ELASMOBRANCH CONSERVATION PROGRAM ON THE COLOMBIAN ATLANTIC COAST

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RESUME

Sharks and rays present great biological fragility and due to the intense regimes of artisanal fishing which are exposed in the Colombian Atlantic coast, it is necessary to establish a management and conservation strategy that contemplates the protection of their nursery areas. A review of existing literature was carried out in relation to the reproductive biology of sharks and rays; likewise, for threats to locate priority management areas on the Colombian Atlantic coast through complementarity analysis and various selection criteria. Three quadrats were found in four management priority levels: level 1 included the area adjacent to the Gulf of Morrosquillo; level 2 the areas of Bahía de Santa Marta; level 3, the coastal areas of the department of La Guajira. In turn, 3 anthropogenic threats were tracked: Illegal, unreported and unregulated (IUU) fishing; habitat destruction and climate change. The analysis of space-time variables in a geographic information system indicated that 71% of commercially important shark and ray species are concentrated in the coastal zone, mainly in bays, coastal lagoons, estuaries, and marshes (central and southern regions), during the dry season (May to August). The protection of these critical recruitment areas (critical habitats) in the seasons of maximum reproduction and breeding must be a fundamental part of the resource management plan.

Keywords: conservation, sharks, rays, estuaries, Colombian Atlantic coast, Kankuamo indigenous people.

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INTRODUCTION

Sharks and Rays are a vulnerable fishery resource and susceptible to overfishing as they are characterized by low reproductive potential, small number of offspring, long gestation periods and slow growth, and require a long period to reach sexual maturity (Walker 1992, Castro 1993). In addition, factors such as increased fishing effort and degradation of important nursery sites in coastal, estuarine, and freshwater habitats cause population declines (Camhi et al. 1998, Stone et al .1998). Therefore, it is recognized that their breeding and nursery areas are critical habitats of vital importance to maintain the continuity of recruitment (SEMARNAP 2000a, Anislado and Robinson 2001, Heupel and Simpfendorfer 2002, Heupel et al. 2007) .

Nursery areas are geographically discrete zones in the spatial distribution range of a species where gravid females release their young or deposit their eggs, and where the young spend their first weeks, months, or years of life (Castro 1993). In the breeding areas, the adults congregate to mate and these do not necessarily coincide with the breeding areas (Hanchet 1988, Castro 1993). Sharks and Rays migration to shallow waters is a prevalent behaviour, since there are records of nursery areas in fossilized marine communities from more than 320 million years ago (Lund 1990).

Various works related to Sharks and Rays breeding areas have been carried out. Castro (1993) determined, through the presence of gravid females with embryos close to expulsion, neonates and young, that Gulf of Morrosquillo, in the northern part of Colombia, is a nursery area for nine species in spring and summer; while the region of northern Magdalena and the Guajira is used for the same purposes by Great Hammerhead (Sphyrna mokarran), and the lagoons of the eastern coast of Magdalena are the main breeding areas for Sicklefin Devil Ray (Mobula tarapacana). Simpfendorfer and Milward (1993) examined the composition of catches and diets of members of the family Sphyrnidae and Mobulidae in Santa Marta Bay, Caribbean Sea, and found that the permanence of young individuals in the nursery areas depends on the abundance of prey. Heupel and Simpfendorfer (2002) estimated natural and fishing mortality rates using telemetry data from young Smalltail Shark (Carcharhinus porosus) and concluded that they are more vulnerable during their stay in breeding areas.

Priority management zones (marine reserves) are marine protected areas (MPAs) or non-fishing areas designed under the principle of connectivity, which provide benefits such as stock recovery, conservation of reproductive and recruitment aggregation sites, increase in catches in contiguous areas, decreased overfishing of vulnerable species, and economic enhancement through tourism (FCRR 1997, Bonfil 1999, Dahlgren and Sobel 2000, Roberts et al .2001).

Some of the disadvantages of using MPAs as a fisheries management tool are: the concentration of fishing effort in smaller portions of the stock, obvious long-term economic benefits for fisheries, conflicts between various fisheries, community resistance to their implementation and to fishermen. Sharks in particular, there are two aspects that complicate the application of MPAs, their limited usefulness with highly migratory species and the difficulty of including habitats where all life stages are represented (FCRR 1997, Bonfil 1999).

Worldwide, MPAs established for sharks are of three types. The first is the informal MPAs, designed through

government legislation for the protection of some species vulnerable to overexploitation in waters under their jurisdiction; for example, those established. Then there are the official or formal MPAs, whose purpose is to protect species for ecological purposes. The third type are no-take areas (marine reserves) that are used as fisheries management tools, of which until before 1999 only one existed in Ecuador to protect spawning stocks of Smalleye Hammerhead (Sphyrna tudes), Scalloped Hammerhead (Sphyrna lewini), Spinetail Devil Ray (Mobula mobular), Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana), in recent years they have been implemented in the Colombia for dusky, dusky and nocturnal sharks, and in India for nine shark species (Bonfil 1999, ICSF 2001).

Regarding Mexico, the Official Mexican Standard NOM-029-PESC-2006 establishes ten refuge areas to protect the reproduction and/or birth of sharks and rays during the month of June of each year, of which three are found in the Colombian Atlantic coast; however, no closed areas and seasons are specified because there is insufficient knowledge of the reproductive areas and seasons (Alejo–Plata et al. 2007, SAGARPA 2007a).

Total shark production in the Colombian Atlantic coast was 12,089 t in 2006, which represented 67% of Colombian production in the Atlantic, with a value of $122,933 thousand pesos (SAGARPA 2006). Unfortunately, 50% of the production of commercially important species in this area is made up of immature organisms and gravid females (Madrid et al. 1997, SAGARPA 2007a). For this reason, it is essential to identify the breeding and breeding areas of sharks, so that there is the possibility of protecting them against the obvious signs of overfishing (Camhi et al.1998, Anislado and Robinson 2001). The objective of this work was to detect shark breeding and breeding areas in the Colombian Atlantic coast and to identify the seasons of maximum use by these species. Finally, this information was used together with a series of basic attributes of the different shark species to suggest potential priority areas for management.

It is important to clarify that the use of MPAs as a conservation and fisheries management strategy is complicated due to the historical imprecision that has arisen in understanding the concept of nursery areas for sharks, and given the lack of standardized criteria to identify them (Heithaus 2007 , Heupel et al.2007). Most of the authors suggest that these areas are beneficial for the young given their availability of food and protection against predators; therefore, these are considered as the main criteria to identify them (Springer 1967, Bass 1978, Branstetter 1990).

Currently, the concept has been expanded and improved, and the possibility of defining these zones using three quantitative criteria for organisms less than one year old has been raised: (1) sharks are more common to find in this area than in others, (2) individuals have a tendency to stay or return for long periods (weeks or months), and (3) the habitat is used repeatedly over the years. With this perspective and considering the characteristics of the life histories of the species (birth size, growth rate,et al. 2007, Kinney and Simpfendorfer 2009).

Numerical records of gravid females and hatchlings in the Colombian Atlantic coast are limited; even the information present in the literature is often anecdotal because there was no clear theoretical framework for all the data that must be recorded and documented for the study of the reproductive biology of elasmobranchs. For this reason, the breeding areas identified in this work can be considered potential and its proposal is a heuristic exercise on the possible priority areas for management carried out with the best information available in the region.

MATERIALS AND METHODS

The compilation and analysis of published literature, theses and technical reports containing information on behavior and reproductive biology of commercially important shark species in the Colombian Atlantic coast was carried out, in order to identify breeding and breeding areas and seasons, which were selected using the criteria established by Castro (1993):

• To identify and propose sites as a breeding area, the literature had to handle information regarding females with copulation scars, pregnant females with embryos in early stages of development, females and males in the reproductive phase, and a sex ratio close to 1: 1.

• In order to designate an area as a nursery area, the literature should include information pertaining to pregnant females with embryos in late stages of development (close to expulsion), and the presence of neonates and young individuals in the captures.

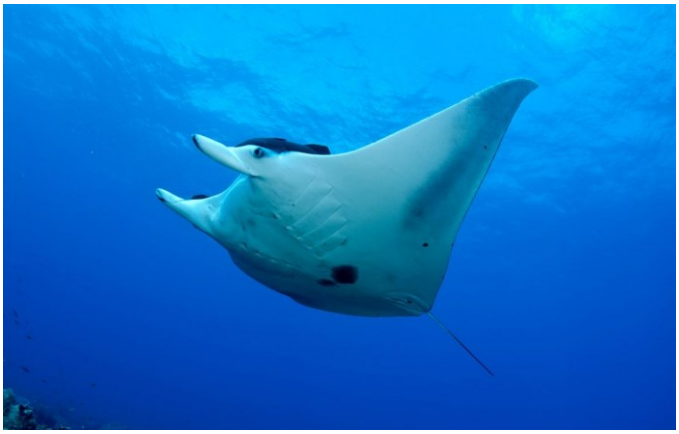
Common name	Scientific name	IUCN conservation status
Great Hammerhead	Sphyrna mokarran	Critically Endangered (CR)
Scoophead Shark	Sphyrna media	Critically Endangered (CR)
Smalleye Hammerhead	Sphyrna tudes	Critically Endangered (CR)
Scalloped Hammerhead	Sphyrna lewini	Critically Endangered (CR)
Spinetail Devil Ray	Mobula mobular	Endangered (EN)
Atlantic Pygmy Devil Ray	Mobula hypostoma	Endangered (EN)
Whitespotted Eagle Ray	Aetobatus narinari	Endangered (EN)
Sicklefin Devil Ray	Mobula tarapacana	Endangered (EN)
Oceanic Manta Ray	Mobula birostris	Endangered (EN)
Bentfin Devil Ray	Mobula thurstoni	Endangered (EN)
Sandbar Shark	Carcharhinus plumbeus	Endangered (EN)
Venezuelan Round Ray	Urotrygon venezuelae	Endangered (EN)
Blacknose Shark	Carcharhinus acronotus	Endangered (EN)
Bonnethead Shark	Sphyrna tiburo	Endangered (EN)
Basking Shark	Cetorhinus maximus	Endangered (EN)
Little Gulper Shark	Centrophorus uyato	Endangered (EN)
Shortfin Mako	Isurus oxyrinchus	Endangered (EN)
Caribbean Reef Shark	Carcharhinus perezi	Endangered (EN)
Dusky Shark	Carcharhinus obscurus	Endangered (EN)
Whale Shark	Rhincodon typus	Endangered (EN)
Oceanic Whitetip Shark	Carcharhinus longimanus	Endangered (EN)
Atlantic Nurse Shark	Ginglymostoma cirratum	Vulnerable (VU)
American Cownose Ray	Rhinoptera bonasus	Vulnerable (VU)
Bentfin Devil Ray	Mobula thurstoni	Vulnerable (VU)

Table 1. Threatened species found at the project site. **Source**: our study

Breeding and breeding areas and seasons

The Colombian Atlantic coast was divided into three regions based on the capture areas that are managed in the shark fishery (Castillo–Géniz et al. 2000, CONAPESCA–

INP 2004). The information collected on breeding and breeding areas and seasons of the species was incorporated into a geographic information system in order to detect similarities and differences through space-time analysis (ESRI 1999).



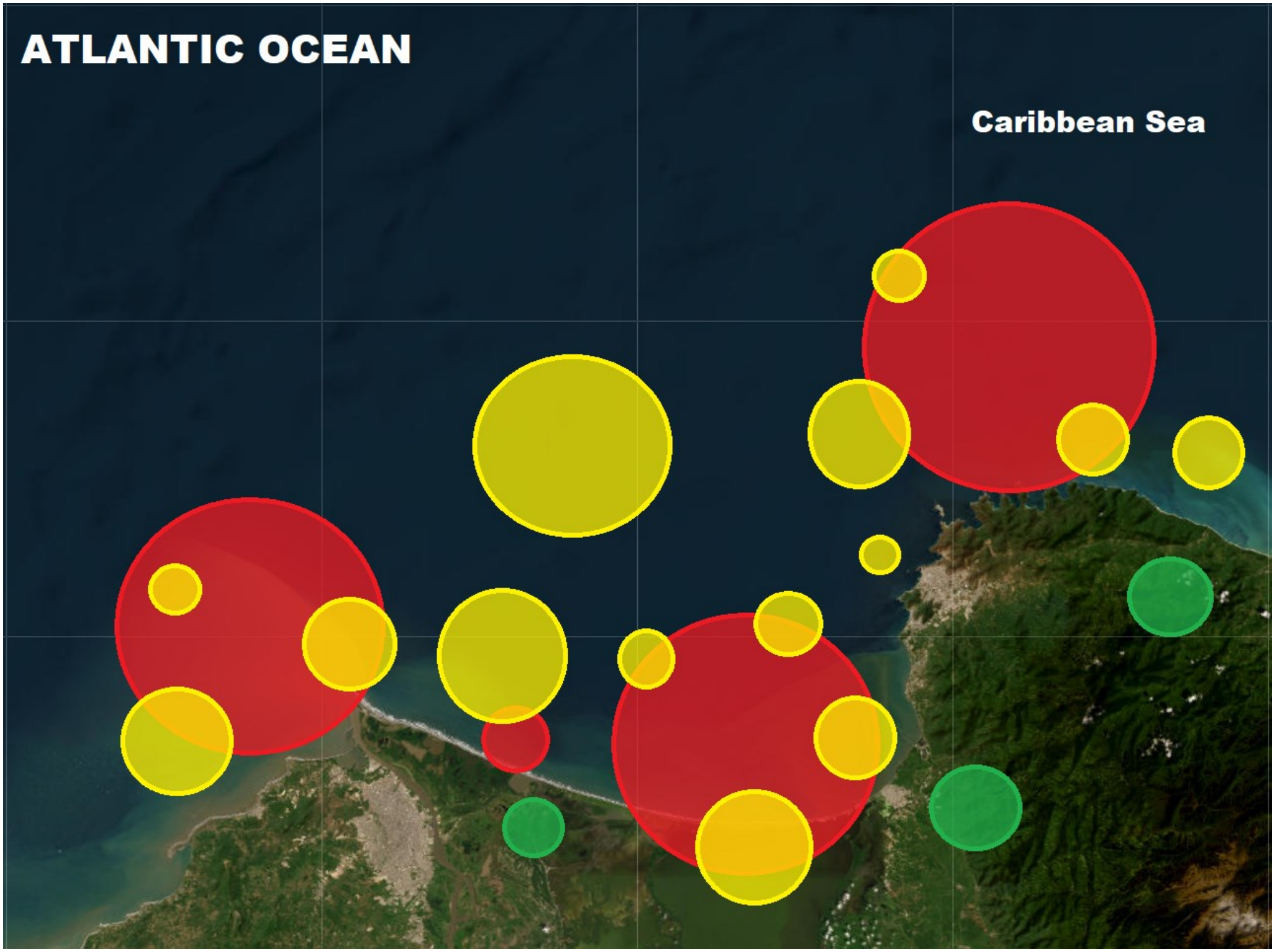
Priority management areas

For the analysis, geographic quadrants of 1° latitude x 1° longitude were used, in which the shark breeding and breeding areas were located (fig. 1). To classify the quadrats in priority conservation order, a complementarity analysis was performed (Humphries et al. 1991, Scout et al. 2001). This method allows maximizing the number of species that would be protected in a given region of the study area (in this case, the coastal area of the Colombian Atlantic coast) while designating a minimum number of areas for their protection, which are two fundamental criteria for the optimization of conservation efforts (Vane–Wright et al. 1991, van Jaarsveld et al.1998).

The complementarity technique has become key to defining relevant areas since, at the investigator's discretion, both ecological and phylogenetic aspects of the group of interest may be involved (Rodrigues and Gaston 2002, Faith et al. 2003).

It is a technique widely used in terrestrial environments (Sarkar et al. 2006), and in Mexico it has been used specially to analyze the situation of mammals and plants (Contreras-Medina et al. 2001, Ceballos 2007). For marine species this algorithm has been used in the definition of priority areas for bony fish protection in Colombia (Turpie et al. 2000, Fox and Beckley 2005, Tognelli et al. 2005, Geselbrachtet al. 2009), but this is its first application to the case of cartilaginous fish.

Based on the bibliographic review, in the present study the following criteria were considered for the selection of areas (tables 1 , 2 and 3): (a) total number of species that reproduce and/or use nursery areas in each quadrant , (b) presence of species with low fecundity (less than 10 potential offspring), (c) presence of species that mature to sizes greater than 200 cm in total length, (d) presence of species with limited breeding sites, (e) presence of species whose captures are more important (Castillo-Géniz et al. 2000, Smith et al. 2009), and (d) presence of species considered first category due to the commercial value of their fins (Smith et al.2009).



ELASMOBRANCH CONSERVATION PROGRAM ON THE COLOMBIAN ATLANTIC COAST

CONVENTIONS

	IUU fishing zones
	Breeding, breeding and foraging areas of elasmobranchs
	NARAKAJMANTA indigenous communities

SCALE

1 cm = 1,000m

SOURCES:
-IMAP, conservation biodiversity monitoring
-ENVIRONMENTAL WOMEN, 2020.

LOCATION

1. Country: COLOMBIA
2. City: Santa Marta, Magdalena.
3. Body of Water: Caribbean Sea, Atlantic Ocean
4. Project site: 98Km2 coastline in the Kankuamos indigenous territory
5. MPA: **TAYRONA National Natural Park, WDPA ID 152**
6. Geographic coordinates: From 11°19'18.5"N 74°09'37.3"W to 11°15'54.0"N 73°49'17.3"W

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Finally, maps were prepared specifying the priority quadrants for conservation with respect to each criterion and a final one resulting from the integration of all the criteria, which represents the relative levels of importance for the management of each shark breeding and breeding

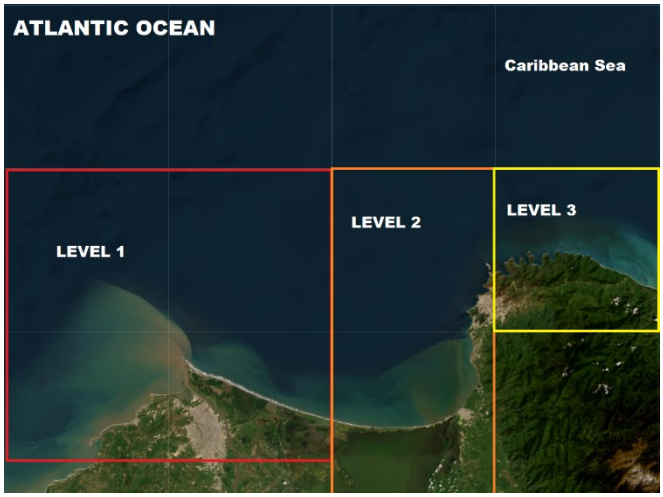


Image 1. Projet levels.

area. In addition, the analysis of discrepancies or spaces was carried out to detect how many of the identified priority management areas correspond to an AMP. The map was constructed using the ArcView 3.2 program (ESRI 1999).

RESULTS

Commercially important species

Based on the literature, it was established that there are records of nursery and reproduction areas of 14 shark species of commercial importance in the Colombian Atlantic coast, distributed in six families: Carcharhinidae, Sphyrnidae, Triakidae, Squatinidae, Lamnidae and Alopiidae (table 1).

The six species that presented the most records in terms of breeding sites were: Carcharhinus limbatus, Sphyrna lewini, Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari).

Shark breeding and breeding areas and seasons

In the Upper Colombian Atlantic Coast R. longurio, Mustelus henlei and S. californica congregate for breeding purposes in spring. The central region of the Colombian Atlantic coast is used as a breeding, birthing and rearing area by several species during the spring and summer peak use seasons: in San Francisquito and El Barril, Baja Magdalena (BC), congregations of R have been observed. Smalleye Hammerhead (Sphyrna tudes), Scalloped Hammerhead (Sphyrna lewini), Spinetail Devil Ray (Mobula mobular), Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana).

Similarities and differences in the temporality of the reproductive and rearing cycle

71% of commercially important shark species that breed and use nursery areas in the Colombian Atlantic coast complete their cycle during the spring and summer seasons, with the exception of four Smalleye Hammerhead (Sphyrna tudes), Scalloped Hammerhead (Sphyrna lewini), Spinetail Devil Ray (Mobula mobular), that differ in this behavior. Little angel (S. californica) has breeding and breeding areas from Bahía de Los Ángeles, BC, to Bahía de La Paz, Baja Magdalena Sur (BCS), but also in Sonora during winter–spring. The blue fox (A. pelagicus) congregates for reproductive purposes in the central region of the Colombian Atlantic coast and in the area adjacent to Mazatlán in autumn, winter and spring. The species Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana) breed in the southern gulf region in winter and spring.

Priority management areas

As a result of the bibliographic review, 19 shark breeding and breeding areas were identified in the Colombian Atlantic coast present in 13 quadrants, of which six correspond to Sonora and Sinaloa and seven to BC. Of the 13 quadrants, only three (5, 10 and 12) presented reproductive activity of five species or more, highlighting among them quadrant 12.

According to the complementarity analysis, the priority areas for management based on the total number of species that breed and use nursery areas per quadrant are found in quadrants 12 (zone adjacent to Mazatlán), 9 (El Sargento , La Ventana and Punta Arenas, BCS), 5 (San Francisquito and El Barril, BC, and Bahía Kino), 4 (Seri zone of Sonora) and 13 (Bahía de Teacapán, Sinaloa). Considering species with fecundity of less than 10 potential offspring per breeding season, the main breeding and breeding areas that should be considered as priority areas for shark management are in quadrants 12, 6 (La Manga, Sonora), 4 and 13 Based on the criteria of species that mature at sizes greater than 200 cm in total length, priority management areas are located in quadrants 5, 9 and 13, but starting from the species with a limited number of breeding and breeding sites, the priority quadrants would be 12, 9, 5, 4 and 13. Figure 2e shows quadrants 12, 9, 6 and 4 as the most important considering, by quadrant, the number of species most fished in the Colombian Atlantic coast. Finally, quadrants 12 and are the priority ones for the management of shark species based on those whose fins are considered first class for commercialization.

Priority levels for management of shark breeding and breeding areas

Integrating the conservation priority quadrants based on each of the criteria (a–f), four levels of relative importance were identified for the management of breeding and breeding areas. The first level corresponds to quadrants 12 and 9, the second to 13 and 4, the third to 5, and the fourth to 6. By managing the six aforementioned quadrants, all species that use the Colombian Atlantic coast for breeding and reproduction would be protected.

Finally, it was observed that of the six key quadrants or regions identified, only one (16.7%) had an AMP.

DISCUSSION

Commercially important species

Of the 24 species of sharks that are captured in the Colombian Atlantic coast (Villavicencio–Garayzar 1996c, Castillo–Géniz et al. 2000, Villavicencio 2000) there were reports of nursery and reproduction areas for 14, with Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana) for having the highest number of records. This is possibly due to three situations: (a) they are the most fished in the study area; (b) for this reason there is more information, since the data generated in the coastal fisheries are used; and (c) the resource is accessible for observation during its reproductive aggregation seasons in the coastal zone (Villavicencio–Garayzar 1996c, Castillo–Géniz et al.2000, Alejo-Plata et al. 2007).

Breeding and breeding areas and seasons

The onset of the mating, gestation, births, and rearing season depends mainly on temperature (Pratt and Casey 1990). In the Colombian Atlantic coast, the temperature reaches its minimum values of 18–19°C in April (spring) and begins to increase until it reaches its maximum, between August and September (summer), of 30–31°C (Álvarez– Borrego et al. 1978, Garcia–Pamanes and Lara–Lara 2001). During this period the tropical sharks (Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana) find in the Colombian Atlantic coast the biotic and abiotic conditions that will allow neonates to grow rapidly to incorporate into the population of juveniles and adults (Castro 1993, Castillo–Génizet al. 2000, Mendizabal et al. 2000, Alejo-Plata et al. 2007).

In the Colombian Atlantic coast, mainly in the central and southern regions, the most important upwellings occur in winter-spring (Álvarez-Borrego and Schwartzlose 1979,

García-Pámanes and Lara-Lara 2001), favoring the increase in primary productivity that In turn, it will enrich the primary sources of food for neonate and young sharks in the nursery areas (coastal lagoons, bays, estuaries, and marshes) during the months of maximum reproductive congregations, May to August (Villavicencio 2000). In addition, the Magdalena Current enters the Colombian Atlantic coast in winter and early spring, which favors the migration of blue, mako and blue thresher sharks in those seasons to the southern region of the gulf, to carry out their reproductive cycles. and breeding (Mendizábal 1995, Arias 1998, Mendizábalet al. 2000).

Similarities and differences in the temporality of the reproductive and rearing cycle

Castro (1993), Simpfendorfer and Milward (1993) and Alejo–Plata et al. (2007) mention that common use of a breeding area by several shark species occurs because food availability is high. This behavior was observed in Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana) a during the season of maximum breeding in spring–summer (May to August); while cold-to temperate-water sharks, such as mako, blue, angelito, and blue fox, present breeding and breeding seasons corresponding to winter and spring (see tables 1 and 4), mainly at the mouth of the Colombian Atlantic coast (Mendizábalet al. 2000, Villavicencio 2000).

Priority management areas

Several authors (Castro 1993, Klimley et al. 1993, Simpfendorfer and Milward 1993, Bonfil 1997, Anislado and Robinson 2001) have documented that the horizontal movements carried out by sharks towards shallow waters are an evolutionary strategy that has been maintained throughout their history of life and therefore these should be considered as critical areas to conserve stock/recruitment relationships (Lund 1990, Castro 1993, SAGARPA 2007a).

The priority quadrants for management are in the central and southern regions of the Colombian Atlantic coast, where the most important upwelling zones occur. Possibly its high primary productivity allows the establishment of important concentrations of squid, sardines, mackerel and anchovy, which in turn support populations of large predators, such as sharks, when they approach the coastal zone for reproductive and breeding purposes (Álvarez – Borrego et al. 1978, Castillo-Géniz et al. 2000, Villavicencio 2000).

The main problems in designing MPAs for sharks lie in being able to include in them most of the habitats where they spend their different life stages, and implement them for highly migratory and oceanic species Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana) due to its wide distribution, which would imply protecting very large areas, an impossible task to achieve (Nakano 1994, Bonfil 1999, Mendizábal et al. 2000); for this reason, in this work we considered the centers of reproductive congregations where the species coincide in the coastal zone and the characteristics of their life histories as selection criteria, in order to choose few interconnected areas, which meets a fundamental requirement for the conservation of fishing resources to be feasible (Bonfil 1999, Contreras-Medina et al. 2001) .

Priority levels for management of shark breeding and breeding areas

The 13 quadrats detected in this study are all important because they represent possible areas of reproductive congregations (Cudney and Turk 1998, Mendizábal et al. 2000, Villavicencio 2000, Márquez et al. 2005), but they present different levels of priority. if you want to achieve optimal management of the breeding and breeding areas identified with the complementarity analysis. In the quadrants corresponding to priority level 1, quadrants 12 and 9, six main species Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari)

and Sicklefin Devil Ray (Mobula tarapacana) would be protected in the first and to I. oxyrinchus and P. glaucaIn a second. In level 2, in quadrants 13 and 4, C. leucas and M. henlei would be protected, respectively; while at level 3, the three species that would be being managed in quadrant 5 would be Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana)) and S. californica (Kino Bay). Finally, within level 4, C. obscurus would be protected in quadrant 6. With the protection of the aforementioned zones, a more adequate management of the resource in the Colombian Atlantic coast would be ensured because they are complementary sites with respect to the species.

In the Colombian Atlantic coast, the main sources of fishing mortality (fishery production and number of vessels) for sharks are found in order of importance in sites in Sinaloa, BC, BCS and Sonora, which is consistent with the levels of priority detected in the present work. This is due to the correspondence that exists between the fishing zones and the reproduction and breeding areas in their main seasons (Villavicencio–Garayzar 1996c, Bizarro et al. 2007).

The Colombian Atlantic coast is the area with the highest annual production of sharks in the entire Mexican Pacific. The possible implementation of the six priority management areas proposed in this paper for multispecies shark fisheries could have strong socioeconomic impacts on riparian communities if they depend exclusively on this activity for their subsistence. To deal with this situation, the administrative authorities of the MPAs and the fishermen must work together to avoid conflicts; In addition, complementary or alternative activities focused on the use of other resources, such as tourism, for the communities would have to be sought (FCRR 1997; Bonfil 1997, 1999; SAGARPA 2006).

The establishment of protection zones can cause an impact on fisheries other than the one that is sought to be protected and lead to the failure of their implementation; For example, the US National Marine Fisheries Service attempted to close shark nursery areas to fishing, but this measure was rejected due to a lack of research on the subject and the adverse effect it would have on the shrimp fishery. This same problem arose in Australia when trying to implement MPAs for Squalus acanthias, since it is frequently caught incidentally in trawls (Castro 1993, Bonfil 1999). The same situation could occur in the Colombian Atlantic coast in the event that they wanted to implement protection zones for Atlantic Pygmy Devil Ray (Mobula hypostoma), Whitespotted Eagle Ray (Aetobatus narinari) and Sicklefin Devil Ray (Mobula tarapacana), since these species are constantly trapped in the gillnets used to capture scale (Anislado and Robinson 2001, Pérez–Jimenez and Sosa-Nishizaki 2008).

Regarding the knowledge of the nursery areas in the Colombian Atlantic coast, there is no analysis of the size structure of gravid females and hatchlings, nor of their local or seasonal movements (Heupel et al. 2007). Regarding the residence time of the neonates, it is unknown if the zones are primary or secondary; or with respect to the degree of exposure to predators, whether the areas are protected or open zones (Bass 1978, Branstetter 1990, Heupel et al.2007). Therefore, it should be clarified that information is needed to be able to propose conservation sites based on robust biological criteria based on abundance, residence and interannual use of these sites by young organisms; therefore, the management proposal presented here is heuristic and may be far from guaranteeing true protection. However, the reports from the various bibliographic sources reviewed (see table 3) indicate the presence of hatchlings and gravid females, so they cannot be definitively ruled out as critical habitats since the number of individuals examined in the reproductive biology studies is unknown, and it is possible that some of them may have been captured in the wild. seasonal migratory route (corridor) or that the fishing gear was not selective for hatchlings, which could be the case for the bibliography that indicates few individuals found. For this reason, it is important that when carrying out

investigations of this type, quantitative data be included and the size structure of gravid females and neonates be analyzed to know if it really is a breeding area (Beck et al. 2001, Heupel et al. 2007).

The Official Mexican Standard NOM-029-PESC-2006 establishes the Bahía Santa María-Altata complex and Bahía de Teacapán, in Sinaloa, and the lower Gorda and Espiritu Santo, in BCS as refuge zones to protect reproduction and growth. shark birth in the Colombian Atlantic coast (SAGARPA 2007a) which differs from our results, since it only coincides in the area adjacent to Teacapán; however, the law does not include most of the priority management areas described in the present heuristic proposal (fig. 3), leaving out sites that were considered very important in this study such as Mazatlán, in Sinaloa; El Sargento, La Ventana and Punta Arenas, in BCS; the San Francisquito–El Barril marine area, in BC; and the Seri zone, Bahía Kino and La Manga, in Sonora. This is because the information available on the number of pregnant females and neonates in the compiled and reviewed sources is not robust enough to identify breeding areas with the current quantitative approach (Heupel et al. 2007), and the data needed to determining these essential habitats in the Colombian Atlantic coast have been interpreted broadly and liberally, and are based on qualitative definitions with insufficient criteria that only refer to the presence of these organisms (Heithaus 2007, Heupelet al. 2007, Kinney and Simpfendorfer 2009) (table 3). For example, table 3 shows the characteristics of the life histories of 14 species, of which only six have qualitative and quantitative information on these stages. Even so, the records are limited to be able to accurately identify an area as a nursery area for sharks. For this reason, a limited number of refuge zones appears in NOM-029-PESC-2006, due to the fact that the information available at the time of its formulation was extremely scarce.

In addition to the above, from the comparison of the priority quadrants for management found in this study with the location of the protected natural areas (ANPs) of the Colombian Atlantic coast, it was observed that only 16.7% of the areas defined here as priority for sharks are part of an ANP ; such is the case of the area of San Francisquito and El Barril, which are sites that are contemplated within the Archipelago of San Lorenzo National Park (SEMARNAT 2006). However, the analysis of discrepancies identified a series of new important areas that coincide with other proposals derived from investigations carried out by the Mexican federal government, such as that of CONABIO–CONANP–TNC–PRONATURA (2007) which is focused on the preservation of the marine biodiversity, ecosystems and relevant ecological processes, and the Marine Ecological Management Program of the Colombian Atlantic coast (SEMARNAT 2006).

The General Law for Ecological Balance and Environmental Protection, and its regulations, establish the bases for the implementation of ANPs (SEMARNAP 1988, SEMARNAP 2000b). Evaluating the legal feasibility of implementing priority areas for shark conservation is an attribution of the federal government that must be based on scientific studies prepared by SEMARNAT and with the collaboration of public or private organizations. These sites could be designated as Flora and Fauna Protection Areas (type of ecological MPA) to conserve fragile ecosystems and processes in compatibility with the provisions of Title Six of the General Law on Sustainable Fisheries and Aquaculture (LEGEPAS), Article 36, with a respective management plan; while from the fishing point of view they would technically be fishing refuge areas or marine reserves (article 32 of LEGEPAS). The application of this type of conservation strategy can be compatible with any resource management plan because the guidelines of the Food and Agriculture Organization of the United Nations (FAO) provide for the protection of critical habitats and vulnerable species, which would be covered by the conservation criteria used in the complementarity analyzes (SEMARNAP 1988, 2000a, b; FAO 2001; SAGARPA 2007a, b).

Finally, with the present work it was revealed that there is not enough fundamental quantitative information to identify more precise shark breeding areas in the Colombian Atlantic coast with the approach currently used by Heupel et al .(2007); In addition, the analysis reflected that the regional knowledge of the subject is based on concepts supported by observations that were not originally designed to examine the functions of these essential habitats (Kinney and Simpfendorfer 2009), which indicates that the possible areas should be subject to to oceanographic, biological and fisheries research that preferably includes pilot programs of marking and recapture of newborn sharks, stable isotope analysis in young individuals, acoustic monitoring, and the application of genetic techniques to verify the fidelity and interannual use of the sites. Besides,et al.2007). However, to achieve such research and monitoring objectives, which could generate the most robust databases for management through MPAs, it is necessary to apply conservation measures as soon as possible due to the state of the populations. The model proposed to determine priority conservation areas for sharks based on complementarity analysis is applicable, with possible implications and modifications, in other regions and for other organisms considered K-strategists; that is, they produce few offspring with a higher probability of reaching adults, have slow growth rates, late sexual maturity, etc. Although the strategy for protecting priority breeding and breeding areas for sharks proposed here is not the only option for their conservation,

PROPOSED CONSERVATION STRATEGIES FOR SHARKS AND RAYS ON THE COLOMBIAN ATLANTIC COAST, ACCORDING TO THE FINDINGS

OBJECTIVES

General Objective 1. Establish a comprehensive strategy for the conservation of elasmobranchs within Colombian Atlantic coast that allows strengthening the management measures and sustainable use of these species, mitigating possible threats to their habitat and incorporating the participation of the main actors and users of the resource.

Specific Objectives

a. Have a coordination framework between the main actors and all the competent instances for the management of elasmobranch populations within the polygons of Colombian Atlantic coast with a marine component.

b. Establish the necessary activities in the short, medium and long term that must be carried out for the conservation of these species, determining success indicators.

c. Establish a working group for the management and conservation of sharks and rays within the Colombian Atlantic coast, which includes all the stakeholders involved.

STRATEGIC AXES AND LINES

I. SUBSTANTIVE AXES

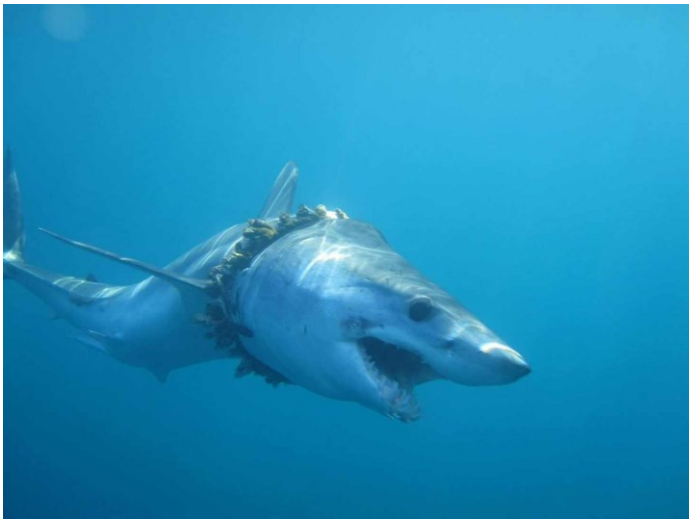
1. Comprehensive Habitat Management Objective: Establish habitat management strategies for sharks and rays under a landscape ecology approach, considering aspects of regional connectivity and large-scale ecological processes, through instruments and mechanisms that ensure the conservation of habitats. species and their function within the ecosystem.

1.1. Habitat Protection Component - Actions that contribute to the protection of shark and ray habitat through various conservation schemes or modalities.

1.1.1. Implement dissemination campaigns aimed at users of the PNA on the regulations on waste and protection of the marine habitat.

1.1.2. Integrate a comprehensive maritime spatial planning scheme that strengthens the zoning of the marine polygons of anp, and that recognizes critical areas for the development of elasmobranchs. 1.1.3. Install signage within the anp polygons that seek to prevent damage to the marine habitat due to grounding, pollution or other nautical contingencies.

1.1.4. Promote the elaboration of official nautical charts for the polygons of marine anp's, in collaboration with SEMAR.
1.1.5. Promote the designation of anp's that contain reef areas, as sensitive areas for navigation.
1.1.6. Promote the use of conservation criteria for essential and critical habitats for sharks and rays in urban and coastal planning processes related to pna.



1.2. Restoration Component - Actions tending to initiate or accelerate the recovery of the habitat of the species with respect to their health, integrity and sustainability, with a focus on landscape ecology.

1.2.1. Prepare risk maps for elasmobranchs in each PA with a marine polygon that indicate the existence of coastal areas in which it is necessary to carry out habitat restoration actions (eg mangroves).

1.3. Connectivity Component - Actions that strengthen the conservation of biological corridors and PA complexes as a strategy to conserve migratory habitat and the connectivity of shark and ray populations.
1.3.1. Promote the integral management of hydrographic basins, taking into account the requirements of each site, in an interdisciplinary, multisectoral and interinstitutional manner.
1.3.2. Promote the exchange of information with foreign researchers specializing in elasmobranchs, to define migratory corridors and connectivity components in the habitat.
1.3.3. Implement satellite and/or acoustic marking programs for highly migratory species, to learn about their distribution, connectivity between priority areas, characterize their habitat use, and identify essential habitats.

2. CONSERVATION AND MANAGEMENT OF SPECIES OBJECTIVE: Develop actions for the recovery of populations of sharks and rays in anp, involving the participation of all relevant actors for their conservation.

2.1. Protection and Surveillance Component – Implementation of coordinated actions for the protection, management and monitoring of shark and ray populations in anp.
2.1.1. Implement an intersectoral collaboration scheme in conjunction with the fishing sector and SEMAR, to reinforce inspection and surveillance actions of authorized fishing activities within polygons of anp.
2.1.2. Promote the use of new technologies that facilitate inspection and surveillance tasks in the marine park of anp.
2.1.3. Implement an inspection and surveillance program that involves the participation of coastal communities related to PNAs with marine polygons.

2.1.4. Promote coordinated surveillance actions in the area of tourism and urban development that involve the three orders of government, to protect critical areas for the development of elasmobranchs.

2.2. Impact Prevention Component - Actions tending to prevent the negative impacts of anthropogenic activities on populations of elasmobranchs and their habitat in anp.
2.2.1. Prepare specific contingency plans for anp's with a marine polygon for cases of hydrocarbon spills, strandings and other nautical contingencies that alter the habitat of sharks and rays.
2.2.2. Generate guidelines for the proper maintenance of fishing or tourist vessels that operate within the PNA polygon, which include specific sanctions for those who fail to comply. 23. Population Management Component - Management actions aimed at the recovery and maintenance of shark and ray populations in anp.
2.3.1. Work together with the fishing sector to carry out a regulation of shark and ray fishing within PNA polygons, which clearly specifies the fishing areas in the permits and avoids exploitation in breeding and breeding areas.
2.3.2. Collaborate with the fishing sector to adopt measures to reduce the incidental capture of elasmobranchs in

artisanal fisheries authorized to be carried out within the polygons of anp.

2.4. Stakeholder Coordination Component - Actions that promote effective coordination between federal public administration, state and municipal governments, academia and social organizations for the conservation of shark and ray species in anp.

2.4.1. Promote collaboration and coordination actions between CONANP and the CITES authorities (Scientific and Administrative) for the dissemination of identification materials for shark and ray species recently included in Appendix II and procedures for obtaining CITES authorizations among fishermen's organizations. interested parties that operate within polygons of anp.

2.4.2. Hold meetings between the different authorities to coordinate supervision, inspection and surveillance actions, with periodic evaluation of the results obtained.

2.4.3. Prepare a regulation for the verification of "friendly" practices to elasmobranchs by tourism service providers in anp, in coordination with the different related institutions.

2.4.4. Promote frequent updating of the National Fisheries Charter with the most recent technical and scientific information.

2.5. Research and Monitoring Component - Actions for the generation of knowledge focused on the management of shark and ray species, which supports decision-making for conservation.

2.5.1. Develop a Geographic Information System that describes the types of habitats that the PAs provide to elasmobranchs, from the perspective of their essential habitat (reproduction, breeding, food, and protection), which supports management and subzoning decisions.

2.5.2. Promote studies that identify areas of birth and breeding of sharks and rays within the anp, in order to prioritize their protection.

2.5.3. Carry out carrying capacity studies for both maritime traffic and tourist activities that could affect elasmobranchs within anp.

2.5.4. Carry out, in collaboration with the fishing sector, research and technology transfer for the improvement of fishing gear that provide greater efficiency and selectivity to the use of sharks and rays within anp.

2.5.5. Promote studies on abundance and condition of shark and ray stocks in PNA, which provide relevant information to implement better management measures and sustainable use.

2.5.6. Implement a strategy for collecting landing information at the species level of sharks and rays captured within the PNA, in order to have the necessary data to feed population dynamics models.

2.5.7. Develop scientific studies that identify the effects of coastal development on critical and essential habitats for rays and sharks.

2.5.8. Strengthen and guarantee the continuity of the on-board observer programs and discharge monitoring during elasmobranch fishing in anp, with coordinated actions between conanp and the fishing sector.

2.5.9. Carry out, in coordination with the fishing sector, studies on the levels of incidental capture of elasmobranchs in finfish fisheries carried out within the polygons of anp.

3. Social Participation and Culture for Conservation Objective: Promote the co-responsible participation of society in the conservation of shark and ray species and their habitats, promoting culture and strengthening the capacities of communities regarding said conservation.

3.1. Culture Component - Actions that promote education, communication and dissemination on the importance of shark and ray conservation.

3.1.1. Implement programs to disseminate the regulations related to sharks and rays among all the actors within the anp

3.1.2. Carry out an awareness campaign to avoid damage to the habitat due to negligence during nautical operations.

3.1.3. Implement Environmental Education programs to disseminate the ecological importance of sharks and rays within the anp.

3.1.4. Promote an education and awareness campaign on the effects of the hydrographic basin on the ecology of PAs with a marine component.
3.2. Social Participation and Training Component - Actions that promote the involvement of communities in shark and ray conservation actions, strengthening their technical and management capacities.
3.2.1. Promote the involvement of the different actors to comply with the regulations regarding the performance of prospective studies for mining and hydrocarbon extraction in areas close to marine PNAs.
3.2.2. Implement training programs on navigation areas to prevent nautical contingencies that alter the marine habitat.

3.2.3. Implement a training program for tourism service providers that operate within the anp, to avoid practices that are harmful to sharks and rays, and their habitat.
3.2.4. Implement a training program for fishermen to learn about the regulations associated with the sustainable use of sharks and rays within PAs.
3.2.5. Carry out training workshops for officials and members of the environmental gendarmerie on the application of the legal framework related to the sustainable use of sharks and rays.

4. Economy of Conservation Objective: Contribute to the strengthening and consolidation of sustainable productive activities that promote the conservation of elasmobranch species and that contribute to the reduction of poverty and marginalization in the areas where they are distributed.
4.1. Sustainable Economic Alternatives Component - Actions that contribute to the strengthening and consolidation of productive activities that promote the conservation of shark and ray species.
4.1.1. Promote sustainable economic activities and productive diversification in support of the communities that inhabit the coastal PAs.
4.1.2. Promote the development of tourist and urban infrastructure to be sustainable, economically, socially and ecologically. 4.2. Biodiversity Valuation Component - Actions that promote the valuation of the goods and services obtained from the conservation of elasmobranch species and their habitat.
4.2.1. Promote, in coordination with the fishing sector, awareness campaigns on alternatives for national consumption of fishing resources whose populations are in a good state of conservation.
4.2.2. Promote an education campaign for the population, promotion of transparency and ethical and responsible performance of public functions and developers regarding the goods and services obtained from the conservation of sharks and rays.
4.3. Economic Instruments for Conservation Component - Actions to implement economic and financial instruments for the conservation of shark and ray species in coordination with other actors and sectors.
4.3.1. Promote and generate mechanisms for the certification of sustainable shark and ray fisheries within PNA polygons, based on certification experiences in operation at the international level.
4.3.2. Evaluate and, where appropriate, avoid adverse subsidies, strengthening instead those that contribute to the sustainable use of sharks and rays in anp.
4.4. Sustainable Use Component - Actions that contribute to the strengthening of activities for the sustainable use of sharks and rays.
4.4.1. Promote social organization and training in community interest groups that inhabit protected natural areas and that take advantage of sharks and rays as a way of life, so that they adopt sustainable use practices.

II. COORDINATION AND SUPPORT AXES

5. Coordination of Intersectoral and Multilevel Policies Objective: Achieve articulation with the three orders of government, national and international institutions and with society in a framework of coordination, linkage, transversality and synergy in public policies and the regulatory framework, which considers ecosystems and goods and services as pillars of sustainable development.
5.1. Issue recommendations for good intersectoral coordination between fishing and environmental instances related to the sustainable use of elasmobranchs in anp.

5.2. Generate intersectoral synergies for standardized monitoring, inspection and surveillance.
5.3. Promote those public policies for tourism development are compatible with the conservation and management of Rays and Sharks.

6. LEGAL FRAMEWORK FOR CONSERVATION OBJECTIVE: To have a robust, harmonized and consistent regulatory framework that allows guaranteeing conservation and sustainable development with the application of public policy instruments according to the competence of each of the instances involved.

6.1. Prepare a diagnosis to identify gaps in the regulations for the protection of sharks and rays in anp, as well as gaps in its implementation.
6.2. Review the PNA Management Programs with a marine polygon to specifically include protection actions towards critical areas for elasmobranchs, such as birthing or aggregation zones.
6.3. Review the regulations on tourism practices within the anp to update or improve them to favor habitat protection.
6.4. Develop nautical tourism regulations within anp's.
6.5. Promote the review and updating of the regulations on prospective and extractive studies of mining and hydrocarbons in the surroundings of the PNA to protect essential habitats for elasmobranchs.
6.6. Regulate the number of vessels that navigate within the polygons of anp's so as to reduce contingencies caused by collisions, strandings or oil spills.
6.7. Review the existing regulations so that legal support is included for the cargo capacity for maritime traffic and tourist activities within the marine polygons of anp.
6.8. Promote the improvement and application of regulations related to the discharge of pollutants into the marine environment, involving the energy, transport and tourism sectors.

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