FIJI MARINE
CONSERVATION & DIVING

Beqa Island, Fiji

FJM Phase 162 Science Report

April 2016 – June 2016

Author: Jane Sarah Giat, S.Si., M.Sc. (Principal Investigator)
## Field Staff

<table>
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<tr>
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<td>Principal Investigator</td>
</tr>
<tr>
<td>Rosalyn Jones (RJ)</td>
<td>Assistant Research Officer</td>
</tr>
<tr>
<td>Olivia Cole (OC)</td>
<td>Assistant Research Officer</td>
</tr>
<tr>
<td>Laurence Pidgeon (LP)</td>
<td>Dive Officer</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.

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 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 is 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 on record (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 the 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 that of the fish caught locally 54% were consumed by the local community
while 46% were either sold outside or to a middleman/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 are very rarely encountered. Other species such as the humphead parrotfish (*Bolbometopon muricatum*), have now become almost completely extinct in Fijian waters (Cumming et al. 2002). Lack of long term monitoring and limited technical expertise hinders assessment of the coral reef fisheries. There’s 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 1.3million 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 plantation 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 run off 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 measureable 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 affect 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 expand the scope of data gathering and engaging more with the community;

Camp and logistics:
• New Solar panels
Scientific Development:
• Implementing benthic baseline survey
• Building a Mangrove nursery

Community:
• Initiated school visits to Korovatu Primary School at Naceva and Beqa-Yana Primary and Secondary School at Raviravi.
• Being invited and present on various village function in Raviravi, Rukua, Naiseusei, and Naceva.

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 rotor 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.

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<thead>
<tr>
<th>Briefing session</th>
<th>Presenter</th>
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<td>Orientation</td>
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<td>Bula and Welcome</td>
<td>JG</td>
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<tr>
<td>Intro to Duties</td>
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<td>Health and Safety</td>
<td>JG</td>
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<td>Dive and Boat Safety</td>
<td>LP</td>
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<td>Surface Cover</td>
<td>LP</td>
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*Table 1. Briefing sessions conducted during phase 162*

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 were RA’s 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 which 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.

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<thead>
<tr>
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<tr>
<td>Mangrove Mapping</td>
<td>JG/OC</td>
</tr>
<tr>
<td>Fish Survey Methodology</td>
<td>JG/RJ/OC</td>
</tr>
<tr>
<td>Fish Anatomy</td>
<td>JG/RJ/OC</td>
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<tr>
<td>Indicator Fish Family</td>
<td>JG/RJ/OC</td>
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<tr>
<td>Indicator Fish Species</td>
<td>JG/RJ/OC</td>
</tr>
<tr>
<td>Other Butterflies and Damsels</td>
<td>JG/RJ/OC</td>
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*Table 2. Science lectures conducted during phase 162*

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 conducting in-water surveys.

2.4 BTEC and Other Qualifications

2 BTEC’s were completed this phase, they are as follows:
1. Name: Charles Joshua Cupples
   BTEC type: Tropical Habitat Conservation
   Title: Variation in Shark Abundance in Relation to Fish Abundance.
   Mentor: Jane Giat & Olivia Cole

2. Name: Emily Yates
   BTEC type: Tropical Habitat Conservation
   Title: Morphological Structure of Corals in Frontier’s Study Sites
   Mentor: Olivia Cole & Rosy Jones

1 CoPE was completed this phase, it is as follows:

1. Name: Charles Joshua Cupples
   Mentor: Jane Giat

   1 Diploma in Tropical Habitat Conservation was completed this phase, it is as follows:

1. Name: Meg Young
   Title: Asessing the Reef Health by Baseline Survey of Fish Indicator Species and Benthic Cover.
   Mentor: Jane Giat & Rosy Jones

3. Research Work Program

3.1 Baseline Survey of Coral Reef Health 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. polypekadion*, *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 3. Survey site coordinates*

<table>
<thead>
<tr>
<th>Site Name</th>
<th>GPS coordinates</th>
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<tbody>
<tr>
<td>Bikini</td>
<td>S 18°23’40.1”</td>
</tr>
<tr>
<td></td>
<td>E 178°05’26.0”</td>
</tr>
<tr>
<td>Mala’s</td>
<td>S 18°24’10.5”</td>
</tr>
<tr>
<td></td>
<td>E 178°05’58.2”</td>
</tr>
<tr>
<td>Rabbit</td>
<td>S 18°24’07.5”</td>
</tr>
<tr>
<td></td>
<td>E 178°06’09.9”</td>
</tr>
<tr>
<td>Vuvalae</td>
<td>S 18°24’07.6”</td>
</tr>
<tr>
<td></td>
<td>E 178°03’54.9”</td>
</tr>
<tr>
<td>Wreck Reef</td>
<td>S 18°22’48.22”</td>
</tr>
<tr>
<td></td>
<td>E 178°05’18.3”</td>
</tr>
<tr>
<td>Snapper</td>
<td>S 18°24’56.7”</td>
</tr>
<tr>
<td></td>
<td>E 178°04’04.4”</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 Naiseuseu and the site is not visited for tourism and is a non-tabu 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 south easterly, 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 south easterly 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.

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 metre 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.

3.1.3.1. Indicator Fish Species Survey

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.

The 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.

3.1.3.2. Benthic Lifeform Survey

Medium-scale monitoring is used to assess the occurrence of coral recruitment and composition of the underlying benthos. During this survey RAs will lay their survey tape, swim back to the starting point. They will a 50 cm x 50 cm quadrant every 5 metres, producing 10 recorded quadrants per transect, recording the benthic composition within each quadrant.

**Surveyor Roles:** RAs undertook various roles during benthic surveys depending on the data being collected and the level of training they had received. As benthic lifeforms are much easier to learn than fish identification, RAs that are on project for four weeks or less will be able to carry out the survey.

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

The role of the quadrant holder was to lead the dive and therefore keep track of all surveyors’ air consumption, dive depth and survey time, in addition to navigating bearings. Quadrant holder will hold the quadrant every 5 metres while the data recorder counts the live benthic cover and underlying substratum. The following data will be collected along each transect:

1) Live benthic cover recorded at 5m intervals, producing 10 recorded quadrant per transect.
   a. Scleractinian corals will be categorized as: Branching, Corymbose, Encrusting, Foliaceous, Massive, Tabular, Columnar, or Laminar.
2) Underlying substratum (i.e., sand, rock, live rock, rubble, or dead coral) quantified at 5 m intervals,

This survey can be taken together with the fish indicator species survey by combining the role of physical surveyor and quadrant holder.

3.1.4 Results

3.1.4.1. Indicator Fish Species Survey

The result of 162 survey data showed that there was a significant recovery in fish abundance ($F = 15.96, p = 0.0001$) compared to data from surveys collected in last quarter (Figure 5). Most significant increase was observed at Wreck reef where there are ~90% increase in fish
abundance, followed by Mala’s Rock with ~68% increase, Vuvale with ~64% increase, Snapper with ~62% increase, Bikini with ~42% increase, and least was observed at Rabbit with ~39% decrease in fish abundance. However, compared to fish abundance of the same time period last year (152 quarter) the fish abundance on 162 quarter is still significantly less ($F = 33.59, \ p < 0.0001$). Wreck reef that had the most increase compared to last quarter, only has ~31% of the fish abundance of previous year. Worst is Bikini which only has ~30%, then Mala’s Rock with ~49%. Vuvale is doing quite well with ~60% stock recovery and Snapper seem to reach the same abundance as the previous year.

Conversely, the species richness result showed a significant decrease ($F = 60.72, \ p < 0.0001$) in the number of species observed in each site during 162 compared to 161 (Figure 6). Most significant decrease in the number of species encountered was at Rabbit with ~56% decrease, followed by Bikini with a ~49% decrease, Snapper with a ~32% decrease, Mala’s Rock and Vuvale with a ~28% decrease, and finally Wreck Reef with a ~23% decrease in species richness. The species richness seems to be back to similar levels that were seen in the 152 quarter as there are no significant differences in the species richness between 162 and 152 quarters ($F = 0.01, \ p = 0.927$).
Family richness on the other hand showed a significant decrease when compared to last quarter ($F = 57.84, p < 0.0001$) and last year ($F = 62.35, p < 0.0001$). Bikini has a ~54% and ~50% decrease compared to 152 and 161 respectively. Rabbit has a 31% and 48% decrease, Vuvale has a 48% and 55% decrease, Wreck Reef has a 28% and 22% decrease, Snapper has a 5% and 38% decrease, and finally Mala’s Rock has a 16% and a 50% decrease in family richness compared to 152 and 161 quarters respectively.

The size composition of fish observed had again shifted quite significantly from 161 to 162 (Figure 8). 161 was dominated by fish in the size range of 10 - 20 cm, however, little to no fish surveyed were larger than 30 cm. The >50 cm category was retired from use last quarter because no fish surveyed were in that size category. 162 however was...
dominated by fish in the size range of >10 cm. Fish larger than 30 cm in size are present in Bikini, Mala’s Rock, and Wreck Reef although in very small number.

Figure 8. Average size categories of fish per transect from 162 quarter compared to 161 quarter.

3.1.4.2. Benthic Lifeform Survey

Benthic lifeform surveys from the 162 quarter showed an overall average of 33% coral cover from all study sites (Figure 9). The highest was found at Mala’s rock, with 45% coral cover, and the lowest was found at Vuvale, with 16% coral cover. The morphologies assemblage is dominated by Encrusted and Corymbose corals, followed by Branching and Massive corals.

Figure 9. Total coral cover and their morphologies from 162 quarter.
Overall, there was approximately 3.7% of dead coral and 3.5% of bleached coral observed in all study sites during the 162 quarter (Figure 10). The largest proportion of dead coral was observed at Mala’s rock, with 6.5% dead coral, and the smallest at Vuvale, where no dead coral was observed at all. The majority of the dead coral are Branching coral followed closely by Corymbose coral. There’s also a large amount of dead Foliose coral (0.8%) in Rabbit and Digitate coral (1.6%) in Snapper. The most bleached coral was observed at Rabbit, with 7.4% of bleached coral, and the least at Vuvale where 1.2% of the coral is bleached. The majority of the bleached coral were Branching coral and Corymbose coral. However, there was a large number of bleached Digitate coral (6.4%) found in Rabbit.

![Figure 10. Total dead coral and bleached coral and their morphologies from 162 quarter.](image)

### 3.1.5 Discussion

The significant recovery of fish abundance on all sites suggested seasonal effect. There’s a possibility that the months from March – June are breeding months, attracting more fishes to the reef (Cohen & Alexander 2013). However, the fish abundance is still very low compared to the data from the same months last year. This means fishing pressure still affects the fish stock in Beqa lagoon massively. Research on fish behavior showed that fish used visual cues 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 a random shape of similar size (Ferrari et al. 2010). This means that it is very possible that fish may have associated diver presence with spear fishing, which in turn causes the fish to hide or run away from surveyors.

Overfishing is often known as the 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).

The decrease in family richness and the shift in size ranges that dominate the reef is also consistent with the effect of fishing pressure. As large top predators are removed from the area (as indicated by the lack of fish >30 cm surveyed and the decrease of large fishes family) 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. However, this quarter the dominating size class is < 10 cm. This is similar to last year’s report, which gives more support to the seasonal effect over fish size assemblages (Cohen & Alexander 2013).

The decrease in species richness from last quarter back to the levels of this time last year indicates seasonal effect. There’s a high possibility that Beqa lagoon have transient fish species that used the reef as either breeding or hunting grounds (Cohen & Alexander 2013). It seems that January – March is the breeding period for some fish species, which attracts their associated predators to Beqa lagoon, and thus increases species richness. The months April – June is where we observe large numbers of small fishes that survived larval stage, and hence the larger number of fish <10 cm is observed. Consequently, the enforcement of the no take area or “tabu” area is essential in the first quarter of the year to help with the recovery of fish stocks.

Three of our sites Mala’s rock, Bikini and Rabbit were already located in “tabu” areas where locals are not allowed to fish (FLMMA, 2013). This indicates that there are other sources of fishing pressure or that locals have ways of circumventing the “tabu” law. Personal communication with the locals indicates that both are happening. Fishing vessels from Suva have been sighted in Beqa waters to fish (pers. Comm. 2016) and locals have been putting in fishing lines in the “tabu” area and pulled up when they had passed the areas (pers. Comm. 2016).

Furthermore the no-take areas (NTA) or “tabu” areas were established almost randomly without consideration for the reef system as a whole. Fernandez et al. (2009) suggested that for a NTA to work it has to represent at least 20% of the reef and non-reef bioregion. He also suggested that the NTA should form a network that represents all habitat types within the region (Fernandez et al. 2009). Our results highlight 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” areas that benefit biodiversity and local fisheries. We did not have the resources and expertise to conduct said studies during this quarter.

Benthic cover surveys revealed a relatively healthy ecosystem. The overall coral cover was close to the average coral cover throughout the country, which is estimated at 45% (Morris and Mackay, 2008). Sykes and Lovell (2009) reported that Fiji’s reefs were remarkably resilient to sudden catastrophic events. The general status of Fiji’s coral reef was considered to be stable, with reefs recovering following disturbance events, and with little evidence of widespread and prolonged stress, damage or loss of coral cover (Chin et al., 2011). This is
reflected by the low number (<4%) of dead coral and bleached coral that is observed in our study sites.

From this it seems as though our study sites suffer from extreme fishing pressure. The fishing activity itself did not cause much damage to the reef system. Whether this is caused by non-destructive fishing methods used by locals (line and spear) (pers comm. 2016) or because Fiji’s reefs were remarkably resilient (Sykes and Lovell, 2009) remains unclear. Longer term monitoring of benthic assemblages is needed to judge the resilience of the reef throughout the year.

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

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 (Polidoro 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).

Fiji has the third largest mangrove area in the Pacific Island region, after PNG and the Solomon Islands. Mangrove areas are one of the better wetland types inventoried in the Pacific Islands (particularly Fiji), though the information sources are fairly dated (Watkins, 1999). The mangrove area was estimated by Spalding et al. (1997) from a forest cover map prepared by the Ministry of Forests, Fiji based on a 1985 survey, with mangroves distinguished using the Fiji Forest Inventory carried out 1966-9. This gave a total mangrove area for Fiji of 517km². Largest areas are on the SE and NW Viti Levu shorelines, and the northern shore of Vanua Levu (Richmond and Ackermann, 1974). Only 19.7 km² of mangrove was recorded for Fiji by Saenger et al. (1983), an area which is not accepted by other writers.

Rehabilitation of degraded mangrove and inshore reef areas will increase their resilience to climate change effects. Site selection should consider value for money, the level of community or stakeholder support, benefits to adjacent systems and the relative risk of sea-level rise. Any rehabilitation program should initially remove the stress that caused decline, decide on whether to use natural regeneration or active replanting techniques, in which case use of local sources of seeds or juveniles will reduce loss of genetic variation across Fiji. This mapping exercise aimed to collect baseline data before rehabilitation commences, to enable demonstration of improvement in water quality, reef cover and fisheries with progression of the rehabilitation project.

3.2.2 Mapping Area

Survey done by the WWF showed that Beqa Island is one of the major mangrove habitat in Fiji, housing approximately 72 ha of mangrove. 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 was 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.

![Aerial photograph of mangrove wetland at Vaqa Bay, Beqa Island, marked by red square. Frontier Fiji Marine basecamp marked by red pin. (Source: Google Maps)](image)

Using major features visible on the aerial photograph, we determined the starting point of each transect. The start position of the transect was identified using the GPS and marked using flagging tape. A new data form was used for each vegetation zone along the transect. Notes were taken to help re-locate the position if a GPS was not available, such as marking the point with flagging tape. The transect lines were walked into the forest using a 50 m fibreglass tape. A compass was used to ensure that the transect was perpendicular to the shoreline and stayed straight. Notes were taken on which species were in a zone, which species were abundant, and which species were rare. The width of each zone was also measured (mm).

The degree of impact in the area was assessed at each observation point with a 15m radius. Impact was assessed on a scale from 0 to 5 where 0 is no impact and 5 is severely impacted (Table 4). The surroundings were 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 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>
</tr>
<tr>
<td>1</td>
<td>Slight Impact</td>
<td>76-95</td>
<td>Canopy of trees fairly continuous but some gaps. Some regrowth. Isolated cutting/striping of trees or some evidence of pigs digging up saplings.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate Impact</td>
<td>51-75</td>
<td>Broken canopy of trees with lower regrowth and recruitment areas. Some trees cut and stripped.</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 showing regrowth and there is bare mud.</td>
</tr>
<tr>
<td>4</td>
<td>High Impact</td>
<td>11-30</td>
<td>Only a few trees remain at canopy height. Extensive clearance and some recruitment, large areas of bare mud.</td>
</tr>
<tr>
<td>5</td>
<td>Severe Impact</td>
<td>0-10</td>
<td>Extensive clearance to bare mud, little recruitment, few trees remain alive</td>
</tr>
</tbody>
</table>

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

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

3.2.4. Results

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

Table 5. GPS coordinates of 6 mangrove transects in Vaga Bay

<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>

Approximately 1.26 ha of Mangroves wetland was mapped throughout the 162 quarter. There were four species of true mangroves and one species of associate mangroves (Figure 10). True mangroves dominated the wetland: Black mangroves (*Bruguiera gymnorhiza*) found on the landward edge with ~47% cover. The red mangroves (*Rhizophora stylosa, Rhizophora samoensis*,...
and *Rhizophora x selala* followed closely with ~37%. The majority of them were *Rhizophora x selala* (21% cover). The one associate mangrove species (*Barringtonia asciata*) was found by the high tide line and covered approximately 11% of the wetland. Canopy cover was mostly uniform with only 5% of bare patches throughout the area. Damage observed on the trees was mostly from storm damage. High tide marks varied around 50 – 60 cm on the landward edge and around 90 – 110 cm on the seaward edge. Seaward edge was littered with recruitments, most of them were black mangroves.

**Figure 10. Distribution of Mangrove Species in Vaga Bay**

### 3.2.5 Discussion

All four of true mangrove species present in Vaga Bay are members 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, which is sterile and only occurs if both *Rhizophora stylosa* and *Rhizophora samoensis* are present (Robertson & Alongi 1992). 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) except for *Rhizophora x selala* which are sterile. The majority of red mangroves observed being *Rhizophora x selala* raises concerns about the seaward recruitment.

*Bruguiera gymnorhiza* is a darkly coloured mangrove which only grows to 10 m in height. 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 which soon turn brown (Sheue et al. 2005). 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 19995). 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. The 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 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. The lack of recruitment observed at the seaward edge indicates a lack of growth in that area. This is likely to have been caused by sea level rise which naturally pushes the mangrove area landwards (Krauss et al. 2014). But since the landward edge in Vaqa Bay is dense rainforest (pers. obsv. 2016), the mangrove wetland is unable to expand inland and is likely become reduced in time. Another possible cause is the sterility of the dominating species, *Rhizopora x selala*. This may be remedied by a planting project that focuses on the two other species of red mangroves.

### 3.3. Identifying Blacktip Reef Shark Nursery Grounds
By: Rosalyn Jones

#### 3.3.1. Introduction

Fijian waters play host to a wide variety of elasmobranch species; from large, highly migratory sharks to coastal dwelling rays and reef sharks. Beqa Island is known globally for precisely this reason.

Blacktip reef sharks, *Carcharhinus limbatus*, are commonly sighted around Beqa. They are a coastal species found in tropical and sub-tropical reef systems. They can reach a maximum length of 1.8m and are easily recognised by the black tip and white sub-marginal band on their first dorsal fin (Castro, 1996). They favour reef flats and shallow lagoons, using reef systems as
primary hunting grounds. Blacktips are apex predators in many reef systems, including those in Beqa lagoon. Their reproductive cycle occurs over two years; a one year gesticulation period and a one year rest before mating again. Blacktip sharks can be classed as ecosystem engineers – having an above average effect on ecosystem processes (Killam & Parsons, 1989). This makes it imperative to protect them in order to preserve the health of the reef and its associated species.

Globally, elasmobranch species are in a state of severe population decline. The IUCN 2014 Red List classed blacktip sharks as 'near threatened' in their 2014 review. The main causes for decline in blacktips are fishing pressure, both for meat and fins, and being caught accidentally; termed by-catch (Fong & Anderson, 2002). Sharks in Fiji are relatively well protected. Fijian culture dictates that sharks are sacred and it is forbidden in numerous villages to harvest them (Rasalato et al. 2010). However, Fijian shark populations are still threatened by foreign fishing vessels in their waters and the demand for shark fins internationally. An effective way to protect a species is to focus conservation efforts upon areas of key ecological significance; for example nursery grounds (Hueter et al. 2005).

The concept of nursery ground use by some elasmobranch species has been widely recognized in scientific literature for decades (M. Heupel et al. 2007). These are generally classed as 'an area where young are born and reside as they grow towards maturity' (M. Heupel et al. 2007). Genetic studies have identified this behaviour in black tip sharks in New Mexico (Keeney et al. 2003). Keeney et al. (2003) also identified natal philopatry within the species; adults return to the same area to breed and give birth. This phenomenon results in genetic heterogeneity between sub-populations meaning that each individual stock requires protection to preserve species genetic diversity (Hueter et al. 2005).

However, there is no definitive method for correctly identifying a nursery area. M. Heupel et al. (2007) proposes classifying it under three key characteristics:

- Sharks are more commonly encountered in the area than other areas
- Sharks have a tendency to remain or return for extended periods
- The area or habitat is repeatedly used across years

These are widely accepted characteristics of elasmobranch nursery grounds and will be referred to regularly throughout this study. It is also important to account for the size ratio of the population when identifying nursery areas. If the population in the proposed area has a high proportion of juveniles it will also be an indicator of a nursery ground (Duncan et al. 2006).

Beqa has many possible bays and shallow areas that could be potential nursery grounds for blacktip sharks. The sandbar was selected as an initial point of study due to a high number of juvenile and adult blacktip sightings while on recreational visits.

Sandbar is positioned on the lagoon side of the barrier reef, to the west of Beqa Island. It is frequently visited by tourists, primarily from the Duveuni Luxury Resort, increasing boat traffic and noise pollution to the surrounding marine environment. It is also subjected to a high level of fishing pressure from residents of Beqa, both using long lines and spear fishing. Beqa residents
know it as a place where sharks are seen frequently, particularly blacktips. All scuba sites which are being used as a comparison are survey sites located inside Beqa lagoon.

This study hypothesises that the sandbar is a nursery ground for blacktip reef sharks. It also proposes and discusses the extension of the study to further assess other areas of Beqa lagoon where blacktips are regularly sighted. This will help to identify and compare other possible nursery areas through a long term monitoring programme. The overarching aim is to make recommendations regarding blacktip conservation management in Beqa.

3.3.2. Methodology

Following site selection, the sandbar was divided into two study areas as their depth and topographies vary significantly. Both sites extend for 50m from the edges of the sandbar.

<table>
<thead>
<tr>
<th>Site</th>
<th>Depth Range (m)</th>
<th>Topography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandbar 1 – facing barrier reef</td>
<td>0.5 – 2.5</td>
<td>Mainly reef with occasional sandy patches, small wreck close to barrier</td>
</tr>
<tr>
<td>Sandbar 2 – facing Beqa Island</td>
<td>0.5 - 14</td>
<td>Large sandy area with the occasional coral bombies</td>
</tr>
</tbody>
</table>

Table 1: Survey site specifics

Snorkel surveys were deemed most appropriate due to the relatively shallow depth ranges of the sites.

Surveyors swim in a 'sweeping' pattern through the site and count individuals appropriately; similar to a belt transect method. Each transect, or sweep, is conducted for 10 minutes which is timed by the observer using a dive watch. Minute breaks are kept in between transects as a minimum to ensure each replicate is independent. This also reduces the possibility of double counting an individual. Surveyors aim to conduct five transects during their 'in water' sessions if conditions are favourable.

Slates are used to record survey times, visibility (m) and current, demonstrated in Table 2. Current speed is divided into 6 categories; 0 being no current and 6 being a very strong current. If current is above 5 or visibility is <5m then surveys are suspended until environmental conditions improve.

Upon sighting a blacktip shark, surveyors record sighting time, length estimate (m) and interaction time – how long the shark was within sight for. Length estimate can give an idea of sexual maturity. Killam & Parsons (1989) identified three size classes in blacktip reef sharks which will be used to identify individuals as juveniles, adolescents or adults. Interaction time can be used to make implications of the behaviour of the individual. Short interaction times suggest that the shark was wary of the observer, whereas longer interaction times suggest that the individual may be used to human presence. The slate also has space for a 'comment' box. In this
area surveyors can record any specific markings the shark may have which would help to identify it in the future. Behaviour notes and sightings of other shark species can also be noted in this box.

<table>
<thead>
<tr>
<th>Transect no.</th>
<th>Start time</th>
<th>Sighting time</th>
<th>Length estimate (m)</th>
<th>Interaction time (s)</th>
<th>Additional Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.32</td>
<td>14.35</td>
<td>0.75</td>
<td>20</td>
<td>Came within 5m</td>
</tr>
</tbody>
</table>

*Table 2: Layout of the survey slate*

Surveys for both Sandbar sites are conducted on a weekly basis. Dedicated snorkel surveys started at sandbar on the 24/05/16. Thus far two have been completed, the second week being missed due to weather conditions and boat availability.

Data from regular dive and snorkel sites is also used as a comparison. This has been collected sporadically from the 01/05/16. Sharks are sighted opportunistically while conducting fish or coral surveys. Upon sighting a blacktip, length estimates and interaction times are recorded.

Statistical analysis of data this early in the study is limited due to the low number of transects completed; the reliability of such statistical outputs would be very low. For this reason only basic comparisons have been made in this report.

3.3.3. Results

Sandbar 1 recorded the highest number of individuals sighted; reporting five in total. Jane’s Rock and Vaga Bay both had one sighting. Surveyors at Sandbar 2, Mala's Rock, Wreck Reef, Snapper, Vuvale and Bikini all reported no blacktip sightings (figure 1).

*Figure 1: Number of individual sharks recorded compared by site*
With regards to the snorkel survey method, sandbar 1 had more transects completed than sandbar 2 by 4 transects. Snorkel surveys were completed at Jane's Rock only once whereas surveys in Vaga Bay were conducted 8 times. Scuba surveys across sites vary widely in number. Bikini was surveyed the most and Vuvale the least; 6 and 3 times respectively (table 3).

<table>
<thead>
<tr>
<th>Site</th>
<th>Survey Method</th>
<th>Number of surveying trips</th>
<th>Number of transects completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandbar 1</td>
<td>Snorkel</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Sandbar 2</td>
<td>Snorkel</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Jane's Rock</td>
<td>Snorkel</td>
<td>1</td>
<td>n/a</td>
</tr>
<tr>
<td>Mala's Rock</td>
<td>Scuba</td>
<td>4</td>
<td>n/a</td>
</tr>
<tr>
<td>Vaga Bay</td>
<td>Snorkel</td>
<td>8</td>
<td>n/a</td>
</tr>
<tr>
<td>Wreck Reef</td>
<td>Scuba</td>
<td>5</td>
<td>n/a</td>
</tr>
<tr>
<td>Snapper</td>
<td>Scuba</td>
<td>4</td>
<td>n/a</td>
</tr>
<tr>
<td>Vuvale</td>
<td>Scuba</td>
<td>3</td>
<td>n/a</td>
</tr>
<tr>
<td>Bikini</td>
<td>Scuba</td>
<td>6</td>
<td>n/a</td>
</tr>
</tbody>
</table>

*Table 3: Breakdown of survey methods and surveys completed per sites*

Length estimate and interaction time both vary considerably between shark sightings. The smallest individual was 0.5m in length and seen at Vaga Bay and the largest, of 1.6m length, at Sandbar 1. The smallest individual at Vaga Bay also showed the smallest interaction time of 3 seconds. Two individuals at Sandbar 1 gave the longest interaction time of 60 seconds each (table 4).

<table>
<thead>
<tr>
<th>Date of Sighting</th>
<th>Site</th>
<th>Length estimate (m)</th>
<th>Interaction Time (s)</th>
<th>Additional Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>14/05/16</td>
<td>Vaga Bay</td>
<td>0.5</td>
<td>3</td>
<td>Very shy</td>
</tr>
<tr>
<td>29/05/16</td>
<td>Jane's Rock</td>
<td>1.2</td>
<td>10</td>
<td>Seen at a distance of 10m</td>
</tr>
<tr>
<td>24/05/16</td>
<td>Sandbar 1</td>
<td>0.8</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>24/05/16</td>
<td>Sandbar 1</td>
<td>1.5</td>
<td>60</td>
<td>Stayed within 5m for 20s</td>
</tr>
<tr>
<td>24/05/16</td>
<td>Sandbar 1</td>
<td>1.6</td>
<td>10</td>
<td>Swam away quickly</td>
</tr>
<tr>
<td>11/06/16</td>
<td>Sandbar 1</td>
<td>0.75</td>
<td>60</td>
<td>Stayed within 2m for 15s</td>
</tr>
<tr>
<td>11/06/16</td>
<td>Sandbar 1</td>
<td>1.7</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: Details of each shark sighting*

During recreational time on the Sandbar on 11/06, two blacktip sharks of 0.5m and 0.4m respectively were sighted very close to the shore; in no more than 0.5m of water. Sharks of other species were also sighted while conducting surveys. At sites Bikini, Mala's Rock, Wreck Reef, Vuvale and Snapper, white tip reef shark are commonly sighted. The exact number of these sightings has not been recorded. At Sandbar 1 on 11/06 a 2m tawny nurse shark was sighted resting inside the wreck very close to the barrier lagoon.
3.3.4. Discussion

Preliminary data is extremely promising, especially in terms of determining whether sandbar is a nursery area. Juveniles and adults have been sighted, which is very exciting, and the presence of other shark species indicates that the area is also an important area for other shark species.

Blacktips were only recorded in three of the total nine sites; Sandbar 1, Jane's Rock and Vaga Bay. This could be related to the bottom topography of the sites. All nine sites are reef centric but the three sites where sightings occurred have a higher area of sandy patches. It is doubtful that depth is significant to overall blacktip shark presence as the sites are all relatively similar in depth. Further comparison of bottom topography between sites is needed to investigate this hypothesis further.

Alternatively, the differences between sites could perhaps be linked to the presence of white tip reef sharks, a species of reef shark also commonly sighted in Beqa Lagoon. Blacktips and whitetips very rarely occur in the same sites, due to inter-species competition. This is supported by preliminary findings; whitetips are regularly observed in all six sites where blacktips did not occur. Blacktips are also understood to be more evasive of divers than other shark species. The six sites where zero were recorded are all of our most frequently dived sites, with at least one visit per week. This is supported by evidence displayed in table 3; all sightings occurred when snorkel surveys were being conducted. Unless depth demands the use of scuba, snorkel sweep surveys will be used as the primary survey method.

On average, sharks at Sandbar 1 showed the longest interaction time when compared with Vaga Bay and Jane's Rock sightings; 33.4s compared to 3s and 10s respectively. This indicates that individuals at Sandbar 1 are more accustomed to human presence, which correlates with the tourist activity and high fishing pressure recorded. Individuals may have even started associating snorkelers with food as such a large proportion of locals spearfish while snorkeling. Blacktip sharks have been observed stealing fish from lines and fishermen (IUCN, 2014).

Conclusions drawn from preliminary data of such a small sample size are speculative at best. Continued surveying is crucial to identify statistically significant differences between sites. This is particularly important for Vaga Bay and Jane's Rock in order to distinguish whether the single sightings recorded are indicating key habitat areas for blacktip sharks or merely anomalies.

Continuing study will refer to the guidelines set by Heuter et al. (2007):

1. Sharks are more commonly encountered in the area than other areas
2. Sharks have a tendency to remain or return for extended periods
3. The area or habitat is repeatedly used across years

To meet these criteria as many new sites as possible need to be added to draw valid conclusions. Further studies will target sites with different depths, bottom topography and anthropogenic impacts. This extended approach ensures that guideline 1 can be confirmed.
Further studies will attempt to employ photo identification of individuals as a way to assess their tendency to remain in the area. Baby sharks use a small initial area for around 3 months then extend their nursery area. This happened in the gulf Coast of Florida where they were tagged (Heupel & Hueter 2001). Comparisons can be made to this study using photo identification techniques. If the results indicate a large movement of individuals, tagging projects can be pursued using contacts at the University of the South Pacific.

4. 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.

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