17: Total timber volumes for different forest types in the Rewa River mangroves (RRM)

Forest type	Total area of all plots (ha)	Total volume in all plots (m^3)	Stocking (m^3/ha)	Forest type area (ha) in RRM	Total log volume (m^3) in RRM
Bruguiera	1.10	151.52	137.75	1, 978.062	272,478
Mixed mangrove forest	0.11	8.03	73.04	3, 507.368	256,143
Back of mangrove	0.27	20.74	76.82	2, 182.622	167,669
Total (three forest types combined)				1674.052	696,290

The total plot volume per forest type (Column 3 in Table 17) was calculated by summing the log volume of each individual tree assessed in every plot that corresponded to that forest type. The details for individual plots are presented in Appendix 14.

Table 18: Log volume by principal species

Forest type	Log volume (m^3)					
	Dogo	Dabi	Tiri	Selala	Others	Total
Bruguiera forest	267,028		5,450			272,478 (39.1%)
Mixed mangrove forest	69,159	156,247	7,684	2,561	20,491	256,143 (36.8%)
Back of mangrove	73,774	23,474			70,421	167,669 (24.1%)
Total	409,961 (58.8%)	179,721 (25.8%)	13,134 (1.9%)	2,561 (0.4%)	90,912 (13.1%)	696,290 (100%)

By using each species proportion of volume within a particular forest type (from Table 16), the total volume of that species across the whole study area can be calculated. Table 18 shows the estimated volume of each species across the three forest types assessed. Dogo and dabi alone contain almost 85% of the total volume. Over 75% of the total volume is in the *Bruguiera* and mixed mangrove forest types.

7.4 Discussion

Any biomass calculation should focus sampling in only the *Bruguiera* and mixed mangrove forest class, but if species-specific calculations are needed then dogo, tiri and dabi are to be selected for the measurement of wood density.

Above ground biomass is calculated for individual trees and then summed to give a volume per area (hectare). Total tree biomass is measured in metric tonnes, summed to give a total biomass figure per unit area, in this case tonnes per hectare (t/ha).

There are a number of common equations for calculating above ground biomass (W_{AGB}) and below ground biomass (W_{BGB}), for example:

(1) $W_{AGB}=0.251\rho D^{2.46}$(Komiyama *et al.*, 2005)

(2) $W_{AGB}=0.168\rho D^{2.47}$(Chave *et al.*, 2005)

(3) $W_{BGB}=0.199\rho^{0.899}D^{2.22}$(Komiyama *et al.*, 2005)

where,

D=stem diameter (cm),

ρ=species-specific wood density (t/m^3).

Prop roots can be included either in the above ground or below ground calculations.

Once the biomass weight has been calculated for each species, it can then be summed up to give a total biomass per hectare. For our situation it is advisable to only focus on the species which contains the bulk of the biomass, which are *B. gymnorhiza*, *Rhizophora* spp. and *X. granatum*. Therefore the densities of these three species will have to be taken as the basis for species specific biomass calculation.

The measurement for *Rhizophora* spp. will be a different as it has multiple stems and is more characteristic of a shrub than a tree. Due to this, it would be impossible to measure the diameter and bole height of *Rhizophora* as we do for *B. gymnorhiza* and *X. granatum*, thus *Rhizophora* will have to be cut up and have its dry weight taken. The biomass for *Rhizophora* will therefore be calculated based on the area and multiplied by the total biomass weight per unit area (t/ha).

Once the total biomass is calculated for each of these species, the carbon content can be estimated as being approximately 50% of the biomass weight (Payton and Weaver, 2011).

After each of the above ground and below ground biomass has been estimated for each tree, it has to be totalled up for each tree and for each plot. From this the total biomass per hectare can be calculated by dividing the total biomass weight with the total area involved.

Carbon content can be calculated using conversion coefficients (which must be calculated for Fiji) for the stems, branches and leaves, and from this result, a mean carbon stock can also be calculated for each of the vegetation types.

The construction of an allometric equation for estimating biomass, and the calculation of wood densities for *B. gymnorhiza*, *Rhizophora* spp. and *X. granatum* will be the focus of the subsequent set of activities in the near future.

8 FISHERIES INVENTORY SURVEY

Aisake Batibasaga, William Saladrau and Neema Nand

8.1 Introduction

The mangrove ecosystem is a unique wetland that occurs in intertidal zone (the area between high and low water marks). Occupying the space between land and water, the mangrove ecosystem supports both marine and freshwater fish community assemblages, as well as a unique plant community.

Mangrove forests are extremely important resources that are vital for the socio economic development of any country given that are relatively large human population lives along the coastal area and most depend on the local fisheries resources for their livelihood (Kathiresan, 2012).

According to Lal (1990) intact mangroves were estimated to be worth FJD 5, 468 per hectare per year from fisheries alone, while the commercial and subsistence net economic value of mangrove-associated fisheries products were estimated to be worth FJD 31 million per year. Despite concerted efforts to curb mangrove forest destruction and raise awareness of their importance, the loss of mangrove resources and habitats continues to occur in many coastal areas in Fiji. This is most apparent in major urban centres like Suva where the increasing human population has put pressure on infrastructure development and urban expansion.

The mangrove fisheries survey was done to document the fisheries resources found in the Rewa River mangroves and its contribution towards communities as source of livelihood from fisheries. This information is vital for fisheries resource management in Fiji and for mangrove management in Fiji. The data collected is also important for appraising the value of mangroves as fisheries habitat, feeding, breeding and nursery ground.

8.2 Methodology

8.2.1 Survey locations

The actual survey sites were preselected to include the diverse habitats that make up the mangrove ecosystem for the MESCAL Fiji Project. It is referred to as the RRM and it includes the lower RRM area to the north-easterly mangrove forest within the Kaba Peninsular to the coastal mangroves near Viwa Island.

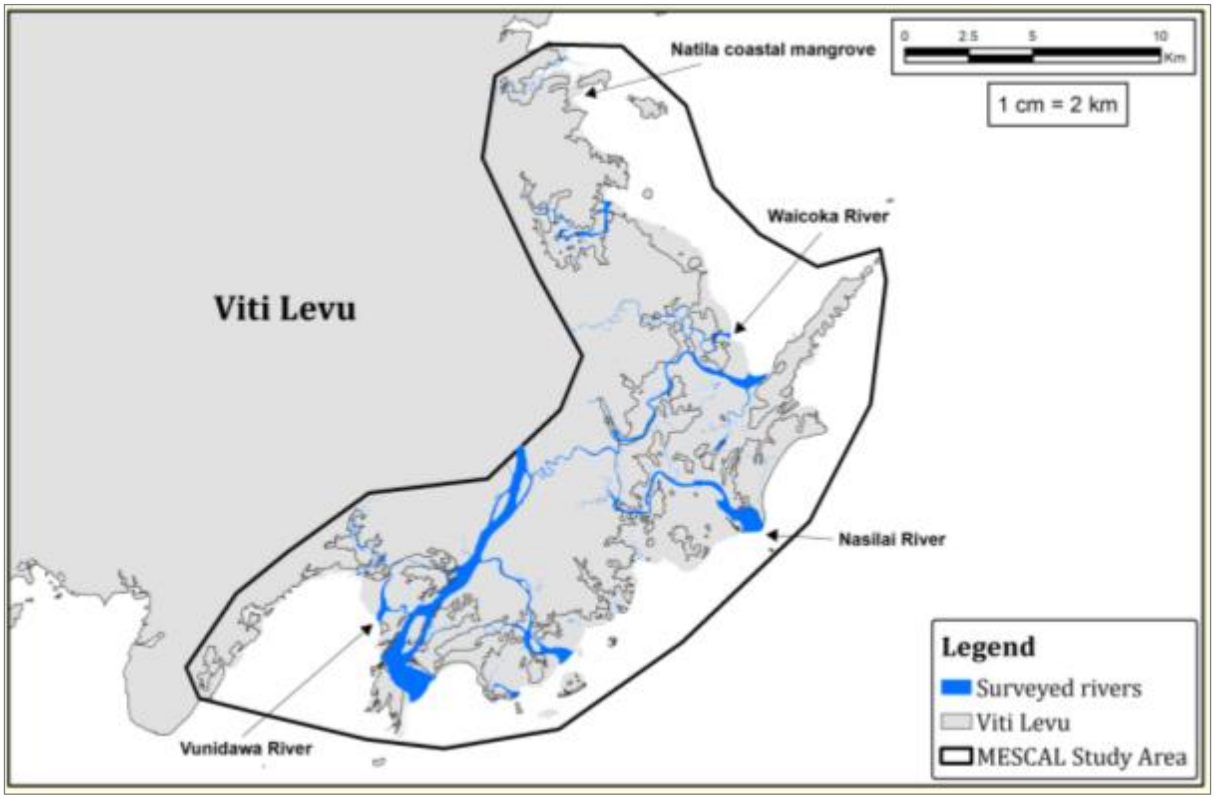

Figure 32: Map of fisheries survey areas

Figure 32 shows the four core study areas that were pre-selected for rapid data collection across the Rewa River mangroves:

Station 1: Natila Settlement coastal mangrove front. Natila located within the Viwa coastal region, and is not connected directly to any major river system.

Station 2: Waicoka River and coastal mangrove system. Waicoka is found immediately north-west of the Kaba Peninsular. Waicoka is connected to Waicoka River, and the associated mangrove forest and intertidal zones.

Station 3: Nasilai River, and inner mangrove forest site. Nasilai River mouth is connected to the Rewa River through the Nasilai River, which is a smaller tributary of the Rewa River, is found north-east of the main Rewa River mouth

Station 4: Vunidawa River and associated mangrove areas. Vutia is located at the lower reaches of the Rewa River, and is connected to the main Rewa River by a smaller tributary called Vunidawa River. Vutia is about 1.5km from the main Rewa River mouth that flows out into Laucala Bay.

The two groups of marine and brackish water organisms assessed in the pre-selected study area along the RRM were the fin fish and non-finfish species. The following fish sampling methods were deployed:

8.2.2 Fin fish survey

Gill nets

Three different mesh sizes of Gill nets were used depending on the water depth, width, and the fish species targeted. Three mesh sizes were used:

- 3 inch mesh gill net used along fringes of mangroves, river mouths and lower estuaries with sea grass and coral substratum.
- 2 inch mesh gill net used in the upper mid river areas and smaller river tributaries.
- 1 inch mesh gill net placed across creeks.

Handheld nets (push-nets)

These were used in shallow tidal drains and partially emptied creeks during low tides to capture docile fish species that normally lie on muddy bottom of the river. During high tides at night, hand-held nets were also used to capture fish that enter through the village-based drainage system.

Set nets

The set nets were deployed during full high tide and checked 3 hours later to coincide with the receding tide. They were also deployed at night to capture nocturnal and other benthic species that are difficult to catch during the day.

Creel survey

Creel surveys were undertaken to record catches made by small scale or recreational fishermen. It involved interviews of fisher folks and the inspection of their catches at the fishing ground and/or and landing sites. Data recorded included fishing method, fishing locality, species name, measured lengths (cm) and weights (g), duration of fishing trip and the number of people involved in the fishing.

Drag net (yara)

This particular method sampling involves three to four individuals holding 1″ mesh net (1 coil) along the beach, with one person to hold each end of the net, whilst the other two people chase or drive the fish towards the middle of the net. Both ends of the net would be pulled-in gradually to form a circle, or otherwise the nets are dragged onto the shoreline, thus trapping the fishes. These assessments target schools of marine fishes that move or forage across the mangroves in search of food or to seek shelter from

larger predatory fishes. Catch obtained from this assessment were recorded for species name, number (density), length (cm) and weight (g).

8.2.3 Non-fin fish survey

Different data collection methods or a combination of one or two methods were used for mobile and immobile invertebrates, where appropriate.

Opportunistic survey

This involved walking through mangrove forests, tidal pools and benthic substrates during low tide documenting invertebrate species encountered. Those that cannot be identified on the field were collected for later taxonomic analysis in the laboratory.

Push nets

Hand-held nets with 30mm mesh size were used to capture species that are to be found in shallow creeks, tidal pools and on estuarine mudflats. This is done during low tide in the upper reaches of rivers and creeks, and in village drain outlets, where the water depth is shallow to ankle-deep only.

Creel survey

Catch data was recorded from fisher's that normally target commercial invertebrate species (such as crabs and shrimps), where species name, size, weight, duration of fishing, and number of people involved were recorded.

Quadrat sampling

This sampling method was utilised at one site to obtain the density of bivalves (largely the ark shells, *Anadara antequata* and associated bivalves such as *Gafarium tumidum* that are found within the intertidal sand and mudflats of Natila Settlement coastal zone.

Quadrats of 1 m^2 in size were excavated and the bivalves in the quadrat area counted and their lengths measured. This method is largely used for sampling burrowing organisms such as bivalves, polychaetes and sipunculid-like worms and gastropods.

8.2.4 Data analysis

Finfish data was analysed using the programme Pasgear 2 (Kolding and Skalevik, 2009). The percentage index of relative importance (%IRI) was used to calculate the relative importance and diversity of the different taxa(Pinkas *et al.*, 1971, Kolding, 1989, Kolding, 1999). This index is a measure of relative abundance in terms of the number,

weight and frequency of occurrence in the catches. For each species (*j*) the percentage IRI is calculated by the following formula:

$$\%IRI_j = \frac{(\%\mathrm{N}_j + \%\mathrm{W}_j) \times \%\mathrm{F}_j}{\sum_{\mathrm{i}=1}^{\mathrm{S}}(\%\mathrm{N}_i + \%\mathrm{W}_i) \times \%\mathrm{F}_i} \times 100$$

where,

- $\%\mathrm{N}_j$ and $\%\mathrm{W}_j$ are the percentage number and weight of that species in the total catch.
- $\%\mathrm{F}_j$ is the percentage frequency of occurrence of that species in the total number of settings.
- S is the total number of species.

To measure the number of species weighed by their relative abundance, the Shannon diversity index, H′, (Begon *et al.*, 1990) was used, and is expressed as:

$$H' = -\sum_{i=1}^{S}(\mathrm{P}_i \times \ln \mathrm{P}_i)$$

where,

- P_i is the portion of the entire population made up of species *i*
- S is the total number of species.

The Shannon index assumes that individuals were randomly sampled from an 'indefinitely large' population, and that all species were represented in the sample. The value of the Shannon diversity index usually ranges between 1.5 and 3.5. A higher value of H′ indicates higher species diversity.

The index of evenness, J′, (Begon *et al.*, 1990)was also calculated which showed the ratio between observed diversity and maximum diversity, and was calculated using the following formula:

$$\mathrm{J}' = \frac{\mathrm{H}'}{\mathrm{H}'_{\max}} = \frac{\mathrm{H}'}{\ln(\mathrm{S})}$$

where,

- H′ is the Shannon diversity index
- $\mathrm{H}'_{\max}$ is the maximum possible diversity, equivalent to ln(S)
- S is the total number of taxa

J' is constrained between the range of 0 and 1, with J'=0 representing a population in which there is only one taxon, and J'=1 representing a population in which there are more than one taxon and all taxa are equally abundant.

8.3 Results

8.3.1 Fin fish diversity

A total of 761 fishes were caught and recorded at the survey site, comprising 121 species in 47 families (Figure 33).

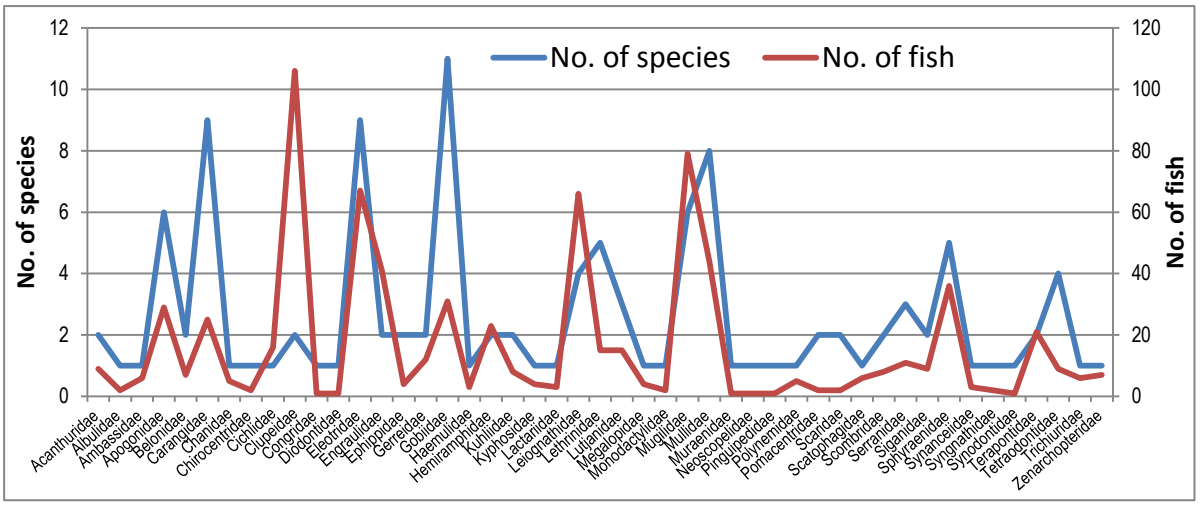

Figure 33: Number of species and number of individuals caught, by family

The five most abundant fish families were Gobiidae (11 species), Carangidae (9 species), Eleotridae (9 species), Mullidae (8 species) and Apogonidae (6 species). The other families has between 1and 5 species recorded, with 21 fish families having only one species recorded and fourteen families having only two.

The family Clupeidae had the most number of fish caught, with 106 samples recorded, from just two species. The Mugilidae had a fish count of 79 from five different species, and the family Eleotridae had 67 fish from nine species. The rest of the families had fish counts ranging from 1 to 66.

The diversity of the species recorded at each of the four sites was analysed to give an overview of the fin fish productivity at each site (Table 19).Waicoka and Vutia recorded the highest total number of fish families (39 and 32, respectively) although the number of species at Waicoka (97) was more than at Vutia (58). At the Natila site 27 species from 20 families were recorded, while at Nasilai site only ten fish species from eight fish families were recorded.

Table 19: Number of families and species of fish recorded per site

Site	No.of families	No.of species
Station 1: Natila	20	27
Station 2: Waicoka	39	96
Station 3: Nasilai	8	10
Station 4: Vutia	32	58

The Index of Relative Importance (IRI) was graphed(Figure 34) to show the relationship of the three parameters of fish shock dynamics, namely, percentage weight, percentage number and percentage frequency for all fish families identified during the survey.

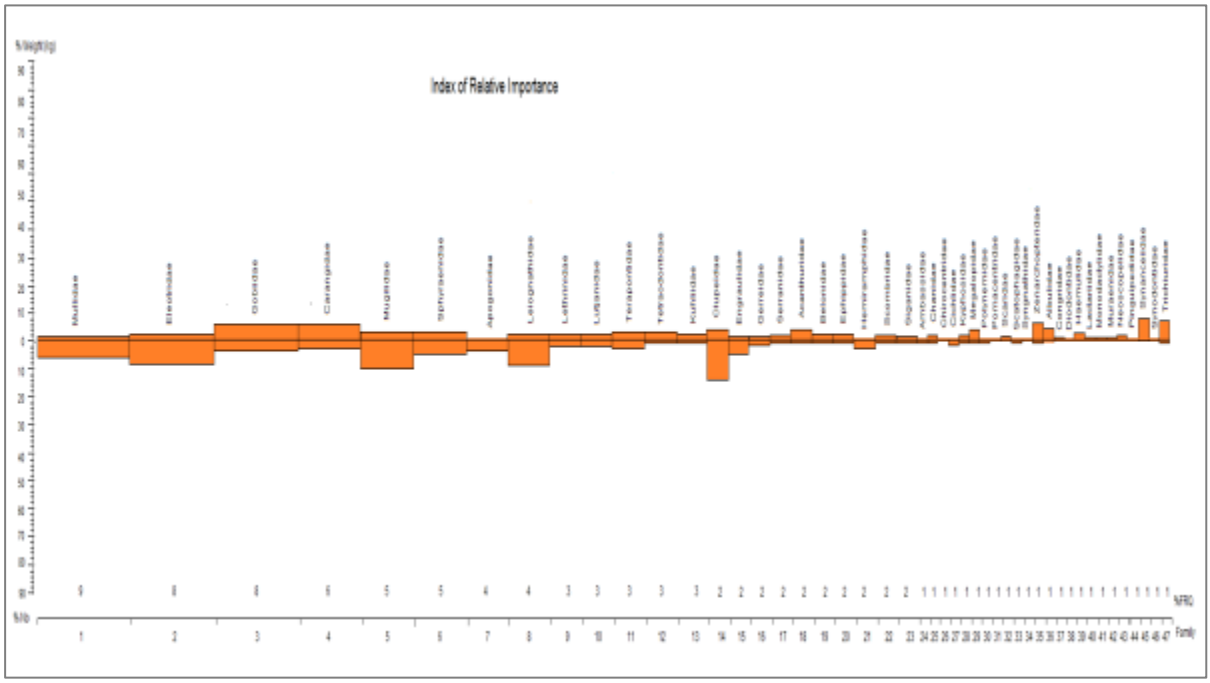

Figure 34: Index of Relative Importance for 47 fin fish families recorded

The frequency of occurrence ranged from 0.5% to 8.8%. The Mullidae family had the highest frequency of occurrence (8.8%), followed by the family Eleotridae (8.3%) and Gobiidae (7.8%).

The weights of fish in the families are relatively low compared to their numbers,, implying the presence of smaller weight fish.

The Shannon Index (H) was 3.15 for the total sample indicating a high diversity of species at the site and the evenness index (J') was 0.66, indicating a relatively even distribution of fish stock in the study area.

8.3.2 Fin fish families

- Acanthuridae (surgeonfish): The only two fish species recorded were *Acanthurus dussumieri* and *Acanthurus mata* observed foraging or sheltering within the submerged roots of the mangroves 300m from the river mouth during high tide.

Their sizes were estimated to be approximately 12.5cm and 17cm respectively. Both species were juveniles (perhaps 4-5 months old).

- Albulidae (bonefish): There was only one species recorded for this fish family, and was identified as *Albula vulpes*. The fish was caught by gillnet from the river mouth at Nasilai Village measuring 51cm in length.
- Ambassidae (glassfish): Only 1 species of this family was found in the samples. This species was identified as *Ambassis miops*, and is known to be found in blackish water and have glass like transparent body.
- Apogonidae (cardinalfish): The fish were caught only by handheld nets (10mm mesh sizes) during low tides in dried-up rivers and creeks. Six species were recorded with the most common species recorded being *Apogon amboinensis* and later followed by *A. lateralis*. *A. amboinensis* also had the greater average size compared to the rest of the species.
- Belonidae (needlefish): Needlefishes are slender long animals that swim on the surface of the water surface and in this survey two species was recorded from this fish family and identified as *Tylosurus crocodilus* and *Strongylura incise*.
- Carangidae (trevallies): There were nine different species (*Caranx melampygus, C. papuensis, C. sexfasciatus, C. ignobilis, Gnathanodon speciosus, Scomberoides lysan, Selar crumenophthalmus, Trachinotus blochii*) were recorded from this family. *Selar crumenthalmops* (purse-eyed scad) are smaller carangid species, which are seasonal and commonly encountered as near shore large schooling pelagic species. Commonly observed during the summer months in Fiji, and large schools could be netted from near shore areas, especially near mangrove and estuarine bays. Over-exploitation and destruction of mangrove areas have led to their decline and reduction in biomass and productivity where they are normally found. *Trachinotus blochii* (snub-nosed dart- qawaqawa), is a common mangrove, estuarine and intertidal species across the Rewa and Tailevu coastal zones. Overfishing and destruction of mangrove areas across these study sites may be the main reason for declining catches and occurrence.
- Chanidae (milkfish): Only one species was recorded from the family Chanidae. This species was *Chanos chanos*. A total of five fish were collected for this species, from the Waicoka and Vutia sites. The size of these was relatively smaller than its average size, and may be in juvenile phase.

- Chirocentridae (wolf herrings): Only one species was encountered from this family and was identified to species level as *Chirocentrus dorab* (voivoi). Two fish were recorded from this survey: 41 cm and 70 cm, respectively.
- Cichlidae (cichlids): One very common introduced fish in the fresh and brackish water creek systems in this study were the tilapia fish, and the common species that was recorded was *Oreochromis mossambicus*. The currently farmed hybrid fish was also collected, particularly from Waicoka stream, creek and tidal drain systems, which is the genetically improved tilapia fish (GIFT). Most of the GIFT fish were caught on handheld nets across the Waicoka Village tidal drainage system, and which were largely juveniles and sub-adults (10-21cm).
- Clupeidae (herrings): Two species of the family Clupeidae was identified. These were the species *Herklotsichthys quadrimaculatus* and *Sardinella fijiense*. These species were caught in only two sites, Waicoka and Vutia, and are known to be targeted for subsistence consumption, although not targeted often.
- Congridae (congers and eels): Only one species was collected during the whole survey. This was from the species *Conger cinereus*.
- Diodontidae (porcupinefish): The Diodontidae family was rarely seen during the survey at the sites. The only record of this during the survey was of the species *Diodon liturosus*, occurring only once.
- Eleotridae (sleepers): Nine species were identified from this family and their sizes were taken. *Bostrychus sinensis* and *Eleotris fusca* were caught from the handheld nets used, and sizes of these ranged from 10cm to 18cm. However, *Eleotris melanosoma* is a commercial species and was recorded from local women who target this fish for sale and for subsistence requirements, thus size distribution could reach above 23cm in some cases. The two common sleeper species found at Waicoka was E*. melanosoma* and *E. fusca*. This species were seen in the small streams, creeks and the tidal drains. The largest size of *E. melanosoma* caught was 21 cm. Sizes of *O. porocephala* (kurukoto) ranged from 8cm to 40cm, whilst common sizes recorded were around 16-20 cm and 21-25 cm. The largest size recorded was 40 cm, and the smallest species measured at 8cm. This species was very common in Vutia Village, and is a very important food fish among the local village households there. *O. porocephala* (Spangled gudgeon) is a good mangrove and estuarine habitat indicator species, and its presence and diversity in size and higher density and biomass indicates a healthy and

productive habitat unit. There wasn't many occurrence of this species recorded in the other three sites, and this could be due to the connectivity of the habitat unit with downstream and upstream exchanges of other life history stages. This fish may need longer upstream areas to help bolster recruitment, and thus the large density of the species observed at Vutia (which is at the lower reaches of the RRM area).

- Engraulidae (anchovies): Two species at the Nasilai and Vutia sites were *Stolephorus indicus* and *Thryssa baelama*. These occurred in small schools and were sometimes targeted by the fishermen for fishing line bait.
- Ephippidae (batfish): The species *Platax teira* and *Platax orbicularis* were caught at Vutia, Waicoka and Nasilai sites.
- Gerreidae (silversides): Two species were recorded from this fish family and the species was identified to be *Geres oyena* and *Gerres macrosoma*. These species were and were encountered and recorded only once during this survey
- Gobiidae (gobies): Gobies were the most diverse family, with eleven different species recorded. All the gobies were obtained with handheld nets during low tide in pools of water within mangrove swamps, and along the river banks. Few gobies are an important fish, they are however significant prey for commercial fish such as rock cod (groupers) and snappers. The presence of large number of gobies therefore indicates a decrease in the number of these commercial species. A vast number of gobies were caught along the Waicoka and Nasilai sites, indicating a healthy mangrove system in these areas.
- Haemulidae (grunts): Only three individuals were recorded, all of which were *Plectorhinchus gibbosus*, commonly known as Harry hot lips.
- Hemiramphidae (halfbeaks): Two common half-beaks recorded were *Hemiramphus far* and *Zenarchopterus dispar*. They were common through the four sites and found along the outskirts of the mangrove to the top creeks of the upper river, and even in village drains that are affected by the tides. Individuals that were caught with handheld nets ranged from 8cm to 15cm in length.
- Kuhliidae (flagtails): Two species were caught using gillnets: *Kuhlia marginatus* (spotted flagtail) and *Kuhlia rupestris* (jungle perch). *K. rupestris* (sakelo) is largely a freshwater species, but may move downstream for breeding.
- Kyphosidae (sea chubs): The only species observed for this family was *Kyphosus vaigiensis* (brassy chub).

- Lactariidae (false trevallies): The species *Lactarius lactarius* has been observed to be seasonal, and is common during the summer months, but is clearly declining within its natural ranges within the two major islands, and across the major rivers and mangrove systems in Fiji. It is an important food fish, as well as a commercial species across other regions in Fiji, particularly in the Western Division. A large mature individual was caught by gillnet at Vutia during the survey. The fish is a rare catch and was unfamiliar to the communities at Vutia. The catch coincided with unusual heavy rainfall and high turbidity of the river system for two consecutive days. This fish is a good indicator species for mangrove and estuarine ecosystem health and productivity, whose occurrence could diminish with continuous overfishing and degradation of mangrove and estuarine habitat units.
- Leiognathidae (ponyfish): There were four species of ponyfish identified in this survey and are *Gazza minuta*, *Leiognathus equulus, L. fasciatus* and *L. rivulatus*. This fish type dominated the entire survey and was caught in almost all the nets that were deployed overnight or during the day, as well as being recorded from local fishers' catch. The majority of the ponyfish ranged in size room 6 to15cm. 75% of the fish were less than 10cm long, indicating these were mostly juveniles, and that the mangroves and associated habitat units are important nursery areas for these species.
- Lethrinidae (emperors): Emperors are one of the main food fish species of Fiji and during this survey five species were recorded. *Lethrinus harak* was the most common, followed by *L. miniatus*. *L. reticulatus* was the least abundant of the five species. The different species showed wide distribution in terms of size, with *L. harak* showing a wider distribution in terms of its length compared to *L. miniatus*. The majority of individuals of these two species were in the large range, showing that these fishes are adults and sub-adults using the estuarine areas and intertidal or littoral zones for foraging purposes.
- Lutjanidae (snappers): A total of six species were recorded, but this list is certainly not exhaustive: other species which could be included under this family include *Lutjanus russelli, L. gibbus, L. ehrenbergi* and *L. kasmira*. Snappers are primarily found on coral reef ecosystems, but move between mangroves, estuarine habitat areas, seagrass beds and inner reef lagoons. The fish in this group are active predators, and feed mainly on fish species, but crab species,

shrimps, gastropods, cephalopods and planktons are also consumed. The larger lutjanid species are also target for angling such as mangrove jack (*L. argentimaculatus*), red bass (*L. bohar*), and green jobfish (*Aprion virescens*). Although commercially important as a food fish, snappers are at risk of ciguatera infection. The ciguatoxin is caused by a toxic dinoflagellate (*Gambierdiscus toxicus*) found on dead corals, benthic algae and sea grass blades, which are first ingested by herbivorous fishes, and which are later eaten by larger predatory fishes. The toxin is accumulated and passed across the food chain, and the larger carnivorous fishes accumulate the most toxins with time. Some species are highly poisonous compared to others, e.g. *L. rivulatus* (known as regurawa because of the potent toxin the species is known to have).

- Megalopidae (tarpons): the only species recorded from this survey was *Megalops cyprinoides,* which was caught on two occasions by local fishermen and had an average length of about 30 cm.
- Monodactylidae (moonfish): A single species, *Monodactylus argenteus*, was recorded in this survey. A few of the moonfishes are also brackish water species.
- Mugilidae (mullets): Mullets had the second highest number of species recorded (five species). They were caught by gillnet sets, and also recorded from interviews with local fishermen and women who normally target these species for commercial purpose. Altogether there were 43 counts of mullets caught with gillnet, creel surveys, and handheld push-net. The largest mullet recorded was 23cm (*C. subviridis*) and the smallest recorded was 5cm. Different species of mullets had varying size distributions but the majority of the population was less than 15cm in length. This information clearly supports the fact that the mangrove and the estuarine mid-and lower river zones are important nursery areas for most of the species encountered.
- Mullidae (goatfish): The survey recorded eight species of goatfish: *Mulloidichthys vanicolensis, Parupeneus barberinus, P. cyclostomus, P. indicus, P. trifasciatus, Upeneus vittatus, U. taeniopterus* and *U. tragula*. *P. bifasciatus* dominated numbers recorded during the survey and was the most common.
- Muraenidae (moray eels): Although common in tropical waters, only one starry moray eel (*Echidna nebulosa*) was recorded.
- Neoscopelidae (lanternfish): One specimen of the species *Neoscopelus macrolepidotus* was recorded.

- Pinguipedidae (sandperch): The species *Parapercis clathrata* was recorded at the Waicoka site.
- Polynemidae (threadfins): Only a single genus was recorded from this family and that was *Polydactylus plebeius*. This fish genus is a good indicator of habitat health, and its presence and density may equate to the present habitat unit health and productivity. The threadfins usually use the mangrove and estuarine ecosystem for foraging, as well as spawning and nursery areas.
- Pomacentridae (damselfish): Two species were recorded at Waicoka site. These were *Pomacentrus spilotoceps* and *Neopomacentrus violascens*.
- Scaridae (parrotfish): Two species was recorded from this family and identified as *Scarus rivulatus* and *Calotomus spinidens*. These fish was caught by gillnet a few meters away from the river mouths and streams of Vutia and Waicoka sites.
- Scatophagidae (scats): Scats are common residents of the mangrove areas, and the one species that is common to mangroves, estuarine and even higher reaches of Fiji's river systems is *Scatophagus argus*. Large sized fishes were recorded from the creel survey while over eleven juvenile specimens were collected from the shallow areas during low tides.
- Scombridae (mackerel): Two different species of contrasting characteristics were recorded from this fish family during this survey: *Rastrelliger kanagurta* (long-jawed mackerel) and *Scomberomorous commerson* (narrow-barred Spanish mackerel). *S. commerson* is a huge pelagic fish which is largely spawned and nurtured within the estuarine and mangrove ecosystem when young, before it migrates offshore to adjoining offshore reef systems. This is an important commercial and angling species in Fiji; and elsewhere in the Indo-Pacific region.
- Serranidae (groupers): There were only three species recorded, although the creel catch and interviews showed that a number of other species are common and found within the estuarine and mangrove areas. The absence of most of the grouper species from the estuarine system may be symptomatic of high levels exploitations, or habitat alteration and degradation.
- Siganidae (rabbitfish): Rabbitfish are commonly in mangrove area and were recorded from the hand-held nets and the gill nets. Small-sized *Siganus vermiculatus* (juvenile) rabbitfish were caught by handheld nets in the pools that are half-filled during low tide whilst larger sizes were caught in gillnets.

- Sphyraenidae (barracudas): Five species from a single genus were recorded from this family: *Sphyraena putnamae, S. obtusata, S. forsteni, S. flavicauda* and S*. barracuda*.
- Synancidae (stonefish): One of the rare finds of this survey was the stonefish identified as *Synanceia horiida,* recorded in the pools that exist in mangrove swamps at low tide.
- Syngnathidae (seahorse): The only sea horse recorded was *Hippocampus kuda*, the spotted seahorse.
- Synodontidae (lizardfish): Only one species, *Synodus variegatus,* was caught during the survey.
- Terapontidae (grunters): Two species were recorded: *Terapon jarbua* and *Mesopristes kneri*. The two species are a contrast to each other due to the fact that *T. jarbua* is the most common fish along our coastlines and beaches, whilst *M. kneri* is a rare endemic species, and occurs in estuarine and mangrove ecosystems. *M. kneri* is a seasonal species, and aggregates across the estuarine and mangrove habitats during spawning season which commences in October in Fiji and continues through the summer months.
- Tetraodontidae (puffers): Three species of puffers were caught in the handheld nets: *Arothron manilensis*, *A. nigropunctatus*, and *A. hispidus.* A fourth species, *A. mappa*, was recorded from the creel assessment at Nasilai. The fish sizes recorded showed that the individuals caught were juveniles (5-8 cm), since adults are known to attain lengths of more than 40 cm.
- Trichiuridae (hairtails): One species was recorded, locally known as beleti in Rewa and Tailevu, but as tovisi in southern and southwestern Viti Levu. This is a common estuarine and mangrove fish species, which also forms large aggregations during the summer months in Fiji. It is an important subsistence species, as well as a commercial species within the artisanal fisheries sector. The presence of this species and its high density aggregations indicates a productive and healthy mangrove, an intact estuarine habitat unit and productive intertidal bays and lagoon systems.
- Zenarchopteridae (viviparous halfbeaks): The only species recorded was *Zenarchopterus dispar* at the Vutia and Natila sites.

8.3.3 Sharks and rays

Four species of shark and three species of ray were recorded (Table 20). The shark species observed were the juveniles of the black tip and white-tip sharks, as well as the juveniles of scalloped hammerhead sharks. Bull sharks were also seen near mangroves. Judging by their size, the shark species recorded were in their juvenile phase.

Table 20: Sharks and rays recorded during the survey

Scientific name	Family	Common name
Triaenodon obesus	Carcharhinidae	Whitetip reef shark
Carcharhinus limbatus	Carcharhinidae	Blacktip shark
Sphyrna lewini	Sphyrnidae	Scalloped hammerhead
Carcharhinus leucas	Carcharhinidae	Bull shark
Dasyatis kuhli	Dasyatidae	Blue-spotted stingray
Taeniura lymma	Dasyatidae	Ribbontail stingray
Aetobatus narinari	Myliobatinae	Spotted eagle ray

The presence of shark juveniles along the estuaries indicates that the mangroves and large rivers are an important breeding ground for these species. Estuarine and mangrove habitats are important nursery areas for young coastal or coral reef shark species. Bull sharks occur between both freshwater and marine environment. The presence of shark juveniles is also an important indicator of the health of the river, estuarine, and mangrove ecosystems. Degraded ecosystems would have low fish diversity and density, and would thus not support the juveniles of these coastal shark species. Other shark species that were reported to be also present within the rivers and estuarine bay areas were the gray reef shark, and the tawny nurse shark. The three ray species recorded (the blue-spotted, ribbontail and spotted eagle stingrays) ranged in size from 35cm to 70cm.

8.3.4 Invertebrates

Five categories of invertebrates were also recorded during the survey: crabs, prawns, gastropods and bivalves, echinoderms, and seagrasses and other species (Table 21).

Table 21: List of invertebrates recorded from the Rewa River mangroves

Category	Scientific Name	Common Name	Local Name
Crabs	*Calappa hepatica*	common box crab	qari-qumia
	Calappa sp.1 *(unidentified)*	box crab	qumuqumu
	Cardiosoma carnifex	land crab	lairo
	Charybdis sp.1	green swimmer crab	qari-saidroka
	Eryphnia sebana	red-eye crab	taqalito, motodi
	Grapsus albolineatus	shore-crab	saravi
	Metopograpsus messor	black mangrove crab	kukaloa
	Ocypode cerathopthalma	ghost/sand crab	kaoki
	Parthenope sp.1	seaweed crab	qari-saulima.

Category	Scientific Name	Common Name	Local Name
	Plagusia dentipes	shore crab	qari-sedravu
	Portunus pelagicus	sand or ghost crab	kauke
	Schizophyrs sp.1	spider crab	qari-riba
	Scylla serata	green mangrove crab	qari dina, qari.
	Sesarma erythrodactyla	red clawed mangrove crab	kuka
	Thalassina anamola	mud lobster	mana
	Thelamita crenata	swimmer crab	qarivatu
	Uca coarctata	fiddler crab	toto
	Varuna litterata	Sargassum crab	sarakali
Prawns	*Macrobrachium equidens*	river prawn	sasakadi
	Macrobrachium lar	freshwater prawn	ura dina
	Macrobrachium rosenbergii	giant Malaysian freshwater prawn	vidiki (thick claws)
	Palaemon concinnus	mangrove prawn	moci
	Penaeus monodon	giant tiger prawn	ura kei ra saqa
Gastropods & bivalves	*Anadara antiquata*	ark shell	kaikoso
	Atactodea striata	surf clam	sigawale
	Cerithium nodulosum	horn shell	siciyara
	Crassostrea gigas	giant Pacific oyster	dio levu
	Crassotrea mordax	mangrove oysters	dio
	Garfarium tumidum	venus shell	kaidiri
	Lambis lambis	spider shell	yaga
	Modiolus agripetus	mangrove mussel	kuku
	Nerita polita	polished nerite	madrali
	Periglypta puerpera	hardshell calm	bu
	Pinctada magaritifera	black lip pearl	civa
	Pinctada magaritifera	jewel box shell	bu
	Pinctada martensi	pigmy pearl shell	civaciva
	Polinices flemingiana	moon snail	drevula
	Spondylus ducalis	thorny oyster	kolakola
	Strombus gibberulus	stromb	golea
	Strombus luhuanus	red lipped stromb	tivikea
	Tapes literata	littleneck clam	kaivadra
	Turbo chrysostomus	turban shell	lasawa
	Vasticardium sp.	coconut scrapper cockle	kainiu
Sea cucumbers (Echinoderms)	*Actinopyga mauritiana*	surf redfish	tarase
	Holothuria atra	lollyfish	lolly
	Holothuria scabra	sandfish	dairo
	Holothuria whitmaei	black teatfish	loaloa
Seaweeds & other species	*Acanthozostera gemmata*	chiton	tadruku
	Cassiopea sp.	upsidedown jelly fish	drose
	Caulerpa racemosa	seagrapes	nama
	Caulerpa sp.	seagrapes	namakeibelo
	Dolabella sp.	black seahare	veata-ika
	Dolabella auricularia	green seahare	veata
	Hypnia nidifica	maidenhair	lumi-cevata
	Lingula unguis	lamp shell	voce
	Siphonosoma australe	peanut worm	ibo
	Sipunculus sp.	peanut worm	vetuna

The survey identified several different types of crab species, and one mud lobster that inhabits the mangrove areas of the Rewa River. Four of the crab species could not be identified down to species level, being relatively rare and new records. The unidentified species were from the

Natila site (unidentified box crab), and from the Nasilai lower estuarine sand flats (swimmer, spider and seaweed crabs).

Five prawn species were recorded, the majority of which were obtained through the use of handheld nets. The gastropods and bivalves were gleaned using different collection methods, during low tide in the mangroves.

Four species of echinoderms (sea cucumbers) were recorded along the mangrove beach front on one of the sites exposed to the ocean influence. The two most abundant species were: *Holothuria scabra* (dairo) and *Holothuria atra* (lollyfish).

The survey also captured information on the common sea grapes, and algal species, as well as other invertebrate species in the survey areas.

8.4 Discussion

There is a direct correlation between the number of fish species and the catchment forest cover in an area (Keith, 2003, Jenkins, 2009). The most common fish species of the mid-reaches of rivers and mangrove ecosystems are the gobies and gudgeons, which are easily affected by the reduction in forest cover or the degradation of the natural ecosystem.

This was clearly observed in this survey by comparing fish diversity and abundance at different sites in the study area. The Natila site had the lowest numbers of gudgeons, gobies and other mangrove associated species. Only two gobies and one gudgeon were recorded from Natila during the two day sampling period there (17-18 October, 2012), despite it being a rural and relatively isolated site in Tailevu Province. At Natila there has been significant mangrove harvesting for subsistence firewood usage. Another factor that may also have affected the local species diversity at his site is the construction of traditional mud causeways which are a barrier for larval exchange and influxes of freshwater between the coastal regions of the village and upstream freshwater sources.

When the survey moved southwards to Waicoka Village, there were relatively more fish species recorded, since there has been a greater effort on the part of the community to protect their mangrove forest. However, there were other factors that may have affected species diversity, such as the presence of a very high population of invasive *Oreochromis* spp., exacerbated by the destruction of mangroves from adjoining villages for the construction of roads, and increased village infrastructure expansion. The main species

that observed and harvested at Waicoka were the Ebony and Brown gudgeon, and the gobies (*Awaous spp*.). Of all the fish species found within the rivers and mangrove habitats, amphidromous gobies have the highest level of endemicity within oceanic island systems(Jenkins *et al.*, 2010).

The loss of natural forest and catchment vegetation cover has been demonstrated to be related to substantial loss in native fish and invertebrate species (Haynes, 1999).This also includes the reduction in native fish species after the introduction of the tilapia fish. The effects of introduction are intensified because this exotic species is more easily established in a degraded environment.

Natila and Vutia were noted to have been more exposed to development pressures, such as roads and causeway constructions, as well as being subjected to more anthropogenic activities. Vutia, located within the Rewa River delta area, is a site that has been continuously affected by heavy flooding incidences and siltation for the last three to four decades. The lower reaches of the Rewa River (where Vutia is located), and the estuarine areas has been subjected to large scale dredging in 2010 and 2011, thus presenting a more damaged mangrove and riverine system with less species diversity.

However, there are good indicators of biological productivity and species differentiation within the Rewa River mangrove area, and that it was clear that a number of species found in the lower reaches of the Rewa River were not found in the other three sites e.g. a number of gobies, gudgeon, and larger mangrove and coral reef associated species were only found within the Vutia sites (lower reaches of the Rewa River), and were not recorded or are relatively rare at the other three study sites.

Jenkins *et al*, (2010), have indicated that of the following four factors are considered together on the mid-reaches of a number of Fijian river systems, that is: (i) effects of Oreochromis spp. introduction, (ii) catchment forest cover, (iii) distance upstream, and (iv) distance downstream from river mouths; only the presence of invasive tilapia and catchment forest cover were found to be significant. This study further found that areas where tilapia had been introduced and established had seven fewer species of amphidromous gudgeons and gobies, compared to the sites that were free of tilapia.

At a national scale assessment on rivers and estuarine systems across Fiji, it was commonly observed that the mean number of fish species dropped by 11 within the mid to lower reaches of most of the river systems that had established populations of invasive tilapia species (Jenkins *et al.*, 2010).

Other fish species that were noted to be absent from such tilapia-impacted sites included *Chanos chanos* (milkfish), *Ophiocara porocephala* (spangled gudgeon), *Albula vulpes* (bonefish), *Lactarius lactarius* (false trevally), *Zenarchopterus dispar* (river garfish), *Lutjanus argentimaculatus* (mangrove jack), *Hippocampus kuda* (sea horse), and *Microphis branchyurus branchyurus* (estuarine pipefish).

As is clearly noted in this study from Natila, and the other three fish sampling stations, the health and expanse of catchment forest areas were significantly related to the total number of species, and the density of fish recorded from each coastal site (study sites all situated on the lower reaches of the river system and littoral zones). This also shows that species and habitat connectivity between the upstream and downstream river system is very important for maintaining high or natural levels of species diversity. Generalist feeders or omnivores, such as *Ambassis miops*, *Awaous ocellaris*, *Eleotris melanosoma* and *E. fuscus*, were not readily affected by the presence of invasive tilapia fish species.

Eleotris melanosoma (black gudgeon) is found across the South Pacific, and spans across the Indo-Pacific region as a demersal but amphidromous species. This means that this fish can move across and live in different types of salinity conditions (freshwater, marine and brackish-water systems), and is included in the IUCN Red List as a near-threatened species (still classed as lower risk). As was observed across the Waicoka and Nasilai estuarine ecosystems, and within the tidal village drains and minor tributaries (common at Waicoka), it was commonly found amongst submerged bank vegetation. This gudgeon, which was very common at Waicoka, was clearly observed to be unaffected by the heavy colonisation of a number of tilapia hybrid strains (which included the current high performing genetically improved tilapia fish strain, the GIFT fish), largely because *E. melanosoma* is a dioecious fish, where the eggs are released into the stream or creek benthos, and fertilised by the males externally. Parent fish guard the eggs until they hatch out. Most gudgeons brood their eggs and young by hiding them under heavy vegetative debris, and in the nook and crannies of rocks and the banks of the streams, creeks and drain systems (observed at Waicoka Village), where the tilapia and other predators would not be able to get access to the eggs and young to feed upon them.

Froese and Pauly (2009) have documented that *Oreochromis* spp. is known to feed on both fish larvae and juveniles. Larvae and post-larval stages of gudgeon and gobies which migrate between freshwater and marine ecosystems would be highly vulnerable

during their downstream and upriver migrations. Manmade structures such as dams and causeways block these fishes' seasonal migrations between the upstream freshwater, and downstream marine ecosystems.

A diadromous species is one that is migratory between the sea and freshwater. There are two kinds of diadromous species, anadromous and catadromous. An anadromous species spends most of its life at sea, but migrates to freshwater to breed. Eels and other fish species are classified as catadromous: they spend most of their lives in freshwater, and migrate downstream to the sea to breed. Maes *et al* (2007) demonstrated that anadromous fish species within the Scheldt River in Western Europe, are affected by hypoxic zones in the tidal estuaries, which could effectively block off their passage to their natal spawning sites upstream. From these observations on altered or degraded water conditions within temperate regions, it is logical to infer that the freshwater pulses from degraded habitat units could also affect the migration of tropical amphidromous juvenile fishes.

8.5 Conclusion

The life cycle connections between targeted fish species and mangrove areas, in particular, should be highlighted, stressing the importance of mangrove areas not just to fish and invertebrate species that are traditionally associated with mangroves, but also to fish species usually caught further offshore.

Fisheries management has traditionally meant focussing on resource extraction: at fishing itself which would include setting limits to fish size, catch size and seasons, as well as gears to be used and specifications such as the number of boats and licenses that can operate in a given fishery or fishing area. However, fisheries management also needs to include management of the actual areas of fisheries resource production i.e. fisheries habitat. This management approach can be reduced down to 'input' and 'output' controls.

The importance of habitat to fisheries productivity has gained recognition in Fiji and other Pacific island countries over the last twelve years, and has been strengthened through the establishment of marine protected areas. Coral reefs and mangroves are now given priority by communities, non-government organizations, and government stakeholders for protection. Mangroves in Fiji had previously been considered by coastal communities, government and decision makers as having very low utility, or intangible

economic value and thus many mangrove areas were destroyed for alternative uses such as urban residential expansion, and commercial infrastructure developments.

9 SOCIOECONOMIC STUDY

Patrick Fong

9.1 Introduction

Understanding the social, cultural and economic or livelihood importance of an ecological system is important in the quest to sustainably develop and manage it. Unless policy makers are aware of these parameters and unless resource management policies are aligned with community livelihood needs, resource management programs are most likely to fail or be unsustainable in the long term. Patterns of community resource use, seasonal trends of important activities and totemic resources are just some examples of information that needs to be considered when conservation programs are planned and implemented.

In this study, information on the relevance of the mangrove system within the Rewa Delta to livelihoods is the main focus. This mangrove system has been identified as an important conservation area in Fiji's State of the Environment Report (Watling and Chape, 1992) and the Fiji National Biodiversity Strategic and Action Plan (Government of Fiji, 2007) because of its historical and cultural significances and for its biological importance. The Rewa Delta is the most biologically diverse and the largest mangrove system in Fiji in terms of land area. It supports a large human population (over 75% of whom are traditional land owners), and filters about two thirds of all fresh water that makes its way into the sea off the island of Viti Levu. The associated intertidal mudflats also play a very important role in providing connectivity to migrating birds.

Creating a system of protected areas in Fiji is important for the conservation of its high terrestrial biodiversity. However, natural science perspectives on ecological sustainability need to incorporate social science, especially human behaviour and aspirations, since it is these factors that have been shown to be the main drivers of resource degradation and overexploitation.

The aims of this study were to:

- document the social, cultural and economic importance of the mangrove system to communities within the Rewa Delta,

- in discussion with communities, identify threats to the sustainability of the mangrove system, explore the management actions already implemented and identify management opportunities that exist.

This data will supplement that provided by the rapid biodiversity assessment, together providing a package for the relevant authorities in Fiji to develop a management program of the area, which will incorporate the linkages between the natural resources and community livelihood needs.

9.2 Methodology

The aim of this study was to assess the social, cultural and economic importance of the Rewa River mangroves to communities within the area. Certain aspects of the sustainable livelihood framework were adopted in the research methodology so that critical information related to the objectives of the assessment could be gathered. To accomplish this, a mixture of key informant, focus group and household interviews were conducted at all the study sites. All interviews were conducted verbally in the Fijian language (Bau dialect), and the information recorded in English.

To maintain a collaborative effort, all stakeholders in the study sites were informed of the survey prior to the field visits. Letters were sent to the Rewa and Tailevu Provincial Council Offices and presentations were conducted in various fora where the study sites were represented. Prior to the survey, staff of the Tailevu and Rewa Provincial Office were consulted and background information on the study sites was collected. Through this exercise, the survey team was able to identify potential key informants and focus groups to be interviewed.

The key informant interviews and focus group discussions gathered qualitative data using open-ended questions which were then used to support the explanations for some findings from the statistical analysis. The intention of the focus group discussions and key informant interviews were to address the following specific areas:

- general perceptions of what people feel about the mangrove system,
- general perceptions on the importance of mangrove on their livelihoods,
- cultural importance of mangrove,
- waste management and hygiene,
- resource governance and village social systems,
- access and use of resources and rights,

- vulnerability (including maintenance of cultural and spiritual values),
- some aspects of resource threats and resource management opportunities.

The focus group discussions were conducted in groups of 4-10 individuals who work together or have similar social responsibilities within the community. Three focus group discussions from each village were undertaken; the village elders, the women's group and the youth group. This method was conducted mainly to evaluate how each group perceived the mangrove system and how they have been affected by it.

The key informants included local chiefs, village headmen, traditional fisherman clan chief, youth leaders, women's group leaders, the village nurse, village headman, fishermen and fisherwomen, church minister and village elders. Key informants were asked about the importance of the mangrove system and encouraged to freely express themselves and provide detailed accounts of the relevant study sections.

Quantitative data were collected through household interviews using a structured questionnaire (see Appendix 17). In this study a 'household' means all people sharing the same kitchen and work together to "put food on the same table" through economic activities. The emphasis of this method was to collect data on community demographics, household economics, and perceptions on the social, cultural and economic importance of mangrove and resource use patterns. The intention of the household interviews was to address the following specific areas:

- household livelihood and food security,
- resource use pattern,
- income and economic activities,
- community health,
- mangrove awareness and compliance,
- non-monetary benefits,
- participation and involvement,
- local values and beliefs about marine resources,
- resource governance,
- mangrove threats and management opportunities.

9.2.1 The study sites

The study was carried out in ten villages in the Rewa Delta that were chosen to represent the socioeconomic settings, resources and mangrove use patterns of this

region (Figure 35). The study included five villages from Tailevu Province: Kiuva, Dromuna, Naivakacau, Matamaivere and Nasilai (Nakelo), and five from Rewa Province: Nasilai (Rewa), Muanaira, Nukui, Kinoya and Nakorovou.

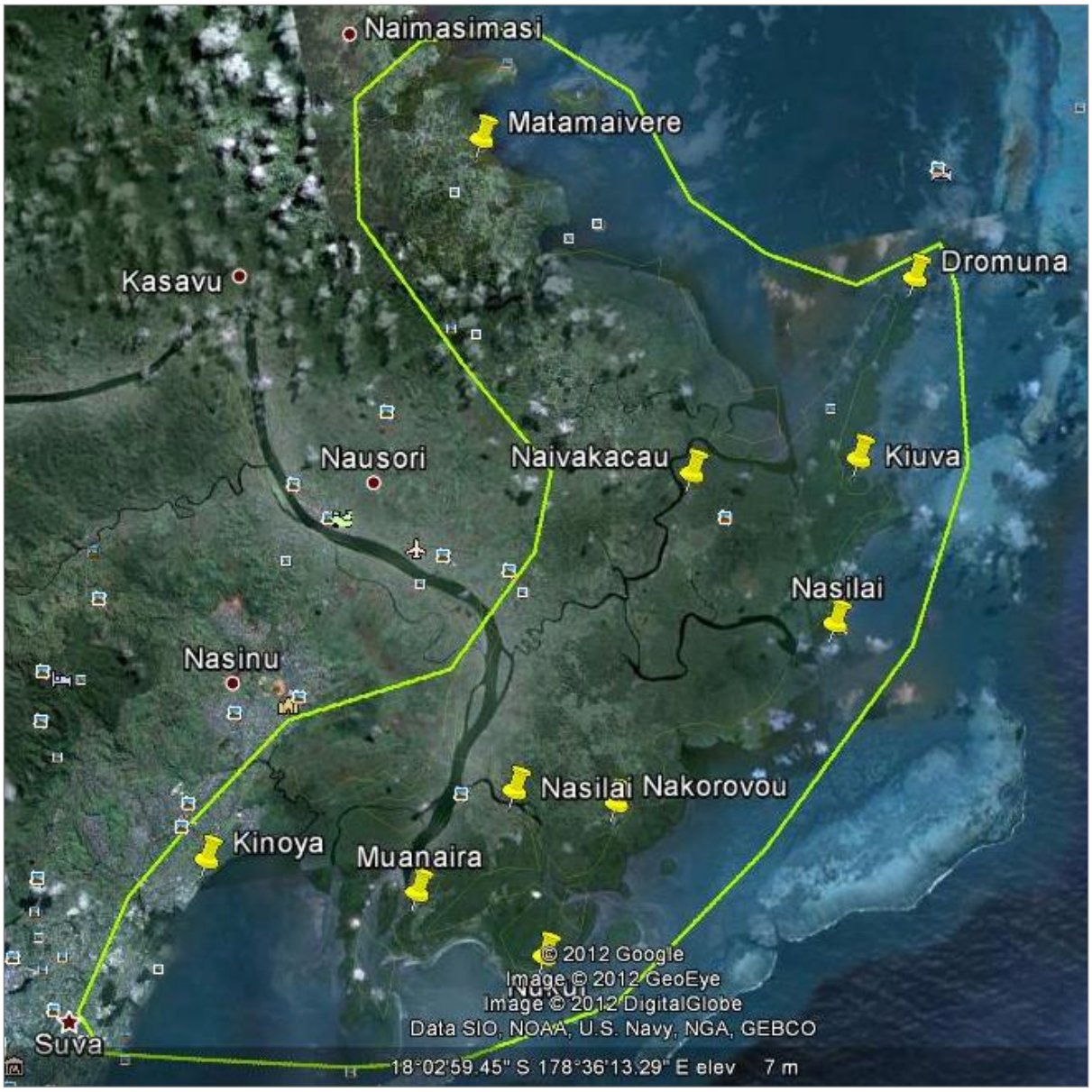

Figure 35: Map of ten villages included in the socioeconomic survey

9.3 Results

9.3.1 Population, education and infrastructure development

The demographic information of the ten study sites is summarised in Table 22. The total population in these sites was 2233, Kinoya village being the most populated with 431 inhabitants. Located within Suva's peri-urban area, Kinoya village is not only home to people who are descendants of the original inhabitants, but also to people from other parts of Fiji who now work and live in Suva. Nasilai Village in Nakelo district (Tailevu)

had the lowest population of 115. The average population across all the study sites was 223.

Table 22: Summary of demographic information of the socioeconomic study sites

Village name	No. of households	Total population	Age of oldest person	Average number per household
Nasilai (Nakelo)	32	115	76	4
Matamaivere	49	147	83	3
Naivakacau	35	181	78	5
Dromuna	29	106	74	4
Kiuva	62	287	80	5
Kinoya	76	431	86	6
Nakorovou	77	402	82	5
Nasilai (Rewa)	31	153	78	5
Vutia	47	257	75	5
Nukui	44	154	73	4
Total	**482**	**2233**	**79**	**5**

The total number of households within the ten study sites was 482, with the highest number (77) in Nakorovou Village and the lowest (31) in Nasilai Village in Rewa. The average number of households per village was 48.

Across the ten study sites, the average number of people residing in a household was five. Kinoya village had the highest average (six people per household) with Matamaivere having the lowest (three people per household).

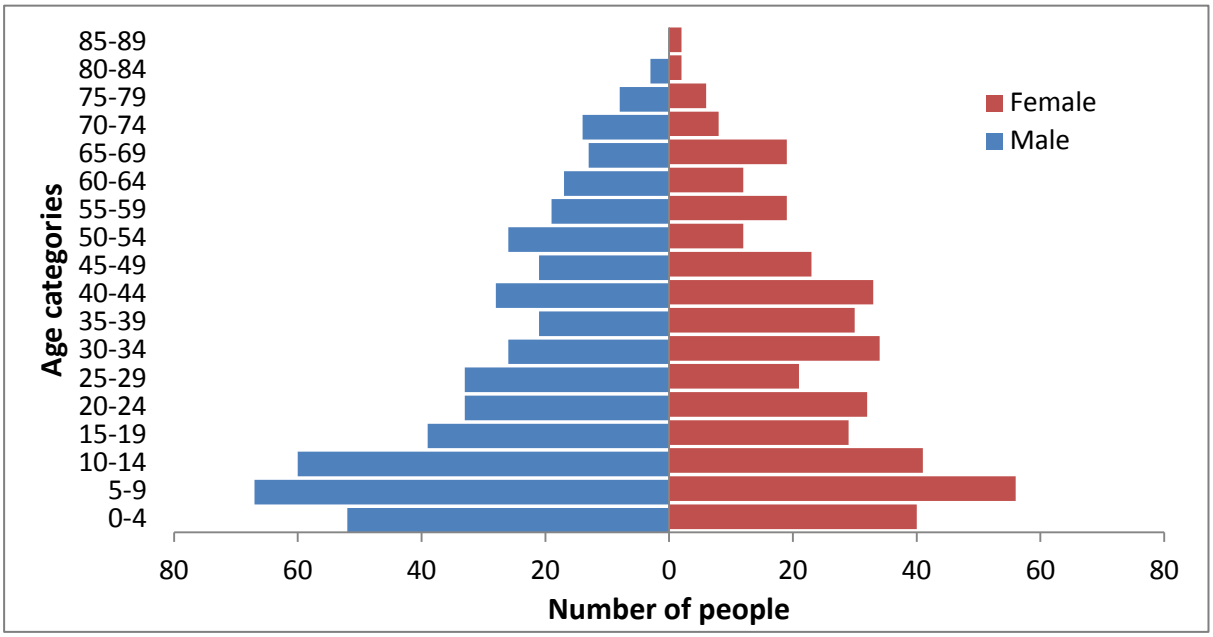

Figure 36: Survey area population breakdown by gender and age group

The age-sex population structure (Figure 36), shows a pyramid that is not consistent with the national one. Instead it indicates there are a large number of people at the base of the pyramid (categories 5-9 and 10-14 years old), but a reduced number in the

category of 0-4 years, which implies a decline in birth rate in these ten villages in recent years.

Despite the small sample size, it is clear that women in the villages sampled live longer than the men. In all the ten villages, the split between males and females is approximately 53:47. The median age of the population in the ten study sites is 24, which is similar to the national average of 24.6 years.

Education

Overall, the majority of respondents were educated to primary school level (57%), while 41% had secondary education and above, and around 2% had no formal education at all. The eighteen respondents who had no formal education were assisted by other members of the household who were present during the interview. This education pattern was comparable when considering only the respondents identified as being heads of the household: 52% educated up to primary school level, 42% above secondary level (with 10% having some tertiary education), and 6% with no formal education at all.

Considering that people in Fiji usually start education at the age of five (kindergarten or pre-school level), 10% of the population fall below this age group. The remaining 90% consist of those who are still undertaking or have obtained primary education (47%), secondary education (24%), or tertiary education (12%), and those who have never had formal education (7%).

Across the ten study sites, the average time spent in formal education was 8.3 years. The overall educational attainment of household members in the sites is high in comparison to the national average. This is largely attributed to the easy accessibility of schools in the area, as well as the fact that being close to the Central Division education offices, the school management bodies are able to more easily access infrastructural development assistance for the improvement of school facilities.

In terms of educational infrastructure (Table 23), each village has access to a primary school which is either owned by the village or by the district. Kinoya Village has access to an even wider range of primary schools within the greater Suva area. The schools in the other nine villages are accessible by foot, the average distance being 1 km. The furthest distance between a village and its nearest school is the 2.3 km from Kiuva village to Nasamila Primary School.

Table 23: Community primary school information

Village name	Primary School	Level	Distance from village (km)
Nasilai/Nakelo	Nasamila Primary School	Class 8	2.1
Matamaivere	Namara District School	Class 8	1.6
Naivakacau	Ratu Veikoso Primary School	Class 8	1.6
Dromuna	Kaba Primary School	Class 8	next to village boundary
Kiuva	Nasamila Primary School	Class 8	2.3
Kinoya	Various schools within Suva area	Class 8	varies, depending on school
Nakorovou	Dreketi District School	Class 8	next to village boundary
Nasilai/Rewa	Vunikavika Primary School	Class 8	0.5
Muanaira	Vutia Primary School	Class 8	0.4
Nukui	Nukui Village School	Class 8	next to village boundary

Village Infrastructure

All the houses in the ten study sites had roofs made from corrugated iron. There was more variation in wall material: 44% of households used corrugated iron, 36% wood and 20 % concrete (Figure 37).

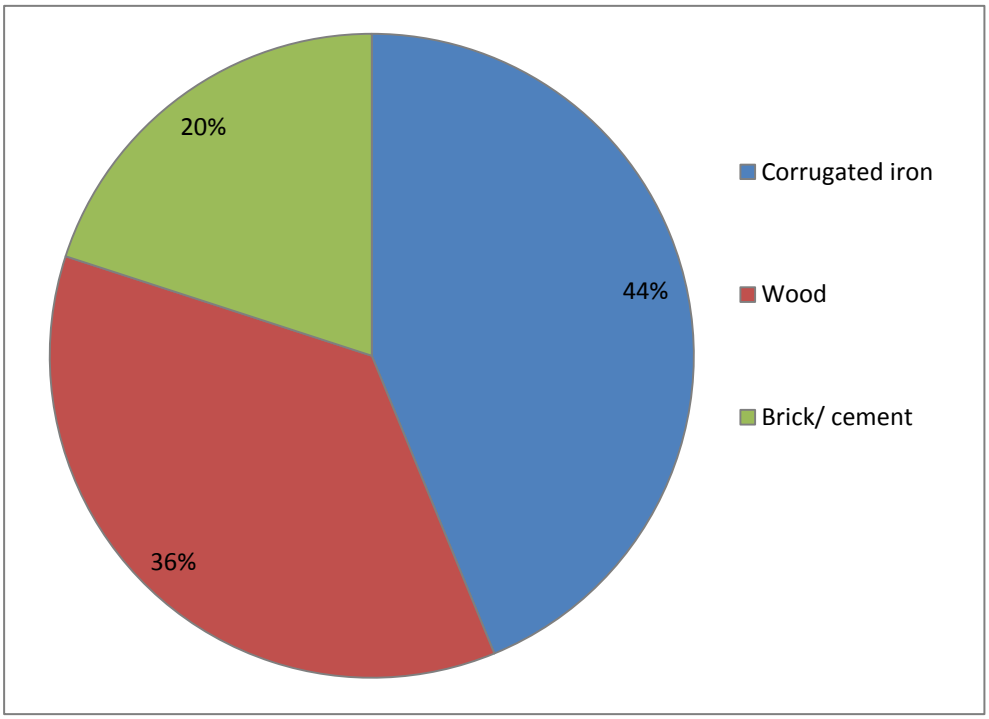

Figure 37: Wall materials of houses

In terms of toilet type, 64% of the households had a flush toilet, while 34% had water seal toilets. A small proportion of the households had a pit toilet (1%), and the remaining 1% stated that they did not have a proper toilet facility (Figure 38).

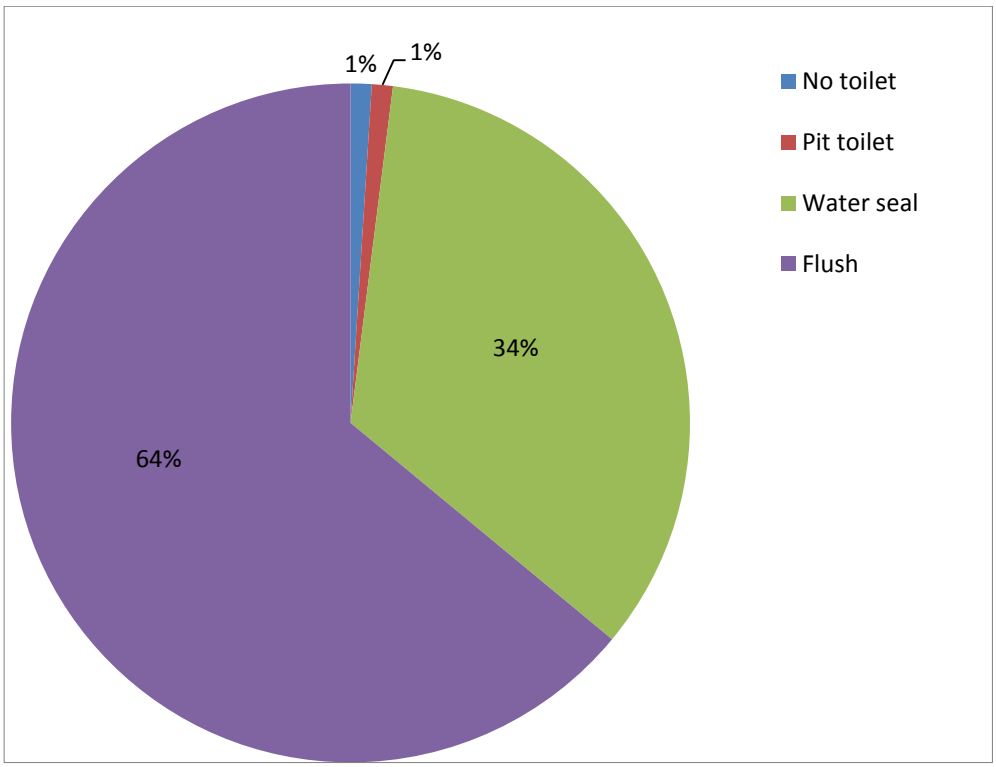

Figure 38: Household toilet types

Table 24 summarises the main forms of communally owned infrastructure present in some, if not all of the villages, and presents information on the importance of these key village buildings as mentioned by the respondents.

Table 24: Village infrastructure

Infrastructure	Purpose according to respondents	Village
Village hall	The village hall is a key physical asset in promoting social cohesion within a community. It is the venue for hosting village events such as weddings, traditional ceremonies, village council meetings and traditional council meetings such as bose vanua. The village hall is also used for village social gatherings such as kava sessions in the evening after completion of a communal task or for casual social gatherings. In some of the villages, a section of the village hall is usually closed off for storage of keys.	All 10 villages
Village dispensary	This facility is important for the storage of medical supplies, and is also where the village nurse performs basic medical procedures such as treating common skin diseases, cleaning and dressing wounds, and supplying basic medicine such as paracetamol tablets. The facility usually has a bed where a patient can rest while further medical assistance, such as an ambulance, is summoned.	Vutia, Nakorovou, Kiuva, Naivakacau
Church	Churches are the venue for religious gatherings, including weddings and funerals, as well as for meetings of religious institutions such as the Christian Youth Group and monthly meetings. Also, the structure itself is a physical asset in maintaining communal cohesion.	All 10 villages
Pastor's house	The house is constructed by the village that hosts the religious leader	Kiuva, Dromuna, Nasilai (Nakelo), Nakorovou

9.3.2 Livelihood and food security (income and resource use patterns)

Figure 39 outlines the main income sources reported from the ten study sites, in terms of the percentage of households that engaged in the activity. The primary income source is the sale of fish, which is engaged in by 46% of households, followed by the sale of mangrove invertebrates (34% of households). The sale of mangrove wood for firewood is the least dependent source of income at only 1% of the total household.

Earning income from formal employment in urban centers is also a significant source in the study sites (22% of the total households). The majority of the households that earn income in this way are in Kinoya, Nasilai (Rewa), Nasilai (Nakelo), Naivakacau, Kiuva, Nakorovou villages, all of which have access to roads and daily public transportation services. Even though Matamaivere village also has access to the public road, it does not have access to a reliable public transport and the distance to the urban centers is quite far. The remaining villages, Muanaira, Nukui and Dromuna, can only be accessed by sea.

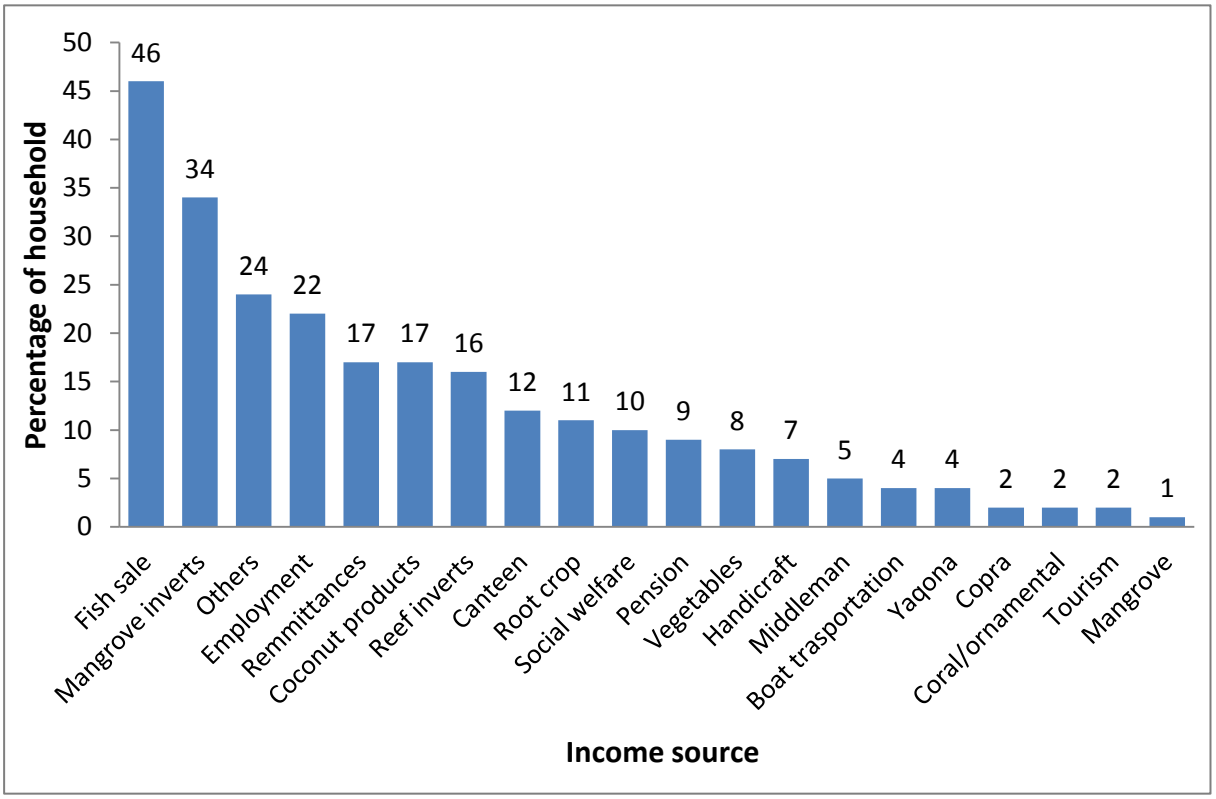

Figure 39: Percentage of households earning an income from various sources.

Worth noting too is the dependency of 17% of households on remittances (money sent by family and relatives who reside in other parts of Fiji or abroad), as well as on the sale of coconut products (mostly coconut oil and sasa brooms).

The average household monthly income is $253. The highest income, as highlighted in Figure 40, is gained from the sale of fish at $143/month followed by employment at

$142. The third highest income comes from the sale of mangrove invertebrates ($70/month), followed by remittances ($42/month).

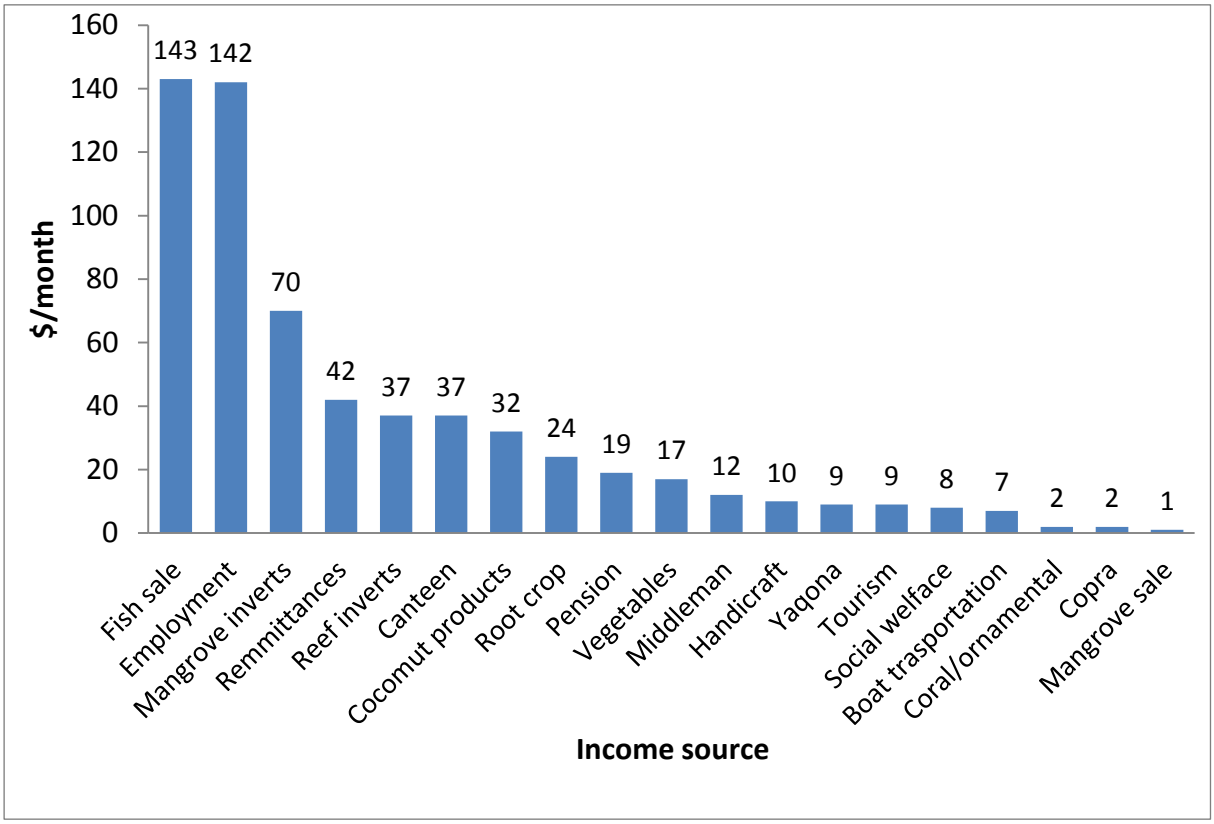

Figure 40: Income source and average household monthly income

From the above results, it is clear that the mangroves and their associated resources play an important role in the economic activities of the ten study sites. The majority of income gained is from the sale of fish and mangrove invertebrates such as mud lobster and mud crab. Most of these resources live or are associated with the mangrove system throughout their life cycle. The mangrove system acts as a home or refuge to these resources, therefore its sustainability is not only critical to the resources *per se* but, more importantly, to the communities in this region who depend on these resources for their livelihoods.

During the focus group interviews, the group was asked to list the top three resources that households within their community depend on for their livelihood. The results from these discussions noted that fish, mud crab/mud lobster and coconuts were the top three. The discussions also highlighted that these resources are mainly harvested within the mangrove system: fish mainly in waterways and mud crabs and mud lobsters inside the mangrove forest.

The discussions further noted that the distance that the locals travelled to access these critical areas of the mangrove system is generally less than 1 km. However, they will travel further if the need arises to collect more, such as during communal gatherings or major fundraising events.

Respondents highlighted that coconuts are mainly harvested at the back of the mangrove system. The back of the mangrove system can be described as a slightly raised area where only the neap tide waters can reach. Apart from coconut trees, the back of the mangrove contains other trees and crops critical for food security, as well as plants of importance for traditional herbal medicine.

9.3.3 Fishing gear

Figure 41 shows the percentage of households using different fishing methods. The most common fishing method in the three study area is hook and line, due to its low cost and high returns. The second most common fishing method is trapping while gleaning is the third.

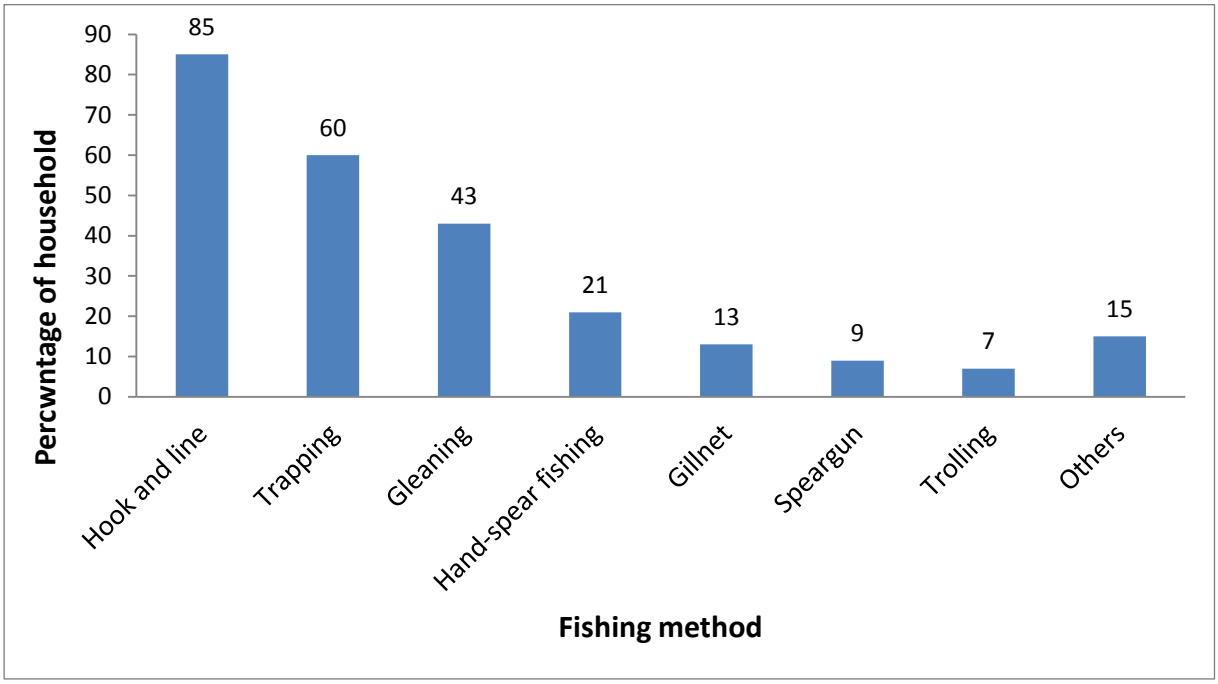

Figure 41: Percentage of households that utilise different types of fishing gear

Trapping is mostly done to catch mud lobster and the practice is important in terms of personnel identity, as it is a skill acquired through traditional knowledge specific to this region. Hand-spear fishing, used by 21% of households, is carried out in three ways: while swimming, diving or by throwing (aiming from above the water surface). Gillnets are used by approximately 13% of households despite their destructive nature and calls for discontinuing their use.

The low utilization of other fishing methods is due to their low productivity, high cost and poor availability. In terms of average weekly income and the quantity of catch per week, gillnets provide the greatest returns, followed by trapping, and hook and line. This is most probably the main reason why gillnets continue to be used despite calls to ban them.

9.3.4 Mangrove wood usage

The primary use of harvested mangroves is as firewood (Figure 42).The vast majority (92%) of the households stated that they use dry mangrove as their primary fuelwood whist only a few (5%) use green mangrove. Mangrove firewood is used by these households on a daily basis, generally for domestic cooking. From the focus group discussions, the use of mangrove for firewood increases when there is a big gathering in the village for traditional and religious purposes and during the holiday season.

Other major uses include the harvesting of green mangroves for house posts (22%), fence posts (12%), traditional herbal medicine (19%) and the construction of simple household furniture (10%). Other uses (14%) include seaweed farming, poles for non-motorised punts and other domestic purposes.

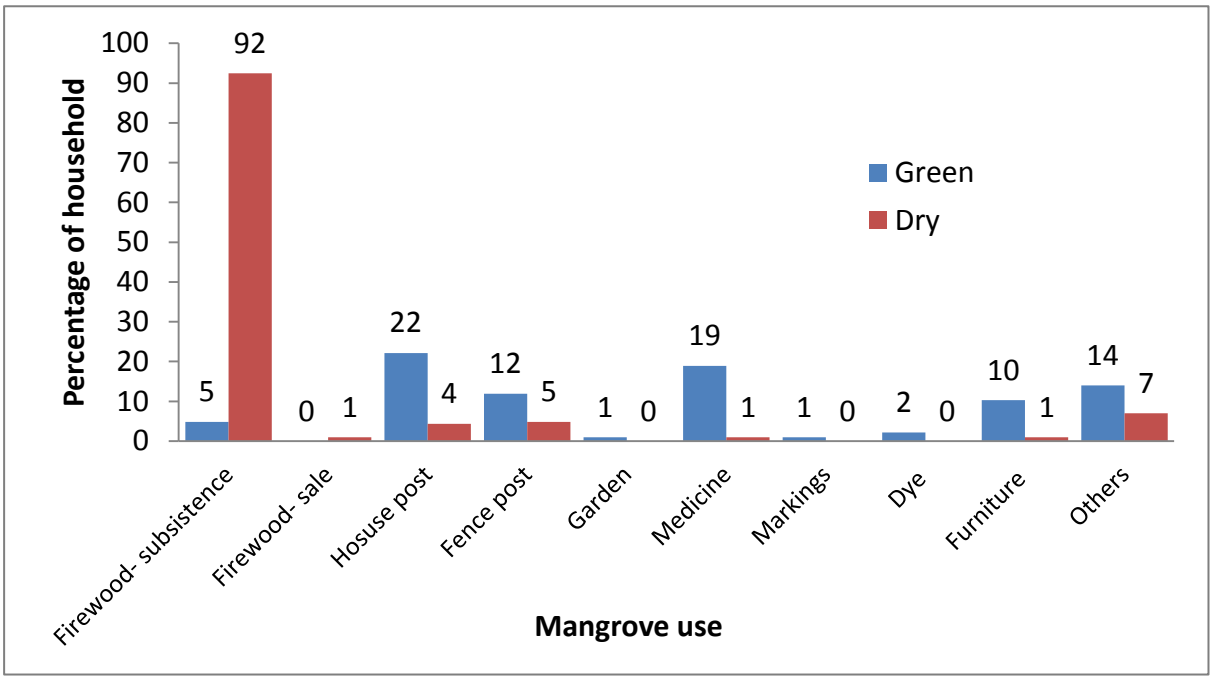

Figure 42 Percentage of households and mangrove use

Being located on flat land with marshland, the Rewa Delta lacks proper wood for the above uses, but since mangrove forest is in abundance, the local people have limited options but to use mangroves.

For the 185 households sampled, the amount of mangroves used in a month for each purpose is recorded in Table 25. The consumption of mangrove for firewood is high at 805 bundles, however, the majority is dry wood as already highlighted in the previous figure. Also, in terms of green mangrove used for firewood, the number is low since a mangrove tree can produce more than one bundle of firewood, depending on the size of the tree. For the sample household, the range is 2 – 10, with a mean of four. Combining other uses (house and fence post, garden, furniture, pole and use in seaweed farming), which mostly require green mangrove; the number of trees harvested by these households (n=185) in the past month is 508.

Table 25: Amount of wood harvested

Mangrove use	Total amount harvested per month (n=185)
Subsistence firewood	805 bundle
Firewood for sale	10 bundle
House post	203 trees
Fence post	86 trees
Garden	15 trees
Traditional herbal medicine	22 trees
Markings	5 trees
Dye	3 trees
Furniture	25 trees
Others	179 trees

In terms of harvesting methods, the majority of the households still use knife and axe to cut mangrove trees (Figure 43). The use of chainsaw in these villages is not significant as only a few can afford to purchase and frequently use it. Chainsaw is mostly used when a large number of mangrove trees are needed for firewood, house and fence post.

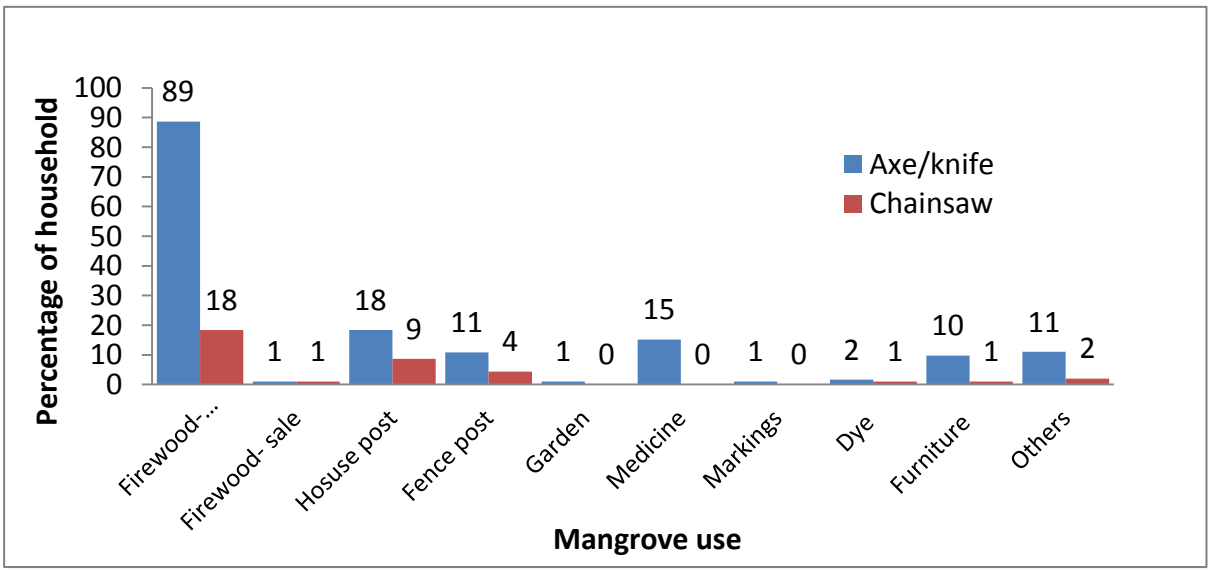

Figure 43: Percentage of household with mangrove harvesting method

In terms of harvester (Figure 44), the majority (78%) are male youth and men followed by youth female and women then children (3%). Only 7% stated that they do not use mangrove for any purpose**.**

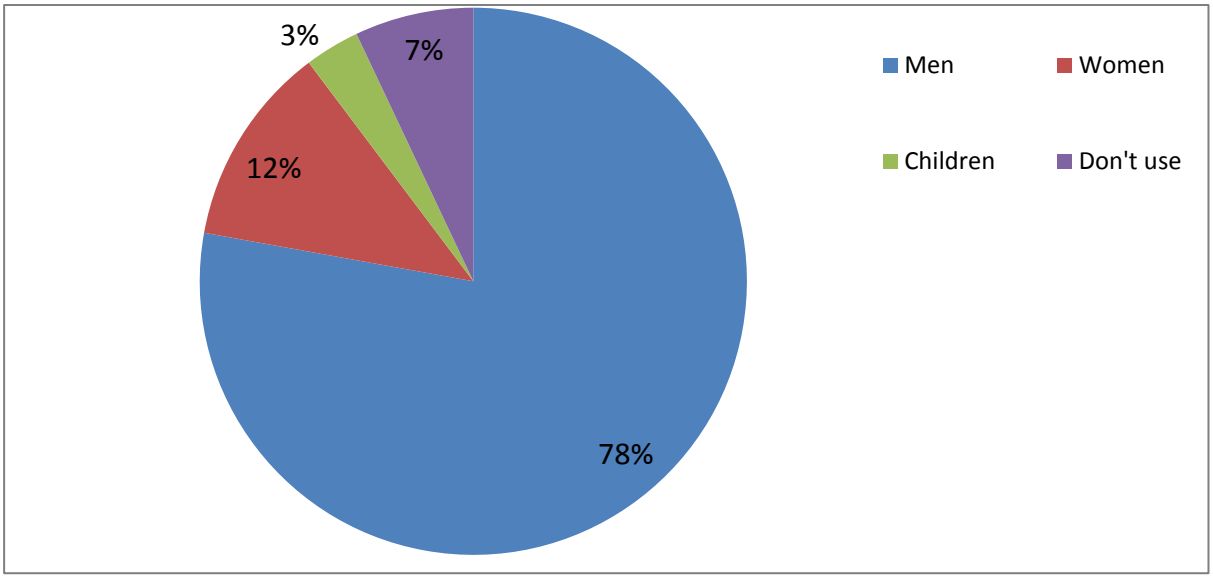

Figure 44: Groups identified by households as main harvesters of mangroves

Interviewers also asked about preferences for different mangrove species depending on usage (Table 26). There were no species preferences reported for firewood or marking purposes. However, for other uses, there were certain preferences on the mangrove species to be used, due to the various unique features of each species. For instance, sagale and dogo are tall and straight, therefore, are used for house and fence posts and also for furniture construction.

Dabi (*Xylocarpus granatum* and *X. moluccensis*), sinu (*Excoecaria agallocha*) and tiri (*Rhizophora stylosa* and *R. samoensis*) have some medicinal properties and are used for traditional herbal healing purposes.

Table 26: Mangrove species preference for community use

Mangrove use	Community preference
Firewood- subsistence	No preference
Firewood- sale	dogo
House post	sagale, dogo
Fence post	sagale, dogo
Garden	sagale, dogo
Medicine	dabi, sinu, tiri
Markings	No preference
Dye	dogo
Furniture	sagale, dogo
Other uses	dogo for poles, but no preference for seaweed farming

Respondents were asked to gauge the manner in which they were harvesting mangrove forests, in terms of sustainability. The majority of the respondents (72%) stated that they do not utilise any sustainable approaches when harvesting mangroves, while only 28% stated that they do have such considerations.

Most of the sustainable approaches mentioned by the respondents are based on communal decisions during the village council meeting. In most cases, certain members of the community who are aware of destructive harvesting practices highlight it in one of the meetings. Discussions usually conclude with some management decisions made by the community.

The practices below are examples of some sustainable harvesting approach highlighted by the respondents and currently implemented in Naivakacau, Dromuna and Nakorovou village:

- harvesting of dry mangroves rather than green mangroves for subsistence firewood,
- harvesting of appropriate amount needed by the household and avoid unnecessary cutting,
- avoiding harvesting of small mangrove trees,
- rotational cutting and avoiding over-harvesting in one particular area,
- setting a quota for each household (in Naivakacau village).

Other initiatives already undertaken within the area to ensure the sustainable use of the mangroves and resources associated with it include:

- The Vanua Rewa Council with endorsement from the Roko Tui Dreketi; paramount chief of *Rewa* province has banned all commercial selling of mangroves but only for subsistence purposes. In a few years back, the majority of commercial harvest of mangrove for firewood was conducted in villages within Rewa Province. The ban was in response to the concerns raised by the locals on the destructive impacts of the practice.
- The District Council meetings within Rewa Province have consistently reminded village headmen and village chief of the ban and the need to oversee the sustainable use of their resources which in a way has encouraged the local people to protect the mangrove system.

- The Department of Environment together with Fisheries Department have been advising some villages on the need to stop the unsustainable harvest of mangroves and importance of protecting their resources.
- Most village meetings within the Rewa province have endorsed the ban during the village meetings and agreed to protect/conserve mangrove ecosystem
- To date, there is no mangrove license given.
- The establishment of tabu areas within the iqoliqoli have also contributed to the protection of the mangrove since the boundary of the tabu areas include mangrove forests.
- Replanting of mangroves has also taken place, even though at a small scale. In 2006, the youth group of Kinoya Village planted mangrove around the village beachfront and today, these mangrove have grown and people are now able to catch fish within these areas. A similar initiative was undertaken by Seru Serevi and family from Nakorovou village in 2011.
- Relevant authorities have consistently provide advices to communities on overharvesting of mangrove resources

9.3.5 Community mangrove issues

According to the results from the focus group discussions, one of the key challenges to the sustainability of the mangrove system is the implementation of unsustainable development programs, most of which are coordinated by various government departments.

One example given was the Rewa River dredging project which started in 2010. The project was implemented by China Railway First Group Fiji Limited and coordinated by the Land and Water Resources Management Division of the Ministry of Agriculture. During the implementing phase, the company redirected the dumping of dredge spoils in areas of dense mangrove forests. This resulted in the destruction of these forests together with the marine resources associated with it and other plants important to community livelihoods, such as coconut trees.

In another example, in Matamaivere a portion of the mangrove forest adjacent to the village was cleared with a directive from the Lands Department and Tailevu Provincial Council, for construction of a village hall.

Other key challenges highlighted by the focus group discussions include:

- illegal cutting of mangrove forest by outsiders,

- use of chainsaws by community members for harvesting of mangroves,
- absence of sustainable harvesting approaches in communities,
- lack of awareness of the importance of the mangrove system and the resources associated with it,
- increase in population which has resulted in the need for more mangrove fuel wood,
- use of mangrove bark for traditional herbal medicine and dye result in the destruction of these trees,
- greater impacts of king tides,
- communities in this region starting to experience scarcity in marine resource stock,
- improper disposal of village solid and liquid waste.

9.4 Conclusion

From this study, it can be concluded that:

- The mangrove system within the Rewa Delta area plays a vital role in sustaining community livelihoods.
- The majority of households depend heavily on the mangrove system for earning an income.
- The main source of income in the 10 communities surveyed is from the sale of fish, mud-crab and mud-lobster.
- Mangroves are being used extensively for subsistence firewood, construction and fishery equipment (poles and seaweed farming).
- A few species of mangrove provide traditional herbal medicine to these communities.
- Mangrove consumption in terms of fuelwood increases when there is a family gathering and during the school holiday period when the number of people in the village increases.
- The Rewa River mangrove system is under threat from destructive human practices, for instance, poor development programs; as well as climate change-related phenomena such as sea level rise.
- Marine resources within this system are declining.

- Some initiatives have already been implemented to manage the mangrove system and associated resources. This can be seen as an opportunity to further develop strategies to successfully manage these resources.

To ensure the long term sustainability of the mangrove system and associated resources within the Rewa Delta area, it is recommended that:

1. Livelihood options are enhanced so that less pressure is exerted on the mangrove system and associated resources.
2. Unsustainable fishing practices be banned, e.g. the use of small mesh size gillnets that catch juvenile fish, and the use of fish poison. Fishermen should be encouraged to use spearing, night fishing, hook and line and fish traps.
3. Fishermen be made aware of destructive fishing practices and other relevant issues such as releasing undersized fish and invertebrates back into the environment.
4. Community based participatory projects be implemented to replant suitable mangrove species in priority areas.
5. Education and awareness programmes focus on improving community understanding of sustainable harvesting of mangrove resources.
6. Community-based marine reserves be established which incorporate the mangrove system. Some examples of such initiatives relevant to Tailevu and Rewa provinces include the programs implemented in Navakavu (Suva district), Noco district and Verata, Tailevu.
7. National and provincial government institutions work with community decision making bodies such as village councils in the formulation of mangrove management programs.

10 ARCHAEOLOGICAL SURVEY

Elia Nakoro, Sakiusa Kataiwai and Usaia Gaunavou

10.1 Introduction

Fiji has an ancient, complex and unique cultural heritage preserved in its archaeological sites. Unfortunately, much of this record has been carelessly destroyed through human activity. The large scale of current and planned land development activity in Fiji places the surviving sites at grave risk. The events of the coming decade are crucial to the preservation of Fiji's archaeological heritage.

The archaeological record is irreplaceable and it is likely that within the life of this generation, much of the history of some 150 generations will be lost. In the rural areas, Fiji's archaeological record, almost three millennium of unwritten history, has not been left untouched by twentieth century developments. Agriculture, forestry, urbanisation and paraphernalia of associated infrastructure developments, have and continue to threaten this delicate aspect of Fiji's heritage. Nature too has taken its toll on many of these ancient sites: recent agricultural development, particularly the increase in mechanisation, is a very real threat to the archaeology of Fiji's lowland areas. As more marginal land is brought under grazing schemes this threat is extended to the more remote hill fortifications.

In the vicinity of the growing provincial towns, ancient sites might come under increasing pressure from town expansion schemes and related infrastructure development. Intra and inter regional infrastructure development such as roads, electricity, telecommunication transmitter stations and sewerage reticulation continue to disturb or eradicate archaeological features. Many of the more inaccessible sites though unharmed by man have reverted to nature and root systems resulting in partial or total destruction of archaeological deposits.

10.2 Methodology

A literature review was carried out to identify known archaeological sites in the study area. The team went through archival records of the archaeology database of cultural sites and

also reference materials of travels and studies that have been undertaken within the Rewa and Tailevu provinces. The Rewa River mangrove study area is immense and the archaeology team attempted to cover as much of the area as possible. A team of three people conducted surface reconnaissance, recorded oral narratives, constructed sketches of all visible cultural footprints and recorded all GPS coordinates. The team also traversed the area in search of undocumented sites and managed to discover several sites that were unknown to the local inhabitants

10.3 Results

10.3.1 Archaeological site descriptions

Table 27 presents a summary of the archaeological sites documented from the MESCAL project area, including .their related cultural features. There are 27 sites in total.

Table 27: Archaeological sites identified in the MESCAL project area

Site name	Plots/ Village	Site type	Site ID *	Related cultural features
1. Nautu	Natila	Installation site	Korovou O27/70	House mounds and installation mound
2. Delainavutu		Ring ditch fortification	Korovou O27/71	Causeways and ring ditch, shell middens and pottery shards
3. Naceva		Hill fortification	Korovou O27/72	Terraces
4. Nakanalo		Old village	Korovou O27/75	Settlement Platform
5. Valesa		Old village	Korovou O27/74	None
6. Nakarawa		Old village	Korovou O27/73	Terrace and settlement platform
7. Natena		Old village	Korovou O27/76	Obscured with lush vegetation
8. Kubuna		Sacred site	Korovou O27/51	House mound, skeletal remains, shell middens and pottery shards
9. Unknown	Waicoka	Ring ditch fortification	Korovou O27/80	Causeways and ring ditch
10.Unknown		Old village	Korovou O27/81	House mounds
11.Unknown		Ring ditch fortification	Korovou O27/79	Causeway, ring ditch, house mounds
12.Waicoka		Ring ditch fortification	Korovou O27/77	Causeways, ring ditch, burial mounds and cemented burials
13.Nasoto		Ring ditch fortification	Korovou O27/78	Causeway, ring ditch, shell middens and pottery shards
14.Vatoa		Old village	Korovou O27/82	House mounds
15.Naivitavi	Nasilai	Ring ditch fortification	Nausori O28/87	Causeways, ring ditch, house mounds, recent cement burials, old burial mounds, bathing pond and pond for human bodies
16.Vadrai		Old village	Nausori O28/84	None
17.Unknown		Ring ditch fortification	Nausori O28/26	Ditches
18.Nakua		Old village	Nausori O28/83	Shell middens and pottery shards
19.Unknown		Ancestral burial ground	Nausori O28/86	Single burial mound
20.Unknown		Ring ditch fortification	Nausori O28/85	Causeway, shell middens, pottery shards

Site name	Plots/ Village	Site type	Site ID *	Related cultural features
21.Yavu ni gone dau	Muanaira	House mound	Suva O29/34	Single house mound
22.Tavuya		Old village	Suva O29/35	Burial mounds both recent and old
23.Navadratolu		Ancestral burial ground	Suva O29/27	Burial mounds
24.Naivisere		House mound	Suva O29/28	Single house mound
25.Nukucagina		House mound	Suva O29/29	Single house mound
26.Unknown		Sacred site	Suva O29/31	Sacred dilo (*Calophyllum inophyllum*) tree and pottery shards
27.Sautabu nei Roko Tui Dreketi		Sacred burial ground	Suva O29/30	Single cement burial
** The site identification number is a standard Fiji Museum accession site number following the Fiji Map index in relation to the Fiji Topographic maps supplied by the Lands Department				

A fuller description of each site is given below.

1. Site Identification Number: Korovou 027/70

Site Name: Nautu (Appendix 17, Figure 45)

Site Type: Installation site

Location: S 17.956671 E 178.577777

Elevation: 52 m

The installation site belonging to the people from the settlement of Natila is situated about 615 m along the Loganisebi access road, south-west of Matamaivere Village. This sacred site has been partially decimated by road construction. The site sits on a ridge line that was dissected by the access road at a height of about 5 m from road level. Remains of the spot are two mounds, one being a house mound 6 m long and 4 m wide and the other is an installation mound, circular in form, with a diameter of 2 m and almost 2 m in height. Plain pottery shards were recovered together with shell middens of Venus ark, a bivalve locally known as kaikoso (*Anadara antiquate*).

The vegetation of the site is a clear indicator of cultural activities, including vasili (*Cordyline terminalis*), uci (*Euodia hortensis*) and sacasaca (*Codiaeum variegatum*), as well as balabala tree ferns (*Cyathea* spp.) scattered across the area. There is evidence that the site is maintained every now and then as the mounds were clear of undergrowth cover.

Brief account

According to Taniela Cakau, an elder and local guide from Natila Village, Nautu literally translates to one shifting firewood or having the ends meet so that it burns well. Similarly, Nautu was the meeting point of all the travellers from Nakauvadra before establishing the outer islands.

2. Site Identification Number: Korovou 027/71

Site Name:	Delainavutu (Appendix 17, Figure 46)
Site Type:	Ring Ditch Fortification
Location:	S 17.955212 E 178.579067
Elevation:	39 m

Situated less than 220m northeast from the previous site, Delainavutu is a spectacular human induced landform, structured to protect its inhabitants in the 16th and 17th century. This enormous fortification structure is about 60 m in diameter containing a circular trench, which is almost 5-7 m wide. The circular trench is disrupted at four places and these causeways provide a link and access into the fort. The causeways are less than 2 m wide but are wider at the base due to the process of slow erosion. The inside of the fort is lushly covered with thickets of cassava (*Manihot esculenta*), vines and creepers. Several indicator plants grow in the vicinity, such as dawa (*Pometia pinnata*), moli karo (*Citrus limon*), kavika (*Syzygium malaccense*) and ivi or Tahitian chestnut (*Inocarpus fagifer*).

Unfortunately, a local man originally from Batiki is planting taro (*Colocasia esculenta*) in the trenches to the north and east side, on the causeways and moving into the fort. Moreover the land area surrounding the site is being utilised by the locals for subsistence farming.

3. Site Identification Number: Korovou 027/72

Site Name:	Naceva (Appendix 17, Figure 47)
Site Type:	Hill fortification
Location:	S 17.960786 E 178.588242
Elevation:	29 m

This site was used as a safe haven for women and children during times of war. It is located approximately 1.27 km further down the Loganisebi road from the Nautu installation site. The site is on a hill along a ridge enveloped by paragrass (*Brachiaria mutica)*. The extent of the site was difficult to determine however, it was obvious that the site has three terraces judging from the different heights in the over growth. Growing on the site is vaivai (*Albizia saman*) with a few scattered African tulip trees (*Spathodea campanulata*). At the foot of the hill are guava trees (*Psidium guajava*) covered with creepers.

Over the years, the site has been greatly disturbed by cattle grazing. The piece of land was under agricultural lease issued and the local guide has recollections of the presence of the remains of mounds which are now totally obliterated.

4. Site Identification Number: Korovou 027/75

Site Name:	Nakanalo (Appendix 17, Figure 48)
Site Type:	Old village/koro makawa
Location:	S 17.962488 E 178.592390
Elevation:	26 m

Approximately 470 m down the road from the previously described site Naceva hill fortification, is Nakanalo old village site. Nakanalo is directly translated as eating in secret. The site overlooks the Loganisebi access road towering to more than 20 m high. The site itself is a flat platform 60 m long, 40 m wide to the east and 10 m wide to the west. The site has been disturbed through subsistence agricultural activities, with an extensive cassava plantation to the east and taro cultivation to the west. The platform is concealed by vines and creepers and shows evidence of human disturbance from farming. The site was once vegetated with African tulip trees and has been cleared to make way for cultivation. At the outskirts of the platform, cevuga (*Hedychium coronarium*) and African tulip trees dominate.

Brief account

According to the guide, their people moved from Naceva to Nakanalo before making their way further down to Valesa and Nakarawa. The site got its name when a lady from Bau visited Nakanalo with her child wrapped around behind her and was nibbling on a big fish bone. When the locals saw this, they passed comments to the lady saying that they would bring the small fishes to them and keep the big ones to themselves.

5. Site Identification Number: Korovou 027/75

Site Name:	Valesa (Appendix 17, Figure 49)
Site Type:	Old village/koro makawa
Location:	S 17.960786 E 178.588242
Elevation:	44 m

This site is situated about 1.3 km north-west of the closest village, Natila. Upon inspection, it was apparent that the site had undergone major disturbance with the construction of the

Loganisebi Road, which runs through the site, removing a major portion of the site and its remnants. The site is built upon a ridge with slopes descending to the north including areas to the west and south also defined by declining slopes. The central portion of the site currently accommodates a residence with two other residences situated at the foot of the ridge to the west and another situated along the ridge further northwest.

Valesa is heavily disturbed and occupants from the area use the northern slopes to cultivate cassava and carry out various other activities that have over the years altered and removed cultural forms that may have existed. Due to the major negative impacts generated by infrastructural and agricultural factors, the team could not identify tangible aspects that could support the oral accounts of early settlement in the area. The site has been documented nevertheless.

6. Site Identification Number: Korovou 027/51

Site Name: Kubuna (Appendix 17, Figure 52)
Site Type: Sacred site
Location: S 17.959589 E 178.605632
Elevation: 7 m

This site is located along the coast, 1.5 km southeast from the village of Natila. A waterway through the mangrove swamps goes around Kubuna, separating it from the mainland during high tide. The island is high with an elevation of about 22 m above sea level. On the seaward side the ocean has eaten away the portion of the land facing the sea, leaving a high cliff where human skeletal remains and pottery shards are piercing through the lower stratigraphy.

The small island is littered with pottery shards and shell middens of kaikoso. Some of the shards have decorations of shell impressions and incisions on it resembling those latter designs in the Fijian pottery-making sequence referred to as the Ra phase. There is a single house mound on the island, which was erected on the hill for the Roko Tui Bau's home. A portion of the mound has been eroded by the sea.

Brief account

To a handful of people that know the history of the island, Kubuna is extremely significant and sacred as this was where the first chief of Bau or Roko Tui Bau, Vueti was installed, and the house mound was where the people of the yavusa Ratu settled him to be their leader. Vueti is said to be

from Verata and was installed due to his physical build. During this time the island of Bau was called Butoni. Because he frequently visited Butoni he decided to make it his home and he asked his people specifically the itokatoka Bete, yavusa Ratu to stay back and look after the land and to oversee the process of the drawe ni qele. This is a traditional process of taking one's harvest to the chief in acknowledgement for the use of the land.

The significance of Kubuna is made reference to in the presentation of the isevusevu which addresses "*…vakaturaga I Kubuna, vua na gone turaga na Vunivalu, turaga na Tui Kaba…*" representing those from the provinces of Tailevu, Naitasiri, parts of Ra and Ba, Lomaiviti, or the Kubuna confederacy. Kubuna is referring to this site as the ancestral origin of leadership for these provinces.

7. Site Identification Number: Korovou 027/73

Site Name:	Nakarawa (Appendix 17, Figure 50)
Site Type:	Old village/koro makawa
Location:	S 17.961256, E 178.607005
Elevation:	10 m

The site known as Nakarawa is about 170 m south-east of the previous Kubuna site. Nakarawa is on a hill separated from Kubuna by a small bay. The site is on a hill, rising from a terrace about 2 m high. The terrace, which is 4 m wide, encircles a raised platform that is over 30 m in diameter. The platform contains no house mound, but there is a recent burial mound belonging to the Toganivalu family who use the land for agricultural purposes. The whole area is lushly vegetated with paragrass, vaivai seedlings and sacasaca, and entangled with vines and creepers.

Brief account: from stories passed down from earlier generations, Nakarawa was where the members of the yavusa Ratu resided. These are the same people that installed Vueti to be the Roko Tui Bau. From Nakarawa, the people erected Vueti's residence on the island as his chiefly abode. Today, descendants of those from Nakarawa are residing at Natila Settlement while others have moved to the Lomaiviti group.

8. Site Identification Number: Korovou 027/76

Site Name:	Natena (Appendix 17, Figure 51)
Site Type:	Old village/Koro makawa
Location:	S 17.965945 E 178.604061
Elevation:	23 m

424 m before the end of Loganisebi road and nineteen metres perpendicular toward the right while facing the ocean is the old village called Natena. Accessing the site was rather difficult as it is densely vegetated with thickets of thin bamboos or gasau (*Saccharum edule*) and wild cassava. Due to the dense cover it was impossible to move around and scout for cultural remains however some of the plants growing on the site indicate human occupation such as coconut (*Cocos nucifera*, 8 in total), mango (*Mangifera indica*), sacasaca and vasili.

Given the physical limitation, the local guide confirmed that the site belonged to the people of Kiuva Village. In fact it is their ancestral site of origin where reference is made during traditional protocols to address the chief of Kiuva village (…*i Natena vua na gone turaga na Roko Tui Kiuva*…).

9. Site Identification Number: Korovou 027/80

Site Name:	Unknown (Appendix 17, Figure 53)
Site Type:	Ring ditch fortification
Location:	S 18.014773 E 178.615769
Elevation:	7 m

A ring ditched fortification setup is located in the swamps about 450 m north-east of Dravo Village. The site has a surrounding vegetation of mainly ivi which also marks about three quarters of the outer edge of the ditch from the west, north and east while the south side faces an open area of grassland and plantations thickly covered with tall grasses. A walking track dissects the fortified site, an access route into the field of ivi and plantations while the remaining area is thickly covered with paragrass, scattered coconut palms and African tulip trees.

The outline of the ditches is still visible and filled with water having a width of about 2 m around. Due to the overgrowth only two causeways allowing access into the site were identified, each having a width of 1 m. The natural processes of erosion and infilling have contributed to the shallowness of the ditches as well as the fact that the causeways are wider at their base.

When asked, men from nearby villages had no idea of the existence of this human-induced cultural landform, one that is trampled upon every day for agriculture-related activities.

10. Site Identification Number: Korovou 027/81

Site Name:	Unknown (Appendix 17, Figure 54)
Site Type:	Old village/koro makawa
Location:	S 18.016663 E 178.623543
Elevation:	27 m

This site is located approximately 450 m north-east of Naisogovau Village which is the closest village in the area apart from Dravo Village to the west. The cultural site is bordered within agricultural land utilised by the neighbouring villages with cultural features represented by three raised earthen mounds that were rectangular in shape, and measured approximately 5 m x 6 m.

The site is quite diminutive in size; the three mound features are constructed within a 10 m x 15 m perimeter. As the area has been used for agricultural activities over the years, possible cultural features that may have existed extensively outside of the identified site have been permanently removed from their historical locations.

Overgrown grass, African tulip trees and manawi (*Koelreuteria elegans*) define the major vegetation in the area with an abundance of shrubs and scattered coconut trees along the periphery of the surrounding area.

11. Site Identification Number: Korovou 027/79

Site Name:	Unknown (Naisogovau), (Appendix 17, Figure 55)
Site Type:	Ring ditch fortification
Location:	S 18.019755 E 178.618133
Elevation:	10 m

This site is quite extensive, situated about 200 m west of the closest village of Naisogovau. The site is accommodated within dense vegetation dominated by ivi trees and surrounded by grassland that extends north towards the river. Mangrove swamps border the east and agricultural land is found along the periphery of the identified site area.

The site was a ring ditch settlement with a complex system of ditches and mound features upon these ditches. Altogether, a total of five house mounds were identified, defined by raised rectangular earthen mounds, including a single causeway that was located to the southeast of the site area.

The causeway had undergone erosion processes and the structure was elongated across the ditch at a length of 3.8 m. An area to the east of the site area accommodates breeding of livestock as constructed pigpens were aligned along the ditch. The ditch along the east continues, rotating towards the south. However, a section of the ditch had been disturbed by agricultural farming.

The site extends to about 63 m towards the west in which site features are limited and covers an area of about 71 m on a north to south orientation with agricultural plots bordering the southern side of the site area.

12. Site Identification Number: Korovou 027/77

Site Name:	Waicoka makawa (Appendix 17, Figure 56)
Site Type:	Ring ditch fortification
Location:	S18.017185 E178.64 E
Elevation:	15 m

This site is located beside the access road that links Waicoka Village to Vatoa Village. It is about 450 m north by road from Waicoka Village en-route to Vatoa while Vatoa is located about 2 km north from the site. The site is classified as a ring ditch fortification where a ditch encircles the entire site and forms an ellipse rather than the common irregular circle that is typical of a ring-ditch. The site lies in a north-south orientation.

There are four causeways that provide access to the site. These causeways are situated at the four corners of the ring ditch, each at a uniform distance from one another. Causeway One is situated on the northeast end and is about 3 m wide and 17 m long while causeway two is situated on the south end about 3 m wide and 16 m long. Causeway three is situated on the southwest end of the ring ditch. It is 4 m wide and 17 m long. The final causeway is 17 m long and 3 m wide and is situated on the northwest end.

Additionally, there is an outer ditch that encircles the entire site and runs parallel to the ring ditch. The distance between the inner and outer ditch is approximately 18-20 m on all sides. Within the inner ditch, at the centre of the site, assumed to be the occupied area, there is a great concentration of pottery shards composed of plain body and rim shards scattered on the ground. There is also a high presence of seashell remains (largely arc-shell species) and a high presence of burials within the central part of the site (more than 30

burials). There is a bathing pond 10 m in diameter situated on the north-west end, in between the inner -ditch and the outer ditch.

The vegetation is classified as secondary anthropogenic vegetation with coconut trees dominating the terrain. Other species present are of traditional significance including breadfruit or uto (*Artocarpus altilis*), screwpine or vadra (*Pandanus tectorius*), sacasaca, vaivai, and different species of ferns, fern allies, vines and creepers.

Brief account

The site was said to have been occupied by the yavusa Nakorolevu when they originally moved from Nasoto old village that moved eastward and closer to the sea to be able to eat fish and seafood.

13. Site Identification Number: Korovou 027/78

Site Name:	Nasoto (Appendix 17, Figure 57)
Site Type:	Ring ditch fortification
Location:	18.018328 S 178.635405 E
Elevation:	14 m

Nasoto is located about half a kilometre northwest of Waicoka Village and about half a kilometre southwest of Waicoka makawa site. The main means of access to the site is by track from Waicoka Village. Similar to the Waicoka makawa site, Nasoto is a ring ditch fortification. It is in the outline of an irregular circular structure and has a diameter of approximately 30 m. There is a causeway on the southern end of the site, 4.7 m wide and 10 m long. The length of this causeway is also the width of the ditch that begins on the southern end and encircles the site to the east side extending northwards to where it ends. The ditch that continues from the northwest and goes down to the south was inundated with mud making it difficult to see the outline of the causeway due to the thick grass vegetation. Outside the ditch, on the southern end, there is a high concentration of seashells scattered, while some are protruding from the ground.

Additionally, at the southern end there is an abundance of pottery shards: plain rim shards, decorated (incised) body shards and some 'mat' impressed body shards. The site is scarcely vegetated, with the primary vegetation being grassland. A single tamarind shrub stands at the western end of the site where the ditch can no longer be seen.

Brief account

The site was said to have been the first place in the Waicoka area where the ancestors of the Yavusa Nakorolevu of Waicoka, settled when they travelled down from their Yavutu (Nausori). Separated from their kinsmen from Nausori village, they travelled eastwards until they reached and settled at Mokani. They then left Mokani and travelled further east until they reached Nasoto. They again left Nasoto and travelled east to Waicoka makawa where they finally settled. It is believed that the ancestors of the Yavusa Nakorolevu moved eastward toward the coast in order to have fish and seafood (kana wai tui).

14. Site Identification Number: Korovou 027/82

Site Name:	Vatoa (Appendix 17, Figure 58)
Site Type:	Old village site
Location:	S18.006594 E178.634217 E
Elevation:	18 m

The site is situated beside the road about 600 m south-south-east of Vatoa Village, in between Vatoa and Waicoka villages. It is located about 20 m west of the road. To the east are mangrove swamps. The site is an old village site. There are a total of five mounds, four of which are house-mounds approximately 5m wide and 7m long each while the fifth mound is the old church mound, having dimensions of 11m by 7m. Of the house mounds, three are situated close to each other on the central part of the site.

The chiefly house mound, known as Vunivesi is situated about 50m to the south, relative to the central part while the church mound is situated about 40m southwest relative to the central part of the site. On each of the four house mounds, there are burials (more than 30 burials) both old and current and this is due to the fact that the site owners, yavusa Davetalevu of Vatoa Village, are using the site as their burial grounds. Many of the burials have coral rock alignments around them, indicating older graves, while some were modern concrete burials, suggesting recent burials. Additionally, there was an abundance of plain pottery shards and seashells scattered on the ground surface. The site is vegetated with secondary vegetation and is surrounded by swamp and marshland. It is primarily coconut woodland with occasional breadfruit, dawa and ylang-ylang (*Cananga odorata*), locally known as makosoi. Some of the indicator species present includes sacasaca and uci.

Brief account

The site was occupied by the yavusa Davetalevu after the Vunivalu of Bau presented this piece of land to them. Before they settled on Vatoa, they were living in Navitiviti (also known as Loi), which is also within the vicinity, though their ancestral roots trace back to Rairaiwasa, on Bau Island. They came to the mainland following directives of the Vunivalu of Bau. Traditionally, they are known as the "Qase nei Na Vunivalu" or Elders of the Vunivalu of Bau. They are originally Waimaro people in Tailevu and their high chief was Tui Vatoa whose yavutu is Vatoa close to Vadrakula, opposite Nailega Village in Namalata district, Tailevu. The title of Tui Vatoa was transferred to the Vunivalu of Bau when the yavusa Davetalevu settled on Bau and their tribal leader is now titled Namalo.

15. Site Identification Number: Nausori 028/87

Site Name:	Naivitavi (Appendix 17, Figure 59)
Site Type:	Ring ditch fortification
Location:	S 18.053077 E 178.676359
Elevation:	6 m

This site contains an enormous fortification located in the mangroves approximately 400 m northwest of Kiuva Village. Naivitavi is almost 180 m long and 155 m wide with several other related sites located hundreds of meters east towards the coast. These are sites belonging to the gonedau (fisherman) and mataisau (craftsman) clans, which are separate from the main fortified settlement.

There was a difficulty in surveying the site as it was heavily infested with mosquitoes however it was noted that the site is enclosed with a single ring ditch, elliptical in form. The total number of causeways to the site could not be established. A few house mounds within the site were separately enclosed; each with its own ring ditch, while close to the south entrance is a ditch where human bodies or war trophies were plunged. This was known as the tobu ni bokola.

The structure of the settlement at Naivitavi is still clear to the people or clan ownership of house mounds according to the different status of each individual. The site has remnant mounds for the chief or Roko Tui Kiuva, his warriors, priest, and commoners. As such the people of Kiuva today are still linked to Naivitavi by burying their relatives according to their respective dela ni yavu or ancestral mounds.

16. Site Identification Number: Nausori 028/84

Site Name:	Vadrai yavutu (Appendix 17, Figure 60)
Site Type:	Old village/koro makawa
Location:	S 18.079331 E 178.656108
Elevation:	12 m

The site is adjacent to the main access road in the area, just across from the village of Vadrai with Nasilai Village situated about 410 m to the south. The site extends upon an area covering about 85 m x 75 m on flatland adjacent to the main excess road, with the present village situated across the road, just along the Nasilai shoreline. Upon first glance, it is understood that the site has been continually utilised for the purpose of agricultural activities and a predominant area of land to the west, is defined by swamps and mangrove cover. The site surface has been ploughed for agricultural plots and irrigation systems and rotation processes, to upgrade and maintain soil fertility and agricultural produce. These activities have contributed to the disturbance of cultural features that may have existed among the site surface, permanently removing any evidence of house mounds however visible among the tilt soil were scatters of pottery shards (plainware), and an abundance of shell middens which are remains marine resources that the early villagers consumed.

The site is bordered by duruka (*Saccharum edule*) plots that surrounded the area of old settlement with the site surface containing vegetable plots of English cabbages (*Brassica oleracea* var. *capitata*), egg plants(*Solanum melongena*) and fruit trees mainly consisting of pawpaw (*Carica papaya*). Much of the land has been cultivated over the years altering the original cultural landscape and its remnants; however, confirmation from village elders and evidence discovered was sufficient to ascertain the site's significance and its place in history of the village of Vadrai.

17. Site Identification Number: Nausori 028/26

Site Name:	Unknown (Appendix 17, Figure 61)
Site Type:	Ring ditch fortification
Location:	S 18.075619 E 178.655725
Elevation:	18 m

The site is situated about 520 m north from Vadrai Village, just adjacent to the main excess road in the area and hidden within dense vegetation isolated within an area dominated by swampy grassland and agricultural farming.

The site accommodates a system of swamp ditches that may have possibly been constructed as defensive ditches, however, there includes a number of small ditches depicting a complex system of set up, possibly formed by natural factors that may have contributed to such features. The site area does not contain any form of house mounds or relevant cultural features as the area is vulnerable to erosion processes that have affected the site's original structure over the years.

The vegetation cover in within which the site is bordered is approximately 73 m long and 62 m wide and dominated by ivi trees, cevuga and vasili plants.

18. Site Identification Number: Nausori 028/83

Site Name:	Nakua (Appendix 17, Figure 62)
Site Type:	Old village/Koro makawa
Location:	S 18.083508 E 178.654478
Elevation:	41 m

This site is at the south-eastern corner of Nasilai village and is bordered with current houses. The site covers an area about 45 m long (north- south) and 41 m wide (east-west). Upon inspection, the site did not reveal preserved cultural features as coastal erosion processes and human activities around the area have greatly disturbed the site. The village guide pointed out areas that contained house mounds, however, only a vague description could be observed by the team, represented by a gradually raised surface at the initial area of inspection.

Villagers are utilising land to the east for agriculture (cassava, taro and vegetable farming). An irrigation system and some residences constructed around the area alter the cultural landscape. The team found pottery body and rim shards as well as an abundance of shell middens scattered on the surface of the site. This was the initial area occupied by the village ancestors, until the expansion of settlement towards the west, where the current village is situated.

19. Site Identification Number: Nausori O28/86

Site Name:	Unknown
Site Type:	Ancestral burial ground
Location:	S18.066489 S 178.601742 E
Elevation:	8 m

The site is located along the banks of the Wainibokasi River, about 180 m inland from the river, on the west bank. Naimalovau Village is located on the east bank of the river, opposite the site. Nabitu Village is located about 700 m further west from the site while Lomainasau is located just less than a kilometer southwest of the site.

The site contains a single large burial mound measuring 12 m x 7 m. There are two large vesi (*Intsia bijuga*) trees present within the site, one at the northwest and one at the southwest corner of the burial mound. Typical of a burial site, there are indicator species present such as sacasaca and uci that have outgrown plants in the shrub layer, giving us an idea of how old the burial is. The vegetation of the site, therefore, is also secondary anthropogenic forest. Around the site there is a change in vegetation into the mangrove forest.

20. Site Identification Number: Nausori O28/85

Site Name:	Unknown
Site Type:	Ring ditch fortification
Location:	S 18.08989 E 178.647439
Elevation:	13 m

The site is about 1 km southwest of Nasilai Village, on the opposite side of the river. It is situated about 50 m off the riverbank, past the mangrove zone (*Rhizophora* spp.) within a coconut grove.

The site is a ring ditch fortification, oriented in the northwest to southeast direction, is ovular and has a diameter of about 100m. A single causeway was identified at the south-east end of the site, 3 m wide and 4 m long. Additionally, there are pottery scatters (a mixture of plainware and decorated body and rim shards), about 300 m northwest of the site and also at a distance of 50 m northwest of the causeway. Seashell remains (arc shell and mussels) and coral fragments are scattered across the site (70% cover).

21. Site Identification Number: Suva O29/34

Site Name:	Yavu ni gone dau (Appendix 17, Figure 63)
Site Type:	House mound/yavu
Location:	S 18.138821 E 178.553452
Elevation:	14 m

This site is located about 1km south from Tavuya Village and about 350m northeast from the Mataisuva coastline with the main track to Tavuya Village situated adjacently to the site area. The site is currently being occupied by descendants and contains a residential plot, a traditional bure and an incomplete concrete foundation. Along the site track, the team identified pottery shards – Plainware, scattered among the surface. The site is bordered by dense vegetation dominated by ivi trees to the west and mangrove swamps to the east.

Brief account

This site is the ancestral settlement of villagers from Lomanikoro, to whom occupying the area was a traditional duty, sacredly in servitude to the Roko Tui Dreketi. According to the village guides, when the high chief spoke of his need (vosa mana) to consume turtle (vonu or na ika bula as it is referred to in the province), his wish would be granted when a turtle would be washed up on the Mataisuva foreshore, injured with a missing limb due to the attack by a sacred moray eel (dabea). Upon discovery by the ancestral settlers, they are immediately made aware of the high chief's yearning and take it to him for his meal.

22. Site Identification Number: Suva O29/35

Site Name:	Tavuya yavutu (Appendix 17, Figure 64)
Site Type:	Old village site/Koro makawa
Location:	S 18.132781 E 178.554561
Elevation:	9 m

The site is the ancestral settlement of the village of Tavuya and is located adjacent to the current village, about 92 m to the southwest along the main track that leads to Mataisuva beach. This site is extensive, covering a large area, which is currently being utilised by villagers as a planting ground in which the surface has been cultivated over the years and irrigation systems constructed to assist the farming of root crops and vegetables. Upon inspection, the site did not reveal any cultural features that ascertain settlement as agricultural activities may possibly have altered the cultural landscape. The only area

unused by farmers was the bulubulu or burial ground where recent and old burials were accommodated. The burial area covered a minor section of the site as the burials were bordered by dalo ni tana (*Xanthosoma saggitifolium*) and taro plots. The site is portioned between forest cover and cleared agricultural land with mangrove swamps defining the periphery of site area to the west and east.

23. Site Identification Number: Suva O29/27

Site Name:	Navadratolu (Appendix 17, Figure 65)
Site Type:	Ancestral burial ground
Location:	S18.142611 E178.536531
Elevation:	15 m

The site is located on the western end of Mataisuva bay, situated about 1.3 km south of Muanaira Village, Vutia. It is an ancestral burial site and lies parallel to the coastline of Mataisuva Bay. The site is situated along the back-beach about 10m wide in the north direction and extends for about 150 m in the northeast direction from the first burial at the western most end of the bay, near the main Rewa River mouth. Graves easily exceed 30 in number and are lined with coral rocks.

Situated along the back-beach, the vegetation composes of largely coastal littoral plant species such as dilo (*Calophyllum inophyllum*), vutu rakaraka (*Barringtonia asiatica*), vadra, and uto. In addition, indicator species common to cultural sites were also present including sacasaca and cevuga

This ancestral burial ground belongs to the Vanua of Vutia and, according to the guide, was their forefathers' final resting place. It is traditionally the burial grounds of the people of Vutia but today the people of Vutia are no longer using it as it is too far away.

24. Site Identification Number: Suva O29/28

Site Name:	Naivisere (Appendix 17, Figure 66)
Site Type:	House mound/yavu
Location:	S 18.12722 E 178.541036
Elevation:	14 m

Naivisere site is situated in between Narocivo and Muanaicake villages, about 30m to the north off the track that links the two villages. The site is a single house mound that is highly

vegetated with secondary vegetation, having vegetation cover of 70%. It belongs to the mata ni vanua clan of Naivisere, who are now living in Narocivo. They are traditionally from Rewa (Lomanikoro), although they are in close proximity to Vutia. History states that the people of Narocivo were already occupying the area when the people of Vutia came to settle where they are today.

25. Site Identification Number: Suva O29/29

Site Name:	Nukucagina
Site Type:	House mound/yavu
Location:	S 18.127762 E 178.539612
Elevation:	13 m

Site is situated within Muanaicake Village, opposite the village rara. Similar to the above mentioned Naivisere site, it consists of a single house mound, having dimensions of about "10 m x 6 m", where the outlines of the mound is clearly visible, having been scarcely vegetated. The only vegetation found at this site is grass, which is properly maintained by a grass cutter since it is within the village area. The mound is the chiefly house mound of the "Turaga na Tunidau" – the paramount chief of Vutia and a high chief of the Rewa chiefdom. So important was this chiefly title in the Rewa chiefdom that only the "Roko Tui Dreketi" – the chieftain supreme of the Burebasaga Confederacy, installs each successor to the title.

26. Site Identification Number: Suva O29/31

Site Name:	Unknown
Site Type:	Sacred site
Location:	S 18.12723 E 178.539199
Elevation:	34 m

The site is located 70 m north-west of Nukucagina site, adjacent to the village rara. It comprised a huge dilo tree, about 30m high to the first branch. On the ground around the dilo tree, there are scattered pottery shards – rims and body fragments, all of which were plain. There was a high presence of these shards within the site. This site is a sacred site and according to locals, the dilo tree was quite old. Their ancestors would gather under the tree and dance to the chanting of vucu (traditional chants). These vucu were given to their ancestors by the ancestral gods.

27. Site Identification Number: Suva O29/30

Site Name:	Sau tabu nei Roko Tui Dreketi
Site Type:	Sacred burial ground/Sau tabu
Location:	S 18.127979 E 178.539211
Elevation:	31 m

This site is located less than 50 m south-west of the yavu Nukucagina and 80 m directly south of the sacred site mentioned above. It is situated beside the Muanaicake village footpath. It is a single chiefly burial site, in the form of a rectangular tomb 20 m x 15 m. It has been cemented and a memorial is placed in the centre of the tomb. The chiefly tomb is the burial of one of the Roko Tui Dreketi, during the times of tribal warfare and cannibalism. The people of Vutia are traditionally the warriors of the Roko Tui Dreketi, through the leadership of the Vunivalu of Rewa. It is said that during a tribal war in Rewa, when the Roko Tui Dreketi was killed, the people of Vutia brought the upper portion of the chiefly body – from the hip to the head – to Vutia, in an effort to prevent enemies from getting away with the chiefly corpse. These warriors of Vutia then buried the chiefly corpse at their own retreat in Vutia and have thus protected their paramount chief until today.

10.3.2 Valuation of cultural heritage

Cultural heritage has been redefined as an asset of historic, cultural, and socio-economic significance in a contemporary society (Hubbard 1993; Riganti and Nijkamp 2007). In defining cultural heritage sites for lending purposes, the World Bank often describes tangible and intangible heritage as cultural assets. This is the typical area where investment in capital facilities that are expected to be long lasting and to yield a rate of return overtime. It is rather difficult to provide valuation for cultural heritage however valuation is derived by looking at the economic and cultural value of the sites.

The economic values of the sites are relatively easy to measure, at least in principal. When using economic value, it can distinguish between use and non-use values (Table 28), which are the direct value to consumers of the heritage services as a private good and the value accruing to those who experience the benefits of the heritage as a public good(Licciardi and Amirtahmaseb, 2009). Sometimes this is referred to as market and non-market value.

Table 28: Value of cultural heritage and applicable valuation methods, adapted from Licciardi and Amirtahmaseb (2009)

Categories of Value		Components of Value	Indicators	Applicable Pricing methodology	Advantage of Methodology
Use	extractive consumption	scientific or research, historic	archaeological treasures, historical exhibits, structures (tangible resources)	Market pricing methods	use market price
	recreational	social, economic or aesthetic	transportation cost, opportunity cost, access fee	Travel cost	based on generalised travel cost to destination
	aesthetic value	aesthetic	transportation cost, opportunity cost, access fee	Travel cost, Hedonic pricing, Contingent valuation	market price of rent and wage, and generalised travel cost to destination
non-use	existence, option and bequest	aesthetic, historic, scientific or research, social or economic	willingness to pay avoid damages to cultural resources	Contingent valuation	able to capture the non-market attributes of the goods

In describing the use value, most of the identified cultural heritage sites during the MESCAL field survey are land related which means cultural features on the surface of an area that could be used for farming activities to yield profit. In this case the use value will be reflected in the individual benefits that tourists enjoy as a result of their visit. On the other hand, the non-use value would be those cultural heritage sites yielding public good benefits of environmental benefits such as a forest reserve, gardens, marine parks and the likes. The similarity between environmental and cultural assets has meant that the methodologies developed for estimating the non-use values for environmental assets have been readily transferable to the heritage context (Pagiola 1996; Navrud and Ready 2002).

Table 29:Deconstructed elements of cultural value, from Licciardi and Amirtahmaseb (2009)

Aesthetic Value	Symbolic value	Spiritual Value

The site may possess and display beauty in some fundamental sense, whether that quality is somehow intrinsic to the site or whether it only comes into being in the consumption of it by the viewer. Under the general heading of aesthetic value we might also include the relationship of the site to the landscape in which it is situated, that is, all the environmental qualities relevant to the site and its surrounds.	The site may convey meaning and information that helps the community in which the site is located to interpret the community's identity and to assert its cultural personality, for example, the site may symbolise some event or experience of historical or cultural importance. The value of the site as a representation of meaning may be particularly important in its educational function, not just for the young but also for advancing the knowledgebase and level of understanding of the whole community.	Spiritual value conveyed by the site may contribute to the sense of identity both of the community living in or around the site and also of visitors to the site. It may provide them with a sense of cultural confidence and of connectedness between the local and the global. Spiritual value may also be experienced as a sense of awe, delight, wonderment, religious recognition, or connection with the infinite. In addition, the realization that similar spiritual value is created by other sites in other communities may promote intercultural dialogue and understanding.
Social value	**Historic Value**	**Authenticity Value**
The interpretation of culture as shared values and believes that bind groups together suggests that the social value of the heritage site might be rejected in the way it contributes toward social stability and cohesion in the community. The site may impinge upon or interact with the way of living in the community, helping to identify the group values that make the community a desirable place to live and work.	This value, however it is received, is inarguably intrinsic to the site and of all the components of cultural value it is probably the most readily identifiable in objective terms. Perhaps its principal benefit in the way in which historic value assists in defining identity, by providing a connectedness with the past and revealing the origins of the present. This value is manifested by the celebration of the culture and its artefacts that we inherit from the past. As UNESCO points put "Our cultural and natural heritage is both irreplaceable sources of life and inspiration."	The site may be valued for its own sake because it is real not false, and because it is unique. An important concomitant characteristic is that the site has integrity, variously defined in different circumstances, which must be safeguarded. Protection of the site's integrity, however interpreted, maybe a significant constraint imposed on project decision making when cultural value is taken into account.
Scientific Value		
The site may be important for its scientific content or as source or object for scholarly study.		

In a contrasting situation, the cultural value has no such unit of account. An initial step in constructing a theory of cultural value can be made by recognizing that it is a concept reflecting a number of different dimensions of value, not all of them may be present in a particular case and their significance may vary from one situation to another. If so, it might be possible to disaggregate the cultural value of some cultural good or service into its constituent elements (Table 29). A site can be deconstructed into the following components: aesthetic, symbolic, spiritual, social, historic, authenticity and spiritual value.

Table 30 illustrates the cultural value of the heritage sites according to the components and constituents from deconstructing cultural value. In some of the cases, the sites consist of all the elements and place them on a significant scale of importance. The table also highlights the importance of the sites according to local and national significance. Local significance of the sites is described as its importance to the owners and those that dwell close to the sites. For instance, the site may not belong to a family that lives close by but do they value it as a source of identity and history to the site owners? Do they respect the sites because of what it contains? These are some of the challenges that need to be highlighted today.

An institution that is mandated to look after the affairs of all community heritage sites, must take into account all the cultural values even if the site is not important locally or to the community surrounding it. At national level, all cultural sites, no matter the size are significant. The rationale behind this is that indigenous Fijians are nomadic people both in the pre-history and the historical context of Fiji. However, this illustrates that land ownership and cultural sites ownership are two different concepts and issues.

Table 30: Cultural value of MESCAL archaeological sites

Plots	Site name	Site type	Related cultural features	Cultural Value	Significance Ratings	
					Local	National
Natila village	*Nautu*	Installation site	House mounds and installation mound	1☐ 2☒3☒ 4☒ 5☒ 6☒7☐	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Delainavutu	Ring ditch fortification	Causeways and ring ditch, shell middens and pottery shards	1☒ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Naceva	Hill fortification	Terraces	1☐ 2☒3☐ 4☒ 5☐ 6☒7☐	1☐ 2☐3☐ 4☒ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Nakanalo	Old village	Settlement Platform	1☐ 2☐3☐ 4☒ 5☐ 6☒7☐	1☐ 2☐3☐ 4☒ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Valesa	Old village	None	1☒ 2☐3☐ 4☐ 5☐ 6☒7☐	1☒ 2☐3☐ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Nakarawa	Old village	Terrace and settlement platform	1☐ 2☐3☐ 4☒ 5☐ 6☒7☐	1☐ 2☐3☐ 4☒ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Natena	Old village	Obscured with lush vegetation	1☐ 2☐3☐ 4☐ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Kubuna	Sacred site	House mound, skeletal remains, shell middens and pottery shards	1☐ 2☐3☐ 4☐ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
Waicoka village	Unknown	Ring ditch fortification	Causeways and ring ditch	1☐ 2☐3☐ 4☐ 5☐ 6☒7☒	1☐ 2☐3☒ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Unknown	Old village	House mounds	1☒ 2☐3☐ 4☐ 5☐ 6☒7☒	1☐ 2☐3☒ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Unknown	Ring ditch fortification	Causeway, ring ditch, house mounds	1☒ 2☐3☐ 4☐ 5☐ 6☒7☒	1☐ 2☐3☒ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Waicoka	Ring ditch fortification	Causeways, ring ditch, burial mounds and cemented burials	1☒ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Nasoto	Ring ditch fortification	Causeway, ring ditch, shell middens and pottery shards	1☐ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Vatoa	Old village	House mounds	1☒ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
Nasilai village	*Naivitavi*	Ring ditch fortification	Causeways, ring ditch, house mounds, recent cement burials, old burial mounds, bathing pond ,pond for human bodies	1☐ 2☐3☐ 4☐ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Vadrai	Old village	None	1☐ 2☒3☒ 4☒ 5☒ 6☒7☒	1☒ 2☐3☐ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Unknown	Ring ditch fortification	Ditches	1☐ 2☐3☒ 4☐ 5☐ 6☒7☒	1☐ 2☐3☒ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Nakua	Old village	Shell middens and pottery shards	1☐ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☒ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Unknown	Ancestral burial ground	Single burial mound	1☐ 2☐3☐ 4☐ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Unknown	Ring ditch fortification	Causeway, shell middens and pottery shards	1☐ 2☐3☒ 4☐ 5☐ 6☒7☒	1☐ 2☐3☒ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
Muanaira village	*Yavu ni gone dau*	House mound	Single house mound	1☐ 2☒3☐ 4☒ 5☒ 6☒7☐	1☐ 2☐3☒ 4☐ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Tavuya	Old village	Burial mounds both recent and old	1☐ 2☒3☒ 4☒ 5☒ 6☒7☐	1☐ 2☐3☐ 4☒ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Navadratolu	Ancestral burial ground	Burial mounds	1☒ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Naivisere	House mound	Single house mound	1☐ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Nukucagina	House mound	Single house mound	1☒ 2☒3☐ 4☒ 5☒ 6☒7☐	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒
	Unknown	Sacred site	Sacred dilo (*Calophyllum inophyllum*) tree and pottery shards	1☒ 2☒3☒ 4☒ 5☒ 6☒7☐	1☐ 2☐3☐ 4☒ 5☐	1☐ 2☐3☐ 4☐ 5☒
	Sautabu nei RokoTui Dreketi	Sacred burial ground	Single cement burial	1☒ 2☒3☒ 4☒ 5☒ 6☒7☒	1☐ 2☐3☐ 4☐ 5☒	1☐ 2☐3☐ 4☐ 5☒

Note: Ratings-the more the value the greater the significance; Cultural value keys-1: Aesthetic value 2: Symbolic value 3: Spiritual value 4: Social value 5: Historic value 6: Authenticity value 7: Scientific value

10.4 Discussion

The history of the itaukei or indigenous Fijians is one that is dynamic and has evolved over the years. Comparable to any native culture, people responded to different life-changing situations in different ways. In the context of the early settlers of Fiji, climate and environment change attributed to changing lifestyles, their dependency on coastal resources, a shift from coastal to inland settlement, the practice of shifting cultivation, the use of water irrigation and terraces. There are also accounts of people being displaced throughout the region because of civil instability. As people move about they leave behind footprints of history and oral narratives related to significant events, and these are passed down from one generation to another.

Today, these cultural features are on the verge of destruction from changing social and economic conditions. Development in most cases is a chief threat to the security and existence of remnants of cultural heritage sites as highlighted earlier. This is also the result of poor planning and collaboration between government departments. To address such issues, studies and surveys similar to this one best capture and tabulate an inventory of significant cultural areas. Such data is useful to planners and decision makers. Nature has also taken its toll, however this is beyond human control. In relation to the objectives of the MESCAL project, the coastal areas are dealing with the threat of climate change, and the phenomenal sea level rise which will adversely affected many important cultural heritage sites in Fiji by causing deterioration, partial damage, total destruction or the loss of cultural value.

To justify the importance of cultural heritage sites and the need to preserve and conserve such relics, they represent masterpieces of community effort and creative knowledge in shaping landforms and monuments. They also bear testimony to cultural traditions of the early indigenous Fijians and illustrate prominent stages in Fijian history with artistic works of outstanding local and national significance.

These sites need protection from the effects of all natural and man-made disturbances because of their importance in cultural heritage and evolution – a legacy from the past which must be preserved for future generations as they are irreplaceable sources of inspiration and points of reference to identity, intelligence and civilisation.

The inspection of the forest vegetation revealed that there is much history contained within the study area pertaining to traditional and cultural development and linked strongly to the identity of its people.

Such history should be preserved whether they are tangible or intangible cultural assets. In this case, some evidence of cultural features has been destroyed or greatly impacted by human inhabitancy, in the form of rearing livestock, agricultural activities, and natural processes.

The Fiji Museum Archaeology Department recommends that:

- proper documentation of the survey and oral history is undertaken to avoid the loss of traditional knowledge about these sites.
- the Fiji Museum Archaeology Department is included in any future surveys of the area to allow for the completion of the survey in the overlooked areas within the survey region.
- the villagers should be made aware of the threat that livestock and agricultural farming pose to their ancestral grounds
- that the department is involved in presenting findings and creating awareness should there be any workshop planned for these regions.

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Appendix 1. Vascular flora species list

Origin Intr. = Introduction, [AB]Intr.= Aboriginal introduction **Abundance** (qualitative assessment): C=common, LC=locally common, VC = Very common, UC = Uncommon, WS=Widespread
Uses: CL=cultural, CM= cosmetics, CS=construction, FD=food, FL=fuel, FR=fodder, MD=medicine, OR=ornamental, EV= Environmental, TB=timber, TL=tools,

Scientific Name	Family	Origin	Abundance	Common name (Fijian)	Uses	Site 1	Site 2	Site 3	Site 4
Ferns and fern allies									
Acrostichum aureum L.	Vittariaceae	Native	VC, WS	borete	Fd., Med., Env.	X	X	X	X
Angiopteris evecta (Forster) Hoffman	Marattiaceae	Native	UC	basovi	Fd., Con.	X	X	X	X
Asplenium australasicum (J. Sm.) Hook.	Aspleniaceae	Native	C	*bird's nest*	Orn.	X	X	X	X
Culcita straminea (Labillardiere) Maxon	Cyatheaceae	Native	VC, WS		Env.	X	X	X	X
Cyathea lunulata (G. Forst.) Copel.	Cyatheaceae	Native	UC	balabala	Cv., Con.	X	X	X	X
Davallia solida (Forster) Swartz	Davalliaceae	Native	C		Med.		X	X	X
Dicranopteris linearis (Burmann) Underwood	Gleicheniaceae	Native	LC	bracken fern, qato	Con., Env.	X	X		X
Diplazium harpeodes T. Moore	Arthyriaceae	Native	LC	lalabe	Fd.	X	X	X	X
Drynaria rigidula (Swartz) Beddome	Polypodiaceae	Native	LC			X	X	X	X
Lomagramma cordipinna Holttum	Lomariopsidaceae	Native	C, WS	creeping fern	Cd., Fs.		X	X	X
Lycopodium cernuum L.	Lycopodiaceae	Native	UC	lewa ninini	Orn.	X	X		
Lycopodium sp.	Lycopodiaceae	Native	C	tassel fern	Orn.	X	X		
Nephrolepis biserrata (Sw.) Schott	Davalliaceae	Native	VC, WS		Env.	X	X	X	X
Ophioglossum pendulum L.	Ophioglossaceae	Native	UC				X	X	
Phymatosorus grossus (Langsd.&Fisch.) Brownlie	Polypodiaceae	Native	UC	vativati	Med.	X	X	X	X
Pteris pacifica Hieronymus	Vittariaceae	Native	UC			X		X	
Pyrrosia adnascens (Swartz) Ching	Polypodiaceae	Native	VC, WS		Med.	X	X	X	
Vaginularia angustissima (Brackenridge) Mettenius	Vittariaceae	Native	C	mokomokoni ivi		X	X	X	X
Dicotyledons									
Abrus precatorius L.	Fabaceae	Native	LC	lera	Cos.	X	X	X	X
Achyranthes aspera L.	Amaranthaceae	Intr.	UC			X	X	X	
Adenanthera pavinova L.	Fabaceae	Intr.	LC	red bead tree	Fl., Cul., Cos.	X	X	X	X
Ageratum conyzoides L.	Asteraceae	Intr.	C	botebotekoro	Med., Rel.	X	X	X	X
Albizia saman (Jacq.) F.v.Muell.	Mimosaceae	Intr.	LC	vaivai	Con., Tb.,Cv., Fl., Env.	X	X	X	X
Aleurites moluccana (L.) Willd.	Euphorbiaceae	Native	UC	lauci	Fd., Cos., Con., Fl.	X	X	X	X
Alphitonia zizyphoides (Spreng.) A.Gray	Rhamnaceae	Native	LC, WS	doi	Med., Con., Tb., Fl.	X	X	X	X
Annona glabra L.	Annonaceae	Intr.	LC, WS	uto ni bulumakau	Fd., Fl.	X	X	X	X
Annona muricata L.	Annonaceae	Intr.	UC	sour sop	Fd., Med.	X	X		X

Scientific Name	Family	Origin	Abundance	Common name (Fijian)	Uses	Site 1	Site 2	Site 3	Site 4
Artocarpus altilis (Parkinson) Fosberg	Moraceae	Intr./[AB]Intr.	C	breadfruit, uto	Fd., Med., Con., Fl.	X	X	X	X
Astronidium sp.	Melastomataceae	Native	C						
Azadirachta indica A.H.L.	Meliaceae	Intr.	UC		Med., Fl.	X		X	X
Barringtonia asiatica (L.) Kurz	Barringtoniaceae	Native	LC	vutu rakaraka	Con., Env.	X	X	X	X
Barringtonia edulis Seem.	Barringtoniaceae	Endemic	LC	vutu kana	Fd., Con., Tb.	X	X	X	X
Barringtonia racemosa (L.) Spreng.	Barringtoniaceae	Native	LC, WS	vutu wai	Env.	X	X	X	X
Bischofia javanica Bl.	Euphorbiaceae	Native	C	koka	Med., Con., Fl., Env.,Cul.	X	X	X	X
Bruguiera gymnorhiza (L.) Lam.	Rhizophoraceae	Native	LC, WS	dogo	Med., Con., Tb.,Fl., Env.	X	X	X	X
Caesalpinia bonduc (L.) Roxb.	Caesalpiniaceae	Native	UC	sili, soni	Med.			X	X
Calophyllum inophyllum L.	Clusiaceae	Native	LC	dilo	Med., Orn.,Con., Env.	X	X	X	
Cananga odorata (Lam.) Hook.f. & Thoms.	Annonaceae	Native?	UC	makosoi	Orn., Con., Fl.	X	X	X	X
Canavalia rosea (Sw.) DC.	Fabaceae	Native	LC	drawala, drautolu	Env.	X		X	X
Capsicum frutescens L.	Solanaceae	Intr.	LC	chilli, boro	Fd., Med.	X	X	X	X
Carica papaya L.	Cariacaceae	Intr.	C	pawpaw	Fd., Med.	X	X	X	X
Cassytha filiformis L.	Cassythaceae	Native	C	dodder		X	X	X	X
Celtis vitiensis A.C.Sm.	Ulmaceae	Native	UC		Fl.	X	X		
Cerbera manghas L.	Apocynaceae	Native	LC, WS	vasa	Fl.	X	X	X	X
Citharexylum spinosum L.	Verbenaceae	Intr.	UC	fiddle wood	Con., Fl.	X	X	X	
Citrus maxima (L.) Osbeck	Rutaceae	[AB]Intr.	UC	moli kana, moli kania	Fd., Med.				
Citrus ×limon (L.) Osbeck	Rutaceae	[AB]Intr.	UC	moli karo	Fd., Med., Con., Fl.	X	X	X	
Clerodendrum inerme (L.) Gaertn.	Verbenaceae	Intr.	LC	verevere	Med.	X	X	X	X
Clidemia hirta (L.) D.	Melastomataceae	Intr.	LC, WS	Koster's curse	Med.	X	X	X	
Coccinia grandis (L.) Voigt	Cucurbitaceae	Intr.	LC		Fd., Med.	X	X	X	X
Codiaeum variegatum (L.) Rumph. ex A.Juss.	Euphorbiaceae	[AB]Intr.	UC	sacasaca	Med., Orn.,Cul.	X	X	X	
Connarus pickeringii A.Gray	Connaraceae	Native	LC, WS	wa vutu	Cd.	X	X	X	X
Crotalaria pallida Aiton	Fabaceae	Intr.	LC			X	X		
Dalbergia candenatensis (Dennst.) Prain	Fabaceae	Native	UC	denimana	Med.	X		X	X
Derris malaccense (Benth.) Prain	Fabaceae	Intr.	LC	duva niukini	Cd., Fs.,Cul.	X	X	X	X
Derris trifoliata Lour.	Fabaceae	Native	C, WS	duva	Cd.			X	X
Dillenia biflora (A.Gray) martelli ex Dur. & Jacks.	Dilleniaceae	Native	LC	kuluva	Con., Fl.	X	X	X	X
Dracontomelon vitiense Engl.	Anacardiaceae	Native	UC	tarawau	Fd., Med., Con., Fl.	X	X	X	X
Dysoxylum richii (A.Gray) C.DC.	Meliaceae	Endemic	LC	tarawau kei rakaka	Med., Con., Tb., Fl.		X	X	
Elattostachys falcata (A.Gray) Merr. Perry	Sapindaceae	Native	LC	marasa	Con., Orn.				
Entada phaseoloides (L.) Merr.	Mimosaceae	Native	C, WS	wa lai	Med., Cul.,Env.		X	X	X

Scientific Name	Family	Origin	Abundance	Common name (Fijian)	Uses	Site 1	Site 2	Site 3	Site 4
Erythrina variegata L.	Fabaceae	[AB]Intr.	UC	drala					
Euodia hortensis J.R. & G.Forst.	Rutaceae	[AB]Intr.	LC	uci	Med., Cul.	X	X	X	
Excoecaria agallocha L.	Rhizophoraceae	Native	LC, WS	sinugaga	Med., Cul.	X	X	X	X
Ficus prolixa Forst.f.Fl.	Moraceae	Native	UC	baka ni viti	Rel.			X	
Ficus storckii var. kajewskii (Summerhayes) Corner	Moraceae	Native	UC	nunu	Tb., Con.	X		X	
Ficus theophrastoides Seem	Moraceae	Native	UC	lololo tagane	Med.	X	X	X	X
Ficus vitiensis Seem.	Moraceae	Endemic	LC, WS	lololo	Fd., Con.	X	X	X	
Glochidion sp.	Phyllanthaceae	Native	LC	molau	Med., Con., Fl.	X	X	X	
Grewia crenata (G.Forst.) Schinz & Guillaumin	Tiliaceae	Native	UC	siti	Med.	X	X	X	
Guettarda speciosa L.	Rubiaceae	Native	LC	buabua	Tb., Med.	X			
Heritiera littoralis Ait.	Sterculiaceae	Native	UC	kedra ivi na yalewa kalou	Con., Tb., Fl.	X	X	X	
Hernandia nymphaeifolia (Presl) Kubitzki	Hernandiaceae	Native	LC	evuevu	Con., Med., Fd.	X			
Hetaeria oblongifolia Bl.	Orchidaceae	Native	UC			X			
Hibiscus tiliaceus L.	Malvaceae	Native	C, WS	vau	Med., Con., Cd., Env., Fl., Tl.	X		X	X
Hyptis pectinata (L.) Poit.	Lamiaceae	Intr.	LC		Med.	X	X	X	
Indigofera suffruticosa Mill.	Fabaceae	Intr.	LC		Weed	X	X	X	
Indigofera trita var. scabra (Roth) Ali	Fabaceae	Intr.	LC		Weed	X			
Inocarpus fagifer (Parkinson) Fosberg	Fabaceae	Native	LC, WS	ivi	Fd.,Med., Con., Tl., Env.	X	X	X	X
Intsia bijuga (Colebr.) Kuntze	Caesalpiniaceae	Native	UC	vesi	Con., Tot., Fl., Tb.,Env.	X		X	X
Ipomoea obscura (L.) Ker-Gawl.	Convolvulaceae	Native	LC			X	X	X	
Ipomoea pes-caprae (L.) R.Br.	Convolvulaceae	Native	LC	wa bula	Med., Env.			X	X
Jatropha curcas L.	Euphorbiaceae	Intr.	UC		Med., Con.	X	X	X	X
Kingiodendron platycarpum B.L.Burtt	Caesalpiniaceae	Endemic	UC	moivi	Con., Tb.	X	X	X	
Lagerstroemia speciosa (L.) Pers.	Lythraceae	Intr.	UC	pride of india	Fl., Orn.	X	X		
Lantana camara L.	Verbenaceae	Intr.	UC	lantana	Med., Weed	X	X	X	
Leucaena leucocephala (Lam.) de Wit	Mimosaceae	Intr.	C, WS	vaivai	Fd.,Con., Fl., Env.	X	X		
Lumnitzera littorea (Jack) Voigt	Combretaceae	Native	UC	sagale	Con., Tb., Fl.	X	X	X	X
Macaranga harveyana (Muell. Arg.) Muell.	Euphorbiaceae	Native	LC, WS	gadoa	Con., Fl., Env.	X	X	X	X
Macaranga sp.	Euphorbiaceae	Native		gadoa	Con.	X	X	X	
Maesa tabacifolia Mez	Myrsinaceae	Native	LC	matameragigi	Med.	X	X	X	
Mangifera indica L.	Anacardiaceae	Intr.	C	mango	Fd., Rel., Fl., Env.	X	X	X	X
Manihot esculenta Crantz	Euphorbiaceae	[AB]Intr.	LC	cassava, tavioka	Fd.	X	X	X	X
Micromelum minutum (Forst.f.) Seem.	Rutaceae	Native	UC	qiqila	Med., Fl.	X	X	X	
Mikania micrantha H.B.K.	Asteraceae	Intr.	C	wabosucu	Med., Env.	X	X	X	X

Scientific Name	Family	Origin	Abundance	Common name (Fijian)	Uses	Site 1	Site 2	Site 3	Site 4
Mimosa pudica L.	Mimosaceae	Intr.	C	cogadrogadro		X	X		
Morinda citrifolia L.	Rubiaceae	Native	C	kura	Med., Con., Cv., Fl., Fd., Tl.	X	X	X	X
Neisosperma oppositifolium (Lam.) Fosberg & Sachet	Apocynaceae	Native	UC	vao	Fd.,Fl., Con., Env.	X	X	X	X
Oxalis corniculata L.	Oxalidaceae	Intr.	UC			X	X		
Parsonsia laevis (A.Gray) Markgraf	Apocynaceae	Native	C, WS			X	X	X	X
Passiflora aurantia Forst.	Passifloraceae	Native	UC		Fd.		X	X	X
Passiflora foetida L. var. hispida (DC. ex Triana & Planch.)	Passifloraceae	Intr.	LC		Fd., Weed	X	X	X	
Passiflora suberosa L.	Passifloraceae	Intr.	UC			X			
Persea americana Mill.	Lauraceae	Intr.	UC	avacado	Fd.	X	X	X	X
Physalis peruviana L.	Solanaceae	Intr.	LC	tukitukiyadre	Fd., Med.	X	X	X	X
Piper aduncum L.	Piperaceae	Intr.	LC	onalulu	Fl., Weed, Env.	X	X	X	
Pittosporum sp.	Pittosporaceae	Native	LC			X			
Planchonella grayana St.John	Sapotaceae	Native	UC	bau	Con., Tb.	X	X	X	X
Plerandra cf. grayi Seem.	Araliaceae	Endemic	UC	sole					X
Polygala paniculata L.	Polygalaceae	Intr./ [AB]Intr.	LC			X		X	
Pometia pinnata J.R. Forst. & G. Forst.	Sapindaceae	Native	UC	dawa	Fl., Med., Con., Tb., Fl., Tl.	X	X	X	X
Pongamia pinnata (L.) Pierre	Fabaceae	Native	UC	vesiwai	Med., Con., Tb.,Fl., Tl..			X	
Premna serratifolia L.	Verbenaceae	Native	LC, WS	yaro	Med., Con., Tb.,	X	X	X	X
Psidium guajava L.	Myrtaceae	Intr.	C	quawa	Fd., Med., Con., Fl.	X	X	X	
Rhizophora samoensis (Hochr.) Salvoza	Rhizophoraceae	Native	LC, WS	tiri	Med., Con., Fl., Env.	X	X	X	X
Rhizophora stylosa Griffith	Rhizophoraceae	Native	LC, WS	tiri	Med., Con., Fl., Env.	X	X	X	
Rhizophora × selala (Salvoza) Toml.	Rhizophoraceae	Native	LC, WS	selala	Med., Con., Fl., Tl.,Env.		X	X	X
Ricinus communis L.	Euphorbiaceae	Intr.	UC	castor oil		X	X	X	X
Scaevola sericea Vahl	Goodeniaceae	Native	LC	vevedu	Med., Fl.				
Schefflera actinophylla Harms	Araliaceae	Intr.	UC	queensland umbrella tree	Orn.				X
Senna occidentalis (L.) Link	Caesalpiniaceae	Intr.	LC		Weed	X	X	X	
Senna tora (L.) Roxb.	Caesalpiniaceae	Intr.	UC		Weed	X	X	X	
Sida acuta Burm.f.Fl.	Malvaceae	Intr.		deniose	Med., Tl..	X	X	X	
Sida rhombifolia L.	Malvaceae	Intr.	C	denime, broomweed	Med., Tl..	X	X	X	
Solanum torvum Sw.	Solanaceae	Intr.	UC	prickly solanum	Weed	X	X	X	X
Spathodea campanulata Beauv.	Bignoniaceae	Intr.	C	african tulip	Orn.,Weed, Env.	X	X	X	X
Spondias dulcis Parkinson	Anacardiaceae	Intr.	C	wi	Fd., Med.	X			
Stachytarpheta urticaefolia (Salisb.) Sims	Verbenaceae	Intr.	C	blue rat's tail	Weed	X	X	X	X
Stillingia pacifica Müll.Arg.	Euphorbiaceae	Native	UC				X		X

Scientific Name	Family	Origin	Abundance	Common name (Fijian)	Uses	Site 1	Site 2	Site 3	Site 4
Swietenia macrophylla King	Meliaceae	Intr.	UC	mahogany	Tb., Con., Fl., Cv.	X	X		X
Synedrella nodiflora (L.) Gaertn.	Asteraceae	Intr.	C		Weed	X	X	X	X
Syzygium malaccense (L.) Merr. & L.M.Perry	Myrtaceae	[AB]Intr.	C	kavika	Fd., Med., Con., Fl.	X		X	
Syzygium richii (A.Gray) Merr. Perry	Myrtaceae	[AB]Intr.	C	kavika ni waitui		X			
Tarenna sumbucina (Forst. F.) Durand ex Drake.	Rubiaceae	Native	C		Med., Fl., Con.	X			
Terminalia catappa L.	Combretaceae	Native	UC	tavola	Fd.,Med., Con., Tb., Orn.	X		X	X
Terminalia litoralis Seem.	Combretaceae	Native	UC		Fd.,Med., Tb., Con., Env.				
Terminalia samoensis Rech.	Combretaceae	Native	UC		Fd., Con., Tb.		X	X	
Urena lobata L.	Malvaceae	Intr.	C		Weed	X	X		
Vavaea amicorum Benth.	Meliaceae	Native	UC	cevua	Con., Fl.				
Vernonia cinerea (L.) Less.	Asteraceae	Intr.	C	kaukamea	Med.	X	X	X	X
Vigna marina (Burm.) Merr.	Fabaceae	Native	LC		Med., Env.			X	
Vitex trifolia L.	Verbenaceae	Native	UC	vulokaka	Med.	X	X		
Wedelia triloba (L.) Hitchc.	Asteraceae	Intr.	LC	wedelia	Orn., Weed	X	X	X	X
Xanthium pungens Wallr.	Asteraceae	Intr.	UC		Weed	X		X	
Xylocarpus granatum J. Koenig	Meliaceae	Native	LC, WS	dabi	Med., Con., Tb.,Fl., Env.	X	X	X	X
Monocotyledons									
Alocasia macrorrhiza (L.) G.Don	Araceae	[AB]Intr.	LC	via, viagaga	Fd.,Orn.	X	X	X	X
Axonopus affinis Chase	Poaceae	Intr./ [AB]Intr.	C			X			X
Bambusa vulgaris Schrader ex Wendl.	Poaceae	[AB]Intr.		bitu ni vavalagi	Fd.,Con., Fl., Env.	X		X	
Brachiaria mutica (Forssk.) Stapf	Poaceae	Intr./ [AB]Intr.	LC	paragrass	Fdr.	X	X	X	
Cocos nucifera L.	Arecaceae	Native	VC	niu, coconut	Fd.,Con.,Med.,Cos., Cd., Env.	X	X	X	X
Colocasia esculenta (L.) Schott	Araceae	Intr./ [AB]Intr.		dalo	Fd.	X	X	X	X
Commelina diffusa Burm.f.	Commelinaceae	Native	UC	cobulabula	Med.	X			
Cordyline fruticosa (L.) A.Chev.	Agavaceae	[AB]Intr.	C	qai	Fd., Med., Cos.	X	X	X	X
Crinum asiaticum L.	Amaryllidaceae	Native	C	viavia	Orn.	X	X	X	X
Cyperus rotundus L.	Cyperaceae	Intr./ [AB]Intr.	UC	nut grass		X	X		X
Cyrtosperma chamissonis (Schott) Merr.	Araceae	[AB]Intr.		giant swamp taro	Fd.	X	X	X	X
Digitaria ciliaris (Retz.) Koeler	Poaceae	Intr./ [AB]Intr.	C		Weed	X	X		
Dioscorea bulbifera L.	Dioscoreaceae	Native	C	kaile	Fd.	X	X	X	X
Dioscorea nummularia Lam.	Dioscoreaceae	[AB]Intr.	UC	tivoli	Fd.	X	X	X	X
Echinochloa colona (L.) Link	Poaceae	Intr./ [AB]Intr.	C		Fdr.		X	X	
Eichhornia crassipes (Mart.) Solms	Pontederiaceae	Intr.	UC	water hyacinth	Weed	X	X	X	
Eleusine indica (L.) Gaertn.	Poaceae	Intr./ [AB]Intr.	C	covatu	Weed, Med.	X	X	X	

Scientific Name	Family	Origin	Abundance	Common name (Fijian)	Uses	Site 1	Site 2	Site 3	Site 4
Epipremnum pinnatum (L.) Engl.	Araceae	Native	LC, WS	yalu	Med.	X	X	X	X
Grammatophyllum elegans Reichenb.f.	Orchidaceae	Native	LC	mangrove/Veisari orchid	Orn.	X	X	X	X
Hetaeria oblongifolia Bl.	Orchidaceae	Native	LC					X	
Ischaemum indicum (Houtt.) Merr.	Poaceae	Intr./ABIntr.	C	batiki blue grass	Fdr.	X	X		
Miscanthus floridulus (Labill.) Warb. ex K.Schum. & Lauterb.	Poaceae	Native	LC	reed, gasau	Con.	X	X	X	X
Monochoria vaginalis (Burm.f.) Presl.	Pontederiaceae	Native	LC	bekabekairaga	Weed	X		X	X
Nicolaia elatior (Jack) Horan	Zingiberaceae	Intr.	UC	torch ginger	Orn.	X			
Oberonia equitans (G.Forst.) Mutel	Orchidaceae	Native	UC					X	
Pandanus adorantinus sensu Seem.	Pandanaceae	ABIntr.	LC	voivoi		X		X	
Pandanus tectorius Parkinson ex Du Roi	Pandanaceae	Native	C, WS	vadra	Med.		X	X	
Panicum maximum Jacq.	Poaceae	Intr./ABIntr.	LC	Guinea grass		X	X		
Paspalum conjugatum Bergius	Poaceae	Intr./ABIntr.	LC	t-grass	Fdr.	X	X	X	
Paspalum distichum L.	Poaceae	Intr./ABIntr.	LC			X	X	X	
Pennisetum polystachyon (L.) J.A.&J.H.Schultes	Poaceae	Intr./ABIntr.	LC	mission grass	Con., Fdr.	X		X	
Scirpodendron ghaeri (Gaertn.) Merr.	Cyperaceae	Native	LC	vulu, misimisi	Con.	X	X	X	X
Sporobolus diander (Retz.) Beauv.	Poaceae	Intr./ABIntr.	C			X	X	X	
Tacca leontopetaloides (L.) Kuntze	Taccaceae	Native	UC	yabia	Fd.	X	X	X	X
Veitchia joannis H.Wendl.	Arecaceae	Native	UC	saqiwa	Fd., Con.	X	X		
Zingiber zerumbet (L.) Sm.	Zingiberaceae	ABIntr.	UC	lalaya	Med.	X	X	X	X

Appendix 2. Vegetation community structure assessment plot data

Key:

Parametres	Principal Vegetation/Habitat type	Species	
No. Ind. ≥5cm=Number of individuals greater or equal to 5cm No.tree spp.=Number of tree species Most comm. spp.= Most common species No.ind.≥10cm=Number of Individual more than or equal to 10centimeters of diameter at breast height Av.dbh (cm)=Average diameter at breast height (cm) B.area (stems≥10cm dbh)=Basal Area (of stems over 10cm dbh) Dom. sp.=Dominant species Rel.dom.(%)=Relative dominance No. dead trees>5cm=Number of dead trees over 5 cmdbh Av.bole-canopy(m)=Average of bole to canopy height (meters)	Mang. = Mangrove forest Rhi_man_for=*Rhizophora* mangrove forest Bru_man -for= *Bruguiera* mangrove forest Mix_Mang.=Mixed mangrove Back_Mang.=Back of the mangrove forest Coas.Beac.=Coastal Beach Vegetation Lowl.=Lowland Rainforest	Adn_pav=Adnenthera pavinova Ann_gla=Annona glabra Art_alt=Artocarpus altilis Ast_con=Astronidium confertiflorum Bar_edu=Barringtonia edulis Cer_man=Cerbera manghas Coc_nuc=Cocos nucifera Dys_ric=Dysoxyllum richii Exc_aga=Excoecaria agallocha Gue_spe=Guettarda speciosa Her_spp=*Hernandia* spp. Hib_til=Hibiscus tiliaceus	Ino_fag=Inocarpus fagifer Ins_bij=Instia bijuga Jar_cur=Jatropha curcas Leu_leu=Leuceana leucophylla Mac_see=Macaranga seemanni Mag_ind=Magnifera indica Mor_cit=Morinda citrifolia Pan_tec=Pandanus tectorius Rhi_spp=*Rhizophora* spp. Rhi_x_sel=Rhizophora × selala Spa_cam=Spathodea campanulata Ter_cat=Terminalia catappa Xyl_gra=Xylocarpus granatum

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T1 P1	17-9-12	1	-17.95656, 178.59408	Mang.	Bac_man_forest	5	7	5	none	7.0-120.0	34.79	6.4	93.84	Bar_edu	Ino_fag	Ino_fag (66%)
T1 P2	17-9-12	1	-17.95669, 178.59416	Mang.	Bac_man_forest	4	18	14	none	6.0-65.0	39.89	7.0	92.61	Ino_fag	Ino_fag	Ino_fag (93%)
T1 P3	17-9-12	1	-17.95671, 178.59427	Mang.	Bac_man_forest	5	10	8	none	5.0-64	26.7	7.2	94.22	Ino_fag	Ino_fag	Ino_fag (76%)
T1 P4	17-9-12	1	-17.95646, 178.59403	Mang.	Bac_man_forest	4	9	6	none	7.0-36	17.22	9.1	90.32	Ino_fag	Ino_fag	Ino_fag (70%)
T1 P5	17-9-12	1	-17.95641, 178.59394	Mang.	Bac_man_forest	2	12	10	none	7.0-43	16.50	9.9	92.42	Ino_fag	Ino_fag	Ino_fag (87%)
T1 P6	17-9-12	1	-17.95646, 178.59389	Mang.	Bac_man_forest	2	13	12	none	5-160	35.31	9.8	98.91	Ino_fag	Ino_fag	Ino_fag (35%)
T1 P7	17-9-12	1	-17.95638, 178.59401	Mang.	Bac_man_forest	4	6	5	none	8.0-81	36.50	10.1	96.35	Ino_fag	Bar_edu	Bar_edu (37%)
T1 P8	17-9-12	1	-17.95603, 178.5941	Slope	Lowl sec for	4	8	8	none	10.0-81.0	25.38	9.1	100.00	Dys_ric	Spa_cam	Spa_cam (40%)
T1 P9	17-9-12	1	-17.95603, 178.5941	Slope	Lowl sec for	2	5	5	none	37.0-117.0	74.60	15.9	100.00	Mag_ind	Ins_bij	Ins_bij (41%)
T2 P1	18-9-12	1	-17.95575, 178.59209	Slope	Lowl sec for	4	9	9	none	19.0-60.0	34.33	8.3	100.00	Mag_ind	Mag_ind	Mag_ind (66%)
T3 P1	18-9-12	1	-17.96196, 178.59408	Slope	Lowl sec for	4	10	10	none	27.0-99.0	53.30	12.0	100.00	Ino_fag	Ino_fag	Ino_fag (50%)

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T3 P2	18-9-12	1	-17.96196, 178.59408	Slope	Lowl sec for	2	8	7	none	10.0-60.0	33.50	14.2	96.27	Spa_cam	Spa_cam	Spa_cam (93%)
T3 P3	18-9-12	1	-17.95958, 178.59536	Slope	Lowl sec for	11	14	11	none	6.0-93.0	21.21	7.6	92.59	Spa_cam	Leu_leu	Leu_leu (31%)
T4 P1	18-9-12	1	-17.95878, 178.59599	Mang.	Bac_man_forest	3	6	6	none	23.0-54.0	34.17	6.3	100.00	Coc_nuc	Ino_fag	Xyl_gra (26%)
T4 P2	18-9-12	1	-17.95886, 178.59612	Mang.	Bac_man_forest	5	8	8	none	5.0-91.0	27.50	5.8	96.36	Coc_nuc	Cer_man	Cer_man (33%)
T4 P3	18-9-12	1	-17.95827, 178.59608	Mang.	Bac_man_forest	6	10	9	1	7.0-51.0	20.9	9.1	97.70	Bru_gym	Xyl_gra	Xyl_gra (43%)
T4 P4	18-9-12	1	-17.95827, 178.59608	Mang.	Bac_man_forest	4	8	8	none	16.0-62.0	32.6	11.3	100.00	Ann_gla	Xyl_gra	Xyl_gra (52%)
T5 P1	18-9-12	1	-17.95752, 178.59714	Mang.	*Bru*_man_for	1	12	11	none	5.0-34.0	16.67	5.1	93.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P2	18-9-12	1	-17.95752, 178.59714	Mang.	Mix_man_forest	2	10	2	none	5.0-14.0	6.81	1.9	22.94	Rhi_spp.	Rhi_spp.	Rhi_spp. (89%)
T5 P3	18-9-12	1	-17.95752, 178.59714	Mang.	Mix_man_forest	2	11	2	none	5.0-20.0	7.55	5.1	36.14	Rhi_spp.	Rhi_spp.	Rhi_spp. (24%)
T5 P4	18-9-12	1	-17.95728, 178.5973	Mang.	Mix_man_forest	2	7	0	none	5.0-9.0	6.57	2.8	0.00	Bru_gym	Bru_gym	Bru_gym (74%)
T5 P5	18-9-12	1	-17.95728, 178.5973	Mang.	*Rhi*_man -for	22	14	0	none	5.0-10.0	6.41	3.0	7.09	Rhi_spp.	Rhi_spp.	Rhi_spp. (100%)
T6 P1	18-9-12	1	-17.96978, 178.59865	Mang.	*Bru*_man_for	2	14	11	none	6.0-50.0	19.29	5.3	99.26	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P2	18-9-12	1	-17.96978, 178.59864	Mang.	*Bru*_man_for	1	20	20	none	12.0-37.0	19.75	7.0	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P3	18-9-12	1	-17.96978, 178.59864	Mang.	Mix_man_forest	3	12	12	none	16.0-45.0	3.09	7.4	100.00	Bru_gym	Rhi_x_sel	Bru_gym (69%)
T6 P4	18-9-12	1	-17.96979, 178.59891	Mang.	Mix_man_forest	2	12	9	none	8.0-34.0	17.58	6.0	88.15	Bru_gym	Bru_gym	Bru_gym (87%)
T6 P5	18-9-12	1	-17.96991, 178.59903	Mang.	Mix_man_forest	3	15	12	none	7.0-31.0	14.41	4.2	91.02	Bru_gym	Bru_gym	Bru_gym (74%)
T1 P1	19-9-12	2	-18.00682, 178.63528	Mang.	Mix_man_forest	3	6	5	none	7.0-38.0	24.83	4.9	95.30	Bru_gym	Bru_gym	Bru_gym (67%)
T1 P2	19-9-12	2	-18.00683, 178.63532	Mang.	Mix_man_forest	3	11	11	none	13.0-39.0	25.45	4.8	100.00	Bru_gym	Bru_gym	Bru_gym (56%)
T1 P3	19-9-12	2	-18.0068, 178.63532	Mang.	*Rhi*_man -for	2	10	7	none	5.0-23.0	14.00	1.52	87.86	Rhi_spp.	Rhi_x_ sel	Rhi_spp. (36%)
T1 P4	19-9-12	2	-18.00683, 178.63551	Mang.	*Rhi*_man -for	3	8	4	none	5.0-109.0	25.63	1.20	86.83	Rhi_spp.	Rhi_x_ sel	Rhi_x_ sel (56%)
T1 P5	19-9-12	2	-18.00679, 178.63556	Mang.	Rhi_man_for	1	13	8	none	5.0-45.0	20.05	1.42	92.44	Rhi_spp.	Rhi_spp.	Rhi_spp. (100%)
T1 P6	19-9-12	2	-18.00695, 178.63571	Mang.	Mix_man_forest	2	12	8	none	5.0-42.0	14.25	3.5	85.38	Rhi_spp.	Rhi_spp.	Rhi_spp. (80%)
T1 P7	19-9-12	2	-18.00694, 178.63581	Mang.	Mix_man_forest	2	21	19	none	5.0-49.0	32.14	4.7	98.22	Bru_gym	Bru_gym	Bru_gym (88%)
T1 P8	19-9-12	2	-18.00694, 178.63581	Mang.	Mix_man_forest	1	2	0	none	5	5.00	3.7	0.00	none	none	n/a
T1 P9	19-9-12	2	-18.00692, 178.63616	Mang.	Mix_man_forest	2	11	9	none	6.0-87.0	22.64	4.2	94.78	Rhi_spp.	Rhi_spp.	Rhi_spp. (35%)
T1 P10	19-9-12	2	-18.00691, 178.63617	Mang.	Mix_man_forest	2	12	9	none	5.0-60.0	18.92	4.8	92.51	Rhi_spp.	Rhi_spp.	Rhi_spp. (71%)
T2 P1	19-9-12	2	-18.00694, 178.63599	Mang.	*Bru*_man_for	1	8	8	none	21.0-69.0	41.38	7.7	100.00	Bru_gym	Bru_gym	Bru_gym (100%)

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T2 P2	19-9-12	2	-18.00694, 178.63599	Mang.	*Bru*_man_for	1	9	8	none	5.0-58.0	28.44	7.3	98.05	Bru_gym	Bru_gym	Bru_gym (100%)
T2 P3	19-9-12	2	-18.00692, 178.636	Mang.	*Bru*_man_for	1	8	7	none	5.0-59.0	22.13	5.0	97.18	Bru_gym	Bru_gym	Bru_gym (100%)
T2 P4	19-9-12	2	-18.00667, 178.63598	Mang.	*Bru*_man_for	1	8	6	none	5.0-51.0	29.88	7.0	95.82	Bru_gym	Bru_gym	Bru_gym (100%)
T2 P5	19-9-12	2	-18.00657, 178.63592	Mang.	*Bru*_man_for	1	12	9	none	5.0-51.0	24.08	6.2	94.12	Bru_gym	Bru_gym	Bru_gym (100%)
T2 P6	19-9-12	2	-18.00655, 178.63595	Mang.	*Bru*_man_for	1	18	14	none	5.0-48.0	21.67	6.6	95.90	Bru_gym	Bru_gym	Bru_gym (100%)
T2 P7	19-9-12	2	-18.00647, 178.63593	Mang.	*Bru*_man_for	1	11	7	none	5.0-37.0	20.50	6.4	88.69	Bru_gym	Bru_gym	Bru_gym (100%)
T3 P1	19-9-12	2	-18.00647, 178.63593	Mang.	*Bru*_man_for	1	7	6	none	8.0-58.0	39.00	11.0	97.07	Bru_gym	Bru_gym	Bru_gym (100%)
T3 P2	19-9-12	2	-18.00647, 178.63593	Mang.	*Bru*_man_for	1	7	7	none	30.0-48.0	40.57	11.9	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T3 P3	20-9-12	2	-17.96222, 178.59832	Mang.	*Bru*_man_for	1	6	6	none	28.0-50.0	38.00	10.0	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T3 P4	20-9-12	2	-17.96222, 178.59832	Mang.	*Bru*_man_for	1	5	5	none	15.0-34.0	25.20	12.2	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T3 P5	20-9-12	2	-17.96222, 178.59832	Mang.	*Bru*_man_for	2	7	6	none	10.0-40.0	27.29	10.0	94.76	Bru_gym	Bru_gym	Bru_gym (95%)
T3 P6	20-9-12	2	-17.96222, 178.59832	Mang.	*Bru*_man_for	1	10	6	none	7.0-35.0	18.30	7.6	91.26	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P1	20-9-12	2	-17.96222, 178.59832	Mang.	Bac_man_forest	3	7	6	none	7.0-27.0	16.57	6.6	93.97	Cer_man	Coc_nuc	Coc_nuc (59%)
T4 P2	20-9-12	2	-17.96222, 178.59832	Mang.	Bac_man_forest	3	9	9	none	15.0-30.0	21.33	7.1	100.00	Coc_nuc	Coc_nuc	Cer_man (16%)
T5 P1	20-9-12	2	-17.96205, 178.59406	Mang.	Bac_man_forest	5	10	10	none	26.0-78.0	43.30	8.5	100.00	Coc_nuc	Mag_ind	Mag_ind (18%)
T5 P2	20-9-12	2	-17.96205, 178.59406	Mang.	Bac_man_forest	4	6	6	none	11.0-91.0	34.50	8.7	100.00	Art_alt	Mag_ind	Mag_ind (44%)
T6 P1	20-9-12	2	-17.95878, 178.59599	Mang.	*Bru*_man_for	1	16	16	none	14.0-90.0	28.50	7.8	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T7 P1	20-9-12	2	-17.95878, 178.59599	Mang.	Bac_man_forest	7	11	8	none	7.0-46.0	15.64	7.1	24.04	Ann_gla	Ast_con	Ast_con (7%)
T7 P10	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	5	13	9	none	6.0-28.0	17.31	7.8	88.89	Exc_aga	Mag_ind	Mag_ind (42%)
T7 P2	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	5	20	16	none	5.0-23.0	16.00	8.4	87.81	Coc_nuc	Coc_nuc	Coc_nuc (53%)
T7 P3	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	7	14	7	none	5.0-67.0	17.21	6.8	80.91	Ann_gla	Ino_fag	Ino_fag (31%)
T7 P4	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	5	13	11	none	5.0-70.0	23.08	8.6	96.00	Coc_nuc	Ann_gla	Ann_gla (26%)
T7 P5	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	4	9	8	none	5.0-28.0	18.78	8.4	97.04	Coc_nuc	Coc_nuc	Coc_nuc (53%)
T7 P6	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	6	19	17	none	5.0-26.0	20.95	8.5	97.24	Coc_nuc	Coc_nuc	Coc_nuc (59%)
T7 P7	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	5	13	11	none	5.0-26.0	18.15	7.5	95.34	Coc_nuc	Coc_nuc	Coc_nuc (77%)
T7 P8	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	3	8	6	none	5.0-24.0	14.63	8.4	90.60	Hib_til	Coc_nuc	Coc_nuc (21%)
T7 P9	20-9-12	2	-17.95886, 178.59612	Mang.	Bac_man_forest	2	12	12	1	17.0-38.0	25.58	8.2	100.00	Mag_ind	Mag_ind	Mag_ind (71%)

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T8 P1	20-9-12	2	-17.95827, 178.59608	Mang.	*Bru*_man_for	1	7	5	none	5.0-55.0	22.71	7.9	93.08	Bru_gym	Bru_gym	Bru_gym (100%)
T8 P2	20-9-12	2	-17.95827, 178.59608	Mang.	*Bru*_man_for	1	15	13	none	5.0-33.0	23.40	9.6	96.87	Bru_gym	Bru_gym	Bru_gym (100%)
T8 P3	20-9-12	2	-17.95827, 178.59608	Mang.	*Bru*_man_for	1	11	10	none	8.0-36.0	26.09	9.6	97.21	Bru_gym	Bru_gym	Bru_gym (100%)
T8 P4	20-9-12	2	-17.95827, 178.59608	Mang.	*Bru*_man_for	2	9	7	none	6.0-68.0	29.11	7.4	95.42	Bru_gym	Bru_gym	Bru_gym (95%)
T8 P5	20-9-12	2	-17.95827, 178.59608	Mang.	*Bru*_man_for	1	4	3	none	5.0-75.0	30.50	7.6	95.90	Bru_gym	Bru_gym	Bru_gym (100%)
T9 P1	20-9-12	2	-17.95745, 178.59693	Mang.	*Bru*_man_for	1	16	16	2	5.0-40	24.50	9.7	96.17	Bru_gym	Bru_gym	Bru_gym (100%)
T9 P2	20-9-12	2	-17.95745, 178.59693	Mang.	*Bru*_man_for	1	15	10	none	5.0-34.0	17.67	8.9	88.30	Bru_gym	Bru_gym	Bru_gym (100%)
T9 P3	20-9-12	2	-17.95745, 178.59693	Mang.	*Bru*_man_for	1	9	8	none	6.0-84.0	35.11	9.4	98.10	Bru_gym	Bru_gym	Bru_gym (100%)
T10 P1	21-9-12	2	-18.02224, 178.63837	Mang.	Bac_man_forest	2	4	4	none	22.0-102.0	55.38	8.3	100.00	Mag_ind	Mag_ind	Mag_ind (84%)
T10 P2	21-9-12	2	-18.02224, 178.63837	Mang.	Bac_man_forest	6	6	6	none	27.0-77.0	37.33	10.6	100.00	Mag_ind	Mag_ind	Mag_ind (53%)
T10 P3	21-9-12	2	-18.02224, 178.63837	Mang.	Bac_man_forest	2	5	5	none	9.0-133.0	41.60	7.6	100.00	Ino_fag	Ino_fag	Ino_fag (91%)
T10 P4	21-9-12	2	-18.02224, 178.63837	Mang.	Bac_man_forest	4	11	11	none	9.0-105.0	35.00	8.3	97.66	Ino_fag	Ino_fag	Ino_fag (86%)
T11 P1	21-9-12	2	-18.01988, 178.63937	Mang.	Bac_man_forest	3	8	8	none	16.0-117.0	61.63	10.4	100.00	Ino_fag	Mag_ind	Mag_ind (24%)
T11 P2	21-9-12	2	-18.01988, 178.63937	Mang.	Bac_man_forest	6	8	5	none	6.0-57.0	19.25	5.8	2.03	Ino_fag	Ino_fag	Ino_fag (37%)
T11 P3	21-9-12	2	-18.01988, 178.63937	Mang.	Bac_man_forest	3	8	8	none	15.0-149.0	55.50	6.5	100.00	Ino_fag	Ino_fag	Ino_fag (86%)
T12 P1	21-9-12	2	-18.01597, 178.63715	Mang.	Bac_man_forest	3	10	10	none	27.0-67.0	41.60	9.4	100.00	Ino_fag	Ino_fag	Ino_fag (70%)
T12 P2	21-9-12	2	-18.01597, 178.63715	Mang.	Bac_man_forest	4	17	14	none	6.0-69.0	25.06	8.8	94.84	Ino_fag	Ino_fag	Ino_fag (65%)
T12 P3	21-9-12	2	-18.01597, 178.63715	Lowl.	Bac_man_forest	5	12	6	none	6.0-142.0	31.25	8.6	88.80	Ino_fag	Ino_fag	Ino_fag (47%)
T13 P1	21-9-12	2	-18.02963, 178.6268	Mang.	*Bru*_man_for	1	15	7	none	5.0-47.0	19.13	6.8	81.18	Bru_gym	Bru_gym	Bru_gym (100%)
T13 P2	21-9-12	2	-18.02963, 178.6268	Mang.	*Bru*_man_for	1	13	11	none	5.0-48.0	32.00	9.9	98.80	Bru_gym	Bru_gym	Bru_gym (100%)
T13 P3	21-9-12	2	-18.02963, 178.6268	Mang.	*Bru*_man_for	1	9	9	none	12.0-98.0	31.22	8.7	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T13 P4	21-9-12	2	-18.02963, 178.6268	Mang.	*Bru*_man_for	1	9	7	none	5.0-118.0	31.89	8.7	94.08	Bru_gym	Bru_gym	Bru_gym (100%)
T13 P5	21-9-12	2	-18.02963, 178.6268	Mang.	*Bru*_man_for	1	7	7	none	12.0-40.0	26.29	9.4	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T14 P1	21-9-12	2	-18.02874, 178.6277	Mang.	*Bru*_man_for	1	8	8	1	12.0-46.0	31.38	6.8	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T14 P2	21-9-12	2	-18.02874, 178.6277	Mang.	*Bru*_man_for	1	6	5	none	5.0-36.0	25.33	8.3	96.71	Bru_gym	Bru_gym	Bru_gym (100%)
T14 P3	21-9-12	2	-18.02874, 178.6277	Mang.	*Bru*_man_for	2	14	10	none	5.0-40.0	18.07	6.2	90.51	Bru_gym	Bru_gym	Bru_gym (91%)
T14 P4	21-9-12	2	-18.02874, 178.6277	Mang.	*Bru*_man_for	2	12	11	none	5.0-61.0	20.42	7.9	97.96	Bru_gym	Bru_gym	Bru_gym (98%)

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T14 P5	21-9-12	2	-18.02874, 178.6277	Mang.	*Bru*_man_for	2	9	8	none	5.0-30.0	21.89	8.1	97.46	Bru_gym	Bru_gym	Bru_gym (97%)
T15 P1	21-9-12	2	-18.02793, 178.62949	Mang.	Bac_man_forest	5	15	9	1	5.0-55.0	15.80	6.1	81.43	And_pav	And_pav	And_pav (54%)
T15 P2	21-9-12	2	-18.02793, 178.62949	Mang.	Bac_man_forest	5	10	8	none	5.0-28.0	20.80	6.1	288.94	Coc_nuc	Coc_nuc	Coc_nuc (50%)
T15 P3	21-9-12	2	-18.02793, 178.62949	Mang.	Bac_man_forest	6	7	7	none	13.0-60.0	25.43	5.4	100.00	Bar_rac	And_pav	And_pav (34%)
T16 P1	21-9-12	2	-18.02791, 178.62949	Mang.	*Bru*_man_for	1	3	3	none	18.0-22.0	20.00	8.6	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T16 P2	21-9-12	2	-18.02791, 178.62949	Mang.	*Bru*_man_for	1	11	7	none	6.0-22.0	12.09	7.7	77.44	Bru_gym	Bru_gym	Bru_gym (100%)
T16 P3	21-9-12	2	-18.02791, 178.62949	Mang.	*Bru*_man_for	1	4	4	none	17.0-56.0	34.00	9.5	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T17 P1	21-9-12	2	-18.03621, 178.64637	Mang.	*Bru*_man_for	1	3	3	none	25.0-58.0	40.33	8.6	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T17 P2	21-9-12	2	-18.03621, 178.64637	Mang.	*Bru*_man_for	1	10	3	none	5.0-52.0	14.80	5.7	2.00	Bru_gym	Bru_gym	Bru_gym (100%)
T17 P3	21-9-12	2	-18.03621, 178.64637	Mang.	*Bru*_man_for	1	8	8	1	12.0-66.0	31.50	7.8	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T17 P4	21-9-12	2	-18.03621, 178.64637	Mang.	*Bru*_man_for	1	2	1	none	5.0-13.0	9.00	3.5	72.20	Bru_gym	Bru_gym	Bru_gym (100%)
T17 P5	21-9-12	2	-18.03621, 178.64637	Mang.	*Bru*_man_for	1	5	4	none	9.0-44.0	25.00	8.7	92.80	Bru_gym	Bru_gym	Bru_gym (100%)
T1 P1	24-9-12	3	-18.0644, 178.65006	Mang.	Bac_man_forest	6	8	7	none	8.0-178.0	50.88	10.6	98.03	Ino_ fag	Ino_fag	Ino_fag (65%)
T1 P2	24-9-12	3	-18.06435, 178.64998	Mang.	Bac_man_forest	4	9	7	none	5.0-60.0	25.67	9.6	94.81	Art_alt	Art_alt	Art_alt (65%)
T1 P3	24-9-12	3	-18.06437, 178.64991	Mang.	Bac_man_forest	7	12	9	1	7.0-32.0	19.75	9.9	91.56	Coc_nuc	Coc_nuc	Coc_nuc (51%)
T1 P4	24-9-12	3	-18.06453, 178.64965	Mang.	Bac_man_forest	8	12	7	none	6.0-41.0	19.08	7.3	85.59	Coc_nuc	Mor_cit	Mor_cit (86%)
T1 P5	24-9-12	3	-18.0645, 178.6496	Mang.	Bac_man_forest	3	9	9	none	9.0-45.0	25.33	9.4	96.05	Coc_nuc	Coc_nuc	Coc_nuc (66%)
T2a P1	24-9-12	3	-18.06485, 178.66526	CB.	Coa_bea_forest	2	8	8	none	16.0-36.0	26.38	10.3	100.00	Coc_nuc	Coc_nuc	Coc_nuc (84%)
T2a P2	24-9-12	3	-18.06474, 178.66513	CB.	Coa_bea_forest	2	14	14	none	15.0-30.0	18.29	8.6	100.00	None	Coc_nuc	Coc_nuc (55%)
T2a P3	24-9-12	3	-18.06471, 178.66511	CB	Coa_bea_forest	3	10	9	none	5.0-21.0	19.80	7.8	97.47	Pan_tec	Ter_cat	Ter_cat (33%)
T2b P1	24-9-12	3	-18.06463, 178.66501	CB	Coa_bea_forest	5	10	8	none	7.0-39.0	16.70	6.6	99.40	None	Mac_see	Mac_see (23%)
T2b P2	24-9-12	3	-18.08134, 178.65795	CB	Coa_bea_forest	4	11	11	none	12.0-97.0	31.55	6.7	100.00	Coc_nuc	Her_spp.	Her_spp. (28%)
T2b P3	24-9-12	3	-18.08137, 178.65784	CB.	Coa_bea_forest	2	9	9	none	12.0-51.0	22.89	4.6	100.00	Pan_tec	Gue_spe	Gue_spe (25%)
T2c P1	24-9-12	3	-18.07732, 178.65852	CB	Coa_bea_forest	2	11	11	none	13.0-29.0	21.91	5.6	100.00	Pan_tec	Coc_nuc	Coc_nuc (68%)
T2c P2	24-9-12	3	-18.07725, 178.65841	CB	Coa_bea_forest	4	14	13	none	9.0-18.0	14.79	5.4	95.65	Pan_tec	Pan_tec	Pan_tec (75%)
T2c P3	24-9-12	3	-18.07721, 178.65834	CB	Coa_bea_forest	4	12	12	none	13.0-129.0	29.50	9.4	100.00	Pan_tec	Jat_cur	Jat_ cur (36%)
T3 P1	25-9-12	3	-18.08598, 178.61374	Mang.	Bac_man_forest	6	19	10	none	5.0-27.0	14.11	6.3	76.87	Xyl_gra	Coc_nuc	Coc_nuc (51%)

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T3 P2	25-9-12	3	-18.08598, 178.61365	Mang.	Bac_man_forest	4	13	10	none	6.0-28.0	15.15	8.4	89.85	Ann_gla	Coc_nuc	Coc_nuc (58%)
T3 P3	25-9-12	3	-18.08609, 178.61382	Mang.	Bac_man_forest	5	10	7	none	5.0-26.0	19.90	8.3	90.45	Ann_gla	Ann_gla	Ann_gla (38%)
T3 P4	25-9-12	3	-18.08629, 178.61379	Mang.	Bac_man_forest	5	11	5	none	5.0-25.0	12.27	6.9	68.89	Ann_gla	Coc_nuc	Coc_nuc (19%)
T3 P5	25-9-12	3	-18.08634, 178.61378	Mang.	Bac_man_forest	4	17	10	none	5.0-28.0	15.18	8.1	85.66	Ann_gla	Coc_nuc	Coc_nuc (57%)
T3 P6	25-9-12	3	-18.08638, 178.61377	Mang.	Bac_man_forest	5	20	11	none	6.0-45.0	15.10	8.1	77.48	Coc_nuc & Ann_gla	Ino_ fag	Coc_nuc (44%)
T3 P7	25-9-12	3	-18.08662, 178.61379	Mang.	Bac_man_forest	4	11	11	none	5.0-74.0	24.67	10.3	98.31	Coc_nuc	Ino_ fag	Ino_fag (25%)
T3 P8	25-9-12	3	-18.08671, 178.61376	Mang.	Bac_man_forest	4	20	13	none	5.0-29.0	15.20	8.4	84.54	Ann_gla	Coc_nuc	Coc_nuc (53%)
T3 P9	25-9-12	3	-18.08673, 178.61377	Mang.	Bac_man_forest	5	21	17	none	5.0-34.0	18.90	8.0	93.70	Coc_nuc	Rhi_spp.	Xyl_gra (21%)
T3 P10	25-9-12	3	-18.08682, 178.61369	Mang.	Bac_man_forest	5	14	8	none	6.0-33.0	16.79	7.9	81.28	Coc_nuc	Xyl_gra	Xyl_gra (81%)
T4 P1	25-9-12	3	-18.08053, 178.61535	Mang.	*Bru*_man_for	1	16	11	none	5.0-55.0	24.25	9.2	92.01	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P2	25-9-12	3	-18.0805, 178.61546	Mang.	*Bru*_man_for	1	8	7	none	8.0-47.0	27.75	11.5	96.40	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P3	25-9-12	3	-18.08067, 178.61552	Mang.	*Bru*_man_for	1	6	6	none	17.0-49.0	41.50	15.3	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P4	25-9-12	3	-18.08036, 178.61579	Mang.	*Bru*_man_for	1	10	9	none	5.0-49.0	33.90	11.9	98.53	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P5	25-9-12	3	-18.08036, 178.61579	Mang.	*Bru*_man_for	1	11	10	none	5.0-45.0	26.82	8.8	98.31	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P6	25-9-12	3	-18.08027, 178.61585	Mang.	*Bru*_man_for	1	12	12	none	10.0-51.0	29.17	10.8	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P7	25-9-12	3	-18.08014, 178.61589	Mang.	*Bru*_man_for	1	10	10	3	23.0-44.0	33.10	12.3	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P8	25-9-12	3	-18.08012, 178.61604	Mang.	*Bru*_man_for	1	11	10	3	9.0-55.0	35.82	10.6	97.72	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P9	25-9-12	3	-18.07996, 178.61611	Mang.	*Bru*_man_for	1	12	12	1	11.0-36.0	26.83	10.4	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T4 P10	25-9-12	3	-18.08001, 178.61587	Mang.	*Bru*_man_for	1	12	12	none	11.0-65.0	35.75	11.1	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P1	25-9-12	3	-18.07638, 178.62858	Mang.	*Bru*_man_for	1	7	7	none	31.0-38.0	34.43	11.4	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P2	25-9-12	3	-18.07644, 178.62857	Mang.	*Bru*_man_for	1	6	6	1	36.0-105.0	59.17	12.0	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P3	25-9-12	3	-18.07644, 178.62857	Mang.	*Bru*_man_for	1	6	6	none	18.0-77.0	57.17	12.6	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P4	25-9-12	3	-18.07655, 178.62864	Mang.	*Bru*_man_for	1	8	8	none	13.0-101.0	60.13	13.4	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P5	25-9-12	3	-18.07675, 178.62849	Mang.	*Bru*_man_for	1	9	9	none	10.0-68.0	38.44	11.5	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P6	25-9-12	3	-18.07677, 178.62847	Mang.	*Bru*_man_for	1	6	6	1	21.0-61.0	33.50	12.7	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P7	25-9-12	3	-18.07705, 178.62837	Mang.	*Bru*_man_for	1	7	7	none	14.0-67.0	37.86	14.5	100.00	Bru_gym	Bru_gym	Bru_gym (100%)

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T5 P8	25-9-12	3	-18.07708, 178.62831	Mang.	*Bru*_man_for	1	11	11	1	10.0-86.0	35.55	9.8	94.88	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P9	25-9-12	3	-18.07721, 178.6284	Mang.	*Bru*_man_for	1	9	9	none	28.0-55.0	42.56	11.8	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T5 P10	25-9-12	3	-18.07732, 178.62835	Mang.	*Bru*_man_for	1	10	7	none	5.0-113.0	44.70	9.5	95.30	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P1	25-9-12	3	-18.07741, 178.62842	Mang.	*Bru*_man_for	1	6	6	none	40.0-94.0	60.83	14.4	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P2	25-9-12	3	-18.07754, 178.6284	Mang.	*Bru*_man_for	1	6	5	none	5.0-48.0	29.00	10.1	94.25	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P3	25-9-12	3	-18.07759, 178.62845	Mang.	*Bru*_man_for	1	9	9	none	12.0-57.0	33.44	11.6	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P4	26-9-12	3	-18.08749, 178.64586	Mang.	*Bru*_man_for	1	8	8	none	12.0-94.0	52.13	12.2	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P5	26-9-12	3	-18.08764, 178.64583	Mang.	*Bru*_man_for	1	8	7	none	7.0-91.0	34.38	8.6	97.45	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P6	26-9-12	3	-18.08784, 178.64575	Mang.	*Bru*_man_for	1	11	11	none	11.0-59.0	35.27	9.6	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T6 P7	26-9-12	3	-18.08783, 178.64576	Mang.	*Bru*_man_for	4	6	4	none	5.0-102.0	33.50	1.80	95.02	Exc_aga	Exc_aga	Exc_aga (80%)
T6 P9	26-9-12	3	-18.08786, 178.64555	Mang.	*Bru*_man_for	1	11	11	2	12.0-83.0	37.27	10.5	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T7 P1	26-9-12	3	-18.08809, 178.64548	Mang.	*Bru*_man_for	1	15	15	2	12.0-91.0	41.33	12.0	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T7 P2	26-9-12	3	-18.08815, 178.6453	Mang.	*Bru*_man_for	1	12	12	none	18.0-83.0	36.75	12.3	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T7 P3	26-9-12	3	-18.08814, 178.6453	Mang.	*Bru*_man_for	1	16	16	none	17.0-99.0	38.31	12.3	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T7 P4	26-9-12	3	-18.08792, 178.64514	Mang.	*Bru*_man_for	1	14	14	none	16.0-44.0	32.86	12.5	100.00	Bru_gym	Bru_gym	Bru_gym (100%)
T7 P5	26-9-12	3	-18.08935, 178.64702	Mang.	Bac_man_forest	6	12	10	1	6.0-24.0	16.58	7.3	100.00	Coc_nuc	Coc_nuc	Coc_nuc (53%)
T7 P6	26-9-12	3	-18.08938, 178.64705	Mang.	Bac_man_forest	7	19	16	none	5.0-34.0	20.68	8.2	95.42	Coc_nuc	Bru_gym	Bru_gym (12%)
T7 P7	26-9-12	3	-18.08952, 178.64711	Mang.	Bac_man_forest	2	7	7	none	14.0-53.0	24.57	7.1	100.00	Coc_nuc	Coc_nuc	Coc_nuc (92%)
T7 P8	26-9-12	3	-18.08962, 178.64708	Mang.	Bac_man_forest	2	14	14	none	19.0-30.0	23.14	9.6	100.00	Coc_nuc	Ins_bij	Ins_bij (29%)
T7 P9	26-9-12	3	-18.08963, 178.64713	Mang.	Bac_man_forest	5	17	13	none	5.0-52.0	20.35	8.6	92.20	Coc_nuc	Ins_bij	Ins_bij (41%)
T7 P10	26-9-12	3	-18.08963, 178.64713	Mang.	Bac_man_forest	4	11	8	none	5.0-94.0	27.00	7.1	94.61	Ins_bij	Ins_bij	Ins_bij (32%)
T8 P1	26-9-12	3	-18.08982, 178.64725	Mang.	Bac_man_forest	2	11	7	none	5.0-39.0	18.27	6.3	86.57	Ino_ fag	Ino_ fag	Ino_fag (41%)
T8 P2	26-9-12	3	-18.08991, 178.64734	Mang.	Bac_man_forest	2	10	10	1	11.0-49.0	23.60	9.4	100.00	Coc_nuc	Ins_bij	Ins_bij (21%)
T8 P3	26-9-12	3	-18.08996, 178.64752	Mang.	Bac_man_forest	4	10	9	1	5.0-37.0	22.80	11.2	223.00	Coc_nuc	Coc_nuc	Coc_nuc (61%)
T8 P4	26-9-12	3	-18.08997, 178.64753	Mang.	Bac_man_forest	3	15	12	none	5.0-50.0	22.27	8.6	95.21	Ins_bij	Ins_bij	Ins_bij (58%)
T1 P1	27-9-12	4	-18.11482, 178.52613	Mang.	Mix_man_forest	2	41	19	1	5.0-28.0	9.63	7.5	64.56	Bru_gym	Bru_gym	Bru_gym. (52%)
T1 P2	27-9-12	4	-18.11485, 178.52617	Mang.	*Bru*_man_for	2	25	5	4	5.0-25.0	9.00	7.0	42.67	Bru_gym	Bru_gym	Bru_gym (92%)

Plot ID	Date	Site	Coordinates	Principal VegetationType	Forest/Habitat Type	No. tree spp.	≥5cm	≥10cm	dead > 5cm	dbh Range (cm)	Av.dbh (cm)	Av. bole -canopy (m)	B.area (stems≥ 10cm dbh)	Most common	Largest trees	Dominant (%)
T1 P3	27-9-12	4	-18.11481, 178.52625	Mang.	*Bru*_man_for	2	42	10	3	5.0-25.0	8.14	7.9	40.35	Bru_gym	Bru_gym	Bru_gym (100%)
T1 P4	27-9-12	4	-18.11479, 178.52624	Mang.	*Bru*_man_for	2	57	56	6	5.0-31.0	8.00	8.6	32.46	Bru_gym	Bru_gym	Bru_gym (99%)
T2 P2	27-9-12	4	-18.10726, 178.51959	Mang.	*Bru*_man_for	2	26	12	4	5.0-39.0	10.58	6.6	65.82	Bru_gym	Bru_gym	Bru_gym (95%)
T2 P3	27-9-12	4	-18.10725, 178.51961	Mang.	*Bru*_man_for	2	28	7	4	5.0-13.0	8.04	6.6	33.78	Bru_gym	Bru_gym	Bru_gym (96%)
T2 P4	27-9-12	4	-18.12224, 178.5258	Mang.	*Bru*_man_for	2	20	12	2	5.0-43.0	13.20	8.8	81.82	Bru_gym	Bru_gym	Bru_gym (100%)
T2 P5	27-9-12	4	-18.13044, 178.51973	Mang.	Bac_man_forest	8	23	15	none	5.0-89.0	19.00	7.5	87.19	Bar_rac	Ino_fag	Ino_fag (29%)
T2 P6	27-9-12	4	-18.12956, 178.53677	Mang.	Bac_man_forest	4	23	11	none	5.0-46.0	11.65	6.2	70.15	Bar_rac	Bar_rac	Bar_rac (69%)
T2 P7	27-9-12	4	-18.12934, 178.53718	Mang.	Bac_man_forest	4	14	10	none	5.0-20.0	13.07	6.2	87.43	Bar_rac	Coc_nuc	Coc_nuc (11%)
T2 P8	27-9-12	4	-18.12914, 178.53728	Mang.	Bac_man_forest	6	16	13	none	7.0-43.0	16.00	6.6	96.09	Hib_til	Ino_fag	Ino_fag (17%)
T2 P9	27-9-12	4	-18.12931, 178.53754	Mang.	Bac_man_forest	6	22	10	none	5.0-21.0	10.59	5.4	60.09	Bar_rac	Pan_tec	Pan_tec (9%)
T2P1	27-9-12	4	-18.11482, 178.52613	Mang.	Mix_man_forest	2	24	13	2	5.0-38.0	11.63	6.4	75.99	Bru_gym	Bru_gym	Bru_gym (88%)

Appendix 3. Forest/habitat type descriptions and impact status

Cover	Vegetation type	Forest/Habitat type	Impacts	Forest/Habitat Description	Occurrence (plot references)
Forested	Mangrove	*Rhizophora*	Low	Primary forest, 80-100% canopy cover; <15% ground cover and very low regeneration of mangrove species; dominated exclusively with *Rhizophora* spp. where relative dominance of >90%. No known history of logging or human habitation. Absence of introduced species. Regularly inundated with brackish water.	Observed at Sites 2 and 3.
Forested	Mangrove	*Rhizophora*	Medium	Transition (secondary and primary) forest; 50 -80% canopy and ground cover; dominated with *Rhizophora* spp., may have history of damage from natural disasters and/or other activities. Absence of introduced species. Regularly inundated with brackish water.	Observed at Site 4. Assessed at Site 1(T5 P5) and Site 2 (T1P3-5).
Forested	Mangrove	*Rhizophora*	High	Secondary forest; <50% canopy with ground cover of up to 100%; has a history of damage from natural disasters and/or human habitation, logging and other activities; dominated with *Rhizophora* spp. Density is very high and trees are generally shorter (not stunted). Absence of introduced species. Regularly inundated with brackish water.	Observed at Sites 1, 2, 3, 4.
Forested	Mangrove	Mixed mangrove	Low	Primary forest, 80-100% canopy cover; <15% ground cover and very low regeneration of mangrove species; two or three mangrove species with > 10% relative dominance. No known history of logging, farming and /or human habitation. Absence of introduced species; regularly inundated with brackish water.	Observed at Sites 2, 3.
Forested	Mangrove	Mixed mangrove	Medium	Transition (secondary and primary) forest; 50-80% canopy and ground cover. Two or more mangrove species with > 10% relative dominance; may have history of damage from natural disasters and/or human habitation, logging and/or other activities. Absence of introduced species. Regularly inundated with brackish water.	Observed and assessed at Site 1 (T5 P2-4, T6P3-5), Site 2. (T1P1-10) and Site 4(T1P1, T2P1).
Forested	Mangrove	Mixed mangrove	High	Secondary forest; <50% canopy with ground cover of up to 100%; has a history of damage from natural disasters and/or human habitation, logging and other activities; dominated by several mangrove species. Density is very high and trees are generally shorter (not stunted). Absence of introduced species. Regularly inundated with brackish water.	Observed but not assessed at sites2, 3 and 4.
Forested	Mangrove	*Bruguiera*	Low	Primary forest; 80-100% canopy cover; <15% ground cover and very low regeneration; dominated exclusively with *Bruguiera gymnorhiza*where relative dominance of >90%. No known history of logging, farming and /or human habitation. Absence of introduced species; regularly inundated with brackish water.	Observed but not assessed at Sites 2 and 3.

Cover	Vegetation type	Forest/Habitat type	Impacts	Forest/Habitat Description	Occurrence (plot references)
Forested	Mangrove	*Bruguiera*	Medium	Transition (secondary and primary) forest; 50 -80% canopy and ground cover; dominated with *B. gymnorhiza*; may have history of damage from natural disasters and/or human habitation, logging and other activities; regularly inundated with brackish water.	Observed and assessed at Site 1 (T5P1,T6P1-2), Site 2(T2P1-7,T3P1-6,T6P1 &P7,T8P1-5,T9P1-3,T13P1-5,T14P1-5,T16P1-3,T17P1-5), Site 3 (T4P1-10,T5P1-10,T6P1-9, T7P1-4) and Site 4(T1P2-4,T2P2-4).
Forested	Mangrove	*Bruguiera*	High	Secondary forest; <50% canopy with ground cover of up to 100%; has a history of damage from natural disasters and/or human habitation, logging and other activities; dominated with *B. gymnorhiza*. Density is very high and trees are generally shorter (not stunted). Absence of introduced species. Regularly inundated with brackish water.	Observed but not assessed at Sites 1, 2, 3 and 4.
Forested	Mangrove	Back of the Mangrove	Low	Primary forest, 75-100% canopy cover with < 25% ground cover, and a low regeneration of mangrove and its associated species. Can be dominated by up to 5 species where the relative dominance is around 50%. Most species recorded are native. No known history of logging or human habitation. Absence of introduced species. Regularly inundated with brackish water.	Not observed
Forested	Mangrove	Back of the Mangrove	Medium	Transition (secondary and primary) forest; 40-75% canopy and ground cover; can be dominated by up to 5 species and these are both mangrove and non-mangrove species some of which are introduced and culturally important species; known history of logging or human habitation; the forest is regularly visited by the local community; sections of the undulating substrate is regularly inundated with brackish water.	Observed and assessed at Site 1 (T1P1-7; T4P1-4), Site 2 (T4P1-2, T5P1-2, T7P1-10, T10P1-4,T11P1-3, T12P1-3,T5P1-3), Site 3 (T1P1-5; T3P1-10; T7P5-10; T8P1-4) and Site 4 (T2P5-9).
Forested	Mangrove	Back of the Mangrove	High	Secondary forest; 25-40% canopy and 75-100% ground cover; most species are introduced or are culturally important and usually dominated by species like *Annona glabra*; has a history of damage from natural disasters and/or human habitation and where logging and agricultural activities take place; other activities; absence of any mangrove species is not unusual; sections of the undulated substrate is regularly inundated with brackish water.	Observed but not assessed at Sites 1, 2, 3 and 4.
Forested	Coastal Beach	Coastal beach forest and strand vegetation	Low	Primary forest, 75-100% canopy cover with up to 75% ground cover, strand vegetation with 75-100% ground cover; obvious strand, shrub, tree zonation; general absence of introduced species; no history of human habitation.	Not observed
Forested	Coastal Beach	Coastal beach forest and strand vegetation	Medium	Transition (secondary and primary) forest; 50-75% canopy cover; 80-100% ground cover; strand vegetation mostly made up of exotic species like *Wedelia triloba*, despite elements of coastal beach species present; presence of introduced species and some culturally important species; little evidence of coastal erosion; coastal forest is regularly visited by the local community.	Observed but not assessed at Site 4. Observed and assessed at Site 3 (T2aP1-3; T2bP1-3; T2cP1-3).

Cover	Vegetation type	Forest/Habitat type	Impacts	Forest/Habitat Description	Occurrence (plot references)
Forested	Coastal Beach	Coastal beach forest and strand vegetation	High	Secondary forest; <50% canopy cover; 100% ground cover; has a history of damage from natural disasters and/or human habitation and other activities; high % of exotic species present although remnant coastal forest remains with extensive coastal erosion; trees regularly washed away; pools of stagnant seawater locked behind the coastal forest.	Not observed
Forested	Lowland	Slope	Low	Primary forest, 75-100% canopy cover with 25-50% ground cover; most species are native, with one or two naturalised exotic species; no history of significant damage from natural disasters and/or human habitation and other activities. No records of flooding or landslides in the area.	Not observed
Forested	Lowland	Slope	Medium	Transition (secondary and primary) forest; 50-75% canopy cover; 50-75% ground cover; has a history of damage from natural disasters and/or human habitation, agricultural development and other activities; presence of introduced species and some culturally important species; the forest is regularly visited by the local community and occurs at slightly higher elevations than the mangrove vegetation.	Not observed
Forested	Lowland	Slope	High	Secondary forest; <40% canopy cover; 75-100% ground cover; has a history of damage from natural disasters, human habitation and extensive agricultural activities; plant species are mostly alien species and also dominated by exotic and anthropogenic species.	Observed and assessed atSite1 (T1P8-9, T2P1, T3P1-3).

Appendix 4. Avifauna species list

Group	Common Name	Family	Scientific Name
Birds	Barking pigeon	Columbidae	*Ducula latrans*
	Bar-tailed godwit	Scolopacidae	*Limosa lapponica*
	Collared lory	Psittacidae	*Phigys solitaries*
	Crested tern	Laridae	*Sterna bergii*
	Eastern reef heron	Ardeidae	*Agretta sacra*
	Far-eastern curlew	Scolopacidae	*Numenius madagascariensis*
	Fiji bush warbler	Sylviidae	*Cettia ruficapilla*
	Fiji goshawk	Accipitridae	*Accipiter rufitorquoes*
	Fiji parrotfinch	Ploceidae	*Erythrura pealii*
	Fiji woodswallow	Artamidae	*Artamus mentalis*
	Golden dove	Columbidae	*Chrysoenas luteovirens*
	Jungle myna	Sturnidae	*Acridotheres fuscus*
	Lesser frigate	Fregatidae	*Fregata ariel*
	Lesser shrikebill	Monarchidae	*Clytorhynchus vitiensis*
	Mangrove heron	Ardeidae	*Butorides striatus*
	Many-coloured fruit dove	Columbidae	*Ptilinopus perousii*
	Orange-breasted myzomela	Meliphagidae	*Myzomela jugularis*
	Pacific black duck	Anatidae	*Anas superciliosa*
	Pacific golden plover	Charadriidae	*Pluvialis fulva*
	Pacific harrier	Accipitridae	*Circus approximans*
	Polynesian triller	Campephagidae	*Lalage maculosa*
	Red avadavat	Ploceidae	*Amandava amandava*
	Red-vented bulbul	Sturnidae	*Pycnonotus cafer*
	Ruddy turnstone	Scolopacidae	*Arenaria interpres*
	Scarlet robin	Eopsaltriidae	*Petroica multicolor*
	Silvereye	Zosteropidae	*Zosterops lateralis*
	Slaty monarch	Monarchidae	*Mayrornis lesson*
	Spotted dove	Columbidae	*Streptopelia chinensis*
	Streaked fantail	Monarchidae	*Rhipidura spilodera*
	Terek sandpiper	Scolopacidae	*Xenus cinereus*
	Vanikoro broadbill	Monarchidae	*Myiagra vanikoroensis*
	Wandering tattler	Scolopacidae	*Heteroscelus incanus*
	Wattled honeyeater	Meliphagidae	*Foulehaio carunculata*
	White-collared kingfisher	Alcedinidae	*Todirhamphus chloris*
	White-faced heron	Ardeidae	*Ardea novaehollandiae*
	White-rumped swiftlet	Apodidae	*Aerodramus spodiopygius*
Bats	Pacific flying fox	Pteropodidae	*Pteropus tonganus*
	Samoan flying fox	Pteropodidae	*Pteropus samoensis*

Appendix 5. Avifauna abundance (per hectare) across different habitats

Species Common Names	Habitats								
	Rhi	Mix	Bru	Bom	BoP	Coa	HuP	Fru	Sec
Landbirds									
Barking pigeon	0	0	0	0	0	0	0	0	1.8
Collared lory	0	0	0.2	0.1	0	0	1	0	0.5
Fiji bush warbler	0	0.1	0	0.6	1.1	0	0.3	0.7	0.3
Fiji goshawk	0	0	0	0.1	0	0	0	0	0
Fiji parrotfinch	0	0	0	0	0	0	0.5	0	0
Fiji woodswallow	0	0	0	0	0	0.8	0	0.3	0.5
Golden dove	0	0	0.1	0.1	0	0	0	0.1	0.8
Jungle myna	0.7	0.6	0.7	0.8	1.3	0.4	5.3	2.7	3.6
Lesser shrikebill	0	0	0	0.1	0	0	0.2	0.6	0
Many-coloured fruit dove	0.1	0.1	0	0.1	0	0	0	0	0
Orange-breasted myzomela	0.7	0.7	1.5	0.7	0.8	1.3	1.6	1.4	1
Pacific black duck	0.3	0.1	0	0.1	0	0	0.2	0.3	0
Pacific harrier	0.1	0	0	0.1	0	0	0	0	0
Polynesian triller	0.2	0.2	0.6	1	0.2	0	1	1	1.8
Red avadavat	0	0	0	0	0	0.4	0.8	0.4	0
Red-vented bulbul	0.1	0	0.5	0.3	0.6	0	1.4	0.1	1.5
Scarlet robin	0	0	0	0	0.2	0	0.2	0	0
Silvereye	1	0	0.4	2.5	2.1	0.4	4	4.2	5.1
Slaty monarch	0.1	0.1	0.4	0.8	0	0.8	0.2	0.8	0.3
Streaked fantail	0	0	0	0	0.2	0	0	0.1	0
Spotted dove	0	0	0.1	0	0.2	0.8	0.5	0.7	0.3
Vanikoro broadbill	0.6	0.7	1	0.8	1.5	0.8	1.4	1.3	1.3
Wattled honeyeater	3.8	3.9	3.3	1.9	2.3	0.8	1.3	1.8	3.3
White-collared kingfisher	0.9	1.2	1.8	1.3	1.1	0.4	0.5	0.6	1.3
White-rumped swiftlet	0.1	0.1	0	0.3	0.8	2.5	1.4	0.1	1.3
Eastern reef heron	0.2	0.2	0.1	0.1	0	0.4	0.2	0	0
Mangrove heron	0	0.1	0.2	0	0	0	0	0	0
White-faced heron	0	0	0	0	0.2	0	0	0	0
Bats									
Pacific flying fox	0	0.1	0	0	0.8	0	0.2	0.4	0.5
Samoan flying fox	0	0.1	0	0.2	0	0	0	0	0

*Habitat types: Rhi=Rhizophora, Mix=Mixed mangroves, Bru=Bruguiera, Bom=Back-of-the-mangrove, BoP=Borete & Pandanus swamp, Coa=Coastal, HuP=Human habitation & Plantation, Fru=Fruit trees, Sec=Secondary forest, Sho=Shoreline

Appendix 6. Gill net data for MESCAL fisheries survey

Date	Latitude	Longitude	Operation number	Time set	Time retrieved	System	Zone	Site
18/09/2012	na	na	MG1-1	na	na	Natila	Downstream mangrove	1
18/09/2012	17.93751	178.58855	MG1-2	na	na	Natila	Downstream mangrove	1
18/09/2012	na	na	MG1-3	na	na	Natila	Downstream mangrove	1
18/09/2012	na	na	MG1-4	na	na	Natila	Downstream mangrove	2
18/09/2012	17.93634	178.58803	MG1-5	na	na	Natila	Downstream mangrove	2
18/09/2012	17.93643	178.58841	MG1-6	na	na	Natila	Downstream mangrove	2
19/09/2012	18.01518	178.625	MG2-1	11:20am	12:20pm	Waicoka	Upstream mangrove	1
19/09/2012	18.01416	178.62581	MG2-2	11:25am	12:25pm	Waicoka	Upstream mangrove	1
19/09/2012	18.01214	178.6281	MG2-3	11:35am	12:35pm	Waicoka	Upstream mangrove	1
19/09/2012	18.0152	178.62956	MG2-4	12:45pm	1:45pm	Waicoka	Upstream mangrove	2
19/09/2012	18.01592	178.62938	MG2-5	12:55pm	2:05pm	Waicoka	Upstream mangrove	2
19/09/2012	18.01712	178.62819	MG2-6	1:05pm	2:15pm	Waicoka	Upstream mangrove	2
19/09/2012	18.0274	178.63466	MG2-7	4:55pm	5:55pm	Waicoka	Downstream mangrove	1
19/09/2012	18.02759	178.63536	MG2-8	5:00pm	6:00pm	Waicoka	Downstream mangrove	1
19/09/2012	18.02814	178.63617	MG2-9	5:05pm	6:05pm	Waicoka	Downstream mangrove	1
20/09/2012	18.02222	178.63602	MG2-10	8:25am	9:25am	Waicoka	Downstream mangrove	2
20/09/2012	18.02147	178.63492	MG2-11	8:30am	9:30am	Waicoka	Downstream mangrove	2
20/09/2012	18.02051	178.63382	MG2-12	8:35am	9:35am	Waicoka	Downstream mangrove	2
20/09/2012	18.02257	178.64081	MG2-13	10:10am	11:10am	Waicoka	River mouth	1
20/09/2012	18.02246	178.64174	MG2-14	10:20am	11:20am	Waicoka	River mouth	1
20/09/2012	18.02263	178.64301	MG2-15	10:25am	11:25am	Waicoka	River mouth	1
20/09/2012	18.02184	178.64391	MG2-16	11:40am	12:40pm	Waicoka	River mouth	2
20/09/2012	18.02184	178.64285	MG2-17	11:45am	12:55pm	Waicoka	River mouth	2
20/09/2012	18.02169	178.6445	MG2-18	11:55am	1:00pm	Waicoka	River mouth	2
21/09/2012	18.01972	178.64655	MG2-19	10:10am	11:10am	Waicoka	Coastal mangrove	1
21/09/2012	18.01849	178.64651	MG2-20	10:20am	11:20am	Waicoka	Coastal mangrove	1
21/09/2012	18.01724	178.64609	MG2-21	10:25am	11:25am	Waicoka	Coastal mangrove	1
21/09/2012	18.01561	178.64549	MG2-22	11:45am	12:45pm	Waicoka	Coastal mangrove	2
21/09/2012	18.01375	178.64461	MG2-23	11:50am	12:50pm	Waicoka	Coastal mangrove	2
21/09/2012	18.01171	178.64226	MG2-24	12:00pm	1:00pm	Waicoka	Coastal mangrove	2
24/09/2012	18.08971	178.65007	MG3-1	3:05pm	4:05pm	Nasilai	River mouth	1
24/09/2012	18.08845	178.64903	MG3-2	3:10pm	4:10pm	Nasilai	River mouth	1
24/09/2012	18.08815	178.64746	MG3-3	3:15pm	4:15pm	Nasilai	River mouth	1
24/09/2012	18.08416	178.64838	MG3-4	4:30pm	5:30pm	Nasilai	River mouth	2
24/09/2012	18.08414	178.64728	MG3-5	4:45pm	5:45pm	Nasilai	River mouth	2
24/09/2012	18.0839	178.64636	MG3-6	4:55pm	5:55pm	Nasilai	River mouth	2

Date	Latitude	Longitude	Operation number	Time set	Time retrieved	System	Zone	Site
25/09/2012	18.07693	178.64299	MG3-7	6:55am	7:55am	Nasilai	Downstream mangrove	1
25/09/2012	18.07599	178.64229	MG3-8	7:00am	8:00am	Nasilai	Downstream mangrove	1
25/09/2012	18.07539	178.64162	MG3-9	7:10am	8:10am	Nasilai	Downstream mangrove	1
25/09/2012	18.07473	178.62674	MG3-10	10:40am	11:45am	Nasilai	Downstream mangrove	2
25/09/2012	18.07512	178.62878	MG3-11	10:50am	11:50am	Nasilai	Downstream mangrove	2
25/09/2012	18.07508	178.63081	MG3-12	11:00am	12:00pm	Nasilai	Downstream mangrove	2
26/09/2012	18.08486	178.60622	MG3-13	10:10am	11:10am	Nasilai	Upstream mangrove	1
26/09/2012	18.08285	178.60429	MG3-14	10:15am	11:20am	Nasilai	Upstream mangrove	1
26/09/2012	18.08224	178.60362	MG3-15	10:20am	11:30am	Nasilai	Upstream mangrove	1
26/09/2012	18.07772	178.60498	MG3-16	11:40am	11:50am	Nasilai	Upstream mangrove	2
26/09/2012	18.0761	178.60516	MG3-17	11:45am	12:55am	Nasilai	Upstream mangrove	2
26/09/2012	18.07463	178.60458	MG3-18	11:50am	1:05am	Nasilai	Upstream mangrove	2
27/09/2012	18.11610	178.51697	MG4-1	7:50am	8:50am	Vunidawa	Downstream mangrove	1
27/09/2012	18.11381	178.51738	MG4-2	8:00am	9:00am	Vunidawa	Downstream mangrove	1
27/09/2012	18.11078	178.51750	MG4-3	8:10am	9:10am	Vunidawa	Downstream mangrove	1
27/09/2012	18.10686	178.52020	MG4-4	1:10pm	2:15pm	Vunidawa	Downstream mangrove	2
27/09/2012	18.10563	178.51991	MG4-5	1:15pm	2:18pm	Vunidawa	Downstream mangrove	2
27/09/2012	18.10417	178.52101	MG4-6	1:20pm	2:28pm	Vunidawa	Downstream mangrove	2
27/09/2012	18.10666	178.54155	MG4-7	2:50pm	3:55pm	Vunidawa	Upstream mangrove	1
27/09/2012	18.10603	178.53964	MG4-8	3:00pm	4:00pm	Vunidawa	Upstream mangrove	1
27/09/2012	18.10512	178.53799	MG4-9	3:05pm	4:05pm	Vunidawa	Upstream mangrove	1
28/09/2012	18.10475	178.53593	MG4-10	7:55am	8:55am	Vunidawa	Upstream mangrove	2
28/09/2012	18.10464	178.53490	MG4-11	8:00am	9:00am	Vunidawa	Upstream mangrove	2
28/09/2012	18.10424	178.53319	MG4-12	8:05am	9:05am	Vunidawa	Upstream mangrove	2

Appendix 7. Fyke net data for MESCAL fisheries survey.

Date	Latitude	Longitude	Operation number	Time set	Time retrieved	Zone	Site	Habitat type
18/09/2012	17.93708	178.5878	MF1-1	7:00am	12:30pm	Downstream mangrove	1	Drain
20/09/2012	18.02267	178.63142	MF2-1	8:40am	3:05pm	Downstream mangrove	1	Drain
21/09/2012	18.02337	178.63989	MF2-2	10:00pm	4:00am	Downstream mangrove	2	Drain
25/09/2012	18.0774	178.64198	MF3-1	2:35pm	9:30pm	Downstream mangrove	1	Drain
27/09/2012	18.11559	178.5162	MF4-1	3:20pm	10:30pm	Downstream mangrove	1	Drain

Appendix 8. Cast net data for MESCAL fisheries survey

Date	Latitude	Longitude	Operation number	System	Site	Habitat type	Zone	Comments
19/09/2012	18.0171	178.62764	MC2-1	Waicoka	1	Low angle	Upstream mangrove	Start
19/09/2012	18.01595	178.62631	MC2-10	Waicoka	1	Low angle	Upstream mangrove	End
19/09/2012	18.01595	178.62631	MC2-11	Waicoka	1	Steep	Upstream mangrove	Start
19/09/2012	18.01721	178.62793	MC2-20	Waicoka	1	Steep	Upstream mangrove	End
19/09/2012	18.01896	178.62805	MC2-21	Waicoka	2	Low angle	Upstream mangrove	Start
19/09/2012	18.02092	178.62827	MC2-30	Waicoka	2	Low angle	Upstream mangrove	End
19/09/2012	18.02092	178.62827	MC2-31	Waicoka	2	Steep	Upstream mangrove	Start
19/09/2012	18.02336	178.62975	MC2-40	Waicoka	2	Steep	Upstream mangrove	End
19/09/2012	18.02841	178.63617	MC2-41	Waicoka	1	Steep	Downstream mangrove	Start
19/09/2012	18.02859	178.6382	MC2-50	Waicoka	1	Steep	Downstream mangrove	End
20/09/2012	18.02275	178.62962	MC2-51	Waicoka	1	Low angle	Downstream mangrove	Start
20/09/2012	18.02262	178.63106	MC2-60	Waicoka	1	Low angle	Downstream mangrove	End
20/09/2012	18.02267	178.63142	MC2-61	Waicoka	2	Steep	Downstream mangrove	Start
20/09/2012	18.02059	178.63295	MC2-70	Waicoka	2	Steep	Downstream mangrove	End
20/09/2012	18.02672	178.63448	MC2-71	Waicoka	2	Low angle	Downstream mangrove	Start
20/09/2012	18.02809	178.63638	MC2-80	Waicoka	2	Low angle	Downstream mangrove	End
20/09/2012	18.02453	178.63974	MC2-81	Waicoka	1	Low angle	River mouth	Start
20/09/2012	18.0217	178.64102	MC2-90	Waicoka	1	Low angle	River mouth	End
21/09/2012	18.01254	178.64624	MC2-91	Waicoka	1	Low angle	River mouth	Start
21/09/2012	18.01967	178.64659	MC2-100	Waicoka	1	Low angle	River mouth	End
21/09/2012	18.01264	178.64528	MC2-101	Waicoka	2	Low angle	River mouth	Start
21/09/2012	18.02453	178.6484	MC2-110	Waicoka	2	Low angle	River mouth	End
21/09/2012	18.02348	178.64496	MC2-111	Waicoka	2	Low angle	River mouth	Start
21/09/2012	18.02265	178.64046	MC2-120	Waicoka	2	Low angle	River mouth	End
25/09/2012	18.07576	178.63835	MC3-1	Nasilai	1	Low angle	Downstream mangrove	Start
25/09/2012	18.07633	178.64085	MC3-10	Nasilai	1	Low angle	Downstream mangrove	End
25/09/2012	18.07494	178.63168	MC3-11	Nasilai	2	Low angle	Downstream mangrove	Start
25/09/2012	18.07406	178.6349	MC3-20	Nasilai	2	Low angle	Downstream mangrove	End
25/09/2012	18.07437	178.63911	MC3-21	Nasilai	1	Steep	Downstream mangrove	Start
25/09/2012	18.07515	178.6412	MC3-30	Nasilai	1	Steep	Downstream mangrove	End
25/09/2012	18.07664	178.64276	MC3-31	Nasilai	2	Steep	Downstream mangrove	Start
25/09/2012	18.07906	178.64415	MC3-40	Nasilai	2	Steep	Downstream mangrove	End
26/09/2012	18.08048	178.60443	MC3-41	Nasilai	1	Low angle	Upstream mangrove	Start
26/09/2012	18.081	178.604	MC3-50	Nasilai	1	Low angle	Upstream mangrove	End
26/09/2012	18.07888	178.60216	MC3-51	Nasilai	2	Low angle	Upstream mangrove	Start
26/09/2012	18.07875	178.60191	MC3-60	Nasilai	2	Low angle	Upstream mangrove	End

Date	Latitude	Longitude	Operation number	System	Site	Habitat type	Zone	Comments
26/09/2012	18.06441	178.5974	MC3-61	Nasilai	1	Steep	Upstream mangrove	Start
26/09/2012	18.06499	178.59616	MC3-70	Nasilai	1	Steep	Upstream mangrove	End
26/09/2012	18.06207	178.60092	MC3-71	Nasilai	2	Steep	Upstream mangrove	Start
26/09/2012	18.06292	178.60242	MC3-80	Nasilai	2	Steep	Upstream mangrove	End
27/09/2012	18.10807	178.51993	MC4-1	Vunidawa	1	Low angle	Downstream mangrove	Start
27/09/2012	18.11001	178.51834	MC4-10	Vunidawa	1	Low angle	Downstream mangrove	End
27/09/2012	18.10890	178.51981	MC4-11	Vunidawa	1	Steep	Downstream mangrove	Start
27/09/2012	18.11011	178.51883	MC4-20	Vunidawa	1	Steep	Downstream mangrove	End
28/09/2012	18.10652	178.52008	MC4-21	Vunidawa	2	Low angle	Downstream mangrove	Start
28/09/2012	18.10791	178.51999	MC4-30	Vunidawa	2	Low angle	Downstream mangrove	End
28/09/2012	18.10533	178.51990	MC4-31	Vunidawa	2	Steep	Downstream mangrove	Start
28/09/2012	18.10258	178.52316	MC4-40	Vunidawa	2	Steep	Downstream mangrove	End

Appendix 9. Beach seine data for MESCAL fisheries survey.

Date	Latitude	Longitude	Operation number	Net number	System	Site	Habitat type
18/09/2012	17.93879	178.58896	MB1-3	3	Natila	1	River mouth/mudflats
20/09/2012	18.02157	178.64714	MB2-1	1	Waicoka	1	River mouth/mudflats
20/09/2012	18.02318	178.64597	MB2-4	4	Waicoka	2	River mouth/mudflats
25/09/2012	18.08675	178.65305	MB3-1	1	Nasilai	1	River mouth/mudflats
25/09/2012	18.05861	178.65353	MB3-5	5	Nasilai	2	River mouth/mudflats
27/09/2012	18.12305	178.51494	MB4-1	1	Vunidawa	1	River mouth/mudflats
27/09/2012	18.12183	178.51540	MB4-5	5	Vunidawa	2	River mouth/mudflats

Appendix 10. Water quality data for fish and crustacean survey

Date	Site	Operation	Gear type	Time	Log number	Temp. (°C)	pH	DO (mg/l)	Salinity (ppt.)	Turbidity (NTU)	Secchi disc (m)
18/09/2012	Natila	MF1-1	Fyke	6:45am	MF1-1	25.90	7.33	7.50	17.71	6.2	0.68
18/09/2012	Natila	MF1-1	Fyke	12:45pm	MF1-1	26.70	7.24	5.45	18.82	2.3	1.25
18/09/2012	Natila	MB1-3	Beach seine	1:15pm	MB1-3	27.30	6.8	0.07	17.23	22.0	na
18/09/2012	Natila	MG1-1	Gill net	7:10am	MG1-1	25.90	7.33	7.50	17.71	6.2	0.68
18/09/2012	Natila	MG1-2	Gill net	7:20am	MG1-2	25.90	7.33	7.50	17.71	6.2	0.68
18/09/2012	Natila	MG1-3	Gill net	7:30am	MG1-3	26.60	7.62	7.87	21.55	0.8	1.54
18/09/2012	Natila	MG1-4	Gill net	10:45am	MG1-4	26.40	7.26	5.80	18.66	7.1	0.87
18/09/2012	Natila	MG1-5	Gill net	11:00am	MG1-5	26.40	7.26	5.80	18.66	7.1	0.87
18/09/2012	Natila	MG1-6	Gill net	12:00am	MG1-6	26.40	7.26	5.80	18.66	7.1	0.87
18/09/2012	Natila	MC1-1	Cast net	11:10am	MC1-1	26.40	7.26	5.80	18.66	7.1	0.87
18/09/2012	Natila	MC1-4	Cast net	3:30pm	MC1-4	29.90	6.87	5.31	29.06	34.5	na
19/09/2012	Natila	MG1-7	Gill net	8:05am	MG1-7	27.20	7.54	6.80	20.85	0.0	na
19/09/2012	Natila	MG1-8	Gill net	8:15am	MG1-8	27.20	7.54	6.80	20.85	0.0	na
19/09/2012	Natila	MG1-9	Gill net	8:20am	MG1-8	27.20	7.54	6.80	20.85	0.0	na
19/09/2012	Waicoka	MG2-1	Gill net	11:10am	MG1-8	27.40	6.61	4.50	9.99	0.0	1.20
19/09/2012	Waicoka	MG2-2	Gill net	11:25am	MG2-2	27.40	6.61	4.50	9.99	0.0	1.20
19/09/2012	Waicoka	MG2-3	Gill net	11:30am	MG2-3	27.50	6.71	3.90	10.08	0.0	1.20
19/09/2012	Waicoka	MG2-4	Gill net	12:45pm	MG2-4	28.10	6.92	4.64	9.98	1.6	1.25
19/09/2012	Waicoka	MG2-5	Gill net	12:55pm	MG2-5	28.10	6.92	4.64	9.98	1.6	1.25
19/09/2012	Waicoka	MG2-6	Gill net	1:05pm	MG2-6	28.00	6.91	4.57	9.94	0.0	1.00
19/09/2012	Waicoka	MC2-1	Cast net	2:20pm	MC2-1	28.20	6.9	5.00	9.86	1.8	1.30
19/09/2012	Waicoka	MC2-11	Cast net	3:45pm	MC2-11	30.10	6.54	5.70	9.80	4.0	1.10
19/09/2012	Waicoka	MC2-21	Cast net	4:05pm	MC2-21	30.10	6.54	5.70	9.80	4.0	1.10
19/09/2012	Waicoka	MG2-7	Gill net	4:40pm	MG2-7	28.40	6.65	5.55	10.22	0.2	1.20
19/09/2012	Waicoka	MG2-8	Gill net	4:55pm	MG2-8	28.40	6.65	5.55	10.22	0.2	1.20
19/09/2012	Waicoka	MG2-9	Gill net	5:00pm	MG2-9	28.40	6.65	5.55	10.22	0.2	1.20
19/09/2012	Waicoka	MC2-31	Cast net	5:05pm	MC2-31	28.40	6.65	5.55	10.22	0.2	1.20
20/09/2012	Waicoka	MG2-10	Gill net	8:20am	MG2-10	26.60	7.05	6.22	12.12	6.5	1.00
20/09/2012	Waicoka	MG2-11	Gill net	8:25am	MG2-11	26.60	7.05	6.22	12.12	6.5	1.00
20/09/2012	Waicoka	MG2-12	Gill net	8:32am	MG2-12	26.50	7.12	6.07	12.05	7.8	1.05
20/09/2012	Waicoka	MF2-1	Fyke	8:40am	MF2-1	26.60	6.73	6.11	11.80	4.7	0.95
20/09/2012	Waicoka	MG2-13	Gill net	10:05am	MG2-13	26.60	7.08	7.26	16.17	3.4	1.05
20/09/2012	Waicoka	MG2-14	Gill net	10:20am	MG2-14	26.60	7.08	7.26	16.17	3.4	1.05
20/09/2012	Waicoka	MG2-15	Gill net	10:25am	MG2-15	26.60	7.23	7.24	15.87	2.5	1.20
20/09/2012	Waicoka	MG2-16	Gill net	11:35am	MG2-16	27.00	7.33	7.08	14.95	3.2	1.20
20/09/2012	Waicoka	MG2-17	Gill net	11:50am	MG2-17	27.00	7.33	7.08	14.95	3.2	1.20

Date	Site	Operation	Gear type	Time	Log number	Temp. (°C)	pH	DO (mg/l)	Salinity (ppt.)	Turbidity (NTU)	Secchi disc (m)
20/09/2012	Waicoka	MG2-18	Gill net	11:55am	MG2-18	26.90	7.40	6.89	14.12	4.3	0.95
20/09/2012	Waicoka	MC2-51	Cast net	2:20pm	MC2-51	28.40	6.76	5.45	10.72	0.0	1.35
20/09/2012	Waicoka	MB2-1	Beach seine	3:20pm	MB2-1	29.00	6.89	7.54	12.89	124.00	na
20/09/2012	Waicoka	MC2-71	Cast net	4:20pm	MC2-71	27.60	6.59	6.66	10.81	0.60	1.00
20/09/2012	Waicoka	MC2-81	Cast net	4:45pm	MC2-81	27.80	6.76	6.18	10.99	4.00	0.80
24/09/2012	Nasilai	MG3-1	Gill net	3:00pm	MG3-1	24.90	7.06	7.41	15.78	0.00	na
24/09/2012	Nasilai	MG3-3	Gill net	3:15pm	MG3-3	25.43	7.55	7.28	16.99	1.30	na
24/09/2012	Nasilai	MG3-4	Gill net	4:30am	MG3-4	25.10	7.20	5.8	12.99	1.40	na
25/09/2012	Nasilai	MG3-7	Gill net	6:45am	MG3-7	24.30	6.47	5.08	16.17	0.40	1.00
25/09/2012	Nasilai	MC3-1	Cast net	7:20am	MC3-1	24.20	6.67	5.32	16.20	18.90	0.55
25/09/2012	Nasilai	MB3-1	Beach seine	9:35am	MB3-1	24.80	6.36	7.51	16.31	6.40	na
25/09/2012	Nasilai	MG3-10	Gill net	10:35am	MG3-10	25.40	6.78	7.28	15.41	22.30	0.45
25/09/2012	Nasilai	MC3-11	Cast net	10:55am	MC3-11	25.70	6.58	7.97	15.35	9.90	0.55
25/09/2012	Nasilai	MC3-21	Cast net	11:25am	MC3-21	26.70	6.45	7.01	16.22	2.30	0.95
25/09/2012	Nasilai	MC3-31	Cast net	4:48am	MC3-31	26.60	6.65	7.00	17.14	0.00	1.10
25/09/2012	Nasilai	MG3-13	Gill net	12:55pm	MG3-13	25.60	7.10	8.26	15.51	9.00	0.60
25/09/2012	Nasilai	MF3-1	Fyke	2:35pm	MF3-1	27.00	7.42	7.49	21.45	0.00	1.30
26/09/2012	Nasilai	MG3-13	Gill net	10:10am	MG3-13	25.30	6.48	7.54	6.26	27.60	0.55
26/09/2012	Nasilai	MG3-16	Gill net	11:50am	MG3-16	25.90	6.70	8.56	6.00	17.50	0.50
26/09/2012	Nasilai	MC3-41	Cast net	12:40pm	MC3-41	26.50	6.91	7.45	2.32	11.30	0.53
27/09/2012	Vunidawa	MG4-1	Gill	7:50am	MG4-1	24.70	6.86	6.76	2.57	9.90	0.40
27/09/2012	Vunidawa	MC4-1	Gill	8:20am	MC4-1	24.70	6.98	6.60	2.33	9.60	0.40
27/09/2012	Vunidawa	MB4-1	Beach seine	12:30pm	MB4-1	24.80	7.23	7.60	0.26	34.50	0.15
27/09/2012	Vunidawa	MG4-4	Gill	2:00pm	MG4-4	25.60	6.97	7.26	2.43	7.90	0.45
27/09/2012	Vunidawa	MG4-7	Gill	2:50pm	MG4-7	25.60	7.18	7.57	0.30	32.00	0.20
27/09/2012	Vunidawa	MF4-1	Fyke	3:20pm	MF4-1	25.30	6.86	7.79	1.58	24.80	0.25
28/09/2012	Vunidawa	MG4-10	Gill	7:50am	MG4-10	23.90	6.76	6.78	0.29	30.30	0.25

Appendix 11. Fish and crustacean abundance, size and biomass

River	Zone	Method	*Species*	Abundance	Average Size (cm)	Total Biomass (kg)
Natila	Downstream	Gill	*Caranx papuensis*	3	21	0.532
Natila	Downstream	Fyke	*Plectorhinchus albovittatus*	1	9	0.015
Natila	Downstream	Fyke	*Arothron manilensis*	1	4	0.002
Natila	Downstream	Cast	*Zenarchopterus dispar*	17	10	na
Natila	River mouth	Gill	*Caranx papuensis*	3	19	0.417
Natila	River mouth	Gill	*Megalops cyprinoides*	4	31	1.614
Natila	River mouth	Gill	*Mugil cephalus*	1	18	0.082
Natila	River mouth	Cast	*Apogon* spp.	1	6	na
Natila	River mouth	Cast	*Epinephelus* sp.	1	15	na
Natila	River mouth	Cast	*Leiognathus equulus*	8	3.5	0.014
Natila	River mouth	Cast	*Lutjanus russelli*	2	4	0.001
Natila	River mouth	Cast	*Mugil cephalus*	27	6	0.114
Natila	River mouth	Cast	*Penaeus monodon*	2	12	na
Natila	River mouth	Cast	cf. *Hippocampus* sp.	1	na	na
Natila	River mouth	Cast	*Stolephorus indicus*	3	5	0.005
Natila	River mouth	Cast	*Zenarchopterus dispar*	3	12	na
Natila	River mouth	Beach seine	*Epinephelus* spp.	1	4	na
Natila	River mouth	Beach seine	*Leiognathus equulus*	1	6	0.006
Natila	River mouth	Beach seine	*Mugil cephalus*	26	11	0.462
Natila	River mouth	Beach seine	cf. *Hippocampus* sp.	1	na	na
Natila	Coastal	Gill	*Scomberoides tol*	1	20	0.065
Waicoka	Upstream	Gill	*Mugil cephalus*	4	19	0.394
Waicoka	Upstream	Gill	*Caranx papuensis*	1	14	0.053
Waicoka	Upstream	Gill	*Leiognathus equulus*	4	10	0.103
Waicoka	Upstream	Gill	*Mugil cephalus*	3	19	0.280
Waicoka	Upstream	Gill	*Sardinella fijiense*	5	16	0.302
Waicoka	Upstream	Cast	*Leiognathus equulus*	5	5	0.059
Waicoka	Upstream	Cast	*Stolephorus indicus*	33	6	0.030
Waicoka	Downstream	Gill	*Gazza minuta*	1	11	0.032
Waicoka	Downstream	Gill	*Lactarius lactarius*	1	15	0.038
Waicoka	Downstream	Gill	*Lutjanus argentimaculatus*	1	42	1.144
Waicoka	Downstream	Gill	*Mugil cephalus*	13	20	1.559
Waicoka	Downstream	Gill	*Rastrelliger kanagurta*	1	22	0.168
Waicoka	Downstream	Gill	*Sardinella fijiense*	3	15	0.163
Waicoka	Downstream	Cast	*Apogon* sp.	1	4	na
Waicoka	Downstream	Cast	*Gazza minuta*	3	5	0.011
Waicoka	Downstream	Cast	*Leiognathus equulus*	2	3	0.001
Waicoka	Downstream	Cast	*Microphis retzi*	1	8	na
Waicoka	Downstream	Cast	*Mugil cephalus*	3	8	0.018
Waicoka	Downstream	Cast	*Palaemon concinnus*	26	3	na
Waicoka	Downstream	Cast	*Sardinella fijiense*	1	11	0.021
Waicoka	Downstream	Cast	*Stolephorus indicus*	11	6	0.012
Waicoka	Downstream	Fyke	*Zenarchopterus dispar*	1	13	na
Waicoka	Downstream	Fyke	*Leiognathus equulus*	1	7	0.009
Waicoka	Downstream	Fyke	*Lutjanus argentimaculatus*	1	13	0.043

River	Zone	Method	*Species*	Abundance	Average Size (cm)	Total Biomass (kg)
Waicoka	Downstream	Fyke	*Eleotridae*	2	8	na
Waicoka	Downstream	Fyke	Undentified crab	1	11	na
Waicoka	Downstream	Fyke	*Palaemon concinnus*	3	5	na
Waicoka	Downstream	Fyke	Unidentified goby	2	8	na
Waicoka	Downstream	Fyke	*Apogon* spp.	148	3	na
Waicoka	Downstream	Fyke	*Belobranchus belobranhus*	1	10	na
Waicoka	Downstream	Fyke	*Bostrychus sinensis*	8	16	0.565
Waicoka	Downstream	Fyke	*Butis amboinensis*	2	8	0.008
Waicoka	Downstream	Fyke	*Lutjanus fulviflamma*	3	12	0.133
Waicoka	Downstream	Fyke	*Mugil cephalus*	20	12	0.535
Waicoka	Downstream	Fyke	*Palaemon concinnus*	42	5	na
Waicoka	Downstream	Fyke	*Penaeus monodon*	3	11	na
Waicoka	Downstream	Fyke	*Siganus vermiculatus*	2	9	0.023
Waicoka	Downstream	Fyke	*Zenarchopterus dispar*	4	13	na
Waicoka	River mouth	Gill	*Caranx papuensis*	1	14	0.053
Waicoka	River mouth	Gill	*Chanos chanos*	1	19	0.105
Waicoka	River mouth	Gill	*Chirocentrus dorab*	1	30	0.132
Waicoka	River mouth	Gill	*Leiognathus equulus*	3	10	0.073
Waicoka	River mouth	Gill	*Portunus sanguinolentus*	1	7	na
Waicoka	River mouth	Gill	*Tylosurus crocodilus crocodilus*	1	58	0.372
Waicoka	River mouth	Gill	*Upeneus vittatus*	1	22	0.224
Waicoka	River mouth	Cast	*Gazza minuta*	1	3	0.001
Waicoka	River mouth	Cast	*Gerres longirostris*	1	11	na
Waicoka	River mouth	Cast	*Leiognathus equulus*	51	6	0.975
Waicoka	River mouth	Cast	*Leiognathus faciatus*	1	4	0.001
Waicoka	River mouth	Cast	*Mugil cephalus*	2	10	0.027
Waicoka	River mouth	Cast	*Stolephorus indicus*	8	7	0.012
Waicoka	River mouth	Cast	*Zenarchopterus dispar*	3	13	na
Waicoka	River mouth	Beach seine	*Leiognathus equulus*	59	6	0.324
Waicoka	River mouth	Beach seine	*Mugil cephalus*	17	14	0.726
Waicoka	River mouth	Beach seine	*Penaeus monodon*	1	17	na
Waicoka	River mouth	Beach seine	*Portunus sanguinolentus*	2	11	na
Waicoka	River mouth	Beach seine	*Siganus vermiculatus*	1	10	0.019
Waicoka	River mouth	Beach seine	*Macrophthalmus* sp.	3	4	na
Waicoka	Coastal	Gill	*Portunus sanguinolentus*	2	9	na
Waicoka	Coastal	Gill	*Leoignathus equulus*	1	9	0.019
Nasilai	Upstream	Gill	*Conus* spp.	1	9	na
Nasilai	Upstream	Gill	*Mugil cephalus*	3	18	0.247
Nasilai	Upstream	Gill	*Peneaus monodon*	1	15	na
Nasilai	Upstream	Gill	*Sardinella fijiense*	5	16	0.320
Nasilai	Upstream	Cast	*Apogon* sp.	12	6	na
Nasilai	Upstream	Cast	*Leiognathus equulus*	13	5	0.046
Nasilai	Upstream	Cast	*Palaemon concinnus*	2	6	na
Nasilai	Upstream	Cast	*Penaeus monodon*	3	16	na
Nasilai	Upstream	Cast	*Sardinella fijiense*	1	11	0.021
Nasilai	Upstream	Cast	*Stolephorus indicus*	9	5	0.005
Nasilai	Upstream	Cast	*Zenarchopterus dispar*	2	11	na
Nasilai	Downstream	Gill	*Caranx papuensis*	1	33	0.645

River	Zone	Method	*Species*	Abundance	Average Size (cm)	Total Biomass (kg)
Nasilai	Downstream	Gill	*Sardinella fijiense*	1	18	0.087
Nasilai	Downstream	Gill	*Leiognathus equulus*	2	11	0.063
Nasilai	Downstream	Gill	*Lutjanus fulvus*	1	12	0.034
Nasilai	Downstream	Gill	*Mugil cephalus*	3	19	0.313
Nasilai	Downstream	Gill	*Sardinella fijiense*	2	15	0.102
Nasilai	Downstream	Gill	*Valamugil seheli*	1	18	0.079
Nasilai	Downstream	Cast	*Caranx sexfasciatus*	1	5	0.003
Nasilai	Downstream	Cast	*Leignathus splendens*	10	4	0.021
Nasilai	Downstream	Cast	*Leiognathus equulus*	13	4	0.036
Nasilai	Downstream	Cast	*Mugil cephalus*	1	7	0.004
Nasilai	Downstream	Fyke	*Lutjanus fulvus*	2	10	0.034
Nasilai	Downstream	Fyke	*Stolephorus indicus*	2	7	0.003
Nasilai	Downstream	Fyke	*Arothron manilensis*	1	3	0.001
Nasilai	Downstream	Fyke	*Apogon* spp.	26	6	na
Nasilai	Downstream	Fyke	*Scorpionfish* spp.	1	4	na
Nasilai	River mouth	Gill	*Lethrinus amboninensis*	14	14	na
Nasilai	River mouth	Gill	*Upeneus vittatus*	1	21	0.192
Nasilai	River mouth	Gill	*Mugil cephalus*	3	19	0.291
Nasilai	River mouth	Gill	*Gerres longirostris*	1	13	na
Nasilai	River mouth	Gill	*Leiognathus equulus*	1	10	0.026
Nasilai	River mouth	Gill	*Scylla serrata*	1	10	na
Nasilai	River mouth	Beach seine	*Caranx papuensis*	1	10	0.020
Nasilai	River mouth	Beach seine	*Mugil cephalus*	4	14	0.155
Nasilai	River mouth	Beach seine	*Siganus vermiculatus*	1	17	0.096
Nasilai	River mouth	Beach seine	*Terapon jarbua*	2	12	0.065
Vunidawa	Upstream	Gill	*Kuhlia marginata*	2	18	0.222
Vunidawa	Upstream	Gill	*Megalops cyprinoides*	1	20	0.108
Vunidawa	Upstream	Gill	*Mugil cephalus*	2	16.5	0.129
Vunidawa	Upstream	Gill	*Scylla serrata*	1	10	na
Vunidawa	Downstream	Gill	*Mugil cephalus*	3	17	0.208
Vunidawa	Downstream	Gill	*Sphyraena qenie*	1	32	0.610
Vunidawa	Downstream	Cast	*Apogon* spp.	22	4	na
Vunidawa	Downstream	Cast	*Caranx papuensis*	2	9	0.025
Vunidawa	Downstream	Cast	*Gazza minuta*	2	2	0.000
Vunidawa	Downstream	Cast	*Bostrychus sinensis*	1	3	na
Vunidawa	Downstream	Cast	*Leiognathus equulus*	28	2	0.021
Vunidawa	Downstream	Cast	*Lutjanus argentimaculatus*	1	14	0.053
Vunidawa	Downstream	Cast	*Mugil cephalus*	1	5	0.002
Vunidawa	Downstream	Cast	*Palaemon concinnus*	4	2	na
Vunidawa	Downstream	Cast	*Penaeus monodon*	6	6	na
Vunidawa	Downstream	Cast	*Stolephorus indicus*	10	3	0.002
Vunidawa	Downstream	Cast	*Zenarchopterus dispar*	4	13	na
Vunidawa	Downstream	Fyke	*Apogon* spp.	2	6	na
Vunidawa	Downstream	Fyke	*Bostrychus sinensis*	5	7	0.030
Vunidawa	Downstream	Fyke	*Gymnothorax* sp. (cf. *dorsalis*)	1	151	1.210
Vunidawa	Downstream	Fyke	*Leiognathus equulus*	1	8	0.013
Vunidawa	Downstream	Fyke	*Lutjanus argentimaculatus*	1	10	0.021
Vunidawa	Downstream	Fyke	*Palaemon concinnus*	18	5	na

River	Zone	Method	*Species*	Abundance	Average Size (cm)	Total Biomass (kg)
Vunidawa	Downstream	Fyke	*Pisodonophis* sp.	1	98	0.800
Vunidawa	Downstream	Fyke	*Scylla serrata*	1	7	na
Vunidawa	River mouth	Beach seine	*Leiognathus equulus*	1	2	0.000
Vunidawa	River mouth	Beach seine	*Mesopristes kneri*	1	3	na
Vunidawa	River mouth	Beach seine	*Mugil cephalus*	2	16	0.137
Vunidawa	River mouth	Beach seine	*Palaemon concinnus*	1	2	na
Vunidawa	River mouth	Beach seine	*Scylla serrata*	1	4	na
Vunidawa	River mouth	Beach seine	*Zenarchopterus dispar*	1	14	na
Vunidawa	Coastal	Gill	*Mugil cephalus*	2	18	0.164
Vunidawa	Coastal	Gill	*Sphyraena qenie*	1	36	na

Appendix 12. Fish and crustacean species list and inherent values

Status is given as native or endemic. Value are food (consumed by villagers), Ecological (Eco) is predator or prey in the system and/or baitfish.

Family	Species	Local name	Status	Value
Megalopidae	*Megalops cyprinoides*	yavula	Native	Food/Eco
Muraenidae	*Gymnothorax* sp. (cf. *dorsalis*)	dabea	Native	Food/Eco
Ophichthidae	*Pisodonophis* sp.		Native	Food/Eco
Clupeidae	*Sardinella fijiense*	daniva	Native	Food/Eco
Engraulidae	*Stolephorus indicus*		Native	Baitfish/Eco
Chirocentridae	*Chirocentrus dorab*	voivoi	Native	Food/Eco
Belonidae	*Tylosurus crocodilus crocodilus*		Native	Food/Eco
Hemiramphidae	*Zenarchopterus dispar*		Native	Food/Eco
Syngnathidae	*Microphis retzi*		Native	Eco
	cf. *Hippocampus* sp.		Native	Eco
Scopaenidae	Unidentified scorpion fish		Native	Eco
Serrenidae	*Epinephelus* sp.	kavu	Native	Food/Eco
Terapontidae	*Mesopristes kneri*	reve	Endemic	Food/Eco
	Terapon jarbua	qitawa	Native	Food/Eco
Kuhliidae	*Kuhlia marginata*	ika droka	Native	Food/Eco
Apogonidae	*Apogon* spp.	tina	Native	Food/Eco
Lactaridae	*Lactarius lactarius*	kela	Native	Food/Eco
Carangidae	*Caranx sexfaciatus*	saqa	Native	Food/Eco
	Caranx papuensis	saqa	Native	Food/Eco
	Scomberiodes tol	votonimoli	Native	Food/Eco
Leiognathidae	*Gazza minuta*	kaikai	Native	Food/Eco
	Leiognathus equulus	kaikai	Native	Food/Eco
	Leiognathus faciatus	kaikai	Native	Food/Eco
	Leiognathus splendens	kaikai	Native	Food/Eco
Lutjanidae	*Lutjanus argentimaculatus*	damu ni vei tiri	Native	Food/Eco
	Lutjanus fulviflamma	kake	Native	Food/Eco
	Lutjanus fulvus	tanabe	Native	Food/Eco
	Lutjanus russelli	guru	Native	Food/Eco
Gerridae	*Gerres longirostris*	matu	Native	Food/Eco
Heamulidae	*Plectorhinchus albovittatus*	sevaseva	Native	Food/Eco
Lethrinidae	*Lethrinus amboninensis*	kabatia	Native	Food/Eco
Mullidae	*Upeneus vittatus*	kake	Native	Food/Eco
Mugilidae	*Mugil cephalus*	kanace	Native	Food/Eco
	Valamugil seheli	kanace	Native	Food/Eco
Eleotridae	*Belobranchus belobranhus*		Native	Food/Eco
	Bostrychus sinensis		Native	Food/Eco
	Butis amboinensis		Native	Food/Eco
Gobiidae	Unidentified goby		Native	Eco
Siganidae	*Siganus vermiculatus*	nuqa	Native	Food/Eco
Sphyraenidae	*Sphyraena qenie*	oqo	Native	Food/Eco
Scombriidae	*Rastrelliger kanagurta*		Native	Food/Eco
Chanidae	*Chanos chanos*	yawa	Native	Food/Eco
Tetraodontidae	*Arothron manilensis*	sumusumu	Native	Food/Eco

Family	Species	Local name	Status	Value
Crustaceans				
Macrophthalmidae	*Macrophthalmus* sp.		Native	Food/Eco
Palaemonidae	*Palaemon concinnus*	moci	Native	Food/Eco
Penaeidae	*Penaeus monodon*	ura	Native	Food/Eco
Portunidae	*Portunus sanguinolentus*		Native	Food/Eco
	Scylla serrata	qari	Native	Food/Eco

Appendix 13. Timber volume assessment plots: location and data

Forest type	Plot #	Coordinates		Species association	Plot size (m)	Plot area (ha)	Timber volume (m^3)	Timberdensity (m^3/ha)
		Latitude	Longitude					
*Bruguiera*forest	1	1987948	3888334	D	50 x 10	0.05	3.48	69.60
	2	1988008	3888417	D	50 x 10	0.05	20.59	411.84
	3	1988144	3888400	D	30 x 10	0.03	1.05	35.03
	4	1987953	3886432	D	10 x 10	0.01	1.92	192.40
	5	1988880	3886643	D	40 x 10	0.04	3.13	78.30
	6	1988220	3886599	D	40 x 10	0.04	9.48	236.95
	8	1975623	3875970	D	20 x 10	0.02	0.88	43.90
	9	1975476	3875908	D	30 x 10	0.03	2.87	95.60
	10	1976739	3876981	D	10 x 10	0.01	1.11	110.50
	11	1976119	3876378	D	50 x 10	0.05	7.25	144.96
	13	1976441	3876863	D	50 x 10	0.05	2.15	43.04
	14	1988016	3881269	D	50 x 10	0.05	5.38	107.68
	15	1984196	3893069	D	50 x 10	0.05	2.27	45.44
	16	1984207	3893125	D	20 x 10	0.02	0.73	36.30
	17	1988097	3886308	D	10 x 10	0.01	1.16	115.60
	18	1980127	3874583	D	30 x 10	0.03	7.37	245.50
	19	1987793	3885877	D	50 x 10	0.05	3.41	68.12
	21	1985585	3879997	D	30 x 10	0.03	6.03	201.10
	23	1987216	3886754	D	10 x 10	0.01	1.28	128.10
	24	1986640	3887669	D	40 x 10	0.04	9.46	236.58
	25	1987789	3886922	D	10 x 10	0.01	0.74	74.20
	26	1989359	3880371	D	40 x 10	0.04	0.18	4.58
	28	1988010	3885354	D	50 x 10	0.05	4.37	87.36
	30	1987143	3886017	D	50 x 10	0.05	1.16	23.16
	31	1985614	3880366	D	50 x 10	0.05	6.58	131.64
	33	1985853	3881481	D	50 x 10	0.05	17.94	358.70
	34	1986640	3887669	D	50 x 10	0.05	9.20	183.98
	37	1986974	3881324	D	40 x 10	0.04	4.85	121.15
	39	1988827	3880696	D	50 x 10	0.05	3.94	78.70
	43	1980162	3874605	D	20 x 10	0.02	6.78	338.85
	47	1987948	3888334	D	20 x 10	0.02	4.80	240.20
Total for *Bruguiera* forest						**1.10**	**151.52**	**137.75**
Mixed mangrove	22	1984281	3893830	DTBO	20 x 10	0.02	0.65	32.65
	35	1986111	3887155	DTBO	10 x 10	0.01	0.90	90.40
	36	1975920	3876126	DTBO	30 x 10	0.03	5.20	173.17
	38	1983917	3892718	DTBO	20 x 10	0.02	0.23	11.70
	40	1984266	3893871	DTBO	20 x 10	0.02	0.21	10.70
	44	1985624	3880311	DTBO	10 x 10	0.01	0.83	83.40
Total for mixed mangrove						**0.11**	**8.03**	**73.04**
Back of the mangrove	7	1988802	3886434	DO	40 x 10	0.04	4.94	123.58
	12	1976336	3876484	DO	50 x 10	0.05	3.21	64.26
	20	1986640	3887669	DO	20 x 10	0.02	0.69	34.40
	27	1983412	3894531	DO	10 x 10	0.01	0.53	52.80
	29	1980078	3874455	DO	30 x 10	0.03	5.03	167.50
	32	1986640	3887669	DO	20 x 10	0.02	1.08	54.00
	41	1984223	3893838	DO	10 x 10	0.01	0.13	12.90
	42	1985538	3879984	DO	50 x 10	0.05	2.62	52.46
	45	1984398	3893863	DO	10 x 10	0.01	1.03	103.10
	46	1986111	3887156	DO	30 x 10	0.03	1.48	49.40
Total for back of the mangrove						**0.27**	**20.74**	**76.82**

Appendix 14. Timber volume assessment plot data by species

Plot no.	Plot area (ha)	Dogo		Tiri		Dabi		Selala		Others		Volume (m^3)	Plot density (m^3/ha)
		Volume (m^3)	Density (m^3/ha)	Volume (m^3)	Density (m^3/ha)	Volume (m^3)	Density (m^3/ha)	Volume (m^3)	Density (m^3/ha)	Volume (m^3)	Density (m^3/ha)		
1	0.05	3.360	67.198	0.120	2.406							3.480	69.604
2	0.05	20.592	411.840									20.592	411.840
3	0.03			1.051	35.047							1.051	35.047
4	0.01	1.924	192.400									1.924	192.400
5	0.04	3.132	78.295									3.132	78.295
6	0.04	9.456	236.405	0.022	0.558							9.479	236.963
7	0.04	4.133	103.320							0.810	20.243	4.943	123.563
8	0.02	0.696	34.775	0.183	9.145							0.878	43.920
9	0.03	2.869	95.617									2.869	95.617
10	0.01	1.093	109.270	0.012	1.230							1.105	110.510
11	0.05	7.249	144.970									7.249	144.970
12	0.05	1.746	34.926			2.831	56.616			0.012	0.246	4.590	91.790
13	0.05	2.981	59.618			0.093	1.858					3.074	61.476
14	0.05	6.706	134.112	0.986	19.712							7.691	153.826
15	0.05	0.139	2.788			0.003	0.066					0.143	2.854
16	0.03	0.843	28.093			0.186	6.200	0.008	0.270			1.037	34.567
17	0.01	1.103	110.310	0.549	54.860							1.652	165.170
18	0.03	7.365	245.507									7.365	245.507
19	0.03	4.866	162.200									4.866	162.200
20	0.02	0.456	22.810							0.526	26.305	0.982	49.115
21	0.03	8.619	287.283	0.021	0.707							8.640	287.993
22	0.02	0.889	44.455	0.031	1.540	0.013	0.645					0.933	46.640
23	0.01	1.830	182.960									1.830	182.960
24	0.04	13.519	337.965									13.519	337.965
25	0.01			0.959	95.930							0.959	95.930
26	0.04	0.106	2.643	0.156	3.908							0.262	6.550
27	0.01									0.754	75.420	0.754	75.420
28	0.05	6.240	124.792									6.240	124.792
29	0.03					1.031	34.377			6.092	203.077	7.124	237.453
30	0.05	1.654	33.080									1.654	33.080
31	0.05	9.403	188.060									9.403	188.060
32	0.02									1.542	77.110	1.542	77.110
33	0.05	25.501	510.010	0.121	2.412							25.621	512.420
34	0.05	13.141	262.828									13.141	262.828
35	0.01	0.551	55.080	0.139	13.910	0.479	47.900			0.122	12.220	1.291	129.110
36	0.03	0.963	32.110	0.088	2.920	6.370	212.337					7.421	247.370
37	0.04	6.923	173.070									6.923	173.070
38	0.02	0.215	10.770			0.101	5.050	0.018	0.885			0.334	16.700
39	0.05	5.622	112.438									5.622	112.438
40	0.02	0.210	10.500									0.210	10.500
41	0.01					0.147	14.740	0.037	3.710			0.185	18.450
42	0.05	3.704	74.086	0.008	0.164					0.035	0.706	3.748	74.956
43	0.02	9.673	483.670									9.673	483.670
44	0.01	0.227	22.720	0.127	12.730			0.075	7.500	0.762	76.180	1.191	119.130
45	0.01									1.472	147.220	1.472	147.220
46	0.03	0.482	16.063							1.001	33.353	1.483	49.417
47	0.02	6.776	338.800	0.157	7.835							6.933	346.640
	1.47	**196.954**	**5577.837**	**4.731**	**265.012**	**11.255**	**379.788**	**0.138**	**12.365**	**13.129**	**672.080**	**226.207**	**153.882**

Appendix 15. Index of relative importance (IRI) of fish families

Fish Family	Number	% number	Weight (kg)	% weight	FRQ	% FRQ	IRI	% IRI	H	J
Acanthuridae	9	1.18	6.756	4.17	3	1.56	8.368	1.30	0.052	
Albulidae	2	0.26	6.843	4.23	1	0.52	2.338	0.36	0.016	
Ambassidae	6	0.79	0.024	0.01	2	1.04	0.837	0.13	0.038	
Apogonidae	29	3.81	0.116	0.07	8	4.17	16.177	2.51	0.125	
Belonidae	7	0.92	2.896	1.79	3	1.56	4.232	0.66	0.043	
Carangidae	25	3.29	9.822	6.07	12	6.25	58.451	9.06	0.112	
Chanidae	5	0.66	3.781	2.34	2	1.04	3.117	0.48	0.033	
Chirocentridae	2	0.26	0.578	0.36	2	1.04	0.646	0.10	0.016	
Cichlidae	16	2.10	0.544	0.34	2	1.04	2.540	0.39	0.081	
Clupeidae	106	13.93	5.968	3.69	4	2.08	36.699	5.69	0.275	
Congridae	1	0.13	1.782	1.10	1	0.52	0.642	0.10	0.009	
Diodontidae	1	0.13	0.134	0.08	1	0.52	0.112	0.02	0.009	
Eleotridae	67	8.80	3.015	1.86	16	8.33	88.888	13.78	0.214	
Engraulidae	41	5.39	2.025	1.25	4	2.08	13.830	2.14	0.157	
Ephippidae	4	0.53	3.946	2.44	3	1.56	4.630	0.72	0.028	
Gerreidae	12	1.58	1.776	1.10	4	2.08	5.571	0.86	0.065	
Gobiidae	31	4.07	9.956	6.15	15	7.81	79.870	12.39	0.13	
Haemulidae	3	0.39	4.781	2.95	1	0.52	1.743	0.27	0.022	
Hemiramphidae	23	3.02	0.552	0.34	3	1.56	5.255	0.81	0.106	
Kuhliidae	8	1.05	3.761	2.32	5	2.60	8.788	1.36	0.048	
Kyphosidae	4	0.53	3.223	1.99	2	1.04	2.621	0.41	0.028	
Lactariidae	3	0.39	1.245	0.77	1	0.52	0.606	0.09	0.022	
Leiognathidae	66	8.67	2.706	1.67	7	3.65	37.714	5.85	0.212	
Lethrinidae	15	1.97	3.123	1.93	6	3.13	12.188	1.89	0.077	
Lutjanidae	15	1.97	4.023	2.48	6	3.13	13.925	2.16	0.077	
Megalopidae	4	0.53	5.782	3.57	2	1.04	4.268	0.66	0.028	
Monodactylidae	2	0.26	1.231	0.76	1	0.52	0.533	0.08	0.016	
Mugilidae	79	10.38	5.293	3.27	9	4.69	63.987	9.92	0.235	
Mullidae	44	5.78	1.848	1.14	17	8.85	61.301	9.51	0.165	
Muraenidae	1	0.13	0.981	0.61	1	0.52	0.384	0.06	0.009	
Neoscopelidae	1	0.13	3.219	1.99	1	0.52	1.104	0.17	0.009	
Pinguipedidae	1	0.13	0.419	0.26	1	0.52	0.203	0.03	0.009	
Polynemidae	5	0.66	0.12	0.07	2	1.04	0.762	0.12	0.033	
Pomacentridae	2	0.26	0.289	0.18	2	1.04	0.460	0.07	0.016	
Scaridae	2	0.26	1.447	0.89	2	1.04	1.205	0.19	0.016	
Scatophagidae	6	0.79	0.396	0.24	2	1.04	1.076	0.17	0.038	
Scombridae	8	1.05	2.688	1.66	3	1.56	4.237	0.66	0.048	
Serranidae	11	1.45	3.894	2.41	4	2.08	8.022	1.24	0.061	
Siganidae	9	1.18	2.254	1.39	3	1.56	4.023	0.62	0.052	
Sphyraenidae	36	4.73	5.076	3.14	9	4.69	36.872	5.72	0.144	
Synanceiidae	3	0.39	13.457	8.31	1	0.52	4.535	0.70	0.022	
Syngnathidae	2	0.26	0.017	0.01	2	1.04	0.285	0.04	0.016	
Synodontidae	1	0.13	0.419	0.26	1	0.52	0.203	0.03	0.009	
Terapontidae	21	2.76	4.872	3.01	6	3.13	18.028	2.80	0.099	
Tetraodontidae	9	1.18	4.734	2.92	6	3.13	12.834	1.99	0.052	
Trichiuridae	6	0.79	11.002	6.80	1	0.52	3.950	0.61	0.038	
Zenarchopteridae	7	0.92	9.078	5.61	2	1.04	6.799	1.05	0.043	
TOTAL	**761**	**100**	**161.892**	**100**	**192**	**100**	**644.858**	**100**	**3.151**	**0.657**

Appendix 16. Fish species catch abundance by site

Site	Family	Species	Common name	Catch
1. Natila	Ambassidae	*Ambassis miops*	Glass perchlet	3
1. Natila	Apogonidae	*Apogon amboinensis*	Abiona cardinal fish	7
1. Natila	Belonidae	*Strongylura incisa*	Reef needlefish	4
1. Natila	Carangidae	*Carangoides orthogrammus*	Yellow spotted trevally	1
1. Natila	Carangidae	*Trachinotus blochii*	Snubnose pompano	3
1. Natila	Eleotridae	*Eleotris melanosoma*	Black gudgeon	3
1. Natila	Ephippidae	*Platax teira*	Longfin batfish	2
1. Natila	Gobiidae	*Amoya* sp.1 (Gobiidae)	Amoya goby	1
1. Natila	Gobiidae	*Cristatogobius aurimaculatus*	Goby	8
1. Natila	Haemulidae	*Plectorhinchus gibbosus*	Harry hotlips	3
1. Natila	Hemiramphidae	*Hyporhamphus dussumieri*	Dussumier's halfbeak	4
1. Natila	Kuhliidae	*Kuhlia marginata*	Dark-margined flagtail	2
1. Natila	Kyphosidae	*Kyphosus vaigiensis*	Brassy chub	2
1. Natila	Leiognathidae	*Gazza minuta*	Tooth pony	3
1. Natila	Leiognathidae	*Leiognathus equulus*	Common ponyfish	4
1. Natila	Mugilidae	*Crenimugil crenilabis*	Fringelip mullet	3
1. Natila	Mugilidae	*Mugil buchanani*	Bluetail mullet	5
1. Natila	Mugilidae	*Valamugil engeli*	Dwarf Mullet	18
1. Natila	Mullidae	*Upeneus taeniopterus*	Finstripe goatfish	5
1. Natila	Serranidae	*Epinephelus bleekeri*	Dusky grouper	2
1. Natila	Siganidae	*Siganus vermiculatus*	Vermiculated spinefoot	4
1. Natila	Sphyraenidae	*Sphyraena flavicauda*	Yellowtail barracuda	3
1. Natila	Terapontidae	*Mesopristes kneri*	Orange-spotted therapon	2
1. Natila	Tetraodontidae	*Arothron hispidus*	Striped puffer	1
1. Natila	Tetraodontidae	*Arothron manilensis*	Grey puffer	3
1. Natila	Tetraodontidae	*Arothron mappa*	Pufferfish	2
1. Natila	Zenarchopteridae	*Zenarchopterus dispar*	Half beak	4
2. Waicoka	Acanthuridae	*Acanthurus mata*	Yellow mask surgeon fish	2
2. Waicoka	Ambassidae	*Ambassis miops*	Glass perch	3
2. Waicoka	Apogonidae	*Apogon cookii*	Cook's apogon	2
2. Waicoka	Apogonidae	*Apogon fragilis*	cardinal fish	5
2. Waicoka	Apogonidae	*Apogon lateralis*	Humpback cardinal fish	4
2. Waicoka	Apogonidae	*Apogon rupellii*	Gobble gut apogon	2
2. Waicoka	Apogonidae	*Pristiapogon fraenatus*	Bridled cardinalfish	3
2. Waicoka	Carangidae	*Caranx melampygus*	Bluefin trevally	3
2. Waicoka	Carangidae	*Caranx papuensis*	Fast brassy trevally	1
2. Waicoka	Carangidae	*Caranx sexfasciatus*	Bigeye trevally	2
2. Waicoka	Carangidae	*Caranx ignobilis*	Great travally	1
2. Waicoka	Carangidae	*Gnathanodon speciosus*	Golden trevally	1
2. Waicoka	Carangidae	*Selar crumenophthalmus*	Bigeye scad	3
2. Waicoka	Chanidae	*Chanos chanos*	milkfish	3
2. Waicoka	Chirocentridae	*Chirocentrus dorab*	Dorab wolf-herring	1
2. Waicoka	Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	16
2. Waicoka	Clupeidae	*Herklotsichthys quadrimaculatus*	Goldspot herring	45
2. Waicoka	Clupeidae	*Sardinella fijiense*	Fiji sardinella	3
2. Waicoka	Congridae	*Conger cinereus*	Conger eel	1

2. Waicoka	Diodontidae	*Diodon liturosus*	Black-blotched porcupinefish	1
2. Waicoka	Eleotridae	*Bostrichthys sinensis*	Four-eyed sleeper	2
2. Waicoka	Eleotridae	*Butis amboinensis*	Olive flat head gudgeon	2
2. Waicoka	Eleotridae	*Eleotris melanosoma*	Black gudgeon	17
2. Waicoka	Eleotridae	*Eleotris fusca*	Dusky sleeper	10
2. Waicoka	Eleotridae	*Giuris margaritacea*	Snakehead gudgeon	2
2. Waicoka	Eleotridae	*Giurus hoedti*	Snakehead gudgeon	1
2. Waicoka	Eleotridae	*Ophiocara porocephala*	Northern mud gudgeon	3
2. Waicoka	Eleotridae	*Oxyeleotris marmorata*	Marble goby	2
2. Waicoka	Ephippidae	*Platax orbicularis*	Orbicular batfish	1
2. Waicoka	Gerreidae	*Gerres macrosoma*	Slender silver-biddy	2
2. Waicoka	Gerreidae	*Gerres oyena*	Silver biddy	4
2. Waicoka	Gobiidae	*Awaous melanocephalus*	Large snout goby	1
2. Waicoka	Gobiidae	*Awaous ocellaris*	Spotfin river goby	1
2. Waicoka	Gobiidae	*Awaous guamensis*	Pacific river goby	1
2. Waicoka	Gobiidae	*Bathygobius fuscus*	Common Goby	2
2. Waicoka	Gobiidae	*Glossogobius bicirrhosus*	Bearded goby	1
2. Waicoka	Gobiidae	*Periophthalmus argentilineatus*	Barred mudskipper	5
2. Waicoka	Gobiidae	*Psammogobius biocellatus*	Sleepy goby	1
2. Waicoka	Hemiramphidae	*Hemiramphus far*	Black-barred halfbeak	4
2. Waicoka	Hemiramphidae	*Hyporhamphus dussumieri*	Goatfish	15
2. Waicoka	Kuhliidae	*Kuhlia marginata*	Dark-margined flagtail	4
2. Waicoka	Kuhliidae	*Kuhlia rupestris*	Rock flagtail	1
2. Waicoka	Kyphosidae	*Kyphosus vaigiensis*	Brassy chub	2
2. Waicoka	Leiognathidae	*Gazza minuta*	Ponyfish	6
2. Waicoka	Leiognathidae	*Leiognathus equulus*	Ponyfish	12
2. Waicoka	Leiognathidae	*Leiognathus fasciatus*	Striped ponyfish	3
2. Waicoka	Leiognathidae	*Leiognathus rivulatus*	Rivulated snapper	1
2. Waicoka	Lethrinidae	*Gymnocranius grandoculis*	Blue-lined large-eye bream	2
2. Waicoka	Lethrinidae	*Lethrinus harak*	Thumbprint emperor	4
2. Waicoka	Lethrinidae	*Lethrinus miniatus*	Trumpet emperor	2
2. Waicoka	Lethrinidae	*Lethrinus semicinctus*	Black blotch emperor	1
2. Waicoka	Lutjanidae	*Lutjanus fulviflamma*	Dory snapper	3
2. Waicoka	Lutjanidae	*Lutjanus fulvus*	Black tail snapper	5
2. Waicoka	Lutjanidae	*Lutjanus argentimaculatus*	Mangrove red snapper	3
2. Waicoka	Megalopidae	*Megalops cyprinoides*	Indo-Pacific tarpon	2
2. Waicoka	Monodactylidae	*Monodactylus argenteus*	Silver moony	2
2. Waicoka	Mugilidae	*Liza vaigiensis*	Diamond scale mullet	4
2. Waicoka	Mugilidae	*Mugil cephalus*	Flathead grey mullet	1
2. Waicoka	Mugilidae	*Mugil subviridis*	Greenback mullet	4
2. Waicoka	Mugilidae	*Valamugil engeli*	Dwarf mullet	8
2. Waicoka	Mullidae	*Mulloidichthys vanicolensis*	Yellowfin goatfish	3
2. Waicoka	Mullidae	*Parupeneus barberinus*	Dash-and-dot goatfish	3
2. Waicoka	Mullidae	*Parupeneus cyclostomus*	Gold-saddle goatfish	1
2. Waicoka	Mullidae	*Parupeneus indicus*	Indian Goatfish	6
2. Waicoka	Mullidae	*Parupeneus trifasciatus*	Doublebar goatfish	1
2. Waicoka	Mullidae	*Upeneus vittatus*	Striped goatfish	4
2. Waicoka	Mullidae	*Upeneus tragula*	Freckled goatfish	2
2. Waicoka	Muraenidae	*Echidna nebulosa*	Starry moray eel	1

2. Waicoka	Neoscopelidae	*Neoscopelus macrolepidotus*	Large-scaled lantern fish	1
2. Waicoka	Pinguipedidae	*Parapercis clathrata*	Latticed sandperch	1
2. Waicoka	Polynemidae	*Polydactylus plebeius*	Striped threadfin	2
2. Waicoka	Pomacentridae	*Neopomacentrus violascens*	Violet demoiselle	1
2. Waicoka	Pomacentridae	*Pomacentrus spilotoceps*	Violet damsel fish	1
2. Waicoka	Scaridae	*Calotomus spinidens*	Ragged toothed parrot fish	1
2. Waicoka	Scatophagidae	*Scatophagus argus*	Spotted scat	3
2. Waicoka	Scombridae	*Rastrelliger kanagurta*	Long-jawed mackerel	4
2. Waicoka	Scombridae	*Scomberomorus commerson*	Narrow-barred Spanish mackerel	2
2. Waicoka	Serranidae	*Epinephelus caeruleopunctatus*	Whitespotted grouper	4
2. Waicoka	Serranidae	*Serranus microdon*	Camouflage grouper	2
2. Waicoka	Siganidae	*Siganus vermiculatus*	Vermiculate rabbitfish	4
2. Waicoka	Sphyraenidae	*Sphyraena barracuda*	Giant barracuda	1
2. Waicoka	Sphyraenidae	*Sphyraena putnamae*	Sawtooth barracuda	4
2. Waicoka	Syngnathidae	*Hippocampus kuda*	Spotted seahorse	1
2. Waicoka	Terapontidae	*Mesopristes kneri*	Orange-spotted therapon	4
2. Waicoka	Terapontidae	*Tarpon jarbua*	Crescent perch	8
2. Waicoka	Tetraodontidae	*Arothron hispidus*	Striped puffer fish	1
2. Waicoka	Tetraodontidae	*Canthigaster solandri*	Mimic puffer	1
2. Waicoka	Trichiuridae	*Trichiurus lepturus*	Large head hair tail	6
3. Nasilai	Belonidae	*Tylosurus crocodilus*	Hound needlefish	1
3. Nasilai	Carangidae	*Trachinotus blochii*	Snubnose pompano	1
3. Nasilai	Engraulidae	*Stolephorus indicus*	Indian anchovy	4
3. Nasilai	Engraulidae	*Thryssa baelama*	Baelama anchovy	4
3. Nasilai	Mullidae	*Upeneus vittatus*	Striped Goatfish	12
3. Nasilai	Sphyraenidae	*Sphyraena flavicauda*	Yellowtail barracuda	4
3. Nasilai	Sphyraenidae	*Sphyraena obtusata*	Yellowtail barracuda	2
3. Nasilai	Synanceiidae	*Synanceia horiida*	Estuarine stonefish	3
3. Nasilai	Synodontidae	*Synodus variegatus*	Variegated lizardfish	1
3. Nasilai	Terapontidae	*Tarpon jarbua*	Crescent perch	5
4. Vutia	Acanthuridae	*Acanthurus dussumieri*	Half beak goatfish	6
4. Vutia	Acanthuridae	*Acanthurus mata*	Yellow mask surgeon fish	1
4. Vutia	Albulidae	*Albula vulpes*	Bonefish	2
4. Vutia	Apogonidae	*Apogon amboinensis*	Abiona cardinal Fish	3
4. Vutia	Apogonidae	*Apogon lateralis*	Humpback apocon	3
4. Vutia	Belonidae	*Tylosurus crocodilus*	Hound needlefish	2
4. Vutia	Carangidae	*Caranx melampygus*	Bluefin Trevally	3
4. Vutia	Carangidae	*Caranx sexfasciatus*	Bigeye trevally	3
4. Vutia	Carangidae	*Scomberoides lysan*	Doublespotted queenfish	3
4. Vutia	Chanidae	*Chanos chanos*	Milkfish	2
4. Vutia	Chirocentridae	*Chirocentrus dorab*	Dorab wolf-herring	1
4. Vutia	Clupeidae	*Herklotsichthys quadrimaculatus*	Goldspot Herring	45
4. Vutia	Clupeidae	*Sardinella fijiense*	Fiji sardinella	13
4. Vutia	Eleotridae	*Butis butis*	Flathead gudgeon	1
4. Vutia	Eleotridae	*Eleotris melanosoma*	Black gudgeon	4
4. Vutia	Eleotridae	*Eleotris fusca*	Dusky sleeper	2
4. Vutia	Eleotridae	*Giuris margaritacea*	Snakehead gudgeon	1
4. Vutia	Eleotridae	*Ophiocara porocephala*	Northern mud gudgeon	17
4. Vutia	Engraulidae	*Stolephorus indicus*	Indian anchovy	6

4. Vutia	Engraulidae	*Thryssa baelama*	Baelama anchovy	27
4. Vutia	Ephippidae	*Platax teira*	Longfin batfish	1
4. Vutia	Gerreidae	*Gerres macrosoma*	Slender silver-biddy	2
4. Vutia	Gerreidae	*Gerres oyena*	Silver biddy	4
4. Vutia	Gobiidae	*Awaous guamensis*	River goby	1
4. Vutia	Gobiidae	*Caragobius urolepis*	Blind/blood goby	1
4. Vutia	Gobiidae	*Cristatogobius aurimaculatus*	Goby	1
4. Vutia	Gobiidae	*Periophthalmus argentilineatus*	Barred mudskipper	3
4. Vutia	Gobiidae	*Periophthalmus kalolo*	Common mudskipper	3
4. Vutia	Gobiidae	*Psammogobius biocellatus*	Sleepy goby	1
4. Vutia	Kuhliidae	*Kuhlia rupestris*	Rock flagtail	1
4. Vutia	Lactariidae	*Lactarius lactarius*	False trevally	3
4. Vutia	Leiognathidae	*Leiognathus equulus*	Ponyfish	37
4. Vutia	Lethrinidae	*Lethrinus harak*	Thumbprint Emperor	4
4. Vutia	Lethrinidae	*Lethrinus reticulatus*	Red snout emperor	2
4. Vutia	Lutjanidae	*Lutjanus fulviflamma*	Dory snapper	1
4. Vutia	Lutjanidae	*Lutjanus fulvus*	Black tail Snapper	3
4. Vutia	Megalopidae	*Megalops cyprinoides*	Indo-Pacific tarpon	2
4. Vutia	Mugilidae	*Liza vaigiensis*	Diamond scale mullet	7
4. Vutia	Mugilidae	*Mugil cephalus*	Flathead grey mullet	3
4. Vutia	Mugilidae	*Mugil subviridis*	Greenback mullet	5
4. Vutia	Mugilidae	*Valamugil engeli*	Dwarf mullet	21
4. Vutia	Mullidae	*Mulloidichthys vanicolensis*	Yellowfin goatfish	2
4. Vutia	Mullidae	*Parupeneus barberinus*	Dash-and-dot goatfish	2
4. Vutia	Mullidae	*Upeneus vittatus*	Striped goatfish	3
4. Vutia	Polynemidae	*Polydactylus plebeius*	Striped Threadfin	3
4. Vutia	Scaridae	*Scarus rivulatus*	Rivulated parrotfish	1
4. Vutia	Scatophagidae	*Scatophagus argus*	Spotted scat	3
4. Vutia	Scombridae	*Scomberomorus commerson*	Narrow-barred Spanish mackerel	2
4. Vutia	Serranidae	*Epinephelus caeruleopunctatus*	Whitespotted grouper	3
4. Vutia	Siganidae	*Siganus argenteus*	Streamlined spinefoot	1
4. Vutia	Sphyraenidae	*Sphyraena barracuda*	Giant barracuda	1
4. Vutia	Sphyraenidae	*Sphyraena flavicauda*	Yellowtail barracuda	4
4. Vutia	Sphyraenidae	*Sphyraena forsteni*	Bigeye barracuda	13
4. Vutia	Sphyraenidae	*Sphyraena obtusata*	Yellow Tail barracuda	4
4. Vutia	Syngnathidae	*Hippocampus kuda*	Spotted seahorse	1
4. Vutia	Terapontidae	*Mesopristes kneri*	Orange-spotted therapon	2
4. Vutia	Tetraodontidae	*Arothron hispidus*	Stripe puffer	1
4. Vutia	Zenarchopteridae	*Zenarchopterus dispar*	River Half beak	3

Appendix 17. Socioeconomic study questionnaire

Socioeconomic Survey: Household Questionnaire

MESCAL BACKGROUND

The **Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL)** project is an attempt to encourage the necessary actions needed in implementing countries (Fiji, Vanuatu, Solomon Islands, Samoa and Tonga) to promote appropriate management of mangroves for sustainable livelihood and protection of coastal communities. The MESCAL Regional Project is administered by the IUCN Regional Oceania Office under its Water and Wetlands Programme and implemented through the Department of Environment. The German Federal Ministry for Environment, Nature Conservation and Nuclear Safety supports this project within the framework of the International Climate Initiative. The MESCAL Fiji Project is aiming at 'strengthening mangrove management in Fiji.

SECTION 1: POPULATION, EDUCATION AND HOUSING

Complete list of all the people who normally live and eat their meals together in this household beginning with your immediate family and then the extended family.

Q1 NAME	Q2. SEX Male 1 Female 2	Q4 AGE	5.SCHOOL Is [name] attending school now? Yes. 1 No. 2 <if "2", continue to next member>	6.LEVEL Highest level of education? 1. No Education 2. Primary 3. Secondary 4. Tertiary 5. Other (specify)	Q7 ORIGINAL VILLAGE [if from study site then go to Q9]	Q8 REASON FOR RESIDING HERE 1. Married here 2. Vasu 3. Friend's village

Q9 Record the main material of the walls and roof of the house <u>without asking</u>. Please circle choice.

9a House wall type		9b Roof		9c Toilet type	
1	Bamboo	1	Thatch/ leaves	1	No toilet
2	Corrugated iron	2	Tile	2	Pit toilet
3	Wood	3	Corrugated	3	Water seal
4	Brick/ cement	4	Concrete and tiles	4	Flush
5	Other, specify	5	Other, specify	5	Other, specify

SECTION 2: DURABLE ASSETS (Fill 1 if present or 0 if none)

Q10: Furniture and appliance ownership

stereo/radio	sewing machine	cooking stove
tape/cd player	DVD player	washing machine
gas stove	T.V	microwave
bed	refrigerator	electric fan

SECTION 3: LIVELIHOOD AND FOOD SECURITY (INCOME AND RESOURCE USE PATTERN

Q11. Please indicate which are the sources of income that your family rely on and the amount earned per month? For category 1-5, please list 3 key resources and where each are usually fished?

Income Source	Tick if source 1=Yes 0=N0	Cash income earned [in FJD/month]	List the 3 main resources (For Q1-5)	Where are they harvested? 1. River 2. Creeks 3. Mangrove forests 4. Intertidal areas 5. Lagoon and inshore 6. Offshore
1. Fin fish fishing			i ii iii	
2. See Cucumber collecting			i ii iii	
3. Other Sea food collection (e.g. mudlobster/mud crab / sea urchin)			i ii iii	
4. Seaweed cultivation			i ii iii	
5. Coral / ornamental fish collection			i ii iii	
6. Boat operation / sea transportation				
7. Middle-men agent for marine products				
8. Farming Staple and root crops				
9. Farming Vegetables				
10. Farming *yaqona*				
11. Canteen business (groceries, kava, cigarette etc.)				
12. Tourism (hotel and land lease etc.)				
13. Handicraft / basket weaving				
14. Wood/mangrove selling				
15. Copra				
16. Coconut products e.g. Virgin oil, broom				
17. Pension				
18. Remittances				
19. Social welfare				
20. Work at urban centers				
21. Other income sources, specify …				

Q12. How far from the village boundary is the place where you usually fish for mangrove fish and crustaceans.

	a. <1km from village boundary		b.1-3km from village boundary		c. >3 km from village boundary

SECTION 4: FISHING GEAR

Q13. Tick the appropriate boxes to indicate how often the main methods of fishing are used by the household regardless of fishing area.

Methods	This method used _____ of the time				
	None	1/4	1/2	3/4	All
Hand collecting or gleaning					
Diving/speargun, snorkel, mask, fins					
Hook and line					
Trolling					
Gill netting					
Spearfishing					
Trapping/tudai					
Others (specify)					

Q14. Destructive fishing methods used

Methods	This method used _____ of the time				
	None	1/4	1/2	3/4	All
Duva					
Laying of gillnet overnight					
Breaking of corals and rocks					
Use of undersized net					
Night fishing					

SECTION 5: USE OF MANGROVES

Q15. In what ways does your family use the mangroves trees/wood?

Use key below for each box 1= Yes 2= No	a. Type of mangrove		b. Harvesting method	
	Green	Dry	Knife	Chainsaw
a. Subsistence firewood				
b. Selling firewood				
c. House post				
d. Fencing post				
e. Gardening				
f. Medicinal products (medicine and ointments				
g. Markings				
h. Dye				
i. Furniture (chairs, tables, shelves, utensils, boat masts, paddles, fishing equipment)				
j. Other Uses (specify)				

Q16. Does your family sell mangrove for firewood and/or other mangrove wood products

	0=No		1=Yes

Q17. If yes, where is the market?

Q18. Where do you get the mangroves for selling? (Please mark on the map the area you usually go to)?

	a. <1km from village boundary		b.1-3km from village boundary		c. >3 km from village boundary

Q19. Do you consider some sustainable approaches when cutting down mangrove forest?

	0=No		1=Yes

If **YES**, what are they?

1	
2	
3	

Q20. What different types of mangroves are you using for these things (provide local name)?

Use	Mangrove type
Subsistence firewood	
Selling firewood	
House post	
Fencing post	
Gardening	
Markings	
Medicinal products	
Dye	
Furniture (chairs, tables etc)	
Other Uses (specify)	

Q21. How often do you cut the mangrove TREES in a week for the following uses? How many bundles/posts?

Uses	In a week: 1=Daily 2=Every second day 3=Twice a week 4=Once a week	In a month:
Subsistence firewood		+ no. of bundles
Selling firewood		+ no. of bundles
House post		+ no of posts
Fencing post		+ no. of posts
Gardening		+ no. of trees
Markings		+ no. of trees
Medicinal products (medicine/ointments)		+ no. of trees
Dye		+ no. of trees
Furniture (chairs, tables etc)		+ no. of trees
Other uses (specify)		+ no. of trees

Q22. If the family is using the mangroves, who's the one who usually cuts the mangroves? Please circle choice

1. Adult male	2. Adult female	3. Children

Q23. What are some other trees you use for firewood and house posts? Please list

Other trees used for firewood	Other trees used for house post

Q24. How often do you use those different types of trees/wood in a week for firewood? (get an estimate of the number of bundles used per week in the household: 1-2 times 10%, 3-4 times 40%, 5-more times 80%)

Firewood	How many times a week and number of bundles?
1.	
2.	
3.	
4.	

SECTION 6: RESOURCE USE PATTERN

Q25. Please fill the details of the people from your household who have gone fishing in the past 7 days?

Household members	Sex	Number of trips	Approx. hours/trip	Mostly fish in: 1. River 2. Creeks 3. Inside mangrove forests 4. Intertidal areas 5. Lagoon and inshore 6. Offshore

SECTION 7: CHALLENGES AND MANAGEMENT

Q26. What are some of the threats/challenges that the mangrove systems in your area are faced with? Please list

1	
2	
3	

Q27. What are some of the management actions already implemented to protect/conserve the mangrove system? Please list

1	
2	
3	

Thank you for your cooperation

Appendix 18. Archaeological site photographs

Figure 45: Team recording Nautu installation site.

Figure 46: The fortification ditch at Delainavutu used for subsistence agriculture

Figure 47: The overgrown Naceva site

Figure 48: Flat platform at Nakanalo site

Figure 49: Heavily disturbed Valesa site

Figure 50: The terraced platform at Nakarawa site.

Figure 51: Arrow showing Natena site

Figure 52: The cultural layer at Kubuna sacred site

Figure 53: Unknown fortified site near Dravo village

Figure 54: House mound covered in overgrown grass and undergrowth at this unknown site

Figure 55: Degraded house mound at unknown site (Naisogovau)

Figure 56: Village guide standing on causeway at Waicoka makawa

Figure 57: Guide looking into ditch at Nasoto

Figure 58: Village guide pointing out degraded house mound at Vatoa

Figure 59: Burial at Naivitavi site, Kiuva

Figure 60: Pottery shards and shell middens at Vadrai vavatu

Figure 61: Visible ditch surrounding east side of unknown site

Figure 62: Agricultural activities occurring at Nakua site

Figure 63: Location of fisher folk yavutu

Figure 64: Bulubulu situated at Tavuya yavutu

Figure 65: Burial area covered in overgrown vegetation at Navadratolu

Figure 66: Naivisere site situated within these dense vegetation