Shark Survey Report

I. INTRODUCTION

Coastal tropical water elasmobranchs are among the most threatened elasmobranchs, due to overexploitation and habitat destruction. Typically, these species present conservative life history traits such as late maturity, low fecundity and slow growth rates. Moreover, these species generally are top predators in many vulnerable ecosystems such as coral reefs; therefore these important species act as keystone and umbrella species for entire ecosystems (Chapman *et al.* 2005). The depletion of these top predators has a strong effect on entire ecosystems and species with a high economic value (Myers *et al.* 2007; Baum & Worm 2009). Knowledge about abundance, movement patterns and habitat use of tropical coastal sharks is key to develop successful long-term conservation and management plans in these essential species and vulnerable areas (Brunnschweiler & Earle 2006; Chapman *et al.* 2006). Moreover, coastal tropical sharks have a very high socio-economical value in many developing countries, generating ~$1 billion USD annually from the eco-tourism and fishing industries (Cisneros-Montemayor & Barnes-Mauthe 2013). However, declining of shark populations due to high fishing pressure have been well documented all around the world (Myers & Worm 2003; Simpfendorfer *et al.* 2008; Ward-Paige *et al.* 2010a; Worm *et al.* 2013).

Marine Protected Areas (MPAs) have played an important marine conservation role since the 1990s (Kelleher *et al.* 1995). During the Convention on Biological Diversity (CBD) in 2010, parties agreed to designate 10% of the Ocean as MPA by 2020, although only 2.3% had been achieved by 2013 (Techera & Klein 2014). Many MPAs remain on paper for years and some of the implemented ones have very poor management, monitoring and enforcement. Therefore, it is key to revise periodically the status of the established MPAs to address their effectiveness and improve their management and monitoring (Techera & Klein 2014).

There are several methodologies to estimate abundance of elasmobranchs including Baited Remote Underwater Videos (BRUVs), dive surveys and longline fishing surveys. The accuracy of diver-based counts has been questioned in the past, due to the tendency to overestimate numbers (Ward-Paige *et al.* 2010b). Although, the use of survey dives to study the abundance of elasmobranch and fish species have been used many times in the past around the world with successful results (Ward-Paige *et al.* 2010a; Rizzari *et al.* 2014). Additionally, Rizzari et al. 2014 evaluated four different survey methods including survey dives and BRUVs. They found comparable estimates for shark densities between these two methods, with no evidence for biases in diving surveys (Rizzari *et al.* 2014). Furthermore, Ward-Paige et al. (2010) studied the abundance of elasmobranchs in the Caribbean Sea from 1993 to 2008. They found a large-scale absence of sharks in areas with high fishing pressure.

Sharks were more abundant in areas with very low human population, or marine protected areas (Ward-Paige *et al.* 2010a).

The main objective of the study is to assess the abundance of sharks, rays, turtles and predatory fish species in a coastal tropical lagoon in Fiji, although only results for sharks, rays and turtles are shown in this report. In addition, we compared our preliminary findings between established Marine Protected Areas (MPAs) and fished areas around the lagoon to address their effectiveness in protecting elasmobranchs, turtles and commercially valuable species.

II. METHODS

A. Site Description

Beqa Lagoon lies just south of Fiji's main Island, Viti Levu. The lagoon consists of over 100 square of water surrounded by 30 kilometers of barrier reef (Fig.1). Beqa Lagoon is a famous dive site, and known worldwide as the Soft Coral Capital of the World. Beqa Lagoon has also several medium to small size MPAs established mostly by the local communities and one bigger MPA established by an NGO. We focus our diving effort in seven different areas including two of these MPAs and their corresponding "control" areas (Fig.1).

B. Survey Method

A total of eight survey dives are conducted every week throughout the year with volunteers. Divers conduct the underwater roaming survey in a group following a dive leader and record all the species sightings of sharks, rays, turtles and predatory fish species over 30 cm. Data is recorded on slates and for each individual length is estimated and sex is recorded if possible, as well as abiotic variables such as current, temperature, and visibility. Prior to the survey dives the volunteers have to learn how to identify 11 shark species (Silvertip Shark, Whitetip Reef Shark, Sicklefin Lemon Shark, Tawny Nurse Shark, Zebra Shark, Blacktip Reef Shark, Grey Reef Shark, Bull Shark, Tiger Shark, Scalloped Hammerhead Shark, Great Hammerhead Shark), 5 species of rays (Bluespotted Ribbontail Ray, Bluespotted Stingray, Giant Reef Ray, Spotted Eagle Ray and Reef Manta Ray) and 2 turtle species (Hawksbill Turtle and Green Turtle). In addition, volunteers will be trained to identify all predatory fish species and how to estimate their length. The length is estimated with the aid of a "T-stick" which is held close to the species encountered to obtain a better guess of the size. A T-stick is a PVC

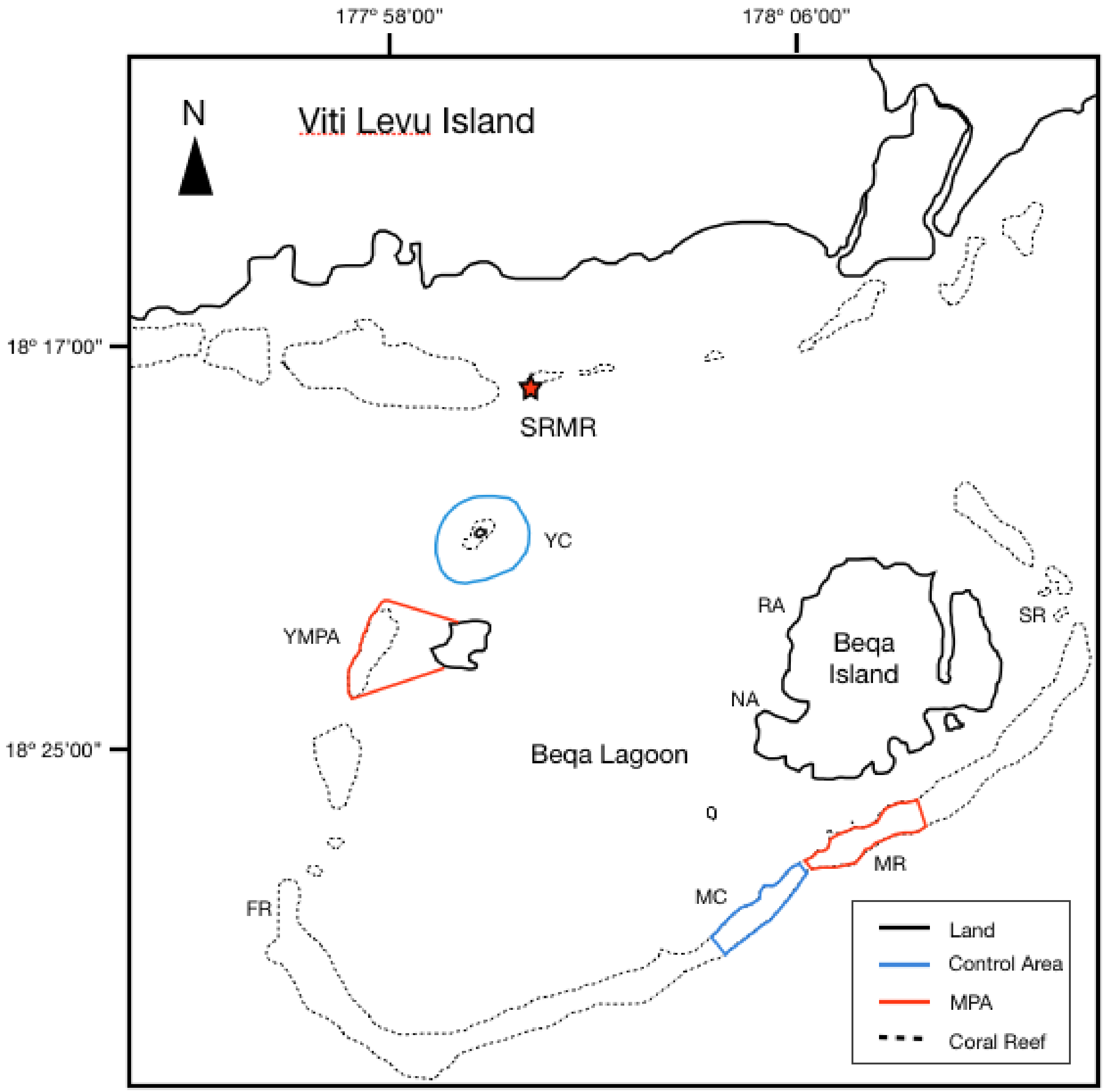

Figure 1. Map of Beqa Lagoon showing the different areas studied during survey dives. Yanuca MPA (YMPA), Yanuca Control (YC), Medium Reserve (MR) Medium Control (MC), Small Region (SR), and Frigates (FR).

pipe which measures 1 meter in length, has a 30 cm piece attached to the top of it and is marked every 10 cm. The survey dives run from 30 to 35 minutes and are between 5 and 20 meters depth. Our diving protocol requires every single diver to start the dive at the same time. This is to avoid overestimation of numbers. Every diver must record the bottom time at every individual sighting, in order to compare sightings once at the surface. After each dive, the data is be entered and closely reviewed by Projects Abroad scientists to avoid biases and overestimation of numbers.

The data recorded on slates underwater is combined and transcribed into three databases: The Global Shark Campaign database, E-sharks and The Great Fiji Shark Count. The Global Sharks Campaign database was created by Projects Abroad and records all sharks, rays and turtles, their length and sex. E-shark (www.e-shark.org) is an online data based used by divers worldwide and records sightings of sharks, rays, turtles, jellyfish and garbage. The Great Fiji Shark Count is a local database that records an individual's observations on a dive. It records the divers´ number of dives in their life, the number of dives in Fiji and the number and species of sharks, rays and turtles seen by that person.

A. Data Analysis

Data analysis was conducted on the shark, ray and turtle data. At this stage we do not have enough replicates in each region to be able to give confident results about the effects of the reserves however preliminary results are given. Data was analysed to show which regions are significantly different from each other in terms of shark, ray and turtle observations. The statistical software, JMP (JMP® 2013) was used and the Wilcoxon test for non-parametric data was done as well as the Wilcoxon´s pair-wise tests between regions for all variables.

III. RESULTS

From March to November a total of 194 dives have been done around Beqa Lagoon. When all sightings (sharks, rays and turtles) were analyzed together, SRMR was significantly different from all other regions, but Frigates ($p = 0.0703$, Fig.2). The total number of sharks spotted in all regions is 430 compared to 114 and 53 observations for turtles and rays respectively.

1. Shark Sightings

The greatest number of sharks was found in SRMR and FR with a maximum of 39 and an average of 5 shark sightings in SRMR and a maximum of 10 sharks and an average of 3 sharks in FR. No significant difference was found between these two regions ($\alpha < 0.05$), although a significant difference was found between SRMR and all other regions (p-value <0.01). FR was only found to be significantly different from YC and YMPA, which had the least number of sharks with an average of 1 and a maximum of 3 and 5 respectively. The low number of sharks found in YC and YMPA is significantly different to all other regions (p-value <0.001) except for MC as this region is observed to have fewer sharks than the other regions with a median of 2 and a maximum of 7 sightings. The regions not specifically mentioned fall between the greatest and the least number of sharks (Fig. 2).

2. Turtle Sightings

Turtle sightings data shows that FR and SR have been observed to have highest turtle sightings than all other regions with a median of 1 and a maximum of 6 and 3 sightings respectively and are significantly different to all other regions (p-value <0.05) except for SRMR. SRMR was also shown to have significantly higher turtle sightings than MR and YC (p-value <0.05). MC and YC were observed to have the least observations of turtles so far. The average turtle sightings for the other regions is close to zero however the outliers show that on certain dives 1 to 4 turtles were seen (Fig. 2)

3. Ray Sightings

The greatest numbers of rays was observed in MR with an average number of one ray being seen per dive. MR was found to be significantly different to all regions (p-value < 0.01) except for SRMR and MC, which have a median of 0.4 and 0.5 ray sightings respectively. The means for the other regions was very close to zero except on a few dives that are shown as outliers in Fig. 2. YMPA had the lowest ray sightings and was found to be significantly different from MC and SRMR (p-value <0.05).

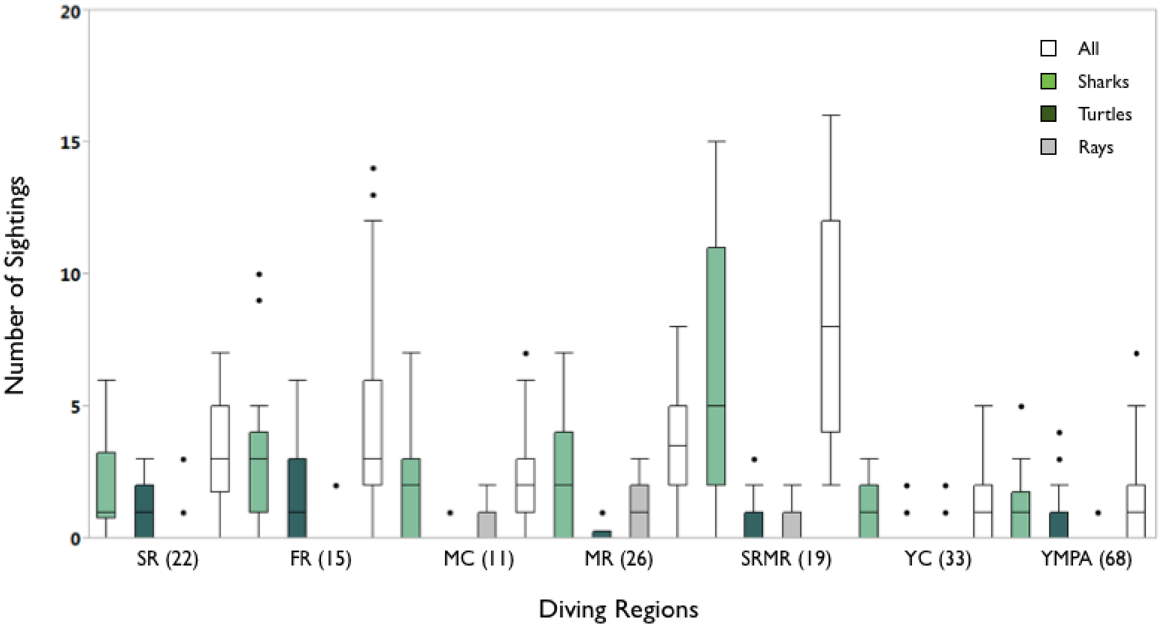

Figure 2. Plot showing the results of the Global Shark Campaign survey dives conducted by Projects Abroad volunteers between March and November 2014 in the different regions around Beqa Lagoon. Two outliers for the shark obvervations in SRMR are not shown here and have values of 39 and 29. Number of dives per region are shown in parentheses.

IV. DISCUSSION

The data collected by our volunteers since March 2014 shows some very interested aspects. The most consistent result across all comparisons was that SRMR is significantly different from any other place around Beqa Lagoon. These results have several explanations. Shark Reef Marine Reserve has been declared a National Marine Park since October 2014 and has been a Marine Reserve since 2003. This reserve has been very well managed by a local dive operator and the Galoa community since it was first established (Brunnschweiler & Earle 2006; Brunnschweiler 2010). SRMR is a non-take zone with only one operator working in the area. This setup is unique around the world and is one of the most successful local conservation projects. SRMR is also a provisioning site for shark species, specially bull sharks (*Carcharhinus leucas*), grey reef sharks (*Carcharhinus amblyrhinchos*), whitetip reef sharks (*Triaenodon abesus*), and blacktip reef sharks (*Carcharhinus melanopterus*). Even though sharks in this area have proven not to have changes in the long-term behavior, short-term diel movement patterns have been modified (Brunnschweiler & Barnett 2013). These changes in movement patterns of these shark species are also the reason why the number of sightings in SRMR is so much higher than any other region around Beqa Lagoon. For further information about SRMR please read (Brunnschweiler & Earle 2006; Brunnschweiler 2010; Brunnschweiler & Baensch 2011; Brunnschweiler *et al.* 2014).

Another interesting region for discussion is Frigates (FR, Fig.1). This area is the second least dived (n=15) of all the regions, only above the medium control (n=11), however it shows the second higher average of shark sightings and the highest average for turtle sightings (Fig. 2). In Frigates there is a special area, no longer than 100 meters, where a large number of whitetips aggregate and are usually seen resting on the bottom. This area is the reason why sharks sightings are so high in Frigates. Most turtles have been seen in this area as well, and schools of big snappers are a common sighting (Projects Abroad Global Shark Campaign Data). There is no apparent reason why this area has such a large number of predators, and further research must be conducted. The low number of dives in this region is likely to be the cause for the lack of significant differences found when compared to other surveyed regions.

Turtle sightings are higher in Frigates, SRMR and the Small Region (SR, Fig. 1). These regions have the best coral cover when compared to the other surveyed areas (Projects Abroad Marine Biologists personal communication). Healthy coral reef have been widely documented to support high numbers of low level consumers such as parrot fishes and turtles.

Rays were the least sighted group during our 194 survey dives (n=53). The Medium Reserve, Medium Control and SRMR regions were the most successful ones in terms of ray sightings (Fig. 2). Both MR and MC regions are low profile reefs with extensive sand flats were the largest number of blue-spotted stingrays. This type of habitat is typical for this benthic ray species. In addition, a large number of blue-spotted ribbontail rays have been spotted in the inside of SRMR, where there is an extensive area covered with low profile branching coral, where this species use to hide. Eagle rays and Manta rays have been spotted very few times due to either low abundance in the lagoon or repulsive behavior against large number of divers.

No major differences were found between Marine Reserves and their respective Control Areas, excluding SRMR of course. To properly assess the effectiveness of these MPAs, fish count data must be included in order to evaluate the reserve correctly. Local fishermen targeting fish species such as snappers and groupers exploit most areas around Beqa Lagoon. Usually, these fishermen do not target sharks and/or rays, although they are a desirable bycatch, either for personal consumption or for selling them in fish markets in Suva (local fishermen personal communication).

Data will continue to be collected over the entire year for sharks, rays, turtles and predatory fish species. Once a year is completed, seasonal trends as well as species specific distributions might be evident and could compared across regions, in order to determine the areas of highest conservation priority.

V. References

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