Sharks and Rays in Cuban Coral Reefs: Ecology, Fisheries, and Conservation

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Abstract

Many species of sharks and their relatives show a strong affinity to coral reefs and add high value to reef fisheries and tourism. Despite the economic and ecological importance of these elasmobranchs to reef systems, a recent study found no sharks on almost 20% of surveyed coral reefs around the world. In this chapter, we review relevant information on the elasmobranchs of Cuba's coral reefs and their fisheries, biology, and ecology, including new data collected as part of several multinational collaborative projects in Cuba. Many elasmobranch species are considered endangered or threatened in various parts of the world, but their legal protection in Cuba is very limited. Cuban stakeholders who utilize elasmobranchs are diverse, necessitating strong coordination among several sectors for sound management. Status and trends of elasmobranch populations in Cuba are uncertain, but population levels appear to be low and decreasing, likely due to overfishing. Movement patterns of these populations include the Wider Caribbean Region and beyond. Cuban marine protected areas do not seem to play a significant role in elasmobranch protection, except in the Jardines de la Reina National Park, but even in this park sharks and rays are threatened. We discuss research topics and management options that include marine protected areas, traditional and modern fisheries tools, and non-consumptive tourism, all with positive examples in Cuba where stakeholders and government must work together for conservation and sustainable use of elasmobranch resources.

Keywords

Cuban reefs · Sharks · Fisheries · Conservation

13.1 Introduction

Nearly one-third of the more than 1100 species of sharks and rays of the world spend at least one phase of their life cycle in coral reef ecosystems (Ebert et al. 2013; Sherman et al. 2020). Some species of large sharks that use this habitat are considered apex predators, while many are considered mesopredators (Roff et al. 2016). Shark predation affects the abundance of prey and may alter herbivore foraging rate and fish distribution through behavioral modification (Madin et al. 2010; McCauley et al. 2014; Rizzari et al. 2014a). Besides their function as important predators, there is a

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Supplementary Information: The online version contains supplementary material available at https://doi.org/10.1007/978-3-031-36719-9_13.

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V. N. Zlatarski et al. (eds.), *Coral Reefs of Cuba*, Coral Reefs of the World 18, https://doi.org/10.1007/978-3-031-36719-9_13

broad range of potential ecological functions of sharks on coral reefs, including nutrient cycling (Schmitz et al. 2010), scavenging (Wilson and Wolkovich 2011), habitat disturbance (Begg et al. 2003), and the removal of invasive species (Wallach et al. 2015).

As a critical marine habitat, coral reefs provide ecological benefits to sharks. The development of coral reefs more than 40 million years ago supported the fast diversification of carcharhinid sharks due to prey and habitat diversity associated with this habitat (Sorenson et al. 2014). Coral reefs provide food for sharks and rays (Hixon and Beets 1993), mating and nursery habitats (Rizzari et al. 2014b), shelter from predation (Whitney et al. 2012), refuge from strong currents (Peach 2002), and parasite removal (Heupel and Bennett 1999; Oliver et al. 2011).

In many parts of the world, shark and ray populations have declined in abundance over the past five decades or more. A recent survey covering many coastal regions found no sharks on almost 20% of the world's coral reefs, and no sharks in several nations with reef systems (MacNeil et al. 2020). In the Caribbean West Indies 50 years ago, sharks were sighted "anywhere at any time" (Baughman and Springer 1950), while today shark encounters in those same areas are "expected almost nowhere" (Ward-Paige et al. 2010).

Sharks and rays have long been an important fisheries resource in Cuba. Martínez (1947) reported that at the beginning of the twentieth century, US companies captured and sold sharks from Cuban waters, but data were not available until 1959 (Baisre 2018). At that time, official fisheries statistics reported sharks as a single category and not by species. Only the nurse shark (*Ginglymostoma cirratum*) was sporadically reported separately. Rays were reported in the single category of "rays-eagle ray." Attempts to report landings by species started in 2015, as part of the National Plan of Action for the Conservation and Management of the Chondrichthyans of Cuba (NPOA-Sharks) (PAN-Tiburones 2015). The NPOA-Sharks was a Cuban government initiative to adapt international guidelines to the use and protection of sharks and rays in Cuba (FAO 2000). The contribution of sharks and rays to the total fisheries landings in Cuba has ranged from 18% (4570 tons) in the 1980s (Claro et al. 2001a) to 12% (1821 tons) in the 2010s (Baisre 2018). Such fisheries were a source of employment and food for the Cuban people. In the last few decades, landings of elasmobranchs have decreased 79% as a result of overfishing (Baisre 2018).

In this chapter, we review relevant information on sharks and rays in Cuban coral reefs and their fisheries, biology, and ecology, including new data collected as part of several multinational, collaborative projects and the NPOA-Sharks. We also make recommendations for research and management actions to conserve elasmobranch populations in Cuba.

13.2 Materials and Methods

13.2.1 Study Areas

Cuba is situated just south of the Tropic of Cancer, at the intersection of the Atlantic Ocean (north and east sides of the country), the Gulf of Mexico (west), and the Caribbean Sea (south), in the Greater Antilles. The island is surrounded by deep basins and trenches of the Caribbean Sea, the Gulf of Mexico (GOM), the Straits of Florida, and the Bahamas. The coastline of the main island is 5746 km long. The surrounding shelf resembles a submerged plain with an area of 67,831 km^2 (Nuñez-Jiménez 1982). The shelf edge is near the outer border of cays and fringing reefs and drops steeply to 400 m or more. There are four fishery zones in Cuba: the northwestern zone (NW) that stretches from Cabo San Antonio to Punta Hicacos; the north-central/eastern zone (NCE) from Punta Hicacos to Punta de Maisí (including the Sabana-Camagüey Archipelago in north-central Cuba); the southeastern zone (SE) from Punta de Maisí to Bahía de Cienfuegos; and the southwestern zone (SW) from Bahía de Cienfuegos to Cabo San Antonio (Fig. 13.1). These zones have a combination of narrow and wide shelf areas, providing oceanic to neritic conditions in the marine environment, which affects shark and ray species composition.

The NW zone has an area of about 4500 km^2. This is the least important shark and ray fishing ground in Cuba, with an elasmobranch contribution of less than 10% to the nation's total landings (Ramos-Díaz 2019). However, NW subsistence fishermen catch many species of sharks, including oceanic ones, particularly in areas near Havana (Aguilar-Betancourt et al. 2014; Ruiz-Abierno et al. 2021b). From Cabo San Antonio to Punta Gobernadora, the shelf is up to 50 km wide. It narrows in the eastern half and is relatively shallow (less than 10 m deep). Three marine protected areas (MPAs) located in this zone are addressed in this chapter: Banco San Antonio Outstanding Natural Element (BSAONE, 74 km^2), Pretiles Ecological Reserve (PER, 346 km^2), and Levisa Fauna Refuge (LFR, 171 km^2). No fishing regulations currently exist in these MPAs. From Punta Gobernadora to Punta Hicacos, the shelf is only a few km wide and has a steep slope.

The NCE zone comprises about 11,500 km^2. From Punta Hicacos to Cayo Sabinal, the shelf stretches up to 60 km from the mainland, but only a few km from most of the cays. It is relatively shallow, generally less than 10 m deep. This is the second-most important fishing ground for sharks and rays in Cuba, with about one-third of the nation's total landings of elasmobranchs (Ramos-Díaz 2019), mostly neritic species. From Cayo Sabinal to Punta Maisí, the shelf is only a few km wide with a steep slope. This portion of the NCE zone is not

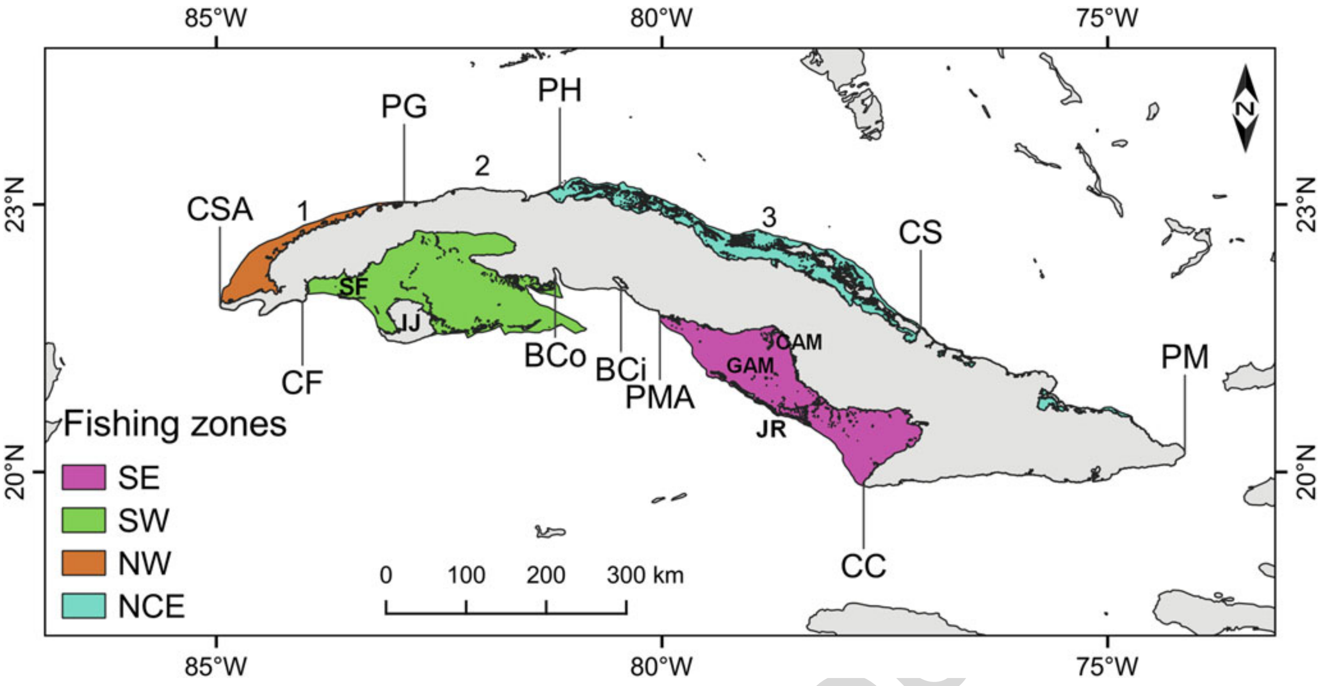


Fig. 13.1 Study areas. Cuba and its fishery zones: northwestern (NW), north-central/eastern (NCE), southeastern (SE), southwestern (SW). Legend: CSA, Cabo San Antonio; (1) Colorados Archipelago; PG, Punta Gobernadora; (2) Havana; PH, Punta Hicacos; (3) Sabana-Camagüey Archipelago; CS, Cayo Sabinal; PM, Punta Maisí; CC, Cabo Cruz; PMA, Punta María Aguilar; BCi, Bahía Cienfuegos; BCo, Bahía Cochinos; CF, Cabo Francés; JR, Jardines de la Reina Archipelago; CAM, Cayos Ana María; GAM, Golfo Ana María; IJ, Isla de la Juventud; SF, Cayos San Felipe

very important for shark and ray fisheries in Cuba, and most elasmobranch species in this area are oceanic.

The SE zone comprises about 19,000 km^2. From Punta Maisí to Cabo Cruz, the shelf is only a few kilometers wide. This portion of the SE zone has a steep slope with a maximum depth of 7041 m on the northern border of the Cayman Trench, the second deepest trench in the Atlantic Ocean; on the mainland side, it is bordered by the Sierra Maestra mountain range (Claro et al. 2001b). This portion is not very important for shark and ray fisheries in Cuba, and most elasmobranch species found here are oceanic. From Cabo Cruz to Punta María Aguilar, the shelf is up to 100 km wide and relatively shallow, typically less than 30 m deep. These are the most important shark and ray fishing grounds in Cuba, with a contribution of about half of the nation's total landings of elasmobranchs (Ramos-Díaz 2019), mostly neritic species. We have studied three regions in this portion: Jardines de la Reina (JR), Cayos de Ana María (CAM), and Golfo de Ana María (GAM). CAM is a group of small islands nearest to mainland Cuba and is subject to the highest fishing pressure. GAM is twice as far from mainland Cuba as CAM and experiences lower fishing pressure. JR is the farthest and least fished of the three. Three MPAs located in these regions were studied: Jardines de la Reina National Park (JRNP) (2010 km^2), Cayos de Ana María Fauna Refuge (CAMFR, 181 km^2), and Macurije Santa María Fauna Refuge (MSMFR, 91 km^2). Only in the JRNP is fishing strongly regulated (only lobster fishing and catch-and-release fly fishing are allowed). However, enforcement of fishing regulations in the JRNP shows a protection gradient that goes from stronger in the central zone to weaker in the western and eastern zones (Pina-Amargós et al. 2014a). From Punta María Aguilar to Bahía de Cienfuegos, the shelf is only a few km wide with a steep slope seaward and the Guamuahaya Mountains to the landside. This portion is not very important for shark and ray fisheries in Cuba; most of its elasmobranch species are oceanic.

The SW zone has an area of about 22,000 km^2. From Bahía de Cienfuegos to Bahía de Cochinos, the shelf is narrow and has a steep slope seaward and the Guamuahaya Mountains to the landside. This portion is not very important for Cuban shark and ray fisheries and most elasmobranch species here are oceanic. From Bahía de Cochinos to Cabo Francés, the shelf is wide (up to 150 km) and relatively shallow (less than 10 m deep). This is the second-most important fishing ground for rays in Cuba, with a contribution of about one-third of the nation's total landings (Ramos-Díaz 2019), mostly neritic species. Shark catch is less important in this area, with less than 10 % of the nation's shark landings. We have studied two regions in this portion: Isla de la Juventud (IJ) and Cayos de San Felipe (SF). Three MPAs were studied in these regions: Punta Francés National Park

Table 13.1 Sample size (gear and specimens) of fisheries-dependent and -independent data collection

	Gear						Specimens									
	Zone						SE		SW		NW		NCE		Total	
	Sex	SE	SW	NW	NCE	Total	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
FD	LL	80,121	1,070,000	NA	100,109	1,250,230	253	228	188	123	NA	NA	458	147	896	498
	GN	22	7	63	91	183										
	BT	NA	NA	NA	8	8										
FI	LL	5950	803	NA	NA	6753	146	145	15	18	10	5	NA	NA	171	168
	SL	21,750	NA	NA	NA	21,750										
	DL	24	3798	816	NA	4638										
	HL	3	5	6	NA	14										

FD, fisheries-dependent data; FI, fisheries-independent data; SE, southeastern; SW, southwestern; NW, northwestern; NCE, north-central/eastern; ♀, female; ♂, male; LL, longline, hook-hour; GN, gillnet, 1000 m-hour; BT, "boliche" trawl, hour; SL, set line, hook-hour; DL, drumline, hook-hour; HL, handline, hook-hour; NA, not available

(PFNP, 30 km^2), Southern Isla de la Juventud Managed Resources Protected Area (SIJPAMR, 96 km^2), and San Felipe National Park (SFNP, 242 km^2). Fishing is regulated within the PFNP and the SFNP, but enforcement is weak (Pina-Amargós et al. 2014b). From Cabo Francés to Cabo San Antonio, the shelf is only a few kilometers wide and has a steep slope. This portion is not very important for shark and ray fisheries in Cuba; most of the elasmobranch species here are oceanic.

13.2.2 Data Collection

We gathered data on elasmobranchs from the literature produced in Cuba, or produced elsewhere but related to Cuba. It is summarized in Sect. 13.3.1. Several pieces of scientific information used to discuss our findings are shown in other sections.

With the support of the NPOA-Sharks project, we collected fisheries-dependent biological data between 2015 and 2017. These surveys were opportunistic. They were conducted on longlines (1,250,240 hook-hour), "boliche" trawls (8 hours), and gillnets (183 1000 m-hour). The "boliche" trawl is used in bottom fish aggregating devices to catch relatively smaller species, while regular trawls cover large areas and catch species of any size. Size, sex, maturity, and brood size data from 1394 specimens were obtained (Table 13.1).

Fisheries-independent biological movement and MPA-related information were collected using fishing gear adapted and standardized for scientific research, as part of several collaborative projects between Cuban and foreign scientific institutions. Elasmobranchs (339 specimens) were caught using longline (6753 hook-hour), set line (21,750 hook-hour), drumline (4638 hook-hour), and handline (14 hook-hour) (Tables 13.1, 13.2 and 13.3). Elasmobranchs were caught using longline, set line, drumline, and handline in the SE zone. Most of the fishing gear in the SE zone was set on and near coral reefs and in mangrove channels (channels with seagrass bottoms fringed by mangroves). In the NW zone, all specimens were caught using drumlines except two silky sharks (*Carcharhinus falciformis*) that were caught using handlines. In the SW zone, all specimens were caught using drumlines except three nurse sharks that were caught using handlines. In the SW and NW zones, most of the gear sets were on seagrass and on or near coral reef habitats. Once sharks and rays were caught, they were restrained along the side of the boat at the sea surface, or brought onboard with seawater flushing through their gills (depending on the size and weight of the animals), to determine size, sex, and maturity, take samples, tag them in the first dorsal fin with external conventional tags (Rototags or dart tags), and release them at the same site. Once the animals were secured, the whole process took no more than three minutes.

In the SE zone, two silky sharks and two Caribbean reef sharks (*C. perezi*) were caught using handlines and tagged to

Table 13.2 Sample size of fisheries-independent data collection per year. E: sampling effort (hook-hour) of longline, set line, and drumline. Specimens of Caribbean reef shark (*Carcharhinus perezi*) in the southwestern zone (SW) and the Jardines de la Reina National Park (JRNP)

Zone		2009	2012	2013	2014	2015	2016	Total
SW	Specimens	3	3	2	2	2	NA	12
	E	934	926	897	914	930	NA	4601
JRNP	Specimens	NA	35	6	25	40	74	180
	E	NA	3347	3156	3452	3298	3367	16,620

NA, not available

Table 13.3 Sample size of the most abundant species per region in the southeastern zone

	CAM	GAM	JRNP West	JRNP Center	JRNP East	Total
RS	0	1	38	104	37	180
NS	4	7	19	16	13	59
LS	0	11	14	5	2	32
E	5509	5571	5487	5634	5499	27,700

RS, Caribbean reef shark (*Carcharhinus perezi*); NS, nurse shark (*Ginglymostoma cirratum*); LS, lemon shark (*Negaprion brevirostris*); E, effort (hook-hour) of longline, set line, and drumline; CAM, Cayos de Ana María; GAM, Golfo de Ana María; JRNP, Jardines de la Reina National Park

assess fidelity to the Farallon dive site, off the southern tip of Cayo Caballones (20.829°N, 78.982°W). This dive site is adjacent to a coral reef on a slope that drops from 20 m to more than 200 m deep. There are three more dive sites nearby (Pipín, Vincent, and Montaña Rusa), but since they are less than 300 m away from Farallón, resightings were recorded together. For many years, dive instructors have attracted sharks by hand-feeding them with fish in all four sites. Resightings of tagged sharks were recorded by Dive Master Noel López Fernández (NLF) at least twice a week between February 2013 and March 2015, with a gap in April–June 2014, when NLF was not available. After March 2015, NLF stopped recording resightings because tags had become unreadable.

We compiled an updated checklist of elasmobranch species in Cuban waters based on PAN-Tiburones (2015), with the addition of cookie cutter shark (*Isistius brasiliensis*) (Ruiz-Abierno et al. 2016) (Supplemental Material Table S13.1). The classification of elasmobranch species followed Weismann's (2016) criteria for higher taxonomic categories and considerations for valid species names, including English common names. Cuban common names were compiled from Claro et al. (1994). Sharpnose sharks, Atlantic sharpnose (*Rhizoprionodon terraenovae*) and Caribbean sharpnose (*R. porosus*), could not be identified at the species level and were treated as a complex of the two species. The common species are those reported by Espinosa (2003) and Ramos-Díaz (2016, 2019). They are listed in order of importance for fisheries according to Espinosa (2003) and Ramos-Díaz (2016, 2019) in Table 13.4, and their relationships with coral reefs and importance for tourism are listed according to Ebert et al. (2013). Coral reef species important for fisheries and tourism are shown as "high" or "low" in terms of their relative importance (Table 13.4). The current status of the species on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2021) and the International Union for the Conservation of Nature (IUCN 2021) was obtained from the web sites of these organizations.

13.2.3 Data Analysis

Comparisons of (1) size of Caribbean reef sharks in the JRNP on a monthly basis, (2) size of same-sex species per fishing zones, (3) Caribbean reef shark abundance over time in the entire area of the JRNP and in the SW zone, and (4) species abundance per regions of the SE zone was analyzed using the non-parametric Kruskal–Wallis test. In the case of (2), the Kruskal–Wallis test statistic was Chi-square (χ^2). In cases where the global test was significant, the multiple comparisons test based on Dunn's ranks with Holm correction (Z) was performed to determine the pairs of categories showing significant differences. The hypothesis of equal sex ratio (1:1) was verified using the Chi-square χ^2 test in cases where five or more individuals of both sexes had to fulfill test premises (Quinn and Keough 2002). Comparisons of size between specimens of different sexes in fishing grounds were performed using the Wilcoxon test. Comparison of size among the JRNP zones was performed using the Anderson–Darling (A) test adjusted for multiple comparisons using the Holm method. For all the analyses, a significance level of $\alpha = 0.05$ was established. All the analyses were carried out using the Dunn test (Dinno 2017), vegan, psych, and PMCMR plus packages along with basic functions in R 4.0.0 language and environment (R Core Team 2020).

13.3 Results and Discussion

13.3.1 Studies on Sharks and Rays in Cuba

Elasmobranch research in Cuba began in the 1800s, when Felipe Poey Aloy described several shark species (Guitart 2000). Poey's legacy has remained to the present; his original description of seven species is still valid (Weigmann 2016). More recently, another Cuban scientist, Dario Guitart Manday, was the first to describe the longfin mako (*Isurus paucus*) in 1966 (Guitart 1966). During the 1960s and 1970s, most research on Cuban sharks focused on species identification and biology (Guitart 1975, 1979). In the early 2000s, several studies of Cuban shark and ray fisheries were published (Claro et al. 2001a; Espinosa 2003). Claro et al. (1994) compiled vast information on the ecology and a fishery of Cuban marine fishes, but relatively little information was related to sharks and rays. Espinosa (2003) assessed shark fisheries in Cuba from the 1960s to the 2000s.

During the last two decades, as part of several collaborative projects between Cuban and foreign scientific

Table 13.4 Common species of sharks and rays of Cuba, their relation to coral reefs, the importance for fisheries and for tourism, and status on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and on the International Union for the Conservation of Nature (IUCN)

Common name in English	Coral reef	Cuban fisheries	Tourism	CITES	IUCN
Nurse shark	C	F	T	NI	DD
Blacktip shark	C	F	T	NI	NT
Silky shark	C	F	T	II	NT
Caribbean sharpnose sharks	C	F	t	NI	LC
Atlantic sharpnose shark	C	F	t	NI	LC
Lemon shark	C	F	T	NI	NT
Great hammerhead	C	F	T	II	EN
Tiger shark	C	F	T	NI	NT
Bull shark	C	F	T	NI	NT
Caribbean reef shark	C	F	T	NI	NT
Blacknose shark	C	F	t	NI	NT
Bonnethead	C	F	T	NI	LC
Spotted eagle ray	C	F	T	NI	NT
Chupare stingray	C	F	T	NI	DD
Southern stingray	C	F	T	NI	NT
Longnose stingray	C	F	T	NI	NT
Atlantic stingray	C	F	T	NI	LC
Giant manta ray	C	f	T	II	EN
Bluntnose stingray	C	f	T	NI	NT
Yellow stingray	C	f	T	NI	LC
Oceanic whitetip shark	c	F	t	II	CE
Shortfin mako	c	F	T	II	VU
Scalloped hammerhead	c	F	T	II	EN
Thresher shark	c	F	t	II	VU
Blue shark	c	F	T	NI	NT
Longfin mako	c	F	t	II	VU
Night shark	c	F	t	NI	VU
Bluntnose sixgill shark	c	F	T	NI	NT
Bigeye sixgill shark	c	F	t	NI	DD
Cuban dogfish	c	F	t	NI	DD
Sandbar shark	c	F	t	NI	VU
Gulper shark	c	f	t	NI	VU
Bignose shark	c	f	t	NI	DD
Dusky shark	c	f	T	NI	EN
Smooth hammerhead	c	f	t	II	VU
Spinner shark	c	f	t	NI	NT
Caribbean lanternshark	c	f	t	NI	LC
Whale shark	c	f	T	II	VU
Broadgill catshark	c	f	t	NI	DD
Roughtail catshark	c	f	t	NI	LC
Cuban ribbontail catshark	c	f	t	NI	DD
Dusky smoothhound	c	f	t	NI	NT

Legend: C, high relationship to coral reefs; c, low relationship to coral reefs; F, high importance for fisheries; f, low importance for fisheries; T, high importance for tourism, t, low importance for tourism; CITES—NI, not included; II, Appendix II; IUCN—DD, data deficient; LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; CE, critically endangered

institutions, we have collected data on composition, biology, movement, fisheries, and conservation issues of elasmobranch species in many parts of Cuba. Graham et al. (2007) reported the movement of whale sharks (*Rhincodon typus*) from the Jardines de la Reina Archipelago (JR) on the southern coast of Cuba to coastal areas of Mexico and Florida. Several checklists of fish species, including elasmobranchs, of southern and northern Cuba have been published (González-Sansón et al. 1997; Aguilar et al. 2000; Claro et al. 1994; de la Guardia et al. 2004, 2018;

Caballero et al. 2004; Pina-Amargós et al. 2007, 2012a, b, 2013; Cobián et al. 2011, 2013; Hernández-Fernández et al. 2013; Hernández-Fernández and Salvat-Torres 2014; Medina-Valmaseda et al. 2014; Hernández-Albernas 2019). Pina-Amargós et al. (2008) described the unidirectional movement of the nurse shark from the reef crest to the reef slope in JR. Hueter et al. (2013) reported whale shark movements along the north and south coasts of Cuba. Aguilar-Betancourt et al. (2014) assessed fisheries in northwestern Cuba. The NPOA-Sharks produced its guidance document in 2015 (PAN-Tiburones 2015). Sellas et al. (2015) investigated the genetic diversity and population structure of the spotted eagle ray (*Aetobatus narinari*) in the northeastern and southwestern portions of the GOM and in the northwestern Caribbean Sea (southwestern Cuba). Ruiz-Abierno et al. (2016) reported the presence of the cookie cutter shark in Cuban waters for the first time. Cabrera-Páez et al. (2016) described a pregnant shortfin mako (*Isurus oxyrinchus*) and her brood that was caught in northwestern Cuba. Briones et al. (2017) discussed fisheries and biological information of the southern stingray (*Hypanus americanus*) (former *Dasyatis*, Last et al. 2016) in southeastern Cuba. Hueter et al. (2017, 2018) presented information about movement patterns of the longfin mako and silky sharks in northwestern Cuba and JR, respectively. Perera-Valderrama et al. (2018) reported that sharks were 2.5–18 times more abundant inside the Jardines de la Reina National Park (JRNP) than outside the park limits. Baisre (2018) presented an overview of Cuban commercial marine fisheries, including sharks. Ramos-Díaz (2019) updated the information on shark and ray fisheries nationwide. Ruiz-Abierno et al. (2020) presented the first study of a shark nursery area in Cuban waters, used by the species lemon shark (*Negaprion brevirostris*), and Ruiz-Abierno et al. (2021a) reported size at maturity for the longfin mako and the oceanic whitetip shark (*Carcharhinus longimanus*), both caught in the small-scale longline fishery operating off northwestern Cuba. Ruiz-Abierno et al. (2021b) described the seasonal abundance and size structure of sharks caught in the pelagic longline fishery off northwestern Cuba. Ecological and fisheries information of sharks and rays from JR was reviewed by Pina-Amargós et al. (2021). The contribution of sharks and rays to the economic value of the coral reefs of JR is described by Figueredo-Martín and Pina-Amargós (see Chap. 23). Besides their importance for fisheries, sharks and rays are also important as tourist attractions in Cuba (Figueredo-Martín et al. 2010; Figueredo-Martín and Pina-Amargós (see Chap. 23)).

Several studies about the movement and connectivity of elasmobranch species in the western Atlantic have included Cuba in their results. The atlas of shark tagging and recapture data of the US National Marine Fisheries Service cooperative shark tagging program (1962–2013) showed that at least sandbar sharks (*Carcharhinus plumbeus*), blue sharks (*Prionace glauca*), shortfin makos, longfin makos, bigeye thresher sharks (*Alopias superciliosus*), silky sharks, night sharks (*C. signatus*), scalloped hammerheads (*Sphyrna lewini*), blacktips sharks (*C. limbatus*), bignose (*C. altimus*), bull sharks (*C. leucas*), dusky sharks (*C. obscurus*), nurse sharks, oceanic whitetip sharks, spinner sharks (*C. brevipinna*), and tiger sharks (*Galeocerdo cuvier*) travel between the US Bahamas and the Cuban EEZ (Exclusive Economic Zone) (Kohler and Turner 2018). One Galapagos shark (*C. galapagensis*) tagged in Ascencion Island was recaptured in northwestern Cuba (Kohler and Turner 2018). Ormond et al. (2017) found Caribbean reef sharks moving in the area of the Cayman Islands (around 150 km across waters 1000 m deep), and tiger sharks and oceanic whitetip sharks moving from the EEZ of the Cayman Islands to the EEZ of other countries, including Cuba. Rooker et al. (2019) found that whale, tiger, and scalloped hammerhead sharks move between the GOM and Cuba. Regional connectivity calls for a cooperative approach for the conservation and sustainable use of these and other migratory elasmobranch species.

13.3.2 Species Richness, Relation to Coral Reefs, Economical Importance, and Conservation Status of Cuban Reef Sharks and Rays

According to the scientific literature, there are at least 68 species of elasmobranchs (5 orders, 16 families, and 43 species of sharks; 5 orders, 12 families, and 25 species of rays) reported for Cuban waters (Supplemental Material Table S13.1). Claro et al. (1994) reported 79 species (54 shark species and 25 ray species), while Claro and Robertson (2010) reported 74 species (49 sharks and 25 rays). The differences between the above lists and our list are related to classification changes, an addition of one species to the Cuba ichthyofauna (Ruiz-Abierno et al. 2016), and species that require confirmation. Of the 68 species, 42 are regarded as common according to Espinosa (2003) and Ramos-Díaz (2016, 2019) (Table 13.4). Of the common species, 20 are strongly attached to coral reefs during at least one phase of their life cycle, but all species make use of coral reef systems. Therefore, we do not exclude any species with relevant information for this chapter (Table 13.4). Of the common elasmobranch species, 28 are highly important for fisheries in Cuba and 23 are highly important for tourism (see Figueredo-Martín and Pina-Amargós (Chap. 23)). Of the common elasmobranch species, ten are included in the CITES listings and 35 have been assessed by the IUCN; the other seven species are data deficient. Of the common sharks and rays species assessed by the IUCN, seven are in the least concern category; 15 are near threatened; eight are vulnerable; four are endangered; and one is critically endangered. In

Cuba, more than 1500 species are protected under the status of Special Significance for Biological Diversity (Resolution 160/11 of the Ministry of Science, Technology and Environment), equivalent to the Red List of Endangered Species. Only three taxa are elasmobranchs (white shark (*Carcharodon carcharias*), whale shark, and sawfishes (*Pristis* spp.)). The only fully protected elasmobranch taxon in Cuba is *Pristis* spp. On November 24, 2017, a smalltooth sawfish (*Pristis pectinata*) was incidentally caught in a gillnet near Cayo Confites, north of Camagüey province. This gear targeted reef sharks and rays and had been deployed at a depth of 20–50 m. The total length (TL) of the sawfish was 381 cm; it was a female and was dead at the time of retrieval from gear. According to the IUCN, this species is Critically Endangered, and as it is fully protected in Cuba (Appendix I of Resolution 160/11). This incidental capture is extremely significant for the conservation of the sawfish and for science. In summary, of the 42 common species, 12 species (28%) have a strong affinity for coral reefs, have high importance for fisheries and tourism, and are included in at least one of the two major international conservation frameworks.

13.3.3 Biology of Cuban Reef Sharks and Rays

13.3.3.1 Fisheries-Independent Ecological Information

In the SE zone, Caribbean reef sharks showed the highest relative abundance (62% of the elasmobranch catch related to the tagging program), followed by nurse sharks (20%), lemon sharks (11%), blacktip sharks (3%), silky sharks (2%), and southern stingrays (2%) (Table 13.5). Pikitch et al. (2005) found a similar species composition at a Belize atoll, although not in the same order, likely due to gear and habitat differences. Many more specimens were caught in the SE zone than in the NW and SW zones (Table 13.5), but the survey effort was less in the last two zones (for survey effort, see Table 13.1). Despite this limitation, in the NW and SW zones, seven and eight species were caught respectively, while six were caught in the SE zone, possibly due to habitat differences and time of day surveys were conducted. Almost 70% of the survey effort in the NW and SW zones was devoted to fishing on seagrass beds at night. Large species such as tiger sharks, great hammerheads (*Sphyrna mokarran*), and bull sharks prefer hunting in this habitat during the night (Ebert et al. 2013), although they also feed during daytime. Since tiger sharks and great hammerheads are known to occur in the SE zone (Pina-Amargós et al. 2007, 2012a, b), they are missing in our surveys probably because our effort focused on coral reefs.

Table 13.5 Fisheries-independent sampling catch by species (number of individuals), sex, and size range on several Cuban zones (2009, 2012–2016). Total length in cm for sharks and disc width for rays

	Catch/zone			Sex		Total length	
Species	SE	SW	NW	F	M	Min	Max
Caribbean reef shark	180	12	2	94	100	74.5	230.0
Nurse shark	59	6	1	34	32	70.0	240.0
Lemon shark	32	5	0	19	18	96.0	242.0
Blacktip shark	8	1	2	6	5	93.5	197.0
Silky shark	5	0	2	3	4	133.5	240.0
Bull shark	0	5	0	0	5	180.0	250.0
Tiger shark	0	1	4	5	0	183.0	265.0
Great hammerhead	0	2	2	0	4	180.0	305.0
Southern stingray	7	1	2	10	0	64.5	116.0

Legend: SE, southeastern zone; SW, southwestern zone; NW, northwestern zone; F, female; M, male; Min, minimum, Max, maximum. See Table 13.1 for sampling effort

Data from the three zones show that three species of sharks (Caribbean reef, nurse, lemon) accounted for almost 90% of the catch. All species in the three zones showed sizes within the range reported in other studies (Pikitch et al. 2005; Tavares 2009a; Castro 2011; Hannan et al. 2012; Brooks et al. 2013, and several sources reported in Castro 2011).

Recapture rates (higher in the SE zone with 7.9%) (Table 13.6) are in the range described for the species in other studies and regions (see review by Kohler and Turner 2018). Our rates are lower than those reported in the Bahamas and Brazil (15.4 and 15.3%, respectively), suggesting a relatively larger population in SE Cuba (Garla et al. 2006a; Bond et al. 2012; Brooks et al. 2013). Other alternative explanations for the lower recapture rate are low fishing effort, low reporting, high tag shedding, and tag biofouling as found in other studies (i.e., Kohler and Turner 2018).

Sizes of Caribbean reef sharks in the JRNP differ among months (2012–2016) ($H = 12.357$, df $= 5$, $p = 0.03$) (Fig. 13.2). Caribbean reef sharks are larger in May than in November ($Z = 3.013$, p-adjusted $= 0.019$). The other months show similar sizes, statistically speaking (Supplemental Material S13.3). Larger size in May is related to the fact that more larger males are caught during this month. Since summer has been reported as the birth season and assuming a gestation of 11–12 months of similar-sized carcharhinids (Soto 2001; Castro 2011), we hypothesize that larger males might be arriving in the JRNP for mating by that time. For years, NLF and authors FPA and TFM have observed large females with bites in JR, likely associated with early summer mating. On the other hand, smaller sizes recorded in November is related to the catch of smaller specimens of both sexes, likely resulting from birthing in late summer (Tavares 2009b; Castro 2011).

Sex ratio of the Caribbean reef shark was not different from the expected 1:1 (SE zone, $N = 180$, $\chi^2 = 0.369$ $p = 0.544$). When Pikitch et al. (2005), Tavares (2009b), and Bond et al. (2017) analyzed sex ratio, they found the same result. However, populations of Caribbean reef sharks

Table 13.6 Recapture information

Zone	Species	Tagged	Recaptured	TD		TL	
				Min	Max	Min	Max
SE	Blacktip shark	4	4	65.5	88.9	11	132
	Reef shark	161	7	0.0	185.2	575	2153
	Nurse shark	56	9	0.0	400.0	26	2070
	Lemon shark	16	3	0.0	79.9	91	2252
SW	Nurse shark	6	1	0.0[a]		365	
	Lemon shark	5	1	352.1		2407	
NW	Great hammerhead	2	1	24.4		335	

SE, southeastern zone; SW, southwestern zone; NW, northwestern zone, quantity of tagged and recaptured specimens, travel distance (TD, km, straight line between tagging and recapture sites), time at liberty (TL, days, number of days between tagging and recapture date); Min, minimum; Max, maximum. See Table 13.1 for sampling effort. Growth rates are shown on Supplemental Material S13.2 due to small sample size

[a] No precise information but recaptured nearby (few kilometers away) the tagging area

in the Bahamas and Brazil were female-dominated (Garla et al. 2006b; Brooks et al. 2013).

13.3.3.2 Fisheries-Dependent Ecological Information

Of the nine species analyzed (minimum of 20 specimens per zone), only three of different sex had different sizes: southern stingray with females larger than males in the SW and NCE zones (SW, $N = 114$, $W = 1609$, $p < 0.001$; NCE, $N = 40$, $W = 226.5$, $p < 0.001$); spotted eagle rays with females larger than males in NCE ($N = 32$, $W = 95$, $p = 0.001$); and tiger sharks with females larger than males in SE ($N = 23$, $W = 8.4$, $p = 0.045$). As for the southern stingray, our findings differ from those of Briones et al. (2017) who found females larger than males in the SE zone in surveys of shrimp trawl catches, likely due to sex-oriented gear selectivity or habitat. Since female elasmobranchs are usually larger than males (Ebert et al. 2013), our findings may suggest local extirpation of larger specimens (females) has occurred, a common situation in fisheries (Stokes and Law 2000; Babcock et al. 2013). This is also supported by female-dominated landings of several elasmobranch species in various Cuban fishing zones (see sex ratio information below). An alternative explanation may include sexual seasonal segregation of mature individuals, also common in elasmobranchs (Braccini and Taylor 2016).

Within each sex, size varied among zones for eight species (Table 13.7). Size differences in smaller spotted eagle rays, nurse sharks, and southern stingrays in NCE might be attributed to gear selectivity (the "boliche" trawl was used). Same-sex elasmobranchs are generally smaller in the SE and NCE zones and generally larger in the SW zone. The fact that

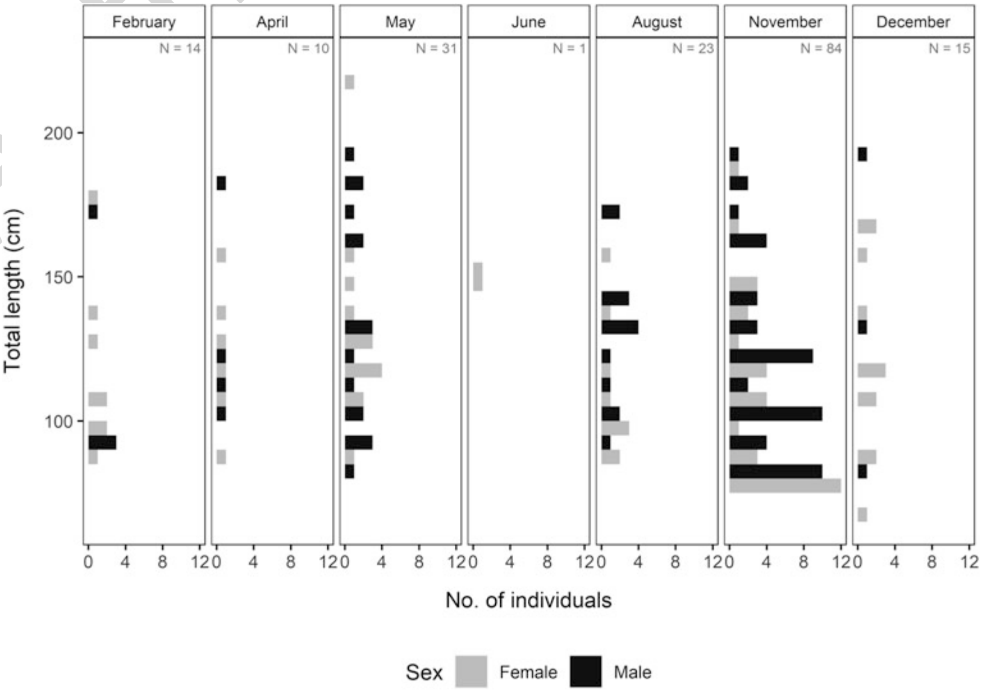


Fig. 13.2 Size composition of Caribbean reef sharks (*Carcharhinus perezi*) in the Jardines de la Reina National Park reported by month and sex from 2012 to 2016

Table 13.7 Size of several same-sex species of shark and rays fished on Cuban zones. Size is total length in cm for sharks and disc width for rays

		Size				
Sex	Species	SE	SW	NCE	χ^2	p
Female	Spotted eagle ray	109.4 ± 16.6 (11)	152.0 ± 10.2 (12)	145.1 ± 11.4 (16)	8.4	0.015
	Blacktip shark	118.7 ± 4.7 (35)	187.2 ± 9.2 (36)	99.3 ± 7.1 (4)	34.16	<0.001
	Tiger shark	240.0 ± 14.6 (9)	184.1 ± 22.9 (8)	176.2 ± 17.5 (14)	8.07	0.018
	Nurse shark	178.3 ± 13.1 (14)	153.8 ± 16.4 (17)	153.1 ± 3.5 (74)	6.4	0.041
	Sixgill shark	106.1 ± 9.1 (7)	340.0 ± 20.0 (2)	NA	4.34	0.037
	Great hammerhead	190.4 ± 13.8 (5)	NA	292.1 ± 12.3 (33)	7.36	0.007
Male	Spotted eagle ray	107.9 ± 10.4 (27)	131.4 ± 16.2 (8)	66.5 ± 5.1 (6)	9.37	0.009
	Silky shark	NA	103.6 ± 1.7 (5)	164.4 ± 25.1 (10)	5.72	0.017
	Blacktip shark	124.0 ± 4.8 (61)	190.2 ± 6.9 (54)	NA	42.96	<0.001
	Southern stingray	60.5 ± 5.5 (16)	54.2 ± 2.6 (18)	49.5 ± 1.1 (24)	6.01	0.049

(± SE), standard error; (#), sample size; SE, southeastern zone; SW, southwestern zone; NCE, north-central/eastern; NA, not available. Kruskal–Wallis test statistic was Chi-square (χ^2)

the SE and NCE zones are reporting the largest landings of elasmobranchs in Cuba (see Sect. 13.3.5) suggests size-induced changes due to fishing pressure (Stokes and Law 2000; Babcock et al. 2013).

Sex ratio of several species in three zones shows dominance of females (Supplemental Material Table S13.4). The three species with more than 100 specimens showed significant deviation from a 1:1 sex ratio and were dominated by females (in the SE zone the sharpnose shark ($N = 118$, $\chi^2 = 3.3898$, $p = 0.066$); in the SW zone the southern stingray ($N = 114$, $\chi^2 = 53.368$, $p \leq 0.001$; in the NCE zone the Caribbean reef shark ($N = 245$, $\chi^2 = 116.58$, $p \leq 0.001$)). Female dominance in landings has also been found in other studies: in southern stingrays in the Cuban SE zone (Briones et al. 2017), as well as in southern stingrays in the USA (Hayne et al. 2018). Several fisheries-independent studies show 1:1 sex ratios in Caribbean reef shark (i.e., Pikitch et al. 2005; Tavares 2009b; Bond et al. 2017; see the last paragraph of Sect. 13.3.3.1), suggesting that our findings on fisheries-dependent samplings are probably related to sex-related differences in fishing mortality. An alternative explanation may include sexual segregation of mature individuals, also common in elasmobranchs (e.g., Braccini and Taylor 2016). However, systematic quantitative surveys are required to test that hypothesis.

Reproductive information on elasmobranchs in Cuba is scarce (Table 13.8). Pregnant nurse sharks accurately measured were in the lower range of size at maturity (Castro 2000). Nurse shark broods ranged from 3 to 11 young. Castro (2000) reported broods from 21 to 50 young, with a mean of 34 young. Because birth of the entire brood may take several weeks, some specimens may appear to have small remaining broods, as some of their progeny had been released in the previous weeks. Female sharpnose sharks mature above 80 cm TL (Ebert et al. 2013), and three of our reported females were under that size. Brood sizes of Atlantic sharpnose sharks ranged from one to seven young and of Caribbean sharpnose sharks from two to six young. Several of our reported broods (17%) had more than seven embryos (Corro-Espinosa et al. 2011; Castro 2011). A pregnant great hammerhead was in the lower range of size at maturity and brood size was within the range reported (Clark and Von Schmidt 1965; Dodrill 1977; Castro 2011). Size of a pregnant tiger shark and brood were in the range of those previously reported (Branstetter et al. 1987; Whitney and Crow 2007; Castro 2011). Pregnant southern stingrays were above the maturity size reported, broods were within the range reported, and female embryos were dominant in the broods as previously reported (Briones et al. 2017). Pregnant longnose stingrays (*Hypanus guttatus*) were above the maturity size reported and broods were within the range reported (da Silva et al. 2018). Information about reproduction of chupare stingray (*Himantura schmardae*) was not available in the literature.

Size of young individuals of a few species was obtained through fisheries surveys between 2015 and 2017 as part of the NPOA-Sharks. Young blacktip sharks were within the size range reported (5 specimens, 60–88 cm TL) (Castillo-Géniz et al. 1998), but one young tiger shark (60 cm TL) was smaller than the smallest reported in the literature (Whitney and Crow 2007; Castro 2011).

13.3.4 Movement Ecology and Critical Habitats for Cuban Reef Sharks

Recaptures of sharks tagged in Cuba reveal a broad range of movements (Table 13.6 and Fig. 13.3). Lemon sharks did not move from the mangrove channels of JR; however, one specimen from IJ crossed the Yucatan Channel. Several specimens traveled relatively long distances from the JR mangrove channels to south central and southeastern Cuba, but one nurse shark did not move from its tagging site in IJ. Four blacktip sharks moved from the northern coral reefs

Table 13.8 Reproductive information of several species of sharks and rays in Cuba. Data shown by ranges (minimum-maximum). Size is total length in cm for sharks and disc width for rays

Zone	Species	Size	Male embryos	Female embryos	Total embryos
SE	Nurse shark (5)	?–220	1–5	1–6	3–11
	Chupare stingray (2)	116–119		2–5	2–5
	Southern stingray (11)	78–105	1	1–4	2–4
	Longnose stingray (2)	92–97	1	2–4	3–5
	Sharpnose shark (22)	63–115	1–8	1–5	2–12
NCE	Longnose stingray (1)	?		4	4
	Great hammerhead (1)	305	21	19	40
	Tiger shark (1)	349	20	16	36

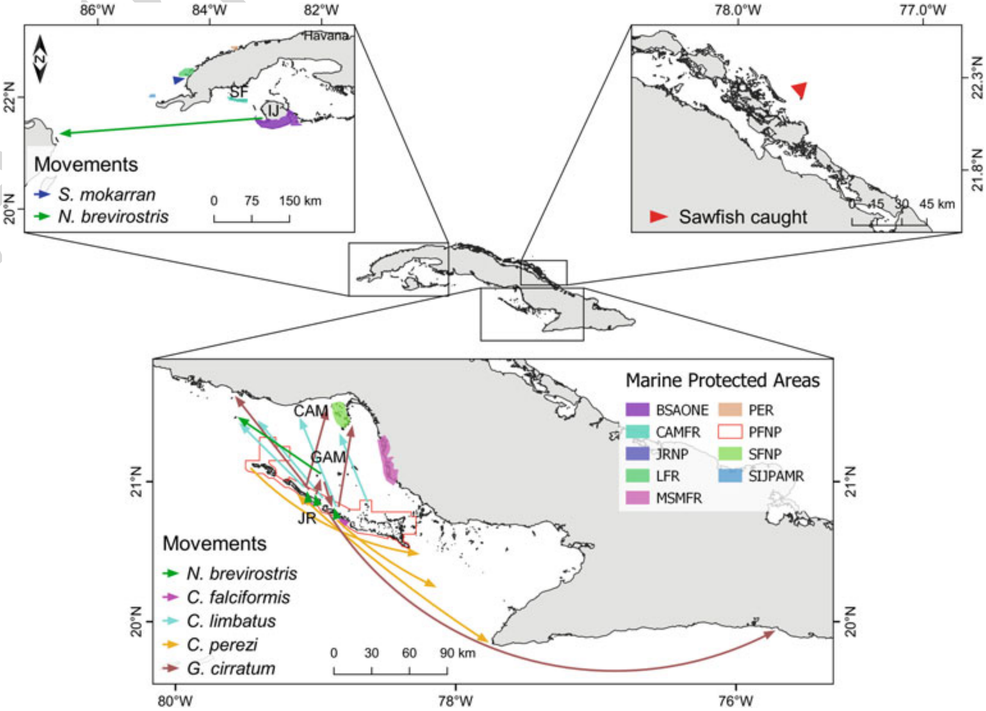
Legend: SE, southeastern zone; NCE, north-central/eastern; the numbers in brackets are sample sizes; ?, inaccurate size

of JR to GAM. Four Caribbean reef sharks moved relatively long distances, while three were recaptured at the tagging site. A great hammerhead was recaptured near the tagging site in the NW zone, almost 1 year after being tagged.

Movement of lemon sharks in JR and IJ is similar to movement reported for this species. All lemon sharks in JR ranged from young to immature and were tagged in mangrove channels and recaptured nearby. At those ages and habitat other studies have shown high site fidelity (in the order of a few km^2) (Gruber et al. 1988). However, other specimens travel longer distances. A female lemon shark tagged in central GAM that traveled 79.9 km towards the GAM eastern portion—after being at large for more than 6 years—was an immature specimen (145 cm TL) when tagged, but likely mature when recaptured. An immature female lemon shark (207 cm TL), tagged in IJ that traveled 352 km to Islas Mujeres, was likely mature when recaptured in Mexico after being at large more than 6.5 years. Similar long-distance movements have been reported for adult lemon sharks (Kohler and Turner 2018), with a maximum distance of 494 km and 10.9 years at large.

We caught lemon sharks in mangrove channels of Cuba at any time of the day, while other authors, e.g., Dodrill (1977), have caught lemon sharks on the Florida Atlantic coast (close to shore) between 16:30 and 08:30, which suggests they spent daytime offshore at those locations. The difference between these studies could be in regard to the size of specimens. Ruiz-Abierno et al. (2020) presented the first study of a shark nursery area in Cuba (for the lemon shark) in La Salina Wildlife Refuge, Zapata Swamp, Cuba, during 2015–2019. They found that the size/age structure of lemon sharks in the area represents a population that has not been disturbed by human influence and recommended to expand the study to other potential nursery areas in Cuba.

Fig. 13.3 Movement of sharks. A, movement in the NW and SW zones; B, movement in the SE zone. Legend: JR, Jardines de la Reina Archipelago; CAM, Cayos Ana María; GAM, Golfo Ana María; IJ, Isla de la Juventud; SF, Cayos San Felipe; BSAONE, Banco San Antonio Outstanding Natural Element; PER, Pretiles Ecological Reserve; LFR, Levisa Fauna Refuge; JRNP, Jardines de la Reina National Park; CAMFR, Cayos de Ana María Fauna Refuge; MSMFR, Macurije Santa María Fauna Refuge; PFNP, Punta Frances National Park; SIJPAMR, Southern Isla de la Juventud Protected Area of Management Resources; SFNP, San Felipe National Park



Nurse shark movements showed a wide range of distances in the Cuban surveyed zones. One nurse shark in IJ and three in JR showed high site fidelity. Three nurse sharks moved dozens of kilometers, two moved 100–200 km, and one approximately 400 km in JR. Only one mature nurse shark was recorded; it was tagged and recaptured in IJ (male, 240 cm TL). This wide range of distances had been reported for this species before. Distance of movement ranged from very short (Carrier 1985), to a few km (Chapman et al. 2005), to dozens of km (Kato and Hernández-Carvallo 1967; Chapman et al. 2005; Kohler and Turner 2018), and to hundreds of km (Kohler and Turner 2018). A previous study described nurse sharks' unidirectional movement of a few hundred meters from the reef crest to the reef slope in a few weeks in JR (Pina-Amargós et al. 2008).

All recaptured blacktip sharks in JR moved dozens of km in relatively few days. Movement distance on the scale of our findings has been published for this species (Kato and Hernández-Carvallo 1967), but other authors have reported shorter movements in longer timeframes (e.g., only 6 km in 2.8 years; Cliff et al. 1996). Larger spatial scale studies showed long-distance movements from hundreds to thousands of km associated with seasonal migrations in the southeastern USA (Florida to/from the Carolinas), western Florida, and Texas to/from Mexico (Clark and von Schmidt 1965; Kohler et al. 1998; Castro 2011) and crossing the Straits of Florida and the Old Bahamas Channel. There are also reports of long-distance movements of 380 km (Govender et al. 1995) and 1183 km. Sexual segregation has been reported for this species (Dodrill 1977; Castro 2011; Drymon et al. 2020), but it does not seem to be the case in our surveys of the northern coral reefs of JR; however, our sample size was too small to prove it.

An immature male great hammerhead (180 cm TL) was recaptured in the NW zone, a few km away from the tagging site, almost 1 year after being tagged. Its relatively limited movement in a relatively long time in that Cuban zone might be due to its maturity stage. Larger great hammerheads are considered to be highly migratory, with movements ranging from 213 to 1180 km (Kohler and Turner 2018).

In JR, Caribbean reef sharks showed movements ranging from high site fidelity (see also resightings below) to relatively long distances (four between 150 and 180 km). However, most of the literature shows high site fidelity and philopatry of this species, with annual horizontal displacement ranging from a few km (Brooks et al. 2013) to a few dozens of km (Pikitch et al. 2005; Ormond et al. 2017; Shipley et al. 2017, 2018; Kohler and Turner 2018).

Our long-distance recaptures of Caribbean reef sharks were made up by two males and one female in June–July, with evidence of reproductive activity (females with fresh mating scars; NLF pers. comm., and authors FPA and TFM personal observations). Long-distance movements of Caribbean reef sharks found by Shipley et al. (2017) also coincided with reproductive activity. Movements of 150 km of two males and two females appear to be more related to size than to sex since TL of all specimens was more than 150 cm at the time of recapture. However, Shipley et al. (2018) hypothesized that males move farther than females. Size-related movement of the Caribbean reef shark is supported by other studies (Garla et al. 2006b) and for other shark species (Nelson 1990; Heupel and Hueter 2002).

Our tagging/recapture data and underwater observations of Caribbean reef sharks do not support ontogenetic segregation by depth as reported by other authors (Shipley et al. 2018). We have caught and observed Caribbean reef sharks of a wide range of sizes in the reef crest lagoon (2–3 m deep), back reef crest (1–2 m deep), front reef crest (1–3 m deep), and deeper coral reefs at the shelf edge. Other studies show that large Caribbean reef sharks are frequently captured in reef lagoons, particularly at night (Pikitch et al. 2005; Bond et al. 2017). Bond et al. (2017) found Caribbean reef sharks of all life stages close to one another in Belize, suggesting that this species does not have discrete nursery areas, and that neonates may be found in microhabitats within coral reef systems with the presence of specimens of older life stages (Garla et al. 2006b; Tavares 2009b; Brooks et al. 2013).

Resightings of silky and Caribbean reef sharks show strong site fidelity of both species to the Farallón dive site (Table 13.9). No resightings or recaptures of these sharks have been made outside this site, despite the year-round dive tourism with daily activities in dozens of sites ranging from 2 to 30 km east and west of the Farallón dive site and the awareness of the tagging program by dive masters and visitors. These sharks are presumably still alive in the same area with at least a few resightings every month, but we have been unable to recapture them and read the tag number to demonstrate it. A few other Caribbean reef sharks, presumably tagged outside the Farallón dive site, have been resighted in the area, but the tag numbers were unreadable. There is only one study previously published of the Caribbean reef shark movements in JR (Hueter et al. 2018). Results from archival and position-only satellite tags suggested the sharks traveled <30 km from the tagging site (Farallón dive site) during up to 7 months after tagging. In addition, resightings of two of these sharks were noted at the dive site 3–4 weeks after tagging. This is consistent with our observations of high site fidelity, but the limited time frame calls for caution, since others have reported longer distance movements for this species in a time frame ranging from a few days to years at large (Kato and Hernández-Carvallo 1967; Musyl et al. 2011; Kohler and Turner 2018). Site fidelity of Caribbean reef and silky sharks to the Farallón dive site might be driven by the provisioning of these sharks

Table 13.9 Resightings of Caribbean reef sharks (*C. perezi*) and silky sharks (*C. falciformis*) around Farallón dive site through time

				2012	2013												2014												2015			
Sp.	No.	Sex	Size	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	Total
Reef	41	f	169	T				2			2		1	3		2	2		1	No resighting effort			2	1	1	1				1		19
Reef	66	f	222	NA					T	1	2			3	1	2		2					1		2				1			15
Silky	42	m	193	T		1												2	1				2	1	2	1		1	1		2	14
Silky	57	f	235	T			1		3	2	2			8	1	4	1	4	3					1	2	2	2	1	1		2	40
Total					0	1	1	2	3	3	6	0	1	14	2	8	3	8	5				5	3	7	4	2	2	3	1	4	88

Legend: Sp, species; no., tag number; size is total length in cm when tagged; T, tagged month; f, female; m, male

by divers (Hueter et al. 2018). The effects of provisioning on sharks have been investigated; most studies (e.g., Maljković and Côté 2011; Hammerschlag et al. 2012; Brunnschweiler and Barnett 2013) have concluded that it does not significantly alter normal animal behavior and health, while others have questioned this conclusion (e.g., Fitzpatrick et al. 2011). In general, when dive ecotourism follows responsible practices, its conservation benefits can outweigh its negative impacts (Heyman et al. 2010; Castro 2011), and the economic value of this activity can be substantial (Haas et al. 2017; Huveneers et al. 2017; Figueredo-Martín and Pina-Amargos (see Chap. 23)).

13.3.5 Fisheries That Impact Reef Sharks and Rays in Cuba

Shark and ray fisheries in Cuba have several stakeholders. Commercial fishers are of two types: fishers hired by government companies (state fishers) and private fishers. Recreational fishers do the activity for leisure, family consumption, and competition, not for profit. However, quite often recreational catch is sold or bartered without records. All fisheries in Cuba, including shark and ray fisheries and elasmobranch catch for research purposes, require permits and licenses from the Cuban government. State fisheries dominate the recorded landings, while private fishermen land 23% of sharks and 13% of rays in Cuba (Ramos-Díaz 2019). Sharks and rays are caught using several methods: longline (vertical anchored, bottom, and drift), gillnets, and trawls (several types including shrimp trawls). According to surveys conducted between 2015 and 2017 for the NPOA-Sharks project, bottom longlines are the most widely used gear to catch elasmobranchs, followed by gillnets. Shrimp trawls report sharks and rays as bycatch (Font 2001; Briones et al. 2017).

Sharks and rays are important fishery resources in Cuba. The contribution of sharks to total landings has ranged from 10.7% in the 1980s to 3.6% in the 2010s, while that of rays have ranged from 10.3% in the 1980s to the current level of 8.6% (Claro et al. 2001a; Baisre 2018).

Shark landings exceeded 2000 tons (t) in 1968 and remained above that level through 1981, when a maximum of 3076 t was reached, followed by a steady decline until 1993 (929 t) (Espinosa 2003). It has been estimated that 64% of this reduction was due to the decrease in the fishing effort and the other 36% was due to the decrease in size and abundance of sharks for unknown causes (Espinosa 2003), but likely in response to the remaining fishing pressure. From 1994 to 1999, shark landings ranged from 1000 to 2000 t and have been in decline since then (Espinosa 2003; Ramos-Díaz 2019), averaging around 500 t in the 2010s (Ramos-Díaz 2019). According to these authors, decrease in landings was due to the reduction of the fishing effort, but data to support that explanation were not provided (Ramos-Díaz 2019). In the past, landings were reported as "sharks" (and as "nurse shark" sometimes) until 2015, when NPOA-Sharks instituted species-specific reporting. However, most of the shark catch is not currently reported at a species level (54% of the total; Ramos-Díaz 2019). Baisre (2018) considered sharks are overfished in Cuba, with a decline of 79% in catches in respect of the maximum landing period. However, different factors such as fishing mortality in all the distribution range of the species, the gear selectivity, and changes in fishing regime should be considered before to be conclusive.

Ray landings averaged over 1800 t in the 1981–1985 period, and increased to more than 2942 t during the 1986–1990 period; it decreased to 1819 t from 1991 to 1995, increased to 2008 t in 2009, and decreased again to 1283 t in the 2010s (Claro et al. 2001a; Ramos-Díaz 2019). Ray landings in Cuba are dominated by stingrays (54%) and by spotted eagle rays (40%) (Ramos-Díaz 2019). Landings were reported as "eagle ray-rays" until 2015, but several species are still reported as one. The recent decline in landings has been attributed to the decrease of the fishing effort, but supporting data have not been provided (Ramos-Díaz 2019).

To assess the influence of the fishing effort on elasmobranch landings, we selected the fishing ports that contribute the most to elasmobranch landings (more than 90%) in the four Cuban fishing zones. Total fishing effort (fishing days) and landings separated by "sharks," "nurse sharks," and "rays-eagle ray" from 1981 to 2013 were available (Supplemental Material S13.5). Data of fishing effort for elasmobranchs are not registered separately; thus, we used total fishing effort as a proxy. We found that in northern Cuba, there is no correspondence between fishing effort and landings, which limits any causal inference between the two variables (Supplemental Material Fig. S13.6C). In the south, the relationship between fishing effort and landings shows a correlation up to 1800 t; after that amount, increase of fishing effort does not result in higher catches (Supplement Material Fig. S13.6D).

Landings of sharks and rays are unevenly distributed among Cuban fishing zones (Fig. 13.1) (Ramos-Díaz 2019). The SE zone dominates landings of sharks (46%) and rays (45%), followed by the NCE zone (42%), SW zone (9%), and NW zone (3%) for sharks. For rays, the SE zone is followed by the SW (29%), NCE (18%), and NW (8%) zones.

Species contribution to landings has changed through time. Since Cuban fisheries did not report shark landings by species for many years, data from the 1980s and 1990s were likely gathered from port surveys, although this was not specified in the study (Espinosa 2003). The only comparative data from the 1980s to the 2010s are the contributions of three shark species (nurse, blacktip, and silky sharks) to recorded landings (Espinosa 2003; Ramos-Díaz 2019). In the 1980s, this group represented 36% of all elasmobranch landings, increasing to 56% in the 1990s and decreasing to 24% in the 2010s (Espinosa 2003; Ramos-Díaz 2019). Separately, nurse shark landings have not changed considerably (from 14 to 16%), blacktip shark landings have decreased (12–5%), and silky shark landings have also decreased (10–3%) (Espinosa 2003; Ramos-Díaz 2019). Between the 1980s and 1990s, a group of five shark species (nurse shark, blacktip shark, and silky shark plus sharpnose shark and lemon shark) increased its contribution to the total landings from 51 to 64% (Espinosa 2003; Ramos-Díaz 2019).

Size composition of landings has changed through time (Table 13.10). Fifty-five percent (55%) of the 20 species with landing data available in at least two timeframes show a negative trend on average size and 65% show an average size under maturity size. Of the four species that contribute the most to historical landings, three species (nurse, blacktip, and silky sharks) show negative trends regarding average size. Their maturity size also shows a negative pattern. Only the sharpnose shark shows a positive trend in both parameters. According to a worldwide study, decrease of shark average size over the past century indicates that the largest individuals are missing due to fishing pressure (Myers et al. 2007).

Banning of shark finning is the only regulation for elasmobranch fisheries in Cuba (Resolution 252/14 Ministry of Food Industry). Management tools such as size limits, bag and possession limits, and closed seasons are not currently implemented in shark and ray fisheries.

13.3.6 MPAs and Cuban Reef Sharks and Rays

Here we address conservation of Cuban reef sharks and rays in MPAs, focusing on MPA size, shark movements related to MPA limits, and shark and ray abundance and size at several spatial scales and protection levels.

Findings related to MPAs and surrounding areas in the surveyed Cuban zones are of limited scope due to the small sample size (except for the JRNP), but worthy of study for hypotheses. Since Cuban MPAs were not designed for shark and ray protection, our objective is not to critique their design but assess their potential for elasmobranch conservation and promote scientific research on the role of Cuban MPAs regarding conservation and sustainable use of sharks and rays.

Based on our tag-recapture data, shark movement related to MPA limits, and MPA size (Perera-Valderrama et al. 2018; Ferro-Azcona et al. (Chap. 22)), we hypothesize that except the JRNP, the Cuban MPAs addressed in this study are too small (2–17% of the JRNP marine area) to protect sharks and rays effectively, particularly adults with greater mobility. Excluding JRNP, only 3 recaptures of 60 specimens tagged were of specimens tagged outside the other 8 MPAs

Table 13.10 Size information of several shark and ray species during different periods of time in Cuba. Size is total length in cm for sharks and disc width for rays. Average size (AS) information according to Espinosa (2003) (1983–1996), Aguilar-Betancourt et al. (2014) (2010–2011), PAN-Tiburones (2015) (2015–2017), and Ruiz-Abierno et al. (2021a) (2010–2019). Maturity sizes (MS) according to Castro (2011) except for the longfin mako (*Isurus paucus*) and oceanic whitetip shark (*Carcharhinus longimanus*) according to Ruiz-Abierno et al. (2021a), spotted eagle ray (*Aetobatus narinari*) according to Schluessel et al. (2010), southern stingray (*Hypanus americanus*) according to Briones et al. (2017), longnose stingray (*Hypanus guttatus*) according to da Silva et al. (2018), giant manta ray (*Mobula birostris*) according to Froese and Pauly (2021)

Variable	Sample size (N)			Size range			Average size (AS)						
Species/ year	1983–1996	2010–2011	2015–2017	1983–1996	2010–2011	2015–2017	1983–1991	1992–1996	2010–2011	2015–2017	Maturity size (MS)	Trend AS	Trend MS
NS	327	NA	150	125–297	NA	69–290	169	214	NA	157	210	–12	–53
BS	340	5	169	122–230	155–185	60–200	164	179	165	141	156	–23	–15
SS	345	20	39	80–314	175–195	96–321	170	171	188	145	232	–25	–87
SH	203	NA	118	51–105	NA	54–115	66	68	NA	85	60	+19	+15
LS	102	9	9	140–285	225–275	85–260	177	216	242	182	235	+5	–53
GH	41	21	25	187–375	188–238	113–400	216	220	238	244	300	+28	–56
OW	207	18	259^{a}	110–256	NA	75–265^{a}	170	172	NA	155^{a}	199	–15	–44
TS	83	11	51	171–404	NA	60–349	227	240	NA	202	310	–25	–108
SM	111	27	2	123–367	NA	205–260	218	216	NA	233	201	+15	+32
BU	48	20	6	179–300	188–270	165–246	206	209	225	218	220	+12	–2
SH	40	NA	14	183–344	NA	145–390	203	208	NA	284	245	+81	+39
TH	65	6	NA	245–425	380–395		317	325	385	NA	330	+13	+55
CR	25	39	242	143–286	150–230	77–203	189	169	170	126	190	–63	–64
BL	43	9	NA	180–300	245–295		210	227	267	NA	220	+57	+47
LM	42	NA	292^{a}	165–352	NA	86–390^{a}	210	NA	NA	248^{a}	230	+38	+18
BK	36	NA	16	87–140	NA	81–112	112	99	NA	101	103	–11	–2
BO	38	NA	NA	65–128	NA		117	101	NA	NA	80	1 time	
NI	57	8	2	184–285	170–247	176–193	197	NA	207	185	200	–12	–15
BG	32	NA	NA	183–285	NA		231	NA	NA	NA	200	1 time	
SX	50	NA	12	225–565	NA	85–360	325	NA	NA	173	450	–152	–277
BY	65	NA	3	97–186	NA	128–147	174	NA	NA	141	146	–33	–5
CD	31	2	6	56–158	55–75	67–165	136	NA	62	122	50	–14	+72
SD	NA	NA	11	NA	NA	100–214	NA	NA	NA	165	185	1 time	
DS	NA	NA	2	NA	NA	234–275	NA	NA	NA	255	270	1 time	
SO	NA	NA	4	NA	NA	105–260	NA	NA	NA	191	240	1 time	
ER	NA	NA	80	NA	NA	32–280	NA	NA	NA	124	150	1 time	
UR	NA	NA	38	NA	NA	52–149	NA	NA	NA	89	NA	1 time	
SR	NA	NA	204	NA	NA	20–110	NA	NA	NA	72	64	This study and Briones et al. (2017)	
			300^{b}			20–137^{b}				57–68^{b}			
LR	NA	NA	154	NA	NA	27–120	NA	NA	NA	67	67	1 time	
GR	NA	NA	9	NA	NA	64–210	NA	NA	NA	125	400	1 time	

NS, nurse shark (*Ginglymostoma cirratum*); BS, blacktip shark (*C. limbatus*); SS, silky shark (*C. falciformis*); SH, sharpnose shark (*Rhizoprionodon* spp.); LS, lemon shark (*Negaprion brevirostris*); GH, great hammerhead (*Sphyrna mokarran*); OW, oceanic whitetip shark (*C. longimanus*); TS, tiger shark (*Galeocerdo cuvier*); SM, shortfin mako (*Isurus oxyrinchus*); BU, bull shark (*C. leucas*); SH, scalloped hammerhead (*S. lewini*); TH, thresher sharks (*Alopias* spp.); CR, Caribbean reef shark (*C. perezi*); BL, blue shark (*Prionace glauca*); LM, longfin mako (*I. paucus*); BK, blacknose shark (*C. acronotus*); BO, bonnethead (*Sphyrna tiburo*); NI, night shark (*C. signatus*); BG, bignose shark (*C. altimus*); SX, Bluntnose sixgill shark (*Hexanchus griseus*); BY, bigeye sixgill (*H. nakamurai*); CD, Cuban dogfish (*Squalus cubensis*); SD, sandbar shark (*C. plumbeus*); DS, dusky shark (*C. obscurus*); SO, smooth hammerhead (*S. zygaena*); ER, spotted eagle ray; UR, chupare stingray (*Himantura schmardae*); SR, southern stingray; LR, longnose stingray; GR, giant manta ray; Trend AS, resulting from the difference between the most recent estimate of average size and the oldest one; Trend MS, resulting from the difference between the most recent estimate of average size and maturity size in the literature; NA, not available

[a] Data of 2010–2019

[b] Briones et al. (2017)

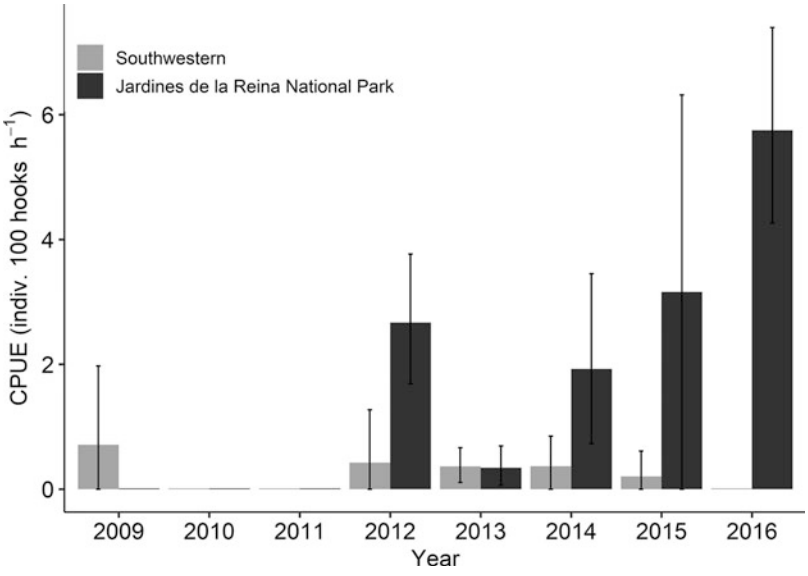
(no recapture of specimens tagged inside those 8 MPAs). Even the JRNP is only partially effective. About half of all recaptures were outside the JRNP (five nurse sharks, four blacktip sharks, and four Caribbean reef sharks), as well as all recaptures of specimens that traveled at least 26 km. At the species level, 100% of recaptured blacktip sharks, about 55% of the nurse sharks, and about 43% of the Caribbean reef sharks moved outside the JRNP, hence the importance of comprehensive management beyond the limits of MPAs.

Other studies have shown that MPAs must be large to protect shark and ray populations from overfishing (Escalle et al. 2015; Graham et al. 2016; Dwyer et al. 2020). Graham et al. (2016) assessed the effect of full protection in the EEZ of the USA and the Bahamas and found that 0%, 18%, and 35% of the regional core habitat use areas for tracked bull sharks, great hammerheads, and tiger sharks, respectively, were fully protected from exploitation, which is not enough to secure their conservation. Escalle et al. (2015) reviewed evidence of the value of no-take zones as a strategy for protecting reef sharks and found that 65% could be beneficial, including no-take zones with some of the same species of our study (Chapman et al. 2005, Caribbean reef shark and nurse shark; Bond et al. 2012, Caribbean reef shark). Other studies not regarded as positive by Escalle et al. (2015) appeared to support high site fidelity to the no-take zone at least during one phase of the life cycle (Heupel et al. 2004, juvenile blacktip shark; Edren and Gruber 2005, juvenile lemon shark; Garla et al. 2006a, b, juvenile Caribbean reef shark). Dwyer et al. (2020) discovered that the world's officially recorded coral reef-based managed areas (with a median width of 9.4 km) would need to be enforced as strict no-take MPAs and be up to five times larger to protect the five reef shark species surveyed.

Caribbean reef shark abundance is different between JRNP and SW zone ($W = 31$, $p = 0.034$) (Fig. 13.4). Caribbean reef shark abundance follows a different temporal pattern when comparing the JRNP ($H = 52.761$, $p < 0.001$) to the SW zone (where PFNP, SIJPAMR, and SFNP are located) ($H = 3.278$, $p = 0.773$) (Fig. 13.4). Catch per unit of effort (CPUE) is higher and increases through time in the JRNP (2012 vs. 2016, $Z = -3.252$, $p = 0.004$; 2014 vs. 2016, $Z = -5.13$, $p < 0.001$), while CPUE is lower and appears to be decreasing in the SW zone. We considered these differences are due, at least to some extent, to the protection effect of the JRNP, although the sampling effort and gear selectivity might also be playing a role in these results. Effects of environmental differences or changes, such as habitat quality (difference between zones and increased/decreased live coral cover or structural complexity), are not supported by scientific evidence (Caballero-Aragón and Perera-Valderrama 2014; Pina-Amargós et al. 2021). Few relevant studies have assessed changes in shark abundance through time in MPAs. In Belize, Pikitch et al. (2005) found total elasmobranch abundance did not change from year to year, and Bond et al. (2017) found the population of Caribbean reef sharks appeared stable, with no significant decline in CPUE. In a remote coral reef of the Indian Ocean, shark catches showed little difference before and after the establishment of the MPA, likely due to illegal fishing (Ferretti et al. 2018).

Size composition related to maturity size in the JRNP supports the premise of fishing-induced effects. Most of the specimens of the three most abundant species caught in the SE zone were below maturity size reported (Fig. 13.5). In the case of nurse and lemon sharks, all specimens were below maturity size. Since we surveyed all main habitats (muddy

Fig. 13.4 Relative abundance (catch per unit of effort, CPUE) of Caribbean reef sharks (*C. perezi*) in the Jardines de la Reina Nacional Park and in the southwestern zone through several years. Bars represent mean values and vertical lines represent 95% confidence intervals. See Table 13.2 for sample size



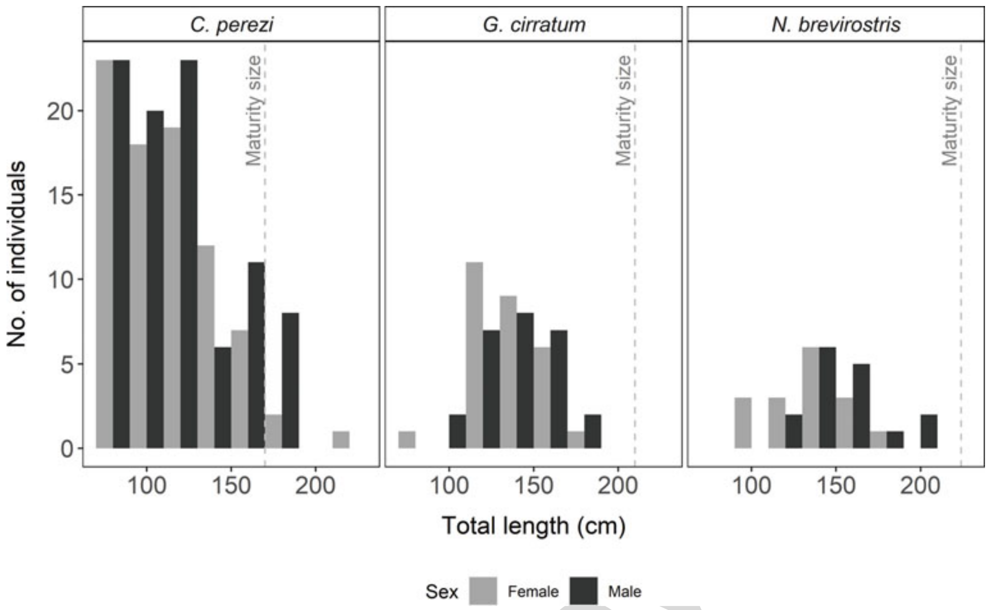


Fig. 13.5 Size composition of several species of sharks (Caribbean reef shark (*C. perezi*), nurse shark (*G. cirratum*), and lemon shark (*N. brevirostris*)) related to maturity size in the southeastern zone

bottoms, seagrass, mangroves, coral reef, and other hard bottoms) from the shallow to the shelf edge (0.5–30 m deep) with high sampling effort (Table 13.1) using longline and set line gear that has proven effective to catch these three species, we assume these findings are not related to gear selectivity, habitat selectivity, or sample size. Considering that about half of the tagged specimens have been caught by fishers outside the JRNP (size-induced mortality is discussed above; see Sect. 13.3.2), the relatively small size of sharks in the JRNP may be an indication of high fishing impact on larger size classes (Bond et al. 2018; Shipley et al. 2018). However, this hypothesis needs to be tested.

The size of Caribbean reef sharks in the JRNP differs among areas (Fig. 13.6). Size in the JRNP Center seems more evenly distributed than that in the JRNP East (dominated by medium-size specimens) or than that in the JRNP West (dominated by small specimens). Statistically speaking, the JRNP Center did not differ marginally from the JRNP East ($A = 2.83$, p-adjusted $= 0.059$) nor the JRNP West ($A = 2.92$, p-adjusted $= 0.059$), but the JRNP East differed from the JRNP West ($A = 5.61$, p-adjusted $= 0.003$). Spatial segregation by size is a common characteristic of many shark species (Mucientes et al. 2009; Speed et al. 2012), which should also be happening in the JRNP Center. The literature does not show consensus on spatial segregation of Caribbean reef sharks by size or age. Several studies at small spatial scales (few dozens of square km) show that all life stages of Caribbean reef sharks occur on the fore reef

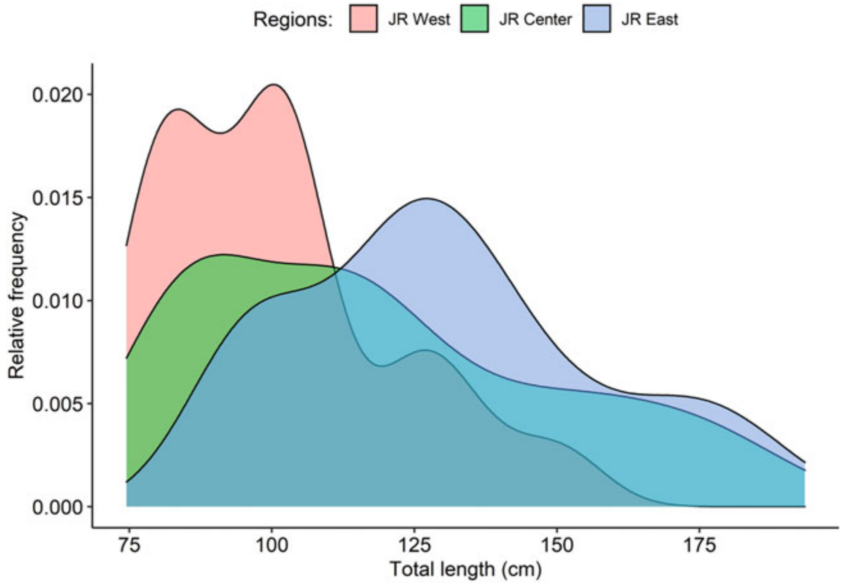


Fig. 13.6 Size composition of Caribbean reef sharks (*C. perezi*) in the Jardines de Reina National Park regions

(Chapman et al. 2005; Pikitch et al. 2005; Garla et al. 2006b; Tavares 2009b; Bond et al. 2012; Bond et al. 2017; this chapter). However, according to Brooks et al. (2013), Caribbean reef shark populations in the Bahamas are ontogenetically segregated, but over a larger geographic scale and a more diverse mosaic of marine habitats than those previously described. This may be the case for the JRNP as well. Other potential explanations for the heterogeneity within the JRNP could be prey availability, or provisioning of reef sharks by tourists in the JRNP Center, which may draw in sharks from the surrounding areas. Although fishes in general are more abundant in the JRNP Center (Pina-Amargós et al. 2014a, b), the magnitude of that difference unlikely leads to size differences in Caribbean reef sharks among the JRNP regions. Our results in Sect. 13.3.3 (particularly resightings) do not support the influence of provisioning on observed large-scale size differences. Based on our findings, an alternative explanation would be that the size spatial pattern is due to size-induced fishing mortality in the JRNP West and the JRNP East, and size-related protection in the JRNP Center (see Table 13.3 for sample size). Fisheries around the JRNP West might be more efficient at targeting medium and large specimens. On the other hand, fisheries around the JRNP East might be more efficient at targeting small specimens. Fisheries size selectivity is a widely recognized fact (Stokes and Law 2000; Babcock et al. 2013). On the other hand, the JRNP Center shows a more balanced size structure, likely due to higher enforcement and compliance with fisheries and MPA regulations (Pina-Amargós et al. 2014a, b). Further research is required to test these hypotheses.

A spatial scale analysis in the SE zone also revealed a level of protection-induced pattern on abundance. We selected the three species with higher number of specimens caught and tagged (Caribbean reef, nurse, and lemon sharks) and compared their abundance among the following regions: CAM, GAM, JRNP West, JRNP Center, and JRNP East (Fig. 13.7). Abundance of Caribbean reef sharks was different among zones ($H = 52.761$, $p < 0.001$). Although there were no significant differences among zones for nurse sharks ($H = 9.081$, $p = 0.059$) and lemon sharks ($H = 5.035$, $p = 0.284$), CAM had the lowest CPUE for the three species, followed by GAM for Caribbean reef and nurse sharks. In all cases, one of the JRNP regions had the highest value of CPUE for the three species. In the case of the Caribbean reef shark, there were several significant differences. CPUE was the highest in the JRNP Center (MPA higher protection level), followed by the JRNP West (MPA lower protection level) and the JRNP East (MPA lower protection level) and the lowest in GAM and CAM (fishing allowed) (Table 13.11). Our results are consistent with studies of Caribbean reef sharks in Belize, Brazil, and Australia that also show higher relative abundance in MPAs (Meekan and Cappo 2004; Garla et al. 2006b; Robbins et al. 2006; Heupel et al. 2009). However, our study goes beyond; it provides a gradient of abundance related to the different level of protection among the regions of a single MPA.

13.4 Conclusions and Recommendations for Research and Management of Reef Sharks and Rays in Cuba

Thirty-two percent of the elasmobranchs reported in Cuba are common species with strong affinity for coral reefs, have high fisheries and tourism importance, and are included in at least one of the two major international conservation frameworks. These facts stress the importance of their conservation and sustainable management in Cuba. However, the

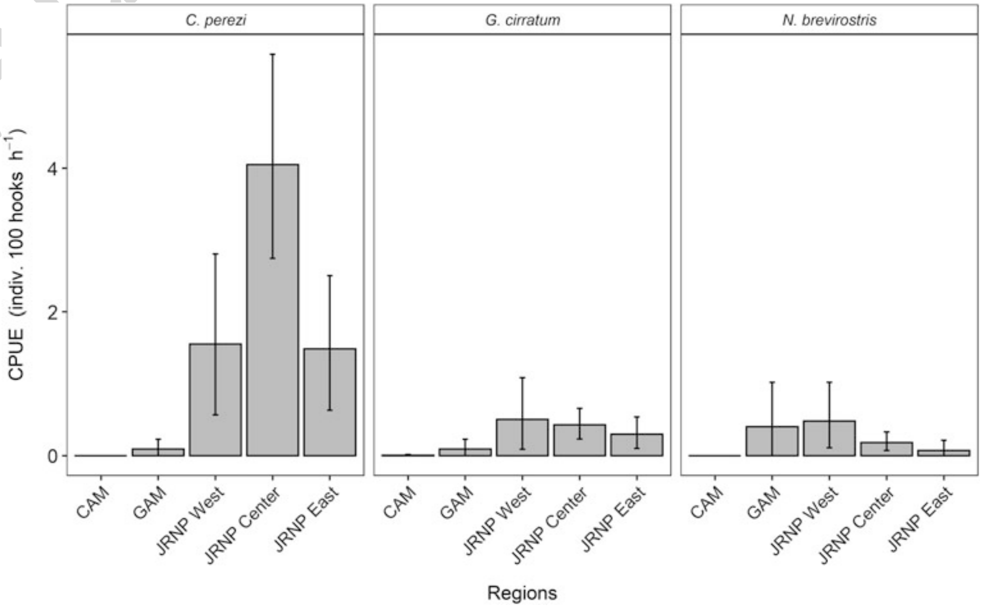


Fig. 13.7 Relative abundance (catch per unit of effort, CPUE) of several shark species (Caribbean reef shark (*C. perezi*), nurse shark (*G. cirratum*), and lemon shark (*N. brevirostris*)) in several regions of the southeastern zone. Bars represent mean values and vertical lines represent 95% confidence intervals. CAM, Cayos de Ana María; GAM, Golfo de Ana María; JRNP, Jardines de la Reina National Park. See Table 13.3 for sample size

Table 13.11 Relative abundance (catch per unit of effort, CPUE) of Caribbean reef sharks (*C. perezi*) in the southeastern regions

Regions	*Z*	*p*-adjusted
CAM–GAM	–0.288	0.387
CAM–JRNP Center	–5.012	**≤0.001**
GAM–JRNP Center	–5.972	**≤0.001**
CAM–JRNP East	–2.121	0.051
GAM–JRNP East	–2.256	**0.048**
JRNP Center–JRNP East	3.325	**0.004**
CAM–JRNP West	–2.289	0.055
GAM–JRNP West	–2.395	**0.050**
JRNP Center–JRNP West	2.466	**0.048**
JRNP East–JRNP West	–0.399	0.690

Legend: CAM, Cayos de Ana María; GAM, Golfo de Ana María; JRNP, Jardines de la Reina; Z, multiple comparisons test based on Dunn's ranks with Holm correction. Bold are statistically significant. See Table 13.3 for sample size

Cuban Red List of Endangered Species currently includes only four elasmobranch species and the only regulation related to elasmobranchs in Cuban fisheries is a ban on shark finning (Resolution 252/14 Ministry of Food Industry). This conservation gap needs to be addressed. There are several elasmobranch species protected by neighboring political jurisdictions. For example, landings of the Caribbean reef shark are prohibited in the US commercial shark fisheries (Garla et al. 2006b). Harvest, possession, sale, and exchange of the great, scalloped, and smooth hammerheads, lemon sharks, and tiger sharks are prohibited within the Florida state waters (FWC 2011). The Bahamas EEZ fully protects all sharks through a ban on commercial and recreational fishing of sharks and trade of all shark products since 2011 (NOAA 2011, Regulation 36D). In April 2015, the Cayman Islands established full legal protection for all shark species and other elasmobranchs in its EEZ (Ormond et al. 2017). In Mexico, a moratorium on the issuance of shark fishing permits was imposed in March 1993 as a precautionary measure to prevent overfishing of shark resources (Castillo-Géniz et al. 1998) and is still in place (Márquez-Farias, personal communication). Shark finning is prohibited and whale sharks are protected by regulations of the Organization for Fisheries and Aquaculture of Central America (OSPESCA) since 2011 (FAO 2018). OSPESCA is a legally binding framework and its members are Belize, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. In addition, Honduras and the Dominican Republic have totally banned all types of shark fisheries in their waters (FAO 2018).

Like in the rest of the world, elasmobranchs in Cuba are under pressure from commercial fisheries, recreational fisheries, tourism, diving/snorkeling, coastal communities, scientists, conservationists, and the general public. Management is even more complicated due to the amount and diversity of fishing gear used; poor data on landings and effort, including incomplete records at species level, misidentification of species, and multiple causes of fishing mortality poorly understood and recorded; and evidence of overfishing. Such a complex scenario exceeds the scope of any single agency and requires a comprehensive approach to accomplish elasmobranch conservation and sustainable use.

Elasmobranch fisheries in Cuba are largely data deficient, which prevents us from making robust conclusions about the status and trends of shark and ray populations. However, overfishing of sharks is a likely scenario in Cuba. Our results are consistent with Baisre's (2018) conclusion that sharks in Cuba were overfished, with a 79% decline in landings. First, shark landings follow a decreasing trend since the 1980s. Second, ray landings also follow a decreasing trend since the 1980s. Third, declines in shark and ray landings could not be explained by effort reduction. Fourth, contribution of shark landings to total landings has decreased since the 1980s. Fifth, the contribution of a group of three shark species (the highest) to shark landings has decreased since the 1990s. Sixth, more than half of the shark species with size data available, in at least two periods between the 1980s and the 2010s, show a decreasing average size and average size below maturity size. Seventh, recent data show size- and sex-induced impacts of fishing (similar sizes between sexes and smaller specimens in the most important elasmobranch fishing zones). Eighth, in surveys conducted between 2015 and 2017, sex ratio of shark and ray landings differs from the expected 1:1, with predominance of females. These findings deserve further study but should be taken into consideration now for the development of management and conservation strategies in Cuba.

The Caribbean reef shark is the most frequently sighted species of carcharhinid in Cuban coral reefs. Caribbean reef shark populations show traits typical of this species in insular, low-latitude reef systems: residency, occurrence of all life stages, use of fore reef, reef crests and lagoons, and spring/summer mating and parturition.

Findings related to movement patterns in Cuban sharks are consistent with other studies. Some individuals show high site fidelity and others travel relatively long distances. More than half of the movements took individuals out of MPA protection. These findings are relevant to Cuban MPA design if conservation and sustainable use of sharks and rays is prioritized. According to Ferro-Azcona et al. (see Chap. 22), almost 60% of the Cuban MPAs are smaller than 100 km^2 and almost half are under management categories that do not include fisheries regulations. Only 20% are larger than 100 km^2 and are under management categories that have fisheries restrictions. Thus, we hypothesize that most Cuban MPAs do not properly protect sharks and rays. Testing that hypothesis is important for conservation and sustainable use of elasmobranchs in Cuba. Spatially speaking, effective conservation of elasmobranchs requires an ecosystem-based management approach, including a zoned management plan in which a fairly large no-take reserve with diverse interconnected habitats is surrounded by a larger fishing regulated area. Management of fisheries and alternative livelihoods such as tourism (Graham et al. 2016; Haas et al. 2017; Figueredo-Martín and Pina-Amargós (see Chap. 23)) are complementary tools to protect species that move dozens of kilometers and beyond.

The JRNP appears to be protecting a portion of its sharks and rays populations, particularly during the young and juvenile phases. About half of shark and ray recaptures show specimens that have not left the MPA. In addition, all resightings have been made near the tagging site, and sex ratio for three shark species in the MPA is 1:1. Finally, the Caribbean reef shark population seems to be increasing in the entire MPA, and it is more abundant and shows a more balanced size composition in the zone with the highest protection level (JRNP Center). Environmental changes do not seem to influence those patterns. The JRNP meets all five criteria associated with effective MPAs identified by Edgar et al. (2014), as it (1) is larger than 100 km^2 (about 2000 km^2); (2) is isolated (minimum distance from mainland of more than 60 km); (3) is well monitored and enforced (permanent cooperative surveillance of the MPA by fisheries inspectors, tourism company, and national park administrator); (4) is partially no-take (only lobster fishing and catch-and-release recreational fly fishing allowed); and (5) has met these criteria for more than 10 years (25 years).

However, the JRNP is vulnerable to fishing. The waters surrounding the park are the main fishing ground for elasmobranchs in Cuba, with almost half of the nation's total catch of sharks and rays. Around half of the tagged and recaptured specimens moved out of the MPA limits and were caught by commercial and spear fishers. Most of them were adult sharks. That is the most likely cause of the dominance of immature specimens and of the spatially related size composition observed in the JRNP.

Elasmobranch movements studied in Cuba are not limited to Cuba's EEZ. Our data, and several previous studies, show connectivity with México, the Cayman Islands, the Bahamas, the USA, and beyond. Regional management and protection actions are needed for the conservation of migratory elasmobranchs.

Opportunities for the conservation of reef sharks and rays include, but are not limited to, the use of several tools: sanctuaries (ban on shark and ray fisheries in territorial waters or the EEZ); closed areas; catch limits; and gear prohibitions (particularly gillnets and longlines as they are the most efficient ones to catch sharks and rays) (MacNeil et al. 2020). The use of those alternatives depends on nation context and trade-offs, including details at smaller spatial scales such as Cuban fishing zones and different use of fishing grounds by specific fishing ports. However, for many heterogeneous and multi-species fisheries, it can be challenging to establish very specific control measures, and in practice, they can prove to be inoperable. In these circumstances, an effective solution to reduce fishing mortality is to establish temporal restrictions. Concomitant with technical specifications on fishing gear, temporary closures have the advantage of protecting species as a group. The time window for prohibiting capture should be established based on the biology of the main species and also considering the most vulnerable species. Research efforts should focus on the generation of fishery-dependent relative abundance indices, on the identification of nursery areas in Cuba, and on documenting the average weight of catches by species as indicators of the fishery, following recommendations of NPOA-Sharks.

In summary, many elasmobranch species in Cuba have strong affinities with its coral reefs. These species have high fisheries and tourism importance, and many are considered threatened at a global scale; however, legal protection in Cuba is very limited. Stakeholders utilizing elasmobranchs are diverse and fisheries are multi-gear and data deficient; consequently, a strong coordination among several sectors for sound management is required. Status and trends of elasmobranch populations in Cuba are uncertain, but they seem to be at low levels and decreasing, likely due to overfishing. Movement patterns of surveyed species are consistent with those of other zones of their distribution range and are not limited to Cuba; they include neighboring countries and beyond. Cuban MPAs do not seemingly play a significant role in elasmobranch protection, except the JRNP, and even this MPA is at risk of fishing impacts. Other potential examples may exist, but have not been documented. Despite this complex scenario, there are management options available that include larger MPAs, temporal restrictions, traditional and modern fisheries tools, and non-consumptive uses such as SCUBA diving and snorkeling ecotourism, all with positive examples in Cuba where stakeholder actions and political will converge for the common good.

Acknowledgments The authors wish to dedicate this chapter to Dr. Darío Guitart Manday for his gigantic contribution to shark research in Cuba. The authors thank the many institutions and their personnel that have advanced shark and ray research and conservation in Cuba through cooperative projects in recent years: Center for Marine Research of the University of Havana, Center for the Research of Coastal Ecosystems, Center for Fisheries Research, Ministry of Food Industry, National Center for Protected Areas, Wildlife Conservation Society (WCS), MarAlliance, Mote Marine Laboratory, Environmental Defense Fund, and World Wildlife Fund. Special thanks to Avalon-Marlin for logistical support in Jardines de la Reina and to the WCS Cuba Program for supporting this endeavor. We greatly appreciate the work of editors and anonymous reviewers for their critical comments that have improved this chapter.

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