ORIGINAL RESEARCH

Relative abundance and use of elasmobranchs in artisanal fisheries of the Lesser Antilles

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ABSTRACT. Shark and ray populations continue to decline in many regions around the world. The contribution of artisanal fisheries to these declines remains poorly understood for many locations. A rapid assessment framework using fisheries-independent sampling and fisher interviews was employed to study elasmobranch occurrence and use in coastal artisanal fisheries of Guadeloupe, Martinique, and Tobago. In-person interviews (n = 405) were conducted between June 2015-June 2017, and baited remote underwater video stations (BRUVS) (n = 50 video drops/reef) were deployed in nine reefs across the islands. The fate of elasmobranchs caught by artisanal fishers varied by island. Martinique reported the highest proportion of fishers keeping their catch for subsistence among the study locations. In Guadeloupe, fishers most frequently sold their catch, and Tobago fishers engaged in both subsistence fishing and sale. Fishers retained almost all animals caught and reported reduced catches of elasmobranch compared to when they started fishing. BRUVS revealed relatively low elasmobranch occurrence and a low Shannon diversity index compared to Caribbean nations with less fishing pressures on elasmobranchs. The present study highlights the need for improved data on, and monitoring of, artisanal fisheries.

Key words: Guadeloupe, Martinique, Tobago, Caribbean, BRUVS, interview surveys.

Abundancia relativa y uso de elasmobranquios en la pesca artesanal de las Antillas Menores

RESUMEN. Las poblaciones de tiburones y rayas continúan disminuyendo en muchas regiones del mundo. La contribución de la pesca artesanal a esta disminución sigue siendo poco conocida en muchos lugares. Se empleó un marco de evaluación rápida que utiliza muestreo independiente de las pesquerías y entrevistas a pescadores para estudiar la presencia y el uso de elasmobranquios en las pesquerías artesanales costeras de Guadalupe, Martinica y Tobago. Se realizaron entrevistas personalmente (n = 405) entre junio de 2015 y junio de 2017, y desplegamos estaciones remotas de video submarino con cebo (BRUVS) (n = 50 lanzamientos de video/arrecife) en nueve arrecifes de las islas. El destino de las capturas de elasmobranquios de los pescadores artesanales varió según la Isla. Martinica informó la mayor proporción de pescadores que conservan sus capturas para el sustento (es decir, pesca de subsistencia) de todas las islas. En Guadalupe, los pescadores principalmente vendieron sus capturas, y los pescadores de Tobago se dedicaron tanto a la pesca de subsistencia como a la venta. También encontramos que los pescadores retuvieron casi todos los ejemplares capturados y reportaron capturas reducidas de elasmobranquios en comparación a cuando comenzaron a pescar.

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BRUVS reveló una presencia de elasmobranquios relativamente baja y un índice de diversidad de Shannon bajo en comparación con las naciones del Caribe con menos presión pesquera sobre los elasmobranquios. El presente estudio destaca la necesidad de mejorar los datos y el seguimiento de las capturas artesanales.

Palabras clave: Guadalupe, Martinica, Tobago, Caribe, BRUVS, encuestas.

INTRODUCTION

Overfishing is the biggest threat facing elasmobranchs (Worm et al. 2005; Davidson et al. 2016), with more than a third of extant species threatened with extinction (MacNeil et al. 2020; Dulvy et al. 2021; Simpfendorfer et al. 2023). Industrial fisheries have been the major driver of declines in the past 50 years, reducing large predatory fish by 90%, contributing to decreases in species diversity of 10-50% and reducing the global abundance of pelagic sharks and rays by 71% (Myers and Worm 2003, 2005; Worm et al. 2005; Pacoureau et al. 2021). While industrial fisheries have a greater capacity, target more economically valuable species, and do not retain large quantities of bycatch compared to artisanal fisheries, small-scale fisheries can have considerable impacts on coastal elasmobranch populations. Indeed, appreciable declines in elasmobranchs associated with human pressures appear to have occurred long before industrial fishing began (Dillon et al. 2021).

Artisanal fisheries are characterized by their traditional fishing methods, low-technology gears, and small crew and boat sizes (Stallings 2009; Belhabib et al. 2020). Artisanal fisheries commonly occur relatively close to shore while industrial fisheries have greater access to pelagic habitats (Nakamura et al. 2022). However, these two sectors are not mutually exclusive due to the large-scale movement and life-history traits of many fishes, and the ability for some artisanal fishers to access pelagic habitats (Horta and Defeo 2012; Deme et al. 2022).

Elasmobranchs that rely on coral reef ecosystems are threatened by fisheries in many areas around the world. A global study of 58 nations revealed an absence of sharks on almost 20% of the surveyed reefs, with reef sharks almost completely absent from reefs in several nations (MacNeil et al. 2020). Shark depletion was strongly related to socio-economic conditions such as poor governance and human population density (MacNeil et al. 2020). Species-level analysis showed declines of 60 to 73% globally for five common reef shark species with weak governance and a lack of shark management resulting in assemblages composed mainly of rays. Shark-dominated assemblages persisted in wealthy nations with strong governance and highly protected marine areas (Simpfendorfer et al. 2023). These results highlight the need to understand regional differences and social factors that affect both stakeholder compliance and the success of management approaches, such as the perspectives of fishers, the gear used, the destination of the catch and fishermen's attitudes towards conservation measures.

Coral reefs and predatory fish are heavily exploited in the Caribbean (Mumby et al. 2012; Pinheiro et al. 2016; MacNeil et al. 2020; Cáceres et al. 2022; Simpfendorfer et al. 2023) and its elasmobranch populations are considered to be some of the most heavily impacted in the world (Ferretti et al. 2010; Ward-Paige et al. 2010, 2011). The use of elasmobranchs as a food source and as a cultural part of cuisine in the region can be traced back to the Aztecs (Applegate et al. 1993) and Mayans (Ritter 2013). It continues to be a staple in many low-income households because of the low local price of the meat (Applegate et. al. 1993; Lack et al. 2014; Dulvy et al. 2017). On a global scale, the shark meat trade is larger in volume and total value than the shark fin trade (Niedermüller et al. 2021).

Artisanal fisheries in the Caribbean, including 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 despite clear declines in reef sharks (Hawkins and Roberts 2004; MacNeil et al. 2020). Although humans have been fishing in the Lesser Antilles for at least 2,000 years, little is known about the extent of artisanal marine exploitation, which has expanded as the use of motorized vessels has spread (Wing and Wing 2001). In addition, fisheries records in the last 50 years are sparse and unreliable (FAO 2022). They generally lack species-specific data for elasmobranchs and often do not include catches that do not enter markets.

In order to optimize methods for gathering data to support management and conservation, scientists and fishery managers need information on how animals are used in artisanal fisheries (i.e. sold to market, kept for consumption or discarded). This is infrequently monitored by local governments, and often unreported to the Fisheries and Agriculture Organization (FAO) of the United Nations. Knowing the fate of the catch can elucidate the limitations of methods such as market surveys by providing better estimates of underreported subsistence catches, recreational catches, bycatch, and illegal fishing catches that may never enter the market.

Using a combination of interview surveys of fishers and baited remote underwater video stations (BRUVS), we set out to 1) characterize catches of elasmobranchs in artisanal fisheries of Guadeloupe, Martinique and Tobago, 2) document the occurrence and relative abundance of reef-associated elasmobranchs, and 3) assess whether there is interisland variation in fisheries that may influence the relative effectiveness of different research or survey methods.

MATERIALS AND METHODS

Study sites

The Lesser Antilles are a group of islands in the eastern Caribbean Sea, stretching 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 ecosystems around the islands (coral reefs, mangrove swamps, estuaries, and coastal lagoons) are relatively shallow, but 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) surrounded by deep water (Ricklefs and Lovette 1999). At 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 1-5 km from the coast.

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 harvested and have historically been used in traditional dishes. According to FAO, in 2021 Trinidad and Tobago had the second largest yearly landings of elasmobranchs (521 t across all fishing sectors; FAO 2022) in the Caribbean, after Cuba. Estimated shark landings of artisanal fisheries rank fourth in volume of all the fisheries resources landed in Trinidad and Tobago (Shing 2006).

As in most parts of the world, the artisanal shark fishery in Trinidad and Tobago has historically been considered a bycatch fishery with a very limited directed component (Shing 1993). However, shark is eaten extensively in both Trinidad and Tobago, where ‘shark and bake’ is a popular street food (Ali et al. 2020). Shark was the fifth most valued type of fish among fishermen in Trinidad (Ali 2019). Therefore, it is likely that there is a directed component to artisanal fisheries for elasmobranchs in Trinidad and Tobago (Figure 2). According to government data, there have been 15 shark species identified from the waters of Trinidad and Tobago that are part of fisheries landings (Henry and Martin 1992). However, elasmobranch data and reported catches are inconsistent. A 2007 FAO

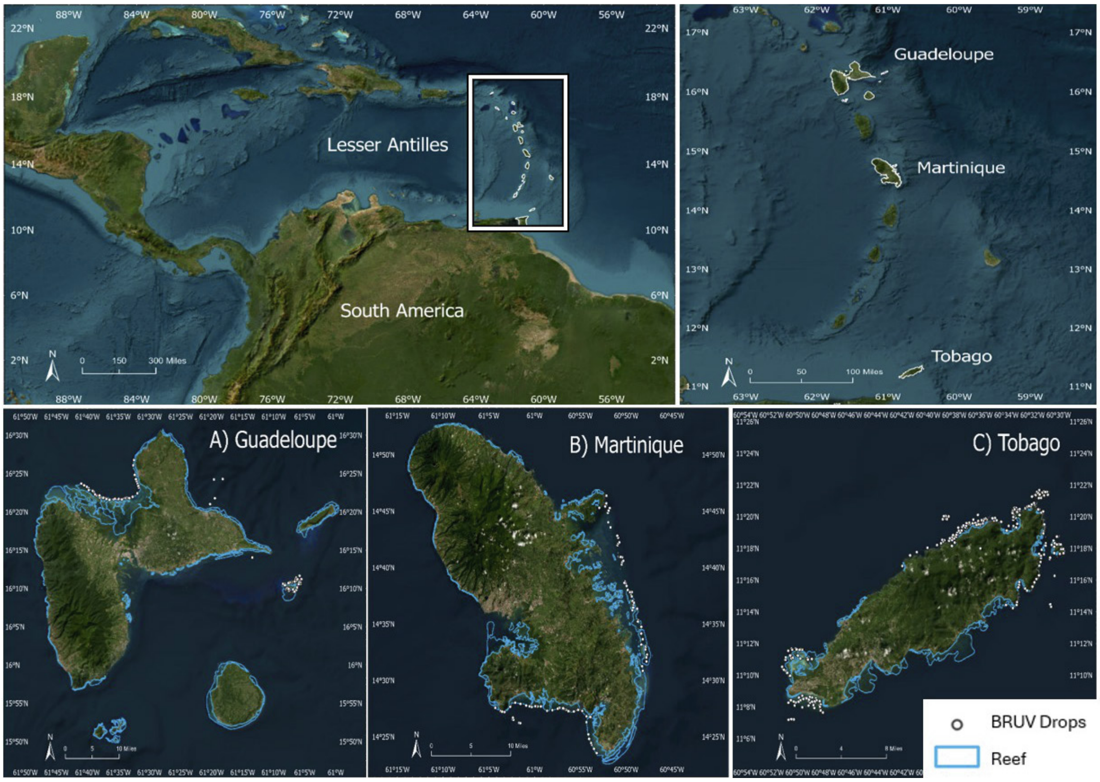

Figure 1. Map of the Lesser Antilles with sample sites of Guadeloupe (A), Martinique (B) and Tobago (C). Coral reef fringe is highlighted in blue and individual BRUV locations are displayed with white dots on the right panel.

report on shark bycatch assumed all catches used for 'shark and bake' to be *Carcharhinus limbatus* (Hutchinson et al. 2012), while government data shows a wide range of shark species in the fishery.

Guadeloupe and Martinique are overseas territories of France. Sharks are not commonly used in French cuisine, but in Guadeloupe and Martinique shark meat is eaten in traditional creole dishes such as 'court-bouillon' and 'blaff'. In Martinique, the liver is also used for medicinal purposes to produce massage oil. 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 are gathered only from officially registered fishers and do not distinguish between commercial, subsistence and artisanal fisheries, although elasmobranch catches likely occur in all three. Additionally, the lowest taxonomic level reported to the FAO for elasmobranchs is grouped simply as 'sharks' or 'rays' with no species-specific information provided. As of 2021, yearly elasmobranch landing data provided to the FAO for Guadeloupe fluctuated between 8-36 t annually in the last decade. Martinique reported between 1-47 t of elasmobranchs landed annually by all fishery sectors since 2011 (FAO 2022).

According to Gobert (2000), Martinique has one of the most exploited reefs in the Lesser Antilles while Guadeloupe imports around 50% of seafood that is consumed (Aldrich and Connel 1992; Frotté et al. 2009). The majority of the fishing fleet in Guadeloupe and Martinique is made up of small vessels, which primarily focus on coastal species for commercial (FAO 2004) and subsistence purposes (Chakalall 1995).

Figure 2. Sharpnose sharks (*Rhizoprionodon* spp.) piled up at fishing dock (A). Some female sharpnose individuals were pregnant, hinting at a potential nearby breeding ground (B). Caribbean Reef shark (*Carcharhinus perezii*) landed by artisanal fishers at the beach, this species appeared on BRUVS and was reported by fishers (C). Night shark (*Carcharhinus signatus*) being processed at a fishing facility, this species was not identified by BRUVS nor fishers (D). All images are from Tobago.

Interviews

Interviews were completed in person and all answers were written down by interviewers while interviews were in progress. Since elasmobranch species can be difficult to describe and identify, the FAO Identification Guide to Common Sharks and Rays of the Caribbean (FAO 2016) was used so fishers could identify species they catch. 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 interviews, fishers were first asked about their age, previous involvement in interview surveys and fishing practices, including occupation, fishing background, fishing gears used, habitats they fish, soak times, fishing boats, and number of crew members. Subsequent questions focused on their level of knowledge on sharks and rays, including catch frequency and seasonality. Interviewees were also asked whether elasmobranchs were their targeted species, caught as bycatch or retained as by-product, and the ultimate fate of the catch they retained (sold, retained for consumption, or a combination of both). Fishers were also asked about their perceptions of shark and ray population trends since they started fishing. For Guadeloupe and Martinique, questions were only asked about elasmobranchs generally and were not divided into separate shark and ray categories.

BRUVS

The relative abundance and species richness of elasmobranchs in coral reef habitats were surveyed using baited remote underwater video stations (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 herring *Clupea harengus*) attached to a pole that extended from the frame into the camera's field of view.

The BRUVS sampling locations were chosen 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 4 km^2 of reef area. Since Martinique has a thin fringing reef surrounding the islands, reefs were chosen by their proximity to large fishing towns with one reef on the Atlantic side and one reef on the Caribbean side. Guadeloupe also has a thin fringing reef surrounding the island. One reef was chosen in the national park Grand Cul-de-Sac Marin where partial fisheries are allowed, and the other reef was along the adjacent islands of Petit Terre nature reserve that is completely protected and uninhabited. Tobago has a larger coral reef area surrounding it on the easternmost and westernmost points of the island, so 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. One of the reefs in the west, Buccoo, is within Buccoo Reef Marine Park (BRMP) which was established in 1973 as a no-fishing zone.

BRUVS were deployed during daylight hours on days when logistics and weather allowed. Individual BRUVS were deployed from a boat using a rope and in-water personnel to orient the BRUVS facing down current. No BRUVS were simultaneously deployed within 500 m 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 BRUVS deployments. At both the start and end of each deployment environmental variables were measured including bottom depth with a handheld depth Vexilar Handheld Digital Sonar. Water temperature, salinity, and dissolved oxygen were measured with a YSI Pro 2030.

Data analysis

Chi-square test was used to assess differences in catch fate (eaten, sold, etc.) and perceptions of elasmobranch populations within and among islands with a *post-hoc* Bonferroni adjustment, since the explanatory variable had more than three groups. Analyses were conducted using R software version 1.1.463 with the MASS4 library (R Core Team 2016). All values reported are means ± SD unless otherwise noted.

All videos were reviewed 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 of each species within a single frame (MaxN) during a deployment (Bond et al. 2012).

Because of the zero-inflated nature of the data, we used a hurdle modeling approach to investigate spatial variation in elasmobranch relative abundance. First, we used a logistic regression to assess variation in occurrence (i.e. presence/absence). Then, for those BRUVS deployments with at least one elasmobranch present, we assessed variation in MaxN using a GLM with a truncated poisson distribution and log link. We conducted a first analysis to compare across islands, and then separate analyses to investigate variation among reefs of each island.

RESULTS

Interviews

A total of 404 interview surveys were conducted across the Lesser Antilles. Ninety-four interviews were conducted in Guadeloupe from April-June 2015, 121 surveys were conducted in Martinique between April-July 2016, and 189 surveys were conducted in Tobago in June 2017.

Guadeloupe

Men made up 98.9% (n = 93 of 94) of the fishers interviewed. Interviewed fishers were on average 46 ± 11.5 years old (range: 19 to 60 years old) and had an average fishing experience of 19.4 ± 8.1 years (range: 1 to 50 years). The average boat size was 8.0 ± 4.5 m, with crews of 2.4 ± 0.96 members. The most common boat type used by interviewed fishers was a 'Saintoise' (n = 90 of 94, 95.7%). These wood or fiberglass vessels are 5-10 m long and lack a deck. 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 was handlines, followed by gillnets and then traps or pots for fish and/or lobsters and crabs. Fishers reported a total of seven gears and used up to five gears at any given time (Figure 3). 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. There was a significant difference between Guadeloupe and Martinique (χ^2 ,(3, N = 215), 23.58, p <.00001) with respect to perception of elasmobranch populations. Martinique fishers reported more perceiving an elasmobranch population decline, while Guadeloupe fishers reported more the perception that elasmobranchs populations were unchanged than in Martinique.

Overall, 69.1% (n = 65 of 94) of fishers an-

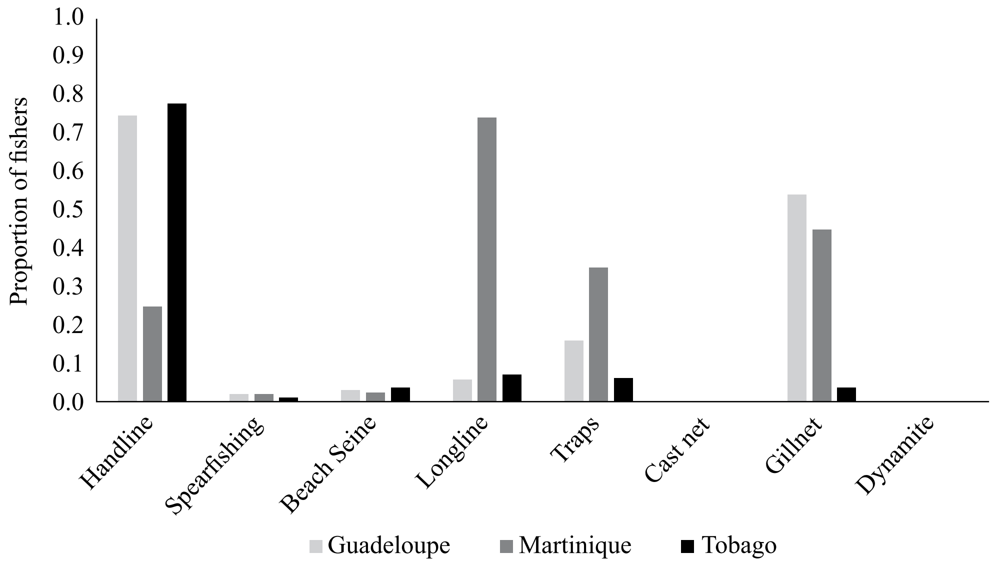

Figure 3. Seven most commonly self-reported fishing practices by artisanal fishers in the Lesser Antilles.

swered '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 12 elasmobranch taxa in their catches with nurse sharks (*Ginglymostoma cirratum*), hammerhead sharks (*Sphyrna* spp.), and makos (*Isurus* spp.) reported the most frequently (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 4). When calculated as a proportion of fishers who answered, there was a significant difference between Guadeloupe and Martinique (χ^2 ,(3, N = 198), 24.00, p <.00001)

Table 1. List of elasmobranchs (species and proportion) reported by fishers across all three islands, in order of proportion.

Martinique (n = 121)	Guadeloupe (n = 94)	Tobago (n = 189)
1) *Isurus* spp. 0.41 (n = 49)	*Hypamus americanus* 0.30 (n = 28)	*Carcharhinus limbatus* 0.25 (n = 48)
2) *Ginglymostoma cirratum* 0.39 (n = 47)	*Ginglymostoma cirratum* 0.25 (n = 23)	*Sphyrna* spp. 0.15 (n = 28)
3) *Sphyrna* spp. 0.39 (n = 47)	*Isurus* spp. 0.19 (n = 18)	*Ginglymostoma cirratum* 0.07 (n = 14)
4) *C. longimanus* 0.26 (n = 32)	*Sphyrna* spp. 0.18 (n = 17)	*G. cuvier* 0.05 (n = 9)
5) *G. cuvier* 0.22 (n = 27)	*G. cuvier* 0.15 (n = 14)	*Rhizoprionodon* spp. 0.04 (n = 8)
6) *P. glauca* 0.19 (n = 23)	*Aetobatus narinari* 0.12 (n = 11)	*P. glauca* 0.04 (n = 7)
7) *Hypamus americanus* 0.18 (n = 22)	*N. brevirostris* 0.07 (n = 7)	*C. plumbeus* 0.04 (n = 7)
8) *Aetobatus narinari* 0.14 (n = 17)	*P. glauca* 0.07 (n = 7)	*C. leucas* 0.03 (n = 6)
9) *R. typus* 0.14 (n = 17)	*Chimaera* spp. 0.05 (n = 5)	*Hypamus americanus* 0.03 (n = 5)
10) *C. leucas* 0.12 (n = 15)	*H. perlo* 0.01 (n = 1)	*Carcharhinus perezii* 0.02 (n = 3)
11) *Alopias* spp. 0.12 (n = 14)	*C. falciformis* 0.01 (n = 1)	*N. brevirostris* 0.02 (n = 3)
12) *H. griseus* 0.09 (n = 11)	*C. taurus* 0.01 (n = 1)	*Isurus* spp. 0.02 (n = 3)
13) *N. brevirostris* 0.08 (n = 10)		*Alopias* spp. 0.01 (n = 2)
14) *Mobula* spp. 0.07 (n = 8)		*Mobula* sp. 0.005 (n = 1)
15) *C. acronotus* 0.05 (n = 6)		*C. longimanus* 0.05 (n = 1)
16) *C. taurus* 0.03 (n = 4)		
17) *O. ferox* 0.03 (n = 3)		
18) *Carcharhinus limbatus* 0.02 (n = 2)		
19) *Carcharhinus perezii* 0.02 (n = 2)		
20) *D. licha* 0.02 (n = 2)		
21) *D. centroura* 0.02 (n = 2)		
22) *Rhizoprionodo*n spp. 0.02 (n = 2)		
23) *C. falciformis* 0.01 (n = 1)		

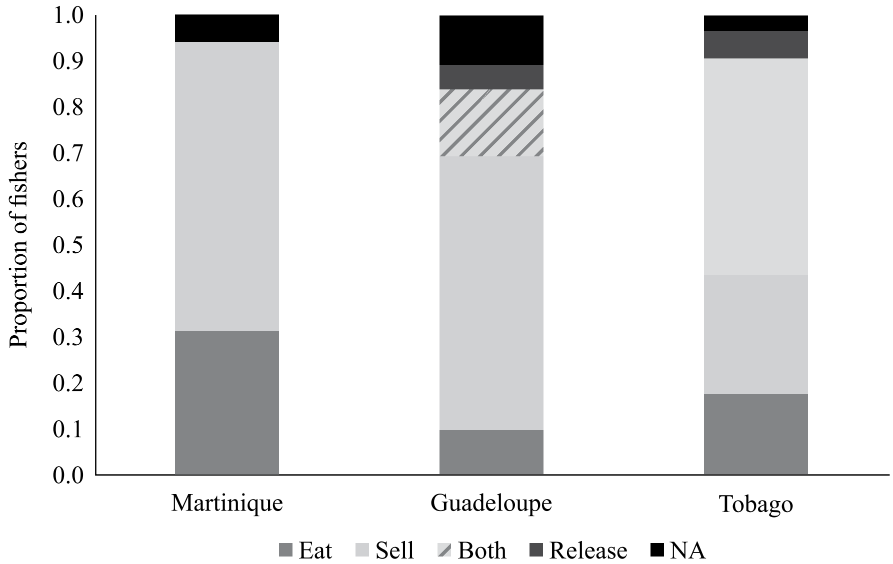

Figure 4. Proportion of fishers that reported keeping elasmobranch catches to eat, sell, or both.

with respect to the fate of elasmobranch catches. All categories were significantly different across these islands, except for the 'sell' category. Martinique fishers reported to eat more and release less than in Guadeloupe, while Guadeloupe fishers reported more a combination of both eat and sell (depending on the market) than in Martinique (Table 2).

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	18.340	3	1.85e^{-5}
Sell	2.996	3	0.083
Release	3.962	3	0.046
Both	14.699	3	0.0001

Martinique

All fishers interviewed (n = 121) were men. They 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), and had an average boat size of 6.0 ± 2.5 m. 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 m and commonly has sails. The second most common boat type reported was a 'Bateau de pêche', this term is used to describe a fiberglass boat measuring 10-20 m that is used for semi-industrial trawling and was reported by 8.3% (n = 10 of 121) of fishers. When reporting the top three gears they used, 74% (n = 90 of 121) of fishers reported using longlines, 45% (n = 54 of 121) of fishers reported gillnets, and 29% (n = 35 of 121) of fishers used traps.

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 did not answer the question. Fishers identified twenty-two shark taxa and two ray taxa in their catches. Makos (*Isurus* spp.), hammerhead sharks (*Sphyrna* spp.), and nurse sharks (*G. cirratum*) were reported most frequently (Table 1).

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 ± 2.3 m and with an average crew size of 2.2 ± 1.0 members. Almost all surveyed fishers used a 'pirogue' (n = 168 of 189, 88.8%) which typically is a small wooden, or fiberglass boat 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 capable of staying at sea several days and measuring 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 used, 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 three gear by 6.3% of fishers (n = 12 of 189) (Figure 3). 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.

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 shark populations are similar, 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, 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. There was a significant difference in Tobago (χ^2 ,(3, N = 378), 28.23, p <.00001) with respect to perception of shark and ray populations. Tobago fishers reported perceiving a decline in shark populations more than in ray populations, and Tobago fishers reported perceiving an increase in ray populations more than in shark populations.

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) 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 identified thirteen elasmobranch taxa in their catches, encompassing nine shark taxa and four ray taxa with hammerhead sharks (Sphyrnidae), blacktip sharks (*C. limbatus*), and nurse sharks (*G. cirratum*) reported the most frequently. 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 4). 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 sharks and rays in Tobago (χ^2 ,(3, N = 302), 212.42, p <.00001) with respect to fate of elasmobranch catch. The Bonferroni test revealed that all categories were significantly different across sharks and rays in Tobago (Table 3). Fishers were more likely to release rays than sharks, and to not answer the question regarding ray fate of catch. Fishers were more likely to eat, sell, and both (eat and sell) sharks than rays.

BRUVS

Seven species of sharks and two species of ray were observed on the 450 BRUVS deployments across all islands (Table 4). Sharks were present on 10% (n = 10 of 100) and rays were present on 14% (n = 14 of 100) of drops off Guadeloupe. Sharks were not present in any drops and rays were present on 10% (n = 10 of 100) of drops off 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. At Guadeloupe the species with highest relative abundances were *G. cirratum* and *Hypamus americanus*, which appeared on 7% and 12% of all BRUVS, respectively. Although Guadeloupe had three more species than Martinique on BRUVS, *C. perezii*, *Carcharhinus* sp. and *Aetobatus narinari* only appeared on one BRUVS each (1%), and overall, at least one elasmobranch appeared on 22% of all BRUVS. Likewise, the species with highest relative abundance off Tobago were *G. cirratum* and *H. americanus*, which appeared on 7.2% and 12.4% of all BRUVs respectively (Table 4).

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	$2.2e^{-16}$

The number of elasmobranch species observed per BRUV video varied across islands. Martinique had 1 ± 0.41 species per drop on average when present. Guadeloupe had 1.05 ± 0.46 species per drop on average, and Tobago had 1.21 ± 0.60 species per drop on average. When elasmobranchs were present, Martinique had an average MaxN of 1± 0.17 SD, Guadeloupe had 1 ± 0.21 MaxN, and Tobago had 1.17 ± 0.34 MaxN.

Table 4. List of elasmobranchs (species and proportions) that appeared on BRUVS across all three islands.

Martinique (n = 100)	Guadeloupe (n = 100)	Tobago (n = 250)
1) *Hypamus americanu*s 0.01 (n = 10)	*Hypamus americanus* 0.12 (n = 12)	*Hypamus americanus* 0.12 (n = 31)
	Ginglymostoma cirratum 0.07 (n = 7)	*Ginglymostoma cirratum* 0.07 (n = 18)
	Carcharhinus perezii 0.01 (n = 1)	*Rhizoprionodo*n spp. 0.04 (n = 11)
	Charcharhinus spp. 0.01 (n = 1)	*Carcharhinus perezii* 0.04 (n = 11)
	Aetobatus narinari 0.01 (n = 1)	*G. cuvier* 0.02 (n = 4)
		Sphyrna mokarran 0.01 (n = 2)
		Aetobatus narinari 0.01 (n = 2)
		Charcharhinus spp. 0.004 (n = 1)
		N. brevirostris 0.004 (n = 1)

There was a significant difference in elasmobranch occurrence across islands (Log. Reg., z = -2.1, P = 0.04), with Guadeloupe having more than twice the elasmobranch occurrence of Martinique, and Tobago having more than triple the elasmobranch occurrence than Martinique. There was no variation among islands in mean MaxN when elasmobranchs were present (GLM, z = -0.005, P = 0.99; Appendix Table A1), with MaxN values near 1 for all islands.

There was variation in elasmobranch occurrence across reefs at Guadeloupe and Tobago. At Guadeloupe, the uninhabited and protected reef Petit Terre had four times higher occurrence of elasmobranchs (Log. Reg., z = 3.12, P <0.001; Appendix Table A2). At Tobago, the reef Charlotteville (TBC) had a lower occurrence of elasmobranchs (Log. Reg., z = -2.34, P = 0.02; Appendix Table A4), with almost half the elasmobranch occurrence compared to the other reefs. Within Martinique there was no difference in elasmobranch occurrence among reefs (Log. Reg., z = -0.88, P = 0.38; Appendix Table A3). Additionally, Martinique did not have any sharks on the BRUVS, and there was never a MaxN for rays above 1. There were no significant differences in MaxN when elasmobranchs were present among reefs within Guadeloupe (GLM, z = -0.6, P = 0.95) and Tobago (GLM, z = -0.75, P = 0.45) (Appendix Tables A2-4).

DISCUSSION

Overall, elasmobranch diversity and relative abundance was low in Guadeloupe, Martinique, and Tobago but comparable to other sites in the Caribbean. Depletion of core coral reef shark species (e.g. *C. perezii*, *G. cirratum*) from these three islands in the Lesser Antilles is very similar to species depletion observed in Jamaica, Montserrat, Dominican Republic, and Barbados (Simpfendorfer et al. 2023). Considering shark conservation potential on a global scale, Guadeloupe and Martinique were ranked near the bottom with the Dominican Republic, Jamaica and the Dutch Antilles (MacNeil et al. 2020). Such widespread declines highlight the ongoing challenges for shark conservation in the Caribbean (Talwar et al. 2022).

The 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, fisher reports of catching pelagic species (e.g. *Isurus* spp.) hints they are going further offshore to obtain their target catch. Previous studies have shown diminishing elasmobranch populations in the greater Caribbean region, with fishers expanding their ranges further offshore as a sign of overexploitation (Bunce et al. 2008; Vermeij et al. 2019). Our study also highlights significant geographic variation in elasmobranch occurrence across the Lesser Antilles, with notable differences observed among Guadeloupe, Martinique, and Tobago. The higher occurrence of elasmobranchs in Guadeloupe and Tobago compared to Martinique suggests that local factors such as habitat protection, fishing pressure, and environmental conditions play a role in determining elasmobranch presence.

Martinique and Guadeloupe, despite receiving similar economic support from France and the European Union, show notable differences in elasmobranch populations, likely due to differences in management and fishing practices. Guadeloupe has two marine national parks with no-fishing zones, while Martinique lacks protected areas. This absence of protection may contribute to lower elasmobranch diversity and abundance in Martinique. Furthermore, the use of longlines in Martinique, a practice banned in protected areas of many countries due to its negative impact on shark populations (Morgan and Carlson 2010; Ward-Paige et al. 2010; Gallagher et al. 2014; Butcher et al. 2015; Gilman et al. 2016), exacerbates the pressure on reef-associated elasmobranchs. Prohibiting longlines and gillnets can contribute to relatively high reef-associated shark abundances (MacNeil et al. 2020), although effects vary by species (Smart et al. 2020; Booth et al. 2022). Given the absence of historical data on elasmobranch populations before industrial fishing, protected areas provide critical baselines for comparison. In the Bahamas and Belize, where shark protection is enforced, BRUV data indicate higher shark occurrence rates (30-70%) and greater species diversity (Brooks et al. 2011; Bond et al. 2012; Clementi et al. 2021). These protected areas showcase the potential benefits of stringent conservation measures, contrasting sharply with the lower occurrence and diversity observed in our study sites.

Interview surveys indicate that while only 10% of fishers target elasmobranchs, 85-90% retain their catches, with significant variation in usage across the islands. Martinique reports the highest proportion of subsistence retention (31.4%), Guadeloupe the highest for sale (59.8%), and Tobago a balance of both retention and sale (47%). This disparity highlights the need for tailored management strategies that consider local cultural and economic contexts. Furthermore, understanding what proportion of catch is kept for sustenance or traded directly, as opposed to what enters the market, is important for reconstructing unreported catches. Although market surveys are a common approach to estimating landings, this method may underestimate catches on islands like Tobago and Martinique, where fishers keep much of their elasmobranch catch for consumption or local trade. In such areas, monitoring landings or a combination of interviews and market surveys will be more effective.

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 (MacNeil et al. 2020; Pacoureau et al. 2021; Sherman et al. 2023) alongside an increased fishing effort (Bell et al. 2017; Simpfendorfer et al. 2023; Worm et al. 2024). It is possible fishers could have under-reported their shark catches in fear of stricter fishing restrictions and catch limits. However, it is important to note that in Tobago, Guadeloupe, and Martinique most sharks are not protected, limiting fishers' incentives for under-reporting the shark catch. In addition, given that targeted shark fishing is not common and that gears such as gillnets and longlines are being used, it is likely that there is also overfishing of herbivore and mesopredator populations that also impact elasmobranchs.

Given that about 37% of all chondrichthyans around the world are listed as Vulnerable, Endangered or Critically Endangered on the IUCN Red List (Dulvy et al. 2021), our findings underscore the urgent need for improved elasmobranch management in Guadeloupe, Martinique, and Tobago. Considering Martinique's low species richness and shark abundance, the island could benefit significantly from banning less selective fishing gear like longlines and gillnets, and establishing protected areas. Both Martinique and Guadeloupe, lacking a National Plan of Action (NPOA) specific to their local needs, would benefit from localized assessments and regional action plans for the Caribbean. Trinidad and Tobago, still lacks a finalized NPOA and effective gear restrictions despite efforts since 2016, indicating a need for accelerated conservation measures. Additionally, the Buccoo Reef Marine Park in Tobago is 7 km^2 and is likely too small to be efficient, given the lack of significant differences on the BRUVS data collected in and outside the park (Cook et al. 2024; Goetze et al. 2024). For all three islands, further baseline research on the state of local elasmobranch populations, larger protected areas embedded with effective fisheries management strategies (Goetze et al. 2024) that include community input, and the creation of a NPOA could contribute to the improvement of elasmobranch conservation and management.

Future interview surveys should ask fishers to break down the species composition and weight distribution of their catches and should inquire about 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. To understand how important elasmobranchs are to their livelihood, these surveys should also ask how much they depend on sharks for protein intake (how often do they cook and eat shark), the average price consumers pay for shark products, and if they have cultural reasons for consuming sharks.

Further research is needed to explore the socio-economic factors that influence fisher behavior and perceptions, as well as the ecological impacts of different fishing gears on elasmobranch populations. Long-term monitoring through BRUVS and other non-invasive methods will be essential for tracking population trends and assessing the effectiveness of conservation measures. Understanding the reasons behind fisher perceptions and addressing them through community engagement and education will be vital for achieving sustainable fisheries management in the Lesser Antilles. In conclusion, the conservation and management of elasmobranchs in the Lesser Antilles require urgent attention. Establishing larger protected areas, developing tailored NPOAs, and conducting further baseline research are crucial steps towards sustainable fisheries management and the preservation of these vital marine species.

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Author contributions

Camila Cáceres: conceptualization; data curation; formal analysis; funding acquisition; investigations; methodology; project administration; resources; software; supervision; validation; visualization; writing original draft; writing review and editing. Lauren Ali: data curation; investigations; writing original draft; writing review and editing. Oceane Beaufort: data curation; investigations; writing original draft; writing review and editing. Welldon Mapp: investigations. Aljoscha Wothke: investigations; resources; writing original draft; writing review and editing. Bethan Roberts: visualization. Philip Matich: investigations; writing original draft; writing review and editing. Michael Heihaus: conceptualization; funding acquisition; methodology; project administration; resources; software; supervision; validation; writing original draft; writing review and editing.

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APPENDIX

Table 1. Hurdle results for elasmobranch occurrence (binomial) and MaxN (poisson) across islands.

	Estimate	Standard error	z value	Pr(>|z|)
Count model coefficients (truncated poisson with log link)				
(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)				
(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*

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

Table 2. Hurdle results for elasmobranch occurrence (binomial) and MaxN (poisson) across Guadeloupe reefs.

	Estimate	Standard error	z value	Pr(>|z|)
Count model coefficients (truncated poisson with log link)				
(Intercept)	-0.767	0.966	-0.794	0.427
Reef GPT	-12.041	201.475	-0.060	0.952
Zero hurdle model coefficients (binomial with logit link)				
(Intercept)	-2.442	0.521	-4.685	2.8e-06***
Reef GPT	1.867	0.598	3.11	0.0018**

***0; **0.001.
Number of iterations in BFGS optimization: 1,025.
Log-likelihood: -49.03 on 4 Df.

Table 3. Hurdle results for elasmobranch occurrence (binomial) and MaxN (poisson) across Martinique reefs.

	Estimate	Standard error	z value	Pr(>|z|)
Count model coefficients (truncated poisson with log link)				
(Intercept)	-19.649	9,245.540	-0.002	0.998
Reef MQR2	-2.558	43,040.256	0.000	1.000
Zero hurdle model coefficients (binomial with logit link)				
(Intercept)	-1.6582	0.3858	-4.299	1.72e-05***
Reef MQR2	-0.5390	0.6091	-0.885	0.376

***0.

Number of iterations in BFGS optimization: 35.

Log-likelihood: -38.24 on 4 Df.

Table 4. Hurdle results for elasmobranch occurrence (binomial) and MaxN (poisson) across Tobago reefs.

	Estimate	Standard error	z value	Pr(>|z|)
Count model coefficients (truncated poisson with log link)				
(Intercept)	-1.0381	0.5620	-1.847	0.0647
Reef TBBS	0.3948	0.7399	0.534	0.5936
Reef TBC	-0.1119	1.1262	-0.099	0.9209
Reef TBN	-0.8584	1.1367	-0.755	0.4501
Reef TBS	0.3687	0.7081	0.521	0.6026
Zero hurdle model coefficients (binomial with logit link)				
(Intercept)	-0.7538	0.3032	-2.486	0.0129*
Reef TBBS	-0.1907	0.4372	-0.436	0.6627
Reef TBC	-1.2387	0.5304	-2.335	0.0195*
Reef TBN	-0.2922	0.4426	-0.660	0.5091
Reef TBS	0.1784	0.4227	0.422	0.6730

*0.01.

Number of iterations in BFGS optimization: 12.

Log-likelihood: -177.1 on 10 Df.