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Citizen Science as a Tool to Get Baseline Ecological and Biological Data on Sharks and Rays in a Data-Poor Region

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Abstract: The Mexican Caribbean is in one of the regions with the greatest diversity of elasmobranchs in the world. However, the population status of most of the shark and ray species in this region is unknown. We used a citizen science program based on divers to collect data about the diversity, abundance, and distribution of elasmobranchs in this region. We visited dive centers in six locations and performed structured interviews with divemasters, instructors, and owners of the diving centers. In total, 79 divers were interviewed, of which 69% had more than five years' experience diving in the Mexican Caribbean. Divers could identify 24 elasmobranch species for this region. Most of the divers (82%) reported a decrease in sightings of sharks and rays. Rays were the most frequently sighted species by divers (89%), and the spotted eagle ray (*A. narinari*) was the most common elasmobranch species reported in the region. Citizen science was a useful approach gathering for baseline information about sharks and rays in the Mexican Caribbean, increasing our knowledge of the abundance and distribution of some species in this region. Citizen science affords the opportunity to obtain long-term data that can be useful for management and conservation.

Keywords: sharks; rays; monitoring; coral reef; scuba diving

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1. Introduction

Elasmobranchs constitute a diverse group that occupies a wide range of aquatic habitats around the world. Some species spend their lives in the same habitat, but the majority are often mobile and move between different habitats during their lifetime. Shark and ray populations have decreased dramatically due to climate change, overfishing, and habitat degradation, and in some regions, the status of their populations is unknown, impeding the creation and application of management strategies [1]. The last global IUCN Red List of Threatened Species assessment of elasmobranchs (2013 to 2021) revealed a critical reduction in their populations, estimating that over one-third of the shark and ray species are globally threatened with extinction and more than 75% of species are threatened throughout tropical and sub-tropical coastal and pelagic waters [1].

The Western Central Atlantic Region including the Caribbean Sea is considered one of the hotspots of shark and ray biodiversity in the world, showing the highest diversity and regional endemism of elasmobranchs in tropical America [2,3]. In the Mexican Caribbean, 85 elasmobranch species (49 sharks and 36 rays) are reported that represent 41% of the country's biodiversity [4], but the population status of most of these species is unknown. Information about the elasmobranch population in this region is only available for the most charismatic species, such as the whale shark (*Rhincodon typus*), oceanic manta ray (*Mobula birrostris*), and whitespotted eagle ray (*Aetobatus narinari*) [5–7].

Sharks and rays represent an important resource for the local fisheries and the tourism industry in the Mexican Caribbean, contributing significantly to the local economy [8]. Multiple species are targeted or caught as bycatch in coastal and artisanal fisheries in this region and rays are an important component of the bycatch in the shrimp fishery [9,10]. Regionally, several management strategies have been implemented, such as temporal bans, net regulations, and no fishing areas for sharks and rays, but the lack of enforcement is evident and consistent in the Mexican Caribbean, decreasing the impact of these tools for shark and ray conservation. The lack of long-term monitoring of elasmobranch populations as well as data concerning ecological and biological aspects of these species complicate the evaluation and implementation of regional management tools.

Elasmobranch population status is often estimated using data from fisheries (dependent or independent). In most cases, only the commercially important species are included, and extractive sampling is sometimes used, which can affect the population and is not recommended for rare or threatened species, as is the case for many elasmobranch species [11]. More suitable alternatives to extractive methods for describing and monitoring elasmobranch populations include underwater visual censuses (UVC) conducted by scientific divers and the baited remote under water video stations (BRUVS). However, the implementation of these methods can require significant effort and financial investment, limiting their potential use for long-term monitoring [12].

To improve elasmobranch conservation, ecological and biological data are needed around the world [1], which necessitates a large logistical effort and high financial investment. This is the main concern for low, lower-middle, and middle-income countries where governmental investment in research is very poor and biodiversity conservation is not a priority. In those countries with limited data availability, it is important to implement other cost-effective methods to collect ecological and biological data, which can enable long-term monitoring to increase knowledge of the status of elasmobranch populations [1].

Citizen science programs to collect data about the environment and species have been widely used and represent a cost-effective tool to collect data in marine environments [13]. Citizen science is a method that integrates public outreach and scientific data collection, which allows amateur participation in scientific research and monitoring [13,14]. These programs are valuable for conservation and promote the reconnection between people and nature [14]. However, while citizen science programs are now popular and increasingly used in several countries, they are lacking in many others. Citizen science programs have improved our understanding of the abundance, diversity, presence, and distribution of different elasmobranch species [15]. Most of the citizen science projects on sharks and rays have involved non-scientific divers in the collection of ecological and biological data, demonstrating the method's success in compiling observations for the determination of long-term population trends [11,16–18].

The Mexican Caribbean has a large tourism industry and is considered one of the best diving destinations in the world. Therefore, in the present study, our goal was to explore the utility of a citizen science program based on divers to collect baseline data on the diversity and distribution of elasmobranch species in the Mexican Caribbean.

2. Materials and Methods

2.1. Study Area

The Mexican Caribbean Region is comprised of the coastal zone of the State of Quintana Roo, delimited between Cape Catoche in the north of the state (21°36′18″ N; 87°06′13″ W) to the border with Belize in the South (18°09′45″N; 87°48′50″ W), with approximately 865 km of coastline (Figure 1). This region is part of the northern portion of the Mesoamerican Barrier Reef System (MBRS), the second-largest coral reef system in the world, and the Atlantic Ocean. This system extends to the coastal waters of Mexico, Belize, Guatemala, and Honduras and has high marine biodiversity.

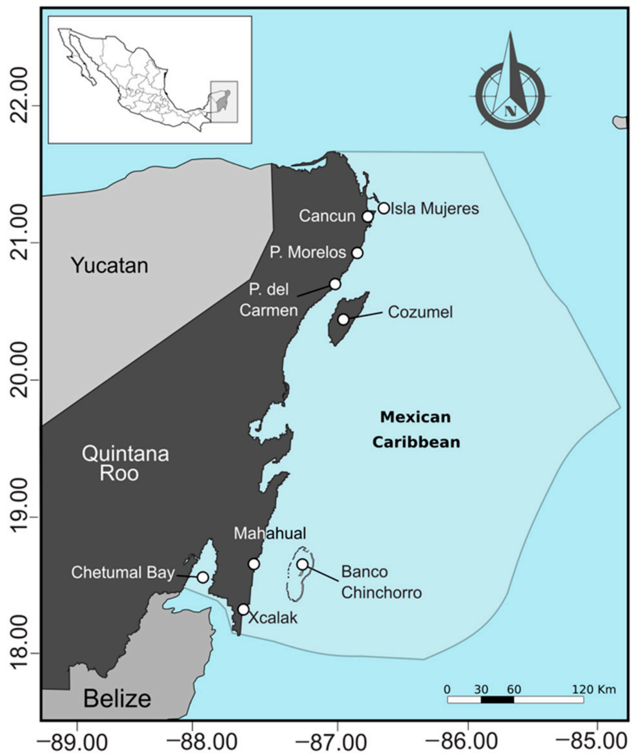

Figure 1. Study area showing the five locations in which interviews were performed.

2.2. Data Collection

We used two citizen science approaches [13,14] to collect information about sharks and rays in the Mexican Caribbean. We conducted surveys to collect data using local ecological knowledge (LEK) and collected data from the diver's direct observations (sighting reports) of sharks and rays in this region.

In August 2018, we performed an online data search looking for the contact information of the main dive centers in Cancun, Isla Mujeres, Puerto Morelos, Cozumel, Mahahual, and Xcalak to create a database. Between September 2018 and December 2020, we visited dive centers and performed structured interviews with divemasters, diving instructors, and when possible, the owners of each dive center to collect information about the shark and ray species. The interview consisted of four sections: (i) diver personal data; (ii) scuba diving experience in years of each diver internationally and in the Mexican Caribbean; (iii) knowledge of shark and ray species identification, where an image of elasmobranch species was shown to ask what species divers could identify, and the main sites of shark and ray sightings in the Mexican Caribbean; and (iv) information concerning the perception of the status of shark and ray populations, the trends of the populations, and the main factors that influence those trends. We also asked each diver about their interest in being part of a monitoring program for sharks and rays in the Mexican Caribbean. An identification guide (ID guide) for coastal shark and ray species in the Mexican Caribbean was designed to present to the divers during the interview to accurately identify individuals to the species level.

We created a sighting report on paper and online in Google forms (Google Inc., Mountain View, CA, USA) to share with the divers who wanted to be part of the monitoring. Divers contributed their data by filling out this form every time they observed a shark or ray during their diving activities. In the sighting report, we asked for information about the dive site (name and coordinates if possible), dive characteristics (date, time, duration, depth, water temperature, visibility, current), and the species observed by the diver (common or scientific name, behavior, estimated size and if possible, sex, and a photograph). Finally, we left a space to add any comments divers wanted to share with us. We gave the ID guide to each diver involved in the monitoring to help in the identification of future sightings. Additionally, we gave three IDs regarding sharks and rays in the Mexican Caribbean, including characteristics of the coastal species likely observed during a recreational dive, to improve the identification and quality of the reports to divers, rangers, and personnel working in the marine protected areas in this region. A database with all the sighting reports and associated data was created and summary analyses were performed.

3. Results

We visited in total 31 dive centers in the Mexican Caribbean, namely 22 in the north (Cancún, I. Mujeres, Puerto Morelos, and Cozumel) and nine in the south (Mahahual and Xcalak). During our visits, we performed 79 surveys with divers, and between August 2018 and December 2020 we received 499 sighting reports from 14 divers (four from Isla Mujeres, three from Cancún, four from Puerto Morelos, one for Cozumel, two from Mahahual).

3.1. Local Ecological Knowledge

In total, 79 divers (divemasters and instructors) were interviewed, of which 69% had more than five years of diving in the Mexican Caribbean. The mean number of years of diving experience in the region was 17 years. Mahahual and Xcalak were the locations in which we found the higher percentage of divers with less than five years of experience diving in the Mexican Caribbean.

During the interviews, divers identified 24 elasmobranches (10 rays and 14 sharks) species for this region. The locality in which divers identified a higher number of species was Cancún (22 species, 12 sharks, and 10 rays), followed by Puerto Morelos (19 species, 12 sharks, and seven rays) and Isla Mujeres (18 species, 11 sharks, and seven rays) (Table 1). The most common species reported by the divers were southern stingray (*Hypanus americanus*), yellow stingray (*Urobatis jamaisensis*), nurse shark (*Ginglymostoma cirratum*), blacktip shark (*Carcharhinus limbatus*), Caribbean reef shark (*Carcharhinus perezi*), and bull shark (*Carcharhinus leucas*) (Table 1).

Table 1. Sharks and rays species identified by divers in the Mexican Caribbean. (*) Presence of the specie.

Species	Cancun	Puerto Morelos	Cozumel	Isla Mujeres	Mahahual-Xcalak
Pseudobatos lentiginosus	*				
Narcine brasiliensis	*				*
Hypanus americanus	*	*	*	*	*
Hypanus guttatus	*	*	*	*	*
Aetobatus narinari	*	*	*	*	*
Urobatis jamaicensis	*	*	*	*	*
Styracura schmardae	*				
Mobula hypostoma	*	*		*	
Mobula birostris	*	*		*	*
Rhinoptera sp.	*	*		*	*
Isurus oxyrinchus	*	*	*		
Rhincodon typus		*		*	
Ginglymostoma cirratum	*	*	*	*	*
Rhizoprionodon sp.		*		*	*
Negaprion brevirostris	*	*		*	*
Galeocerdo cuvier	*	*	*	*	*
Carcharhinus leucas	*	*	*	*	*
Carcharhinus limbatus	*	*	*	*	*
Carcharhinus perezi	*	*	*	*	*
Carcharhinus plumbeus	*				
Carcharhinus longimanus	*				
Sphyrna tiburo	*	*		*	
Sphyrna mokarran	*	*	*	*	*
Sphyrna lewini	*	*		*	
Total	22	19	11	18	15

Most of the divers interviewed (73.4% n = 58) perceived a change in the abundance of sharks and rays in the Mexican Caribbean, and 81% of those divers reported a decrease in shark and ray population, attributing this change mainly to fisheries (41%), climate changes (38%, change in water temperature and natural events like hurricanes), and coastal development (24%). Other threats to sharks and rays that divers mentioned in this region are the increase of sargassum (10%), tourism, and pollution (14%). Only 26.6% of the divers interviewed reported no changes in shark and ray populations or an increase particularly reported for offshore areas near Cozumel (Table 2).

Table 2. Number of divers with a perception of elasmobranch populations changes and the perceived causes of population decrease.

			Causes of Population Decrease				
Location	**No Changes or Increase**	**Population Decrease**	**Climate Change**	**Coastal Development**	**Fisheries**	**Tourism and Pollution**	**Sargassum**
Cancún	7	19	5	4	11	4	0
Cozumel	1	1	0	0	0	0	0
I. Mujeres	4	14	6	3	7	1	2
Mahahual	4	10	6		2		3
P. Morelos	5	14	5	7	4	3	1
Total	21	58	22	14	24	8	6

A high percentage of divers (85%) reported that sharks and rays were not their objectives in the diving activity and they did not sell special packages that guaranteed the observation of these species, except in the case of the whale shark (*Rhincodon typus*), mako shark (*Isurus oxyrinchus*), bull shark (*C. leucas*), the whitespotted eagle ray (*Aetobatus narinari*), and oceanic manta ray (*Mobula birostris*), which do have defined observation seasons in which sighting these species are the objective in snorkeling and diving activities.

3.2. Sightings Report Program

Of the interviewed divers (n = 79), 90% manifested interest in participating in the shark and ray monitoring but only 20% were active in sending their sighting reports. Therefore, we had at least one diver participating in the monitoring in each location. Between August 2018 and December 2020, we receive 499 sighting reports of elasmobranchs in the Mexican Caribbean, 51% from Isla Mujeres, 31% from Mahahual, 16% from Puerto Morelos, and 2% from Cancún. Rays were more frequently sighted by divers (89%) than sharks (11%), and the whitespotted eagle ray (*A. narinari*) was the most common elasmobranch species reported in the region. The oceanic manta ray and the Atlantic devil ray were the second and third ray species in terms of number of sightings but were reported as incidental sightings by divers in Isla Mujeres as they were not observed during the dive. Otherwise, the southern stingray (*H. americanus*) and the yellow stingray (*U. jamaisensis*) had more sighting reports in the region overall. For sharks, the species most frequently sighted was the nurse shark (*G. cirratum*), followed by the Caribbean reef shark (*C. perezi*) and the great hammerhead shark (*S. mokarran*) (Figure 2).

In cases where behavior of the individuals was reported by divers (n = 80), they reported mostly individuals resting on the bottom (51%), and 21% reported feeding behaviors. Regarding the reaction that the animals had in the presence of the divers, most of them moved away from the divers (58%) while a smaller percentage did not react (29%).

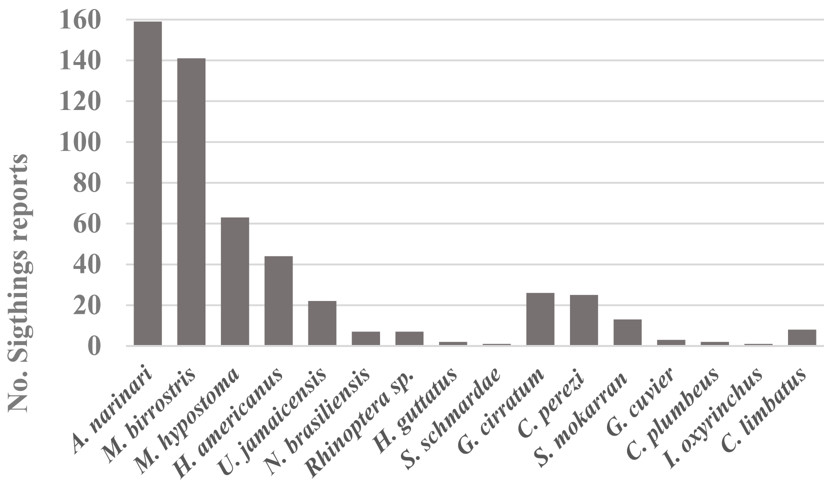

Figure 2. Number of sighting reports by specie in the Mexican Caribbean in 29 months.

4. Discussion

The integration of multiple knowledge sources for assessing species abundance, diversity, and distribution have increased over the past years as various studies have combined local ecological knowledge and scientific data to understand population trends. Although the Mexican Caribbean is in a hot spot of elasmobranch biodiversity, the scarcity of information concerning the abundance, diversity, distribution, and population status is evident. We took advantage of the high volume of diving activities in this region to collect data about sharks and rays by performing interviews with divemasters and instructors. Most of the divers interviewed have been diving for more than five years and were very knowledgeable about the shark and ray species distributed in the region. They could identify at least 24 elasmobranches (10 rays and 14 sharks) that they have seen in this region. The elasmobranch species reported by divers are mainly coastal species due to the depth limitation for this activity. In the Mexican Caribbean, other authors using fisheries monitoring and direct sampling reported a similar diversity of coastal sharks and rays in this region [19,20].

We observed that less experienced divers cannot identify the same number of species because they have spent less time diving in this region. A diver's experience is a key component to obtain accurate data about shark and ray diversity as has been reported in other studies explaining that experienced recreational divers (e.g., divemasters and instructors) are familiar with the features of regularly visited sites and the species diversity and can provide good information, even for more elusive species [16].

The elasmobranch species commonly observed by divers in the Mexican Caribbean were the southern stingray (*H. americanus*), yellow stingray (*U. jamaisensis*), nurse shark (*G. cirratum*), blacktip shark (*C. limbatus*), and Caribbean reef shark (*C. perezi*). This is concordant with other regions in the Caribbean, in which other methods have been used to determine the abundance and diversity of elasmobranchs. For example, in the Bahamas, where researchers used longlines and BRUVS to obtain the distribution and abundance of sharks, a high abundance of nurse sharks and Caribbean reef sharks was found [21]. Similarly, nurse sharks and Caribbean reef sharks were commonly captured on longlines in Belize [22]. For rays, other studies in the Caribbean showed the high abundance of the yellow stingray in the coral reef ecosystems [11], so the data obtained here through the local ecological knowledge are supported by other studies using conventional methods [23].

The decline of shark and ray populations worldwide in the last decades is well known [1,24], particularly in the Caribbean where recent studies have provided evidence of the decline of reef shark populations [23,25]. This is concordant with the perception of the divers interviewed in our study who perceived a decline in the number sharks and rays in the Mexican Caribbean in the last decade. The use of LEK was shown to be useful to collect invaluable data for describing population trends and providing insight into patterns that may warrant further investigation [16]. The main causes divers in the Mexican

Caribbean thought are contributing to the population decline of sharks and rays in this region were fisheries, climate change, particularly the changes in water temperature and the strengthening of natural events such as hurricanes, and coastal development, where they mention particularly the degradation of the coral reef and mangroves due to coastal infrastructure development. Other threats that divers mention for sharks and rays in this region are the increase of sargassum along the coast in recent years, the increasing number of tourists each year, and pollution. Globally, overfishing, habitat loss, climate change, and pollution are the main causes of the elasmobranch population decline worldwide [1] as described by the divers interviewed in this study in the Mexican Caribbean.

Divers reported that, from the 24 species commonly seen in the Mexican Caribbean, only five shark and ray species are targeted for the diving industry in this region, but only two have an established activity, the whale shark (*Rhincodon typus*) during summer and bull shark (*C. leucas*) during winter. The whale shark was not reported by divers here, because this species is observed mainly in the open sea during the aggregation season. The other three species, namely the mako shark (*I. oxyrinchus),* the whitespotted eagle ray (*A. narinari*), and the oceanic manta ray (*M. birrostris*), do not have a well-established activity and only some diving centers offer interactions with these species on their websites for tourism. Touristic activities, such as those performed with elasmobranchs in the Mexican Caribbean, have the potential to gather information through citizen science programs. Due to this, some of these species are the most studied in the Mexican Caribbean, and some citizen sciences programs have already estimated population sizes through photo ID approaches [5].

Because sharks and rays are charismatic fishes, divers in the Mexican Caribbean have showed high interest in participating in data collection for these species, but motivation decreased with time and at the end only 20% of divers were actively sending their sighting reports. Motivation is one of the hardest parts of the participation of citizen scientists for long periods, as has been reported before [13]. We have highly motivated people that signed up for our monitoring (90% of the interviewed divers) because sharks and rays are charismatic species and the monitoring incorporated SCUBA diving activity. These two points seem to increase the motivation of citizen scientists [13]. Motivating participants to continue or expand their participation is often a greater challenge, as we observed in this study. Other authors mention that this decrease in motivation occurred most of the time when the project involves reporting 'zero data', which disengages the participants [13] and is probably what happened in the Mexican Caribbean where the frequency of shark and ray observations is very low. Despite this, we expect more participation and sighting reports, with the participation of at least one diver in each location. This allows us to have data from each location and to reduce the need for repetitive reports from the same individual in the same area. So, we have reports from only one diver in one day in one diving site and this reduces abundance overestimations of the species, data that we will analyze in future publications.

The reduction in shark populations in the Caribbean has recently been documented where most of the reefs in this region have been reported with a very low abundance of sharks [23,25], as was seen in the Mexican Caribbean in the present study, based on the very low number of sightings. Additionally, batoids were more frequently sighted (89%) than sharks (11%). The prevalence of rays on coral reefs, as we found here, was also reported in other studies [26] and may be related to the decrease of sharks on coral reefs due to a trophic cascade [26–29]. However, further research is needed to make conclusive statements about this phenomenon in the Mexican Caribbean. The most frequently reported ray in the reefs was the spotted eagle ray (*A. narinari*), the southern stingray (*H. americanus*), and the yellow stingray (*U. jamaisensis*). These species are common coral reef users and exhibit site affinity, as other authors have demonstrated using conventional methods, such as BRUVS and Photo ID, as well as citizen science methods [11,30–32]. In the Caribbean, the most abundant shark species in the reef are the nurse shark (*G. cirratum*) and the Caribbean reef shark (*C. perezi*) [22,30,33], as was found in the Mexican Caribbean based on the sighting reports. Another species that was reported frequently on the reefs of the Mexican Caribbean was the great hammerhead shark (*S. mokarran*), as occurred in other reefs in this region as in the Turks and Caicos [30]. This finding is of important regional concern since this hammerhead species is considered Critically Endangered worldwide, so more data are needed on the distribution and abundance of the species to improve the conservation actions to preserve the population in the Mesoamerican reef.

Since 2005, there has been a growing demand for sharks and rays in tourist activities worldwide [33–35], especially in the Mexican Caribbean, where the inclusion of shark and ray species in local ecotourism packages has aroused greater interest in the conservation of populations. Several authors have shown that elasmobranch populations can be affected by anthropogenic activities, such as fishing and boat traffic [34,35], which can affect the degree to which the species leave the areas and seek refuge in other regions [36]. The health of the reefs also affects the abundance of reef elasmobranch species [37,38], which is important to take into account, especially in the study area located within the Mesoamerican reef system.

The citizen science approach used here, based on the local ecological knowledge and the participation of citizen scientists to collect data, was a valuable tool to collect baseline data in the Mexican Caribbean. Our study provided important data about the diversity of coastal elasmobranch species associated with coral reefs and their distribution. Information about habitat use and the abundance of the species could also be collected and analyzed using citizen science [16]. Our work offers a wide view of the population status and allowed us to generate new hypotheses and gave us guidance for further research to improve the conservation of this species in the region. Finally, citizen science is a useful tool to describe important ecological patterns that might otherwise go unnoticed due to poor data or insufficient timeframes [15,16]. This is of particular importance in the most vulnerable and rapidly changing ecosystems that are also among the most data-poor regions, especially in low, lower-middle, and middle-income countries, such as the ones in the Mesoamerican reef region. Therefore, we conclude that the use of citizen science is a very useful tool to generate valid long-term data on the most vulnerable elasmobranch species in countries in which the financial investment in other monitoring methods is limited.

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Institutional Review Board Statement: All activities were performed according to Mexican laws and regulations. No animal manipulation was performed. No ethical conflicts exist in the realization of this work.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data generated or analyzed during this study are included in this published article.

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