Assessing the effectiveness of a bottom up approach to marine protected area management: A study of Beqa Island, Fiji.

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Declaration

I hereby confirm that I am the sole author of this thesis and it is a product of my own academic research.

Joshua Peters
Abstract

This thesis considers the problems encountered when dealing with socially enforced protected areas, known as Tabu areas, using Beqa Island within Fiji as a Case study. By evaluating the health of the reef using indicator fish, coral cover, Coral:Macrolalgea and Coral:Expired Coral and looking at levels of overfishing using overfishing indicator fish. There were no statistically significant results between Tabu areas and non-Tabu, this shows the shortcomings associated with using a bottom-up approach and how they are not always effective. By incorporating government managed strategies, it is theorised about how we could improve the declining reefs which surround Beqa, in a way which are approved by local populations. By doing this a management plan can be initiated, this management plan considers each individual problem that these reefs face, peer-pressure enforcement, rules open to interpretation, boat routes passing through the current Tabu areas, little mangrove protection and reefs which need rubble removed and coral restoration. The management plan which is recommended suggests incorporating the government into these areas, providing enforcement, improving education, utilizing adaptive co-management, monitoring reef health and adding both coral and mangrove nurseries to the surrounding areas. These are recommended for a period of roughly 10 years, after this, it is recommended to revert to Tabu areas, with small amounts of government funding and monitoring, as the risk of Beqa Island losing its cultural identity was such a large concern. These recommendations are hopefully sustainable for the villages which rely on these reefs, as well as the flora and fauna which reside in them.
For Sharon and Wayne, who provided me with the means and the will to do this research.
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Acronyms and Vernacular

Qoliqoli- Fijian word for a traditional fishing ground. Not to be confused with the Qoliqoli bill of 2006, a piece of legislation which proposed transfer of propriety rights of said Qoliqoli.

Beqa (M-Ben-ga)- The island in which this study takes place. Pronunciation is often wrong, a “q” is said as a “g” and a “m” sound is put in front.

Tabu (Tan-Boo) – A bottom up marine protection strategy, areas are chosen by local chiefs in which fishing is prohibited, the main objective of this research is looking into the effectiveness of Tabu areas. Pronounced with a “n” after the ta-.

Taukei-(I-Ta-key)- Name of local population of indigenous Fijian people. Pronounced with a “i” sound in front.

MPA- Marine Protected area, in this instance used only to refer to government enforced and patrolled areas, not Tabus.

FLMMA- Fiji Locally Managed Marine Area Network, an organisation which helps to educate and manage local artisanal fisheries around Fiji.

IAT- Independent assessment team, proposed team which helps maintain and monitor management strategies.

TEK- Traditional Ecological knowledge, knowledge gained by speaking to experienced fishermen within the area.
“It is a curious situation that the sea, from which life first arose, should now be threatened by the activities of one form of that life. But the sea, though changed in a sinister way, will continue to exist: the threat is rather to life itself.” – Rachel Carson, 1951

1.0 Introduction

The small Pacific Island nation of Fiji, is composed of 333 islands, and has a population of about 892,000 (2015). Tourism is the largest economic sector in Fiji due to the many islands, coral reefs and attractive tropical climate. The capital city, Suva, is on the island of Vitu Levu, the largest Fijian island. Ten kilometres off the coast of Suva, is the island of Beqa. (WHO Fiji, 2017)

Beqa Island has an area of 36 square kilometres and a maximum elevation of 462 meters. Nine small villages are located around the coast of Beqa Island and are home to the 4000 inhabitants of the island (National Geographic Fiji, 2017). The island is a very popular tourist destination for SCUBA divers, it hosts two five-star dive resorts and has a six-star resort two kilometres off the coast. Nearly all inhabitants of Beqa rely on the reefs around the island either as a food supply or income through tourism. (National Geographic Fiji, 2017)

Benefitting from the help of local fishermen, volunteers and the local village chief from the town of Rukua, this project aimed to determine strategies for how to balance the conservation of these reefs, while allowing the island inhabitants to continue to use them as a food source, income, and tourism while causing as little damage as possible to the reef ecosystems as possible.
1.1 Rationale

This project aims to explore the efficiency of the current management strategies used in Beqa Island, Fiji and recommend potential improvements which could be made to the system.

This study will give insight into bottom-up, locally-enforced marine protected area management system known locally as “Tabus” used within an area that relies heavily on their coral reefs for sustenance, as opposed to top-down approaches of MPA management.

Fiji was chosen as the location of this study as Fiji's coral reef fisheries are mainly inshore, small-scale subsistence and artisanal fisheries and therefore do not often receive management attention at a national level (Teh L, 2009). Of Fiji's 400 traditional fishing grounds, referred to as Qoliqoli, around 70 are over-exploited while 250 are fully developed (Teh L, 2009). Beqa lagoon was chosen due to having no large-scale fishing, agriculture or horticulture. The only threats to reef health and biodiversity are small scale fishing and recreation (Baker, Frontier Publications, 2015). This allows the research to focus on the traditional fishing grounds and Tabu areas with little outside interference, allowing the isolation of factors leading to variations in data between Tabu and non-Tabu areas.

The two primary uses of the coral reefs around Fiji are tourism and fishing. Tourism within Beqa is reliant on the coral reefs, and their protection is required to maintain tourism activity. Fishing is extractive, taking from the reefs while potentially harming them, a practice which works against the tourism industry and finding a balance is necessary in the face of the expansion of both industries. Tourism brings in about USD 1.1 billion per year in Fiji, making up 37% of the country’s USD. The total value of Fiji's subsistence and artisanal fisheries is around USD 64 million per year (Fiji Country Profile: FAO, 2015). While the contribution of these fisheries to the national GDP is considerably lower than that of the tourism sector, it is the primary food source for most of the Fijian population, especially for those living on the remote islands of the nation (WHO Fiji, 2017).
Considering that coral reefs play a large part in the daily lives of Fijians - providing one of the main food sources - and have for many generations (Dixon, 2017), they have an outstandingly high bequest value. These reefs have an outstanding existence value, the sheer amount of rare and endangered species in these waters which could be protected is enormous. These two values cannot be described in purely monetary terms but should be considered when looking at the importance of implementing a management scheme which will affect the health of Fiji’s reefs.

By assessing Tabus as a management technique, we can evaluate how effectively it is working. Areas for improvement can be identified and recommendations for moving forward with this strategy proposed. Furthermore, improving upon this strategy to maintain the balance between conservation and use can allow for the utilisation of this method elsewhere. If the existing strategy is determined to be ineffective and no longer viable, a new management strategy should be implemented as soon as possible to stop further damage.

1.2 Research Frame

The aim of this thesis is to determine the effectiveness of community based marine management plans (Tabus) using the abundance of indicator species and reef health as indicators of success within the island of Beqa, Fiji. Observing both the reef health and indicator species offers a comprehensive look into the overall state of the reef. The data from these two variables can be combined to determine what attributes of reef Tabu areas offer the best protection, if any at all. Incorporating the local knowledge and desires of residents within the area managerial plans can strengthen the current weaknesses of Tabus in a way which is likely to be accepted by these same residents. This project will address and answer the following research questions.

1. What effect does the use of community allocated marine management areas have on reef health within Beqa Island Fiji?
2. What effect does the use of community allocated marine management areas have on indicator species abundance within Beqa Island, Fiji?
3. What are local fishers’ views on these areas, and how well respected are they?
The frame of this research is limited to one specific bay, which has very little outside anthropogenic influences. Tabu areas modelled off similar belief systems can be found within most Pacific island nations (Barlett, Maltali, Pedro, & Valentine, 2010). Community based management schemes are found within many developing countries with respect to coral reef management, such as those found within Eastern Africa or Central America (Gurney, Pressey, Cinner, Pollnac, & Campell, 2015). The knowledge gained here regarding which aspects of community enforced management are successful and which are unsuccessful can be applied to areas under similar circumstances and a deeper understanding can be formed, allowing for the progression and improvement of coral reef protection methods worldwide.
2.0 Theoretical overview

2.1 Coral overview

2.1.1 What is a coral reef?

Coral reefs are underwater, biologically diverse, ecosystems comprised of a lattice of calcium carbonate structures, which have been secreted by micro fauna, these are commonly referred to as corals. These calcium carbonate structures are secreted by polyps which have formed a symbiotic relationship with microscopic algae known as Zooxanthellae. This relationship is beneficial for both the corals and algae. The algae provide energy for the coral through photosynthesis in return for a safe habitat (Deas, 2005).

Corals and coral reefs are typically found between 3-30 meters’ depth and a low turbidity. Clear waters allow as much sunlight through as possible, maximising the amount of photosynthesis which can be performed as this is where 90% of the coral’s energy comes from. Temperatures between 28-32°C allow Zooxanthellae to be highly efficient without succumbing to stress (Deas, 2005).

The literature surrounding coral reefs is extensive with books dating as far back as 1955 “Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll” (Odum & Odum, 1955). This is one of the earlier examples, which goes into extensive detail over coral reef biology using a case study. Even earlier was the research done by Charles Darwin: “The structure and distribution of coral reefs. Being the first part of the geology of the voyage of the Beagle, under the command of Capt. Fitzroy, R.N. during the years 1832 to 1836”, where he went into classifications of different types of reefs. Since these early years in reef research, an immense amount of research has been done on coral fauna and flora, often focusing on threats to coral existence and management. One example of this is “The influence of resilience-based management on coral reef monitoring: A systematic review” (Lam, Doropoulos, & PJ, 2017), which focuses on management and highlights how, in recent years, there is a larger emphasis on assessment and research, using dynamic plans rather than the more traditional static plans. Armed with a large range of literature concerning reef management, successful aspects of reef management practises in comparable regions can
be applied to the improve the situation within Beqa Island Tabus, allowing for the most the most effective measures to be used.

### 2.1.2 Importance of reefs to the world

“Rainforests of the sea” is a term often used to describe coral reefs \(\text{\cite{Knowlton2001}}\), a large amount of fauna which resides within them have made them desirable sources of fish, crustaceans, and shellfish for communities for many centuries \(\text{\cite{NOAA2017}}\). As of 2017, they are estimated to make 18 billion USD a year globally from services and fish supply \(\text{\cite{WHO Fiji2017}}\). An estimate from 2017 \(\text{\cite{WWF2017}}\) states that 450 million people from 109 nations live within 100 km of a coral reef. Those residing near healthy reefs receive multiple benefits to local economies in multiple sectors including fisheries and tourism through the provision of harvestable resources and the more aesthetic contribution to desirable holiday locations, increasing revenue for: hotels, diving tours, restaurants and fishing trips \(\text{\cite{WWF2017}}\).

Coral reefs also provide more passive contributions to humans, working with mangroves they have a buffering effect on shorelines, slowing the momentum of waves. This has multiple benefits, it slows down coastline erosion acting as a natural barrier, reducing property damage and economic investment, protecting wetland areas which are also known to be fragile ecosystems \(\text{\cite{NOAA2017}}\).

### 2.1.3 Importance of reefs to Fiji.

As of 2014 a significant portion of the exports from Fiji relied on corals, these include but are not limited to: non-fillet frozen fish = 8.4% (USD97.6m), processed fish = 4.9% (USD57.6mi). fish fillets = 2.2% (USD25.4m), non-fillet fresh fish 1.7% (USD20.1m), molluscs 0.5% (USD5.77m), coral and shells= 0.2% (USD2.31m), processed fish = 0.12% (USD1.44m), and edible crustaceans = 0.021% (USD240k) \(\text{\cite{OEC2017}}\).

Due to a large amount of coral produce in the area, Fiji has little foodstuff imports, with only USD122m yearly and only USD104m with alcohol and tobacco removed \(\text{\cite{OEC2017}}\). This makes fisheries Fijis third highest economic sector. The loss of reefs and subsequently reef based fish, would not only decrease the amount of exports but also force imports to be raised for the country in order to sustain its population, shifting the economy to another sector.
which would more than likely have large negative economic consequences (Garcia, Rice, & Charles, 2014). On the larger islands of Fiji, this shift would be easier to deal with, however on smaller communities, which rely more heavily on corals, it could be devastating, and one such island which would suffer is Beqa (Mccarthy, et al., 2013).

When Fiji was hit by Cyclone Winston over 40% of the population were “drastically” affected, with the average fresh fish consumption going from 6 times a week to 2.5 in the areas most heavily hit, (Delany & Sautner, 2016) . These numbers were mainly due to damaged equipment, making reefs unavailable, it does, however, give a look into what the state of the country would be without coral reefs.

2.1.4 Importance of reefs to Beqa Island

Beqa Island relies on the corals which surround the island. Due to the islands’ high slopes and large forested areas, the only place which remains habitable is the shoreline, thus, all nine villages are located on the shore. While exact numbers and statistics have not been recorded on the island itself, per the local guide (Malakai Tabaka, Personal communication, August 14, 2016) roughly 60%-80% of the people on the island use reefs for fishing.

All fit and able male residents are required to fish in one way or another, either from a boat or with snorkelling equipment. In the absence of other duties, a large proportion of females either net fish from the shore or help sell fish on larger islands. Most of the fish caught is used as food in the villages or for trade for agricultural produce (Malakai Tabaka, Personal communication, August 14, 2016). In some seasons sea cucumbers are fished. While fishing for sea cucumbers, the rules of Tabu areas do not apply. In the few months in which they are in season, significantly more profit is made from their harvest than during all other months combined (Malakai Tabaka, Personal communication, August 14, 2016).

With a decline in coral reef health, these villages would no longer be able to sustain themselves, and the island’s residents would most likely have to migrate to the larger islands.
2.2 Threats to reefs within Fiji.

Coral reefs are one of the most vulnerable ecosystems on earth, due to large amounts of anthropogenic exploitation and their high susceptibility to the effects of climate change (Pratchett, Munday, Wilson, & Graham, 2011)

2.2.1 Warmer oceans

Since the 1950s, An overwhelming amount of data states that the atmosphere is warming due to increased usages of greenhouse gasses. In the years between 1950 and 2010, the average global average has increased by roughly 1.25°C (NOAA, 2011). While this may seem a negligible change, the small window in which corals can flourish is only around 4-5°C (excluding cold water corals), and long exposure (several weeks) to temperatures over 32°C can cause corals to undergo what is known as a bleaching event (Woodley, Downs, Bruckner, Porter, & Galloway, 2015). Bleaching occurs when corals expel the zooxanthellae from their tissues as the algae can no longer continue the symbiotic relationship. Zooxanthellae give corals their bright and distinguishing colours. Without them, these corals are a bright white colour as their calcium carbonate skeleton is exposed. Bleached corals are weaker, and more vulnerable to disease but can still survive in this state for long periods of time. These widespread bleaching events are becoming more and more common in recent years (Woodley, Downs, Bruckner, Porter, & Galloway, 2015).

Some small amounts of localised bleaching occur in Pacific nations during most summers. The first recorded bleaching event was in 1979, with 60 separate events occurring between 1979 and 1990 (per NOAA, 2017). Since 1990 their frequency has increased even more, with 2014-2017 being one large continuous bleaching event (NOAA, 2017).

Recent (Hooidink, et al., 2016) projections have been made by the new Paris Agreement, and many outcomes have been predicted. Hooidink, et al. (2016) used multiple models to predict when various countries will be exposed to annual severe bleaching, with the global average being at 2043 and 99% of the world succumbing to these events by the end of the century, with most of Fiji being around the year 2050, and Beqa Island only at 2035.
2.2.2 Ocean acidification

The pH of the waters around Beqa already dropping by 0.5 since 1991. Doney, Ruckelshaus, Duffy, & Barry (2012) describes ocean acidification as “Rising atmospheric carbon dioxide (CO₂), primarily from human fossil fuel combustion, reduces ocean pH and causes wholesale shifts in seawater carbonate chemistry.”

In September of 2016, the concentration of carbon dioxide exceeded the threshold of 400ppm (parts per million) with this still rising and expected to hit 500ppm before 2050. The increased acidity caused by this added carbon dioxide is a cause concern for coral reefs, as it decreases the levels of biogenic calcium carbonate production and may nullify the growth of reef calcifies which are vital for maintaining a coral reef (Pandolfi, Connoly, Marshall, & Cohen, 2011).

Ocean acidification is a widely-researched topic in recent years, and this research has yielded multiple predictions of the effects of ocean acidification, covering all aspects of the marine environment from deep sea to the shoreline (Orr, et al., 2005). Feely, Sabine, Hernandez-Ayon, Lanson, & Hales, (2008) show that there is sufficient evidence to suggest that the effects of anthropogenic ocean acidification are reaching deeper water by observing acidified upwelled water on the continental shelf around Central America. (Guinotte, et al., 2006). The authors predict that while the deep sea will be less vulnerable until 2099, up to 70% of tested environments will have negative impacts caused by ocean acidification (Feely et al., 2008).

The predicted effects of ocean acidification have been researched in over 200+ published papers. Kroeker, et al. (2013) have done an extensive analysis of these papers, putting them into comparable terms. They show that the most vulnerable marine biota are coral residing larvae, with mollusc larvae being particularly vulnerable. All of this reviewed research revealed that those organisms in comparatively warmer waters are the most vulnerable.

2.2.3 Crown of thorns (Acanthaster planci)

The sea star Acanthaster planci, more commonly referred to as the “crown of thorns” are predators which feed on reef building corals. These sea stars are prone to population outbreaks leading to an emergence of large packs of the animals, which can inflict widespread damage to coral populations (Kayal, et al., 2012). While the cause of these
outbreaks is currently widely contested and subject to large amount of scientific controversy, currently the most supported theory is that while in larval stage, the crown of thorns requires large amounts of nutrients, and that increasing anthropogenic run off in recent years could be responsible for providing these large amounts of nutrients to the larvae (Kayal, et al., 2012).

As Brodie et al (2006) suggests in a case study on the Great Barrier Reef, there could be a direct relationship between the nutrient content and crown of thorn population. Nutrient discharge from rivers into the Great Barrier Reef has increased four times, and within these areas, the amount of A. planci larvae is double that of surrounding areas with larval survival rates being 10 times that of surrounding areas when just double the amount of large phytoplankton is present.

Crown of thorns sea stars have been greatly responsible for the decline in coral reef coverage in the Great Barrier Reef within recent years. Since the 1960s, divers have killed or removed more than 17 million A. planci from Indo-Pacific coral reefs. One reason A. planci are so hard to manage are that the drivers of their population explosions are largely unknown, despite a large amount of research, and current management techniques, therefore, focus on reducing all possible causes of A. planci proliferation (Babcock RC, 2016). A. planci is a very large concern for pacific islands and could well be a leading threat to the health of the coral reefs of Fiji.

2.2.4 Overfishing

Overfishing has several formal definitions, all which generally describe it as the act of removing fish from an area at a quicker rate than they can reproduce, eventually leading to the overall degradation of a population, and is therefore a non-sustainable use of ocean resources (Zaneveld, Burkepile, Shantz, & Pritchard, 2016).

Overfishing is considered a widespread problem; worldwide it is estimated that 52% of fish stocks are fully exploited, 20% are moderately exploited, 17% are overexploited, 7% are depleted and 1% are recovering from depletion. Overfishing is most commonly seen in recreational and artisanal fisheries such as those surrounding Beqa Island (Teh L, 2009).
There are many examples of how much damage overfishing can do to an ecosystem, one of the most popular examples are that of Newfoundland and Labrador, Canada. This case study highlights the ecological and economical dangers associated with overfishing. In 1992 the region’s Atlantic cod fishery suffered greatly when the fish appeared to disappear overnight (Hutchings & Myers, 2011). After overfishing for several decades, they had fully depleted the stock levels, causing 40,000 people to lose their jobs and livelihoods, leaving the ecosystem in ruins and the whole area economically in a state of decay. The impacts were still being felt 20 years later, with the cod never fully returning to the area and the local population struggling to replace their main source of income (Hutchings & Myers, 2011).

Newfoundland is an extreme example of overfishing however it is a forewarning to the damage overfishing can have on an economy. While the effects may vary based on local circumstances, a fishery collapse could happen to Beqa Island if its reefs are not properly monitored and managed (Hutchings & Myers, 2011) . “Ultimately, managers will need to explicitly address conflicts between increasing demand for fish and the need to maintain ecosystem services” (Pratchett, Hoey, & Wilson, 2014, p. 42) . It is important to actively prevent overfishing, while many of the other problems associated with coral reefs must be dealt with on an international level, but should not be overlooked, overfishing can be managed locally with proper management plans and research. That is the aim of this project.

2.3 Indicator species in Fiji

Indicator species are a sub-section of focal species, those which are believed to be valuable for management, understanding, and conservation of the ecosystem in which they reside (Crosby & Reese, 1996). Focal species also include: keystone species, umbrella species, and flagship species, the indicator species are those which use an ecosystem for protection, food and recruitment, therefore they reflect change in ecosystem processes. This makes them the most used for the understanding of reef management and they will be used for this project. There are many thousands of marine species found in the Pacific, and it is therefore not practical to survey these. An indicative subset of species is therefore chosen to reflect the population (Caldwell ZR, 2016).
2.3.1 Indicator fish showing overfishing

The indicator species which have been shown to most effectively indicate large amounts of overfishing in reefs are parrotfish (*Scaridae*) (20cm+), Snapper and emperor fish (*Lethrinidae*), barracudas (*Serranidae*), sweetlips (*Sphyraena*) and larger groupers (*Plectorhinchus*) (30cm+) (Hourigon, Tricas, & Reese, 1988). A Global Assessment of Human effects on Coral Reefs (Hodgson G, 1999) identifies these families as some of the best indicator families for showing overfishing as they are found in reefs worldwide and are often main targets for fishermen. In Beqa Island, these are also the fish species that are mainly caught (observational data), because of their large size and ease of catch. A comparative loss of these six fish families within some areas of the reef would provide evidence of overfishing in these areas (Crosby & Reese, 1996).

It should be noted that the effectiveness of certain indicator fish is under scrutiny. Due to the large and complex nature of coral reefs, indicator fish can show more than one form of damage to the ecosystem. For example, declines in sweetlips populations can be an indicator of several different bad fishing practises, including overfishing, dynamite fishing, cyanide fishing or targeted fishing for the use of aquariums. There have been no documented cases of dynamite, cyanide or targeted aquarium fishing occurring in Beqa, as such, declines in the population of sweetlips are assumed to be caused by overfishing, the same concept can be applied to the grouper family (Hourigon, Tricas, & Reese, 1988).

2.3.2 Indicator species to show reef health

Indicator species can be used to show the general “health” of a reef compared to other surrounding corals (Hourigon, Tricas, & Reese, 1988). This is because corals are sessile and have no way to avoid stress events, the reef fishes, however, are mobile and can move between reef systems to a healthier area. Studies show that damselfish (*Chaetodontidae*) and butterfly fish (*Pomacentridae*) are most sensitive to reef degradation (Hourigon, Tricas, & Reese, 1988). Angelfish have been shown to favour more structurally complex reefs and are sensitive to physical degradation such as anchor damage. Damselfish and butterfly fish both use the reef for protection and foraging, damselfish feed on Copepods and Caridea while butterflyfish are mainly corallivores and therefore rely on the live tissues of corals as their primary source of sustenance, with some species such as the chevroned butterflyfish which
feed exclusively on coral will leave reefs following only a small amounts of degradation (Crosby & Reese, 1996). The large metabolic demand of these species means they must have a constant supply of live corals to feed on, which makes them the most used and reliable reef indicator fish (Christine, 2010; Pratchett, 2005).

These species can provide an early warning system that the health of a reef is in decline, caused by various anthropogenic effects. Awareness of such declines would encourage change, thus supporting the local communities such as Beqa, which rely on the reefs to continue to use the reefs in a sustainable manner (Mccarthy, et al., 2013).

2.4 Benthic Environment

The benthic environment of coral reefs is considered a complex biological community, with varying levels and proportions of organisms. Several biotic and abiotic factors contribute to what is known as the community composition within the reef (Bruce, Meirelles, & Garcia, 2012).

Coral community composition is very fragile. Changes to this composition can be used to indicate that various problems are occurring within the reef. Reef structures are very reliant on reef building corals known as hermatypic corals, which provide the structures used for both habitat and recruitment for most reef residing fish (McField & Patricia, 2007). A “healthy reef” should be comprised of a high level of hermatypic corals, moderate levels of sponge and coralline algae, low levels of macroalgae and almost no rubble, dead coral and bleached coral. Non-coral dominated reefs will lead to a collapse of reef structure, with the fauna migrating to more complex and healthy reef habitats (Hourigon, Tricas, & Reese, 1988). If this happens to the reefs surrounding Beqa Island where locals fish, their livelihood may be endangered.

Coral cover, and the “Coral:Macroalgae” and “Coral:Expired coral” ratios are three statistics which can be used to show the overall health of a reef (Bruce, Meirelles, & Garcia, 2012). Hermatypic corals are relied on so heavily by the ecosystem fauna that their percentage of cover on the reef gives a useful statistic when comparing to other reefs. This number is also easy to compare between sites, making it widely used in reef research involving benthic substrates (Bruce, Meirelles, & Garcia, 2012). The Coral:Macroalgae ratio provides a good
indication of which of the two is winning in the competition to use up the available space. The live Coral:Expired coral ratio is used to indicate how much of the reef has been destroyed, often for various anthropogenic reasons, such as anchor damage, SCUBA damage and bleaching. Expired coral has little value to the surrounding people or to marine fauna, using up valuable space in an environment where space is already limited (McField & Patricia, 2007). The dead coral can be used for coral mining, although this will be a one-time profitable strategy to clear dead coral and make room for further management strategies (Albert, Olds, Albert, Cruz-Trinidad, & Schwarz, 2015).

Coral cover, Coral:Macroalgae and live Coral:Expired coral all naturally vary from site to site. Variation may be due to temperature difference, wave energy or more direct anthropogenic effect, making a healthy reef hard to define (McField & Patricia, 2007). If there are multiple reefs in a crowded location, however, such as in Beqa, then comparing them with each other is a viable method that can shows which reefs are potentially the healthiest in that area. Healthy reefs are needed within Beqa to maintain a sustainable lifestyle and the larger the area in which fish spawn, the easier the enforcement of management plans, allowing for more fishing in the area.

2.5 Fiji’s coral management

To keep the review of Fiji’s current law and legislation as concise as possible the only book used to review the artisanal fishery law and governance is “A Review of Near Shore Fisheries Law & Governance in Fiji” (Sloan & Chand, 2015). This is a recent document, which summarises all the recreational, artisanal and commercial fishery laws and legislation into one document.

2.5.1 Fisheries Act 1942

The key piece of legislation involved with the regulation of the fisheries surrounding Beqa is the 1942 fisheries act. The primary role of this piece of legislation is to restrict fisheries management, limiting the use of permit and licensing in regards to artisanal fisheries. This means that the local population (Taukiei) have rights to each artisanal fishing ground (Qoliqoli) and determine their own laws for fishing in these areas. All Taukiei members fishing within a Qoliqoli must be registered with the local government, however, no permit is
required beyond this if fishing is for subsistence purposes. A fishing permit is, however, required for all those not fishing within their own Qoliqoli. Apart from this, all other responsibility falls to the Taukiei members, they are charged with mapping the Qoliqoli areas and resolving any disputes that may arise over membership. All mapped Qoliqoli areas are submitted to the affairs board and kept there for future reference.

The power to enforce laws and regulations pertaining to the use of Qoliqoli is vested within the state, who can make all final decisions, and these responsibilities are often delegated to the chief of the Taukiei to which the Qoliqoli belongs. The chief of the local Taukiei people may provide a permit for someone from outside the area to fish within their controlled Qoliqoli. However, if the government wishes, they can enforce laws which supersede the Taukiei traditional fishing rights. This is because while the Chief has control over the land, the land still belongs to the government. This can be enforced to prohibit the permit of certain types of fishing, to limit fish size, to limit fish catch and to place restrictions on nets, however, currently the chiefs in Beqa have enforced none of these, opting for a straight out ban on all boat fishing activities.

2.5.2 Local education.

The Fiji Locally Managed Marine Area Network (FLMMA) is an organisation that helps educate and manage local artisanal fisheries around Fiji. The members themselves have no power to enforce any laws and allow the Qoliqoli communities to make all decisions. The FLMMA use local knowledge and relevant information to recommend practises that will benefit the constituent families and villages. This may occur through the recommendation to close areas, to stop fishing a species or stop the use of certain fishing gear.

Beqa Island has received advice from the FLMMA and in September of 2004 the Ministry of Tourism, the University of the South Pacific and the Native Land Trust Board assisted the residents of Beqa with making a Qoliqoli management plan. This involved a two-day workshop, which took place in the village of Rukua. This workshop used local advice to produce a rough community guide management plan using technology that would not usually be available to the community, such as geographic information systems (MSP, 2014).
3.0 Research methods

3.1 Study site

Beqa Lagoon bay, off the coast of Beqa Island, Fiji was chosen as the research site. This bay supports four coral patches, two of which are protected by the laws of Tabu, and two of which are not (see Figure 1). Beqa lagoon was chosen for its lack of large-scale fishing, agriculture and horticulture. The only threats to reef health and biodiversity are small-scale fishing and recreation (Baker, frontier-ca publications, 2016). Below is a description of each of the 4 coral patches that were studied.

Figure 1 A map of Beqa corals and Tabus Created using Google Earth.
1. Bikini (Tabu Area) – Bikini has an average depth of approximately 7.5 meters with a maximum depth of 20 meters. The Bikini area is rarely visited by tourists and is a no-take zone, with exceptions being made for important celebrations or funerals.

2. Rabbit (Tabu Area) – Rabbit is an inshore site the average depth is 6 meters and the maximum depth is 12 meters. There is absolutely no tourism here and the entire area is a no-take zone, except for fishing from shore.

3. Mala’s (Non-Tabu) – Mala is a partially sheltered site, with three rivers close to the dive site, causing small amounts of fresh water mixing within the area. The average depth is just under 8 meters, however, there is a steep outer ridge which can hit a maximum depth of 18 meters. The site is utilised mainly for parrotfish, unicorn fish, porcupinefish, rabbitfish, surgeonfish and goatfish harvesting. This site receives little tourism.

4. Vuvale (Non-Tabu) – Vuvale is an extremely large, sheltered, site. The site is made up of various patch reefs with inter-dispersed coral bombies. The average depth is 8 meters, with a maximum of 16 meters. This site is furthest out of the bay, it is mostly fished by cucumber fishers but is a desirable spot for diving if the conditions are safe enough to make it.

3.2 Control conditions

To keep all data as reliable as possible, multiple parameters were restricted. Dives were done between the hours of 10am and 4pm, to prevent possible changes in fish abundance and variation in prominent fish species depending on the level of sunlight. To restrict the effects of current and turbulence, on any day where the wind was above a Beaufort 4 the site was classed as “not safe for diving”. The out-of-bay dive sites (Vuvale and Bikini) are vulnerable to high currents. In these conditions divers encountered multiple problems such as tape measures moving position and fish seeking shelter. If these problems got out of hand the dive was cancelled, a result which occurred three times. These difficulties had a possible consequence of skewing the results, which could have shown a high abundance of larger fish that can withstand these conditions and a lower abundance of species more vulnerable to high current speeds.

Within the bay (Rabbit and Malas) diving visibility could be very low. If the visibility was at any point less than 7 meters the dive was deemed too unreliable and was called off. The diver who was performing the fish transects needed to see at least 5 meters in any direction, and a
2-meter buffer was added for safety. To avoid interference from local fishermen, which may cause dispersal of fish, if a fisherman was at the dive site at the time of arriving, or arrived during the dive, it was called off. While this scenario was planned for, it never occurred.

The diver performing the fish transect had to undergo multiple practise dives and size calibration tests to ensure that data would be correctly and reliably recorded. The size calibrations were performed underwater, showing the participant multiple fake fish of a known length at varying distance in a random order. Only when 100% had been achieved three times in a row would actual dives take place.

3.3 Team Roles

Each dive consisted of three members, each with multiple roles. To keep all results as reliable as possible, the roles of the members did not change between dives. The team leader was the first member, this member’s role was to ensure safe dive practise, keep the other divers organised, and make sure there were no mistakes in data collection. The dive leader was also in charge of bearing directions and taking the photos of the benthic environment. The first research assistant’s tasks were to follow behind the dive leader laying the tape, measuring and recording the data for the fish transects. The second research assistant’s job was to hold the quadrat at a steady level for the benthic survey.

Upon arriving at the desired site the boat would tie to the pre-set anchor lines. The team of divers then followed the anchor line down to reef level. Next, they swam in a pre-set bearing to one side of the anchor. These pre-set bearings had been worked out to ensure that at no point would surveying leave the boundaries of the reef. After 10 meters in the pre-set direction a tape-measure was laid perpendicular to the existing tape, from here the 50m tape was laid out, with the dive leader at the front with a compass, followed by the two assistants. After the tape measure had been set, the team swam back to the start point and waited five minutes to ensure that fish abundance returned to normal levels. On a 50m transect Dickens (2011) showed that without a five minute wait the presence of the invasive action of SCUBA can decrease fish levels by on average 29%. This process is repeated at 10m intervals each side of the anchor line, and with each 50m tape measure providing 2 transects, this gives rise to a total of 20 transects per dive site.
3.4 Fish Transects

Once the five-minute waiting period was over, the first research assistant set off at a slow pace roughly 2.5m above the transect line. Every fish observed on each side and in front of the diver within a 5m distance was recorded, creating a 5m x 5m x 5m cube observation box. This was done for 20 meters before completion. The 5m in front did not apply after 15m and no fish off the end of the transect were recorded. Continuing forward, from 20-30m no data was recorded, until the next transect started at 30m and continued up to 50m. To record this data, research assistant one carried a slate, on this slate all fish that occupied the area were written, either in family or species form, depending on whether just the family name was indicative of the individual(s) or if it was species dependent. This slate also had 6 columns to allow for size, these size categories were, <10cm, 11-20cm, 21-30cm, 31-40cm, 41-50cm and 50cm+. The fish belt survey was chosen over stationary point count or a timed swim for both ease and the commonality of the method in the literature, allowing results to be easily compared with other literature. While it was found that 89% of researchers use one of the three techniques described, out of these 89% 56% used belts transects. This study aims to compare the use of Tabu areas with law enforced MPAs, requiring that the methodology used here be chosen for its ability to compare widely within the reef management literature. (Caldwell ZR, 2016). The surveyed species and families were selected as they represented the bulk of the visually apparent benthic reef fishes in Beqa. Previous research around the area (Baker, Frontier Publications, 2015; Baker, frontier-ca publications, 2016) only recorded the presence of the species named below within the area.

The full list of the 74-surveyed species and families recorded during this study is as follows: Bicolour Angelfish, Lemon peel Angelfish, Regal Angelfish, Semicircle Angelfish, other Angelfish. Great Barracuda, Yellowtail Barracuda, Blackbacked Butterflyfish, Dotted Butterflyfish, Eastern Triangle Butterflyfish, Humphead Bannerfish, Latticed Butterflyfish, Lined Butterflyfish, Longnosed Butterflyfish, Masked Bannerfish, Pacific Doublesaddled Butterflyfish, Penant Bannerfish, Raccoon Butterflyfish, Redfin Butterflyfish, Saddleback Butterflyfish, Saddled Butterflyfish, Speckled Butterflyfish, Teardrop Butterflyfish,

### 3.5 Coral Quadrats

The Team Leader and second Research Assistant were roughly 3 meters behind the first research assistant, making sure not to go in front of the research assistant, which could skew fish data. The second Research assistant lays a 50cm by 50cm quadrat to the right-hand side of the tape measure. A quadrat was laid every 2 meters, starting at 2 meters and ending at 20 meters, and the same from 32 meters to 50 meters. The team leader made sure the top left hand corner of the quadrat was lined up with the desired distance. Once in place the team leader used an underwater camera to take a photo of the transect, making sure it was as straight as possible, the quadrat must be placed as close to the reef as possible without touching it. This method provided 10 photos per transect, 200 per site and 800 overall, which were used for data analysis.

### 3.6 Fishermen survey

A qualitative survey was done on 15 fishermen from the villages of Nissaseu and Rakoua. The aim of this survey was to explore opinions of the Tabu areas that surround Beqa bay and how they can be improved.

The questions were as follows.

How often do you fish? (every day, several times a week, once a week, several times a month, once a month)

Do you know what a Tabu area is? (If yes then explain)
What do you mainly aim to fish? (Sea cucumber or fish, Tabu areas differ for each)

Do you ever fish in Tabu areas?

How well do you think these Tabu areas work in terms of fish protection? (1-10 with 10 being best)

How much do you think other villagers respect these areas? (1-10 with 10 being best)

How much better do you think enforced areas with punishments would work? (1-10 5 being neutral, 10 a lot better, 1 a lot worse)

Do you anchor when you fish?

On this map please tick up to three areas in which you fish the most? (Map is printed map of the area which does not include Tabu areas, however does include indicators to help data be more accurate such as sand bars etc.)

These surveys were conducted one-on-one in a private room, whereby the participants were given complete anonymity and it was explained that because the results would be used to recommend management techniques complete honesty would be needed, and these results would not be used in any incriminating way. While all those interviewed did speak English, a translator accompanied the interviewer always, to make sure all questions were completely understood. The current results of the study were not shown to interviewees however they later had the option to find results through email.

3.7 Data analysis

For analysis, quadrat photos were cropped to show only the inside of the quadrat and run through a program called Coral Point Count (CPC4.1). This program puts 10 red dots on the photo randomly. The points were then labelled under one of the following categories; hard coral, Gorgonian, sponge, Zoanthid, macroalgae, other live, dead coral with algae, coralline algae, diseased coral, sand, pavement, rubble, bleached, tape or wand. This quadrat data was then imported into Microsoft Excel. The coral point method was used rather than a normal belt transect method due to its ability to show rare or incidental events which may occur (Roberts TE, 2016). Within Microsoft Excel, the following were calculated Coral Cover, Coral:Expired Coral and Coral:Macroalgae. Each sites benthic data was converted to a pie chart, a pie chart was chosen as they show proportional and percentage data best.
The fish abundance data was counted and placed into Microsoft Excel. The statistical test being used for the fish abundance data is a paired T-test. A paired T-test is used to compare two population means where you have two samples in which observations in one sample can be paired with observations in the other sample. The benthic data does not fit this test, as overall the cover is always 100% and having an increase in some substrates may not always be good. The benthic data will be compared visually, being deemed not statistically significant if there is a standard error bar overlap. The survey will be analysed per question.

### 3.8 Equipment used

*Table 1. List of equipment used.*

<table>
<thead>
<tr>
<th>Safety</th>
<th>Dive gear</th>
<th>Data recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Oxygen kit</td>
<td>Buoyancy control device</td>
<td>Dive slates</td>
</tr>
<tr>
<td>First aid kit</td>
<td>Regulators</td>
<td>50x50cm quadrat</td>
</tr>
<tr>
<td>Boat</td>
<td>5mm wetsuit</td>
<td>Underwater camera</td>
</tr>
<tr>
<td>Air tanks</td>
<td></td>
<td>2x 50m tape</td>
</tr>
<tr>
<td>Fins</td>
<td></td>
<td>1x 15m tape</td>
</tr>
<tr>
<td>Dive watch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.0 Results.

4.1 Indicator fish

Within the following sections blue is used to represent Tabu areas and grey to represent non-Tabu areas. When standard error bars do not overlap, it cannot be concluded if the difference between two means is statistically significant. If there is an overlap between standard error bars, then the difference between the two is not statistically significant.

4.1.1 Overfishing Indicators

*Scaridae* (figure 2) found only at Bikini (N = 5) and Mala (N = 1). Larger fish are usually found within deeper areas outside of the bay, so finding none at Vuvale is concerning.
Figure 3 shows there was no *Lethrinidae* found within the bay (Rabbit and Mala), and only one found in unprotected areas (Vuvale and Mala). This result were not as expected, it had been made clear by the local advisor that this was a species often fished in these areas, although not as much within recent years. Bikini yielded the highest abundance of the *Lethrinidae* indicator, which was only present in Bikini (N = 4) and vuvale (N = 1).
No Serranidae (30cm>) (Figure 4) were found in either Tabu area, within the unprotected areas there was presence Mala (N=1) and Vuvale (N=1). The reason for this is unknown, which such a small number being found in both Mala and Vuvale it is possibly co incidental.

*Sphyraena* (Figure 5) were only found in Bikini (N=52), were there was a large abundance of them. These were often found in schools, usually of the species *Sphyraeba forsteri*. While it is likely the same school was recorded on multiple dives the species clearly preferred this area and did not stray from it.
Figure 6 Showing abundance of Plectorhinchus for each site.

Figure 6 shows, *Plectorhinchus* were found at all sites, although in small numbers. Rabbit, Bikini and Vuvale (N=1) and Mala (N=2), Mala would be expected to be the worst as it is within the bay and also unprotected.

Out of the 20 fish transects done for Rabbit it had the lowest total (N=1) overfishing indicator fish, out of the fishes’ present (N=2048). Malas had the third lowest total (N=4) individuals of overfishing indicator species from its total (N=1533). Overall, the Bikini study site yielded the highest abundance (N=62) of overfishing indicator fish individuals when all five species
(Scaridae, Lethrinidae, Serranidae, Sphyraena, Plectorhinchus) were combined (Figure 7). This is skewed data by the large schools of *Sphyraena guachancho*. The incidence of *Sphyraena* (N=52) (Figure 4) was on average 20 times higher than the other indicator fish found in Bikini (N= 2.5). If *Sphyraena* were removed from the analysis Bikini would not have fared so well when compared to other sites. Vuvale had the second lowest overfishing indicator fish (N = 3). Having less than Mala (N = 4) which was expected to be the lowest.

A paired T-test was performed on the overfishing indicators within Beqa Lagoon of Rabbit and Mala. This was set at an alpha level of 0.05 (95% certainty). The null hypothesis was there is no statistical difference in population levels between the non-Tabu and the Tabu. The paired T-test gave a T stat of 2.449, while the critical T stat was 2.776. The lowest alpha level which could be accepted was 0.07. This means the null hypothesis should be accepted, there is no statistical difference within the overfishing indicators between non-Tabu and Tabu within the bay.

A paired T-test was performed on the overfishing indicators outside of the bay of Bikini and Vuvale. This was set at an alpha level of 0.05 (95% certainty). The null hypothesis was there is no statistical difference in population levels of overfishing indicator fish between the non-Tabu and the Tabu out of the bay. The paired T-test gave a T stat of 1.168, while the critical T stat was 2.776. The lowest alpha level which could be accepted was 0.308. This means the null hypothesis should be accepted, there is no statistical difference within the overfishing indicators between non-Tabu and Tabu outside the bay.
4.1.2 Reef Health Indicators.

Two species of the reef health indicators previously described were observed in the dive sites of Beqa Lagoon, these were the butterfly fish and the damsel fish. Both separately and combined, these two indicator species were of the highest abundance in Vuvale – a non-Tabu site.

A maximum of (N=176) butterfly fish were observed in Vuvale, followed by (N=155) in Bikini, (N=101) in Mala, and (N=100) in Rabbit.

*Figure 8 Abundance of Chaetodontidae for each site.*
Over 100 *Chaetodontidae* were found in all four locations, with the amount increasing with the distance from the bay. A maximum of (N=176) butterfly fish were observed in Vuvale, followed by (N=155) in Bikini, (N=101) in Mala, and (N=100) in Rabbit.

![Damsel Fish (Pomacentridae) totals for each site](image)

*Figure 9 Abundance of Pomacentridae for each site.*

The abundance of *Pomacentridae* varies significantly between each site. A maximum of (N=3305) damsel fish were observed in Vuvale, followed by (N=1624) in Rabbit, (N=1178) in Mala, and (N=988) in Bikini.

A paired T-test was performed on the reef health indicator fish of Rabbit and Mala. This was set at an alpha level of 0.05 (95% certainty). The null hypothesis was there is no statistical difference in population levels of reef health indicator fish between non-Tabu and Tabu. The paired T-test gave a T stat of 0.996 while the critical T stat was 12.706. The lowest alpha level which could be accepted is 0.501. This means the null hypothesis should be accepted, there is no statistical difference within reef health indicators between non-Tabu and Tabu within the bay.

A paired T-test was performed on the reef health indicator fish of Bikini and Vuvale. This was set at an alpha level of 0.05 (95% certainty). The null hypothesis was there is no statistical difference in population levels of reef health indicator fish between non-Tabu and Tabu. The paired T-test gave a T stat of 1.018 while the critical T stat was 12.706. The lowest alpha level which could be accepted is 0.494. This means the null hypothesis should be
accepted, there is no statistical difference within reef health indicators between non-Tabu and Tabu outside of the bay.

4.1.3 Fish Size

Table 2 Showing fish size amounts per site in respective size categories (cm)

<table>
<thead>
<tr>
<th></th>
<th>1-10cm</th>
<th>11-20cm</th>
<th>21-30cm</th>
<th>31+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rabbit</td>
<td>1957</td>
<td>84</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Mala</td>
<td>1394</td>
<td>84</td>
<td>74</td>
<td>1</td>
</tr>
<tr>
<td>Bikini</td>
<td>1573</td>
<td>187</td>
<td>9</td>
<td>52</td>
</tr>
<tr>
<td>Vuvale</td>
<td>3708</td>
<td>264</td>
<td>17</td>
<td>1</td>
</tr>
</tbody>
</table>

Rabbit had no fish present over 31 cm, it had (N=7) 21-30 cm, (N=84) 11-20 cm and (N=1957) fish sized 1-10 cm. Rabbit had the highest percentage of fish falling into the 1-10 cm category (95.5%).

Mala does have many fish in the size category 21-30 cm a (N=74), compared to Rabbits (N=7), Bikinis (N=9) and Vuvales (N=17), Mala only has one fish in the category 31+ which was a Sweetlips. Mala has the third highest percentage of fish falling into the 1-10 cm category (89.7%).

Bikini is the only site with a significant amount of fish within the size category 31+ (N=52), all 52 of these observations were of the species *Sphyraeba forsteri*, the indicator fish which skewed the data previously. With the *Sphyraeba* the percentage of 1-10 cm was the lowest (86.3%) without the *Sphyraeba* this was also the case (88.9%).

Vuvale has the highest number of fish in the size range of 11-20 cm (N=264), although very few larger than this, from 21-30 cm (N=17) and 31 cm+ (N=1). Vuvale has the second highest amount of fish sized 1-10 cm (92.9%).

The size results show a steady increase of larger sized fish moving out of the bay as would be expected (Rabbit, Mala, Bikini), however the outlier to this result is Vuvale. It could be assumed that the larger fish are more likely to be targeted and the size decrease is a consequence of fishing within the area.
4.2 Benthic Data

4.2.1 Breakdown per site

- SAND, PAVEMENT, RUBBLE (SPR)
- CORAL (C)
- DEAD CORAL WITH ALGAE (DCA)
- SPONGES (S)
- MACROALGAE (MA)
- UNKNOWNNS (U)
- CORALLINE ALGAE (CA)
- ZOANTHIDS (Z)
- OTHER LIVE (OL)
- GORGONIANS (G)
- DISEASED CORALS (DC)

*Figure 10 Key used for all Benthic Data, not included to make pie graphs clearer.*
In Rabbit (Figure 11) we can see that sand, pavement and rubble was the highest category at (40.3%), there is also a low amount of sponge. Only (26.6%) was coral which is very low.
Mala (Figure 12) has coral as the third highest category with both rubble and dead coral coming before it. While Mala only has 1% less coral than Rabbit, Mala has 4% more dead coral.
Bikini (Figure 13) benthic has coral as the largest percentage cover (44.3%). The rubble (41.85%) is about the same as Mala and Rabbit. This site has a very low percentage of dead coral with algae, compared to the rest of the sites (9.8%) and also very low Macroalgae (0.1%).
Figure 14 Full composition of Vavale benthic

Vuvale (Figure 14) has the highest percentage of rubble out of the four sites (47.22%). It also has the highest percentage of sponge (2.8%). Although it has a high level of rubble, sand and pavement it has a low percentage of dead coral with algae (7.6%).

The large size of the reef means it has a high representation of sand and pavement patches with (N=233) spots out of (N=2000) being sand and (N=274) being pavement. The reef is (37.8%) hard reef building corals, which is the second highest, behind Bikini.
4.2.2 Coral cover (%)

Bikini had the highest living coral coverage (44.3%), followed by Vuvale (37.8%), Rabbit (26.6%) and Mala (25.2%). There is a greater coral cover within the two out of bay reefs than the two sites within the bay. Interestingly both Tabu areas have a greater cover than their non-Tabu counterparts, although the difference between Rabbit and Mala is not statistically significant.
4.2.3 Coral:Macroalgae ratio

Bikini had the greatest Coral:Macroalgae ratio (17.8:1), followed by Vuvale (7.7:1), Rabbit (5.6:1) and Mala (5.4:1). Similar to the results of the % coral cover analysis previously described, both Tabu areas yielded a higher Coral:Macroalgae ratio than their non-Tabu counterparts. Once again, the difference between Rabbit and Mala is not statistically significant.
4.2.4 Coral:Expired Coral

![Coral:Expired Coral Ratio](image)

Both Rabbit (1.1:1) and Mala (1:1) have a live Coral:Expired coral ratio of close to 1:1, while Bikini (4.6:1) and Vuvale (4.3:1) sit much higher, at over 4:1. Again the Tabu sites yield the higher ratios when compared to their non-Tabu counterparts. There is no statistical significance between Tabus and Non-Tabus for Coral:Expired Coral.

4.3 Interview analysis

The interviews were conducted on 18 people from varying villages. The average fishermen fishes around three times a week, with the lowest being once and the highest being four times. All eighteen-people asked knew what a Tabu areas was. Fourteen of the people just fished fish, while four also targeted cucumbers. Generally, Tabu areas were a good thing in the area, however the opinion on this ranged from thinking they were useless and had no impact to them being very useful.

The consensus on whether others respected these areas was the most varied out of all the questions, with eleven people giving a ten, indicating full respect, while seven people gave a one, indicating no respect whatsoever. In respect to government enforced MPAs, one person thought they would be worse off, however eleven opted for a five, which meant it would make no difference and six people for a ten saying it would help dramatically, it should be
noted that all six of these people said that nobody respects the Tabu areas as they are. Out of the eighteen-people asked, twelve anchor and six do not, the six which do not proceed to explain they fish from the shore in Rabbit, and therefore do not need to anchor.

The map (Figure 18, shown later within this section) which has been produced from the interviews shows areas most targeted by fishermen, Mala is clearly very fished, as is Rabbit, Rabbit is however all shore fished. Areas surrounding Bikini are heavily targeted also. The full results for each question can be found below.

4.3.1 How often do you fish per week?

Table 3 Data analysis of question one from survey.

<table>
<thead>
<tr>
<th>How often do you fish?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.722222</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.253157</td>
</tr>
<tr>
<td>Median</td>
<td>3</td>
</tr>
<tr>
<td>Mode</td>
<td>3</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.074055</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>1.153595</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-1.03974</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.33497</td>
</tr>
<tr>
<td>Range</td>
<td>3</td>
</tr>
<tr>
<td>Minimum</td>
<td>1</td>
</tr>
<tr>
<td>Maximum</td>
<td>4</td>
</tr>
<tr>
<td>Count</td>
<td>18</td>
</tr>
</tbody>
</table>

The mean amount of times fished a week is 2.7, with the median and mode both being 3. While the minimum is 1 this was an outlier with only one person saying this.

4.3.2 Do you understand what a Tabu Is?

Table 4 Data analysis of question two from survey.

<table>
<thead>
<tr>
<th>Do you know what a Tabu is?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of yes</td>
<td>18</td>
</tr>
<tr>
<td>Count</td>
<td>18</td>
</tr>
</tbody>
</table>
Out of all eighteen people surveyed all said they knew what a Tabu area is. The participants could easily explain that they were not allowed to fish in these areas.

### 4.3.3 What do you mainly fish?

<table>
<thead>
<tr>
<th>What is it you mainly fish?</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>14</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>0</td>
</tr>
<tr>
<td>Both</td>
<td>4</td>
</tr>
<tr>
<td>Count</td>
<td>18</td>
</tr>
</tbody>
</table>

Out of the eighteen surveyed no people just fished cucumbers, which was most likely as they are very seasonal. Fourteen only targeted fish, explaining they did not have the equipment to reach the deeper but more profitable cucumbers.

### 4.3.4 How well do Tabu areas work (1-10)?

**Table 6 Data analysis of question four from survey.**

<table>
<thead>
<tr>
<th>How well do Tabu areas work</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>8.388889</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.626949</td>
</tr>
<tr>
<td>Median</td>
<td>9.5</td>
</tr>
<tr>
<td>Mode</td>
<td>10</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.659918</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>7.075163</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>4.270888</td>
</tr>
<tr>
<td>Skewness</td>
<td>-2.20262</td>
</tr>
<tr>
<td>Range</td>
<td>9</td>
</tr>
<tr>
<td>Minimum</td>
<td>1</td>
</tr>
<tr>
<td>Maximum</td>
<td>10</td>
</tr>
<tr>
<td>Count</td>
<td>18</td>
</tr>
</tbody>
</table>

Most people thought the Tabu areas worked perfectly, at 10/10 with it being the mode. The median was 9.5 and the mean was 8.3. Interestingly the fishers either thought they worked very well or not at all, given this question a range of 9.
4.3.5 How much do you think other fishermen respect these areas? (1-10)

Table 7 Data analysis of question five from survey.

<table>
<thead>
<tr>
<th>How much do you think others respect the Tabu area?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Standard Error</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Mode</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sample Variance</td>
</tr>
<tr>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
<tr>
<td>Count</td>
</tr>
<tr>
<td>Number of 1s</td>
</tr>
<tr>
<td>Number of 10s</td>
</tr>
</tbody>
</table>

This question had a large split. Out of the eighteen fishers interviewed all either gave either a 10, indicating no one every fished in these Tabu area, or a 1 indicating no one respected them at all. Seven people interviewed gave a 1, while eleven people gave a 10. While this gives a mean of 6.5 this is misleading as there is such a high range.

4.3.6 Comparatively how much better would government enforced protected areas work (1-10)?

Table 8 Data analysis of question six from survey.

<table>
<thead>
<tr>
<th>How well would government enforced areas work instead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Standard Error</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Mode</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Sample Variance</td>
</tr>
<tr>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
</tr>
</tbody>
</table>
This question had a range of 9, however only one person chose 1. Eleven of the eighteen people surveyed opted with 5, stating that it would not make a difference, because the Tabu areas already worked so well. One person said it was a 1, saying that it would be extremely detrimental. Six out of the eighteen said it would make a huge difference, interestingly all six of these also said that the Tabu areas are not respected.

### 4.3.7 Do you anchor when fishing?

*Table 9 Data analysis of question seven from survey.*

<table>
<thead>
<tr>
<th>Do you anchor when fishing?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>12</td>
</tr>
<tr>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td>Count</td>
<td>18</td>
</tr>
</tbody>
</table>

Out of the eighteen-people asked 12 said they anchor and 6 did not anchor, despite there being anchor lines at every site. The six that did not anchor are the six that fish from the shore in Tabu.
4.3.8 Most fished areas

Each fisherman was asked to show where their preferred fishing spot was, for cucumbers and fishing. On the map presented there was place markers such as villages to help the results be more accurate and Tabu areas, were shown however reefs were not. Six people said they fished in Tabu areas, all around Rabbit from the shore. There was five people who fished in Mala and six who fished out of the bay for fish. All those who targeted cucumbers were further out in the deeper parts, with three in Vuvale.
5.0 Discussion

5.1 Results analysis

5.1.1 Rabbit

Rabbit is the site closest to the shoreline and considered a Tabu area, although people can still fish in this area if it is from the shoreline, an issue that will be discussed later on when explaining the problems associated with Tabu areas. The appearance of very few fisheries target species and a low number of large fish indicates that this fishing ground is depleted. While this area is classed as a Tabu it is not enforced as one, as it allows the use of net shore fishing. The area likely sees high fishing intensity as it is used as the sole fishing ground for those without a boat.

Perhaps as a result of this high fishing intensity, the reef health of this area is poor. While it does have above average abundance of both reef health indicator species, this result is misleading considering the % coral cover, Coral:Macroalgae and Coral:Expired coral results. The area has (26%) coral cover. The area also has a Coral:Macroalgae cover of (5.8:1), and a (1:1) ratio of coral:expired coral. Although the results for Coral:Macroalgae cover on the Rabbit reef are not ideal, the results for Coral:Expired coral coverage on this reef are even more pressing. The 1:1 ratio of live coral to expired coral indicates that there is just as much dead coral as living. Of the (N=2000) data points tested for this reef (N=440) were of dead coral.

Rabbit is one of the most important reefs, if not the most important to Beqa. As the closest of the four reefs to the shoreline, it not only slows down potential erosion by buffering wave action, but also provides an easily accessible source of fish to fishermen who do not have access to a boat and therefore cannot make the journey to sites further offshore. The factors impacting the health of this reef is numerous, including terrestrial run off, overfishing, predation by the crown of thorns, and boat traffic. The impacts of these factors are clearly visible in the degraded quality of the reef and the loss of the reef could potentially be detrimental to the mangrove forest nearby, which would have implications for all reefs in the area. Mangroves function as important nursery grounds for reef fishes by providing shelter
during their most vulnerable stages. WWF (2017) reports that there are up to 25 times more species of reef fish on corals close to healthy mangroves compared to corals adjacent to unhealthy or felled mangroves. By letting the coral reef around Rabbit get to such a bad state this could potentially impact these mangroves, extending consequences to other reefs in the region.

5.1.2 Mala

Mala is the second closest study site to the shoreline. The site is not a Tabu and as such locals which fall into the Qoliqoli area are free to fish within this area unreservedly. Per the survey, this is the most used site, most likely since it is the closest non-Tabu area that allows the full use of all equipment. The reef has seen a decline in popularity in recent years as fishermen have shifted their efforts to reefs with a higher catch rate.

Malas has the lowest % coral cover of any of the sites (25%), indicating the reef is in the process of dying and cannot keep up with the high fishing pressure. The poor reef coral cover also will have caused the outmigration of fish from the area, as reef health has become too low to support them, decreasing the reef’s carrying capacity. While the % coral cover is low, once again Coral:Macroalgae is not a major issue. Although the ratio is the lowest of the four sites, it is not considered to be at a dangerous level, and just like in the case of Rabbit the Coral:Expired coral ratio is approximately (1:1). The reef is incredibly unhealthy and is mainly rubble and dead coral; out of the (N=2000) points (N=530) were rubble (does not include sand and pavement) and (N=535) were dead coral with algae, for a total of (N=1065) dead coral points out of (N=2000) overall.

Mala is frequently used by the surrounding villages, as it is the easiest Qoliqoli to access. If Malas is no longer viable as a fishing site, the people would have to travel out of the bay into rougher conditions to fish. This is not always possible - especially during the rainy seasons - and if the health of the Malas reef declines further the surrounding people will likely suffer. The reef has already exceeded its carrying capacity in terms of supporting fishing activities and management plans should be put into place as soon as possible.
5.1.3 Bikini

Bikini is just outside of the bay, and is therefore not impacted heavily by the surrounding villages, and is a respected Tabu area. The site has the highest numbers of Scaridae, Lethrinidae, Sphyraena and a total abundance of 62 fishing indicator fish. This is significant when compared to Rabbit’s 1, Mala’s 4 and Vuvale’s 3. It can be concluded that this area is not currently overfished, a result which is supported by the interview data, in which no fishermen indicated that they fish in this area.

The only negative result from the analysis on Bikini is that it had the lowest number of the fishing indicator species Pomacentridae. Bikini had the highest percentage of hard corals, with (44.3%) of the total (N=2000) points being hard coral, (9.8%) dead coral with Algae. Bikini also has the highest % coral cover, and Coral:Macroalgae and live coral: expired coral ratios. The Coral:Macroalgae ratio for this site is (17.8:1), which is considerably higher than all the other sites tested. Bikini yielded a Coral:Expired coral ratio of (4.6:1), which is 4 times higher than that of Malas. The site has the highest number of 31cm+ fish (N=52), compared to the other sites, which had only 2 fish between the three sites combined. These larger fish present in Bikini would be the first to be targeted if this site were to lose its Tabu protection.

While it is clear, this is the healthiest of the sites and the least fished, it may not last. With the surrounding sites clearly under a lot of strain, the villagers may be forced to eventually fish elsewhere. While Bikini is currently considered a Tabu area, the village chief will most likely put the needs of his people before the needs of the reef, and the eventual opening of the reef for fishing may be the only way for the local people to survive. For this reef to survive, Rabbit and Malas - the two most accessible fishing areas for locals - must be managed correctly.

5.1.4 Vuvale

Vuvale is the furthest study site from shore, and thus, it is not convenient for fishermen to be travelling this far every day (25 minutes by boat). The time of year at which this site is the easiest to access corresponds with cucumber season. All villagers that participate in the cucumber fishery (according to the interviews) responded that this was where they fished for cucumbers and they always anchor here. While there is a buoy on this site for mooring,
fishermen must move around the area, anchoring at different locations to increase cucumber catch and make the trip worthwhile. Additionally, rough waves are typical of the offshore location of Vuvale, and maintaining mobility in these conditions can be important for safety. The site should still be considered overfished, given the low abundance of all overfishing indicator fish.

The Vuvale reef is less favoured by fishermen when compared to the closer and more accessible Malas reef. During the sea cucumber season, it provides the region with a high income. Similar to the Bikini reef, Vuvales may function as a backup to reefs closer to shore and its sustainability relies on the continuing health of these reefs, for without them fishermen would be forced to shift their fishing effort to Vuvale.

5.2 Interview analysis

The purpose of these interviews was to find out the local populations fishing habits, opinions on current practises and to gage reactions about the possibilities of new management strategies.

Although all eighteen participants said they knew the rules of the Tabu, six interviewees admitted to fishing within Tabu areas from the shoreline. Stating that if they threw nets from the land, they never entered the Tabu and this was fine, breaking no rules of the Tabu. The seven interviewees who said that these areas were not respected at all, referred to such practises, saying that it was in fact against the rules of the Tabu. The six candidates that said they fished in these areas around Rabbit said all areas were very well respected. This led to a lot of confusion and clearer rules of these areas must be put in place. A hard copy of all rules and locations of restricted areas should be publicly available.

When the possibility of a conversion to a more government-controlled area was suggested the general reaction was hesitant but positive. While one candidate said, it would not work, six said it would be very beneficial. Especially in terms of clarifying rules, all six of these also said the areas were not respected in any way. The main concern amongst those who rated the idea a five (eleven candidates), was how long it would last, with six of them stating this as a concern. It was made clear that while they would be in favour of this idea they would not like it to be a permanent one, the reason for this varied for each candidate, however, five of the
eleven mentioned the word “culture” within their answer. Each candidate was interviewed separately and this was a semi-structured interview so finding a conclusive answer to why they would not like this as a long-term solution was difficult. One answer was that each island within Fiji is different, by upholding local values, traditions and systems they keep their identity.

5.3 Effectiveness of Tabu areas

The dynamic nature of the world’s oceans means that comparing data sets between different locations can be challenging. In an effort to address this challenge, the four sites in this study will be separated based on their location relative to shore; inside the bay area (Rabbit and Mala) and outside of the bay area (Bikini and Vuvale). This eliminates as many external factors as possible.

5.3.1 In the bay area (Rabbit and Mala)

Despite its status as a non-Tabu protected site, Mala, yielded the highest abundance of overfishing indicators for all fish species, while the appearance of only one individual of one indicator species (*Plectorhinchus*) was recorded in the Tabu protected site, Rabbit. This difference in abundance of indicators was, however, determined to be not statistically significant. The result of no significance is likely, in this case, a result of the small number of recordings for indicator species at these sites; ranging from just 0 – 2 individuals.

Rabbit was not shown to have a healthier reef than Mala, the paired T-test showed no statistical significance between the two in terms of reef health indicator fish. While Mala is scored slightly higher in all three of % coral cover, coral: microalgae and live coral: expired coral categories, this result was again determined to be not statistically significant. Using the standard error bars there is an overlap on all three of these results, showing there is no statistical significance between the two sites. This lack of significant results combined with the same problem in the overfishing indicators analysis makes determining the effectiveness of the Tabu management scheme challenging. With there being no statistical difference
between the two-reef health’s and more fish in the non-Tabu area, it can be seen the Tabu area is not working as intended.

5.3.2 Outside of the bay (Bikini and Vuvale)

Comparing the two reef sites outside of the bay, Bikini and Vuvale, there is a more notable difference between the two than what was seen in the previous pairing. With respect to overfishing indicator species, Bikini presented with a noticeably higher abundance of three of the indicator species: five Scaridae compared to Vuvale’s one, four Lethrinidae compared to Vuvale’s one, and fifty-two Sphyraena compared to Vuvale’s zero. Outside of these species, both sites had one Plectohinchus and Vuvale had one Serraindae (30cm+) while Bikini had zero. The difference in abundance of overfishing indicator species was again hindered by the relatively small number of recordings and although the difference was noticeable, it could not be verified as statistically significant.

The significant difference in coral cover between the two sites is an indicator of higher reef health in the Bikini reef. This increase in reef health over another offshore study site of no protection (Vuvale) can be assumed to be a result of the Tabu protection. It is, therefore, possible that in the case of the Bikini reef area, the Tabu is working to an extent, however, exactly to what extent it is working cannot be fully understood in the face of a lack of detection of significant trends for many factors of reef health and overfishing.

5.4 Managerial problems

There are many managerial problems that must be acknowledged before recommendations can be implemented. While the population of people that rely on these reefs is only a few thousand, the reefs cannot support them all and some changes must be made in order to alleviate the pressures on the reef. Most of the island is empty and using this space for more livestock would potentially mean less fish would be required to meet the island’s protein demand. This is a problem that cannot be addressed directly and is a problem that must be overcome by the villages themselves.

The lack of infrastructure and resources on the island means there is very little available to survey and monitor these reefs. There is a small volunteer-based environmental camp,
however, this does not have the manpower or the knowledge to implement anything meaningful and long term. In addition, the group faces a barrier of public perception, since the Fijians would prefer not be reliant on others.

The current problems with the reefs can be split into two categories, problems with the Tabu areas and problems with the surrounding environment. Each one of these problems must be addressed with its own managerial solution if these reefs are going to improve.

Tabu areas are currently peer-pressure based and not fully backed by the community. From the surveys, we can see there is a split in opinion of people in terms of the people’s perception of whether or not the system is respected. A considerable proportion of fishermen (38.9%) interviewed think that these areas are not respected at all. Many interview respondents held the opinion that other methods of management would better serve the region. A total of one respondent believed that a government-enforced protected area would be damaging to the area, while six times that many believed that a government-enforced area would provide better results than the Tabu system In deference to this majority, a government enforced marine protected area will be discussed further on. This also solves the problem of constantly changing rules which are always hard to know.

Another problem that made itself evident with these Tabu areas is that they occur on a frequently used boating route. This boating activity can result in the creation of rubble, as seen within both Mala and Rabbit. This is an issue that can be addressed by the creation of designated boating routes, which are clearly marked to avoid collisions with the reefs.

Mangrove protection schemes are known to help maintain these Tabu areas, however, currently, there is no protection for the mangroves around Beqa Lagoon bay. This could be a reason for the low numbers of overfishing indicator fish found within the bay (previously discussed for their role in limiting the identification of significant). Affording better protections to the mangroves of Beqa Island could potentially increase the recruitment of these important food fish species.

The high quantities of dead corals with algae and rubble within the bay was observed to be of concern in some areas. Both Rabbit and Mala were characterised by a coverage of over 60% by these two substrates. The current dead coral and rubble can be removed for profit,
however, every effort should be made to limit the factors suspected of leading to its creation. Rabbit and Mala also have low levels of coral cover (26.6% and 25.2%, respectively), not only must the dead coral and algae be removed but the recovery of the living reef must be facilitated through proper management in these areas.
6.0 Managerial recommendations

The first question which must be answered concerns what the fate of Tabus in the region should be. One possible solution would be to abolish the system in favour of government-enforced marine protected areas (MPAs). Alternatively, if the Tabu system shows enough promise, the better option may be to improve upon the current system. A third option may take the form the structuring of a program that offers a compromise between these two methods. The results show that these Tabu areas are not statistically significant at maintaining higher fish populations. Although no significant difference could be verified between Tabu and non-Tabu areas, the low numbers of overfishing indicator species, in general, may be cause for concern and could indicate overfishing or poor protection under the Tabu system in the bay area more generally. If the populations of these species are indeed being overexploited, any new and/or existing management protocols should aim to address this.

The Tabu areas are important aspects of the Fijian culture and removing them altogether would be disrespectful could lead to conflict, or at the very least, some very divided opinions. A compromise must be met, whereby the areas are given time to recover while respecting local customs. To achieve this, adaptive co-management, which is used within the larger islands of Fiji, will be recommended (Weeks & Jupiter, Adaptive Comanagement of a Marine Protected Area Network in Fiji, 2013). This is not a long-term solution and after an agreed-upon time period, adaptive co-management should be phased out into the Tabu system again. Adaptive co-management has the potential to lead to increased education among villagers, and healthier reefs and mangrove nurseries, leaving the Tabus to flourish after its completion, as will be discussed shortly.

The initial proposition of adaptive co-management may be difficult. Twelve of the eighteen interviewees said that government-enforced MPAs would not be beneficial. Caronetti, Pomeroy, & Richards, (2014) state that there are three pathways to overcoming a lack of political will within small-scale fisheries, and addressing these three pathways will be the first managerial strategy. The first is the importance of leadership, at both the local and national level, with the two working together. The second is the education of the public, which focuses on generating values that help promote the cooperation and compliance of small-scale fishers with management policies. The third is the need for cooperation between
the local and state institutions to ensure policies and enforcement are structured to suit all members.

6.1 Adaptive Co-management

Co-management is the act of two separate bodies working together to manage an area in a way in which one could not achieve on their own. In this case, it would be a co-management between the government and between the locals of Beqa Island. Research by Weeks & Jupiter, (2013) suggests co-management has gained significant traction within recent years, especially in artisanal fisheries. Co-management works to relieve a few of the problems which artisanal fisheries face such as: economic inefficiency, unsustainable use of fishing grounds and skewed resource distribution. Co-management in this case would be the use of government resources and infrastructure, implementing an MPA within the bay, using the local knowledge and manpower of the villagers.

Adaptive management of natural resources is described as an “iterative process of decision making whereby management strategies are progressively changed or adjusted in response to new information”. The adaptability of these protected areas to local circumstances and the sudden changes in these circumstances is paramount to their success. Streamlining MPAs has huge benefits as noted once again by Weeks & Jupiter, (2013) who assert that reefs change and protected areas must change with them. In the case of Beqa Bay, the whole bay should be considered an MPA for now, to allow juvenile migration from mangroves, allowing the fish to return to Rabbit and Mala and maintaining Bikini as a healthy reef. The full plan for this proposed MPA area can be seen in Figure 19.
Limiting the areas that can be fished is great for the reef health, however seriously hinders the population around the area, and a compromise must be met. Vuvale and offshore locations that are often overlooked should be used for fishing, with Bikini opening on rare occasions when food supplies are low. MPAs would be re-assessed by the independent assessment team if they feel they need re adjusting, Mala and Rabbit would remain closed until they have at least recovered to acceptable standards.

One useful case study for understanding the effectiveness of adaptive co-management can be found in the workshop that took place in July of 2010 in the town of Kubulau, Fiji. The workshop was attended by over sixty participants comprised of village representatives, government stakeholders and the Kubulau village chiefs. All suggestions were discussed at length and put through voting systems. The outcomes from this workshop included the implementation of five new Tabu areas, and the expansion of the current Tabu system, achieved by three villages agreeing to increase the current size of their Tabu areas and add large buffers to the district’s no take zones (Weeks & Jupiter, Adaptive Comanagement of a Marine Protected Area Network in Fiji, 2013). This case study is a great example of how integrating co-management and adaptive planning can work well. While Beqa Island may not
be able support such a drastic increase in no-take zones, it is surely a great example of the things adaptive co-management can achieve.

Ultimately, keeping communities educated and focused on the health of their local resources is what will help these reefs in the long run. The community has made it very clear that they wish to be independent and opposing this wish will not help; any new management must work with the existing system (Brewer & Moon, 2015). After ten years of government-led adaptive co-management the system must return to the traditional models, devoid of government enforcement techniques, while still maintaining access to small amounts of government funding if needed.

The use of the traditional ecological knowledge (TEK) of the local community combined with the funding and resources provided by the government may offer many benefits to the local reef health and the natural resources of Beqa Lagoon Bay. Areas that incorporate traditional belief systems such as Tabu areas are more successful in reaching conservation goals in artisanal fisheries (Weeks & Jupiter, Adaptive Comanagement of a Marine Protected Area Network in Fiji, 2013). While the government-enforced MPA does not incorporate the traditional Tabus at first, it will revert to village designated Tabu areas once the health of the reef system and its natural resources are restored. Any MPA project in Beqa Island designed with only biodiversity and conservation in mind must consider the Fijian idealism that restricted areas are a kind of short-term ‘‘food bank’’ that can be opened and closed at will. (Golden, Naisilsisili, Ligairi, & Drew, 2014). The current expected time to revert these areas back to being more traditional Tabu areas is 10 years. Johns, Osborne, & Logan, (2014) studied six reefs, within the Great Barrier Reef, which suffered substantial coral loss and managed to regain at least 50% coral cover, with incredibly consistent results with all of the six achieving this within 10 years, with a minimum of 7 years.

**6.2 Local leadership initiative**

Referring to the first of the recommendations from Caronetti, Pomeroy, & Richards, (2014), leadership at a local level must be improved, something that can be achieved by the “local leadership initiative”. The use of hard law MPAs is shown to work within communities with adequate enforcement. Anderson, et al., (2014) shows that within Grenada MPAs applying fishing restrictions within 2010 saw an increase in both coral cover and fish population within
four years, both things which need improvement in Beqa Island. Weeks, et al., (2014) uses six case studies from around the coral triangle to show how mixing science and local knowledge and community based management leads to the most desirable outcomes, and the need for multi-stakeholder solutions. The initiative requires that a local from every village is elected to represent that village in monthly meetings for the discussion of concerns (or the lack thereof) of the current state and management of these reefs, as raised by their village. In this meeting, the independent assessment team should also be present. This team will comprise of seven university educated Fijians living in Beqa Island. The funding for these would come through a new tourism tax of 10% paid by the many high end resorts in the area, these resorts also benefit from the healthier reefs as the reefs are the main reason tourists visit Beqa. The roles of this team would be:

3x Surveyors- The task of the surveyors is gathering data. This is the most physically demanding of the roles and would be on constant rotation around the island, whereby each rotation around the island would take about 2 years, after which the survey begins again and data is renewed.

2x Patrol officers- The patrol officers would be tasked with enforcing and checking licenses and educating those abusing the rules on the need for the regulations.

1x Information analyst – The information analyst would oversee the analysis and interpretation of the surveyors’ data and assessing which reefs are deemed to be unhealthy and overfished.

1x Team Leader – It is the responsibility of the team leader to stop corruption within the group by checking in with other members and ensure protocols are being followed, while also observing their progress and to reporting said progress to the office of resources in Suva. The team leader will act as the bridge between the locals and government.

While it may seem that this team is counterproductive and will have a cultural clash with the people of Beqa, if they are Fijians it could be successful. The people of Fiji are very passionate about their oceans and with correct education and implementation, could be supportive of this idea.
After roughly ten years of monitoring the independent assessment team will be disbanded, providing that the reef health and fish populations have increased by the amounts suggested in the section “Monitoring of reef health”. This is something which must be done, within the interviews there was concerns of Beqa Island losing its identity and a loss of culture. After the enforcement period is over the government will still monitor reefs, albeit much rarer and support with small funds which can be used for educational workshops and better facilities to show Tabu areas.

6.3 Improve education

Equal opportunity in education is just one aspect of a route to a more just society and more well-managed fisheries. Small adjustments to local education opportunities may increase reef fish health, allowing the reef to support a larger population (Haggan, Brignall, & Peacock, 2002). Instilling the values that would promote cooperation would be done by the independent assessment team. This education would take place in villages over the course of a full day, occurring twice a year. Each session would cover the educational basics and then highlight one case study, varying from workshop to workshop. The educational basics which would be covered in each area would include the damage from anchoring, stressing the importance of using the Buoys which have been erected at every reef site, the importance of reducing litter, the importance of reefs and the resources they provide, the dangers of overfishing, and the importance of sustainable management. These workshops would be completely free, highly advertised and open to all who wish to attend. Case studies utilized in the workshop would include things such as: the collapse of the Newfoundland and Labrador Atlantic cod fishery, the decline of the Great Barrier Reef, and how fisheries management can promote livelihoods, using examples such as Palau.

Rule breakers would also be required to attend mandatory sessions, these would be harsher and more “shocking” courses, led by either the team leader or the patrol officers. These would use more graphic pictures to educate those who break the newly implemented rules. Failing to attend these meetings would result in a harsh fine.
One of the main aims of the education improvements is to facilitate more sustainable and self-reliant communities that have been equipped with the tools and the knowledge to be able to manage their own reefs and resources with as little interference as possible.

Inspiration for educational techniques sourced from (Garcia, Rice, & Charles, 2014).

### 6.4 Monitoring of reef health

Constant monitoring of reef health must be maintained in order for the adaptive management strategies described to be fully effective (Schaffelke, et al., 2009). Using McField & Patricia (2007) as a guideline, and with the aim to implement a benchmark, targets and red flags must be identified for all aspects of reef health that are to be monitored. This monitoring is to be done by the independent assessment team. After the period of enforcement has expired this monitoring will be done every five years by independent contractors.

Indicator species: The benchmark for indicator species will be a 25% increase over four years (vs 2016 levels when original data was recorded) or if the original survey showed no species then to have some present, the two-year monitoring target will just to be on track to meet this. The target will be a 100% increase over all indicator species, with such a low population to start with this is a feasible target. A red flag would be a decrease in any indicator species or a complete lack of any indicator species.

Coral cover: The benchmark for coral cover is a 5% increase over four years, with the two-year assessment on track to meet this target. The target would be a 10% increase over four years. Red flag would be any decrease in coral cover at any site.

Coral:Macroalgae: The benchmark for Coral:Macroalgae is a 5% increase over four years, with the two-year assessment on track to meet this target. The target would be a 10% increase over four years. Red flag would be any increase in Coral:Macroalgae or no change at any site.

Coral:Expired Coral: The benchmark for coral: expired is a 5% increase over four years, with the two-year assessment on track to meet this target. The target would be a 10% increase over four years. Red flag would be any decrease or stagnation of Coral:Expired Coral at any site.
6.5 Coral and Mangrove Nursery

6.6.1 Coral Nursery

(40.3%) and (40.9%) of Mala and Rabbit respectively is rubble, this should be removed to allow fresh coral to grow. Fox, Pet, Dahuri, & Caldwell (2003), show that within the nine reefs they have monitored since 1998 with large amounts of rubble there has been no significant natural recovery. While new recruits tend to spawn in rubble, roughly 10-15 per square meter they do not grow further and die off in this stage. This shows there is potential for these reefs to recover, under the right circumstances. First off, the coral rubble must be removed by hand, taking care not to destroy the few corals which do remain in Mala and Rabbit, this coral rubble will be ground up and recycled for later use. Once this rubble has been removed the independent assessment team’s coral nursery plan can start. This rubble will be not be put to waste, instead it will be sold for cement use within the city of Suva, the money will help continue to fund operations.

The concept for the coral nursery plan is growing reef building corals on moveable cement discs, grinded up from coral rubble, in areas which they grow well and then moving them when large enough to areas with severely depleted corals. For an area to be acceptable for growing these corals it must meet certain criteria. These include being easily accessible, optimal depth 2-5m although deeper sites can be used, clear, good water quality and flow (presence of healthy corals), protection from high surge, permanent residents nearby, MPA status/protection.

The site chosen is shown in figure 19, chosen near to Bikini as this area has been shown to have the healthiest reefs, the area is behind the reefs so will have lower wave impacts and are not on the route in which boats drive into the bay. The site is a little bit deeper than the 2-5meter desirable range, however it is only around 8meters which is still within the depth which corals thrive at. While the original paper recommends using Elkhorn and Staghorn corals, these are not found within Fiji, as of such will be replaced by various corals from the Genus Acropora. All of which are fast growing and reef building.

The process in which these corals are formed is simple and explained in (FOH, 2009). Firstly, using the ground up rubble, discs are formed as a mobile support with fragments of Acropora
corals. These discs are tied to metal trays using fishing lines placed on the seafloor and held down with large rocks. Once these corals are at a large enough size, they are unthreaded and placed within Mala and Rabbit. There are 22 species of Acropora corals found within Beqa, by not specifying which species is used there will be a large variety of corals which form, meaning Rabbit and Malas will have a larger biodiversity and be more resistant to disease and more welcoming of niche fish.

Per (FOH, 2009) the success rate of this strategy is very high, with 80% of corals surviving the transition. One example where this strategy has been incredibly successful is within Laughing Bird Caye, Belize after it was hit by Hurricane Iris. Most people gave up on the reefs around Laughing bird Caye, focusing their resources elsewhere, stating that “There was only rubble left”. This proved to be a great success and as of such the strategy is starting to become a very heavily used technique for kick starting reef growth.

6.6.2 Mangrove nursery

There is currently no protection for the mangroves around the bay. Mangrove forests are inhabited by a large amount of juvenile coral fish species, Serranidea, Lutjanidae and Lethrinidae. Mangroves provide safe shelter and a source of food for the juvenile fish, increasing their overall survival rating compared to other habitats which harbour coral reef juvenile fish (Nagelkerken, et al., 2000). This creates a strong relationship between the fish abundance in coral reefs with mangroves in close vicinity, sometimes up to doubling the numbers of adults in certain species (Mumby & Edwards, 2002).

There is great potential for a mangrove nursery in the area between Rabbit and the shore, as shown in figure 19. This area has everything it needs to be a mangrove nursery, it already has mangroves growing in some parts, it is the perfect substrate and has the right tidal range with input of fresh water from a stream which passes through and saltwater from the sea (Clarke & Johns, 2002). The area has recently seen some parts cut down for use of wood, and to allow easier boat transportation.

The site would have many seeds planted within it at first, after this it would be left to grow of its own accord. Growing the mangles in-situ reduces the amount of work and resources needed dramatically, the environment for these to grow is already suitable, it just needs
protection from human influence, as of such the harvesting of these mangroves would be prohibited. The importance of this ecosystem would also be highlighted at the educational workshops and breaking these rules would induce a fine and a mandatory workshop on the uses and benefits of mangroves.

6.8 Timeline and Conclusion

Table 10 Table showing ideal timeline for management solutions.

<table>
<thead>
<tr>
<th>Year</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>Hiring complete and IAT begin work. First educational workshop. Bay becomes MPA.</td>
</tr>
<tr>
<td>2019</td>
<td>First educational workshop starts, villages vote for representative for leadership</td>
</tr>
<tr>
<td>2020</td>
<td>After more data, has been taken.</td>
</tr>
<tr>
<td>2022</td>
<td>Coral and Mangrove nurseries begin.</td>
</tr>
<tr>
<td>2028</td>
<td>Healthier reefs achieved and MPA removed, returning to village chosen Tabu areas.</td>
</tr>
</tbody>
</table>

This project aimed to answer the following the questions, what effect does the use of community allocated marine management areas have on reef health within Beqa Island Fiji? There is no significant statistical difference between community allocated marine management areas and normally fished reefs within Beqa Island.

What effect does the use of community allocated marine management areas have on indicator species abundance within Beqa Island, Fiji? There is no significant statistical difference between community allocated marine management areas areas and normally fished reefs within Beqa Island.

What are local fishers’ views on these areas, and how well respected are they? The local popultation views on these areas varies greatly. There is a split between those who believe that these areas work and well respected, and those that hold the opinion that these areas are no longer working and no respected.

From the results of this research, the Tabu areas which surround Beqa Island are not proving as effective as they could be. These areas are falling out of favour with the local population, a more modern radical approach must be taken to secure the safety of these Coral reefs in trying times. Addressing the main problems; Enforcement not always effective, difficult to understand rules, no set boat routes, little to no surrounding mangroves, too much rubble and
dead coral and the fact the area needs coral restoration, will improve the health of these reefs. Doing so requires attacking each problem on an individual basis; installing government regulated marine protected areas, improving education, adaptive co-management, local quotas, monitoring of reef health, these improvements will help to bring the Tabus to more modern and known to work Marine Protected Areas. While installing a coral and mangrove nursery will hopefully help replenish the state of the reefs. Re-installing the current Tabu areas with healthier and more abundant reefs allows Beqa Island to keep its identity and stand out amongst the Fijian islands.

![Diagram](image)

*Figure 20 Diagram summing up the roles of Taukei and the Government, before after and during the proposed enforcement period.*

Figure 20 shows the responsibilities of both the Taukei and government during each of the managerial stages. The most important stage is after the enforcement period, finding the correct balance of upholding traditions and customs while having some level of government backing is paramount.

There are a lot of problems with the reefs around Beqa Island and a lot of people relying on their health. By attacking the problems on many fronts, limiting anthropogenic damage and promoting the growth of these ecosystems, hopefully, the damage which have been inflicted can start the process of being healed. The people of Beqa have a strong sense of local pride, once the reefs have recovered full control of the reefs should be giving back to the village chiefs.
7.0 Bibliography


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http://wwf.panda.org/about_our_earth/blue_planet/coasts/coral_reefs/coral_importance/
