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Elasmobranch bycatch of the shrimp trawl fishery along the Pacific coast of Guatemala

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Abstract—In this study, the species composition of bycatch in the shrimp bottom-trawl fishery off the Pacific coast of Guatemala was examined. In total, 15 species of elasmobranchs, including 13 ray species and 2 shark species, were recorded. Of these taxa, 1 species is listed as critically endangered, 4 species are listed as near threatened, 7 species are listed as vulnerable, and 1 species is listed as a species of least concern by the International Union for Conservation of Nature. Currently, there is no official monitoring system for shrimp trawling in Guatemala; therefore, the abundance and biological characteristics of the elasmobranch species caught as bycatch are unknown. This information is lacking because only 5.5% of the registered elasmobranch bycatch was landed and traded for its economic value.

Worldwide, shrimp trawling has the highest discard rate of all fisheries (27% in 2005) (Kelleher, 2005). Although reducing bycatch is important from both economic and management standpoints, bycatch is economically valuable in developing countries and supports food security in many coastal communities (Gillett, 2010; Barreto et al., 2022). Nonetheless, in many Latin American countries, shrimp trawl fisheries are currently banned because they are unsustainable (TNC[1]). In Guatemala, cartilaginous and bony fish species are incidentally caught in the shrimp trawl fishery, which is still permitted. The species that are commercially valuable are retained, and the others are discarded at sea. Shrimp trawling for 5 shrimp species and 1 prawn species is conducted on both the Pacific and Caribbean coasts of Guatemala (TNC[1]). In the 1980s and into the mid-1990s, 60 large vessels and about 1500 artisanal vessels participated in this fishery. Between 1995 and 2000, a notable reduction in catch occurred and has continued to the present day. From 2010 through 2013, 750–1500 metric tons (t) of shrimp (plus 250 t of bycatch species) were landed, but only 150 t of shrimp were landed from 2014 through 2016. In 2016, bycatch (100 t) was greater than the catch of shrimp (50 t) (FAO, 2018).

Ixquiac Cabrera (1998) identified 148 species of bony fish and 11 species of elasmobranchs among the shrimp bycatch from the Pacific coast of Guatemala, although the study did not include a complete annual fishing cycle or information on the biological characteristics of incidentally caught elasmobranchs. Using data from both the artisanal and trawl fisheries operating on the continental shelf,

[1] TNC (The Nature Conservancy). 2018. Planificación espacial marina del Pacífico de Guatemala, 108 p. Proyecto conservación y uso sostenible de la biodiversidad en áreas protegidas marino-costeras. Ministerio de Ambiente y Recursos Naturales, Consejo Nacional de Áreas Protegidas, United Nations Development Programme, and Global Environment Facility. [Available from TNC, 4245 North Fairfax Dr., Ste. 100, Arlington, VA 22203-1606.]

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Ixquiac Cabrera et al.[2] constructed a catalog of batoid species present in the Pacific Ocean off Guatemala and reported 15 species from the families Dasyatidae, Myliobatidae, Urotrygonidae, Rajidae, Rhinobatidae, and Narcinidae. Nonetheless, a notable information gap exists regarding the bycatch of the shrimp trawl fishery. In an effort to fill this gap, we developed a method to evaluate the bycatch of different shrimp trawlers. Some vessels systematically and voluntarily provided samples of their bycatch from each fishing trip so that the composition of the bycatch could be characterized. Through the results of this study, we provide herein a current description of the shrimp trawl fishery in Guatemala and characterize the species composition and biological characteristics of incidentally caught elasmobranchs. These data will aid in managing these species.

Materials and methods

Study area

Bottom trawling is conducted along the Pacific coast of Guatemala within the exclusive economic zone (83,000 km^2) between the 5- and 50-m isobaths (<30 km offshore) (TNC[1]). The low-temperature months are from January through March (28.6–29.1°C), and the high-temperature months are from April through December (29.2–30.2°C) (Ponce Hernández, 2015). Therefore, the temperature of the sea surface in this region is quite stable throughout the year.

The Directorate of Fisheries and Aquaculture Regulations (DIPESCA) of Guatemala conducts official inspections at the industrial landing sites of Puerto San José and Buena Vista. However, many trawlers and small vessels strategically use the alternative artisanal landing zone of Las Lisas, which is located approximately 150 km from the industrial landing sites and has its own fish market. During the rainy season (May–October) when catches are high, fishermen are paid the best prices at Las Lisas.

Monitoring of landings

Crew members of the vessels included in this study voluntarily collected and retained a portion of the organisms that are normally discarded at sea from each fishing trip. We then collected these retained organisms and used them to obtain biological data. Landings from 69 different fishing trips and 8 different trawl vessels were documented in Las Lisas from 2017 through 2022, and portions of elasmobranchs retained from the catches were sampled and photographed. Total length (for sharks, the natural extension of the caudal fin was used), disc width, disc length, and clasper length (in males) were recorded (to the nearest 0.5 cm). The maturity of males was verified by using clasper calcification. Eggs or embryos emerging from the cloaca in females were opportunistically recorded. In addition, trawler crews gathered the elasmobranchs that were to be discarded and collected one sample (5–7 kg) per trip. Each discard specimen was photographed, measured, and identified following Compagno (2001), Ebert and Fowler (2015), and Ebert et al. (2021). For all species, we summarized the main morphological characteristics, sex ratio, and size at first maturity obtained from the literature (Villavicencio Garyzar, 2000; Anislado-Tolentino and Robinson-Mendoza, 2001; López, et al.[3]; Payán et al., 2011; Torres-Huerta[4]; Castellanos Betancourt et al., 2013; Pincay-Espinoza and Romero-Calcedo, 2014; Torres Palacios, 2015; Vélez Tacuri, 2015; Carrera-Fernández et al., 2019; Ronquillo Moreira, 2019; Jiménez García, 2020), along with conservation status according to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2022). Finally, length-frequency histograms were created for species for which data for more than 30 individuals were collected.

Results and discussion

Fishing activity

Five shrimp species, the seabob (*Xiphopenaeus kroyeri*), crystal shrimp (*Penaeus brevirostris*), yellowleg shrimp (*P. californiensis*), whiteleg shrimp (*P. vannamei*), and blue shrimp (*P. stylirostris*), and 1 prawn species, the pelagic red crab (*Pleuroncodes planipes*), are harvested along the Pacific coast of Guatemala (TNC[1]). Bony fish species, such as the bigmouth sanddab (*Citharichthys gilberti*), spotted rose snapper (*Lutjanus guttatus*), and Pacific sierra (*Scomberomorus sierra*) (Jolon-Morales et al.[5]), and shark species, such as the scalloped hammerhead (*Sphyrna lewini*) (FUNMZ[6]), are also caught, landed, and marketed. From 2017 through 2022, 16 active shrimp trawlers, with an average of 5 crew members, average length of 18.66 m (13.00–22.87 m), average net registered weight of 22.37 t [4–87 t], and average gross registered weight of 70.49 t (14–170 t), operated in the

[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, 41 p. Informe finale. Proyecto Fodecyt 34-2006. Fondo Nac. Cienc. Tecnol., Cent. Estud. Mar Acuic., and Organ. Conserv. Medio Ambiente, Guatemala City, Guatemala. [Available from Cent. Estud. Mar Acuic., Univ. San Carlos Guatem., Ciudad Universitaria zona 12, Edificio T-14, 01012 Guatemala City, Guatemala.]

[3] López, J., P. A. Mejía-Falla, and A. F. Navia. 2009. Aspectos biológicos de la raya látigo *Dasyatis longa* (Pisces: Dasyatidae) de la zona central del Pacífico colombiano. Doc. Téc. Fund. SQUALUS FS0109, 39 p. [Available from SQUALUS, Calle 10A No. 72-35, Cali 760001, Colombia.]

[4] Torres-Huerta, A. M. 2012. Peces batoideos de la plataforma continental del Golfo de Tehuantepec, 68 p. Informe final. SNIB-CONABIO proyecto no. HJ031. Inst. Recur., Univ. Mar., Puerto Angel, Mexico. [Available from website.]

[5] Jolon-Morales, M. R., R. Sanchez-Castañeda, J. C. Villagrán-Colón, C. Mechel, and H. A. Kinh. 2005. Estudio sobre los recursos pesqueros (de escama) en el Litoral Pacifico y Mar Caribe de Guatemala, 128 p. Agencia Esp. Coop. Int. and Uni. Manejo Pesca Acuic., Guatemala City, Guatemala.

[6] FUNMZ (Fundación Mundo Azul). 2023. Informe anual 2022, 25 p. FUNMZ, Guatemala City, Guatemala. [Available from website.]

region (Morales[7]). There are no closed seasons to regulate commercial shrimp fishing; as a result, trawling is conducted year-round, although shrimp trawlers are more active during the rainy season (FUNCAGUA[8]). The shrimp trawling fleet requires 30-d permits granted by DIPESCA. Normally, trawling vessels work for 12–15 d at a time, and 4–5 trawl tows are conducted each day (3–4 h of operation in total per day). We observed that trawlers, preferring to reduce fuel costs, made partial landings in Las Lisas with the aid of smaller boats from the fishing community instead of returning to the official docks of Puerto San José and Buena Vista.

A limited number of trained DIPESCA personnel are available to conduct inspections and collect data of commercial shrimp landings to control fishing activities along the Pacific coast of Guatemala; therefore, data are limited and unreliable. High staff turnover within DIPESCA has also resulted in unreported or irregularly reported catches and unreliable data. No monitoring programs currently record the additional organisms captured as bycatch in shrimp trawling activities. Information on bycatch off Guatemala is lacking, although turtles and marine mammals, in addition to elasmobranchs, are known to be captured with shrimp trawling fishing gears.

[7] Morales, J. 2022. Personal commun. Dir. Fish. Aquac. Regul. Km. 22 Carretera al Pacífico, Edificio la Ceiba, tercer nivel, Guatemala City, Guatemala.

[8] FUNCAGUA (Fundación para la Conservación del Agua de la Región Metropolitana de Guatemala). 2020. Clima en Guatemala. [Available from website.]

Landings

In all, 43 trips (62.3% of trips) were conducted during the rainy season, and 26 trips (37.7% of trips) were conducted during the dry season. A total of 1330 elasmobranchs were recorded, belonging to 5 orders, 12 families, and 15 species. Of these 15 species, 1 species is listed as critically endangered, 4 species are listed as near threatened, 7 species are listed as vulnerable, and 1 species is listed as a species of least concern on the IUCN Red List (Table 1) (IUCN, 2022). Overall, 73 elasmobranch individuals (5.5% of the total number of elasmobranchs recorded) were considered commercially valuable and sold. The bycatch mainly comprised 3 ray species, the longtail stingray (*Hypanus longus*), golden cownose ray (*Rhinoptera steindachneri*), and Pacific eagle ray (*Aetobatus laticeps*), and 2 shark species, the scalloped hammerhead and bull shark (*Carcharhinus leucas*). The fins of large sharks (>1 m in total length) were dried and marketed.

Ten elasmobranch species were discarded (number of samples [*n*]=1257, 94.5% of the total number of individuals recorded; Table 1). Of these 10 species, the vermiculate electric ray (*Narcine vermiculata*) (*n*=426) was the most abundant, followed by the Panamic stingray (*Urotrygon aspidura*) (*n*=397), whitesnout guitarfish (*Pseudobatos leucorhynchus*) (*n*=182), giant electric ray (*N. entemedor*)

Table 1

Number of samples (*n*), ratio of males (M) to females (F), size range, and status on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species for elasmobranch species landed by shrimp trawlers in Las Lisas, Guatemala, during 2017–2022. Also noted is whether captured individuals of non-target species were traded in the market (bycatch) or had no commercial value and were returned to the sea dead or alive (discard). The measurement of size (MS) is either total length (TL) or disk width (DW). Sizes at first maturity are from the literature. No data (ND) on size at maturity were available in the literature for *Rostroraja equatorialis*.

Species	*n*	Sex ratio (M:F)	MS	Average size (cm)	Size range (cm)	Size at first maturity (cm)		IUCN status	Discard or Bycatch
						Males	Females		
Narcine vermiculata	426	151:275	TL	20.6	6.0–39.3	11.6	11.6	Least concern	Discard
Urotrygon aspidura	397	153:244	TL	32.9	9.0–94.2	23.0	25.0	Near threatened	Discard
Pseudobatos leucorhynchus	182	58:124	TL	38.2	18.0–63.4	51.2	48.5	Vulnerable	Discard
Narcine entemedor	127	34:93	TL	27.4	14.0–68	47.7	70.0	Vulnerable	Discard
Urotrygon chilensis	72	30:42	DW	18.3	10.0–29.2	16.5	16.0	Near threatened	Discard
Hypanus longus	38	9:29	DW	62.8	7.0–131.0	92.0	120.0	Vulnerable	Bycatch
Zapteryx xyster	27	10:17	TL	36.8	26.0–57.0	46.8	50.0	Vulnerable	Discard
Gymnura crebripunctata	22	15:7	DW	34.9	18.5–54.0	34.2	58.8	Near threatened	Discard
Sphyrna lewini	17	10:7	TL	49.8	42.0–54.0	170.0	190.0	Critically endangered	Bycatch
Rhinoptera steindachneri	15	0:15	DW	39.2	26.0–47.0	71.8	71.8	Near threatened	Bycatch
Aetobatus laticeps	2	0:2	DW	41.1	37.2–45.0	83.2	83.2	Vulnerable	Bycatch
Rostroraja equatorialis	2	0:2	DW	35.1	32.7–37.5	ND	ND	Vulnerable	Discard
Carcharhinus leucas	1	0:1	TL	–	262.0	157.0	180.0	Vulnerable	Bycatch
Gymnura sp.	1	0:1	DW	–	38.0	–	–	–	Discard
Zapteryx sp.	1	1:0	TL	–	38.0	–	–	–	Discard

(n=127]), blotched stingray (*U. chilensis*) (n=72), and longtail stingray (n=38). Other species were represented by less than 30 individuals (Table 1).

In this study, 13 ray species and 2 shark species were identified. About 90% of these species belong to 3 genera, *Narcine*, *Urotrygon*, and *Pseudobatos*, which accounted for 41.6%, 35.3%, and 13.7% of the identified species, respectively. According to the distribution of sizes and sexes recorded for the most abundant species (Fig. 1), trawling could be affecting the breeding areas of the vermiculate electric ray, Panamic stingray, and blotched stingray. At the same time, this trawl fishing zone could be a breeding area for the whitesnout guitarfish, giant electric ray, and longtail stingray. This probable breeding area extends along the Pacific coast of Guatemala, between the isobaths of 5 and 50 m (TNC[1]), where trawling activities take place throughout the year. However, it is necessary to continue monitoring this fishery to be able to determine the extent and temporality of this area according to the different species recorded.

The biological characteristics shared by elasmobranch species (e.g., late sexual maturity and low fecundity) make their populations vulnerable to instability when subjected to direct or incidental fishing pressure (Walker, 1992). The trawl nets used in the Pacific Ocean off Guatemala are not selective, although they have turtle excluding devices. The resulting bycatch is concerning because of the lack of records and data (Gillett, 2010), especially considering that bycatch exceeded the catch volume of targeted shrimp species in Guatemala in 2016 (FAO, 2018).

Conservation and management

In the General Law of Fisheries and Aquaculture of Guatemala, rays are not included as target species in coastal fisheries (MAGA, 2002). In 2021, the Ministry of Agriculture, Livestock, and Food, which oversees DIPESCA, approved the National Action Plan for the Conservation of Chondrichthyans of Guatemala by ministerial agreement (no. 280-2021) (MAGA, 2021) to investigate, manage, and conserve chondrichthyan species in the exclusive economic zones of Guatemala in the Atlantic and Pacific Oceans. Nonetheless, few studies on elasmobranchs that

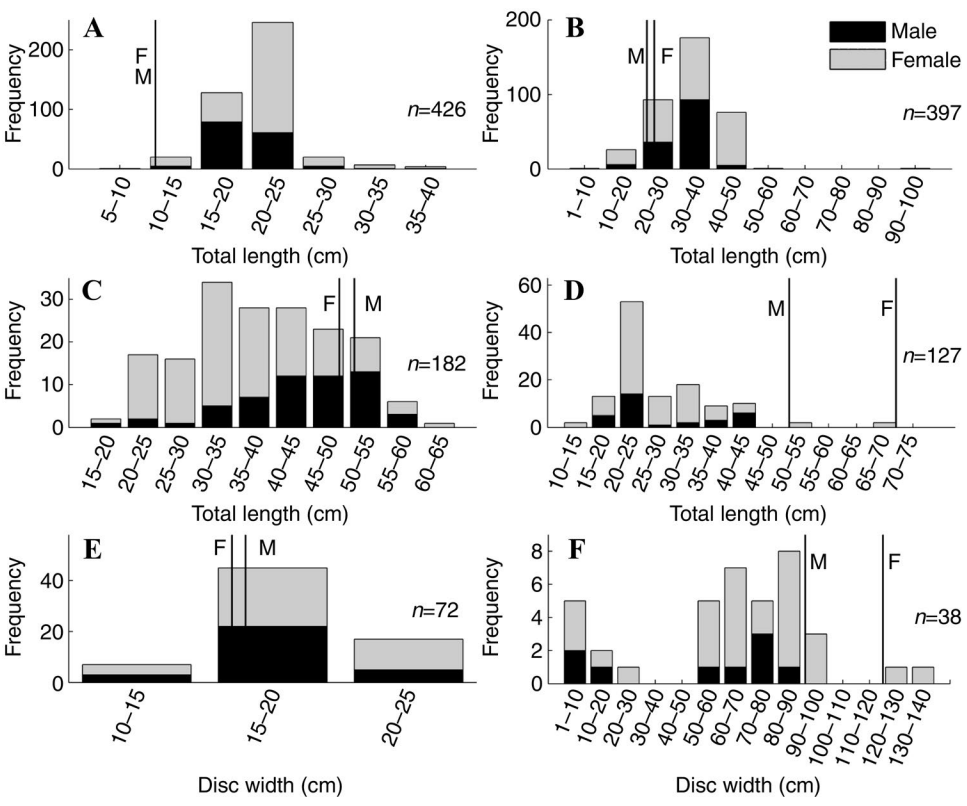

Figure 1

Size–frequency distributions of elasmobranch species landed by shrimp trawlers as bycatch from 2017 through 2022 in Las Lisas, Guatemala: (**A**) vermiculate electric ray (*Narcine vermiculata*), (**B**) Panamic stingray (*Urotrygon aspidura*), (**C**) whitesnout guitarfish (*Pseudobatos leucorhynchus*), (**D**) giant electric ray (*N. entemedor*), (**E**) blotched stingray (*U. chilensis*), and (**F**) longtail stingray (*Hypanus longus*). Histograms are based on the number of organisms sampled (n), not on the total number of individuals captured. The vertical lines indicate lengths at first maturity for males (M) and females (F).

are not commercially valuable, such as the Panamic stingray (Torres Palacios, 2015), which is listed as near threatened on the IUCN Red List (Kyne et al., 2020a), and the blotched stingray (Pincay-Espinoza and Romero-Calcedo, 2014), which also is listed as near threatened on the IUCN Red List (Kyne et al., 2020b), have been done. Therefore, little information is available to inform management decisions. Indeed, the composition and volume of ray bycatch are often unknown, and no research or monitoring efforts are directed at this group of elasmobranch species. As such, the results of this study provide an important characterization of the species composition of elasmobranchs that are normally discarded as bycatch during shrimp trawling activities off Guatemala.

Resumen

Se examinó la composición específica de la captura incidental en la pesquería de arrastre de camarón, en la costa del Pacífico de Guatemala. En total, se registraron 15 especies de elasmobranquios, incluidas 13 especies de rayas y 2 especies de tiburones. De estos taxones, 1 especie está enlistada como en riesgo crítico, 4 especies como casi amenazadas, 7 como vulnerables y 1 como de menor preocupación por la Unión Internacional para la Conservación de la Naturaleza. Actualmente, no existe un sistema oficial de monitoreo de la pesca de arrastre de camarón en Guatemala, por lo que se desconoce la abundancia y las características biológicas de las especies de elasmobranquios capturadas incidentalmente. Se carece de esta información debido a que sólo el 5.5% de la captura incidental de elasmobranquios registrada se desembarcó y comercializó por su valor económico.

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