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Characterization of the artisanal elasmobranch fisheries off the Pacific coast of Guatemala

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Abstract—The landings of the artisanal elasmobranch fisheries of 3 communities located along the Pacific coast of Guatemala from May 2017 through March 2020 were evaluated. Twenty-one elasmobranch species were identified in this study. Bottom longlines used for multispecific fishing captured ray species and represented 59% of the fishing effort. Gill nets captured small shark species and represented 41% of the fishing effort. The most frequently caught species were the longtail stingray (*Hypanus longus*), scalloped hammerhead (*Sphyrna lewini*), and Pacific sharpnose shark (*Rhizoprionodon longurio*), accounting for 47.88%, 33.26%, and 7.97% of landings during the monitoring period, respectively. The landings were mainly neonates and juveniles. Our findings indicate the presence of nursery areas on the continental shelf off Guatemala. This study included the first survey of commercial exploitation of ray species in the artisanal fisheries off the Pacific coast of Guatemala. It is imperative to protect shark nursery areas and to develop management strategies for ray species that are important to artisanal fisheries.

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Despite the widespread consumption and commercialization of elasmobranch catches in Latin America, there are no consistent statistical records and few studies of the catches of elasmobranch species in Guatemala or of products made from captured individuals. Nonetheless, Hacohen-Domené et al. (2020) described an artisanal elasmobranch fishery on the Caribbean coast of Guatemala and evaluated biological data from 688 Chondrichthyan species (24 shark, 6 ray, and 1 chimaera species) landed from January 2015 through July 2017. They concluded that a high proportion of the specimens of shark species for which data were recorded were juveniles. Ruíz Alvarado and Mijangos López (1999) first described the shark fisheries that operate off the Pacific coast of Guatemala and recorded 15 landed species. The most recent study about sharks species, which included a monitoring program of 5 communities along the Pacific coast, was carried out during 2006–2007 by Ixquiac Cabrera et al.[1], who found that the most captured species were the silky shark (*Carcharhinus falciformis*), scalloped hammerhead (*Sphyrna lewini*), and whitenose shark (*Nasolamia velox*). Lastly, in the most recent study about ray species in 2006, Ixquiac Cabrera et al.[2] determined that the main species of Guatemala's continental shelf are the golden cownose ray (*Rhinoptera steindachneri*), longtail stingray (*Hypanus longus*), and blotched stingray (*Urotrygon chilensis*).

The aim of this study was to continuously monitor the landings of artisanal fisheries of 3 Pacific coast communities in Guatemala from May 2017 through

[1] Ixquiac Cabrera, J., I. Franco Arenales, C. A. Tejeda Velásquez, M. R. Sánchez Rodas, and J. A. Sikahall Prado. 2009. Áreas de crianza de tiburones en la plataforma continental del Pacífico de Guatemala: Herramienta para el manejo y aprovechamiento sostenido del recurso tiburón. Proyecto Fodecyt 13-2006, 48 p. Cent. Estud. Mar Acuic., Univ. San Carlos Guatemala, Guatemala City, Guatemala. [In Spanish.] [Available from website.]

[2] Ixquiac Cabrera, M., I. Franco, J. Lemus, S. Méndez, and A. López-Roulet. 2010. Identificación, abundancia, distribución espacial de batoideos (rayas) en el Pacífico guatemalteco. Proyecto Fodecyt 34-2006, 41 p. Fondo Nac. Cienc. Tecnol., Cent. Estud. Mar Acuic., Organ. Conserv. el Medio Ambiente, Guatemala. [In Spanish.] [Available from website.]

March 2020 and ultimately to provide the first characterization of the ray species captured by the artisanal fleet and the shark species present in landings. The information from this study will contribute to the identification of elasmobranch nursery areas in Guatemala and facilitate the design of conservation strategies. Our results highlight the need to establish rays as important fishery species in this region.

Materials and methods

Study area

Approximately 1.8 million people live in the communities along the Pacific coast of Guatemala (14% of the national population), and the main sources of income for these people are related to fishing activities (SEGEPLAN and DOT[3]). The continental platform of Guatemala (14,009 km^2) is narrow, extends ~50 km offshore, and contains the economic exclusive zone of the country. Along the 250-km coastline where Guatemala meets the Pacific Ocean, about 45 communities have artisanal fisheries, in which elasmobranch species are incidentally captured and landed. Three of the largest fishing communities were selected for this study: Las Lisas, Buena Vista, and Sipacate (Fig. 1). These communities were selected for their importance and because their fishing efforts were greater than those of the other communities in the region. The community of Buena Vista was not monitored in the study until January 2019.

Landings

Biological and morphometric data were collected from elasmobranchs sampled from landings between May 2017 and March 2020, in addition to information on fishing effort and gear. Over the study period, sampling was undertaken during 83 visits to the 3 fishing communities: 34 visits in Las Lisas, 35 visits in Sipacate, and 14 visits in Buena Vista. Most individuals were landed whole and were identified to the species level by using identification guides and specialized books (Mejía-Falla et al., 2011; Ebert et al., 2013; Last et al., 2016). The sources for the nomenclature of ray, shark, and shrimp species were Last et al. (2016), Ebert et al. (2013), and Holthuis (1980), respectively. The presence or absence of male claspers was used to determine the sex of each specimen. Maturity was determined by the degree of clasper calcification (males) and the presence of reproductive scars or embryos (females). Size at first maturity was obtained from the literature (Mejía-Salazar, 2007; Navia et al., 2009; Zanella et al., 2009; López-Garro and Zanella, 2015; Pollom et al., 2020). Measurements to the nearest 0.5 cm were recorded for landed individuals in a natural position. For sharks, total length was measured by using the natural extension of the caudal fin (Compagno, 2001), and fork length was recorded. For rays, disc width and disc length were recorded. Total length was also recorded for small rays.

Given that the vessels in the artisanal fisheries used a variable and unquantifiable quantity of fishhooks or nets, the landings per unit of effort (LPUE) was calculated for each species by using fishing nights as the unit of effort. To ensure that calculations were as accurate as possible, an attempt was made to count the total number of elasmobranchs per fishing trip (every shark and ray landed by every boat that arrived at the dock on monitoring days), even if it was not possible to measure all individuals. For species in which the number of sampled individuals (n) was greater than 15, size histograms were generated and compared with information on sexual maturity from the literature.

In Las Lisas, a trawl fishery directed at the whiteleg shrimp (*Litopenaeus vannamei*) and seabob (*Xiphopenaeus kroyeri*) is also present. Data on incidentally caught

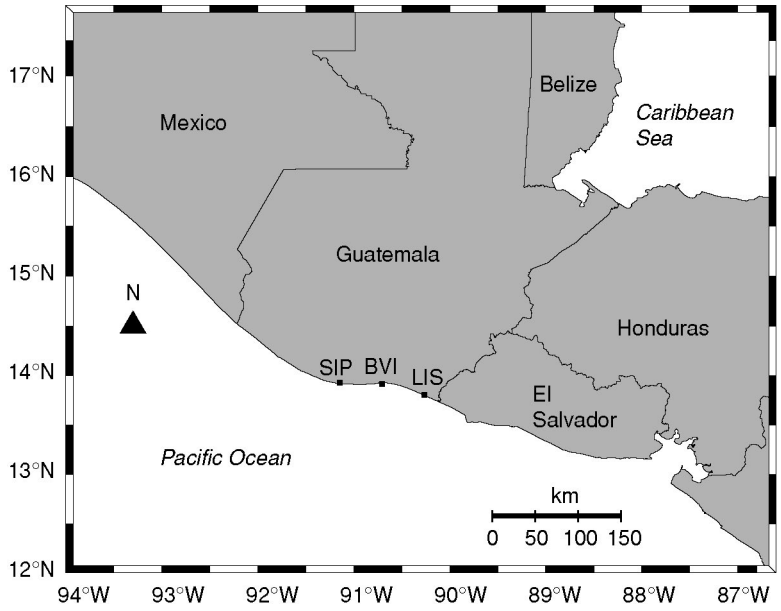

Figure 1

A map of the locations of the 3 communities where landings of ray and shark species in artisanal fisheries were monitored between May 2017 and March 2020. These communities along the Pacific coast of Guatemala are Las Lisas (LIS) in the Santa Rosa Department and Buena Vista (BVI) and Sipacate (SIP) in the Escuintla Department. Landings at Buena Vista were not monitored until January 2019.

[3] SEGEPLAN (Secretaría de Planificación y Programación de la Presidencia) and DOT (Dirección de Ordenamiento Territorial). 2011. Plan de desarrollo integral del litoral del Pacífico, 190 p. SEGEPLAN and DOT, Guatemala City, Guatemala. [In Spanish.] [Available from website.]

elasmobranchs were collected from the landings of the trawl boats in this fishery. Data recorded includes size, sex, and maturity. For this fishery, it was not possible to calculate LPUE.

Results and discussion

Fishing activity

The fishing activities of the communities in this study are carried out year-round, and there are no restrictions or seasonal closures. Fishermen do not engage in other economic activities. The fishermen from Las Lisas worked independently from one another, owned their own boats, and went fishing 5–6 d per week; the durations of their fishing trips were 1–2 nights. The fishermen from Sipacate and Buena Vista were hired by boat owners to work as part of fishing fleets (1–10 boats), and the durations of their fishing trips were generally 2 nights. Two types of fishing gears were identified: bottom and mid-water gill nets made of monofilament (mesh: 4–6 cm; length: 300–700 m; height: 5–7 m) and bottom longlines with small J hooks or Eagle Claw[4] half circle hooks (Wright and McGill Co., Denver, CO; height: 3–6 cm). The gill nets were linked together (maximum of 5 connected nets), remained in the water for 5–6 h, and were used 3–5 times per trip. Although gill nets were set to catch bony fish species, small sharks and rays were incidentally caught as species of moderate-to-high commercial value. The bottom longlines spanned 2–6 km, contained 300–700 hooks, remained in the water for 3–4 h, and were changed 2–4 times per trip. The bottom longlines targeted demersal bony fish and ray species, and some shark species were incidentally caught.

The artisanal fisheries of the communities of Las Lisas, Sipacate, and Buena Vista are classified as commercial demersal and small pelagic fisheries, according to the General Law of Fisheries and Aquaculture of Guatemala (MAGA, 2002), and do not include the capture of elasmobranch species as target species. A notable problem is that artisanal fishing activities are carried out without permits from the Fisheries and Aquaculture Regulations Department of Guatemala because of a lack of resources.

Landings

In Las Lisas, 131 fishing trips were recorded, of which 70 trips (53%) used gill nets and 61 trips (47%) used bottom longlines. In addition, landings of 3 shrimp trawl boats with incidentally caught elasmobranchs were evaluated. Data on 669 elasmobranchs were recorded. In total, 48% (n=321) and 41% (n=274) of the sampled individuals were caught in gill nets and bottom longlines, respectively. Finally, shrimp trawl nets were responsible for only 11% (n=74) of the incidentally caught individuals. In this location, 6 species were identified (3 shark and 3 ray species; Table 1). Only 6% (n=37) of the recorded individuals were mature (Fig. 2).

In Sipacate, fishing vessels use longlines and gill nets simultaneously. During 282 fishing trips (64%), 103 fishing trips (23%), and 57 fishing trips (13%), elasmobranch species were caught with both gears, longlines only, and gill nets only, respectively. In total, 2603 elasmobranchs were recorded, of which 1608 individuals (62%) were captured with bottom longlines and 991 individuals (38%) were captured with gill nets. A total of 16 species were identified (9 shark and 7 ray species; Table 1). Only 7% (n=179) of the specimens were mature (Fig. 2).

In Buena Vista, fishing vessels used longlines and gill nets simultaneously. In 50 fishing trips (57%), 21 fishing trips (24%), and 17 fishing trips (19%), both gears, bottom longlines only, and gill nets only were used, respectively. Information was obtained on 526 elasmobranchs, of which 271 individuals (52%) were captured with bottom longlines and 255 individuals (48%) were captured with gill nets. A total of 17 species were identified in this location (8 shark and 9 ray species; Table 1). Only 4% (n=24) of the specimens were mature (Fig. 2). The statistics for rarely landed species (n<15) in all 3 communities are presented in Table 2.

The LPUE varied over the course of the study, and periods of high LPUE values were determined for each species. The shark species that appeared most in the landings was the scalloped hammerhead (70% of landings), and the longtail stingray was the most common ray (91% of landings). For the longtail stingray, most of the landings occurred during the first months of the year. An increase in landings during the rainy season was observed for the scalloped hammerhead (May–September).

The scalloped hammerhead was 1 of 5 shark species that dominated the landings in Guatemala during 1997–1999 (Ruíz Alvarado et al.[5]), and during 2006–2007, the scalloped hammerhead was the second-most-caught shark species along the Pacific coast of Guatemala. Abundance of scalloped hammerhead has also been observed to be higher during the rainy season in Costa Rica (Zanella et al., 2009) and Mexico (Alejo-Plata et al., 2007) than during other seasons; during the rainy season, waters in coastal areas have higher concentrations of nutrients than during other periods. The fishing areas of the communities of Las Lisas and Sipacate evaluated in our study correspond to 2 of the 3 nursery areas used by scalloped hammerhead that were identified by Ixquiac Cabrera et al.[1], areas in which 88% of the landed individuals were classified as either neonates or juveniles. Ten years later, the results of our study indicate a continued presence of neonates and juveniles in these areas. According to this information and to the 3 criteria

[4] Mention of trade names or commercial companies is for identification purposes only and does not imply endorsement by the National Marine Fisheries Service, NOAA.

[5] Ruíz Alvarado, C., M. Ixquiac Cabrera, C. Baldetti Herrera, and J. Martínez. 2000. Evaluación del potencial de explotación del recurso tiburón en las costas del Pacífico de Guatemala, 56 p. Fondo Nac. Cienc. Tecnol., Cent. Estud. Mar Acuic., Unidad Manejo Pesca Acuic., Guatemala. [In Spanish.] [Available from website.]

Table 1

Statistics for elasmobranch species landed from May 2017 through March 2020 in artisanal fisheries that operate from 3 communities off the Pacific coast of Guatemala: Las Lisas, Sipacate, and Buena Vista. The number of documented individuals (n), percentage of the landing records, landings per unit of effort (LPUE) with fishing nights used as unit of effort, and fishing gear used to capture individuals are provided for each species by community. The LPUE is not presented for vermiculate electric rays (*Narcine vermiculata*) landed in Las Lisas because they were captured by shrimp trawl boats.

	Las Lisas			Sipacate			Buena Vista			
Species	*n*	%	LPUE	*n*	%	LPUE	*n*	%	LPUE	Fishing gear
Hypanus longus	258	39	1.73	1328	51	1.60	239	44	1.39	Bottom longline
Sphyrna lewini	348	52	2.33	716	28	0.86	204	38	1.18	Gill net
Rhizoprionodon longurio				289	11	0.35	15	3	0.08	Gill net
Mustelus lunulatus				170	7	0.20	5	1	0.02	Bottom longline
Carcharhinus limbatus	1	<1	0.01	32	1	0.03	2	<1	0.01	Gill net
Narcine vermiculata	57	9	–	30	1	0.03	4	1	0.02	Gill net
Aetobatus laticeps	4	1	0.02	8	<1	0.01	7	1	0.04	Bottom longline
Pseudobatos leucorhynchus				7	<1	0.01	17	3	0.09	Gill net
Galeocerdo cuvier	1	<1	0.01	7	<1	0.01				Gill net
Narcine entemedor				4	<1	0.01				Bottom longline
Styracura pacifica				3	<1	0.01				Bottom longline
Nasolamia velox				2	<1	<0.01	1	<1	0.01	Gill net
Carcharhinus falciformis				2	<1	<0.01	11	2	0.06	Gill net
Rhinoptera steindachneri				2	<1	<0.01	2	<1	0.01	Bottom longline
Carcharhinus leucas				2	<1	<0.01	1	<1	0.01	Bottom longline
Sphyrna mokarran				1	<1	<0.01				Bottom longline
Mobula thurstoni							25	5	0.14	Gill net
Mobula munkiana							3	1	0.01	Gill net
Urotrygon aspidura							2	<1	0.01	Gill net
Urotrygon chilensis							1	<1	0.01	Gill net
Alopias pelagicus							1	<1	0.01	Bottom longline
Total	669	100		2603	100		540	100		

that were established by Heupel et al. (2007) for the definition of a shark nursery area, it is highly probable that these sites are important nursery areas for the scalloped hammerhead in the eastern central Pacific Ocean.

The 3 criteria of Heupel et al. (2007) used to define a nursery area for shark species are as follows: 1) sharks of a species are most commonly found in a particular area instead of in other areas (for example, the density in some areas is higher than in other areas), 2) neonate and young-of-the-year sharks tend to remain or return for extended periods of time (weeks or months) in an area, and 3) an area or habitat is used repeatedly over the years while other sites are not.

Other shark species also had high incidences of capture during specific times of the year. For example, 75% of the landings of the Pacific sharpnose shark (*Rhizoprionodon longurio*) occurred during November 2018, and blacktip sharks (*C. limbatus*) were caught only from February through May in 2018 and 2019. Seasonality has also been observed for landings of the Pacific sharpnose shark off the Pacific coast of Mexico, with a high proportion of the total catch occurring from November through April (Márquez-Farias, 2005). Interestingly, the Pacific sharpnose shark has not been reported in previous studies of fisheries in Guatemala despite being a common species in the eastern central Pacific Ocean (Márquez-Farias, 2005). Although Ixquiac Cabrera et al.[1] reported that the silky shark was the most abundant shark species in landings recorded in Guatemala during 2006–2007, only a few individuals were observed in our study. The difference in abundance for this species may be a result of the inclusion of offshore longline fisheries in previous studies and the focus of our study on only coastal fisheries.

The results of our study provide the first characterization of ray exploitation in the artisanal fisheries of Guatemala. In total, 11 ray species were identified, with the longtail stingray having the most records (n=1825). It is important to mention that not all ray species are locally exploited, as is the longtail stingray, given that some do not reach large sizes. According to the information obtained in this study, the meat of longtail stingrays was mainly used locally in fillet form. As such, it has become a target species for the multispecies bottom longline fishery in Sipacate and to lesser extents for the fisheries in Las Lisas and Buena Vista. The remaining ray species that reached large sizes and that were occasionally reported were the Pacific eagle ray (*Aetobatus laticeps*), Pacific chupare (*Styracura pacifica*), and golden cownose ray, all of which are consumed

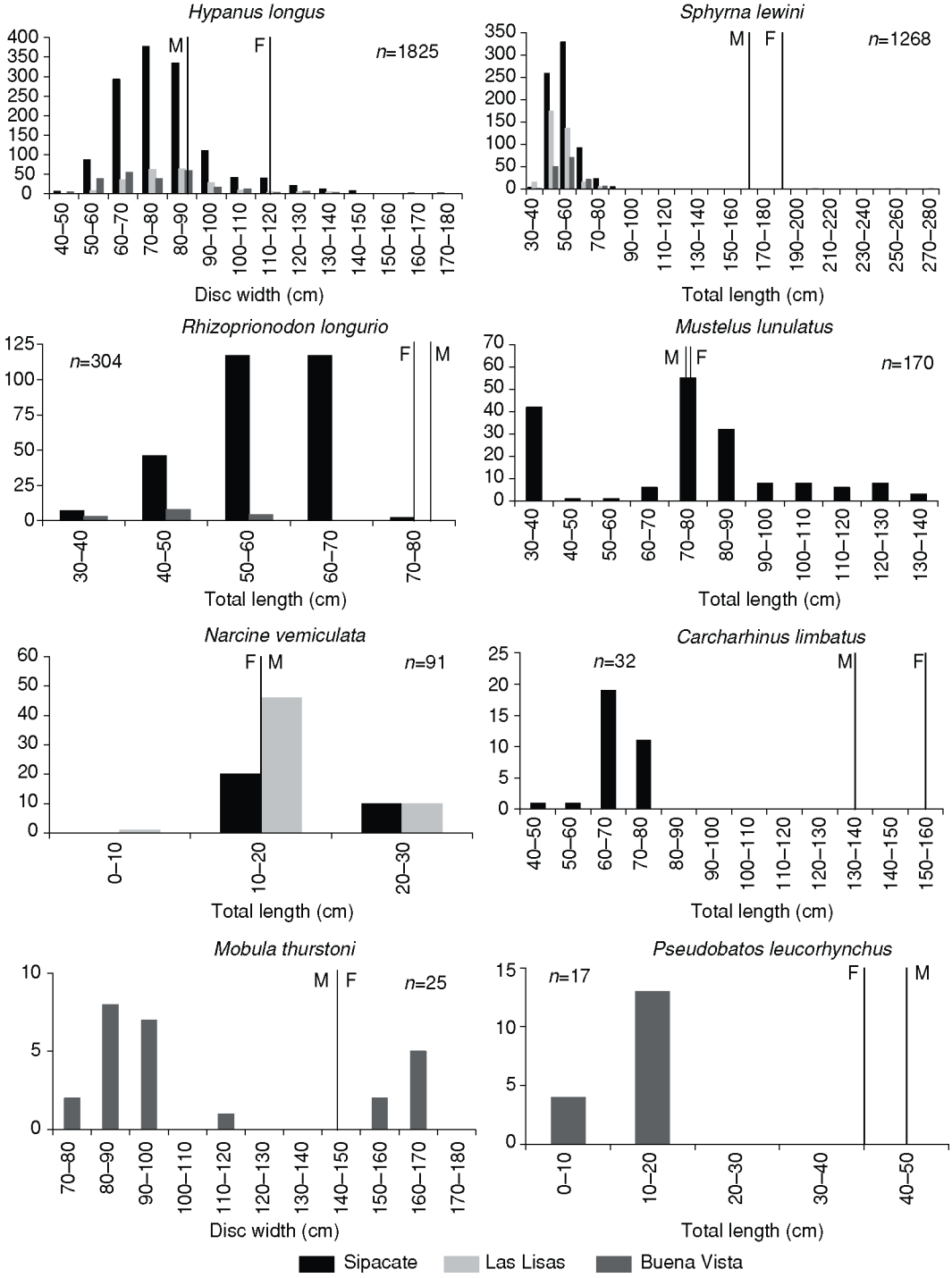

Figure 2

Pooled size-frequency distribution of the elasmobranch species in landings sampled between May 2017 and March 2020 from artisanal fisheries that operate from 3 communities along the Pacific coast of Guatemala: Las Lisas (light gray bars), Buena Vista (medium gray bars), and Sipacate (black bars). Species include the longtail stingray (*Hypanus longus*), scalloped hammerhead (*Sphyrna lewini*), Pacific sharpnose shark (*Rhizoprionodon longurio*), sicklefin smoothhound (*Mustelus lunulatus*), vermiculate electric ray (*Narcine vermiculata*), blacktip shark (*Carcharhinus limbatus*), smoothtail mobula (*Mobula thurstoni*), and whitesnout guitarfish (*Pseudobatos leucorhynchus*). The histograms are based on the number of sampled individuals (*n*) and not necessarily on the total number of individuals captured. The black vertical lines indicate the size at first maturity for males (M) and females (F).

Table 2

Statistics for elasmobranch species rarely landed from May 2017 through March 2020 in artisanal fisheries that operate from 3 communities along the Pacific coast of Guatemala: Las Lisas, Sipacate, and Buena Vista. The number of documented individuals (n), mean size (total length or disc width, depending on the species), and standard error of the mean (SE) are presented for each species by community. The interdorsal lengths of pelagic threshers (*Alopias pelagicus*) were recorded because they were landed without heads or caudal fins. Species are considered rarely landed if n<15.

	Las Lisas			Sipacate			Buena vista		
Species	n	Mean size (cm)	SE	n	Mean size (cm)	SE	n	Mean size (cm)	SE
Aetobatus laticeps	4	79.75	5.09	8	81.81	2.45	7	87.21	10.36
Carcharhinus falciformis				2	92.00	1.00	11	86.45	3.53
Galeocerdo cuvier	1	90.50	–	7	89.29	0.71			
Pseudobatos leucorhynchus				7	32.71	4.43			
Mustelus lunulatus							5	60.01	5.33
Narcine entemedor				4	49.25	10.94			
Rhinoptera steindachneri				2	74.50	9.50	2	77.50	0.50
Narcine vermiculata							4	20.75	1.03
Nasolamia velox				2	59.50	1.50	1	68.00	–
Mobula munkiana							3	101.33	0.33
Styracura pacifica				3	77.33	5.90			
Carcharhinus leucas				2	109.00	11.00	1	262.00	–
Carcharhinus limbatus									
Urotrygon aspidura							2	10.75	0.25
Sphyrna mokarran				1	122.00	–			
Alopias pelagicus							1	16.00	
Urotrygon chilensis							1	10.50	–

locally. Fishermen indicated that the vermiculate electric ray (*Narcine vermiculata*) is used as bait in the bottom longline fisheries. Dulvy et al. (2000) highlighted that batoid species in general are arguably the most vulnerable species in marine fisheries. Clarke et al. (2018) conducted a productivity susceptibility analysis for elasmobranch species in bottom fisheries and revealed that the longtail stingray is one of the most vulnerable species in Costa Rica, mainly because of its low reproductive potential and distribution, which overlaps greatly with shallow-water fishing grounds.

Conservation and management

Although elasmobranch species are not recognized as target species in artisanal fisheries in Guatemala, they are captured in high volumes during several months of the year and, therefore, account for a high percentage of the income of fishermen. There are currently no regulations for the management and conservation of elasmobranch species off the Pacific coast of Guatemala, and most artisanal fleets operate without permits or official records. Although all shark species can be exploited in artisanal, large-scale, or industrial fisheries (MAGA, 2002), ray species are not included as target species for any coastal fishery. Currently, the nongovernmental organization Fundación Mundo Azul and the Fisheries and Aquaculture Regulations Department of Guatemala have created a technical group to supervise and update the management plan for the conservation of Chondrichthyan species in Guatemala (this plan is in the final stages of approval and publication). However, Guatemala has not yet imposed national fishing regulations for any elasmobranch species, as other countries in Latin America, such as Mexico, have done (Saldaña-Ruiz et al., 2019). Off the Pacific coast of Mexico, shark nursery areas have been considered priority areas for elasmobranch conservation, and legislation has banned fishing activities inside those areas (Saldaña-Ruiz et al., 2019).

In Guatemala, it is also necessary to protect elasmobranch nursery areas, particularly for the scalloped hammerhead, which is listed as critically endangered in the IUCN Red List of Threatened Species and uses areas along the coasts of Guatemala during the early stages of its life cycle (Rigby et al., 2019). In addition, it is important to develop adequate management strategies because rays are highly vulnerable to coastal fisheries because of their very low productivity potential (Clarke et al., 2018). Therefore, it is important to support conservation actions and continuous monitoring efforts to improve the management of elasmobranch species in the eastern central Pacific Ocean.

Acknowledgments

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