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Characterizing Elasmobranch Species Diversity, Occurrence and Catches in Small-Scale Fisheries of the Caribbean

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CHARACTERIZING ELASMOBRANCH SPECIES DIVERSITY, OCCURRENCE AND CATCHES IN SMALL-SCALE FISHERIES OF THE CARIBBEAN

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Camila Cáceres

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To: Dean Michael R. Heithaus
College of Arts, Sciences and Education

This dissertation, written by Camila Cáceres, and entitled Characterizing Elasmobranch Species Diversity, Occurrence and Catches in Small-Scale Fisheries of the Caribbean, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

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Florida International University, 2019

DEDICATION

I dedicate this dissertation to all the fishers around the world, particularly sustenance fishers. Your work has taught me the importance of getting up early every day, working hard without the guarantee of a reward, ALWAYS putting family first, giving back to your community, dancing in the rain, and persevering. I dedícate you the song El Pescador (The Fisherman) by AfroColombian singer Totó la Momposina.

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ABSTRACT OF THE DISSERTATION

CHARACTERIZING ELASMOBRANCH SPECIES DIVERSITY, OCCURRENCE AND CATCHES IN SMALL-SCALE FISHERIES OF THE CARIBBEAN

by

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Although 95% of fishers are artisanal, little is known about the magnitude of their catches and impacts on marine ecosystems at a global scale. I used a rapid assessment framework to study elasmobranch occurrence, elasmobranch fisheries, and use in coastal small-scale fisheries in the Caribbean, that combined observational data and fisher's knowledge. A total of 800 Baited Remote Underwater Videos were collected and 660 fisher and ocean-users surveyed across Colombia, Guadeloupe, Martinique, Tobago and the Florida Keys.

In Colombia, elasmobranch abundances were low and I detected no difference between the protected and unprotected reefs. From catch reconstruction, I estimated 9.7 – 254.2 metric tons of elasmobranchs landings from artisanal fisheries off the Caribbean coast of Colombia annually, compared to none reported by the government to FAO in 2014 and six metric tons estimated by Sea Around Us.

In the Lesser Antilles, the fate of artisanal fishers' catches of elasmobranchs varied by island, with Martinique reporting the highest proportion of keeping catch only

for subsistence, Guadeloupe having the highest proportion of keeping catch only to sell, and Tobago reporting the highest proportion for both sustenance and catch. Reconstructed catches were larger than what was reported to the FAO, but encompassed estimates made by Sea Around Us. Using different methodologies, upper estimates, however, ranged two to five times larger than what Sea Around Us estimated.

In the Florida Keys, recreational ocean activities such as fishing and diving are a lucrative businesses, and individuals in these industries represent potentially valuable sources of insight and knowledge on the current state of, and recent changes in, coastal oceans. Fishers reported capturing seven sharks species, while underwater users reported four shark species and BRUVs captured six sharks species. From BRUVs, I found that there are significantly more elasmobranch species captured on camera on the southern portion of the Upper Florida Keys, even though the relative abundance of elasmobranchs was significantly different across all three sampling blocks. These data revealed that fishers and divers agree on the need for protected areas and do not have a conflicting opinion with regards to elasmobranch conservation policies.

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CHAPTER I

GENERAL INTRODUCTION

Overfishing has been a local and regional problem for hundreds of years, and recently has become a global challenge. In addition to collapses of traditionally targeted species (Bundy 2005; Fromentin et al., 2014; Swain and Benoit, 2015), populations of large-bodied marine predators, including marine mammals, and sharks, have been quickly declining on a global scale (Heithaus et. al, 2008). Although humans have historically preferred to fish species near the top of food webs (Pauly et al., 2005; Sethi et. al, 2010), fisheries are now widespread on species at many different trophic levels (Essington et al., 2006). Elasmobranchs (sharks and rays) are mid and upper trophic level predators in oceans worldwide (Cortes 1999). They have been harvested around the world by industrial, artisanal, and recreational fisheries, and they are taken with a variety of fishing gears and vessel types (Prince 2002; Musick and Bonfil 2005). Assessing elasmobranch fisheries has proved difficult in many situations due to lack of species-specific data, a lack of data on population structure, and the highly migratory nature of many species (Calich et al., 2018).

In addition, many sharks are taken illegally and/or catches are not reported (Worm et. al, 2013). Sharks are more susceptible to the effects of fishing compared to bony fishes because of their low fecundity, slow growth and late maturity (Firsk et al., 2001; Mollet and Gailliet 2002; Gailliet 2015). These life history characteristics combined with heavy fisheries pressure has led to significant declines in elasmobranch populations in coastal, reef-associated and pelagic ecosystems (Baum et. al, 2003; Dulvy et al., 2008: Ferreti et al. 2010). Currently there are over 260 elasmobranch species, about 25% of all elasmobranchs around the world, listed as Vulnerable, Endangered or Critically Endangered on the IUCN Red List (Dulvy et al., 2014; IUCN 2019).

Although research and conservation efforts have mostly focused on the effect of industrial fisheries, small-scale fisheries account for more than 95% of fishers in the world, especially in developing countries of the Americas, Africa and the Indo-Pacific region (Pauly, 2006). In Latin America alone, they are an important source of food and income for more than two million people (FAO, 2014). Given their wide occurrence and the large number of dependents, artisanal fisheries are an important economic sector (Johnson et al., 2013) and their impact on elasmobranchs may be significant (Hawkins and Roberts, 2004; Salas et al., 2007; Moore et al., 2010).

My dissertation research focused on identifying elasmobranch species that are common in coastal coral reef artisanal fisheries in the Caribbean, understanding the nature of artisanal fisheries that take elasmobranchs, reconstructing catches of elasmobranch fisheries and characterizing local coral reef elasmobranch relative abundance and species diversity. The goals of this dissertation were: a) to gain insights into the extent and nature of sustenance and artisanal fisheries for elasmobranchs in several Caribbean nations; b) to gain insights into the potential for social science surveys of different ocean user groups (e.g fishers, divers, etc.) to reflect patterns of coastal elasmobranch abundance c) to estimate elasmobranch landings by artisanal fisheries and d) to compare elasmobranch landings to what has been reported to the Fisheries and Agricultural Organization (FAO) of the United Nations and reconstructed catches by the Sea Around Us project.

In Chapter II, I conducted in-person structured interview surveys (n=189) in Colombia at seven main fishing towns around the city of Cartagena and the islands of the

Natural National Park (NNP) Islas del Rosario and San Bernardo to gather information on the composition and use of their catches. I compared elasmobranch and teleost species richness and relative abundance within four coral reef habitats (each >4 km^2) fished by the local communities, using Baited Remote Underwater Video (BRUV) surveys (n=200).

In Chapter III, I used the same methods to study elasmobranch occurrence and use in coastal artisanal fisheries in Guadeloupe, Martinique, and Tobago. These islands provide an insights into artisanal elasmobranch fisheries across a gradient of sociocultural and economic conditions.

In Chapter IV, I studied how different ocean-user groups the Florida Keys perceived current and historical populations of elasmobranchs, to prioritize additional interview and BRUV sampling efforts. Recreational ocean activities such as fishing and diving are a globally lucrative businesses, and individuals in these industries represent potentially valuable sources of insight and knowledge on the current state of, and recent changes in, coastal oceans. I conducted in-person structured interview surveys (N=67) in the Upper Florida Keys and deployed BRUVs (N=150) in the waters offshore.

In my concluding chapter I summarize the results of these studies to provide insights into small-scale coastal fisheries pressures on coral reef- associated elasmobranchs in a variety of socio-economic contexts.

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CHAPTER II

INSIGHTS INTO ELASMOBRANCH AND TELEOST CATCHES IN ARTISANAL FISHERIES IN THE COLOMBIAN CARIBBEAN, BASED ON BAITED REMOTE UNDERWATER VIDEO AND INTERVIEW SURVEYS

Abstract

Although 95% of fishers are artisanal, the magnitude of their catches and impacts on marine ecosystems both at a local and global scales remain poorly understood. I used a rapid assessment framework to study teleost and elasmobranch occurrence, catch and use of catches in coastal artisanal fisheries along the Caribbean coast of Colombia. I conducted in-person structured interview surveys (n=188) during the fall of 2016 at eight fishing towns around the city of Cartagena and the islands of the Natural National Park (NNP) Islas del Rosario and San Bernardo to gather information on the composition of catches and their use. I used Baited Remote Underwater Video (BRUV) surveys to compare elasmobranch and teleost species richness and relative abundance within four coral reef habitats (each >4km^2), where species targeted by fishers occur. Two reefs allowed artisanal fishing while all fishing is prohibited on the other two reefs. Fishers reported capturing eight shark and four ray taxa; 51% reported *Sphyrnidae* spp., 43.9% *Carcharhinus leucas*, 37.7% *Galeocerdo cuvier*, 82.7% *Hypanus americana*, 81.6% *Aetobatus narinari*, and 3.1% *Myliobatis goodei*. Only three shark species and two stingray species were detected by BRUVs: *Negaprion brevirostris, Ginglymostoma cirratum, Rhizoprionodon* spp., *Dasyatis americana* and *Urobatis jamaicensis*. Elasmobranch abundances were low and I detected no difference between protected and unprotected reefs. Fishers reported Lutjanidae, Carangidae and barracuda as the main taxa they target, and although teleost abundances were also low, Tesoro Island had higher relative abundance than the other islands. On the basis of fisher surveys, I estimated 9.7 – 254.2 metric tons of elasmobranchs landings from artisanal fisheries off the Caribbean coast of Colombia annually, which exceeds previous reports and estimates. My data revealed that artisanal fishers continue to

exploit coral reef resources inside MPAs, retain almost all of the species they catch, perceive less elasmobranchs than when they started fishing and the only island that enforced protection had a significantly higher teleost relative abundance. Thus stakeholder inclusion, outreach and capacity building, and enforcement of MPAs is needed to protect and restore marine resources.

Introduction

Fisheries provide three billion people with almost 20% of their average per capita intake of protein, employ over 200 million people, and are valued at over US $60 billion internationally (FAO 2012). Research and reporting efforts have focused largely on industrial fisheries, yet small-scale fisheries account for more than 95% of fishers in the world (Pauly, 2006), and around 32% of the global fisheries catch (Pauly and Zeller, 2015). Given their wide occurrence and the large number of people who depend on them, artisanal fisheries are an important economic sector globally and warrant considerably more investigation and attention from scientists and policy makers than they have received (Johnson et al., 2013).

Artisanal fisheries, similar to industrial and recreational fisheries, also tend to target mid to large-bodied, predatory fish such as sharks and rays (Elasmobranchs), jacks (Carangidae), groupers (Serranidae) and snappers (Lutjanidae) (Stallings 2009). Although long-term time series data are uncommon in developing countries, declines in catch body-size, biomass (McClenachan 2009), and species composition- shifting from shark, grouper and snapper-dominated landings to lower trophic level species such as microinvertivores, omnivores and herbivores (McClanahan and Omukoto 2011)- have been observed.

Low fecundity, slow growth, and late maturity are life history traits that make sharks particularly vulnerable to over-fishing compared to bony fishes, because of their limited capacity to recover quickly (Holden 1974). Estimating elasmobranch artisanal fisheries is, therefore, particularly important for stock assessments and understanding the overall effect of fisheries on elasmobranch populations. However, such assessments have proved difficult due to the absence of species-specific data (Neis et al., 1999).

Elasmobranchs from coastal, reef-associated, and open ocean ecosystems have significantly declined over the last decades (Musick et al., 2000; Baum et. al, 2003; Dulvy et al., 2008; Ferreti et al., 2010). Despite conservation and management efforts in multiple regions around the world (including bans on shark finning, regulation of the shark fin trade, and the establishment of marine protected areas), elasmobranch bycatch and exploitation likely remain at unsustainable levels at a global scale (Worm et al., 2013; Ward-Paige and Worm, 2017; MacKeracher et al., 2018). Some countries, such as Australia, New Zealand, Canada and the United States, have properly managed certain sharks stocks relatively well (Simpfendorfer and Dulvy, 2017; Bradshaw et al., 2018). Currently there are over 260 elasmobranch species around the world listed as Near Threatened, Vulnerable, Endangered or Critically Endangered, and 452 species are listed as Data Deficient on the IUCN Red List (IUCN 2019).

Assessment and management of elasmobranch catches in artisanal fisheries in developing countries is usually absent or minimal (Andrew et al., 2007), despite their socio-economic importance to local communities. In Latin America, it has been estimated that more than two million people depend on artisanal fisheries for income, livelihoods and food security (Oliveira et al., 2019) yet the effect of artisanal fisheries on elasmobranchs has largely gone unstudied (Kroese and Sauer, 1998; Bizzarro et al., 2009; Cartamil 2011; Kiszka et al., 2014; Oliveira et al., 2019). Within South America, Colombia is unique since it has coasts on both the Atlantic and Pacific oceans and has diverse fishery resources both in the artisanal and industrial sectors (Wielgus et al., 2010). Given that within the Caribbean, the western region has been identified as a site with high coral and fish diversity (Roberts et al., 1998) and there is a wide range of population densities on islands of Colombia (from completely uninhabited to the world's most densely populated island), the Colombian Caribbean is an important site to study elasmobranch catches in artisanal fisheries.

In Colombia, the artisanal fisheries on the Caribbean coast employ an estimated 14,000 people, and the most commonly used gears are gillnets, hand-lines, and longlines (Beltrán-Turriago and Villaneda-Jimenez, 2000; De La Hoz et al., 2014). All seafood caught in artisanal fisheries in Colombia is consumed nationally (Magnusson et al., 1983). However, official landings data have been lost during governmental changes of fisheries management agencies, and currently there are only official data from 1975-2019 (Wielgus et al., 2010). In 1975, the families Gerreidae, Centropomidae and Lutjanidaes made up the largest proportion of marine teleosts caught in this fishery. By 2014, estimated tonnage for these families had decreased by six magnitudes, with Haemulidae and Mugilidae contributing the largest proportions to landings (Pauly and Zeller, 2015). Although elasmobranchs have never been the bulk of artisanal landings, their potentially important ecological role (Ferreti et al., 2010; Heupel et al., 2014; Roff et al., 2016) and susceptibility to fisheries (Field et al., 2009; Cortes et al., 2010) call for a need to improve catch records.

Elasmobranch catch data are missing between 1950 and 1975 from government records, and catch records after 1975 are incomplete, with entire years of data missing (Caldas et al., 2009). However, in 2010, Colombia created their first National Plan of Action (NPOA) for the management of chondrichthyan (sharks, rays, and chimaeras) resources. The NPOA highlighted the importance of further evaluating the nature and extent of artisanal fisheries that capture chondrichthyans, particularly in the continental Caribbean region, and calls for all National Natural Parks to be the primary tool for the conservation of chondrichthyans in national waters (Caldas et al., 2010).

Interview surveys can enhance our understanding of the interactions between artisanal fisheries and marine taxa, particularly charismatic species such as marine mammals, elasmobranchs, and sea turtles (Hall and Close, 2007, Moore et al. 2010, Hind 2014). Despite the limitations of social survey data (e.g., data are generally more qualitative than quantitative), the interview method provides insights into species targeted and caught, quantities captured, and gears used in a low-cost and time effective manner (Moore et al., 2010; Carruthers and Neis, 2011; Tesfamichael et al., 2014). Using fishers' knowledge can also elucidate current and historical catch information and can help integrate stakeholders in research and conservation efforts. However, field-based elasmobranch sampling methods should still be used in conjunction with interview surveys to gather information for a more complete understanding of population status.

I used a coupled socio-ecological approach to investigate artisanal reef-associated teleost and elasmobranch catches in coastal habitats in the Colombian Caribbean. Using a combination of fisheries-independent sampling of coral reef habitats using Baited Remote Underwater Video Surveys (BRUVS) and dedicated interview surveys, I set out to 1) characterize the artisanal elasmobranch and teleost catches around the National Natural Park Corales del Rosario and San Bernardo, 2) to document the occurrence and relative abundance of reef-associated elasmobranchs and predatory teleosts, and 3) to assess if the MPAs in the Natural Park contribute to reef-associated fish conservation.

Materials and Methods

Study site

Colombia has coasts on both the Pacific Ocean and Caribbean Sea. It is estimated that over 190,000 fishers in Colombia depend on freshwater and marine resources for their livelihood (Rueda 2001), with 12,500 artisanal fishers on the continental Caribbean coast (Salas et al., 2011). However, for most fishing communities, there is limited information on their fishing practices and social and economic roles. Given that coral reef artisanal fisheries are widespread in the Caribbean (Salas et al., 2007; Dunn et al., 2010; Turner et al., 2014) and that only one of the three national parks in the Colombian Caribbean has coral reefs near a large human population, I developed my project in the National Natural Park Corales del Rosario and San Bernardo. The park is approximately 23 km from the bay of Cartagena, and it was created in 1977 to protect the coral reefs around the Rosario Archipelago. In 1996 it was expanded to include the archipelago of San Bernardo, which is located 43 km south of the Rosario Archipelago. From the original ordinance created in 1977, all industrial fisheries are prohibited within the park and only sustenance fisheries are allowed for native islanders with gillnetting, longlining and dynamite fishing prohibited. Starting in 2000, all fishing, including sustenance fishing, was prohibited off the islands Tesoro (in Rosario) and Mangle (in San Bernardo).

Interview Surveys

Many fishers who live outside the MPA enter the MPA to fish, so I also conducted interviews in fishing towns that are on the outskirts of the park. A total of 188 interview surveys were conducted in seven different islands or towns in and around the MPA Natural National Park Corales del Rosario and San Bernardo Islands, including Isla Grande (n=12), Santa Cruz del Islote (n=25),and Mucura (n=32) which are inside the park, and Baru (n=26), Rincon (n=3), Tierra Bomba (n=48) and Cartagena (n=42) (Figure 1). Four islands with at least 2km^2 of surrounding coral reefs were sampled inside the park with BRUVs; two in the north (Grande and Tesoro in Corales del Rosario) and two in the south (Tintipan and Mangle in Islas San Bernardo; Figure 1). All the islands are of coral origin, with Grande, Tesoro, Tintipan and Mangle surrounded by fringing reef with a steep drop off at 40 meters. It is important to note that Isla Tesoro belongs to the nation's president, and therefore is mostly uninhabited year-round and heavily guarded and patrolled by the Colombian Coast Guard. In contrast, on the same reef tract as Isla Tintipan lies the islet Santa Cruz del Islote, which is the world's most densely populated island, at 1.25 inhabitant per 10 m^2. Tesoro and El Islote provided a considerable gradient in human population density to investigate the effect of artisanal fisheries on reef associated fish.

Questionnaire surveys were conducted in person during the months of Oct.-Nov. 2016. Teleost species were reported by fishers by their common name. However, since most elasmobranch species in Colombia are rare and can be difficult to identify, the FAO Identification Guide to Common Sharks and Rays of the Caribbean was used to verify identifications (Bonfil, 2016) . Certain taxa, such as *Rhizoprionodon* spp., *Sphyrna* spp. and *Mobula* spp., are difficult to identify at the species level without specimens to examine, so I recorded these taxa at the generic level.

The questionnaire was a modification of the methods of Moore et al. (2010). My questionnaire (Appendix I) had a particular focus on elasmobranch captures and use, but also included questions about teleost species that were also targeted and captured. First, questions investigated the interviewee's characteristics: age, gender, occupation and fishing background, monthly fishing effort (days at sea and hours per day), fishing boat characteristics (boat size, engine power and number, and number of fishers in the crew), targeted species, and on fishing gear uses and practices. Questions about sharks and rays included inquiries about catch frequency and seasonality and, whether elasmobranchs are targeted species, caught as bycatch or retained as by-product, as well as the ultimate fate of the catch (sold, retained for consumption, or both). Lastly, perception questions were asked, with fishers having to report whether they believe there are more, less, or the same number of sharks and rays since they started fishing. (Appendix 1).

Low and high estimates of the biomass of elasmobranchs landings were calculated by multiplying the average of the minimum and maximum number of sharks reported per fisher annually, by assumed average weight of catches based on 1) the smallest species reported by fishers (*Rhizopriodonon* spp.; 1 kg/ fishbase.org) and 2) the most common shark species found in Caribbean coral reefs (*Ginglymostoma cirratum*; 15kg/ fishbase.org) respectively. Similarly for rays, biomass of landings reported were calculated by multiplying the minimum and maximum average number of rays reported per fisher, by the assumed average weight of the 1) smallest ray in the Caribbean (*Urobatis jamaicensis*; 1 kilogram/fishbase.org) and 2) the most common ray species found in Caribbean coral reefs (*Hypanus americanus*; 5kg /fishbase.org) respectively.

These estimates were then multiplied by the proportion of fishers that reported keeping elasmobranch catch to eat, sell or trade. The final estimate was divided by average crew size. The same calculations were done for rays. Therefore, I estimated yearly Artisanal Elasmobranch Landings (AEL) in biomass for each island as:

$$AEL = \bar{C} \;\; \overline{W} \;\; Fp$$

(Eqn.1)

where $\bar{C}$ is average number of elasmobranchs caught per fisher in a year, $\overline{W}$ is average weight assumed for the catch. F denotes the number of artisanal fishers in the island, p denotes the proportion of fishers that reported keeping the catch. My method is a modified approach of what Yuniarta et al.'s (2017) method to estimate uncertainty in small-scale tuna catch reconstruction in Indonesia.

Baited Remote Underwater Video Surveys (BRUVS)

Baited cameras have been used to study predatory fish in a variety of habitats, including coral reefs (Brooks et al., 2011; Bond et al. 2012, Wraith et al. 2013, Harvey et al., 2018). I used BRUVs that consisted of a video camera (GoPro-Hero 2) mounted on a metal frame. A small, pre-weighed bait source (1 kg of crushed Atlantic red herring *Opisthonema oglinum*) was attached on a 1m pole in the camera's field of view, with a rope attached to the frame that terminated in a buoy.

Between 24 Sep- 30 Oct 2016, BRUVs were deployed during daylight hours at sampling locations identified by a random number generator that produced latitude and longitude points along the forereefs of the four sample reefs at a depth of 8-40 m. The BRUVs were deployed from the boat using a rope and in-water personnel to orient the BRUV facing down current. The BRUV was allowed to film continuously for ~ 90 minutes after settling to the bottom. Each day, four units were deployed simultaneously, retrieved, rebaited, moved to new locations and deployed for a second time. No BRUVs were simultaneously deployed within 500m of one another. At both the start and end of each deployment environmental variables were measured including bottom depth with a handheld depth Vexilar Handheld Digitial Sonar, and water temperature, salinity, and dissolved oxygen with a YSI Pro 2030.

The BRUVS were deployed at 262 points on the forereefs. I used 50 videos at each site for analyses. I only used deployments that had at least 90 minutes of continuous filming, the water column was at least 50% of the screen image, and visibility >3m. All videos were watched for 90 min from the start time, at normal speed and annotated independently by at least two observers. Data recorded by observers included species identification and the maximum number of individuals from each species (MaxN) within a single frame (Bond et al., 2012). Videos were watched for sharks, rays, and teleost fish that are important in artisanal fisheries, particularly groupers (Serranidae), snappers (Lutjanidae), jacks (Carangidae), grunts (Haemulidae), mackerel (Scombridae) and barracudas (Sphyraenidae).

Data analysis

Since no BRUV had more than one individual of a particular elasmobranch species, and all video durations were virtually identical, I used logistic regression to test the hypothesis that environmental parameters and island would affect the probability of observing a shark or a ray with link logit:

$$Elasmo.prescence \sim Island + Temperature + Dissolved\ Oxygen + Salinity + Depth$$

(Eqn. 2)

where *elasmobranch presence* is the occurrence of sharks and rays (separately), *island* is a fixed effect and *temperature*, *DO, Salinity* and *Depth* are random effects.

Since only five teleost families had MaxN>1, a Generalized Linear Model (GLM) and one-way ANOVAs were run to test for differences in fish family sum of MaxN (Serranidae, Lutjanidae, Haemulidae, Scombridae and Carangidae) across islands, followed by a Tukey Post-hoc test. The R software version 1.1.463 was used with the MASS4 library (R Core Team, 2016). All values reported are mean + SD unless otherwise noted.

Results

Interview survey data

Interviewed fishers were mostly males (90%), on average 46.5 ±15.1 years old (range: 18 - 86) and had an average fishing experience of 30.1 ±16.8 years (range: 4 to 55 years). Average boat size was 5.2 ±3.5 meters in length, with an average crew size of 3.37m ±3.1 members. The most common type of boat used by interviewed fishers was a fiberglass canoe (n= 126 of 188; 67%) with an average size of 5.25m ±3.6, followed by a wooden canoe ("panga", n= 43 of 188; 22.8%) with an average size of 3.8m ±3.6, and the third most common was a large wooden canoe called a ("chalupa", n= 14 of 188; 7.4%) that may or may not have sails and is used for longer trips, with an average size of 18.5m ±5.6. Most fishers (n= 110 of 188, 58.5%) fished on a boat with a motor, with an average of 27.7 ±16.5 HP. The majority of interviewees (n=184 of 188; 97.8%) depended on fishing as their only occupation.

The most common primary fishing practices reported were handlining with one to three hooks (n= 96 of 188; 51%), followed by spearfishing (n= 23 of 188; 12.2%), and beach seining (n= 23 of 188; 12.2%). Fishers reported using nine different fishing techniques, including nooses (n= 6 of 188, 3.3%), traps (n=3 of 188, 1.6%), cast nets (n= 1 of 188, 0.5%), and prohibited gears, such as longlines (n= 9 of 188; 4.8%), and dynamite (n= 1 of 188, 0.5%). Some fishers did not report a gear (n= 26 of 188, 13.8%), and fished simply by free diving and grabbing conchs and crabs by hand (Figure 2). The majority of fishers only used two gears (n=80 of 188; 42.5%), but 35 different gear combinations were reported.

Snappers (Lutjanidae) were reported as the primary target catch by 64.9% of fishers reported as the primary target catch, jacks (Carangidae) by 32.5% and barracuda (Sphyraena spp.) by 22% (Figure 3). Seven out of the ten most commonly sought-after taxa were reef-associated, with bonito (Scombridae) being the only pelagic taxa listed. Fishers identified thirteen elasmobranch taxa in their catches, including eight shark taxa and four ray taxa. Hammerhead sharks (*Sphyrnidae* spp.), bull sharks (*Carcharhinus leucas*), and tiger sharks (*Galeocerdo cuvier*) were reported most frequently (Table 1). *Hypanus americana, Aetobatus narinari*, and *Myliobatis goodei* were the most commonly reported rays (Table 2).

When fishers were asked whether they targeted sharks, 85.6% (n= 161 of 188) indicated they did not. Regardless of whether fishers targeted sharks, 71.3% (n=134 of 188) of them reported keeping the catches to sell, eat, or both. A total of 69.7% (n= 131 of 188) of fishers said they did not target rays, but 77.6% (n= 146 of 188) reported retaining catches. The majority of fishers 83.8% perceived a decline of sharks in the coastal waters since they started fishing, compared to 40.8% of them for batoids. Based on answers by fishers, I estimate landing an average of 5.6-228 metric tons of sharks and 4.07-26.2 rays a year (Table 3).

BRUV data

Although a large variety of teleost taxa were observed on the videos, there was no significant difference in large and commercially important teleost presence between the protected and unprotected sites (GLM: z=-.72; P =.472), and there was no significant effect of any of the environmental variables on teleost presence. Only the families

Serranidae, Lutjanidae, Haemulidae, Scombridae and Carangidae, had a MaxN > 1 consistently across islands (Figures 4-7). There were significant differences in abundances across islands (ANOVA: F=7.82, P<.001), with Tesoro Island having higher MaxN than the other islands (Table 4).

Lutjanidae MaxN was significantly different across islands (ANOVA: F=18.11, P<.0001), with the highest values at Tesoro Island (Table 4). Abundances of Haemulidae were also significantly different across islands (ANOVA: F=3.07, P<.05), with MaxN at Tesoro Island greater than at Mangle (Table 4).

Abundance of Serranidae MaxN varied spatially (ANOVA: F=4.55, P<.01), with Mangle and Tesoro having greater MaxN than Grande Island (Table 4). There was no significant difference in Carangidae (ANOVA: F=1.59, P>.05) or Scombridae (ANOVA: F=1.06, P>.05) MaxN across islands.

Only three shark species and two stingray species were observed: *Negaprion brevirostris, Ginglymostoma cirratum, Rhizoprionodon* spp., *Dasyatis americana* and *Urobatis jamaicensis*. For sharks, 17 out of the 200 BRUV deployments (8.5%) had at least one shark, and 26 out of the 200 BRUV deployments (13%) had at least one batoid. Overall, 40 of the 200 BRUV deployments (20%) recorded at least one elasmobranch. There was no significant difference in shark (GLM: z = -0.684; P = 0.49) or ray (GLM: z = 1.03; P = 0.32) presence between the protected and unprotected islands and there was no significant effect of any of the environmental variables on shark and ray presence/absence, except for salinity (GLM: z = 2.21; P = 0.03).

Discussion

Interview survey data revealed that most fishers do not preferentially target elasmobranchs. Indeed, 84.3% of fishers declared they did not target sharks, and 68.6% mentioned they did not target rays. Although they were not targeted, more than 70% and 75% of fishers caught and retained sharks and rays, respectively, to consume or sell. Wielgus et al. (2010) calculated that 50.6% of total annual catch was retained (for all fish excluding tunas), rather than sold, by small-scale fishers in the Caribbean. I found that for elasmobranchs, the proportion being kept rather than sold was much smaller for both sharks (14.6%) and rays (35.6%). Fishers reported eight shark and four ray taxa as being part of their catches and commonly found in and around the Natural National Park Corales del Rosario and San Bernardo. Out of the eight reported taxa, the most commonly reported three species were large-bodied sharks, despite these sharks being rare in shallow water coral reef habitats and none were recorded on BRUVs. This discrepancy likely is due to large-bodied sharks being more memorable and easily identified.

In other places in the Caribbean where sharks are protected, such as Abaco in the Bahamas, sharks appeared in 70% of BRUV sets (Whitman 2018). Along the continental Caribbean coast of Colombia, sharks are not protected. Although the Natural National Park Corales del Rosario and San Bernardo includes protected areas where industrial fisheries are prohibited and areas were all fishing is prohibited, the size of this area is small compared to the home range sizes of reef sharks (Chapman et al., 2005) and the large-bodied roving taxa reported by fishers. Also, interview survey data revealed that artisanal fishers continue to exploit coral reef resources inside areas were all fishing is prohibited, retain almost all of the animals they catch, and perceive fewer elasmobranchs than they did when they started fishing. Data from BRUVs are consistent with the interview survey data, showing relatively low species richness and relative abundances of elasmobranchs in the sampled area.

Given the nature of the boats and gears used by artisanal fishers in Colombia, most fishers cannot access remote reefs, thus the limited area accessible to most fishers can lead to overexploitation regardless of conservation policies (Abernethy et al., 2007). Fishers self-reported fishing with prohibited gear and fishing in the protected areas at night to avoid being caught by Park personnel, which demonstrates that fishers knowingly ignore conservation policies and explains, at least in part, why I observed no significant difference in elasmobranch in protected and unprotected areas.

Although fishers reported eight shark taxa in their interviews, only four shark taxa (in order of occurrence) *Negaprion brevirostris, Ginglymostoma cirratum, Rhizoprionodon* spp., and *Carcharhinus perezii* appeared on BRUVs. Fishers reported four main batoids, including *Hypanus americana, Aetobatus narinari, Myliobatis goodei* and *Mobula* spp. in interviews. However, only *Hypanus americana* and *Aetobatus narinari* were recorded on the BRUVs.

Large predatory teleosts were reported to be targeted by fishers and appeared in BRUVs at relatively low abundances. A total of 35 teleost species from 16 different families were recorded on BRUVs, but most families had MaxN of 1. Lutjanidae, Carangidae, Haemulidae, Scombridae and Serranidae were the only predatory fish families that were detected across all islands, and Tesoro had significantly higher relative abundances than the rest of the islands. This difference may be the results of Tesoro being the only island where fishing restrictions are enforced, since it is protected and regularly patrolled.

The flexible and informal nature of artisanal fisheries make them very difficult to monitor, particularly in developing countries where these fisheries are most common. At the national level, in 2012, a government agency, the Servicio Estadistico Pesquero Colombiano (SEPEC, Colombian Fisheries Statistical Service) interviewed 4,026 fishers across the country, including the Caribbean and Pacific coasts as well as inland communities near rivers. Most questions asked about their socio-economic status and general census information. No species-specific catch or ecological data were collected (SEPEC 2013). In 2014, SEPEC gathered species-specific data at landing sites across the nation. In a six-month period (January-June), they estimated 21.42 metric tons of sharks and 15.29 metric tons of rays landed along the continental Caribbean coast for artisanal fisheries. They recorded 19 different shark species and eight ray species in the landings, with *Rhizoprionodon porosus* making up the majority, 44.63%, of shark catches and *Dasyatis americana* making up the majority, 42.9%, of ray catches (De La Hoz et al., 2014). For teleosts, Scombridae made up the largest proportion of Caribbean artisanal catches, at 36.6% with an estimated 393.2 tons. The next largest proportion of catches was of Carangidae , which made up 24.6% of the catches with 271.2 tons landed, and Lutjanidae, at 5.3% of landings and 58.1 tons. No data were collected during other months, and no information was gathered on whether the catch was directed, the fate of the catch, the gears used, or fisher's perceptions of stock fluctuations.

The Sea Around Us project has reconstructed undocumented catches in many countries, including Colombia, by observing landings, bycatch ratios, what enters the commercial market, population estimates and, in certain regions, by having on-site scientists recording the catches they observe being brought in by fishers. In Colombia, Sea Around Us estimated that in 2014 small-scale fisheries contributed 98% of the reconstructed officially-reported landings. They estimated unreported catches by assuming 49.6% of total catches (all catches that were not tuna) were consumed by fishers and their families (subsistence), while the rest of the catch entered the economic sector (Lindop et al., 2015).

The year 2014 was the only year with landings data reported by the government to FAO, and estimates developed by Sea Around Us and SEPEC. Reported in 2014 to the FAO were 5,263 metric tons for all marine taxa landings along the Colombian Caribbean coast for both industrial and artisanal fisheries, out of which elasmobranchs had no captures reported. In comparison, Sea Around Us calculated that landings for both industrial and artisanal fisheries totaled 22,890 metric tons for all marine taxa in the Colombian Caribbean, out of which elasmobranchs were not reported nor mentioned. For that same year, SEPEC estimated 21, 427 metric tons of landings in a six-month period for all marine taxa in the Caribbean coast for both industrial and artisanal fisheries, which included 36.71 metric tons of elasmobranchs landed by artisanal fishers. I estimated total elasmobranch biomass landed per year was between 9.7 – 254.2 metric tons, from Caribbean artisanal fisheries only. Given that I am using the average weight of the most common shark and ray species for the upper end of my estimates, and using the number of registered boats instead of the number of fishers as a metric of fishing units, it is likely my upper estimate is overestimating the total elasmobranch catch since all the assumptions used were on the higher end of the spectrum. Similarly, the lower end and best estimate catch reconstructions likely are underestimates since number of registered boats and fishers are probably higher.

On the basis of the intensity of fishing reported by fishers, population trends reported by fishers, elasmobranch catch estimates and BRUV data, it appears that elasmobranch and teleost populations have low relative abundances both inside and outside protected areas. Further involvement of stakeholders, as called by the National Plan of Action for Sharks (Caldas et al., 2010), as well as stricter enforcement of policies in place (given that some fishers disregard them) is needed. However, enforcement can be difficult in developing nations with limited resources (Linnell et al., 2001; Keane et al., 2008;) and therefore community-based conservation methods (Hrbek et al., 2007; Keane et al., 2008; Stacey et al., 2012) may be more effective. My study highlights the challenges that remain in estimating the full extent and nature of artisanal catch and the role it plays in Colombian fisher's livelihood and socio-economics, as well as the importance of interview surveys as a cost and time-effective method that engages local stakeholders.

Interview surveys provide a local point of view and therefore can facilitate the collection of data on a wide range of socio-economic and cultural issues that can aid in conservation. Interviewing fishers can also help alleviate the frustration fisheries stakeholders experience when their perspective is not considered in policy making. Without including local stakeholders in fisheries management and research, conservation measures are unlikely to be effective without community-based regulations if fishers do not cooperate and willingly abide rules. The tension between fishers and enforcement in my study area is highlighted an incident in July 2018 when a group of fishers in Corales del Rosario and San Bernardo attacked the Park Headquarters in Mucura as retaliation for two fishers being arrested for cutting down protected mangroves.

Despite the history of violence and political unrest in Colombia, Colombia currently ranks as the fifth wealthiest country in Latin America in Gross Domestic Product (GPD) per capita (CIA factbook). Colombia was also the seventh country in Latin America, after Chile, Costa Rica, Ecuador, Guatemala Mexico and Uruguay to implement a National Plan of Action for the management of shark and ray resources (NPOA-CO). Colombia's NPOA, alongside Brazil's, is unique in Latina America in providing proposed management strategies. Given that in Colombia elasmobranch catches in artisanal fisheries are likely still being underestimated there remains a need for improved record keeping and stakeholder inclusion in developing countries to ensure successful conservation and management strategies.

Figures

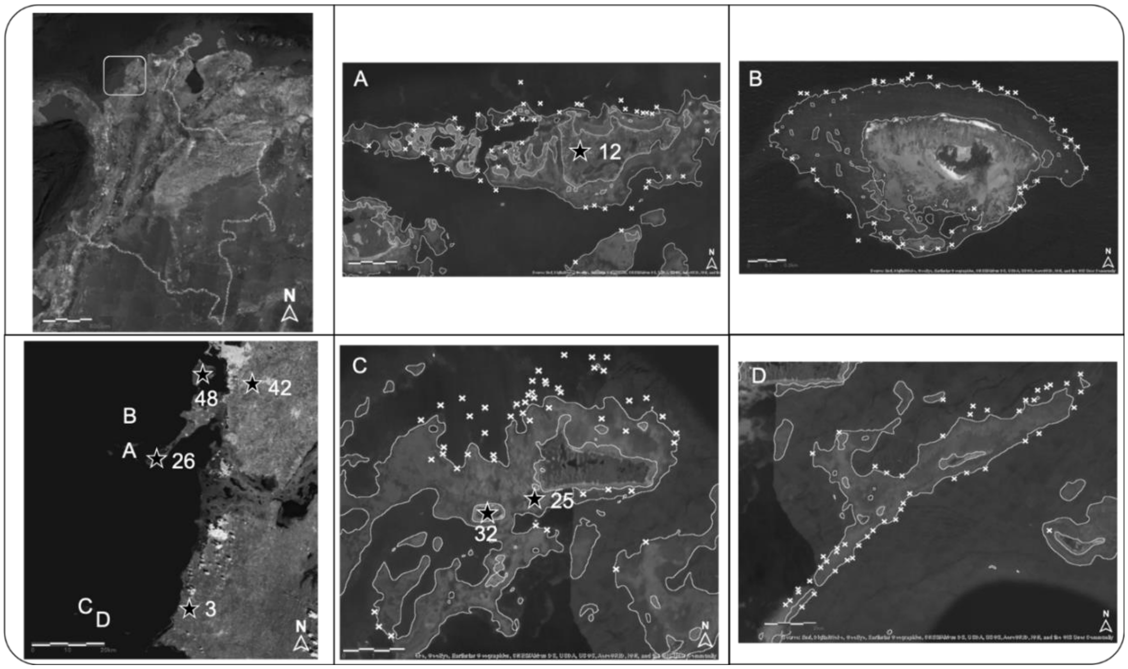

Figure 1. The study occurred along the Caribbean coast of continental Colombia (a,b,c). The outer reef is outlined in white, while dots represent individual BRUV drops, and the numbered black stars denote the number of interview surveys collects at a site. Sampling occurred at Isla Grande (a) in Corales del Rosario, Tesoro (b) in Corales del Rosario, Tintipan Reef (c) in San Bernardo and Mangle Reef (d) in San Bernardo.

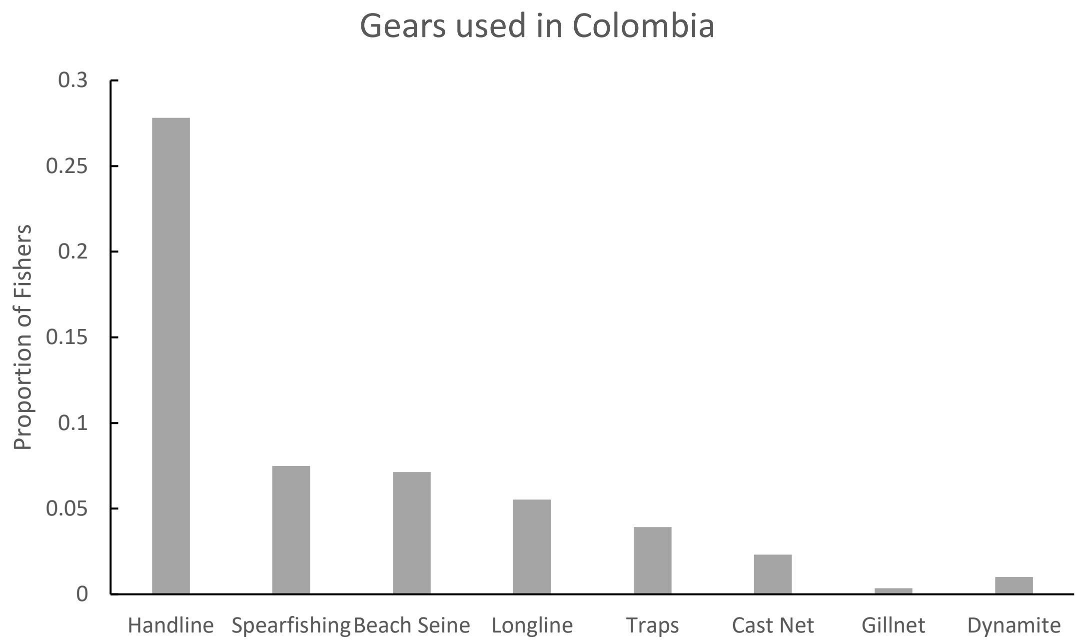

Figure 2. Top eight fishing practices reported by fishers.

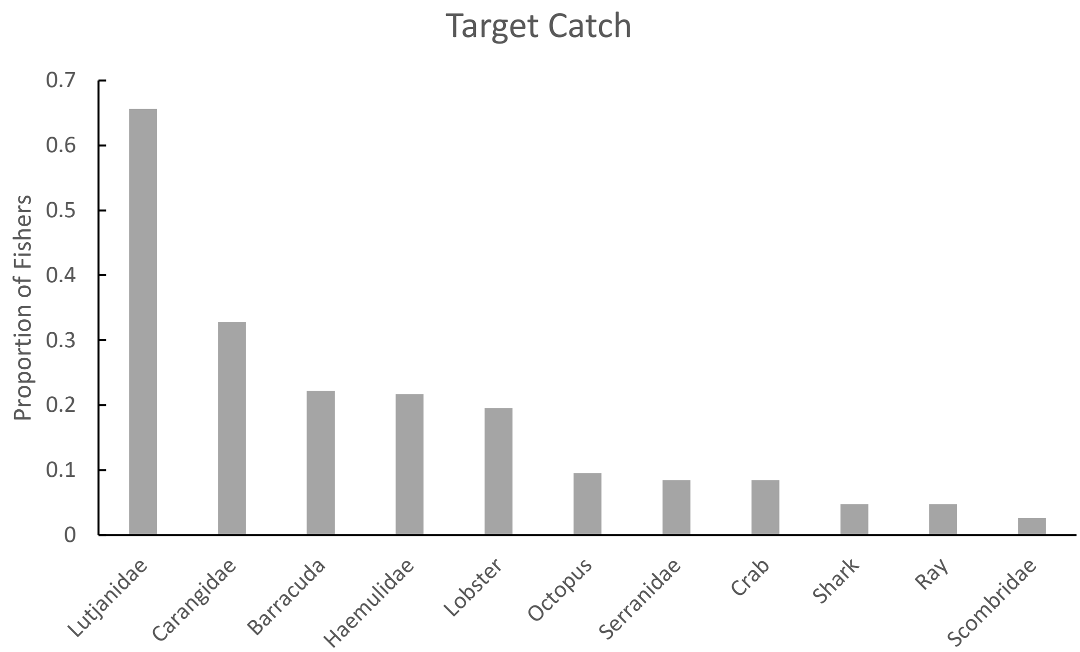

Figure 3. Top eleven taxa reported as targeted by fishers.

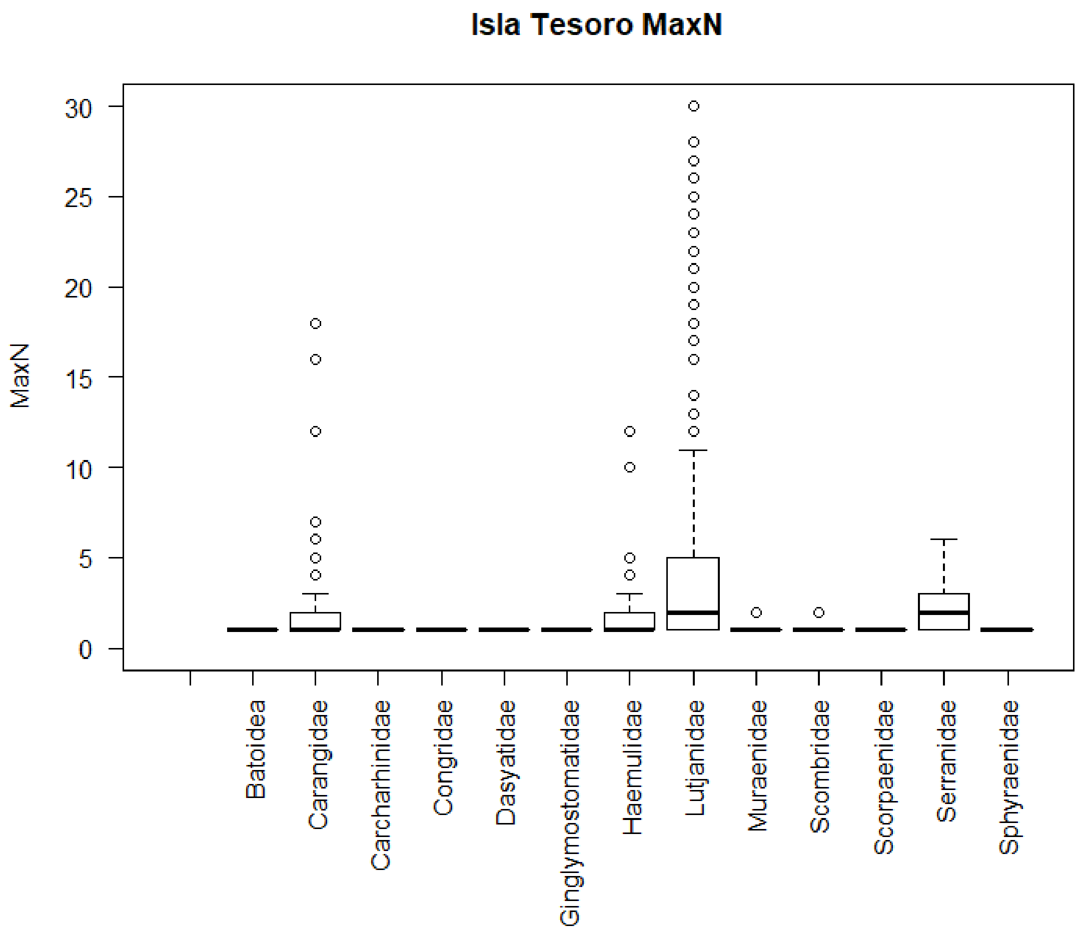

Figure 4. Boxplots of MaxN for fish families observed on BRUVs in Tesoro Island. Boxes show the lower (Q1) and upper (Q3) quartiles, as well as the median observation. Open circles are outliers.

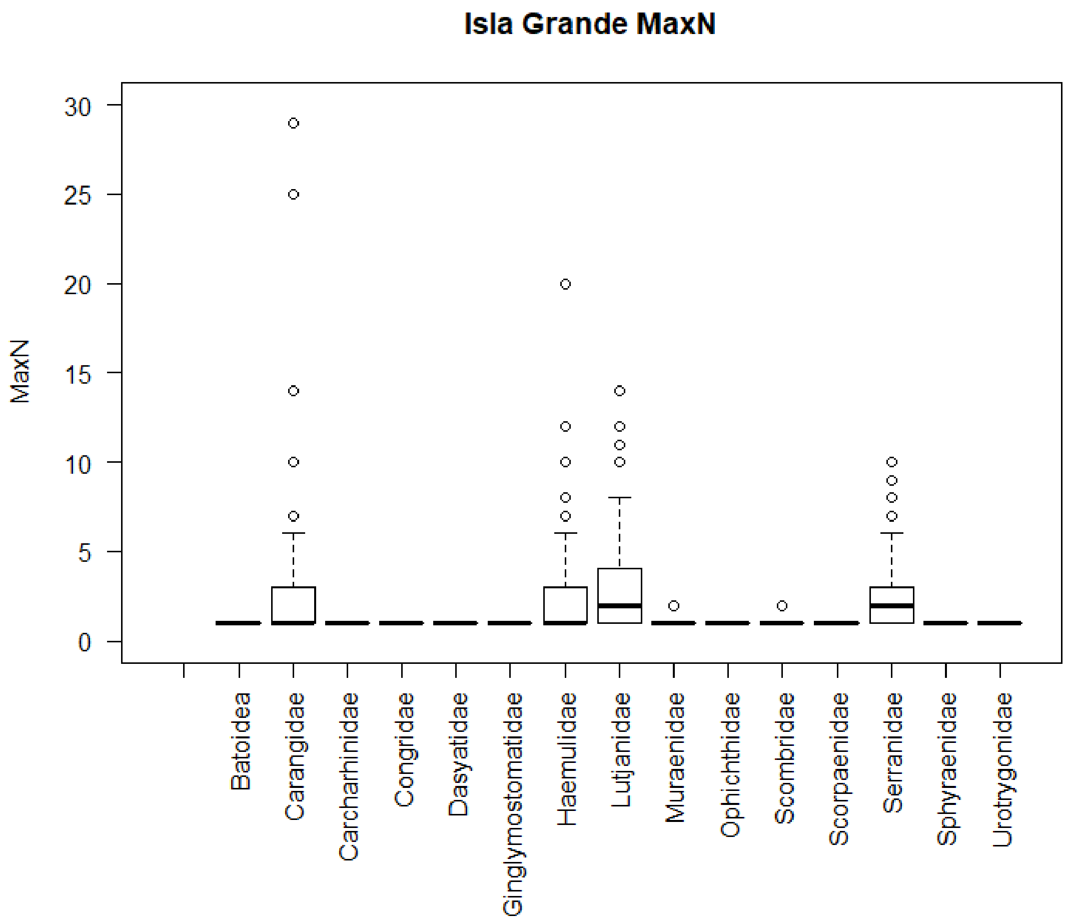

Figure 5. Boxplots of MaxN for fish families observed on BRUVs in Grande Island. Boxes show the lower (Q1) and upper (Q3) quartiles, as well as the median observation. Open circles are outliers.

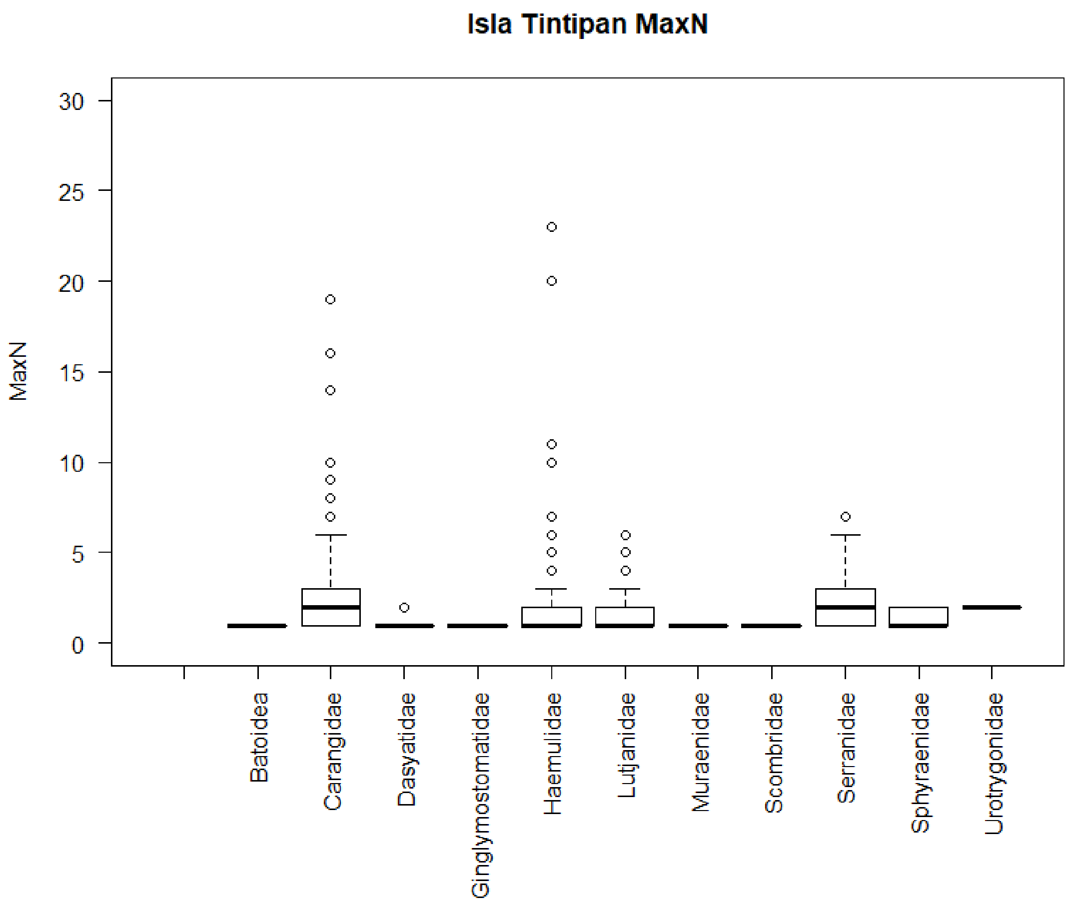

Figure 6. Boxplots of MaxN for fish families observed on BRUVs in Tesoro Island. Boxes show the lower (Q1) and upper (Q3) quartiles, as well as the median observation. Open circles are outliers.

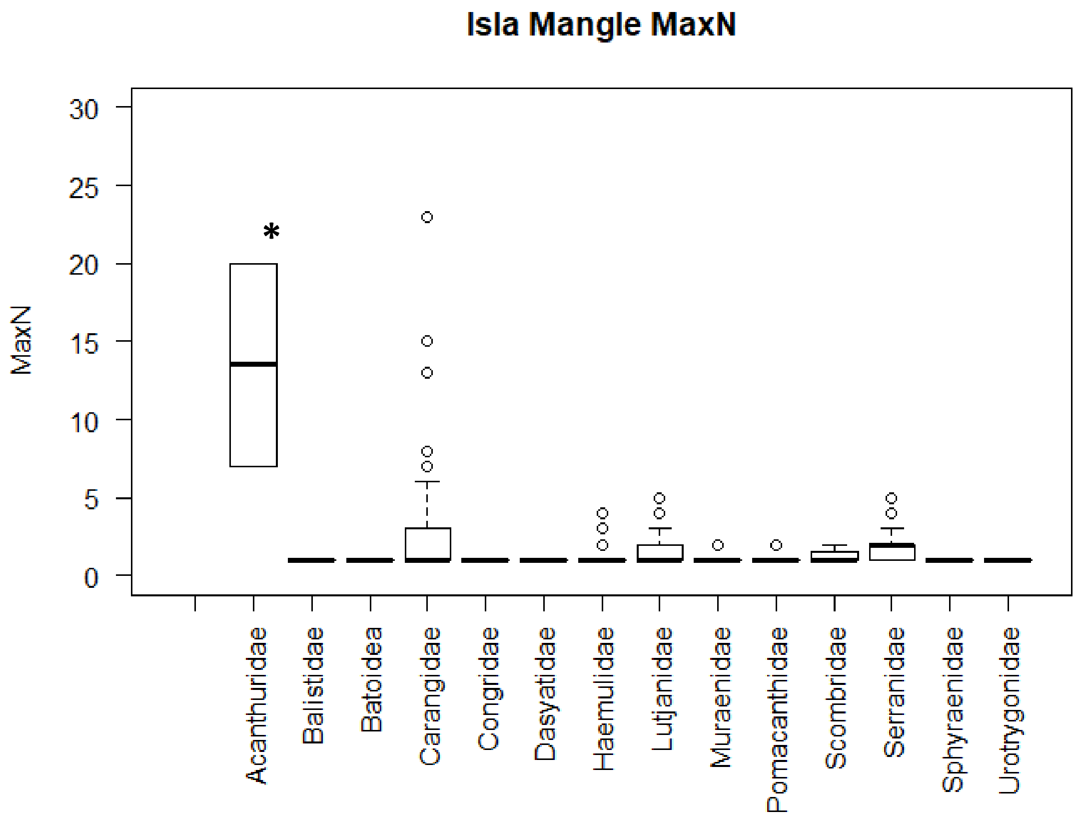

Figure 7. Boxplots of MaxN for fish families observed on BRUVs in Mangle Island. Boxes show the lower (Q1) and upper (Q3) quartiles, as well as the median observation. Open circles are outliers.

Table 1. Shark taxa fishers reported catching, and the proportion of BRUVs where they were observed in protected (n=100) and unprotected reefs (n=100).

Taxa	**Proportion of 189 fishers reporting (n)**	**Proportion of BRUVs in Protected Areas**	**Proportion of BRUVS in Unprotected Areas**
1) Hammerhead Shark, *Sphyrna spp.*	0.52 (98)	0	0
2) Bull Shark, *Carcharhinus leucas*	0.44 (84)	0	0
3) Tiger Shark, *Galeocerdo cuvier*	0.38 (72)	0	0
4) Nurse Shark, *Ginglymostoma cirratum*	0.26 (50)	0.11	0.03
5) Caribbean Reef Shark, *Carcharhinus perezi*	0.11 (21)	0.01	0.01
6) Lemon Shark, *Negaprion brevirostris*	0.09 (18)	0.02	0
7) Blacktip Shark, *Carcharhinus limbatus*	0.05 (10)	0	0
8) Sharpnose Shark, *Rhizoprionodon spp*	0.04 (8)	0.01	0

Table 2. Ray taxa fishers reported catching, and the proportion of BRUVs where they were observed in protected (n=100) and unprotected (n=100) areas.

Taxa	Proportion of 189 fishers reporting (n)	Proportion of BRUVs in Protected Areas	Proportion of BRUVs in Unprotected Areas
1) Southern Stingray *Hypanus americanus*	0.84 (158)	0.08	0.11
2) Spotted Eagle Ray *Aetobatus narinari*	0.83 (156)	0	0.01
3) Southern Eagle Ray *Myliobatis goodei*	0.03 (6)	0	0
4) Mobula *Mobula spp.*	0.02 (3)	0	0
5) Spotted Yellow Ray *Urobatis jamaicensis*	0.0 (0)	0.04	0.06

Table 3. Reconstruction of elasmobranch landings by artisanal sector, compared to other estimates.

	A1. Average Min elasmobranchs landed a year per fisher	A.2 Average Max elasmobranchs landed a year per fisher	B. Number of boats registered	C. Assumed weight	D. Proportion of fishers retaining catch	Total estimated range of elasmobranch landings	Artisanal Elasmobranch catches reconstructed by SAU in 2014:	Elasmobranch catches reported to FAO for all fishing sectors in 2014:	Artisanal Elasmobranch catches reconstructed by SEPEC in 2014:
Sharks	15.3	41.6	500	Min. 1kg Max. 15kg		.731	5.6 - 228T		42.84T
Rays	11.7	40.9	500	Min. 1kg Max. 5kg		.697	4.12 - 6.2T		30.6T
Total							9.7- 234.2T	6.0 T	73.44T

Table 4. Post-hoc comparisons among islands using the Tukey's test (alpha = 0.05) for sum of teleost MaxN, Lutjanidae MaxN, Haemulidae MaxN and Serranidae MaxN.

Dependent variable	(I)Islands	(J) Island	Mean Difference (I-J)	Sig.	95% Confidence interval Lower Bound	Upper Bound
Sum of teleost MaxN	Mangle	Grande	-0.66	0.30	-1.62	0.31
Sum of teleost MaxN	Tesoro	Grande	0.97	0.01	0.18	1.78
Sum of teleost MaxN	Tintipan	Grande	0.03	0.99	-0.88	0.95
Sum of teleost MaxN	Tesoro	Mangle	1.63	<0.0001	0.71	2.56
Sum of teleost MaxN	Tintipan	Mangle	0.69	0.32	-0.34	1.72
Sum of teleost MaxN	Tintipan	Tesoro	-0.94	0.03	-1.83	-0.07
Lutjanidae MaxN	Mangle	Grande	-0.67	0.86	-2.89	1.54
Lutjanidae MaxN	Tesoro	Grande	3.71	<0.0001	1.98	5.44
Lutjanidae MaxN	Tintipan	Grande	-1.19	0.51	-3.42	1.03
Lutjanidae MaxN	Tesoro	Mangle	4.38	<0.0001	2.22	6.55
Lutjanidae MaxN	Tintipan	Mangle	-0.52	0.95	-3.10	2.06
Lutjanidae MaxN	Tintipan	Tesoro	-4.90	<0.0001	-7.08	-2.72
Haemulidae MaxN	Mangle	Grande	-1.06	0.67	-3.47	1.45
Haemulidae MaxN	Tesoro	Grande	0.96	0.49	-0.78	2.70
Haemulidae MaxN	Tintipan	Grande	1.09	0.65	-1.32	3.51
Haemulidae MaxN	Tesoro	Mangle	2.02	0.03	0.14	3.91
Haemulidae MaxN	Tintipan	Mangle	2.15	0.12	-0.37	4.67
Haemulidae MaxN	Tintipan	Tesoro	0.13	0.99	-1.76	2.02
Serranidae MaxN	Mangle	Grande	-0.66	0.03	-1.27	-0.05
Serranidae MaxN	Tesoro	Grande	-0.52	0.02	-0.96	-0.07
Serranidae MaxN	Tintipan	Grande	-0.11	0.95	-0.62	0.41
Serranidae MaxN	Tesoro	Mangle	0.14	0.93	-0.46	0.74
Serranidae MaxN	Tintipan	Mangle	0.55	0.13	-0.10	1.20
Serranidae MaxN	Tintipan	Tesoro	0.41	0.15	-0.09	0.91

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Appendix I.

Cuestionario para la evaluación de la captura de elasmobranquios

Para el entrevistador:

Entrevista Nro: __________

Fecha: __________

Hora del día: ____________

Información sobre la ubicación:

Estado: __________ Comunidad: __________

Pueblo: _____________

Lugar de la entrevista: Muelle En el hogar del pescador Otro: _______________

Si en el muelle, cual es el número de barcos en ese momento?

Circunstancia de la entrevista: saliendo al mar regresando de pesca Otro: __________

Género del entrevistado: Hombre Mujer

Se uso un traductor o persona intermedia para ayudar a realizar esta entrevista? S N

Declaración inicial:

Me llamo __________. Yo trabajo en un proyecto llevado a cabo por la Universidad Internacional de la Florida. Esta organización lleva a cabo una investigación de la pesca y el mar. El objetivo de este proyecto es simplemente aprender más sobre la pesca costera y sus relacion con los tiburones y rayas. Su participación es voluntaria y confidencial. No vamos a grabar su nombre o cualquier información personal o compartir sus respuestas individuales con nadie fuera del equipo de investigación. Sus respuestas honestas no tendrán consecuencias para usted; esto es estrictamente para la investigación académica. Nuestra investigación podría, sin embargo, ser utilizado para ayudar a mejorar el medio ambiente marino y la sostenibilidad de la pesquería a largo plazo. Usted no tiene que responder a cualquier pregunta que no desee, y puede terminar esta entrevista en cualquier momento. La entrevista completa tardará unos 15 - 30 minutos. Nos damos cuenta de que usted está muy ocupado y apreciamos mucho su voluntad por tomar tiempo con nosotros.

Descripción del barco y pescador

¿Qué tipo de barco tiene usted o usa usted para la pesca?

¿Qué tan grande (en metros) es el barco que usted usa para la pesca? __________

Está motorizado el barco? Si no

¿Cuál es la potencia del motor? __________

¿Cuantos pescadores, incluyendo a usted mismo, están en el barco cuando salen a pescar?

cuántos años lleva pescando?

Cuantos años tiene?

Pesca y captura:

Responder a estas preguntas para describir su experiencia individual, no la de su comunidad.

¿Cuáles son los tres tipos de artes de pesca principales que utiliza con mayor frecuencia en el transcurso de un año? (ilustraciones de uso)

Arte 1: ____________________________________

Arte 2: ____________________________________

Arte 3: ____________________________________

Para las tres artes mencionadas anteriormente, llenar detalles de:

Rede de enmalle de fondo. Longitud ___________ Tamaño de la malla________________

Redes de enmalle a la deriva. Longitud __________ Tamaño de la malla__________________

Palangre: tamaño del anzuelo: _________ Número de ganchos _____________

Anzuelo y sedal (1 o pocos ganchos): Redes de arrastre (a lo largo del barco) Fija Otro

Red de cerco o cerco envolvente. Tamaño de malla ____________ Longitud de la red _____________

Cerco de playa (jábega). Tamaño de malla ____________ Longitud de la red _____________

trampas

Otro (describa): __________

¿Durante qué meses del año utiliza cada arte?

Arte 1: _____________________________________

Arte 2: _____________________________________

Arte 3: _____________________________________

Durante los meses mencionados anteriormente, ¿cuántos días por semana pesca con cada arte?

Arte 1: ______________________________________

Arte 2: ______________________________________

Arte 3: ______________________________________

En un día promedio, ¿cuántas horas está en el barco de pesca?

Durante el pico de la temporada de pesca, ¿cuántas horas está en el barco de pesca?

¿Qué está tratando de capturar con cada arte (en orden)?

Arte 1: ______________________________________

Arte 2: ______________________________________

Arte 3: ______________________________________

¿Cuántos días al ano pesca en el arrecife? ¿Y cuantos en el mar abierto?

Rayas

¿Alguna vez ha atrapado rayas al utilizar estas artes? Escribe: Sí No No recuerdo

Arte 1: ______________________________________

Arte 2: ______________________________________

Arte 3: ______________________________________

Cuando capturo una raya, fue:

Captura dirigida capturada incidental subproducto (captura de forma incidental pero se uso)

¿Qué hiciste con las rayas capturadas en los últimos 12 meses?

Descartar muerta Liberar vivas Vender sólo aletas Vender todo el cuerpo Consumo propio

Otros: __________

¿Por qué?____________________________

Si contesto sí a un arte o más, complete lo siguiente:

Arte1: ¿Qué especies se han capturado con esta arte (usar ilustraciones), y que tan seguro esta?

Lista de especies, en orden de más a menos comúnmente atrapados.

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

Durante qué meses del año atrapan rayas con esta arte ?:

Especies 1: ______________________________________

Especies 2: ______________________________________

Especies 3: ______________________________________

¿Cuántas rayas en total atrapo este último año, con esta arte?

marcar con un círculo: 0 1 – 10 11 – 20 21 – 50 50 no sabe

¿En que profundidad del agua y qué tan lejos de la costa estaba pescando cuando los atrapo?

Arte 2: ¿Qué especies se han capturado con esta arte (usar ilustraciones), y que tan seguro esta?

Lista de especies, en orden de más a menos comúnmente atrapados.

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

Durante qué meses del año atrapan rayas con esta arte ?:

Especies 1: ______________________________________

Especies 2: ______________________________________

Especies 3: ______________________________________

¿Cuántas rayas en total atrapo este último año, con esta arte?

marcar con un círculo: 0 1 – 10 11 – 20 21 – 50 50 no sabe

¿En qué profundidad del agua y qué tan lejos de la costa estaba pescando cuando los atrapo?

Arte 3: ¿Qué especies se han capturado con esta arte (usar ilustraciones), y que tan seguro esta?

Lista de especies, en orden de más a menos comúnmente atrapados.

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

¿Durante qué meses del año atrapan rayas con esta arte ?:

Especies 1: ______________________________________

Especies 2: ______________________________________

Especies 3: ______________________________________

¿Cuántas rayas en total atrapo este último año, con esta arte?

marcar con un círculo: 0 1 – 10 11 – 20 21 – 50 50 no sabe

¿En qué profundidad del agua y qué tan lejos de la costa estaba pescando cuando los atrapo?

Tiburones

¿Alguna vez ha atrapado tiburones al utilizar estas artes? Escribe: Sí No No recuerdo

Arte 1: ______________________________________

Arte 2: ______________________________________

Arte 3: ______________________________________

Cuando capturo un tiburón, fue:

Captura dirigida capturada incidental subproducto (captura de forma incidental pero se uso)

¿Qué hiciste con los tiburones capturados en los últimos 12 meses?

Descartar muerto Liberar vivos Vender sólo aletas Vender todo el cuerpo Consumo propio

Otros: ___________

¿Por qué?_____________________________

Si contesto sí a un arte o más, complete lo siguiente:

Arte1: ¿Qué especies se han capturado con esta arte (usar ilustraciones), y que tan seguro esta?

Lista de especies, en orden de más a menos comúnmente atrapados.

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

Durante qué meses del año atrapan tiburones con esta arte ?:

Especies 1: ______________________________________

Especies 2: ______________________________________

Especies 3: ______________________________________

¿Cuántos tiburones en total atrapo este último año, con esta arte?

marcar con un círculo: 0 1 – 10 11 – 20 21 – 50 50 no sabe

¿En que profundidad del agua y qué tan lejos de la costa estaba pescando cuando los atrapo?

Arte 2: ¿Qué especies se han capturado con esta arte (usar ilustraciones), y que tan seguro esta?

Lista de especies, en orden de más a menos comúnmente atrapados.

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

Durante qué meses del año atrapan tiburones con esta arte ?:

Especies 1: ______________________________________

Especies 2: ______________________________________

Especies 3: ______________________________________

¿Cuántos tiburones en total atrapo este último año, con esta arte?

marcar con un círculo: 0 1 – 10 11 – 20 21 – 50 50 no sabe

¿En qué profundidad del agua y qué tan lejos de la costa estaba pescando cuando los atrapo?

Arte 3: ¿Qué especies se han capturado con esta arte (usar ilustraciones), y que tan seguro esta?

Lista de especies, en orden de más a menos comúnmente atrapados.

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

___________________ Muy seguro bastante seguro no estoy seguro

¿Durante qué meses del año atrapan tiburones con esta arte ?:

Especies 1: ______________________________________

Especies 2: ______________________________________

Especies 3: ______________________________________

¿Cuántos tiburones en total atrapo este último año, con esta arte?

marcar con un círculo: 0 1 – 10 11 – 20 21 – 50 50 no sabe

¿En qué profundidad del agua y qué tan lejos de la costa estaba pescando cuando los atrapo?

El riesgo para los pescadores

¿Los tiburones dañan su equipo de pesca? Si no

En caso afirmativo, qué tipos de artes se dañan? _______________________

¿Con qué frecuencia ha sido su equipo dañado por los tiburones en el último año?

marcar con un círculo: 0 1 – 2 3 - 5 6 – 10 > 10 no sabe

¿Los tiburones dañan lo que capturan? Si no

¿Con qué frecuencia ha sido comida/dañada su captura por un tiburón en el último año?

marcar con un círculo: 0 1 - 2 3 – 5 6 – 10 > 10 no sabe

En su vida, ¿alguna vez has sido herido por un tiburón? Si no

Si contesto que si, que tan grave fue su lesión? Muy grave ligeramente grave no fue grave

Si contesto que no, ¿qué tan probable cree usted que sea herido por un tiburón?

Muy probable poco probable no es probable

El Pasado

A comparación de cuando empezó a pescar:

hay más, menos o la misma cantidad de tiburones / rayas en las áreas que usted pesca?

La captura accidental de rayas / tiburones es mayor, menor, igual, o no saben?

La captura accidental de rayas / tiburones es mayor, menor, igual, o no saben?

Preocupaciones

¿Tiene algún comentario general con respecto a sus actividades de pesca que usted piensa que es necesario tener como prioridad? (Rango en orden)

1.

2.

3.

ENTREVISTADOR PARA SOLAMENTE

¿Qué tan abierto y honesto parecio el pescador al responder a las preguntas acerca de sus capturas?

Muy abierto / honesto Algo abierto/ honesto no fue honesto

¿Qué tan interesado y comprometido parecía el pescador durante la entrevista?

Muy interesado moderadamente interesado No le interesa

¿Qué tan seguro parecia el pescador respecto a sus respuestas?

Muy seguro razonablemente seguro Inseguro

CHAPTER III

INSIGHTS INTO ELASMOBRANCH SPECIES DIVERSITY, RELATIVE ABUNDANCES, CATCHES AND USE IN ARTISANAL FISHERIES OF GUADELOUPE, MARTINIQUE AND TOBAGO.

Abstract

Elasmobranch populations are declining in many regions around the world. The contribution of elasmobranch catches in artisanal fisheries to these declines remain poorly known for many locations. I employed a rapid assessment framework that uses fisheries-independent sampling and fisher surveys to study elasmobranch occurrence and use in coastal artisanal fisheries of the Eastern Caribbean for the islands of Guadeloupe, Martinique, and Tobago. I conducted in-person structured interview surveys (n=405) between June 2015 and June 2017 and deployed Baited Remote Underwater Video (BRUV) systems (n=50 video drops/reef) at nine reefs across the islands. Fishers reported catching far more species of sharks (n= 22) and rays (n = 4) than were observed on BRUVs (n = 5 and 2, respectively). The fate of artisanal fishers' catches of elasmobranchs varied by island, with Martinique reporting the highest proportion of fishers keeping their catch for subsistence, Guadeloupe having the highest proportion of keeping their catch to sell, and Tobago reporting the highest proportion for both sustenance and sale. I also found that fishers retained almost all animals caught, and they perceive fewer elasmobranchs than when they started fishing. Artisanal elasmobranch catch reconstructions based on interview data, numbers of boats registered on each island, and a range of assumptions about catch size, were larger than what was reported to the FAO, but encompassed estimates made by Sea Around Us. Therefore, elasmobranch landings may exceed current estimates. These high catches appear to have impacted coral reef elasmobranchs. BRUVs revealed relatively low occurrence, relative abundance and species diversity compared to Caribbean nations with less fishing pressures on

elasmobranchs. The present study highlights the need for improved data on, and monitoring of, artisanal catches.

Introduction

Compared to bony fish, elasmobranchs have lower fecundity, slower growth and late maturity (Frisk et al., 2011; Mollet and Cailliet 2002). This slower somatic growth rate and late maturation makes these species more susceptible to overexploitation (Hayes, 2007; Jiao et al., 2011; Levesque 2013; Miller et al., 2014). Overfishing is the biggest threat elasmobranchs are facing (Pauly et al., 2005; Worm et al., 2009; Davidson et al., 2016; Jabado et al., 2018). Industrial fisheries in the past 50 years appear to have diminished the global biomass of large predatory fish by 90%. Species diversity of these fish has also declined 10-50% (Myers and Worm 2003; Myers et al., 2005; Worm et al. 2005), and 63% of fish stocks worldwide are estimated to require rebuilding (Worm et al., 2009).

Most fisheries management effort has been focused on industrial fisheries because they have been assumed to generate a much larger fishing effort and impact on fish stock compared to the artisanal sector (Belhabib et al., 2014; Belhabib et al., 2018) because of the large size of the boats, crews, and fishing gears, as well as the global economic demand for commercial fish stocks such as tuna. Indeed, industrial fisheries have been identified as the driver behind many stock collapses (Springer et al., 2003; Pinsky et al., 2011; Jacques 2015; Dickey-Collas 2016; Perissi et al., 2017).

Although the effects of industrial fisheries on marine ecosystem are relatively well known (Hampton et al., 2005; Mansfield 2010; Pinsky et al., 2011), the impacts from artisanal fishing have remained difficult to characterize (Adam et al. 1997, Coblentz 1997; Harkins and Roberts 2004). Artisanal fisheries are characterized by their low-technology traditional fishing methods and gears, have small crew and boat sizes, and capture many of the same species as industrial fisheries (Hawkins et al. 2004; Stallings 2009) but in different locations. Unlike industrial and recreational fisheries that target large-bodied species, artisanal fisheries tend to target reef-associated mid-sized upper trophic level fish (Erlandson et al., 2009; Litzow et al., 2009).

Artisanal fisheries commonly occur close to shore near coral reefs while industrial fisheries are greater off-shore in pelagic habitats. But, these two sectors are not mutually exclusive, because of the large-scale movement and life-history traits of many large predatory fish species and the ability for artisanal fishers in some locations to access pelagic habitats (Stergiou et al., 2004; Horta and Defeo, 2012). Coral reef teleosts and elasmobranchs are threatened by fisheries in many areas around the world. Indeed, the vulnerability of reef sharks to overfishing has been highlighted even in a well-managed reef system of a developed country, like the Great Barrier Reef in Australia (Hisano et al., 2011). Given that 58% of the world's coral reefs are within 30 minutes from the closest human population (Maire et al., 2016), the scope and potential impact of fisheries on coral reef elasmobranchs needs to be investigated. In the Caribbean, coral reefs and predatory fish are heavily exploited (Mumby et al., 2004; Stallings 2008; Paddack et al., 2009; Mumby et al., 2012; Pineheiro et al., 2016) and elasmobranch populations are considered to be some of the most heavily impacted in the world (Ward-paige et al., 2010; Ferreti et al., 2010; Ward-Paige et al., 2011).

Artisanal fisheries in the Caribbean occurred long before the arrival of European settlers (Stallings 2009) and continue to be prevalent. The use of elasmobranchs as a food source and as a cultural part of cuisine can be traced back to the Aztecs (Applegate et al., 1993) and Mayans (Ritter et al., 2013) and it continues to be a staple in many low-income households because of the low commercial value of the meat (Applegate et. al., 1993; Lack et al., 2014; Dulvy et al., 2017). Artisanal fisheries in the Caribbean, including in the Lesser Antilles, have been assumed to be sustainable (Gobert 2000; Carder et al., 2012) because of their traditional methods and localized nature. Based on this assumption, many national parks continue to allow artisanal fisheries (Hawkins et al., 2004).

In the Caribbean, historical socio-economic factors (Carder et al., 2007) and culture (Romero and Creswell, 2005), likely have influenced marine exploitation patterns more than ecology. On the basis of archeological fish records in Anguilla, Carder et al. (2007) determined that during the post-saladoid period there was an increase in scombrid fishing despite there being no environmental change. It is likely that economic or social factors contributed to the change in fishing strategies. Similarly, Venezuela, Trinidad and Tobago, Grenada, Barbados, and St. Vincent and the Grenadines share the same marine mammal species and environmental factors, yet different marine mammal exploitation practices arose as a result of cultural circumstances (Romero and Creswell, 2005).

Because of the dispersed nature of artisanal fisheries and challenges of direct monitoring, catch reconstructions are needed to better understand the magnitude and nature of artisanal fisheries and their impact on vulnerable and/or overexploited ecosystems and taxa. It is estimated that on a global level, between 1950 and 2010 nations under reported their total catches on average by 50% (Pauly and Zeller, 2016) because artisanal catches, recreational catches, discarded bycatch and illegal fishing are unreported or underreported (Pauly and Zeller, 2016).

Catch reconstructions are usually done by estimating the fishery effort done by a sector, which requires knowing the number of fishing boats, and the average catches per vessel (Belhabib et al., 2017). However the informal, flexible and multi-gear nature of artisanal fisheries, as well as the limited resources and spatially-dispersed nature of these fisheries in developing countries (Zeller et al., 2006), make it difficult to estimate how many boats comprise the artisanal fleet, how many gears/hooks have been deployed and how long they have been deployed for. In addition species-specific data are often missing and reported as “NA” or “No Data”, which commonly ends up being substituted as “zero catches” in fisheries reports that influence management and conservation policies (Zeller et al., 2006).

In order to optimize methods for gathering data to support catch reconstructions, scientists and fishery managers need to know how animals are being used (i.e., sold to market, kept for consumption or discarded) in artisanal fisheries, which is usually not monitored by local governments or reported to the Fisheries and Agriculture Organization (FAO) of the United Nations. Knowing fate of the catch can improve the accuracy of estimates from methods like market surveys and can aid researchers in choosing the appropriate methods to estimate landings, given that subsistence catches, recreational catches, bycatch and illegal fishing catches may never enter the market.

The Sea Around Us project has focused on trying to reconstruct undocumented catches in artisanal fisheries, by using FAO data and adding by-catch ratios, what enters the commercial market, fisher population estimates and, in certain regions, by having on-site scientists recording the catches they observe being landed by fishers. Sea Around Us estimated that small-scale fisheries, which include artisanal and subsistence fisheries, account for more than 95% of fishers around the world (Pauly 2006) and contribute 32% of global fisheries catch (Pauly and Zeller 2015). Given their wide occurrence and the large number of dependents, artisanal fisheries are an important socioeconomic sector (Johnson et al., 2013) and their impact on vulnerable stocks may be significant.

In order to recognize patterns of elasmobranch exploitation and consumption, there is a need understand the current status of regional elasmobranch populations using a fisheries independent dataset. Baited Remote Underwater Video surveys (BRUVs) have become increasingly popular as a non-invasive method to assess fish communities without putting vulnerable or endangered species at risk of stress-induced post-capture mortality (Colton and Swearer, 2010; Brooks et al., 2011; Lowry et al., 2012).

Herein, I investigated the relative abundance of elasmobranchs on coral reefs and characterized artisanal fisheries for these taxa on three islands in the Lesser Antilles: Tobago, Guadeloupe and Martinique. Although humans have been fishing in the Lesser Antilles for over 2,000 years, little is known about the extent of artisanal marine exploitation (Wing and Wing, 2001). Fisheries records in the last 50 years are sparse and unreliable (FAO 2019). They generally lack species-specific data for elasmobranchs and often do not include catches that never enter markets. As islands, these nations have limited land resources and agriculture alternatives (Cooley et al., 2009). Therefore, they rely heavily on ocean resources for economic and social benefits (Cooley et al., 2009). Fish consumption in Caribbean countries range widely, but many of the islands have consumption rates above the global average (FAO2013). Fish consumption is so high in Guadeloupe, Martinique and Trinidad and Tobago that net imports are needed to meet demand (FAO 2013). However, there are not data on whether there is a net import or export of elasmobranchs on these islands.

Using a combination of fisheries-independent sampling of coral reef habitats using BRUV and interview surveys of fishers, I set out to 1) characterize the artisanal elasmobranch catches of Guadeloupe, Martinique and Tobago, 2) to document the occurrence and relative abundance of reef-associated elasmobranchs and 3) to assess if there is interisland variation that may influence the relative effectiveness of different research or survey methods and 4) to use interview surveys to estimate elasmobranch landings.

Methods

Study Sites

The Lesser Antilles are a group of islands in the eastern Caribbean Sea, that extend from the U.S Virgin Islands to Trinidad and Tobago (Figure 1). These islands form the boundary between the Caribbean Sea and the Atlantic Ocean. Coastal marine environments around the islands generally include shallow waters. Coastal ecosystems (coral reefs, mangrove swamps, estuaries and coastal lagoons) are surrounded by deep oligotrophic seas with inputs from South America (Agard and Gobin, 2000). Guadeloupe, Martinique and Tobago are all high islands of volcanic origin with a limited marine shelf (Smith et al., 1997) that is surrounded by deep water with no connection to the mainland (Ricklefs and Lovette, 1999). Only Tobago does not have an active volcano (Ricklefs and Lovetter, 1999). In Guadeloupe there is a steep drop-off within 5 - 15 km of the coast, in Martinique this occurs within 2 - 10 km of the coast, and in Tobago the shallow shelf only extends within 1 – 5 km of the coast. Coral reefs in the Lesser Antilles have experienced progressive degradation over the past thirty years with less live coral and fewer and smaller fish (Smith et al., 1997).

Tobago

Trinidad and Tobago is located on the continental shelf of northeastern South America about 13 km east of Venezuela. It is one of the few Caribbean island states where sharks are extensively and historically have been used in traditional dishes. According to the FAO in 2017 Trinidad and Tobago had the second largest landings of elasmobranchs in the Caribbean, after Cuba. Trinidad and Tobago landed an estimated 532 metric tons of elasmobranchs for all fishing sectors (FAO 2019). Estimated shark landings of artisanal fisheries rank fourth in volume of the species landed in Trinidad and Tobago (Shing 2006).

As in most parts of the world, the artisanal shark fishery has historically been considered a bycatch fishery with a very limited, directed component (Shing 1993). However, shark is extensively used in both Trinidad and Tobago; curried shark considered a staple dish, as well as the popular street fast food “shark and bake.”

Therefore, it is likely that there is a directed component to artisanal fisheries for elasmobranchs that has not been studied yet.

In Trinidad and Tobago, the artisanal gillnet fishery for carite (*Scomberomorus brasiliensis*) and kingfish (*S. cavalla*) contributed about 60% of the estimated shark landings in the 1980s (Henry and Martin, 1992). According to government data, there have been 15 shark species identified from the waters of Trinidad and Tobago that are part of fisheries' catch (Henry and Martin 1992). Elasmobranch data and reported catches are inconsistent. A 2007 report by the FAO on shark bycatch that is used for "shark and bake" assumed all catches to be *C. limbatus*, while government data shows a wide range of shark species in the fishery. However, government data are not readily available and many years are absent in reports to the FAO.

French West Indies

Guadeloupe and Martinique are overseas territories of France (Figure 1). Sharks are not commonly used in French cuisine or in the French West Indies, however fisheries statistics in Guadeloupe and Martinique are incomplete and it is likely that elasmobranch catches are higher than reported (Zeller and Harper, 2009). Catches reported to the FAO do not distinguish between commercial, subsistence and artisanal fisheries, even though elasmobranch catches likely occur in all three. As of 2019, no elasmobranch landing data have been provided to the FAO for Guadeloupe since 2009. Martinique reported 31 metric tons of elasmobranchs landed by all fishery sectors in 2017 (FAO 2019).

Martinique has one of the most exploited reefs in the lesser Antilles (Gobert 2000) and Guadeloupe imports around 50% of seafood that is consumed (Aldrich &

Connel, 1992; Frotte et al., 2009). The majority of the fishing fleet in Guadeloupe and Martinique is made up of small vessels, which primarily target pelagic fish species for commercial purposes (FAO, 2002). Some vessels operate near shore, targeting reef fishes for commercial and subsistence purposes (Chakalall et al., 1995).

Interview Surveys

Surveys were completed in person and all answers were written by interviewers while the interviews were ongoing. A total of 405 interview surveys were collected in the Lesser Antilles. Ninety-four interview surveys were collected in Guadeloupe from Apr. – Jun. 2015, 121 surveys were collected in Martinique between Apr. -Jul. 2016, and 190 surveys were collected in Tobago in June 2017. Since elasmobranch species are difficult to describe and identify, the FAO Identification Guide to Common Sharks and Rays of the Caribbean (FAO & Bonfil, 2016) was used so fishers could identify species that they catch. Certain taxa that are difficult to identify at the species level, such as *Rhizoprionodon* spp., *Sphyrna* spp. and *Mobula* spp., were recorded at the genus level.

During surveys, fishers were first asked about their age, previous involvement in interview surveys, occupation and fishing background, fishing gears used, practices (habitats where gears are deployed, soak times) and fishing boat characteristics (such as boat size, engine power and number, and number of fishers in the crew) (See Appendix 1 for a list of all questions). Subsequent questions focused on their level of knowledge on sharks and rays, including catch frequency and seasonality. Interviewers also asked whether elasmobranchs were the targeted species, caught as bycatch or retained as by-product, and the ultimate fate of the catch that was retained (sold, retained for consumption, or used as bait). Fishers were also questioned about their perceptions of shark and ray population trends since they started fishing. For Guadeloupe and Martinique, questions were only asked about elasmobranchs generally.

To estimate elasmobranch landings by fishers, interviewers asked how many sharks and rays were caught each month. These data were used to estimate annual catches per individual fisher, assuming that there was no seasonality in catches and that fishers fished all year round, which is taken from answers given by fishers (see Results).

Low and high estimates of the biomass of elasmobranchs landings were calculated by multiplying the average of the minimum and maximum number of sharks reported per fisher annually, by assumed average weight of catches using 1) the smallest species reported by fishers (*Rhizopriodonon* spp.; 1 kg/ fishbase.org) and 2) average weight of the most common shark species found in Caribbean coral reefs (*Ginglymostoma cirratum*; 15kg/ fishbase.org) respectively. Similarly for rays, biomass ray landings reported were calculated by multiplying the minimum and maximum average number of rays reported per fisher, by the assumed average weight of the 1) smallest ray in the Caribbean (*Urobatis jamaicensis*; 1 kilogram/fishbase.org) and 2) by average weight of the most common ray species found in Caribbean coral reefs (*Hypanus americanus*; 20kg /fishbase.org) respectively.

The estimates were then multiplied by the proportion of fishers that reported keeping elasmobranch catches to eat, sell or trade. This final estimate was multiplied by number of registered artisanal boats. The same calculations were done for rays.

Therefore, I estimated yearly Artisanal Elasmobranch Landings (AEL) in biomass for each island as:

$$AEL = \bar{C} \; \bar{W} \; Fp$$

(Eqn.1)

where $\bar{C}$ is average number of elasmobranchs caught per fisher in a year, $\bar{W}$ is average weight assumed for the catch. The variable F is the number of artisanal boats on the island, and p is the proportion of fishers that reported keeping the catch. The equation is a modification of the approach that Yuniarta et al., (2017) developed to estimate uncertainty in small-scale tuna catch reconstruction in Indonesia.

BRUVS

The relative abundance and species richness of elasmobranchs in coral reef habitats were surveyed using baited remote underwater video systems (BRUVs). Each unit consisted of a video camera (GoPro-Hero) mounted on a metal frame that had a small, pre-weighed bait source (1 kg of crushed Atlantic red herring) attached to a pole that extended from the frame into the camera's field of view.

The BRUV sampling locations were chosen by using a random number generator to produce latitude and longitude points within the defined boundary of the study reefs. Two reefs were sampled offshore for both Martinique, and Guadeloupe and five reefs were sampled off Tobago. A reef was defined as at least 4km^2 of reef area. Since Martinique has a thin fringing reef surrounding the islands, the reefs were chosen by their proximity to large fishing towns, one on the Atlantic side and one on the Caribbean side (Figure 1). Guadeloupe also has a thin fringing reef surrounding the island. One reef was chosen in the nature reserve Grand Cul-de-Sac Marin were artisanal fisheries are allowed, and the other reef was along the adjacent island of Petit Terre that is protected and uninhabited (Figure 1). Since Tobago has a larger coral reef area surrounding the island on the easternmost and westernmost points of the island, two reefs were sampled in the west and three reefs in the east, which covered almost the entire perimeter of the island that has good visibility (Figure 1).

BRUVs were deployed during daylight hours on days where logistics and weather allowed. Individual BRUVs were deployed from a boat using a rope and in-water personnel to orient the BRUV facing down current. No BRUVs were simultaneously deployed within 500m of one another. The BRUVs were left to film continuously for at least 80 min after settling to the bottom. Each reef had at least 50 individual BRUV deployments. At both the start and end of each deployment environmental variables were measured including bottom depth with a handheld depth Vexilar Handheld Digitial Sonar, and water temperature, salinity, and dissolved oxygen with a YSI Pro 2030.

Data analysis

All videos were watched at normal speed and annotated independently by at least two observers using the Global FinPrint Annotator software (www.globalfinprint.org). Data recorded by observers included elasmobranch species identification, and the maximum number from each species within a single frame (MaxN) during a deployment

(Bond et al., 2012). The Global FinPrint software captures a still image of all annotations, allowing validation of identifications and count data.

I used hurdle models to first investigate variation in occurrence (i.e., presence/absence) with logistic regression, and then used a GLM to investigate variation in species richness and MaxN per video for sharks and rays, with island as a fixed effect. Additional Generalized Linear Models (GLMs) were done to test if age, years of experience, if fishing was their only occupation and average hours of fishing a day influenced fisher perceptions of elasmobranch populations.

$$Elasmo.prescence \sim island$$

(Eqn. 1)

$$Species\ richness \sim island$$

(Eqn. 2)

$$MaxN \sim island$$

(Eqn. 3)

$$Elasmo.perception \sim Age + Years\ Fishing + Fishing\ only\ occupation + Avg.hours\ of\ fishing$$

(Eqn. 4)

I used a Chi-square to test for differences in catch fate (eaten, sold, etc.) within and among islands with a post-hoc Bonferroni adjustment since the explanatory variable has more than three groups. I used R software version 1.1.463 with the MASS4 library (R Core Team, 2016). All values reported are means ± SD unless otherwise noted.

Results

Surveys

Guadeloupe

Men made up 98.9% of the (n=94) fishers interviewed. Interviewed fishers were on average 46 ±11.54 years old (range: 19 to 60 years old), had an average fishing experience of 19.43 ± 8.1 years (range: 1 to 50 years), had an average boat size of 8.05 ±4.5 meters and an average crew size of 2.4± 0.86 members. The most common boat type used by interviewed fishers is a "Saintoise" (n=90 of 94, 95.7%). These vessels are 5-10 m long, made of wood or fiberglass without a deck and are easily maneuverable. Two fishers (2.2%) used a "Plaisance," which is a pontoon boat measuring 5-8 m. Another two fishers used a "Chalutier" which is a medium-size semi-industrial commercial fishing boat measuring 10-15 m.

When asked to report the top three gears they use, the most common primary gear reported was the bottom set drumline, followed by handlines. The third most common gear were traps or pots, both for fish and/or lobsters and crabs. Fishers reported a total of seven gears, yet fishers reported using up to five gears at any given time (Figure 2).

I did not find any factors that affected fisher's perceptions of elasmobranch populations in Guadeloupe (GLM, z= -0.001, P=0.999). Most fishers 57.4% (n=54 of 94) reported perceiving a decline in elasmobranchs since they started fishing, while 27.6%

(n=26 of 94) perceived that elasmobranch populations were unchanged, 13.8% (n= 13 of 94) chose not to answer the question and only one fisher perceived increases in elasmobranchs.

Overall, 69.1% (n=65 of 94) of fishers answered "all or any fish" as their target species, while 26.6% (n=25 of 94) answered pelagic species such as dolphinfish (Coryphaenidae), tuna (Scombridae), and marlin (Istiophoridae), and 4.2% did not answer the question (n=4 of 94). For elasmobranchs, 74.4% (n= 70 of 94) reported not targeting them, while 9.6% (n=9 of 94) did. Fifteen of 94 fishers chose not to answer the question.

Fishers identified twelve elasmobranch taxa in their catches, ten shark taxa and two ray taxa with nurse sharks (*Ginglymostoma cirratum*), hammerhead sharks (*Sphyrnidae* spp.), and makos (*Isurus* spp.) reported the most frequently (Table 1). *Dasyatis americanus*, *Aetobatus narinari*, and *Myliobatis goodei* were the reported ray species (Table 1). Of fishers that caught elasmobranchs, 84% (n=79 of 94) reported keeping the catches to sell, eat, or both, 5.3% (n=5 of 94) released the animals alive, and 10.6% (n=10 of 94) did not answer the question (Figure 2). When calculated as a proportion of fishers who answered, there was a significant difference between Guadeloupe and Martinique ($\chi 2$,(8, N = 198), 36.21, p <.00001) with respect to fate of elasmobranch catch, and a Bonferroni test revealed all categories were significantly different across these islands, except for the "sell" category (Table 2). Fishers reported landing an average of 3.27-4.44 elasmobranchs a year per fisher, which led us to estimate a biomass 3.5- 70.6 metric tons of elasmobranchs landed yearly by artisanal fishers in Guadeloupe (Table 4).

The majority of fishers 57.4% (n=54 of 94) perceived a decline of elasmobranchs since they started fishing, compared to 27.7% (n=26 of 94) that thought elasmobranchs have stayed the same, 1% (n=1 of 94) that thought they had increased and 14.9% (n=14 of 94) that were unsure or declined to answer the question.

Martinique

All fishers interviewed (n= 121) were men. Interviewed fishers were on average 49.5 ±9.8 years old (range: 24 to 80 years old), had an average fishing experience of 27.6 ± 11.3 years (range: 6 to 56 years), had an average boat size of 6.03 m ±2.5. The most common boat type used by interviewed fishers is a "Yole" or "Gomié (n= 111 of 121, 91.7%) which is a small and narrow wooden canoe made from a hollowed out tree trunk, measuring 6-10 meters and commonly has sails. The second most common boat type was a "Bateau de pêche", a fiberglass boat, measuring 10-20 m, used for semi-industrial trawling with 8.3% (n= 10 of 121). When report the top three gears they use, 39% (n=46 of 121) of fishers reported using longlines, 9.9% (n=12 of 121) of fishers reporting handlines, and 8.26% (n=10 of 121) of fishers used nets. All but one fisher (n=120 of 121) used only one gear (Figure 2).

None of age, years of experience, if fishing was their only occupation nor average hours of fishing a day affect how fishers perceived changes in elasmobranch populations in Guadeloupe (GLM, z= -0.002, P=.998). The majority of fishers 84.3% (n=102 of 121) perceived a decline of elasmobranchs since they started fishing, compared to 3.3% (n=4 of 121) that thought elasmobranch populations were unchanged, and 12.4% (n=15 of 121) that were unsure or declined to answer the question.

Fishers identified twenty-two shark taxa and two ray taxa in their catches. Makos (*Isurus* spp.), hammerhead sharks (*Sphyrnidae* spp.), and nurse sharks (*Ginglymostoma cirratum*) were reported most frequently (Table 1). Southern stingrays (*Dasyatis americanus*),and spotted eagle rays (*Aetobatus narinari*) were the reported ray species (Table 1). Fishers reported landing an average of 1.15 - 2 elasmobranchs a year per fisher, which led to an estimated biomass range of 1.06 – 28.6 metric tons of elasmobranchs landed yearly by artisanal fishers in Martinique (Table 4).

Tobago

All fishers interviewed (n = 189) were male and were on average 41.6 ±13.8 years old (range: 18 - 76). They had an average fishing experience of 22.9 ± 14.1 years (range: 1-60 years), fished from boats that were an average of 8.9 m± 2.3 and an average crew size of 2.2± 1.05 members. Almost all surveyed fishers used a "pirogue" (n= 168 of 189, 88.8%) which typically is a small wooden, or fiberglass canoe that is 7-9 m in length. The second most common boat type listed was a mother boat (n=3 of 189, 1.6%), which are larger pirogues that often have sails and measure 15-20 m in length. A total of 9.5% (n=18 of 189) of fishers fished from land.

When asked to report the top three gears they use, handlines were reported by 78.8% (n=149 of 189) of fishers. Handlines were used from a still boat (26.4%, n=50 of 189), trolling (26.9%, n= 51 of 189), from land (21.6 %, n=41 of 189) or "a la vive" which includes using live bait from the boat (3.7%, n= 7 of 189). Longlines were reported by 7.4% (n=14 of 189) of fishers, with the same proportion reporting using beach seines (7.4%, n=14 of 189). Traps or pots, both for fish and/or lobsters and crabs, were also reported as a top-3 gear by 6.3% of fishers (n=12 of 189) (Figure 2). The majority of fishers reported using two gears on any given day (52.9%, n=100 of 189), but there were 49 different gear combinations reported.

There was no effect of age, years of experience, if fishing was their only occupation and average hours of fishing a day on their perceptions about elasmobranch populations in Tobago (GLM, z= -0.003, P=0.997). Most fishers 40.2% (n=76 of 189) perceived a decline of sharks in the coastal waters since they started fishing, compared to 24.9% (n=47 of 189) that thought sharks have stayed the same, 23.8% (n=45 of 189) that thought they had increased and 11.1% (n=21 of 189) that were unsure or declined to answer the question. In contrast, most fishers 48.1% (n=91 of 189) perceived an increase of rays in the coastal waters since they started fishing, compared to 20.6% (n=39 of 189) that thought rays have stayed the same, and 20.6% (n=39 of 189) that thought they had decreased and 10.6% (n=20 of 189) that were unsure or declined to answer the question.

The top three families listed as the target catch were tuna (48.1%, n=91 of 189), snappers (Lutjanidae) by 46.5% (n=88 of 189), and groupers (Serranidae spp.) by 39.1% (n=76 of 189). Nine out of the eleven most commonly targeted taxa were reef-associated, with tuna (Scombridae) and dolphinfish (Coryphaenidae) being the only pelagic taxa listed.

Fishers reported landing an average of 149.3 – 202.5 sharks and 2.33 - 3.86 rays a year per fisher, which led us to estimate a biomass range of 168.9-2,286 metric tons of elasmobranchs landed yearly by artisanal fishers in Tobago (Table 4). Fishers identified thirteen elasmobranch taxa in their catches, encompassing nine shark taxa and four ray taxa with hammerhead sharks (Sphyrnid*ae*), blacktip sharks (*Carcharhinus limbatus*), and nurse sharks (*Ginglymostoma cirratum*) reported the most frequently (Table 1). *Hypanus americana*, *Aetobatus narinari*, *Manta* spp. and *Dasyatis guttata* were the most commonly reported ray species (Table 1).

When fishers were asked whether they targeted sharks, 12.7% (n=24 of 189) answered affirmatively, while the majority 79.8% (n=149 of 189) responded that they were caught accidentally, and 8.4% (n=16 of 189) chose to not respond. Regardless of whether fishers targeted elasmobranchs, all fishers reported having caught a shark and 90.5% (n=171 of 189) reported keeping the catches to sell (n=49 of 189), eat (n=33 of 189), or both (n=89 of 189), while 6.3% (n=12 of 189) reported releasing the animal alive and 3.2% (n=6 of 189) chose not to answer the question (Figure 3).

When fishers were asked whether they targeted rays, only 2.1% (n=4 of 189) reported that they did, while the majority 59.8%(n=113 of 189) responded that they were caught accidentally, and 38.1% (n=72 of 189) chose to not respond. Regardless of whether fishers targeted rays, only 5.8% (n=11 of 189) of them reported keeping the catches to sell, eat, or both, while 57.1% (n=108 of 189) reported releasing the animal whether it was dead or alive, and 37% (n=70 of 189) chose not to answer the question. When calculated as a proportion of fishers who answered, there was a significant difference across between sharks and rays in Tobago ($\chi 2$,(8, N = 302), 212.42, p <.00001) with respect to fate of elasmobranch catch, and a Bonferroni test revealed the all categories were significantly different across sharks and rays in Tobago (Table 3).

BRUVs

Six species of sharks and two ray species were observed on the 450 BRUVs deployments across all islands (Table 5). Sharks were present on 10% (n= 10 of 100) and rays were present on 14% (n=14 of 100) of drops in Guadeloupe. Sharks were not present in any drops and rays were present on 10% (n=10 of 100) of drops in Martinique. Sharks were present on 35.2% (n= 88 of 250) and rays were present on 20% (n=20 of 250) of drops in Tobago. The number of elasmobranch species of observed per BRUV video varied across islands, with Martinique having on average per drop 1 ± 0.41 species when present, Guadeloupe having 1.05± 0.46 species, and Tobago having 1.21 ± 0.60 species. When elasmobranchs were present, Martinique had an average MaxN per drop of 1± 0.17 SD , Guadeloupe had 1 ± 0.21 MaxN, and Tobago had 1.17 ± 0.34 MaxN.

There was a significant difference in elasmobranch occurrence across islands (Log. Reg., z=-2.1, P=0.04), but not for MaxN when present (GLM, z=-0.005, P=0.99). Within Guadeloupe, the uninhabited and protected reef Petit Terre had higher occurrence of elasmobranchs (Log. Reg., z=3.12, P<0.001). Within Tobago, the reef GPC had a higher occurrence of elasmobranchs (Log. Reg., z=-2.34, P=0.02). Within Martinique there was no difference of elasmobranch occurrence among reefs(Log. Reg., z=-0.64, P=0.53). However, there was no significant differences in MaxN among reefs within Guadeloupe (GLM, z=-0.6, P=0.95) and Tobago (GLM, z=-0.09, P=0.92). (Tables 6 & 7).

Off Guadeloupe the species with highest relative abundance were *Ginglymostoma cirratum* and *Dasyatis americanus*, which appeared on 7% and 12% of all BRUVs respectively. Although Guadeloupe had three more species than Martinique on BRUVs, *Carcharhinus perezi*, *Carcharhinus limbatus* and *Mobula* sp. only appeared on one BRUV each (1%), and overall at least one elasmobranch appeared on 22% of all BRUVs. Likewise, the species with highest relative abundance off Tobago were *Ginglymostoma cirratum* and *Dasyatis americanus*, which appeared on 7.2% and 12.4% of all BRUVs respectively (Table 5).

Discussion

Populations of large marine predators, such as sharks, have been quickly declining on a global scale (Ferreti et al., 2010; Worm et al., 2013; Davidson et al., 2016). Humans have historically preferred to fish mid-to-large bodied species at the top of food webs (Sethi et. al, 2010) yet sharks are more susceptible to the effects of fishing compared to bony fishes due to their low fecundity, relative slow growth and late maturity (Holden 1974). These life history traits mean shark populations grow slowly and cannot easily compensate for the losses to fisheries (Hayes, 2007). Although sharks potentially play an important role in ocean food webs, the broader ecosystem consequences of reduced shark populations on coral reef systems remain unclear (Heithaus et al., 2008; Heithaus et al., 2010; Roff et al., 2016).

Differences in elasmobranch relative abundances between Guadeloupe, Martinique and Tobago may be driven by their geographic location, or by differences in fisheries pressures. The relative abundance and species richness observed from my BRUVs is consistent with diver observations that have sharks heavily depleted across most Caribbean coral reefs (Ward-Paige et al., 2010; Ward-Paige et al., 2011), except for species like *Ginglymostoma cirratum* and *Dasyatis americanus*. Indeed, in Martinique no sharks were recorded on BRUVs. The only elasmobranch recorded was *Dasyatis americanus* on 10% of the BRUVs. Tobago had the largest number of elasmobranch species recorded on camera of the three islands surveyed, with a total of seven elasmobranch species, but still at very low relative abundances with each species being present in less than 5%. Overall, at least one elasmobranch appeared in 32% of all BRUVs in Tobago.

Given that there is no historical information on elasmobranch populations in the Caribbean before the rise of industrial fishing, protected areas can provide a comparison in the greater Caribbean region in the absence of baseline data (Smith et al., 2016). In the Bahamas and Belize, were sharks are protected and protection is enforced, BRUV results have shown the frequency of occurrence of sharks to be between 30-70% (Brooks et al., 2011; Bond et al., 2012*;* Whitman 2018.) which is more than what I found for Tobago, Guadeloupe and Martinique. Additionally, in the Bahamas nine different species of sharks were detected on 68.9% of BRUVs, including large-bodied apex predators like

Galeocerdo cuvier, and *Sphyrna mokarran*. Furthermore, in the Bahamas the most common shark species was *Carcharhinus perezi* and not *Ginglymostoma cirratum*, unlike most places in the Caribbean (Ward-Paige et al., 2010; Whitman 2018.). Similarly, in Belize 11 different species of sharks were captured on BRUVs (Chapman et al., 2011) and the most common species were *Carcharhinus perezi* found on 33.8% of BRUVs (Bond et al., 2019).

Tobago has some of the highest primary productivity in the Caribbean (Agard et al., 1996) due to its proximity to plumes from the Amazon and Orinoco rivers. Furthermore, due to its oil reserves in 2015 Trinidad and Tobago was ranked first as the wealthiest Caribbean country and has the 3rd highest per capita Gross Domestic Products (GDP) in the western hemisphere, only after the United States and Canada (CIA factbook 2018). A productive marine environment and diversity of economic revenues not based on marine resources, such as oil drilling, may explain Tobago's moderately high elasmobranch relative abundance in comparison to other places in the Caribbean. Despite moderately high elasmobranch relative abundance, fishers reported catching more sharks than in any of the other countries sampled, which warrants further research into the productivity of the marine environment and elasmobranch migration in the region.

Overall, elasmobranch diversity and relative abundance was low in Guadeloupe, Martinique and Tobago but comparable to other sites in the Caribbean. Colombia, Tobago and Guadeloupe have similar patterns of elasmobranch occurrence, which were greater than what was observed in Martinique. Given the reconstructed catches, low occurrence, species diversity and MaxN for these sites might be the result of nearly collapsed populations of reef-associated elasmobranchs. Although these data do not confirm that sharks are being overfished in coral reefs, fishers reported catching pelagic species in their catches hints at fishers having to go further and further offshore to capture their target catch. Catching pelagic species could partially explain the high reconstructed catches despite low abundances of elasmobranchs on BRUVs deployed in coral reefs. Previous studies have shown diminishing elasmobranch populations in the greater Caribbean region and fishers expanding their fisheries, by going further offshore, as a sign of overexploitation (Schaeffer, 2001; Bunce et al., 2008).

Martinique and Guadeloupe receive similar economic support from France and the European Union as French territories, have similar human population sizes, and are geologically similar. However, there are no protected areas or national parks in Martinique, while Guadeloupe has two marine national parks. Although Guadeloupe's parks permit artisanal fisheries, industrial fisheries and longlining are not allowed while in Martinique they are. When fishers were asked to list the gears they used, Martinique was the only country that reported using longlines as one of the top three gears. Prohibiting longlines can contribute to relatively high reef-associated shark abundances (Morgan and Carlson, 2010; Ward-Paige et al., 2010; Gallagher et al., 2014; Butcher et al., 2015; Gilan et al., 2016), although effects vary by species. Indeed longlines have been banned in many countries' protected areas, including the Bahamas, the United States, Colombia and Guadeloupe.

Only 10% of fishers in Guadeloupe, Martinique and Tobago reported targeting elasmobranchs, but 85-90% of fishers reporting keeping their elasmobranch catch. What fishers chose to do with their elasmobranch catch varied significantly across islands, with Martinique reporting the highest proportion (31.4%) of keeping catch only for subsistence, Guadeloupe having the highest proportion (59.8%) of keeping catch only to sell, and Tobago reporting the highest proportion (47%) for both sustenance and catch. There was also a significant difference in fate of the catch for both sharks and rays between Colombia and Tobago, with Colombia reporting a larger proportion (42%) of selling shark catch compared to Tobago (25.9%) (See Chapter 2). For rays, 71.8% of fishers in Colombia reported keeping ray catch to eat or sell, while 57.1% fishers in Tobago reported releasing rays dead or alive. Understanding what proportion of catch is kept for sustenance as opposed to what enters the market is important for reconstructing unreported catches. Market surveys are a common approach to estimating landings, which may underestimate catches in islands like Tobago and Martinique, where fishers keep much of their elasmobranch catch for consumption or trade. In such areas, monitoring landings or a combination of interview and market surveys will be more effective.

Differences in what fishers do with their catch is probably driven by differences in elasmobranch availability, market demand and culture. On one side of the spectrum, given that I did not see any sharks in Martinique BRUVs, it is unlikely that there is a high market demand for shark meat if fishers choose to consume elasmobranchs. In Tobago, there is a high demand of elasmobranch meat due to their cultural dishes, and there is also a higher relative abundance of sharks on BRUVs, which may explain why fishers sell or eat their catch likely depending on market value. In Guadeloupe shark meat is not of cultural or culinary significance and understanding why fishers chose to sell elasmobranch catches and who they sell their catches to warrants further research.

Reconstructed catch biomass from Trinidad and Tobago was greater than Guadeloupe and Martinique. Magnitude of biomass landings may be driven by elasmobranch availability, given that elasmobranch species richness and relative abundance followed the same pattern (Tobago had the most, Martinique the least). There are several key assumptions in my calculation for reconstructed catches. First, I did not have data on species composition of catches or sizes of elasmobranchs landed. However, our approach of using average weight of *Rhizopriodonon* spp. as the minimum estimate likely underestimates the total biomass of elasmobranch landed by artisanal fisheries, if fishers are often catching large bodied sharks like *G. cuvier* or *S. mokarran*. Using average weight of *G. cirratum* as the maximum estimate likely overestimates the total biomass of elasmobranch landed by artisanal fisheries, in a place like Martinique medium sized *G. cirratum* are rare. Similarly for rays, using average weight of *U. jamaicensis* as the minimum estimate likely underestimates the total biomass of elasmobranch landed by artisanal fisheries, if fishers are routinely catching rays like *H. americanus* or *Mobula* spp. Using average weight of *H. americanus* as the maximum estimate likely overestimates the total biomass of elasmobranch landed by artisanal fisheries, in a place like Martinique medium sized *H. americanus* are rare.

Secondly it is likely that the number of artisanal fishers and boats on each island is much higher than reported, because there are unlicensed or illegal fishers. It has been estimated that on average illegal fisheries can contribute around 18% of the total catch but it can be much higher for developing countries, up to 30% in the Caribbean and up to 40% in West Africa (Agnew et al., 2009). Lastly, fishers may be underreporting the proportion of elasmobranchs they keep and the number of elasmobranchs landed if they fear retribution or stricter conservation policies (Watson and Pauly, 2001). Catching sharks is a memorable experience, so fishers may over report shark catches more than other fish species because of striking encounters. While the interview method relies on the fisher's honesty, willingness to share information, and quality of their memory, it is unlikely that the data collected is an underestimate of their fishing effort and catches, given my conservative estimates when calculating biomass.

The FAO and Sea Around Us Project both aim to quantify landings in fisheries. Although the FAO split its fisheries statistics into three main categories: documenting biomass of fish landings, documenting fishing effort (fleet size, fishing gears, hours deployed, etc.) and documenting the socio-economic benefits (number in labor force, income, costs, invested capital, etc.), it relies on national governments and local entities to collect and provide the information. Most local governments do not collect data on artisanal and subsistence fisheries, and therefore can only provide FAO with their industrial fishing data. Sea Around Us adds to FAO by reconstructing and extrapolating data to include subsistence catch, artisanal catch, illegal catches and bycatch. Sea Around Us construct their estimates by including and analyzing available fisheries data, as well as population data, and extrapolating data between years that went unreported by national governments.

Here, I have built on FAO and SAU estimates by interviewing fishers directly. Additionally, by using a fisheries-independent method such as BRUVs I was able to get a snapshot of coral reef elasmobranch populations in the coastal waters that artisanal fishers exploit. For Guadeloupe and Martinique, no artisanal landings data was reported to the FAO and SAU's estimates fall within my upper and lower bounds. My upper estimate for Martinique was almost twice what was reconstructed by SAU, and more than four times what was estimated for Guadeloupe. SAU's estimate for Trinidad and Tobago is larger than what I calculated, but my estimate is only for Tobago and does not include Trinidad. There is an estimated 6,000 fishers in Trinidad compared to 1246 fishers in Tobago. It is likely that if I was to reconstruct landings in Trinidad, my minimum and maximum estimates would encompass what SAU estimated.

The majority of the fishers on each island also reported a decline in shark catches since they started fishing, and the reported decline follows a global trend of decreasing shark populations (Burgess et al., 2005; Ferreti et al., 2010; Ward-Paige et al., 2010) alongside an increased fishing effort (Anticamara et al., 2010; Asche et al., 2007; Bell et al., 2017). Although fishers could under report their shark catches in fear of stricter fishing restrictions and catch limits, it is important to note that in Tobago, Guadeloupe and Martinique most sharks (except hammerheads) are not protected and artisanal fishers can fish in national parks.

Given that elasmobranch landings are higher than what is being reported and about 25% of all elasmobranchs around the world are listed as Vulnerable, Endangered or Critically Endangered on the IUCN Red List (Dulvy et al., 2014; IUCN 2014), Guadeloupe, Martinique and Tobago would benefit from improved elasmobranch management and conservation. Since Martinique had the lowest elasmobranch species richness, abundance and catch, it would probably benefit from banning longlines and creating a national park, MPA, or sanctuary. No National Plan of Action (NPOA) has been created for over-seas French territories and both Martinique and Guadeloupe would benefit from a local assessment as well as the implementation of a plan. Trinidad and Tobago also does not have any gear restrictions, protected areas or a NPOA. Trinidad and Tobago has been working on creating a NPOA since 2016, buts as of 2019 no plan has been released. For all three islands, further baseline research on the state of local elasmobranch populations and the creation of a NPOA could greatly contribute to the improvement of elasmobranch conservation and management.

Interviews should ask fishers the breakdown of the species composition in their catch, and the distribution of weights in their catches. Surveys should ask fishers the amount of time they fish in different habitats (coral reef, mangroves, pelagic, etc.), to better understand which ecosystems and species may be impacted by their fishing. Interviews should also ask how much do they depend on sharks for the protein intake (how often do they cook and eat shark), what is the average price consumers pay for shark products, and if they have any cultural reasons for consuming sharks to understand how important are elasmobranchs for their survival and livelihood.

Overfishing of top predators, such as sharks, can affect ecosystems beyond changing the abundance of targeted stocks and by-catch species (Salomon et. al, 2010; Ferreti et al., 2010), and can also affect the broader food web including other commercial species that are critical to the livelihoods of local populations (i.e. Newton et al., 2007; McClenachan 2009; McClanahan and Omukoto, 2011). Furthermore, fishing impacts vary by habitat type, with coastal ecosystems such as coral reefs being particularly susceptible (Dulvy et al., 2014). Coral reefs are among the most diverse marine ecosystems, as well as the most threatened (Bellwood et al., 2004). Unmanaged elasmobranch artisanal fisheries in coral reefs can have a significant impact on the livelihood of over 500 million people worldwide that depend on the goods and services coral reef ecosystems provide (Moberg and Folke,1999). I found that fishers retain almost all animals caught, perceive less elasmobranchs than when they started fishing, and reconstructed catches are much higher than what is being reported to FAO. Therefore, overfishing of coral-reef associated elasmobranchs is of interest because of their potential importance in these critical systems as top predators, in addition to economic and socio-cultural consequences that may occur from the loss of coral reef-associated elasmobranchs.

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Figures

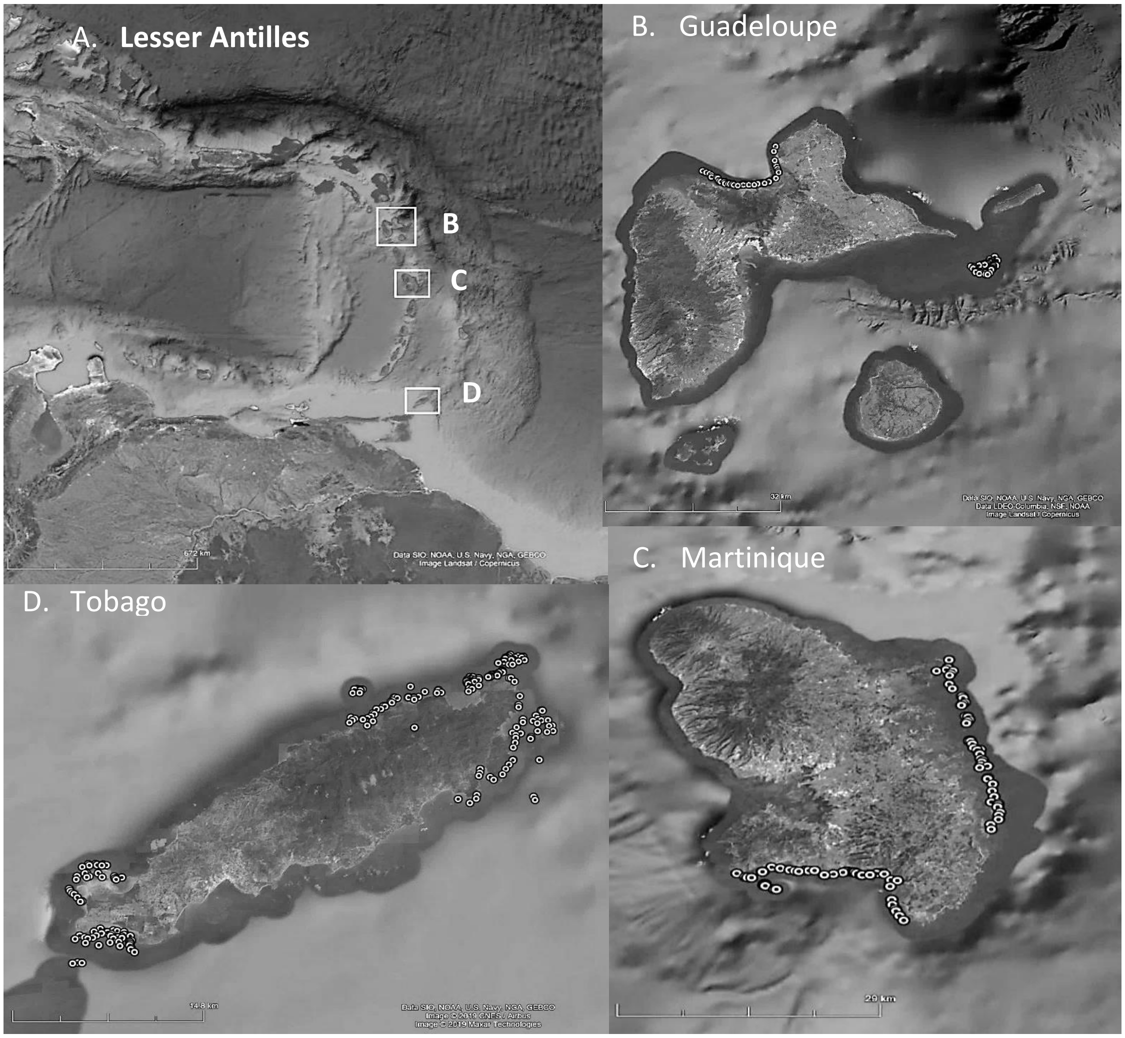

Figure 1. Map of the Lesser Antilles, with sample sites of Guadeloupe, Martinique and Tobago highlighted by white boxes (left). Individual BRUV locations for Tobago are displayed with black and white dots on the right panel.

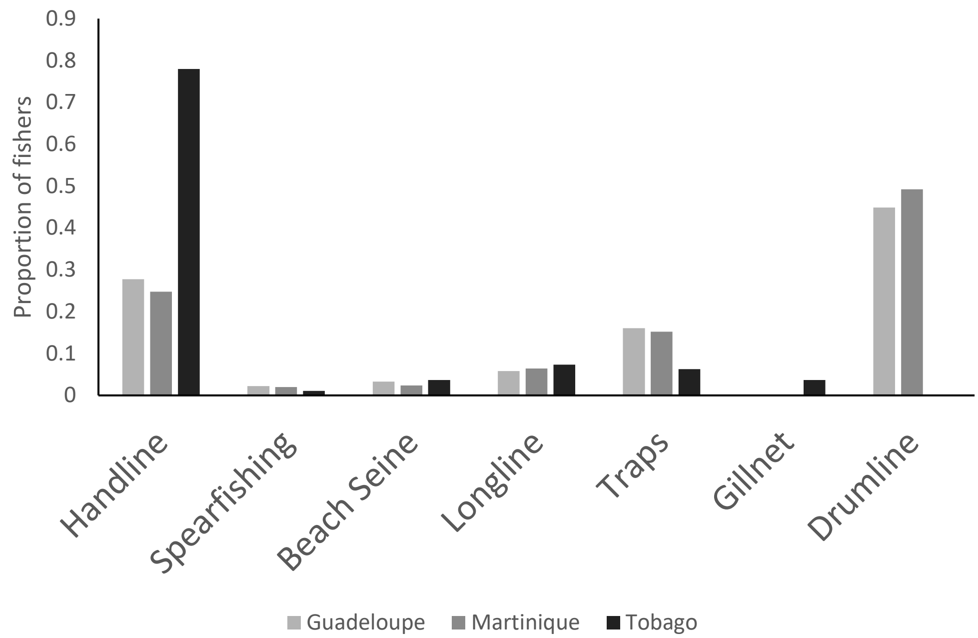

Figure 2. Seven most commonly self-reported fishing practices by artisanal fishers in the Lesser Antilles.

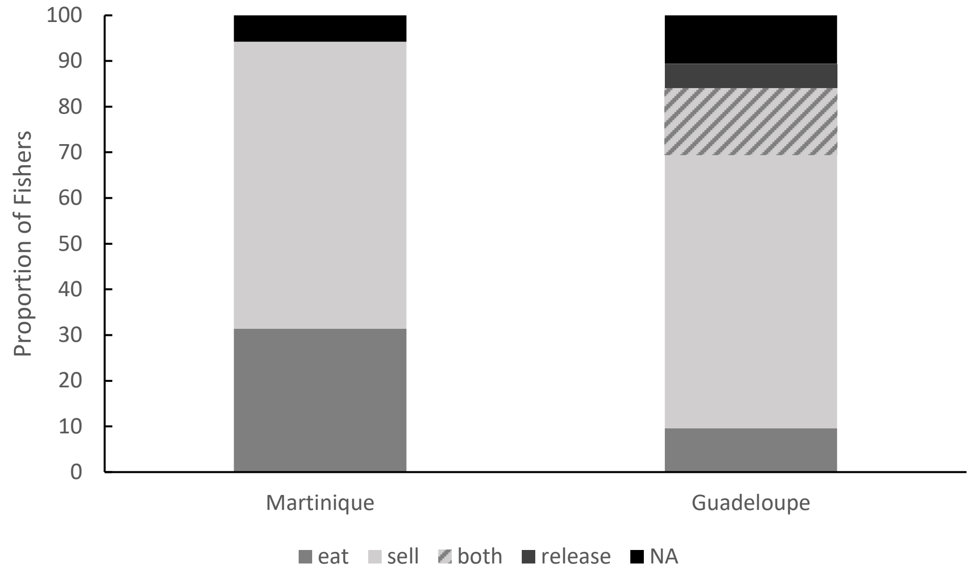

Figure 3 . Proportion of fishers that reported keeping elasmobranch catches to eat, sell, or both.

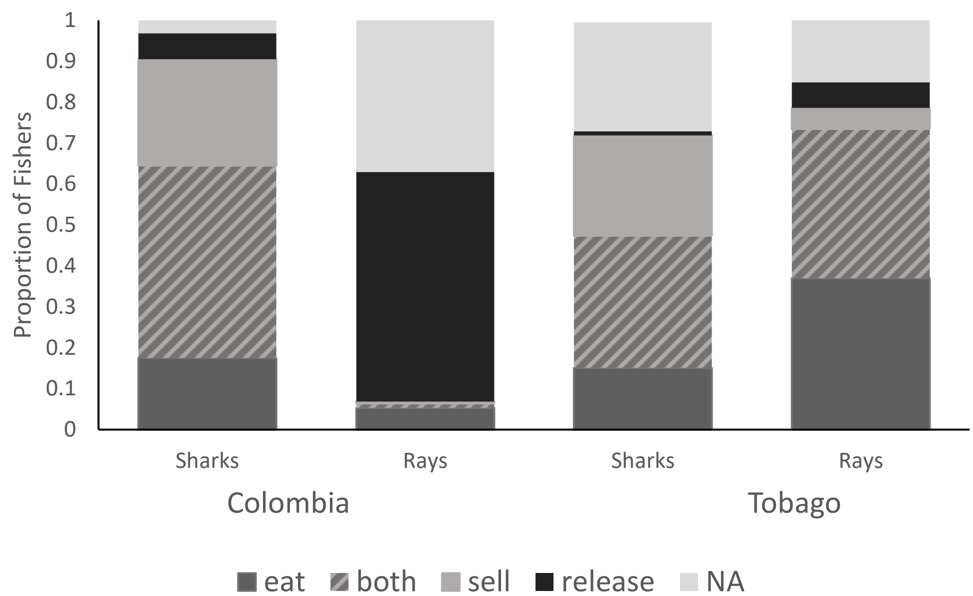

Figure 4. Proportion of fishers that reported keeping shark and ray catches to eat, sell, or both in Colombia and Tobago.

Table 1. List of elasmobranch species reported by fishers across all three islands, in order of proportion.

Martinique (n=121) Species	Prop.	**Guadeloupe** (n=94)	Prop.	**Tobago** (n=189)	Prop.
1) *Isurus* spps.	40.5% (n=49)	*H. americanus*	29.8% (n=28)	*C. limbatus*	25.4% (n= 48)
2) *G. cirratum*	38.8% (n=47)	*G. cirratum*	24.5% (n=23)	*Sphyrna* spps.	14.8% (n=28)
3) *Sphyrna* spps.	38.8% (n=47)	*Isurus* spps.	19.1% (n= 18)	*G. cirratum*	7.4% (n=14)
4) *C. longimanus*	26.4% (n=32)	*Sphyrna* spps.	18% (n=17)	*G. Cuvier*	4.8% (n=9)
5) *G. Cuvier*	22.3% (n=27)	*G. Cuvier*	14.5% (n=14)	*Rhizoprionodo*n spps.	4.2% (n= 8)
6) *P. glauca*	19% (n=23)	*A. narinari*	11.7% (n=11)	*P. glauca*	3.7% (n=7)
7) *H. americanus*	18.2% (n=22)	*N. brevirostris*	7.4% (n=7)	*C. plumbeus*	3.7% (n=7)
8) *A. narinari*	14% (n=17)	*P. glauca*	7.4% (n=7)	*C. leucas*	3.2% (n= 6)
9) *R. typus*	14% (n=17)	*Chimaera* spp.	5.3% (n= 5)	*H. americanus*	2.6% (n=5)
10) *C. leucas*	12.4% (n=15)	*H. perlo*	1.1% (n= 1)	*C. perezi*	1.6% (n= 3)
11) *Alopias* spps.	11.6% (n=14)	*C. falciformis*	1.1% (n= 1)	*N. brevirostris*	1.6% (n=3)
12) *H. griseus*	9.1% (n= 11)	*C. Taurus*	1.1% (n= 1)	*Isurus* spps.	1.6% (n= 3)
13) *N. brevirostris*	8.3% (n=10)			*Alopias* spps.	1.1% (n= 2)
14) *Mobula* spps.	6.6% (n= 8)			*Mobula* sp.	0.5% (n= 1)
15) *C. acronotus*	4.9% (n= 6)			*C. longimanus*	0.5% (n=1)
16) *C. Taurus*	3.3% (n= 4)				

17) *O. ferox*

2.5% (n= 3)

18)*C. limbatus*

1.6% (n= 2)

19) *C. perezi*

1.6% (n= 2)

20) *D. licha*

1.6% (n= 2)

21)*D. centroura*

1.6% (n= 2)

22) *Rhizoprionodo*n spps.

1.6% (n= 2)

23) *C. falciformis*

0.8% (n= 1)

Table 2. Chi-square with post-hoc Bonferroni corrections regarding fate of elasmobranch catch between Guadeloupe and Martinique.

Catch Fate	G- value	Df	p-value
Eat	18.34	3	1.85 e-5
Sell	2.996	3	0.083
Release	3.962	3	0.046
Both	14.699	3	0.0001

Table 3. Chi-square with post-hoc Bonferroni corrections regarding fate of elasmobranch catch between shark and rays in Tobago.

Catch Fate	G- value	Df	p-value
Eat	12.33	3	0.0004
Sell	55.13	3	1.1e-13
Release	84.03	3	2.2e-16
Both	102.42	3	2.2e-16

Table 4. Reconstruction of elasmobranch landings by artisanal sector, across the three islands.

a. Data obtained from EDOM's L'économie bleue dans l'Outre-mer 2018 report.
b. Data obtained from Project GloBAL's country profile on Trinidad and Tobago.

Island	A1. Average Min elasmobranchs landed a year per fisher	A.2 Average Max elasmobranchs landed a year per fisher	B. Number of boats registered	C. Assumed weight	D. Proportion of fishers retaining catch	Total estimated range of elasmobranch landings	Artisanal Elasmobranch catches reconstructed by SAU in 2014:	Elasmobranch catches reported to FAO for all fishing sectors in 2014:
Martinique	1.15	2	1,011[a]	Min. 1kg Max. 15kg	0.909	1.6 – 28.6T	28	NA
Guadeloupe	3.27	4.44	1,231[a]	Min. 1kg Max. 5kg	0.861	3.5 – 70.6T	22.4	NA
Tobago	151.8	206.4	1,246[b]	Min. 1kg Max. 5kg	0.905	168.9 – 2,286	650.8	529

Table 5. List of elasmobranchs that appeared on BRUVs across all three islands.

Martinique (n=100)		**Guadeloupe** (n=100)		**Tobago** (n=250)	
Species	Prop.	Species	Prop.	Species	Prop.
1) *H. americanus*	10% (n=10)	*H. americanus*	12% (n=12)	*H. americanus*	12.4% (n=31)
		G. cirratum	7% (n=7)	*G. cirratum*	7.2% (n=18)
		C. perezi	1% (n= 1)	*Rhizoprionodo*n spps.	4.4% (n= 11)
		C. limbatus	1% (n= 1)	*C. perezi*	4.4% (n= 11)
		Mobula sp.	1% (n= 1)	*G. Cuvier*	1.6% (n=4)
				Sphyrna mokarran	0.8% (n=2)
				Mobula sp.	0.8% (n= 2)
				C. limbatus	0.04% (n= 1)
				N. brevirostris	0.04% (n=1)

Table 6. Hurdle results for elasmobranch occurrence (binomial) and MaxN (poisson) across islands.

Count model coefficients (truncated poisson with log link):				
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-11.574	98.318	-0.118	0.906
Martinique	- 2.423	499.557	-0.005	0.996
Tobago	10.468	98.319	0.106	0.915
Zero hurdle model coefficients (binomial with logit link):				
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-3.0786	0.2181	-14.119	<2e-16 ***
Martinique	-0.8133	0.3868	-2.103	0.0355 *
Tobago	0.5584	0.2452	2.278	0.0227 *

Signif. codes: 0 '***' 0.01 '*'
Number of iterations in BFGS optimization: 39
Log-likelihood: -488.6 on 6 Df

Table 7. Hurdle results for elasmobranch occurrence (binomial) and MaxN (poisson) across Guadeloupe reefs.

Count model coefficients (truncated poisson with log link):				
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-16.050	2161.113	-0.007	0.994
Reef GPT	-3.771	7052.898	-0.001	1.000
Zero hurdle model coefficients (binomial with logit link):				
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-4.1312	0.504	-8.197	2.47e-16 ***
Reef GPT	1.5878	0.5603	2.83	0.0046 **

Signif. codes: 0 '***' 0.001 '**'
Number of iterations in BFGS optimization: 27
Log-likelihood: -85.03 on 4 Df

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Appendix I.

Annexe 1: questionnaire utilisé pour l'évaluation rapide des prises accessoires

POUR INTERVIEWEUR SEULEMENT

Interview #: ___________

Date: ___________ Nom d'Interviewer: ___________

L'heure: _____________

Information sur le lieu:

État: ___________ Communauté: ___________

Village ______________ Landing site (dans la communauté): _____________________

Lieu de l'entrevue: Landing site à la maison du pêcheur autres: ________________

Si au site d'atterrissage, le nombre de bateaux à ce moment?

Interview circonstance:

pêcheur sort en mer pêcheur retour de voyage de pêche autres: ______________

Sexe de la personne interrogée: Homme Femme

Est un traducteur ou d'une personne intermédiaire étant utilisés pour aider à mener cette interview? Oui Non

POUR PÊCHEUR

Déclaration d'ouverture:

Mon nom est ___________. Je travaille sur un projet mené par _________________________. Cette organisation mène des recherches et de la gestion sur la pêche et l'océan. Le but de ce projet est simplement de savoir plus sur la pêche côtière et de leurs relations avec les requins et les raies, car il est de plus en plus l'intérêt sur ces espèces. Votre participation est volontaire et confidentiel. Nous n'allons pas enregistrer votre nom ou toute information personnelle, ou partager vos réponses individuelles avec quiconque en dehors de l'équipe de recherche. Vos réponses honnêtes n'auront pas de conséquences pour vous; c'est strictement pour la recherche universitaire. Notre recherche pourrait, cependant, être utilisée pour aider à améliorer l'environnement marin et la durabilité de la pêche à long terme. Par exemple, elle pourrait conduire à l'élaboration de programmes éducatifs ou de conservation dans certains domaines. Vous n'avez pas à répondre à toutes les questions que vous ne voulez pas, et vous pouvez choisir de mettre fin à cette interview à tout moment. L'interview complète prendra environ 15 à 30 minutes. Nous sommes conscients que vous êtes très occupé et nous apprécions grandement votre volonté de prendre le temps avec nous.

Information de fond:

Avez-vous déjà participé à la recherche / enquête liée à (cercle):

requins? la pêche? mammifères marins? tortues de mer? aucun d'entre eux

Si oui, décrivez:
____

Quel âge avez-vous? __________

Pour combien d'années a été la pêche votre profession? __________

Est la pêche votre profession principale? Oui Non

Est la pêche votre seule occupation? Oui Non

(Si non): Quels sont vos autres occupations? ____________________

Au cours des 12 derniers mois, quels mois avez-vous pêché?
____

Possédez-vous votre propre bateau de pêche? Oui Non

Menez-vous les voyages de pêche ou vous êtes un membre d'équipage sur les voyages que quelqu'un d'autre leads?

Il y a combien de membres dans votre ménage?

Est-ce qu'il y a personnes dans votre ménage qui fait de la pêche avec vous ? Oui Non

Si oui, combien de membres et quelles sont leur rapport à vous?

Est-ce la génération précédente fait de la pêche pour leur profession?

Description du bateau

Quel type de bateau avez-vous ou travaillez-vous sur?

Quel longueur a cet bateau? __________

Est le bateau motorisé? Oui Non

Qu'est que c'est la puissance du moteur? __________

Questions sur la pêche et les captures:

Répondez à ces questions pour décrire votre expérience personnelle, pas celle de votre communauté.

Quelles sont les trois principaux types des matériels de pêche que vous utilisez le plus souvent au cours d'une année? (utilisation illustrations)

Matériel 1: ________________________ __________

Matériel 2: ________________________ __________

Matériel 3: _________________________ __________

Pour les trois types des matériels énumérés au-dessus, remplissez les détails dans:

filets maillants de fond Longueur ___________ Maillage___________________

filets dérivants (drift) Longueur____________ Maillage_________________

long line (nombreux crochets): taille d' hameçon _________ Nombre d'hameçons _________

Hameçon (1 ou peu), cercle: chalut (avec bateau) fixé autres

Seine tournante ou senne surround. Maillage ____________ longueur____________

Senne Beach (la bilonche ?) Maillage ____________ longueur__________________-

Nasses ou casiers _______________________

Autre (précisez): __________

Combien des pêcheurs, y compris vous-même, sont sur le bateau? __________

Pendant quels mois de l'année utilisez-vous chaque matériel?

Matériel 1: _____________________________________

Matériel 2: _____________________________________

Matériel 3: _____________________________________

Pendant les mois énumérés ci-dessus, combien de jours par semaine pêchent vous avec chaque matériel ? Ecrit dessous

1 2-3 4-5 6-7

Matériel 1: ______________________________________

Matériel 2: ______________________________________

Matériel 3: ______________________________________

Sur une journée moyenne, combien d'heures travaillez-vous sur le bateau de pêche?

Au plus fort de la saison de pêche, combien d'heures restez-vous sur le bateau de pêche?

Qu'est-ce que vous essayez d'attraper avec chaque matériel ?

Matériel 1: ______________________________________

Matériel 2: ______________________________________

Matériel 3: ______________________________________

- **Raies**

Avez-vous déjà pris raies avec ces matériels ? Ecrire: Oui Non ne me souviens pas

Matériel 1: ______________________________________

Matériel 2: ______________________________________

Matériel 3: ______________________________________

Si vous écrivez oui dans un ou plus au-dessus, remplissez détails ci-dessous.

Matériel 1: Quelles espèces avez-vous pris avec cet matériel (utilisation illustrations), et comment êtes-vous certain de cela?
Liste des espèces dans l'ordre du plus souvent pour moins couramment pris.
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
Pendant quels mois de l'année avez-vous pris raies avec cet matériel ?:
Espèces 1: ______________________________________
Espèces 2: ______________________________________
Espèces 3: ______________________________________
Combien de raies totale avez-vous attraper dans la dernière année, avec cet matériel?
Encercler un: 0 1 – 10 11-20 21 – 50 > 50 ne sais pas
Dans quelle profondeur d'eau ou comment loin de la côte étiez-vous quand vous les prendre?

Matériel 2: Quelles espèces avez-vous pris avec cet matériel (utilisation illustrations), et comment êtes-vous certain de cela?
Liste des espèces dans l'ordre du plus souvent pour moins couramment pris.
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
Pendant quels mois de l'année avez-vous pris raies avec cet matériel ?:
Espèces 1: ______________________________________
Espèces 2: ______________________________________
Espèces 3: ______________________________________

Combien de raies totale avez-vous attraper dans la dernière année, avec cet matériel?
Encercler un: 0 1 – 10 11-20 21 – 50 > 50 ne sais pas
Dans quelle profondeur d'eau ou comment loin de la côte étiez-vous quand vous les prendre?

Matériel 3: Quelles espèces avez-vous pris avec cet matériel (utilisation illustrations), et comment êtes-vous certain de cela?
Liste des espèces dans l'ordre du plus souvent pour moins couramment pris.
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
___________________ Très sûr assez sûr ne sais pas
Pendant quels mois de l'année avez-vous pris raies avec cet matériel ?:
Espèces 1: ______________________________________
Espèces 2: ______________________________________
Espèces 3: ______________________________________
Combien de raies totale avez-vous attraper dans la dernière année, avec cet matériel?
Encercler un: 0 1 – 10 11-20 21 – 50 > 50 ne sais pas
Dans quelle profondeur d'eau ou comment loin de la côte étiez-vous quand vous les prendre?

- **Requins**

Avez-vous déjà pris requins avec ces matériels ? Ecrire: Oui Non ne me souviens pas

Matériel 1: ______________________________________

Matériel 2: ______________________________________

Matériel 3: ______________________________________

Si vous écrivez oui dans un ou plus au-dessus, remplissez détails ci-dessous.

Matériel 1: Quelles espèces avez-vous pris avec cet matériel (utilisation illustrations), et comment êtes-vous certain de cela?
Liste des espèces dans l'ordre du plus souvent pour moins couramment pris.
___________________ Très sûr assez sûr ne sais pas

__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas

Pendant quels mois de l'année avez-vous pris raies avec cet matériel ?:

Espèces 1: ____________________________________

Espèces 2: ____________________________________

Espèces 3: ____________________________________

Combien de requins totale avez-vous attraper dans la dernière année, avec cet matériel?

Encercler un: 0 1 – 10 11-20 21 – 50 > 50 ne sais pas

Dans quelle profondeur d'eau ou comment loin de la côte étiez-vous quand vous les prendre?

Matériel 2: Quelles espèces avez-vous pris avec cet matériel (utilisation illustrations), et comment êtes-vous certain de cela?

Liste des espèces dans l'ordre du plus souvent pour moins couramment pris.

__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas

Pendant quels mois de l'année avez-vous pris raies avec cet matériel ?:

Espèces 1: ____________________________________

Espèces 2: ____________________________________

Espèces 3: ____________________________________

Combien de requins totale avez-vous attraper dans la dernière année, avec cet matériel?

Encercler un: 0 1 – 10 11-20 21 – 50 > 50 ne sais pas

Dans quelle profondeur d'eau ou comment loin de la côte étiez-vous quand vous les prendre?

Matériel 3: Quelles espèces avez-vous pris avec cet matériel (utilisation illustrations), et comment êtes-vous certain de cela?

Liste des espèces dans l'ordre du plus souvent pour moins couramment pris.

__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas
__________________ Très sûr assez sûr ne sais pas

Pendant quels mois de l'année avez-vous pris raies avec cet matériel ?:

Espèces 1: ____________________________________

Espèces 2: ____________________________________

Espèces 3: ___________________________________

Combien de requins totale avez-vous attraper dans la dernière année, avec cet matériel?
Encercler un: 0 1 – 10 11-20 21 – 50 > 50 ne sais pas
Dans quelle profondeur d'eau ou comment loin de la côte étiez-vous quand vous les prendre?

Autres Matériels

Quels autres matériels de pêche utilisez-vous au cours d'une année? (utilisation illustrations)

Cercle toutes les cases appropriées:

filets maillants de fond Longueur ___________ Maillage__________________

filets dérivants (drift) Longueur____________ Maillage_________________

long line (nombreux crochets): taille d' hameçon _________ Nombre d'hameçons _________

Hameçon (1 ou peu), cercle: chalut (avec bateau) fixé autres

Seine tournante ou senne surround. Maillage ____________ longueur____________

Senne Beach (la bilonche ?) Maillage ____________ longueur__________________-

Nasses ou casiers ______________________

Autre (précisez): __________

Avez-vous déjà pris requins / rayons dans aucun de ces autres matériels? Oui Non Ne me souvient pas

Si oui:

Avec quels autres matériels ont vous les capturés (liste tout ce qui se applique):

____

____

____

Liste des espèces dans l'ordre du plus souvent pour moins couramment pris.

__________________ Très sûr assez sûr ne sais pas

__________________ Très sûr assez sûr ne sais pas

__________________ Très sûr assez sûr ne sais pas

__________________ Très sûr assez sûr ne sais pas

___________________ Très sûr   assez sûr   ne sais pas

Combien de requins / raies avez-vous attraper dans la dernière année, dans ces matériels?

encercler un: 0   1 - 2   3-5   6-10   > 10   ne sais pas

En moyenne, combien de requins / raies avez-vous attraper par mois dans la dernière année, dans ces matériels ?

encercler un: 0 1 - 2 3-5   6-10   > 10   ne sais pas

Quand vous avez attrapé un raie, était-il:

Prises pour cible   par les prises accessoires (capturés accidentellement)

by-product (capturées accidentellement mais a gardé)

Qu'avez-vous fait avec les raies vous pris au cours des derniers mois?

Relâcher vivants

Jeter morte

Vendre seulement ailettes

Vendre tout le corps

Mangent

d'autres:___________

Pourquoi? _____________________________

Lorsque vous avez attrapé un requin, était-il:

Prises pour cible   par les prises accessoires (capturés accidentellement)

by-product (capturées accidentellement mais a gardé)

Qu'avez-vous fait avec les raies vous pris au cours des derniers mois?

Relâcher vivants

Jeter morte

Vendre seulement ailettes

Vendre tout le corps

Mangent

d'autres:__________

Pourquoi? ____________________________

Risques pour les pêcheurs

Est-ce que requins endommager votre matériel de pêche? Oui   Non

Si oui, quels types de matériels endommagent-ils? _______________________

Combien de fois votre matériel été endommagé par les requins dans la dernière année?

encercler un: 0 1 - 2   3-5   6-10   > 10   ne sais pas

Est-ce que requins endommagent vos autres prises? Oui   Non

Combien de fois vos prises été mangé ou endommagé par un requin dans la dernière année?

encercler un: 0 1 - 2   3-5   6-10   > 10   ne sais pas

Dans votre vie, avez-vous déjà été blessé par un requin? Oui   Non

Si oui, comment tombe était votre blessure? Très grave   assez graves   pas graves

Si non, quelle est la probabilité que vous pensez que vous êtes d'être blessé par un requin? Très probable   assez probable   peu probable

Les questions historiques

Par rapport à quand vous avez commencé la pêche:

Est-ce qu’il y a plus, moins ou le même montant de requins / raies dans les domaines où vous pêchez? vous ne savez pas?

Sont les captures accidentelles des rayons/requins dans les matériels de pêche supérieur, inférieur, le même, ou vous ne connaissent pas?

Sont les captures intentionnel des raies/requins t plus ou moins commune, ou le même, ou vous ne connaissent pas?

Préoccupations

Avez-vous des commentaires généraux concernant vos activités de pêche que vous pensez que doivent être abordées en priorité? (rang dans l'ordre)

1.

2.

3.

POUR intervieweur

Comment ouvert et honnête semble le pêcheur à répondre des questions à propos de prises accessoires?

Très ouverte / honnête peu ouverte / honnête pas ouvert/honnête

Comment intéressés et engagés semblait le pêcheur à l'entrevue?

Très intéressé /Modérément intéressés / Pas intéressé

Comment certains semble le pêcheur dans les réponses à des questions numériques?

Très assurer / raisonnablement sûr / Incertain

CHAPTER IV

INSIGHTS INTO ELASMOBRANCH RECREATIONAL FISHERIES AND DIVING IN THE UPPER FLORIDA KEYS, USING DATA FROM BAITED REMOTE UNDERWATER VIDEO AND IN-PERSON INTERVIEW SURVEYS

Abstract

Recreational ocean activities such as fishing and diving are a globally lucrative businesses, and individuals in these industries represent potentially valuable sources of knowledge on the current state of, and recent changes in, coastal oceans. I investigated perceptions of elasmobranch abundance and diversity, as well as attitudes towards management practices, in these industries in the Upper Florida Keys, USA using a rapid assessment framework. I conducted in-person structured interview surveys (N=67) during the summer of 2016. Ocean user perceptions were compared to Baited Remote Underwater Video (BRUV) surveys of elasmobranchs in the same area. Ocean-users were categorized as either surface users, mostly compromised of anglers and boat captains that observe animals from above the water, and underwater users, which were mostly divers and some snorkelers. Surface users reported observing seven sharks species, while underwater users reported four shark species and BRUVs recorded six sharks species. Species identified by all both groups and BRUVs were *Ginglymostoma cirratum*, *Carcharhinus perezii*, and *Sphyrna tiburo.* Three ray species *Hypanus americana*, *Aetobatus narinari*, and *Urobatis jamaicensis* were identified by both groups and BRUVs. Surface users preferred to fish in northern area of the study wite while underwater users preferred using areas in the central portion of the study area. From BRUVs, elasmobranch relative abundances were relatively low, nut there were significantly more elasmobranch species recorded in southern portion of the study

area. The relative abundance of elasmobranchs was significantly different across all three regions of the study. These data revealed that there was a lower proportion of BRUVS with *Sphyrna tiburo* and *Urobatis jamaicensis*s in the northern portion of the study area, that surface and underwater users agree on the need for protected areas and user groups do not have a conflicting opinions with regards to elasmobranch conservation policies.

Introduction

There is a growing need to understand the economic, social and cultural activity associated with the use of ocean resources (Colgan 2013). Currently, one of the main problems with understanding and managing ocean resources is the conflict between the need to preserve these resources while continuing to reap economic benefit from them (Colgan 2013). A variety of communities use ocean resources for recreational purposes, but still derive economic benefits in varying degrees; most notably the recreational fishing and diving industries. Recreational fisheries are fisheries that are driven by the fisher's need for sport, awards or public recognition, and not necessarily for commercial or sustenance purposes (Schramm et al., 1991). However recreational fisheries such as charter fishing, are an industry that provides the community with employment and revenue. Similarly, diving is often considered a recreational hobby associated with tourism, yet dive owners and employees are part of an industry that rely on ocean resources for their livelihood. While workers in these industries spend considerable time on or in the ocean and potentially possess important information on the status and recent changes in the ocean, there are gaps in understanding how these different communities wish to manage resources, perceive changes in resources, and how their opinions compare to one another and to field data.

Recreational fisheries account for 10% of the total global catch, and an estimated 47 million fish are landed every year (Cooke and Cowx 2004). It is likely that the economic revenue generated by recreational fishing on a global scale is similar to the value generated by commercial fisheries (Cooley et al., 2008). In the United States, recreational fishing generates $50 billion in revenue, and has a total $125 billion impact on the economy, including employment for more than 800,000 people (2016 NSFHWR). Although commonly considered a leisure activity, recreational fishing has numerous socioeconomic benefits (Arlinghaus and Cooke, 2009; Tufts et al. 2015) that can also negatively impact fish populations and aquatic environments (Lewin et al. 2006; Cooke et al. 2014). In fact, some recreational catches can surpass commercial catches in certain regions (McPhee et al. 2002; Schroeder and Love 2002), and even the complete collapse of some fisheries have been attributed to recreational fishing (Post et al. 2002). It is estimated that in 2015 in the United States, the annual shark landings in recreational fishing (3,377 Metric Tons) were more than twice the landings by the commercial sector when excluding dogfish (1,673 Metric Tons; NOAA Fisheries of the United States 2015).

Because of their low fecundity and late age at maturity, sharks are particularly vulnerable to overfishing (Musick et al., 2000; Baum et al., 2003) and populations of some species appear to have declined markedly (Ferreti et al., 2010). Given their potentially important role in ecosystem dynamics (e.g Heithaus et al., 2010) these may have serious cascading consequences. The effects of decreasing shark populations on coral reefs, however, remain largely unclear (Roff et al., 2016).

Many efforts have been made in the United States to protect sharks from fisheries pressures (Momigliano and Harcourt, 2014). Unlike many developing nations that do not have the resources to develop and enforce catch limits or other policies, the U.S has implemented many requirements including needing a fishing permit to catch and sell sharks (whether its directed or incidental catch; NMFS, 2006), setting maximum quotas and minimum size limits for certain species, restricting damaging gears, banning shark finning and creating protected areas (Shiffman and Hammerschlag, 2016).

Recreational fishing is not the only watersport that depends on ocean resources and has a major economic value for tourism. Recently, dive-based tourism has become increasingly used as an alternative to extracting resources, especially large bodied animal taxa like sharks (Walters and Samways 2001; Heyman et al., 2010). Recreational scuba diving and snorkeling contributed about $11 billion to the US gross domestic product between 2017-2018 (DEMA 2019).

Florida is a recreational fishing and diving destination. Florida reported over $8 billion in sales for saltwater fishing in 2011 (NMFS 2017 report). Recreational shark fishing makes up an important component of recreational saltwater fishing. Indeed, Florida has one of the largest recreational shark fisheries in the world (Schmied and Burgess 1987; Fisher and Ditton 1993; Figueira and Coleman 2010). In addition, Florida is one of the top destinations for scuba divers and snorkelers in the United States. Scuba diving and snorkeling supported around 26,000 full-time equivalent tourism-related jobs, contributing around USD $904.4 million to the Florida economy between 2017 and 2018 (DEMA 2019). In the Florida Keys more than 33,000 jobs are supported by ocean sources and recreation, accounting for 58% of the local economy and totaling over USD $2.3 billion annually. Between 2007-2008, it was estimated that recreational surface users spent USD $274 million just in the Florida Keys (FKNMS Socioeconomics Factsheet).

Extensive fishing can change ecosystem structure (Pauly et al., 1998; Pauly and Palomares, 2005; Branch 2015; Gilarranz et al., 2016) even in well-managed regions of a developed country. Although the Florida Keys are known as a fishing destination, the average size of trophy fish in Key West declined by 90% (McClenachan 2009) between 1956 to 2007, and 75% of coral reef fish in the Florida Keys are overfished (Chiappone et al., 2000; Ault et al., 2005; McClenachan 2009).

One study in the Florida Keys evaluated reef fish and benthic assemblage structure in protected and unprotected reefs and found that although biomass and mean body lengths for predatory and herbivorous fish species were larger within the protected area, there was no difference in benthic cover (Kramer and Heck, 2007). A similar study looked at fish community structure and invertebrate predation potential in no-take zones and fished sites in the Florida Keys, and found that although there were more piscivores in no-take sites, most of them (~95%) were species that are moderately unexploited (Valentine et al., 2008).

While indications of overfishing remain in the Florida Keys, there have bee management successes leading to stock recovery, including for the Goliath grouper

(*Epinephelus itajara*). In 1990 the Atlantic goliath grouper spawning stock biomass dropped to about 5% of historical levels and a moratorium was created (Porch et al., 2006). By 2006, adult goliath grouper abundance had increased to about 30% of historical levels (Shiedeler et al., 2014) and was removed from the NMFS species of concern list (NMFS 2006). Currently there are multiple large-bodied teleost taxa that are completely protected in the state of Florida including the Goliath grouper and Nassau grouper, as well as 27 different species of sharks (including *Carcharhinus falciformis*, *Galeocerdo cuvier*, and *Sphyrna mokarran*) and ray species (*Pristidae* spp., *Mobula* spp., and *Aetobatus narinari*s) (Florida Rule Chapter 68B- 44). It is unlawful to land, harvest, possess, purchase, sell or exchange these taxa.

The number of recreational dives on coral reefs in Florida are some of the highest globally (Krieger and Chadwick, 2013) and in 1998 the Florida Park system increased the number of mooring buoys. This resulted in an increase in the number of boats on reefs (Causey 2002). A study in 2019 estimated that snorkeling in Florida accounts for about 4.24 million visitor-days per year while scuba diving in Florida accounts for about 4.56 million visitor-days per year (DEMA 2019).Given the number of tourists and visitor-days and their economic importance, local fishing charters and diving business employees are a potential scientific resource and it is important to understand their views and attitudes towards current management efforts.

I used a socio-ecological approach to quantify the impressions of underwater users and recreational fishing industry workers to provide insights into elasmobranch catches/sightings, stakeholder perceptions and opinions on conservation policies, and to compare these impressions to data collected via traditional sampling methods. Specifically, I aimed to 1) characterize perceptions of elasmobranchs held by recreational surface and underwater users in the Upper Florida Keys 2) investigate whether these two stakeholder groups have conflicting perceptions with respect to elasmobranch and ocean management and 3) compare data perceptions of surface users and underwater users to data collected using baited remote underwater video systems (BRUVS).

Methods

Study Site

This study occurred in the Upper Florida Keys. The Florida Keys is an archipelago in southern Florida that extends 250km southwest from mainland Florida to Key West. The Upper Keys start in Biscayne Bay where some keys are uninhabited and inaccessible by car. Moving southwest away from mainland Florida, the inhabited Upper Keys extends from Key Largo to Lower Matecumbe Key.

The Upper Keys reef track was divided into three main sample blocks, the northern (NSB), central (CSB) and southern blocks (SSB). Each block had at least 4 km^2 of coral reef area. BRUVs (n=200) were deployed between 25 May- 8 August, 2016, at locations along the forereefs at a depth of 8-40m that were determined using a random number generator. The Northern Sampling Block covered the reef tract area between Rattlesnake Key and Key Largo, which contains three Sanctuary Preservation Area (SPA) zones, including The Elbow, Key Largo Dry Rocks and Grecian Rocks for a total of ~1.6 km^2 protected areas. Diving is allowed at these SPA zones, but all fishing is prohibited. The Central Sampling Block covered the reef tract area between Key Largo and Tavernier Key, which contains three SPA zones, including French Reef, Conch Reef (which has a research only area and as well as a regular SPA) and the Spiegel Grove for a total of ~2.5 km^2 protected areas. Fishing is prohibited in all these areas, and recreational diving is prohibited in part of Conch Reef. The Southern Sampling Block covered the reef tract area between Kalteux Key and Upper Matecumbe Key, which contains one SPA zones, Davis Reef, for a total of ~0.3 km^2 protected areas. Fishing is prohibited in all these SPAs, and recreational diving is prohibited only in part of the Conch Reef SPA.

The Upper Keys are mostly constituted of fossil coral reefs, while the lower keys are formed of cemented sandbars, and curve west as a results of Gulf Stream currents (Peck and Howden, 1985). The first national marine sanctuary in the Florida Keys was established in 1975 in Key Largo. In 1990, the Florida Keys National Marine Sanctuary was established, which extended the existing sanctuaries to protect 2,800 square nautical miles and North America's most extensive coral reef system (Seeteram, et al., 2019). The Florida Keys National Marine Sanctuary (FKNMS) established spatial management and policies (such as Sanctuary Preservation Areas, Ecological Reserves and fishing and diving regulations) to ensure that activities such as fishing, diving and snorkeling occur have relatively little impact on marine resources while providing economic benefits to the community.

The Florida Keys National Marine Sanctuary is administered by NOAA, but since 60% of the protected area falls in state waters, the sanctuary is also managed by the state of Florida in conjunction with the Florida Fish and Wildlife Commission (FWC). The FKNMS has different zones with varying degrees of restrictions to protect coral reefs and “to avoid conflict by user groups such as underwater users and anglers.” In the Upper Keys, there are two Sanctuary Preservation Areas (SPA) where surface users are allowed, seven SPAs that allow underwater users but not surface users, and two areas that are designated research-only. The FKNMS does not have any additionally elasmobranch-specific regulations beyond those of the state of Florida. As of 1998, anglers are allowed to catch and retain a maximum of two sharks of a certain length per vessel from the list of approved sharks species (Rule: 68B-44.003).

Interview Surveys

A total of 67 interview surveys were conducted in the Upper Florida Keys, across Key Largo, Tavernier, Islamorada, and Marathon (Figure 1). Questionnaire surveys were conducted in person during June 2016. Since some elasmobranch species are rare and can be difficult to identify, the FAO Identification Guide to Common Sharks and Rays of the Caribbean was used (FAO & Bonfil, 2016). Certain taxa, such as *Rhizoprionodon* spp., *Sphyrna* spp. (except for *Sphyrna tiburo*) and *Mobula* spp., are problematic to identify at the species level without specimens to examine, so I recorded these taxa at the genus level.

My questionnaire (Appendix 1) focused on elasmobranch catches and sightings for surface users, and sightings for divers and snorkelers. Background questions were asked about the interviewee’s characteristics: age, gender, occupation and fishing or diving background, monthly days at sea and hours per day, and targeted species. For both ocean-user groups, questions were asked about sharks and rays, including catch/observation frequency and seasonality, perception of changes in shark and ray abundance, and their opinions on management policies.

Baited Remote Underwater Video Surveys (BRUVS)

Baited cameras have been used to study predatory fish in a variety of habitats (Brooks et al., 2011; Bond et al. 2012, Wraith et al. 2013, Harvey et al., 2018), including coral reefs. I used BRUVs that consisted of a video camera (GoPro-Hero) mounted on a metal frame that has a small, pre-weighed bait source (1 kg of crushed Atlantic menhaden *Brevoortia tyrannus*) attached to the end of a 1m pole in the camera's field of view. A rope that terminated in a buoy was attached to the frame.

BRUVs were deployed from the boat during daylight hours using a rope and in-water personnel to orient the BRUV facing down current. The BRUV filmed continuously for ~ 90 minutes after settling to the bottom. Each day, six units were deployed simultaneously, retrieved, rebaited, moved to new locations and deployed for a second time. On days with good weather conditions, BRUVs were deployed for a third time in the same day. No BRUVs were deployed within 500m of one another (Figure 1). At the start and end of each deployment environmental variables were measured including bottom depth with a handheld depth Vexilar Handheld Digitial Sonar, and water temperature, salinity, and dissolved oxygen with a YSI Pro 2030.

I used 50 videos at each sample block for analyses, using those that had at least 90 minutes of continuous filming, the water column was at least 50% of the screen image, and had at least three meters of visibility. All videos were watched for 90 minutes from the start time, at normal speed (1x) and annotated independently by at least two observers using the Global FinPrint Annotator software (www.globalfinprint.org). Data recorded by observers included elasmobranch species identification, and the maximum number from each species within a single frame (MaxN) (Bond et al., 2012). The software captures a still image of all annotations, so I could verify species identifications and count data.

Data analysis

I used Logistic regressions to test the hypothesis that type of ocean-user, age, years of experience and whether they stated if this occupation was their sole source of income had an effect on which sampling blocks they frequented, and whether they supported protecting certain elasmobranch species, setting a minimal catch length for elasmobranchs, or setting up MPA's that are research-only. I used a generalized linear model (GLM) to test the effects of sampling block on occurrence (i.e., presence/absence) and MaxN for each species with a MaxN > 1.

Using relative abundance, species-specific GLMs were only possible for *Sphyrna tiburo*, *Ginglymostoma cirratum*, and *Urobatis jamaicensis* since these were the only species with a MaxN > 1. I also used GLMs to test for spatial differences in the number of elasmobranch species observed per BRUV deployment. Finally, I used Chi Square tests to test whether user groups differed in how they perceived changes in the abundances of elasmobranchs and their potential importance in the environment as well as their opinions on management measures. Statistical tests were conducted in R software version 1.1.463 with the MASS4 library (R Core Team, 2016). Results are reported as mean ± SD unless otherwise noted.

Results

Interview survey data

Surface users

Interviewed surface users were mostly males (78%), were on average 48.8 years ± 23.0 years old (range: 18 - 80), and reported having an average fishing experience of 26.6 years ±13.1 (range: 4 to 50 years). Surface users reported spending an average of 97 hrs ± 12 hrs a month fishing, and reported that each fishing trip lasted on average 5 hrs ± 2 hrs. The majority of interviewees (n=19 of 27; 70.4%) considered recreational fishing their profession and not a hobby, and 51.8% (n=14 of 27) depended on fishing as their only occupation. A total of 7.4% (n=2 of 27) reported fishing only in NSB, 18.5% (n=5 of 27) reported fishing only in CSB, and 18.5% (n=5 of 27) reported fishing only in SSB. Almost half of surface users reported fishing in two study zones with 44.4% (n=12 of 27) fishing in the NSB and CSB and one respondent fished in both NSB and SSB. No surface users reported fishing in all locations or in both CSB and SSB. Finally, one person reported fishing in an area outside the Upper Keys, and one did not answer this question.

Surface users identified ten elasmobranch taxa as part of their catches and observations (n = 7 shark taxa; n = 3 ray taxa). Nurse sharks (*Ginglymostoma cirratum*), Caribbean reef sharks (*Carcharhinus perezii*), and bull sharks (*Carcharhinus leucas*) were reported most frequently (Table 1). Southern stingrays (*Hypanus americanus*) and spotted eagle rays (*Aetobatus narinari*), were the most commonly reported ray species (Table 1).

When asked to rank the importance of sharks to the health of the oceans, all (n=27 of 27) surface users answered that they believe sharks are very important. When asked to rank the importance of sharks to the economy, 40.7% (n= 11 of 27) of surface users considered sharks very important to the economy, 29.6% (n=8 of 27) considered sharks somewhat important, 14.8% (n= 4 of 27) considered sharks a little important, 11.1% (n= 3 of 27) considered sharks not important at all to the economy and one surface user declined to answer. Only two surface users were willing to answer whether they target sharks and what they do with hooked sharks.

The majority of surface users (59.3%; n= 16 of 27) also ranked rays as very important to the health of the oceans, but only 18.5% (n= 5 of 27) considered rays somewhat important to the health of the oceans, no surface users reported rays being a little important, 18.5% (n=5 of 27) reported rays not being important at all, and one surface user declined to answer. Most surface users thought that rays were either very important (25.9%; n=7 of 27) or important (25.9%; n= 7 of 27) to the economy, while 33.3% believed rays being a little important (n=9 of 27) and 11.1% (n= 3 of 27) thought that rays were not important to the economy and one surface user declined to answer (3.7%, n= 1 of 27).

Most surface ocean-users, 44% (n=12 of 27) perceived a dramatic decline in coral reef resources, while 29.6% (n=8 of 27) perceived them as a little worse and 11.1% (n=3 of 27) reported that they stayed the same. Only one surface user (3.7%, n=1) believed there was an improvement in coral reef resources. Two surface users (7.4%, n=2) were unsure and one declined to answer.

More surface users (81.5%; n=22 of 27) believed that protecting shark species from fishing is a good conservation policy than a bad policy (14.8%, n=4 of 27). Those not supporting protections gave reasons such as “there are too many sharks” and “sharks are overpopulated.” One surface user declined to answer. More surface users (81.4%; n= 22 of 27) believed setting minimum catch lengths for certain shark species was a good policy than a bad policy (14.8%, n=4 of 27). Those not supporting catch limits gave reasons such as “catch lengths don’t matter” and “there is no data to back up [the need for minimum catch lengths]”. More surface users (88.8%; n= 24 of 27) believed Marine Protected Areas where there is no fishing and diving allowed was a good policy than a bad policy (11.1%; n=3 of 29) believed it was a bad policy and gave reasons such as “enforcement of such policies won’t work” and “MPAs have too much political power”.

Underwater users

Interviewed underwater users were mostly males (75.6%, n=28 of 37), on average 35.6 years ± 15. 5 years old (range: 18 - 70), and had an average experience of 15.5 years ±10.1 (range: 4 to 51 years). Underwater users spent an average of 43.6 hrs ± 9.8 a month underwater, with each trip lasting on average 2.3 hrs ±1.1 at sea. The majority of interviewees (n=27 of 37; 72.9%) considered diving/snorkeling their profession and not a hobby, and 62.2% (n=23 of 37) depended on diving/snorkeling as their only occupation.

For underwater users, 8.1% (n=3 of 37) reported only visiting NSB, 5.4% (n=2 of 37) only visited in CSB, and 18.9% (n=7 of 37) only visited in SSB. Most underwater users, 35.1% (n=13 of 37) responded to diving/snorkeling in both NSB and CSB, compared to 21.6% (n=8 of 37) reported diving/snorkeling in both CSB and SSB, and zero underwater users that reported diving/snorkeling in NSB and SSB. Two underwater users (5.4%) reported diving/snorkeling in all three reef blocks, two underwater users (5.4%) reported diving/snorkeling in an area outside of Reefs Upper Keys, and one underwater user did not answer the question.

Underwater users reported observing seven elasmobranch taxa during their dives including four shark taxa and three ray taxa. Nurse sharks (*Ginglymostoma cirratum*), caribbean reef sharks (*Carcharhinus perezii*), and bonnetheads (*Sphyrna tiburo*) were reported the most frequently (Table 1). Southern stingrays (*Hypanus americanus*), Jamaican rays (*Urobatis jamaicensis*) and spotted eagle rays (*Aetobatus narinari*) were the most commonly reported ray species (Table 1).

When asked to rank the importance of sharks to the health of the oceans, the overwhelming majority 94.5% (n=35 of 37) of underwater users thought that sharks are very important to the health of the oceans, with only one underwater user (2.7%) responding that sharks are slightly important and one (2.7%) reporting sharks are not important at all. When asked to rank the importance of sharks to the local economy, 70% (n=26 of 37) of underwater users considered sharks very important to the economy, while 13.5% (n= 5 of 37) thought sharks were somewhat important to the economy, 16.2% (n=

6 of 37) reported sharks being a little important and no underwater users responded that sharks are not important to the local economy.

The majority of underwater users 81% (n= 30 of 37) thought that rays are very important to the health of the oceans compared to 5.4% (n= 2 of 37) that thought they were somewhat important. No underwater users thought rays were a little important and 13.5% (n=5 of 37) thought rays are not important to ocean health. A total of 51.4% (n=19 of 37) of underwater users thought that rays were very important to the economy, 29.7% (n= 11 of 37) indicated that they considered rays somewhat important, 10.8% only thought that rays were a little important (n=4 of 37), and 8.1% (n= 3 of 37) considered rays not important to the economy.

Of the underwater users interviewed, 21.6% (n=8 of 37) reported coral reef resources as dramatically worse, 48.6% (n=18 of 37) perceived them to be a little worse, one underwater users (n=1, 2.7%) reported them as staying the same, while 16.2% (n=6 of 37) believed there was a little improvement, one underwater users (n=1, 2.7%) believed there was a dramatic improvement, and 8.1% (n=3 of 37) reporting being unsure.

More underwater users (97.3%, n=36 of 37) believe that protecting shark species from fishing is a good conservation policy, while 2.7% (n=1) believe protecting certain shark species was a bad policy and gave the reason that “not sure protecting them would do anything”. More underwater users (91.9%, n= 34 of 37) believed setting minimum catch lengths for sharks was a good policy, than a bad policy (8.1%, n=3). More underwater users (91.9%; n=34 of 37) believed Marine Protected Areas where there is no fishing and diving allowed of underwater users is a good policy than a bad policy (8.1%, n=3). Those not supporting MPAs gave reasons such as “protected areas get more pressure” and “[there is] more support if you don’t restrict access”.

Comparison of surface vs. underwater ocean users

Surface and underwater users differed in their use of the three sampling blocks, with underwater user visiting SSB significantly more than surface users (GLM, z=2.322, P= 0.02). Where ocean users spent their time was also influenced by years of experience (Table 10). There was no variation between ocean user groups or user characteristics (e.g age, years of experience) in whether they supported protecting certain elasmobranch species, setting a minimal catch length for elasmobranchs, or setting up MPA’s that are research-only, but there were not any significant results.

Chi Square test was used to test whether being a surface or underwater user was correlated with how they ranked different perceptions about elasmobranchs, the environment, and management measures. With respect to the importance of sharks and rays to the health of the oceans and local economy, the only significant result was underwater users ranking sharks as being important to the economy significantly higher than surface users ($\chi2$,(8, N = 63), 5.92, p =0.015). There was no significant difference between surface and underwater users’ perceptions of the health of coral reefs and reef fish, with the majority of all users (67%, n= 46 of 67) reporting that the health of reefs have declined in the last thirty years or since they have been working in the Upper Florida Keys.

BRUV data

Six species of sharks and three ray species were observed on the 150 BRUVs deployments (Table 2). Sharks were present on 46% (n= 23 of 50) of drops in NSB and 64% (n= 32 of 50) of drops in both CSB and SSB. Rays occurred on 16% (n= 8 of 50) of videos in NSB, 32% (n= 16 of 50) of videos in CSB, and 44% (n= 22 of 50) of videos in SSB. The number of elasmobranch species of observed per BRUV video varied among sampling blocks (GLM, z=-3.06, P=.002; Table 9) and increased from north to south with 0.74 ± 0.89 SD species in the north, 0.94 ± 0.89 species in the central block, and 1.43 ± 0.99 species in the south. All six species of sharks and three species of rays were observed on BRUVs deployed in SSB.

Species-specific analyses for relative abundance were only possible for *Sphyrna tiburo*, *Ginglymostoma cirratum*, and *Urobatis jamaicensis,* since these were the only species that had MaxN >1 on BRUVs. There was no significant difference in occurrence amongst these three species (GLM: z=-0.818, P=0.413), and there was no significant difference in *Ginglymostoma cirratum* MaxN across reefs (GLM: z=-.085; P =0.4), but there were significantly fewer *Sphyrna tiburo* (GLM: z=-5.1; p-value<.0001) and fewer *Urobatis jamaicensis*s in NSB (GLM: z=-5.2; p-value<.0001) (Figure 2).

Discussion

Populations of sharks have been declining worldwide, primarily driven by the intensive exploitation from fisheries (Worm et al., 2013; Oliver et al., 2015; Dulvy et al., 2017). Mitigating or slowing down the rate of shark population declines is important because of the potential role sharks pay in ecosystem dynamics (Heithaus et al., 2008; Estes et al., 2011; Ruppert et al., 2013). Even though the Florida Keys are a marine sanctuary with a wide range of habitats suitable for sharks in all life history stages, shark communities in the Keys are known to be dominated by nurse sharks, and have a relatively low abundance of large sharks compared to what might be expected (Heithaus et al., 2007; Ward-Paige et al., 2010).

Despite records from the 1930's to1950's from fishers that show a large variety of shark species and size ranges being caught in the waters around the Florida Keys (Heithaus et al., 2007; McClenachan 2009), the abundance and species composition of sharks in the Florida Keys appears to be greatly reduced (Hueter et al., 2005; Heithaus et al., 2007; Ward-Paige et al., 2010; Graham et al., 2016). Given that sharks are a popular target of recreational fisheries and recreational diving in the Keys, understanding recent populations trends from the perception of local stakeholders is an important source of knowledge. Additionally, successful implementation of conservation management strategies requires communicating with the local community and understanding their perspectives.

Using an interdisciplinary approach of interview surveys and BRUVs, I set out to characterize elasmobranch underwater diversity and relative abundance, as well as perceptions held by recreational industry surface and underwater users in the Upper Florida Keys. The largest proportion of surface users, almost half, reported fishing in both NSB and CSB while the largest proportion of underwater users, over a third, responded to also diving/snorkeling in both NSB and CSB. I expected to observe higher elasmobranch relative abundance and species diversity in SSB since both ocean-user groups reported using SSB the least. This is based on the assumption that ocean-users are not selecting locations based on the probability of encountering elasmobranchs. Consistent with this hypothesis, I found that there are significantly more elasmobranch species captured on camera in SSB compared to NSB and CSB.

The sample design did not allow for a direst test of the effects of effects of human population density on elasmobranchs, but it is likely that NSB experiences more anthropogenic pressure than the other sampling blocks because of its proximity to urban areas and a greater number of tourists. A previous study showed that dive operators in the Upper Keys made the greatest number of trips and attracted the highest total number of divers, while dive operators in the Middle Keys, which SSB borders, had fewer trips (Shivlani & Suman, 2000). A connection between human population density and the absence of sharks and other larger predatory fish on coral reefs has been shown in a variety of locations and contexts (Robbins et al., 2006; Stallings 2009; Ferreti et al., 2010, Ward-Paige et al., 2010) and is likely as a result of the direct and indirect effects of various anthropogenic stressors.

BRUV data suggest that the numbers of sharks and rays increase as you move away from Miami, and the relative abundance of *Sphyrna tiburo* and *Urobatis jamaicensis* in NSB was significantly lower than CSB and SSB. *Sphyrna tiburo* and *Urobatis jamaicensis*s are small-bodied species that usually inhabit shallow water habitats (Spieler et al., 2013; Ward-Paige et al., 2011; Smith and Curran, 2017), potentially making them more susceptible to fishing, disturbances rom boating, diving and snorkeling activities that are common near shore (Knip et al., 2010).

Of the species captured on BRUVs, one is threatened (*Sphyrna mokarran*), two are near threatened (*Carcharhinus perezii* and *Carcharhinus acronotus*), two listed as Least Concern (*Sphyrna tiburo* and *Rhizoprionodon* spp.) and one is data deficient (*Ginglymostoma cirratum*) at the global scale (ICUN 2019). For these species, fishing has been identified by ICUN as the main threat, and diver interviews in the greater-Caribbean region suggest that besides *Ginglymostoma cirratum*s many reef-associated sharks are uncommon (Ward-Paige et al., 2010). All species captured on camera were reported by surface users as being part of their fishery, except for the *Sphyrna mokarran* which is endangered and protected by state law. This is somewhat surprising since catches of, and encounters with, *Sphyrna mokarran* are relatively common in southern Florida, including the Keys and are often posted on social media. It is plausible that surface users did not report catching this species because they are aware of their protection status. This may also explain why the majority of surface users did not answer questions of whether they targeted sharks and the fate of the shark catch (released alive, dead, or kept). Still, declines in sharks in the Upper Florida Keys are unlikely caused solely by mortality in recreational fisheries. Indeed, most elasmobranch species move large distances and have been historically subjected to commercial fisheries (McClenachan 2009; McClenachan et al., 2012) in the Keys and throughout their ranges which appear to have resulted in population declines (e.g Heithaus et al. 2007).

Underwater users also did not report *Sphyrna mokarran.* It is likely that underwater users may not have encountered this species, and although previous studies have used recreational underwater users to study contemporary distribution and sighting frequencies of sharks on reefs in the greater Caribbean (Ward-Paige et al., 2010), there are drawbacks of diving as a scientific tool to study sharks. Sharks may change their behavior if underwater users are in a habitat (Dickens et al., 2011), diving transects consistently yielded the lowest shark densities at the Palmyra Atoll in comparison to other survey methods (McCauley et al., 2012). Furthermore, attraction or repulsion of sharks by underwater users can be species and context-dependent (Heuter et al., 2004; Rizzari et al., 2014).

Surface users identified two shark species, *Carcharhinus leucas* and *Galeocerdo cuvier*, that were not captured on camera. This discrepancy is likely due to their relatively low abundance (e.g Heithaus et al., 2007) and that 225 total hours of footage likely was not enough to ensure detection of rare species. *Carcharhinus leucas, Galeocerdo cuvier* and *Sphyrna mokarran* seasonal variance in abundance (Hueter et al., 1995; Heithaus et al., 2007; Guttridge et al., 2017) could explain the results, because BRUVs in the Upper Keys were deployed in the summer. *Carcharhinus leucas* inhabit Florida waters year-round but abundances in some parts of southern Florida peak in the winter (Hammerschlag et al., 2012), and *Sphyrna mokarran* was more common in the lower Florida Keys during colder months (Heithaus et al., 2007). There is not published information available on the seasonality of *Galeocerdo cuvier* in Florida waters, but they were very rare in a study conducted in the lower Florida Keys in the early 2000s (Heithaus et al., 2007).

Surface users, underwater users and BRUVs all identified the same three ray species. All three ray species frequently inhabit shallow coral reef habitats were underwater users prefer to dive and where BRUVs were deployed. There has not been extensive research on the efficiency of diving surveys at identifying ray species diversity and relative abundance (Ward-Paige et al., 2011; Corcoran et al., 2013). This study suggests that all three methods successfully identified small-scale occurrence in a region where these rays are not targeted by fisheries.

In many parts of the world, underwater users and surface users are in conflict over how to manage ocean resources (de Andrade and de Oliveira Soares, 2017; Lopes and Villasante, 2018) and blame each other as the main source of anthropogenic effects (Johnson and Jackson, 2015). In the Upper Florida Keys, however, I found that surface and underwater users in the Upper Keys have similar views on the ecological importance of sharks, and that they agreed on the need for conservation policies. All surface users agreed that sharks are important to the health of the oceans and 81.5% support conservation policies that would protect certain shark species. In comparison, 94.5% of underwater users agreed that sharks are important to the health of the oceans and the vast majority 97.3% support conservation policies that would protect certain shark species from all fishing. Although there was no significant difference in opinion regarding conservation policies between surface and underwater users, most people interviewed in these groups agreed that protecting sharks and having SPA zones with no human interactions is a good conservation policy.

The only difference between surface and underwater users' perceptions was regarding the important of sharks in the local economy, with underwater users ranking sharks significantly higher than surface users. The lack of knowledge on the socioeconomic importance of elasmobranchs by ocean users and scientists alike highlights the need for increased economic impact studies followed by disseminations of results. Although in recent years there has been an increasing awareness by stakeholders on the potential importance of elasmobranchs to ocean ecosystems (Lewis and Newsome, 2003; Simpfendorfer et al., 2011; Shiffman and Hammerschlag 2014) the present chapter echoes the results from my previous studies that show the general lack of awareness on the socioeconomic benefits elasmobranchs have for ocean-users (MacKeracher et al. 2019; Mizrahi et al., 2019).

Given that elasmobranchs are perceived as socio-economically important to many stakeholders and local communities, additional detailed economic studies would be beneficial. Recent literature focuses on the value of sharks for tourism aimed at shark-specific dives (Brunnshweiler 2010; Gallagher and Hammerschlag, 2011; Vianna et al., 2012; Gallagher et al., 2015) and shark-specific fishing trips (Cisneros-Montemayor et al., 2013; Shiffman and Hammerschlag 2014), yet more studies are needed on the valuation of elasmobranch sources and the economic ecosystem benefits they provide, including the economic benefits that general recreational snorkeling, diving and fishing (not specifically geared to sharks) provide. For future studies, interview surveys should include questions that ask local dive shop owners and recreational fishing charter owners what species clients prefer to see/catch (that may be linked trophically to elasmobranchs), what species are the willing to pay to see/catch, what influences their decisions on how to spend their time and money, what days or seasons provide them with the largest earnings, what proportions of their clients are tourists vs. locals, and how many clients request specifically to dive/catch sharks even if their business is not targeted towards sharks. Additional questions should also ask why surface users/underwater users frequent the reefs they prefer to use, what proportion of their time they spend at each reef, and if there is a seasonality component to fishing and diving activities.

My study shows how in-person interview surveys, of two different stakeholder groups, can provide insights into ocean-users' impressions of elasmobranch trends and importance, that can be ground-truthed when paired with an established field method such as BRUVs .

Most importantly, my study found that there does not seem to be a conflict in opinions with regards to elasmobranch resources between ocean-users. Surface users and underwater users agree on the need to protect certain shark species, to set minimal catch lengths, and to have research-only protected areas in the Florida Keys. Surface users and underwater users agreeing with conservation policies stands in stark contrast to what was found by Suman et al., (1999) where fishers in the keys believed they would suffer from the establishment of no-take zones and that there are "plenty of laws and fishing regulations" that already restrict fishers. Stakeholder opinions appear to have changed as policies have been implemented. Likely, perceived negative impacts of declining catches locally and globally (Heithaus et al., 2007; McClenachan 2009, Ferreti et al., 2010; Harnik et al., 2012; Worm et al., 2013, Dulvy et al., 2014), and number of extreme-weather events like hurricanes and temperature fluctuations (Matich and Heithaus 2012;

Boucek et al., 2017; Strickland et al., 2019) in Florida may change stakeholder opinions. Therefore, interview surveys and socio-economic data should be continuously collected over long periods of time to track changes in perceptions and opinions held by the local communities, in order to create realistic and effective management strategies.

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Figures

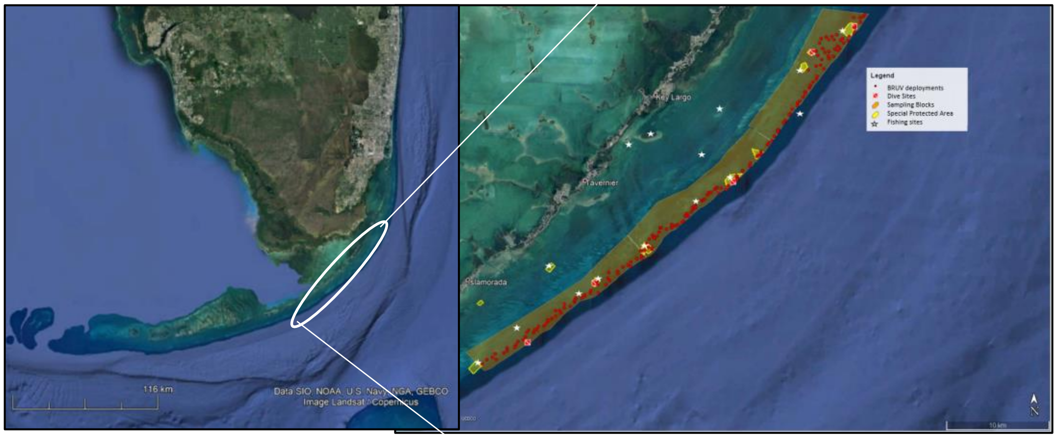

Figure 1. Map of the Florida Upper Keys. Northern, Central and Southern Sampling Blocks are outlined in orange, while Sanctuary Preservation Areas (SPA) are outlined in yellow. Red dots represent BRUV drops, Dive flags show diving locations reported by interviewed underwater users, and white stars show fishing locations reported by interviewed surface users.

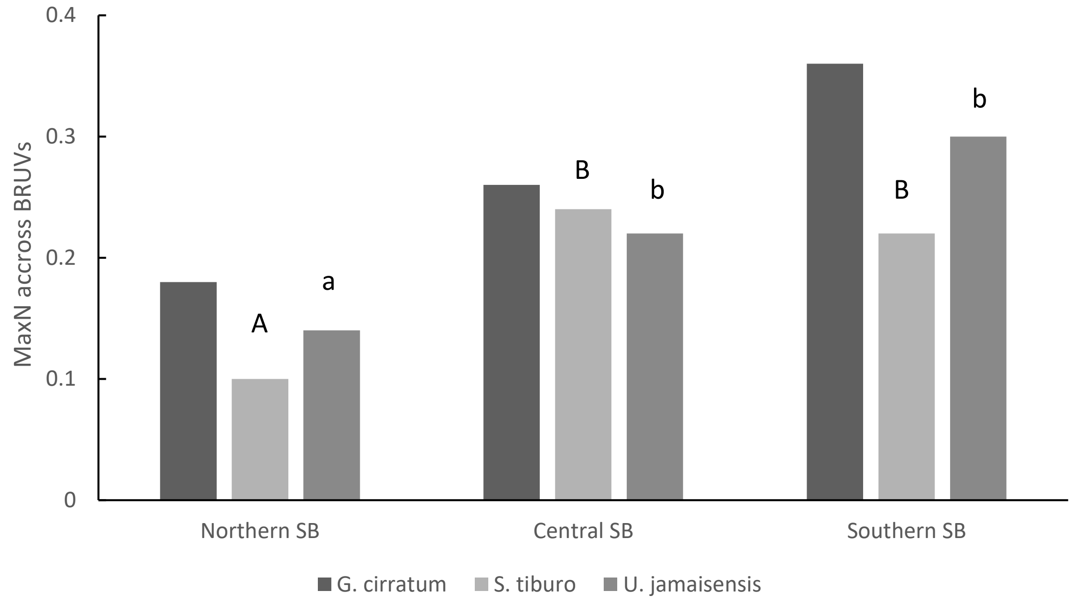

Figure 2. Average MaxN from each species that had MaxN>1. Bars with different letters are significantly different at $p < 0.05$.

Table 1. Elasmobranch species reported by surface users and underwater users, and observed on BRUVs.

	Reported by Surface users	**N= 27**	**Reported by Underwater users**	**N=37**	**Appeared in BRUVs**	**N=150**
Sharks	1.*G. cirratum*	0.66(n=18)	*G. cirratum*	0.92(n=34)	*G. cirratum*	0.28(n= 42)
	2.*C. perezii*	0.07(n= 2)	*C. perezii*	0.03(n=1)	*S. tiburo*	0.19(n= 28)
	3.*C. leucas*	0.07(n= 2)	*S. tiburo*	0.03(n=1)	*C. perezii*	0.08(n= 12)
	4.*Rhizoprionodon spp.*	0.07(n= 2)	No Answer	0.03(n=1)	*Rhizoprionodon spp.*	0.07(n=10)
	5.*S. tiburo*	0.04(n= 1)			*C. acronotus*	0.07(n= 10)
	6.*C. plumbeus*	0.04(n= 1)			*S. mokarran*	0.03(n= 5)
	7.*G. cuvier*	0.04(n= 1)				
Rays	1.*H. americanus*	0.48(n=13)	*H. americanus*	0.65(n= 24)	*U. jamaicensis*	0.2(n=30)
	2.*A. narinari*	0.37(n=10)	*U. jamaicensis*	0.22(n= 8)	*H. americanus*	0.06(n= 9)
	3.*U. jamaicensis*	0.04(n= 1)	*A. narinari*	0.11(n= 4)	*A. narinari*	0.03(n= 4)
	No Answer	0.11(n= 3)	No Answer	0.03(n= 1)		

Table 2. Chi-square post-hoc Bonferroni comparisons of user's opinion on the importance of sharks to the local economy

Catch Fate	G- value	Df	p-value
Very important	5.92	3	0.015
Somewhat important	0.60	3	0.437
A little important	0.33	3	0.563
Not important at all	1.93	3	0.165

Table 3. Results of GLM testing for differences in elasmobranch species diversity across sampling blocks

Sampling Block	z- value	P-value
NSB	-1.832	0.067
CSB	-0.420	0.674
SSB	3.064	0.002

Table 4. Results of Linear Regressions done to test what variables influenced which sampling block ocean-users frequented; shaded *P*s denote significant effects.

	NSB		CSB		SSB	
Variable	*z- value*	*P-value*	*z- value*	*P-value*	*z- value*	*P-value*
Ocean-user type	-0.240	0.8100	-1.596	0.11046	2.322	0.0202
Age	-0.006	0.9950	-0.003	0.99793	0.004	0.9969
Experience	-2.25	0.0245	-2.895	0.00379	2.046	0.0408
Only Occupation	0.618	0.5363	0.543	0.58700	0.905	0.3653

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Appendix 1: Questionnaire used for ocean users in FinPrint locations
FOR INTERVIEWER ONLY
Interview #: __________
Date:__________ Interviewer name:__________
Time of day: ____________
Location Information:
State:__________ Community:__________
Village:_____________
Interview location:
Gender of interviewee: Male Female
Is a translator or intermediate person being used to help conduct this interview? Y N

Opening Statement:
My name is __________. I work on a project conducted by Florida International University. We conduct research about fishing and the ocean. The goal of this project is simply to learn more about sharks and rays, because there are major conservation concerns about these species in the world, including the Caribbean region. Your participation is voluntary and confidential. We will not record your name or any personal contact information or share your individual answers with anyone outside of the research team. Your honest answers will not have any consequences for you; this is strictly for academic research. For example, it could lead to the development of educational or conservation programs in certain areas. You do not have to answer any questions that you do not want to, and you can choose to end this interview at any time. The full interview will take about 15 - 30 minutes. We realize that you are very busy and we greatly appreciate your willingness to take time with us.

Background questions:
When in the ocean, what activity do you spend the most time doing?
Recreational fisher/angler Diver Boat captain/boat crew Spear fishing
other:_________________
Is this a job occupation or a hobby? Job Hobby
If an occupation, is this your only occupation? Yes No
If you have other occupations, is this your primary occupation? Yes No
(If No): What are your other occupations? ____________________
In the past 12 months, which months were you out on the water?
____
For how many years have you been fishing/diving/working in this area of water?
How familiar do you consider yourself to be with this area of water?
Not familiar at all A little familiar Very familiar Unsure
For how many years have you been in this occupation/hobby?__________
Anybody from your household have the same occupation/hobby? Yes No
If yes, how many members and what are their relation to you?
Did your previous generation have the same occupation/hobby?
How old are you?__________

For Divers/spear fishers
How many hours do you spend diving a month?
What is the average duration of your dive? (in hours)
How many sharks do you see per trip, on average?
What are the top species of sharks that are most common in this area?
Species :__________________
Species :__________________
Species :__________________
Species :__________________
Species :__________________

For boat crew/recreational anglers
How many hours do you spend fishing a month?
What is the average duration of a single fishing trip?
How many sharks do you see on average, per fishing trip?
What are the top species of sharks that are most common in this area?
Species :__________________
Species :__________________
Species :__________________
Species :__________________
Species :__________________

Sharks

When you caught a shark, was it:
Targeted catch   by-catch (caught incidentally)   by-product (caught incidentally but kept)

What did you do with the sharks you caught in?
Release alive   Discard dead   Sell only fins   Sell the whole body   Eat   Other: __________

For Shark Species 1:

Point out in the map where you see this species most often.
What months do you see/catch this species most often?
What times of day do you see/catch this species most often?
Do you perceive any other temporal trends for this species? (i.e weather, currents, seasons, etc.)
What depths do you see/catch this species in most often?
What habitat do you see/catch this species in most often? Coral reefs seagrass beds mangroves open water other:_______
In the past five years what trend have you perceived for the population of this species?
Decreasing population   Stable population   Increasing population   Not Sure

How many individuals of this species have you seen/caught in the past year?
0   1 - 10   11 - 20   21 - 50   >50   don't know

For Shark Species 2:
Point out in the map where you see this species most often.
What months do you see/catch this species most often?
What times of day do you see/catch this species most often?
Do you perceive any other temporal trends for this species? (i.e weather, currents, seasons, etc.)
What depths do you see/catch this species in most often?
What habitat do you see/catch this species in most often? Coral reefs seagrass beds mangroves open water other:_______
In the past five years what trend have you perceived for the population of this species?
Decreasing population   Stable population   Increasing population   Not Sure

How many individuals of this species have you seen/caught in the past year?
0   1 - 10   11 - 20   21 - 50   >50   don't know

For Shark Species 3:
Point out in the map where you see this species most often.
What months do you see/catch this species most often?
What times of day do you see/catch this species most often?

Do you perceive any other temporal trends for this species? (i.e weather, currents, seasons, etc.)
What depths do you see/catch this species in most often?
What habitat do you see/catch this species in most often? Coral reefs seagrass beds mangroves open water other:_______
In the past five years what trend have you perceived for the population of this species?
Decreasing population Stable population Increasing population Not Sure

How many individuals of this species have you seen/caught in the past year?
0 1 - 10 11 - 20 21 - 50 >50 don't know

Ray Species
What are the top species of rays that are most common in this area?
Species :__________________
Species :__________________
Species :__________________
Species :__________________
Species :__________________

For Ray Species 1:
Point out in the map where you see this species most often.
What months do you see/catch this species most often?
What times of day do you see/catch this species most often?
Do you perceive any other temporal trends for this species? (i.e weather, currents, seasons, etc.)
What depths do you see/catch this species in most often?
What habitat do you see/catch this species in most often? Coral reefs seagrass beds mangroves open water other:_______
In the past five years what trend have you perceived for the population of this species?
Decreasing population Stable population Increasing population Not Sure

How many individuals of this species have you seen/caught in the past year?
0 1 - 10 11 - 20 21 - 50 >50 don't know

For Ray Species 2:
Point out in the map where you see this species most often.
What months do you see/catch this species most often?
What times of day do you see/catch this species most often?
Do you perceive any other temporal trends for this species? (i.e weather, currents, seasons, etc.)
What depths do you see/catch this species in most often?
What habitat do you see/catch this species in most often? Coral reefs seagrass beds mangroves open water other:_______
In the past five years what trend have you perceived for the population of this species?
Decreasing population Stable population Increasing population Not Sure

How many individuals of this species have you seen/caught in the past year?
0 1 - 10 11 - 20 21 - 50 >50 don't know

For Ray Species 3:
Point out in the map where you see this species most often.
What months do you see/catch this species most often?
What times of day do you see/catch this species most often?
Do you perceive any other temporal trends for this species? (i.e weather, currents, seasons, etc.)
What depths do you see/catch this species in most often?

What habitat do you see/catch this species in most often? Coral reefs seagrass beds mangroves open water other:_______

In the past five years what trend have you perceived for the population of this species?
Decreasing population Stable population Increasing population Not Sure

How many individuals of this species have you seen/caught in the past year?
0 1 - 10 11 - 20 21 - 50 >50 don't know

Perceived Ecological Roles

How important do you think sharks are for the health of the oceans?
Not Important at all A little important Very important Not sure

How important do you think sharks are for the economy of the region?
Not Important at all A little important Very important Not sure

Do you perceive any trends in other organisms in relation to shark populations?
(i.e more/less fish, more/less algae, etc.)

How important do you think rays are for the health of the oceans?
Not Important at all A little important Very important Not sure

How important do you think rays are for the economy of the region?
Not Important at all A little important Very important Not sure

Do you perceive any trends in other organisms in relation to ray populations?
(i.e more/less fish, more/less algae, etc.)

Policy

How do you think the reefs and associated animals have changed since the implementation of the Florida keys sanctuary in 1990?

Dramatically worse A little worse Stayed the same Improved a little Improved dramatically

Do you think protecting certain shark species from fishing is a good or bad conservation policy?

Good Bad Why:

Do you think setting minimum catch lengths for some shark and ray species is a good or bad conservation policy?

Good Bad Why:

Do you think having protected areas where people are not allowed to fish and/or dive is a good or bad conservation policy?

Good Bad Why:

Shark encounters

Do sharks damage your fishing/diving gear? Yes No
If yes, which types of gear do they damage? ______________________
How often has your gear been damaged by sharks in the past year?
circle one: 0 1 - 2 3 - 5 6 - 10 >10 don't know
Do sharks damage any of your other catch? Yes No
How often has your catch been eaten or damaged by a shark in the past year?
circle one: 0 1 - 2 3 - 5 6 - 10 >10 don't know
In your life, have you ever been injured by a shark? Yes No
If yes, how grave was your injury? Very grave fairly grave not grave

If not, how likely do you think you are to be injured by a shark? Very likely fairly likely not likely

Do you have any other comments/information on sharks or rays?

V. GENERAL CONCLUSIONS

As in most of the world, artisanal fisheries in the Caribbean are poorly known since they are highly dispersed, and target multiple species using a diversity of gears; including gillnets, beach and seine nets, hand- and longlines (FAO 2011). However, elasmobranchs have typically not been targeted by artisanal fisheries, but instead are caught incidentally, and are retained as a by-product (valuable bycatch) from longline fisheries focused on more profitable species of teleosts (Diaz et al., 2005).

Population trends and conservation status are not sufficiently understood for many elasmobranch species in the Caribbean (Kyne et al., 2012), and even less is known about the intensity and type of artisanal fisheries that exploit, or incidentally catch, these species. I was able to identify the species most commonly captured and landed, I gained insights into the gears that were most commonly used and I gathered information on their opinions and perceptions of populations trends. From my work I was able to provide a rough estimate of elasmobranch biomass catches by the artisanal fleet and compare to FAO official reports and reconstructions by Sea Around Us.

In Colombia, fishers reported capturing eight shark and four ray taxa; 51% reported *Sphyrnidae* spp., 43.9% *Carcharhinus leucas*, 37.7% *Galeocerdo cuvier*, 82.7% *Dasyatis americana*, 81.6% *Aetobatus narinari*, and 3.1% *Myliobatis goodei*. From BRUVs, only three shark species and two stingray species were detected: *Negaprion brevirostris*, *Ginglymostoma cirratum*, *Rhizoprionodon* spp., *Dasyatis americana* and *Urobatis jamaicensis*. Fewer species appearing on BRUVs than reported by fishers is likely due to BRUV sampling not detecting low density species, and sampling being restricted to coral reef habitats while fishing occurs across a diversity of habitats. Overall, elasmobranch abundances were very low and I detected no differences between the protected and unprotected reefs. Fishers reported Lutjanidae, Carangidae and barracuda as the main taxa they target, and although teleost abundances were also very low, Tesoro Island (which is uninhabited) had significantly higher relative abundance of Lutjanidae, Carangidae and barracuda than the other islands.

This difference may be the results of Tesoro being the only island that is regularly patrolled and protected. On the basis of fisher surveys, I estimated 9.7-254.2 metric tons of elasmobranchs landings from artisanal fisheries off the Caribbean coast of Colombia annually, compared to the zero metric tons reported by the government to FAO (FAO 2014) and the six metric tons reconstructed by Sea Around Us. My data revealed that artisanal fishers continue to exploit coral reef resources inside MPAs, retain almost all of the species they catch, perceive less elasmobranchs than when they started fishing and the only island that enforced protection had a significantly higher teleost relative abundance.

In my second chapter, I explored how the quantity of sharks fishers catch and sell, and what they do with their catches (throw away, eat or sell) varies across countries in the context of island nations with limited agricultural and food sources. My project revealed that artisanal fishers retain almost all animals caught, but whether they sell or keep their elasmobranch catch for personal use varies by island. Across all islands, most fishers perceived less elasmobranchs than when they started fishing. Fishers reported catching far more species of sharks (n= 22) and rays (n = 4) than were observed on BRUVs (n = 5 and 2, respectively). Additionally, my reconstruction of artisanal catches was larger than that reported to the FAO, and upper and lower estimated ranges encompassed what was estimated by Sea Around Us. The upper estimated ranges using my method, however, were two to fives times larger than what SAU estimated. While these estimated may be higher than actual landings, they do raise the possibility that elasmobranch landings may be larger than what is being reported or reconstructed. Combined with relatively low abundances on BRUVS, relative to less heavily exploited regions, my results reinforce concerns that shark and ray populations have declined considerably and remain under threat in many locations in the Caribbean.

Finally, in Chapter 4, I explored how attitudes and perceptions of elasmobranchs by recreational fishers in a developed nation compare to those of another group of stakeholders that also depend on the ocean for their livelihood, recreational divers and snorkelers (underwater users). Fishers reported capturing seven sharks species, while underwater users reported four shark species and BRUVs captured six sharks species. Species identified by all three methods were *Ginglymostoma cirratum*, *Carcharhinus perezii*, and *Sphyrna tiburo*. *Carcharhinus leucas*, *Galeocerdo cuvier*, while *Carcharhinus plumbeus* was reported only by fishers, *Carcharhinus acronotus* and *Sphyrna mokarran* appeared only on BRUVs, and *Rhizoprionodon* spp. was reported by surface users and appeared also on BRUVs, but were not reported by underwater users.

Three ray species *Hypanus americana*, *Aetobatus narinari*, and *Urobatis jamaicensis* were identified by all three methods. From BRUVs, I found that there are significantly more elasmobranch species captured on camera on the southern Upper Florida Keys, even though the relative abundance of elasmobranchs was significantly different across all three sampling blocks. These data revealed that fishers and divers agree on the need for protected areas and do not have a conflicting opinions with regards to elasmobranch conservation policies.

The long-term sustainability of many marine ecosystems is threatened and traditional efforts to manage these systems, either species-specific or by fishing sector, have proven to be insufficient (Mascia 2003). Nonetheless, government entities around the world have taken measures to manage marine resources, such as creating Marine Protected Areas, sanctuaries, issuing fishing permits, and instituting fishing regulations. Specific to elasmobranch resources, countries that agreed to the International Plan of Action for the management of shark resources (IPOA-sharks) created by FAO are expected to create and implement their own National Plan of Action (NPOA-sharks).

All the countries sampled in this dissertation have agreed to IPOA-sharks, and except for Trinidad and Tobago, they have all released their NPOAs. However, creating a NPOA is only the first step towards the management and conservation of elasmobranchs. Further management policies are necessary, as is their implementation. Listed below are some of the management measures each territory has implemented:

Decreasing elasmobranch species diversity and relative abundance (from BRUVs) →

	Florida Keys (U.S)	Tobago (Trinidad and Tobago)	Colombia	Guadeloupe (France)	Martinique (France)
IPOA	✓	✓	✓	✓	✓
NPOA	✓		✓	✓	✓

MPAs	✓		✓	✓	✓
Permits	✓				
Enforcement	✓				

It is interesting to note that the two territories with the highest species diversity and relative abundance (from BRUVs) of elasmobranchs, the Florida Keys and Tobago, differ considerably with the implementation of their management strategies. The high diversity and abundance of elasmobranchs in Trinidad and Tobago warrants further studies of its marine environment and productivity. Nonetheless, for Colombia, Martinique and Guadeloupe the enactment of conservation policies might be prompted by the urgency to protect increasingly diminishing resources, which may not the case for Trinidad and Tobago. The need to implement conservation management policies before overexploitation becomes apparent must be considered in countries where small-scale fisheries are an important source for livelihood.

For my dissertation, I compiled base line data of artisanal fisheries in the Caribbean in a broad context across four nations (Colombia, Tobago, Guadeloupe and Martinique) and their potential impacts on coral-reef associated elasmobranchs. From 800 BRUV samples, I found low levels of elasmobranch occurrence and species diversity across all of these sites. From 660 interview surveys, I discovered that fishers have perceived a decline in elasmobranchs since they started fishing, and determined that their estimated elasmobranch landings are likely higher than what is being reported to the FAO and encompasses the estimates reconstructed from Sea Around Us. Further research is needed to elucidate the social, economic and cultural drivers behind the demand for shark catches, as well as what proportion of their protein intake is derived from elasmobranchs in order to understand the full extent of their reliance on elasmobranchs for their livelihood. Future research should include interview surveys as a method to complement established field data collection, and future studies should have an inherent component of capacity building and stakeholder inclusion in order to improve transparency in data collection and increase support from local communities for conservation policies.

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Caceres, C. "Characterizing small-scale elasmobranch fisheries in the Lesser Antilles. 07-26-19. III Sharks International. Joao Pessoa, Brazil.

Caceres, C. "Characterizing Colombian small-scale elasmobranch fisheries and their potential impacts using social science surveys and BRUV sampling". 06-06-18. III Sharks International. Joao Pessoa, Brazil.

Caceres, C. "Coral reef fish community in the French Scattered Islands". 03-20-18 . Florida International University Annual Scholarly Forum. Miami, Florida.

Caceres, C. "A shark girl in a shark world". 03-22-18. Florida International University's Women Who Lead Conference.

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Caceres, C. "The importance of shark research and conservation" 10-04-17, at the Bi-Annual Colombian Commission for the Ocean. San Andres, Colombia.

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