FJIM Phase 161 Science Report

January 2016 – March 2016

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# Field Staff

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<td>Project Manager</td>
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<td>Jane Giat (JG)</td>
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1. Introduction

1.1 Frontier

Frontier, established in 1989, is a UK-based non-profit NGO. Its mission statement is: “to conserve the world’s most endangered wildlife and threatened habitats and to build sustainable livelihoods for marginalised and under resourced communities in the world’s poorest countries and to create solutions that are apolitical, forward-thinking, community-driven and innovative, and which take into consideration the long-term needs of low income communities”.

Frontier employs non-specialist volunteers, or Research Assistants (RA). Frontier’s marine projects give RAs basic science and species identification training at the beginning of their placement, to enable them to collect data on local fish, benthic and invertebrate species. After working on Gau Island in Fiji conducting baseline surveys, Frontier relocated to Beqa Island, south of mainland Fiji, in order to assess the status of the coral reef systems around Beqa and within Beqa Lagoon.

1.2 Location

Fiji is an archipelago in the South Pacific Ocean composed of 332 islands and 500 islets and cays, with land mass occupying 18,376 km² (Cumming et al., 2002) (Figure 1). Approximately one third of the islands are inhabited and, of these, the two largest islands, Viti Levu and Vanua Levu, contain approximately 90% of Fiji’s population (Vuki et al., 2000).

Figure 1: The Fiji Islands, Beqa circled in red (adapted from Veitayaki, 2006).
Beqa is a large island in the Fijian archipelago and lies within Beqa Lagoon (Figure 2), with the coordinates 18°24’S 178°08’E. The island is located approximately 10 km south of the main island of Viti Levu and has a population of around 3,000 people. Nine villages are present on Beqa, these are; Waisomo, Lalati, Soliyaga, Dakuni, Dakuibeqa, Naceva, Naiseuseu, Rukua and Raviravi.

![Figure 2: Beqa Island with surrounding barrier reef system (Google Earth)](image)

Fiji is world renowned as the Soft Coral Capital of the World and is also home to Beqa Lagoon, which is famous amongst divers. It features over 50 world class dive sites and is frequented by numerous species of mega fauna, including, dolphins, whales, sharks, rays and turtles. The primary source of income on Beqa is tourism, largely through recreational scuba diving. No large scale fishing, agriculture or horticulture occurs and heavy industry is non-existent, therefore the reefs within Beqa Lagoon are unaffected by the potential negative environmental impacts that such industries can bring.

Fiji’s coral reef fisheries are mainly inshore, small-scale subsistence and artisanal fishers and are therefore recognised as not receiving the management attention at a national level. The total value of Fiji’s subsistence and artisanal fisheries was US$64million (FAO 2007). Of Fiji’s 400 traditional fishing grounds (qoliqoli), around 70 are over-exploited while 250 are fully developed (Teh et al. 2008). Various no take or ‘tabu’ areas have been designated by chiefs of the villages to try to control extraction levels as village population’s increase. The ‘tabu’ areas surrounding Beqa can be seen in figure 3. Although village chiefs have no legal right to the reefs, they traditionally lay claim to certain reefs within their territories and consequently have the power to create ‘tabu’ areas on reefs of their choice in order to maintain populations of targeted fish species for subsistence. This unofficial law is expected to be respected and adhered to by all inhabitants of Beqa Island. Studies on other reefs
elsewhere have shown that similar traditional methods are an effective way to control and sustainably manage harvest rates of marine resources (Hoffmann 2002).

Figure 3: Tabu areas around Beqa (FLMMA, 2013).

1.3 Background

Coral reefs are one of the most valuable resources on earth and provide an array of vital ecosystem services (Done et al. 1996), with over one third of all described marine species dependent upon coral reef ecosystems (Reaka-Kudla, 1996).

In recent years, coral reefs in the Southwest Pacific region have sustained large-scale damage as a result of both natural phenomena and anthropogenic activities (Lovell et al. 2004). One hundred years ago the reefs were pristine, human populations were low and fish were harvested only for subsistence (Lovell et al. 2004). Even 30 years ago, remote reefs remained healthy, however, reefs near dense populations began to be overexploited. Some Marine Protected Areas (MPAs) had been created, however, the threats to coral reefs were not yet fully understood. In the last 20 years, pollution, sedimentation and overfishing around dense population centres have increased. As a result, MPA’s and non-protected areas near urban areas have incurred significant stress and consequently their health has declined. Most other reefs situated in rural and isolated areas have remained healthy and many are even recovering from mass bleaching events in 2000 and 2002, still, recovery rates vary between sites, with some showing complete recovery and others showing minimal or no recovery. Beqa Barrier Reef in particular has been showing a slow recovery rate (Lovell et al. 2004).
Fiji is dependent on its low lying coastal regions for its socio-economic development (Teh et al. 2008). This, like many other South Pacific islands, makes it extremely vulnerable to the impacts of climate change. Current predictions indicate a potential rise in global sea levels of between 49.9cm to 1m by 2100 (Solomon et al. 2009). A rise of this size would cause widespread devastation to Fiji’s coastal infrastructure and artificial preservation would be a substantial drain on Fiji’s economy. In addition, the frequency of destructive environmental events are predicted to increase, occurring at a greater frequency than potential recovery (Hutchings et al. 2008).

1.3.1 Natural Sources of Reef Degradation

Natural sources of coral reef degradation include cyclones, coral bleaching and invasive predator outbreaks. 64% of all coral colonies surrounding Fiji suffered mass bleaching in 2000 and in the southern areas of Viti Levu 84% of colonies were affected (Cumming et al. 2002). Since 2002, significant damage has been sustained on coral reefs within the Southwest Pacific region as a result of cyclones (Lovell et al. 2004). Most recently, severe tropical cyclone Winston made a category 5 landfall on Fiji and was the strongest tropical cyclone to make landfall over Fiji in records (Fritz 2016). However, the impact of the cyclone towards reef health has not been assessed. Coral predator outbreaks, specifically the Crown of Thorn starfish (*Acanthaster planci*), have occurred on Fijian reefs since 1965, for periods ranging from two to five years and continue to this day (Zann et al. 1990). This can be attributed to natural fluctuations in availability of planktonic food, water salinity levels and temperature.

1.3.2 Anthropogenic Sources of Reef Degradation

The main anthropogenic sources of reef degradation include overfishing, destructive fishing practices (such as dynamite fishing), poisoning, pollution, deforestation and coral harvesting for the curio and marine aquarium trade (Lovell 2001, Teh et al. 2008).

The fisheries sector is the third largest natural resource sector in Fiji. The main sources of foreign exchange are the tourism industry (contributing 19% to GDP), sugar industry (contributing 8.5%) and then fisheries (contributing 2.5%). Understanding the role of societal and economic factors on fishing is critical for designing appropriate fisheries management strategies. Teh et al., 2008 produced an overview of the socio-economic and ecological perspectives of Fiji’s inland reef fisheries. The result from this overview was that status of Fiji’s reef-associated fisheries at national level is still uncertain due to lack of dependable data on the subsistence fisheries.

Since the 1990's there's been increasing pressure on small scale fisheries due to growing population and demand for fish. A socio-economic study done in Beqa villages Rukua and Yanuca reported, of the fish caught locally 54% were consumed by the local community while 46% were either sold outside or to an agent, presumably to an outside source (MRIS 2012). Common methods for targeting reef fish species include: hand-line, spear, gillnet, seine net, hookah (diving with surface supplied air) and reef gleaning (Teh et al. 2009). Of these methods hand-lining and spearfishing are used most frequently by residents of Rukua and Yanuca (MRIS 2012). Commercial fishing does not occur near the island of Beqa, however, overfishing in other areas may have reduced population numbers to such an extent that species such as *L. harak, L. xanthochilus, L nebulosus and B. muricatum* are not present or very rarely encountered. Other species such as the humphhead parrotfish (*Bolbometopon muricatum*), have now become almost completely extinct in Fijian waters (Cumming et al. 2001).
Lack of long term monitoring and limited technical expertise hinders assessment of the coral reef fisheries. There has been numerous site-specific studies yet no national level evaluation of Fiji’s reef fisheries. To tackle this at a national level the Fisheries Division, Fiji Locally Managed Marine Areas (FLMMA) and the University of the South Pacific have started facilitating coral reef conservation initiatives by conducting socio-economic surveys of marine resource use.

The marine aquarium trade inflicts reef degradation in a variety of ways. According to Fiji’s Fisheries Department annual estimate, 311,097 aquarium fish were exported from Fiji in 2001. Convention of International Trade of Endangered Species (CITES) database recorded that 169,143 ornamental fish and 31,900 invertebrates were exported from Fiji in 2004 to overseas markets. It has also been reported that between 2000 and 2004 annual live rock exports from Fiji increased from 800,000kg in 2000 to 1.3 million kg. Live rock exports are a major problem in Fiji as it significantly diminishes reef ecosystems by reducing the number of available spawning sites for marine species, reducing the buffer areas for sites of increased wave action, and decreasing carbon dioxide sequestration by reducing the amount of photosynthetic material in the marine environment. In 2001, a reported 800,000 kg of ‘live rock’ was harvested and exported; however the actual figure is likely much greater as a substantial quantity is lost in the trimming and grading process (Lovell et al., 2004). Although this has not been observed around Beqa, likely due to tourism being the main activity, there is potential for harvesting to occur in the future.

Pollution in the form of sewage is a major threat to coral reefs in Fiji. Untreated sewage deposited directly into the ocean causes increased levels of phosphates and consequently macro algal blooms and eutrophication (Ginsberg 1994). Coral reefs are unique in that they possess low levels of nutrients and are highly efficient at recycling them. Consequently, they can cope with minor levels of eutrophication, however, when marine ecosystems are highly enriched with chemical nutrients, the result is excessive plant growth in the form of macro algae. Such algae are detrimental to the health of the reef because they use all available oxygen within the water column, causing fish populations to die off. In addition, these algal blooms reduce the amount of light penetrating the water column, inhibiting coral photosynthesis, subsequently causing rapid declines in reef system biodiversity (Fabricius 2005). Unmanaged disposal of raw sewage is common in areas of dense population as well as in popular tourist destinations. Villages on Beqa use pit latrines for sewage, however, because they are close to the coast it is likely that nutrients leach through the soil into the surrounding coastal waters and increase levels of phosphates and nitrates, which in turn negatively affect near shore reefs. It is unclear how the resorts on Beqa manage their waste, but it is likely that septic tanks are employed. Incidents of dumping on reefs along the Coral Coast of Viti Levu, Mamanuca and Suva have been observed (Mosley and Aalbersberg, 2002, Tamata and Thaman, 2001; Zann and Lovell, 1992).

Many families on Beqa lay claim to some plantain regions which they farm, both for local consumption and trading as well as to sell on the mainland (MRIS 2012). It has been noted that there has been an increase in the area of land cleared using slash and burn methodologies to make room for these farms (pers comm, 2015). These areas of clearing will increase sedimentation and the rate at which fresh water is being leached onto the reef. Mangrove forests help stabilize shorelines, filter freshwater runoff and reduce the impact of natural disasters such as tsunamis and hurricanes. In addition, many of the reef fish targeted for consumption are known to depend on the mangroves for refuge from predators and for ontological development (FAO 2007, Giri et al. 2010). According to locals, the areas of mangroves have significantly decreased and with the added impact of slash and burn techniques this is likely to continue (pers comm, 2015). The combination of land clearing
using slash and burn techniques as well as mangrove deforestation will be having measurable impacts on the reef.

1.4 Project Aims & Objectives

The overarching aim of the Fiji Marine Conservation project is to ascertain the health of the reef through the use of baseline surveys in order to inform sustainable management.

Baseline surveys will be used to;

1. Indicate which natural and anthropogenic processes currently effect the reef system.

2. Determine the effectiveness of the current locally managed marine areas.

3. Feed into national data collection objectives through Fiji Fisheries Department and University of the South Pacific (USP)

4. Build awareness and education of local people as to the importance of sustained marine management techniques with the hope to assist with the long term sustainable use of marine resources.

1.5 Phase Achievements

The overall objective of the phase was to keep operation running during less than optimal circumstances as camp experienced two cyclones and severely understaffed. This entailed;

Camp and logistics:
- Completed necessary maintenance for compressor engine and outboard engine
- Implemented surface cover procedure
- Improved boat briefing and dive kit maintenance
- Bunk beds in sleeping quarters
- New showers

Scientific Development:
- Established mangrove mapping and monitoring for Vaqa bay.
- Implementing coral cover snorkel survey

Community:
- Initiated waste disposal management with three villages in the island (Rahiravi, Rukua, and Naiseuseu)
- Implemented monthly lovo with the Matagali family
- Implemented weekly gathering with local families to stimulate small local business

2. Training

2.1 Briefing sessions

- Orientation – staff member takes new volunteers around camp.
• Bula and Welcome – staff member introduces all members of staff, other volunteers and local Fijian family.
• Intro to duties – staff member shows new volunteers rota and where description of duties can be found and outlines what needs doing for each duty.
• Health and safety – staff member outlines important health and safety points for camp and new volunteers then take health and safety and medical tests.
• Dive and Boat Safety – Dive officer explains the possible hazards of diving which may be encountered as well as safety equipment used in case of an incident.
• Surface cover briefing – Dive officer demonstrate procedure of surface covering including emergency procedures such as emergency diver recall, deploying the anchor, re-mooring the boat, and retrieving tired divers.

<table>
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<tr>
<th>Briefing session</th>
<th>Presenter</th>
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<tbody>
<tr>
<td>Orientation</td>
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<tr>
<td>Bula and Welcome</td>
<td>BW/JG/BH</td>
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<tr>
<td>Intro to Duties</td>
<td>BW/JG/BH</td>
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<td>Health and Safety</td>
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<td>Dive and Boat Safety</td>
<td>BH</td>
</tr>
<tr>
<td>Surface Cover</td>
<td>BH</td>
</tr>
</tbody>
</table>

Table 1. Briefing sessions conducted during phase 161

2.2 Science lectures

Research assistants (RA’s), with the support of staff members, are fully responsible for all data collection on FJM. Before RA’s were permitted to conduct surveys, rigorous testing was undertaken. RA’s were given an array of lectures, computer ID tests and in-water ID tests. A pass rate of 95% accuracy was required for theory tests and only when theory and in-water ID tests have been completed RA’s were allowed to start surveying. RA’s were then required to complete two practice surveys before actual benthic and fish surveys could be undertaken and data recorded.

The science lectures given to guide learning are as follows;

• Introduction to Coral Reefs – coral reef biology, function and threats, most common benthic forms found along transects, and how to conduct snorkel survey.
• Mangrove Mapping – Introduction to mangroves and how to conduct transect based surveys for mangrove mapping.
• Fish Survey Methodology – underwater techniques and processes involved in conducting a fish survey
• Fish Anatomy – important parts of fish biology which will help identify indicator and distinguishing features that separate families
• Indicator Fish Family – distinguishing features of indicator fish families.
• Indicator Fish Species – distinguishing features of indicator fish species
• Other Butterflies and Damsels – illustrate which species may get confused with indicator species
### Table 2. Science lectures conducted during phase 161

<table>
<thead>
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<th>Science Lectures</th>
<th>Presenter</th>
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<td>Introduction to Coral Reefs</td>
<td>JG/BH</td>
</tr>
<tr>
<td>Mangrove Mapping</td>
<td>JG</td>
</tr>
<tr>
<td>Fish Survey Methodology</td>
<td>JG/BH</td>
</tr>
<tr>
<td>Fish Anatomy</td>
<td>JG/BH</td>
</tr>
<tr>
<td>Indicator Fish Family</td>
<td>JG/BH</td>
</tr>
<tr>
<td>Indicator Fish Species</td>
<td>JG/BH</td>
</tr>
<tr>
<td>Other Butterflies and Damsels</td>
<td>JG/BH</td>
</tr>
</tbody>
</table>

Additional lectures were often held depending on interest on topics prepared by staff. To date these have included; ecological impact assessment methodology.

### 2.3 Field work training

The following computer ID tests were conducted before in-water tests:

- Indicator fish species
- Fish families
- Master test – encompassing indicators, families and others

A dry run of survey methodology for was also conducted in order to reinforce techniques before conducing in-water surveys.

### 2.4 BTEC

1 BTEC was completed this phase as follows:

1. Name: Elizabeth Warwick-Champion  
   BTEC type: Tropical Habitat Conservation  
   Title: Variation in Fish Abundance in Relation to Site Distance from Beqa Island.  
   Mentor: Brad Harris

### 3. Research Work Program

#### 3.1 Indicator Fish Species Monitoring in Beqa Lagoon

**3.1.1. Introduction**

Beqa Island lies within Beqa Lagoon, 10 km south of the main island of Viti Levu. The island is known for its traditional subsistence village lifestyles, as well as hosting a number of tourism resorts (Burns 1994). Fiji Fisheries department currently monitor the area as part of their national monitoring plan, however, surveys are only conducted once a year in different area around Fiji due to personnel restrictions. FJM’s presence on Beqa aims to contribute to this knowledge gap by directly feeding survey results into work by WWF and Fisheries department initiatives.
The most comprehensive assessment conducted by Fisheries to date was a resource survey for Yanuca and Rukua villages in 2012 by the Marine Resource Inventory Survey (MRIS) team. The overall goal of this survey was to formulate and later implement a management plan for sustainable use of the marine resources. Methodologies included an underwater visual census and socio-economic surveys. It was reported that the main source of income for villagers was fishing and that over 90% of villagers “always” or “sometimes” consumed fresh fish in a week. Also recorded was the most common fish species caught per fishing trip, the top 5 being: *E. polyhekadion, L. harak, L. atkinsoni, C. ignobilis* and *L. gibbus* (MRIS 2012). The survey identified that many of the marine inshore species that usually inhabit the Beqa reef system are under threat due to the continued destruction of the reef system through anthropogenic activities including; pollution from pig farms, reef-walking, over-fishing, anchor damage and the use of destructive fishing methods. It was reported that many of the reefs in the region have a major algae overgrowth problem with large areas of reef totally covered by algae thought to be attributed to the combination of sewage stimulating algae growth and lack of major algae grazers from overfishing.

Indicator species are used to infer reef health trends. Indicator families (emperors, butterflyfish, angelfish, damsel fish and barracudas) are identified to species level as there are many interspecies variations. Angelfish show a preference for structurally complex reefs and are not tolerant to fluctuations in physical variables such as temperature, while barracudas are very tolerant due to ontological and seasonal shifts in habitat range (Christine 2010). Butterflyfish are reported to be very sensitive to reef degradation and have species dependent feeding preferences, while emperors display niche partitioning (Pratchett 2005, Carpenter and Allen 1989).

### 3.1.2 Survey Areas

Beqa lies within Beqa Lagoon, with the coordinates 18°24’S 178°08’E. The island is located approximately 10 km south of the main island of Viti Levu and has a population of around 3,000 people.

Six survey sites were used for reef data collection;

<table>
<thead>
<tr>
<th>Site Name</th>
<th>GPS coordinates</th>
<th>Project</th>
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<tbody>
<tr>
<td>Bikini</td>
<td>S 18°23’40.1” E 178°05’26.0”</td>
<td>All</td>
</tr>
<tr>
<td>Mala’s</td>
<td>S 18°24’10.5” E 178°05’58.2”</td>
<td>All</td>
</tr>
<tr>
<td>Rabbit</td>
<td>S 18°24’07.5” E 178°06’09.9”</td>
<td>Mooring line snapped in Mid-February. All activity suspended for the time being</td>
</tr>
<tr>
<td>Vuvalae</td>
<td>S 18°24’07.6” E 178°03’54.9”</td>
<td>All</td>
</tr>
<tr>
<td>Wreck Reef</td>
<td>S 18°22’48.22” E 178°05’18.3”</td>
<td>All</td>
</tr>
<tr>
<td>Snapper</td>
<td>S 18°24’56.7” E 178°04’04.4”</td>
<td>All</td>
</tr>
<tr>
<td>Location</td>
<td>Latitude</td>
<td>Longitude</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Lunch</td>
<td>S 18°19′40.1″</td>
<td>E 178°06′33.0″</td>
</tr>
<tr>
<td>Heaven</td>
<td>S 18°25′26.5″</td>
<td>E 178°04′42.0″</td>
</tr>
</tbody>
</table>

Bikini – A near-shore site (1.29 nautical miles from camp) protected from westerly winds but is more prone to northerly, southerly and easterly winds. Average depth is 7.5m and a gentle slope drops down to a depth of 20 m on the outer reef. Bikini is outside of Vaqa Bay and so will encounter freshwater dissipating out of the bay and also from the local village of Rukua. The site is rarely visited by Beqa Lagoon Resort for tourism. Bikini is a no take zone and so only fished on rare occasions when the chief opens the site for fishing for celebrations or funerals.

Mala’s – An inshore site (0.56 nautical miles from camp) found within Vaqa Bay and relatively protected from southerly and easterly winds. It is an estuarine environment with three freshwater streams flowing into it. The majority of the reef is at around 8 m, whereas the outer reef is at around 18 m. It is near the local village of Neiseuseu and the site is not visited for tourism and is a non-tabua area. Targeted fish include parrotfish, unicornfish, porcupinefish, rabbitfish, surgeonfish and goatfish.

Rabbit – An inshore site (0.44 nautical miles from camp) located within Vaqa Bay close to river outflows. The site is generally shallow with an average depth of 6 m dropping down to 12 m at the reef edge. The site is not visited for tourism and is a no-take zone.

Vuvalae – an offshore site (2.53 nautical miles from camp) relatively protected from southeasterly, easterly and north easterly winds and usually is not subjected to strong currents. The reef is extremely large, comprising of numerous patch reefs and coral bombies. The average depth is around 8 m dropping down to 16 m at the reef’s edge. Vuvalae is located far away from Beqa and can be difficult to get to because of rough weather conditions. It will encounter no freshwater and there can often be strong currents. The site is not visited for tourism.

Wreck Reef – an offshore site (1.97 nautical miles from camp) very exposed with a purpose sunk wreck is located on the seabed just off the reef at a depth of 22 m. The reef has an average depth of 8 m, however, the edge of the reef has a steep drop off down to a depth of 22 m. There can be strong currents present, however, the site is far enough away from freshwater sources to not be affected by dissipation. The site is rarely visited by Beqa Lagoon Resort for tourism or fishing by the locals.

Snapper – An offshore site (2.42 nautical miles from camp) relatively protected from southeasterly and north easterly winds. The reef has an average depth of 8.5 m with a drop off to 15 m at the reef edge. Six large coral bombies surround the mooring line with depths ranging 3-6 m. Transects are places on patch reefs with areas of sand.

Lunch – An offshore site (4.99 nautical miles from camp) very exposed and dramatically affected by strong winds from all directions as a result. At high tide the survey area is approximately 6 m, however, the site is also comprised of steep drop offs and coral bombies. Lunch is located far away from Beqa and is very difficult to get to because of rough weather conditions. It will encounter no freshwater and the site is not visited for tourism or fishing. Lunch is no longer used for surveying.
Heaven – An offshore site (2.06 nautical miles from camp) to be used for the shark project. The site is relatively protected from south easterly and north easterly winds. Average depth is around 6 m, with drop offs to the west of the site down to a depth of 15 m. The site is mainly patch reef with coral bombies to the east.

3.1.3 Materials and Methods

Baseline Survey Protocol (BSP) was used following standardised Reef Check methodology (Hodgson, 2001). In order to initially set up the permanent transects, fifty meter survey tapes were used to create transect lines spaced 10 m apart. Four permanent transect sites were set up at each of the survey sites and highly visible markers deployed in order to allow RAs to easily locate the transect start points. Transect bearings were kept consistent in order to obtain independent samples to be replicated at each site. Transect lines were laid for a total length of 45 m and this permitted 2 x 20 metre transects to be completed separated by a 5 m gap. Fish surveys were completed using belt transect methodology. During the fish surveyor methodology, RAs would lay the survey tape, swim back to the start point, and wait five minutes for any disturbed fish to return into the transect area. RA’s then swam the length of the survey tape recording all fish seen within a 5m x 5m square from the base of the transect tape measure.

![Fish surveyor methodology](image)

**Figure 4: Fish surveyor methodology, recording all fish seen within a 5m x 5m square from the base of the transect tape measure.**

**Surveyor Roles:** RAs undertook various roles during fish surveys depending on the data being collected and the level of training they had received. As four weeks were required to become fish survey proficient, any RAs on the project for less than four weeks were unable to survey fish and would therefore occupy another surveyor role. Data was collected on fish biodiversity, abundance and size.

Consequently, there were two surveyor roles; physical surveyor and fish surveyor. Provided that research assistants were able to undertake all survey roles, the allocated role rotated on a daily basis.

The role of the physical surveyor was to lead the dive and therefore keep track of all surveyors’ air consumption, dive depth and survey time, in addition to towing the surface marker buoy and navigating bearings. The physical surveyor recorded the depth and time at the start and end of each transect and navigated the set bearing of each transect whilst laying out the tape measure. During fish surveys the physical surveyor remained behind the fish surveyor to reduce disturbance to the fish within the transect area. On completion of the survey the physical surveyor reeled in the tape.
Fish species richness, abundance and size were recorded. Research assistants learn forty-five indicator species and twenty other fish families. Fish size was recorded in categories; 1-10 cm, 11-20 cm, 21-30 cm, 31-40 cm, 41-50 cm and >50 cm. When a fish surveyor encountered a large school of fish, the abundance was estimated and recorded in the most common average size category. Upon completion of a survey dive, RAs directly enter their survey data into the master database.

3.1.4 Results

The result of 161 survey data showed that there was a significant decrease in fish abundance ($F = 43.85, p < 0.0001$) compared to data from surveys collected in 152 (Figure 5). Most significant decrease was observed at Wreck reef where there are more than 95% decrease in fish abundance, followed by Bikini and Mala’s Rock with ~85% decrease, Rabbit with ~82% decrease, Vuvale with ~78% decrease, and least was observed at Snapper with ~62% decrease in fish abundance.

![Fish Abundance](image)

**Figure 5.** Average fish abundance per transect for all survey sites from 161 quarter compared to 152 quarter

The result on the species richness in other hand showed significant increase ($F = 107.42, p = 0.0000$) in the number of species observed in each site during 161 compared to 152 (Figure 6). Most significant increase in number of species encountered was at Snapper with more than 150% increase, followed by Rabbit with ~94% increase, Bikini with ~75% increase, Vuvale with ~57% increase, and finally Mala’s Rock with ~44% increase in species richness. There are no significant increase or decrease in family richness between 152 and 161 (Figure 7).
Figure 6. Average species richness per transect for all survey sites from 161 quarter compared to 152 quarter

Figure 7. Average family richness per transect for all survey sites from 161 quarter compared to 152 quarter

The size composition of fish observed had shifted quite significantly from 152 to 161 (Figure 8). 152 was dominated by fish in the size range 0 – 10 cm, however fish from the two upper size categories were spotted in most sites. Mala’s Rock is the only site to have no fish surveyed in the upper two size categories. 161 was dominated by fish in the size range 10 -20 cm however little to none fish surveyed was larger than 30 cm. The >50 cm category was retired from use because no fish surveyed were in that size categories.
3.1.5 Discussion

The major decrease in fish abundance in all of the sites indicates increasing fishing pressure. Most significant decrease were shown on inshore sites which are at risk of over fishing as they are easily accessible by swimming or kayak from local villages. Research on fish behavior showed that fish used visual cue as well as other myriad cues to detect predators (Karplus & Algom 1981, Holmes et al. 2012). Most fish can correctly identify a specific predator from random shape of similar size (Ferrari et al. 2010), meaning it is very possible that there could be an association between presences of divers with spear fishing activity, which in turn cause the fish to hide or run away from surveyors.
The increasing species richness and the shift in size ranges that dominate the reef is also consistent with effect of fishing pressure. As large top predators are removed from the area (as indicated by the lack of fish >30 cm surveyed) there will be an increase in mid-sized (10 – 20 cm) fish species observed (Jackson et al. 2001). This is a major shift in ecological top-down interaction. Overfishing is often referred as systematic exploitation of resources because after one type or size class is exhausted, the fishing industry will fulfill market demand by exploiting the next size class down (Botsford et al. 1997). Without management this will continue until there’s nothing left to take. Proper management will take advantage of this natural shift, allowing one resource to recover so the fishing industry may switch back and forth rather than systematically fishing down (Botsford et al. 1997, Russ 2002).

Bikini and Rabbit are already located in “tabu” area where locals are not allowed to fish (FLMMA, 2013), this indicates other sources of fishing pressure or locals have ways of circumventing the “tabu” law. Personal communication with locals indicate that both is happening. Fishing vessels from Suva have been sighted in Beqa waters fishing (pers. Comm. 2016) and locals have been putting in fishing lines in “tabu” area and pulled up when they had passed the areas (pers. Comm. 2016). Rabbit is also very close to the shore and highly affected by sedimentation. This may affect the decrease in fish abundance, however it does not explain the similar decrease in other sites,

Furthermore, the no-take areas (NTA) or “tabu” areas were established almost randomly without considerations to the reef system as a whole. Fernandez et al. (2009) suggested that for NTA to work it has to represent at least 20% of reef and non-reef bioregion. He also suggested that the NTA should form a network that represents all habitat type within the region (Fernandez et al. 2009). Our results suggest the need to better manage the establishment of “tabu” areas. However further studies, especially in habitat connectivity and larval dispersal are needed in order to design an effective network of “tabu” area that benefit biodiversity and local fisheries. Currently we did not have the resources and expertise to conduct these studies.

Without benthic cover information it is difficult to determine the overall reef health (Messmer 2010). However, the consistency of family richness throughout the year indicate that the reef is quite stable despite of the apparent pressure (Cohen & Alexander 2013). It seems that there are no invasive species or unnatural species outbreak that caused major shift in Family composition (Cohen & Alexander 2013). However to better assess the overall reef health, benthic cover surveys are necessary.

Observer bias is a constant consideration when gathering data based on visual survey (Cheal & Thompson 1997, Nadon & Stirling 2006). However, since the data within quarters showed consistency, as indicated by the small error bars, even though it was collected by various RAs and AROs, we can put some measure of confidence in the accuracy of the data.

In conclusion, the massive decline in fish abundance observed is likely caused by fishing pressure and not natural sources of disturbance. Better management and enforcement of NTAs is needed to help the fish abundance to recover. However, more data and studies are needed to propose more effective marine resources management. One of the most important data needed are the resilience of the reef system since it will enable assessment of ecological threshold to be done. In order to achieve this benthic surveys to assess the spatial reef resilience of the system are being proposed for the next quarter.
3.2 Mangrove Mapping in Vaga Bay

3.2.1. Introduction

Mangrove forests occur on low energy, sedimentary shorelines of the tropics, between mean tide and high tide elevations (Molony et al. 1995). Mangrove trees have physiological and morphological adaptations to the environmental stresses of their intertidal habitat, of high salinity, low oxygen, poor nutrient availability and substrate mobility (Duggan 2003). These cause the different mangrove species to prefer a particular elevation between mean tide and high tide. True mangrove species occur exclusively in this saline wetland environment, with adaptations such as aerial roots and halophytic strategies (Molony et al. 1995, Duggan 2003).

Mangrove ecosystems provide a useful buffer between the land and the sea. Mangrove forests are a sink for sediment and nutrient-rich runoff, protecting nearshore waters from eutrophication and turbidity to benefit seagrass and coral reef health (Peters et al. 1997). They also provide protection of the land from marine inundation during storms. Mangroves have been shown to be important fish habitats, particularly functioning as a fish nursery (Lal et al. 1984). Mangroves sustain a food chain within the mangrove habitat, and tidal export of mangrove material supports offshore food chains (Ley et al. 2002). Many species of fishes, crustaceans, molluscs, amphibians, reptiles and birds are found in mangroves (Lal et al. 1984, Ley et al. 2002).

Mangrove wetlands are one of the most threatened natural communities worldwide, with about 50% of the global area lost since 1900, and 35% of the global area lost in the past two decades (FAO, 2003; Spalding et al., 2010). Human activities remain a major cause of degradation and loss of mangrove ecosystems in all parts of the world, including the Pacific Islands region (Polidero et al., 2010). Monitoring will measure mangrove extent and condition, and allow mangrove ecosystems to be conserved and managed sustainably to maintain their environmental, ecological, and socioeconomic benefits.

Mangrove ecosystems are also sensitive to climate change impacts, particularly to associated relative sea level rise. Inter-tidal mangroves are most extensively developed on sedimentary shorelines, where mud accretion determines their ability to keep up with sea-level rise (Gillman et al. 2008). The IPCC 4th Assessment projected a global sea level rise of 0.18-0.59 m by 2099 (1.5-9.7 mm per year), and mangrove accretion rates are usually less than this, resulting in dieback at the seaward edge, and inland recruitment. Rise in temperature and the effects of increased CO2 levels should increase mangrove productivity, change phenological patterns, and continue expansion of mangrove species ranges into higher latitudes (Gillman et al. 2008).

This mapping exercise aimed to establish what mangrove resources are present at Vaga Bay and what condition they are in.

3.2.2 Mapping Area

Vaga bay is the largest bay on the west side of Beqa Island. It is approximately 1.2 km wide and 1.5 km deep inshore. There is mangrove wetland present along the inside of the bay which is the characteristic of the sheltered bay area. There are two villages in the bay: Rukua which is located on the north part at the mouth of the bay and Naiseuseu which is located in the south part inside the bay. Both of these villages fish in the bay as part of their livelihood. Mangroves have been shown to be important fish
habitats, particularly functioning as a fish nursery, therefore it is beneficial to assess the condition of Mangroves that are present in the Bay.

3.2.3. Materials and Method

Level 1 monitoring protocol was used following the Manual for Mangrove Monitoring in Pacific Island Regions (Ellison et al. 2012). Firstly we determined the extent of the mangrove forest using the most recent aerial photograph (Figure 9). Vegetation zones were marked based on the photograph and were taken into the field to accurately check the types and positions of the zones, called ground truthing. On the aerial photograph, six transects perpendicular to the coastline were marked. The transects were numbered from one to six from North to South.

![Figure 9. Aerial photograph of mangrove wetland at Vaqa Bay, Beqa Island (Google earth).](image)

Using major features visible on the aerial photograph, we determined the starting point of each transect. The transect start position was identified using the GPS and marked using flagging tape. A new data form for each vegetation zone along the transect was used and notes were taken that will help re-locate this position if without a GPS, such as marking the point with flagging tape. The transect lines are laid into the forest using a 50 m fibreglass tape, using a hand compass to ensure the transect is perpendicular to the shoreline and stays straight. Species are noted and zone recorded, with a measure of abundance taken and the width measurement of each zone (mm).

At each observation point the degree of impact in an area with a 15 m radius around is assessed. Impact is assessed on a scale from 0 to 5 where 0 is no impact and 5 is severely impacted (Table 4). The surrounding area is then inspected visually to determine the cause of Impact. Impact may be direct,
indirect, or both, anthropogenic activities such as piggeries, garbage, illegal cutting, storm damage, etc was recorded.

<table>
<thead>
<tr>
<th>Code</th>
<th>Impact</th>
<th>% Cover</th>
<th>Canopy</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Impact</td>
<td>96-100</td>
<td>Even canopy of trees. No gaps. No evidence of human interference.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Slight Impact</td>
<td>76-95</td>
<td>Canopy of trees fairly continuous but some gaps. Some regrowth.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Isolated cutting/stripping of trees at some evidence of pigs digging up saplings.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Moderate Impact</td>
<td>51-75</td>
<td>Broken canopy of trees with lower regrowth and recruitment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>areas. Some trees cut and stripped.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Rather High Impact</td>
<td>31-50</td>
<td>Tree canopy is uneven, the majority of the area is not</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>showing regrowth and there is bare mud.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>High Impact</td>
<td>11-30</td>
<td>Only a few trees remain at canopy height. Extensive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>clearance and some recruitment, large areas of bare mud</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Severe Impact</td>
<td>0-10</td>
<td>Extensive clearance to bare mud, little recruitment, few</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>trees remain alive.</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Codes used to record the impact of pressure on mangrove ecosystems

The GPS position on the mangrove edge is recorded and condition of the seaward edge is noted, such as any recruitments, or signs of erosion.

3.2.4. Results

Six transects weremarked in Vaqa Bay with GPS coordinates described on Table 5.

<table>
<thead>
<tr>
<th>TRANSECT</th>
<th>SEAWARD EDGE</th>
<th>LANDWARD EDGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S 18°24.265' E 178°06.393'</td>
<td>S 18°24.270' E 178°06.413'</td>
</tr>
<tr>
<td>2</td>
<td>S 18°24.272' E 178°06.393'</td>
<td>S 18°24.276' E 178°06.415'</td>
</tr>
<tr>
<td>3</td>
<td>S 18°24.286' E 178°06.395'</td>
<td>S 18°24.281' E 178°06.418'</td>
</tr>
<tr>
<td>4</td>
<td>S 18°24.324' E 178°06.381'</td>
<td>S 18°24.343' E 178°06.404'</td>
</tr>
<tr>
<td>5</td>
<td>S 18°24.351' E 178°06.369'</td>
<td>S 18°24.368' E 178°06.392'</td>
</tr>
<tr>
<td>6</td>
<td>S 18°24.382' E 178°06.359'</td>
<td>S 18°24.384' E 178°06.379'</td>
</tr>
</tbody>
</table>

Mangrove wetland in Vaqa Bay is composed by two true mangrove species (Bruguiera gymnorhiza and Rhizophora x selala) and one associate mangrove species (Barringtonia asiatica) (Table 6). High tide mark varies around 50 -60 cm on the landward edge and around 90 – 110 cm on the seaward edge. Canopy cover was mostly uniform, except for transect 5 that is right by a creek. Damage observed on the trees was mostly storm damage, however the edge of the mangroves was open with very little recruitment.

<table>
<thead>
<tr>
<th>Transect number</th>
<th>Zone Distance</th>
<th>Species</th>
<th>Percent cover</th>
<th>Impact code</th>
<th>Impact Type</th>
<th>High tide Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>Bruguiera gymnorhiza,</td>
<td>75</td>
<td>0</td>
<td>None</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rhizophora x selala</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>Bruguiera gymnorhiza</td>
<td>90</td>
<td>0</td>
<td>None</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 6. Species composition and health of Mangrove wetland in Vaqa Bay
3.2.5 Discussion

Both of the mangrove species present in Vaqa Bay are member of Rhizophoraceae. The family Rhizophoraceae includes around 135 tropical species of trees and shrubs placed in around 15 genera (Prance 2001). The principal genera in Rhizophoraceae are Bruguiera, Carallia, Cassipourea, Ceriops, Crossostylis, Pellacalyx, and Rhizophora (Spalding et al. 2010). *Rhizophora* is the most conspicuous genus in tropical, coastal mangrove ecosystems (Prance 2001).

*Rhizophora x selala* is a hybrid mangrove that is sterile and only occurs if both *Rhizophora stylosa* and *Rhizophora samoensis* are present (Robertson & Alongi 1992), however, during initial mapping that has been done, none of the parent species were found in the area. This could be the result of habitat degradation that caused the parental trees to die, however, since the mangrove area seems to be quite healthy with dense canopy, it is more likely that it was simply an observer error as the three species are very similar in appearance. All of them are medium sized trees ranging from 8-30m in height (Spalding et al. 2010), their leaves are about 10cm long and slightly rounded with a small spike at the tip (Giesen et al. 2007), the flowers are white and are wind or insect pollinated (Spalding et al. 2010).

*Bruguiera gymnorhiza* is a darkly colored mangrove, that only grows to 10 m in height and its bark is rough and reddish-brown (Allen & Duke 2006). The tree develops short prop-roots rather than long stilt-roots (Giesen et al. 2007), flowers are creamy-white soon turning brown (Sheue et al. 2005) and the sepals are persistent, narrow and slightly tapered. When mature, the spindle-shaped fruits drop and become embedded in the mud in an upright position, where they rapidly develop roots (Allen & Duke 2006). It is found on the seaward side of mangrove swamps, often in the company of *Rhizophora* (Giesen et al. 2007). The two species work together to stabilize the shoreline, provide buffers from storm surges, trap debris and detritus brought in by tides, and provide feeding, breeding, and nursery grounds for a great variety of fish, shellfish, birds, and other wildlife (Smith 1992).

*Barringtonia asiatica* is a species native to mangrove habitats on the tropical coasts and islands of the Indian Ocean and western Pacific Ocean (Molony & Sheaves 1995). It is a small to medium-sized tree growing to 7-25 m tall (Robertson & Alongi 1992). The leaves are narrow obovate, 20–40 cm in length and 10–20 cm in width. Fruit is otherwise aptly known as the Box Fruit, due to distinct square like diagonals jutting out from the cross section of the fruit, given its semi spherical shape form from stem altering to a subpyramidal shape at its base (Giesen et al. 2007). The fruit measures 9–11 cm in

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Storm damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td><em>Barringtonia asciata</em></td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td><em>Bruguiera gymnorhiza</em></td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>33</td>
<td><em>Bruguiera gymnorhiza</em></td>
<td>85</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>21</td>
<td><em>Rhizophora x selala</em></td>
<td>95</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td><em>Bruguiera gymnorhiza</em></td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td><em>Bruguiera gymnorhiza, Rhizophora x selala</em></td>
<td>80</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>Bare</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td><em>Bruguiera gymnorhiza</em></td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td><em>Bruguiera gymnorhiza</em></td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td><em>Bruguiera gymnorhiza</em></td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>38</td>
<td><em>Bruguiera gymnorhiza, Rhizophora x selala</em></td>
<td>80</td>
<td>0</td>
</tr>
</tbody>
</table>
diameter, where a thick spongy fibrous layer covers the 4–5 cm diameter seed (Giesen et al. 2007). All parts of the tree are poisonous, the active poisons including saponins (Tan 2001). The seeds have been ground to a powder to stun or kill fish for easy capture, suffocating the fish where the flesh is unaffected (Tan 2001). This method is commonly used by local villagers in Beqa for fishing (pers. comm 2016).

Overall the mangrove wetlands seem to be healthy with uniform canopy cover. This indicates that the area was relatively free of direct anthropogenic impact such as piggeries, garbage, or illegal cutting. However, without long term monitoring we can’t ascertain if there’s a gradual decline in the mangroves area that was caused by indirect impact such as increase in sea level, sedimentation, and changes in water quality.

Lack of recruitment observed in seaward edge indicates a lack of area growth. This is very likely caused by rise in sea level, which naturally pushes the mangrove area landwards (Krauss et al. 2014). Since the landward edge in Vaqa Bay is dense rainforest (pers. obsv. 2016), the mangrove wetland is unable to expand inland and likely become reduced in time even though this is still highly speculative since we only have one-time data. Long term monitoring is needed to assess if the mangrove wetland in Vaqa bay is being reduced and whether a planting project will be needed for the mangrove assemblages in Vaga Bay.

4. Proposed work programme next phase

4.1. Assessing the spatial resilience of the reef system

4.1.1. Introduction

Our permanent survey sites are sampled in two stages. First is the broad-scale monitoring through manta tows. The initial surveys will be utilized in order to give idea of overall condition of long-term study sites. During these surveys, the underwater area will be mapped using different categories, and main attributes will be noted. Secondly, medium-scale monitoring through visual underwater surveys to assess and habitat complexity will be conducted.

The aim of this project is to create a holistic understanding of the functional state of the reef system. Identifying and monitoring the main attributes that comprise the healthy functionality of the reef through surveys of selected sites. Documentation will be conducted in a categorical manner that will allow producing critical information on complex interactions between different assemblages inhabited on the reef, its environment and prevailing conditions. This study will incorporate several approaches and methodologies producing reliable data that will create a base-line understanding of the area’s environmental structure and functionality.

4.1.2 Broad scale monitoring

4.1.2.1. Materials

- Waterproof hand-held GPS
- Tow rope (17 m) and two harnesses (attached to boat transom and to board)
- Manta board
- Datasheets printed on underwater paper
- Waterproof, digital stopwatch
4.1.2.2. Methods

The broad-scale monitoring will allow exploring the surrounding fringing and barrier reefs for representative habitats that can be replicated and used for the permanent medium-scale surveys. The technique is often referred as “Manta-Tow”. The technique involves towing a snorkel diver (observer) at a constant speed (~2 mph) behind a boat. The observer holds on to a ‘manta board’ (Figure 10) attached to a small boat by a 17-metre length of rope. This person makes a visual assessment of specific variables during each manta tow (2 minutes duration), and records these data on a data sheet attached to the manta board when the boat stops.

![Figure 10. Schematic of the manta board and attachments (from Moran et al. 1989)](image)

The recorded variables are:
- Main substrate type and percentage cover – besides hard coral
  - (i.e., soft coral, dead coral, fleshy macroalgae, rubble and sand);
- Live hard coral cover percentage (increments of 5%);
- Dominant coral morphologies
  - (i.e., Branching, Corymbose, Columnar, Encrusting, Foliaceous, Massive, plate or Laminar);
- Structural complexity (scale 1-6);
- COTS number and size;
- Number of feeding scars;
- Percentage of bleached corals (increments of 5%);
- Other targeted organism (e.g., sharks) and major disturbance (e.g., boat grounding).

4.1.3 Medium scale monitoring

Medium-scale monitoring will use units that are defined by a measured length and/or area of reef, i.e. line intercept transects and photographic point-intercept quadrates. This type of monitoring will add two survey components to the visual census surveying targeted fish species and fish groups that was already ongoing:

1) Visual quadrants surveying the occurrence of coral recruitment and composition of the underlying benthos;
2) Visual census surveying the health state of hard corals and occurrence of detrimental coral predators.

A single habitat is surveyed on each reef area (i.e., fringing and barrier reefs, tabu and nontabu), typically along the first stretch of continuous reef with a slope less than vertical. The selection of a common habitat allows comparisons to be made between reefs both within and between sectors. Within this habitat, three sites are selected, each containing four, permanently marked, 50 metre long transects, lying approximately parallel to the reef crest. Transects are set along the middle of the reef slope (usually at a depth between 6 and 9 m). Where appropriate, deeper sites (between 15 and 20 m) will be created.

4.1.3.1. Materials

- 50 m transect reel
- Slates
- Underwater paper
- Waterproof hand-held GPS
- Camera
- Mobile PVC 0.5 m² quadrant

4.1.3.2. Methods

The following section outlines the procedure for undertaking visual census surveys of a permanent monitoring site.

1. The site is located from the surface using a GPS.
2. Divers/snorkelers enter the water grouped in pairs. The first observer is equipped with a slate, pencil and data sheets, the second buddy carries the tapes.
3. The tape layer follows the observer approximately 5 metres behind, laying a tape measure along the centre line of the transect.
4. The observer lays down the 0.5 m² quadrant every 5 m along the centre line of the transect. The observer record the benthic assemblage and the condition.

The following data will be collected along each transect;

1) Live benthic cover recorded at 5m intervals, producing 10 recorded quadrant per transect.
2) Underlying substratum (i.e., sand, rock, live rock, rubble, or dead coral) quantified at 5 m intervals.
3) Structural complexity will be recorded using both a 6-point scale and by estimating the number of small refuge holes.

Scleractinian corals will be categorized as: Branching, Corymbose, Encrusting, Foliaceous, Massive, Tabular, Columnar, or Laminar.

4.2. Assessing species assemblage in Vaga Bay mangrove ecosystem

4.2.1. Introduction

Mangroves are nursery habitat for many wildlife species, including commercial fish and crustaceans, and thus contribute to sustaining local abundance of fish and shellfish populations. As fish grow and become less vulnerable to predators, they move from the protective mangrove environment to mudflats, seagrass beds and coral reefs where foraging efficiency increases due to changes in their diet. This
project aims to identify faunal species composition in Vaqa Bay and determine the key indicator faunal species of the ecosystem.

4.2.2. Materials

- 50 m transect reel
- Waterproof hand-held GPS
- Underwater Camera
- Computer

4.2.3. Methods

The following section outlines the procedure for assessing faunal composition in Mangrove wetland

1. During high tide lay the 50 m transect reel on the permanent transect points that are marked on section 3.2.3
2. Surveyor carefully walk along the tape and take picture of every fauna sighted within 2.5 m on either side of the transect
3. Fauna in the pictures then identified on a computer

After identification, further research will be done on the ecological role of every species of fauna found. From there we will determined key indicator species that may serve as early warning of habitat disruption and monitor said species.

5. Acknowledgement

We would like to thank the family that owns the land we operate from, especially to Malakai Tabaka and family which had been crucial for our fieldwork. Thanks also to all of the RAs whose had been working hard in collecting all of the data.

6. References


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