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The seasonal importance of small coastal sharks and rays in the artisanal elasmobranch fishery of Sinaloa, Mexico

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Abstract. Seasonal surveys were conducted during 1998–1999 in Sinaloa, Mexico to determine the extent and activities of the artisanal elasmobranch fishery operating in the southeastern Gulf of California. Twenty–eight fishing sites were documented, the majority of which (78.6%) targeted elasmobranchs during some part of the year. Sharks numerically dominated sampled landings (65.0%, *n* = 2390), and catch rates exceeded those of rays during autumn–spring. The scalloped hammerhead, *Sphyrna lewini*, was the primary fishery target during these seasons, with most landings composed of early life stages. During summer, rays, especially *Rhinoptera steindachneri*, were numerically dominant (87.7%). Large sharks were of comparably minor importance in the artisanal fishery during all seasons. Catch composition was similar between spring and winter (SIM_{obs} = 0.393, SIM_{exp} = 0.415; *P* = 0.25), largely because the fishery mainly targeted "cazón" (sharks $\leq$ 1.5 m total length) during this period (e.g., *S. lewini*, *Rhizoprionodon longurio*). Small size classes of large sharks and a wide size range of coastal sharks and rays were primarily observed. In addition, size composition of *S. lewini* and to a lesser extent, *R. longurio* decreased significantly between historic and contemporary landings. Local populations of these species should therefore be closely monitored.

Keywords: catch composition, CPUE, Gulf of California, size composition, sex ratio

Resumen. Importancia estacional de los cazón y rayas en la pesquería artesanal de elasmobranquios de Sinaloa, México. Se realizaron prospecciones estacionales durante 1998–1999 en Sinaloa, México para determinar la magnitud y las actividades de la pesquería artesanal de elasmobranquios del sureste del Golfo de California. Se documentaron veintiocho localidades pesqueras, la mayoría (78.6%) pescaron elasmobranquios en alguna época del año. Los tiburones dominaron numéricamente los desembarques (65.0%, *n* = 2390), sus tasas de captura excedieron a las de rayas en otoño–invierno. El tiburón martillo, *Sphyrna lewini*, fue la principal especie objetivo con la mayoría de los desembarques compuestos por juveniles. En verano, las rayas, especialmente, *Rhinoptera steindachneri*, fueron numéricamente dominantes (87.7%). Los tiburones grandes fueron de menor importancia en todas las temporadas. La composición de las capturas fue similar en primavera e invierno (SIM_{obs} = 0.393, SIM_{exp} = 0.415; *P* = 0.25), debido a que la pesquería pesca "cazón" (tiburones de $\leq$ 1.5 m) durante este periodo (ej., *S. lewini*, *Rhizoprionodon longurio*). De tiburones grandes se observaron tallas pequeñas, mientras que de tiburones costeros y rayas un mayor intervalo de tallas. Además, las tallas de *S. lewini* y *R. longurio* disminuyeron significativamente entre los desembarques históricos y los actuales. Por lo tanto, las poblaciones locales de estas especies deberían ser monitoreadas cuidadosamente.

Palabras clave: composición de la captura, composición por talla, CPUE, Golfo de California, razón sexual

Introduction

Mexico has historically been among the global leaders in shark and ray fishery production (Stevens *et al.* 2000, FAO 2007). Increasing concern regarding the status and sustainability of elasmobranch populations in Mexican waters, however, has prompted the development of a federal management plan and underscored the need for fundamental information on targeted species (DOF 2007). Improved management of Mexican elasmobranch fisheries has been hampered, in part, by a lack of detailed quantitative information on the location and activities of artisanal fishing sites, species composition of landings, and basic life history information of targeted species (Castillo–Géniz *et al.* 1998, Márquez–Farías 2002). The Gulf of California is one of Mexico's most important regions in terms of overall and elasmobranch fisheries production (CONAPESCA 2006). Contemporary and historic data indicate that the state of Sinaloa, which bounds the southeastern Gulf of California, has been consistently among the national leaders in elasmobranch landings (CONAPESCA 2006).

Elasmobranchs landings ranged from 1924–5883 t and averaged 1.6% of total fishery production in Sinaloa during 1996–2006, the most recent available time series (CONAPESCA 2006). Elasmobranch landings from Sinaloa comprised 16.5% of national elasmobranch production during 2006, the greatest of all Mexican states, and averaged 8.0% of national production during 1996–2006. Sharks, especially "tiburón" (sharks > 1.5 m total length), constituted the great majority of reported landings, with rays contributing an average of 9.4% by weight during 1996–2006 (CONAPESCA 2006). However, rays and small sharks (≤ 1.5 m total length), or "cazón," have been reported to constitute a considerable portion of artisanal landings in other regions of the Gulf of California (Bizzarro *et al.* 2009a, Smith *et al.* 2009a) and have supported historic artisanal fisheries in Sinaloa (Saucedo–Barrón *et al.* 1982, Righetty–Rojo & Castro–Morales 1990, Castillo–Géniz 1990).

To improve the understanding, conservation, and management of exploited shark and ray populations in the Gulf of California (GOC), a two–year study was undertaken during 1998–1999 to describe the extent and activities of the artisanal elasmobranch fisheries in each state bordering on the GOC. Manuscripts providing detailed elasmobranch fishery information for Sonora (Bizzarro *et al.*, 2009a), Baja California (Smith *et al.*, 2009a), and Baja California Sur (Bizzarro *et al.*, 2009b) have been recently published. This complementary work on the artisanal elasmobranch fishery of Sinaloa therefore completes the series. Specific objectives were to: 1) determine the locations and activities of elasmobranch fishing sites in Sinaloa; 2) determine seasonal species composition of elasmobranchs from these sites, and 3) provide biological information (size composition, sex ratios) for the primary species in landings. Limited, supplemental information was collected during 2005–2009 and used for comparative purposes with the historic data presented from 1998–1999.

Study Site Information. Bordered by the GOC to the west, mainland Sinaloa contains 640 km of coastline (INEGI 2007). The continental shelf off Sinaloa is relatively wide, with the shelf break typically occurring > 50 km offshore. The shelf is widest off the southern portion of the state, where it may occur > 100 km from shore, and narrowest (~ 20 km) off Isla Altamura (Dauphin & Ness 1991) (Fig. 1). Coastal regions are composed largely of sandy substrates. Lagoons, estuaries, and other insular waters occur extensively throughout Sinaloa.

Sinaloa is one of Mexico's most important states in terms of fishery production, accounting for 17.3% of landings and 20.7% of revenues during 2006 (CONAPESCA 2006). These totals ranked second among Mexican states in both categories. The most important fishery resources in Sinaloa were, in order of descending landings during 1996–2006: tunas, sardines, and shrimps. Shrimp production is the greatest source of revenue among Mexican fishery resources, and Sinaloa landed more shrimp than any other Mexican state during 1996–2006 (CONAPESCA 2006). The main fishery port in Sinaloa is Mazatlán (Fig. 1).

Materials and Methods

Sinaloa was surveyed in spring and autumn of 1998 and during all seasons of 1999. Data were collected specifically during March 2–8, October 1–7, 1998, and January 10–February 17, March 2–16, June 3–17, and November 11–13, 1999. Seasons were defined as follows: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). Camp locations and general fisheries information were collected exclusively during 1998. Camps that directly targeted elasmobranchs were revisited seasonally during 1999 to sample landings and collect biological data. Contemporary observations of the Sinaloa artisanal elasmobranch fishery were made during 2005–2009 from opportunistic field surveys, with all size frequency data collected during 2007–2008.

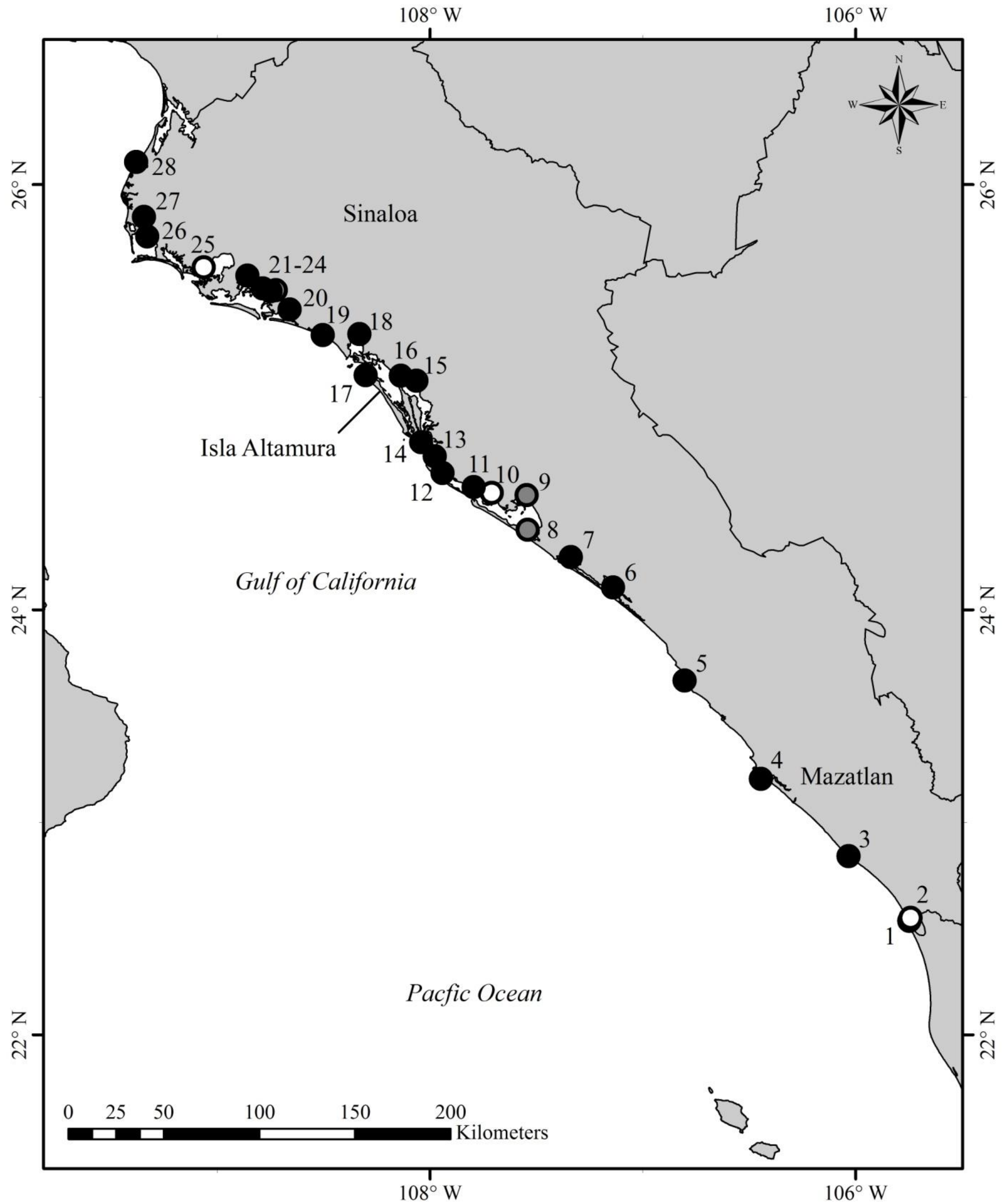

Figure 1. Locations of artisanal fishing sites (*n* = 28) documented in Sinaloa during 1998–1999. Designations are as follows: black dots = elasmobranchs targeted, white dots = elasmobranchs not targeted, gray dots = fishery targets unknown.

Locations of fishing sites were determined from maps, local knowledge of fishing activity, and exploration. Once located, the exact position of each site was determined with a handheld Global Positioning System (GPS) unit. At each site, artisanal fishing vessels ("pangas"), typically 5.5–7.6 m long, open–hulled fiberglass boats with outboard motors of 55–115 hp, were sampled and fishermen were interviewed to determine fishery targets, elasmobranch species composition, fishing locations, and gear types. All references to mesh size of gillnets indicate stretched mesh size (the distance between knots when the mesh is pulled taut). Type of fishing site (A = little to no infrastructure, remote sites with no electricity or running water and small shelters located along the beach; B = moderate infrastructure, sites associated with small towns with limited electricity and/or running water and occasionally permanent dwellings; C = significant infrastructure, sites associated with cities with consistent electricity and running water and permanent dwellings), permanence (1 = permanent, 2 = seasonal), period of activity, and number of active pangas were recorded for each site.

Elasmobranch landings were identified to lowest possible taxonomic level, enumerated, sexed, and measured whenever possible. Gymnurid (i.e., *Gymnura crebripunctata*, *G. marmorata*) and narcinid (i.e., *Narcine entemedor*, *N. vermiculatus*, *Diplobatis ommata*, and a possible undescribed species in this region) rays were grouped into species complexes (i.e., *Gymnura* spp., Narcinidae) because of taxonomic confusion within these genera during the time of surveys. Taxonomic uncertainty involving eastern Pacific gymnurids has since been resolved (Smith *et al.* 2009b). Standard measurements (e.g., stretched total length, disc width) were consistently recorded on linear axes to the nearest 1.0 cm for sampled sharks and rays.

Elasmobranch landings were summed by season and by year to determine species composition. Only landings from vessels targeting elasmobranchs were sampled. Catch per unit effort (CPUE), defined as number of individuals/vessel/trip, was calculated for each season.

All measured specimens were utilized to determine size composition and sex ratio of landings. For all species with $\geq$ 50 measured individuals, potential differences in the size composition of landed females and males were examined using parametric and non–parametric approaches, as appropriate. Raw size data were first evaluated for normality and equality of variances using Shapiro–Wilk and two–tailed variance ratio (*F*) tests, respectively (Zar 1999). When data were determined to be normally distributed and of equal variance, two–tailed *t*–tests were applied to test the hypothesis that mean sizes of females and males did not significantly differ ($\alpha = 0.05$) among landings. Size data that did not meet the assumptions of normality or homoscedasticity were transformed (log, square root) in an attempt to correct for deviations from these assumptions and re–examined with Shapiro Wilk and two–tailed *F*–tests. If transformations were unsuccessful, size data were evaluated using two–tailed non–parametric Mann–Whitney *U* tests (Zar 1999). Additionally, the assumption of equal sex ratios (1:1) within the landings was tested using chi–square analysis with Yates correction for continuity (Zar 1999).

Reproductive status was assessed opportunistically and specimens were assigned to one of the following categories: neonate, juvenile, adult, or gravid. Males with fully calcified claspers that could be easily rotated, coiled epididymides, and differentiated testes were considered mature (Pratt 1979, Ebert 2005). Female maturity was determined by macroscopic inspection of the ovaries and uteri (Martin & Cailliet 1988, Ebert 2005). Mature females had oviducal glands that were well–differentiated from the uteri, and vitellogenic follicles >1.0 cm diameter and/or egg capsules in utero. Neonates of placentally viviparous species could be identified based on the presence of an umbilical scar. A qualitative comparison of observed size to known size at birth was used to distinguish neonates of oviparous or aplacentally viviparous species. Any female containing an embryo or fertilized ova was considered gravid.

Sample size–sufficiency of temporal catch composition estimates was investigated using cumulative taxon curves (Gotelli & Colwell 2001). To determine if landings from a sufficient number of vessels had been sampled to adequately describe catch composition for a time period, the mean cumulative number of elasmobranch taxa present in each vessel was plotted against the randomly pooled number of vessels (Ferry & Cailliet 1996). Catch composition of 5000 randomly selected vessels was resampled using Matlab (ver. 2007b, The MathWorks, Inc., Natick, MA) to calculate a mean and standard deviation estimate for each sample. Using 5000 iterations insured that estimates were precise and increased consistently with increasing sample size. Linear regression of the raw data generated for the last four vessel samples was used to determine if the curve reached an asymptote, signifying an adequate number of samples (Bizzarro *et al.* 2007, 2009a). In a slight modification of this technique, the slope of the regression line (*b*) was used to evaluate samples size sufficiency instead of the *P*–value of the regression. This modified technique was used because the *P*–value associated with *b* is influenced by the precision of curve estimates and the number of iterations (i.e., amount of input data), and may indicate a significant increasing trend even at slopes close to zero. Since $b = 1.00$ signifies perfect agreement and $b = 0.00$ signifies no agreement (Zar 1999), sufficient sample size was achieved at $b < 0.05$.

If a sufficient number of samples was

collected, temporal comparisons of bottom–set longline composition were conducted using randomization tests (Manly 2007). The presence of singletons (vessel landings comprised of only one individual) precluded the use of Morisita's original index (Morisita 1959). Horn's index was therefore applied to proportional species–specific (including species complexes) data to determine similarity of landings among vessels, as recommended by Krebs (1999), The mean similarity value observed between temporal groupings (SIM_{obs}) was determined from similarity values calculated for all possible pair–wise comparisons. A null distribution was then created using catch composition of 1000 vessels bootstrapped from each group to equalize sample size. Resulting pooled data were then resampled back to original sample sizes and similarity values were generated from all possible pair–wise comparisons of catch composition between resampled groups. This process was repeated 1000 times to generate a null distribution of expected mean similarity values (SIM_{exp}). SIM_{obs} was compared to null distribution values to determine if catch composition differed significantly.

Results

Camp characteristics. During 53 survey days in 1998 and 1999, 28 artisanal fishing sites, broadly termed "camps," were identified in Sinaloa (Table I, Fig. 1). Directed fisheries for elasmobranchs were documented at 78.6% (*n* = 22) of these locations. Three sites, SIN–02, SIN–10, and SIN–25, were not found to support active fisheries for elasmobranchs and the occurrence of elasmobranch fisheries could not be verified at three additional sites. Most fishing camps were active throughout the year (96.4%; *n* = 27). Fishing camps were typically well–developed, containing either moderate (*n* = 20) or significant (*n* = 5) infrastructure. The number of pangas actively involved in fishing operations at the time of the surveys ranged from 10 at SIN–18 and SIN–19 to approximately 500 operating from SIN–15. Seasonal variability in the number of active pangas was notable at several camps (e.g., SIN–01, SIN–12, SIN–28). The onset of the shrimp fishing season in September dramatically altered fishing operations and shifted effort among locations.

No systematic surveys of artisanal fishing camps have been conducted in Sinaloa since 1998–1999. However, based on reports from other monitoring programs of the Instituto Nacional de Pesca, some fishing camps are still operational, including: Teacapán (SIN–01), Playa Sur (SIN–04), Barras de Piaxtla (SIN–05), Cospita (SIN–06), Altata (SIN–12), and La Reforma (SIN–15). Most were found to have characteristics that were generally similar to those noted during 1998–99.

Fishery characteristics. All of the 96 vessels sampled during the winter used bottom set longlines. Fishing depths were infrequently recorded, but were reported to occur as shallow as 5–6 m and at depths of ≥ 45 m. Soak times and gear lengths were largely undocumented. Fishermen reported traveling 5–30 km to set gear.

Gear use during the spring fishery consisted primarily of longlines (96.9%) among 64 sampled vessels, with only two boats observed using gillnets. All gear was fished on the bottom, with the exception of one longline set that was fished in the water column. More than one longline or net was typically deployed from each vessel. Fishing depths ranged from 4–90 m. Soak times of longlines were often brief (< 2 hours), but were occasionally fished for ≤ 24 hours. Gillnets were most often soaked for 12–24 hours before retrieval. Mesh sizes of gillnets ranged from 7.6–20.3 cm.

Among 23 combined vessels for which gear use was known from summer (*n* = 21) and autumn (*n* = 2), bottom set gillnets were determined to be most widely used in the summer (85.7%) and longlines set in the water column were exclusively sampled during autumn. Bottom set longlines comprised the remaining 14.3% of the gear recorded during the summer. Bottom set gillnets and longlines were typically fished at ~11–30 m. Gillnet soak times varied from 15–24 hours. Mesh sizes measured 7.6–40.6 cm, with larger mesh sizes (e.g., 21.6 cm, 40.6 cm) most commonly observed.

Seasonal catch composition in Sinaloa was assessed from 3676 total specimens (Table II). Sharks comprised the majority of overall landings (65.0%), with rays contributing 35.0%. Skates and chimaeras were not documented from artisanal landings. The scalloped hammerhead (*Sphyrna lewini*) was the most frequently observed species and was consistently represented in landings during all seasons, comprising 43.1% of the total recorded catch.

The great majority of 1089 specimens recorded from winter landings in Sinaloa were sharks (89.1%) (Table II). Included among these specimens was the only observed pelagic thresher shark, *Alopias pelagicus*. Elasmobranch landings were dominated by two species, *S. lewini* (54.4%) and the Pacific sharpnose shark, *Rhizoprionodon longurio* (27.4%), which accounted for more than 81% of the season's total catch. The smooth hammerhead, *Sphyrna zygaena*, represented an additional 6.4% of winter landings. Catches of rays were primarily composed of diamond stingrays, *Dasyatis dipterura* (8.2%), and speckled guitarfish, *Rhinobatos glaucostigma* (1.8%). A sufficient number of vessels was sampled during winter 1999 to adequately characterize species composition of landings (r^2 = 0.720; b = 0.013).

Table I. Descriptive information for all artisanal fishing camps documented in Sinaloa (SIN) during 1998-1999. Type = A (little to no infrastructure), B (moderate infrastructure), and C (significant infrastructure); Perm. (Permanence) = 1 (permanent) and 2 (seasonal); Active = period of fishing activity; #Pangas = number or range of operational artisanal fishing vessels at the time of survey(s); Elasmo. (elasmobranchs targeted) = Yes (elasmobranchs were targeted during the year) and No (there was no directed fishery for elasmobranchs). Zero values listed for #Pangas indicate that the camp was temporarily inactive (because of weather, holidays, etc.) or seasonally abandoned at the time of survey. In all instances, U = unknown.

Camp Code	Camp Name	Latitude	Longitude	Type	Perm.	Active	#Pangas	Elasmo.
SIN-01	Teacapan	22.536	-105.747	C	1	Year-Round	42-80	Yes
SIN-02	La Brecha	22.551	-105.741	B	1	Year-Round	27	No
SIN-03	Majahual	22.841	-106.033	B	1	Year-Round	22	Yes
SIN-04	Playa Sur	23.204	-106.444	C	1	Year-Round	29	Yes
SIN-05	Barras de Piaxtla	23.667	-106.804	B	1	Year-Round	18-49	Yes
SIN-06	Cospita	24.104	-107.140	B	1	Year-Round	22-35	Yes
SIN-07	El Conchal	24.247	-107.338	B	1	Year-Round	14	Yes
SIN-08	Las Arenitas	24.376	-107.541	B	1	Year-Round	U	U
SIN-09	Las Puentes	24.539	-107.546	B	1	Year-Round	50	U
SIN-10	El Castillo	24.550	-107.710	B	1	Year-Round	U	No
SIN-11	Las Aguamitas	24.577	-107.795	B	1	Year-Round	50	Yes
SIN-12	Altata	24.643	-107.941	C	1	Year-Round	90-200	Yes
SIN-13	Dautillos	24.721	-107.978	B	1	Year-Round	250	Yes
SIN-14	Yameto	24.788	-108.042	A	1	Year-Round	U	Yes
SIN-15	La Reforma	25.077	-108.064	C	1	Year-Round	500	Yes
SIN-16	Costa Azul	25.101	-108.137	B	1	Year-Round	50	Yes
SIN-17	La Riscion - Isla de Altamura	25.103	-108.302	A	2	Dec-Apr	0-15	Yes
SIN-18	Playa Colorada	25.297	-108.332	B	1	Year-Round	10	Yes
SIN-19	Boca del Rio	25.292	-108.504	B	1	Year-Round	10	Yes
SIN-20	El Tortugo	25.412	-108.660	B	1	Year-Round	30	Yes
SIN-21	El Coloradito	25.503	-108.725	B	1	Year-Round	20	U
SIN-22	El Caracol	25.498	-108.749	B	1	Year-Round	50	Yes
SIN-23	Huitussi	25.511	-108.787	B	1	Year-Round	50	Yes
SIN-24	Cerro el Cabézon	25.572	-108.858	B	1	Year-Round	50-60	Yes
SIN-25	Topolobampo	25.610	-109.063	C	1	Year-Round	20	No
SIN-26	El Colorado	25.756	-109.330	B	1	Year-Round	15	Yes
SIN-27	Las Grullas Margen Izquierdo	25.848	-109.345	A	1	Year-Round	23-51	Yes
SIN-28	Las Lajitas	26.107	-109.381	B	1	Year-Round	50-100	Yes

Spring landings were dominated by small sharks and to a lesser extent, rays (Table II). The most common species among landings were *S. lewini* (45.4%), *R. glaucostigma* (22.6%), *R. longurio* (16.0%), and *D. dipterura* (10.1%). The only blue shark (*Prionace glauca*) reported from Sinaloa was observed during spring 1999. An insufficient number of vessels was sampled to adequately characterize species composition of landings during spring 1999 when data from all vessels were used (r^2 = 0.947 b = 0.058). However, when data were limited to vessels using bottom–set longline gear and species (or species–complex) identifications (n = 62), estimates were precise (r^2 = 0.876; b = 0.021).

Table II. Seasonal, annual, and total catch composition of shark and ray landings sampled from artisanal vessels targeting elasmobranch in Sinaloa during 1999. *n* = number of individuals, % = percentage of elasmobranch landings

		Winter		Spring		Summer		Autumn		Total	
Higher Taxon	Lowest Possible Taxon	n	%	n	%	n	%	n	%	n	%
Sharks	*Alopias pelagicus*	1	0.1	0	0.0	0	0.0	0	0.0	1	0.0
	Carcharhinus altimus	1	0.1	0	0.0	0	0.0	0	0.0	1	0.0
	Carcharhinus leucas	0	0.0	0	0.0	2	0.4	0	0.0	2	0.1
	Carcharhinus limbatus	4	0.4	10	0.5	19	4.1	0	0.0	33	0.9
	Carcharhinus obscurus	0	0.0	0	0.0	0	0.0	2	18.2	2	0.1
	Carcharhinus spp.	0	0.0	0	0.0	2	0.4	0	0.0	2	0.1
	Nasolamia velox	4	0.4	4	0.2	0	0.0	0	0.0	8	0.2
	Prionace glauca	0	0.0	1	0.0	0	0.0	0	0.0	1	0.0
	Rhizoprionodon longurio	298	27.4	338	16	7	1.5	1	9.1	644	17.5
	Sphyrna lewini	592	54.4	959	45.4	25	5.4	8	72.3	1584	43.1
	Sphyrna zygaena	70	6.4	40	1.9	2	0.4	0	0.0	112	3.0
	Subtotal	**970**	**89.1**	**1352**	**64.0**	**57**	**12.3**	**11**	**100.0**	**2390**	**65.0**
Rays	*Aetobatus narinari*	0	0.0	0	0.0	3	0.6	0	0.0	3	0.1
	Dasyatis dipterura	89	8.2	214	10.1	26	5.6	0	0.0	329	8.9
	Dasyatis longa	4	0.4	15	0.7	1	0.2	0	0.0	20	0.5
	Dasyatis spp.	0	0.0	8	0.4	0	0.0	0	0.0	8	0.2
	Gymnura spp.	3	0.3	8	0.4	66	14.2	0	0.0	77	2.1
	Mobula munkiana	0	0.0	0	0.0	5	1.1	0	0.0	5	0.1
	Mobula sp.	0	0.0	0	0.0	1	0.2	0	0.0	1	0.0
	Narcinidae	0	0.0	1	0.0	19	4.1	0	0.0	20	0.5
	Rhinobatos glaucostigma	20	1.8	477	22.6	54	11.6	0	0.0	551	15.0
	Rhinobatos spp.	0	0.0	32	1.5	0	0.0	0	0.0	32	0.9
	Rhinoptera steindachneri	3	0.3	3	0.1	233	50.1	0	0.0	239	6.5
	Zapteryx exasperata	0	0.0	1	0.0	0	0.0	0	0.0	1	0.0
	Subtotal	**119**	**10.9**	**759**	**36.0**	**408**	**87.7**	**0**	0.0	**1286**	**35.0**
	Total	**1089**	**100.0**	**2111**	**100.0**	**465**	**100.0**	**11**	**100.0**	**3676**	**100.0**

Summer landings were dominated by rays (87.7%) (Table II). Six ray species and three taxa were recorded. The most frequently occurring species were the golden cownose ray, *Rhinoptera steindachneri* (50.1%) and *R. glaucostigma* (11.6%). Butterfly rays, *Gymnura* spp., accounted for 14.2% of all recorded elasmobranchs during the summer. The pygmy devil ray (*Mobula munkiana*) and spotted eagle ray (*Aetobatus narinari*) were observed exclusively during this season. *Sphyrna lewini* was the only shark species to comprise > 5.0% of summer landings (5.4%). The only bull sharks (n = 2), *Carcharhinus leucas*, documented from Sinaloa surveys were reported from summer landings. Too few vessels were sampled for precise estimates of species composition (r^2 = 0.994; b = 0.097).

Autumn catch composition was described from only 11 specimens landed by two vessels (Table II). Most of these individuals were *S. lewini* (72.7%). No rays were reported during this sampling period.

Variability was evident in vessel–specific catch composition within, but not between temporal sampling periods. Vessel–specific composition of demersal gillnet landings during winter did not differ significantly from that during spring (SIM_{obs} = 0.393, SIM_{exp} = 0.415; P = 0.25). During both seasons, landings were composed primarily of sharks, especially *S. lewini* and to a lesser extent, *R. longurio*. Although ray landings (e.g., *R. glaucostigma*, *D. dipterura*) comprised a substantially greater proportion of vessel–specific landings during spring, most landings were contributed by relatively few vessels. Considerable intraseasonal variability in catch composition was evident during winter (SIM_{winter} = 0.503 ± 0.429) and spring (SIM_{spring} = 0.358 ± 0.463).

Overall CPUE in Sinaloa was greatest during spring (32.0) and at a minimum (5.5) in autumn (Table III). CPUE estimates for sharks were greater than those of rays during all seasons except summer. CPUE exceeded 1.0 for only two species in the winter, *S. lewini* (mean ± SE; 6.1 ± 1.0) and *R. longurio* (3.1 ± 0.5). The greatest catch rates observed in the spring fishery were associated with *S. lewini* (14.5 ± 2.6). This rate represents the greatest species–specific seasonal CPUE among Sinaloa landings. Catch per unit effort values exceeding 1.0 were obtained for three additional species during spring: *R. glaucostigma* (7.2 ± 4.1), *R. longurio* (5.1 ± 1.4), and *D. dipterura* (3.2 ± 1.0). Three taxa, *R. steindachneri*, *Gymnura* spp., and *R. glaucostigma* largely accounted for the elevated CPUE of rays in the summer. Among these, the catch rate was greatest for *R. steindachneri* (11.1 ± 3.5). CPUE exceeded 1.0 for only one shark species, *R. longurio* (1.2 ± 0.7), during summer months. No rays were observed among the landings of two vessels sampled during autumn. CPUE for *S. lewini* (4.0 ± 4.0) was the greatest observed for a species in this season.

Artisanal fishing effort was often opportunistic and directed toward multiple species. Groupers and sea basses (Serranidae), as well as snappers (Lutjanidae), were frequently taken in combination with elasmobranchs in Sinaloan longline fisheries. Croakers (Sciaenidae) and catfishes (Ariidae) were often captured in association with sharks and rays in the bottom set gillnet fishery. Invertebrates landed incidentally by pangas targeting elasmobranchs included shrimps (Penaeidae) and lobsters (Palinuridae).

Contemporary fishery characteristics and those documented during 1998–1999 were generally similar. The scalloped hammerhead, *S. lewini*, remains a commonly landed species from Teacapan to Cospita (SIN–01 to SIN–06), especially during the pupping season (August–November). As a result, small, early life stages are almost exclusively targeted. *R. longurio* is also still commonly landed in Sinaloa, especially during seasonal migrations (winter–spring). Contemporary landings of this species are composed of a mixture of juveniles and adults, including pregnant females. Rays, especially *D. dipterura*, the longtail singray, *D. longa*, *R. glaucostigma*, and *R. steindachneri*, still constitute a considerable proportion of artisanal elasmobranch landings, especially in northern camps. Large sharks such as the shortfin mako shark, *Isurus oxyrinchus*, thresher sharks, *Alopias* spp., and carcharhinids are harvested by industrial longliners and gillnetters that operate in offshore waters. Catch of these species is rare in the contemporary artisanal fishery.

Biological characteristics. Species–specific size and sex composition were available for a subset of the total elasmobranchs recorded in the Sinaloa artisanal fishery (Table IV). Specimens were occasionally dressed prior to offload and overall sampling time was limited to minimize interference with general fishing operations. Size composition of landings varied greatly by species, but small size classes of large sharks and a wide size range of coastal sharks and rays were primarily observed.

Table III. Seasonal catch per unit effort (CPUE = #individuals/vessel/trip) and standard error (SE) of shark, skate, and ray landings sampled in Sinaloa during 1999. Sample size (number of vessels examined) is indicated for each season in parentheses. 0.0 = Values < 0.05.

Higher Taxon	Lowest Possible Taxon	Winter (n = 97)		Spring (n = 66)		Summer (n = 21)		Autumn (n = 2)	
		CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE
Shark	*Alopias pelagicus*	0.0	0.0						
	Carcharhinus altimus	0.0	0.0						
	Carcharhinus leucas					0.1	0.1		
	Carcharhinus limbatus	0.0	0.0	0.2	0.1	0.9	0.7		
	Carcharhinus obscurus							1.0	1.0
	Carcharhinus spp.					0.1	0.1		
	Nasolamia velox	0.0	0.0	0.1	0.0				
	Prionace glauca			0.0	0.0				
	Rhizoprionodon longurio	3.1	0.5	5.1	1.4	0.3	0.2	0.5	0.5
	Sphyrna lewini	6.1	1.0	14.5	2.6	1.2	0.7	4.0	4.0
	Sphyrna zygaena	0.7	0.1	0.6	0.3	0.1	0.1		
	Subtotal	**10.0**	**1.1**	**20.5**	**3.5**	**2.7**	**1.3**	**5.5**	**2.5**
Ray	*Aetobatus narinari*					0.1	0.1		
	Dasyatis dipterura	0.9	0.5	3.2	1.0	1.2	0.5		
	Dasyatis longa	0.0	0.0	0.2	0.1	0.1	0.1		
	Dasyatis spp.			0.1	0.1				
	Gymnura spp.	0.0	0.0	0.1	0.1	3.1	1.5		
	Mobula munkiana					0.2	0.2		
	Mobula sp.					0.1	0.1		
	Narcinidae			0.0	0.0	0.9	0.5		
	Rhinobatos glaucostigma	0.2	0.1	7.2	4.1	2.6	1.7		
	Rhinobatos spp.			0.5	0.5				
	Rhinoptera steindachneri	0.0	0.0	0.0	0.0	11.1	3.5		
	Zapteryx exasperata			0.0	0.0				
	Subtotal	**1.2**	**0.6**	**11.5**	**6.3**	**19.4**	**4.4**	**0.0**	**0.0**

More female (n = 324) than male (n = 266) *R. longurio* were examined from 1999 fishery landings, indicating a significant difference from an expected sex ratio of 1:1 ($\chi^2_{0.05,1}$ = 5.507, P = 0.021). The observed size composition was bimodal, with peaks occurring from 65.0–74.9 cm and 85.0–99.9 cm stretched total length, STL (Fig. 2a). The smallest and largest specimens measured 30 cm and 125 cm STL, respectively (Table IV). Average female size was (mean ± SD) 91.6 ± 17.2 cm STL. Mean male length was slightly smaller (89.4 ± 14.5 cm STL). Observed differences in STL were determined to differ significantly between sexes (U = 47,452.50, P = 0.034).

The majority of *R. longurio* specimens inspected during winter (70.0%, n = 180) and approximately half of those inspected during spring (48.7%, n = 57) were juveniles. Gravid *R. longurio* were encountered during winter (10.5%, n = 27) and early spring (16.2%, n = 19). The remaining observed specimens were non–gravid adults (winter = 19.5%, n = 50; spring = 35.0%, n = 41).

Size composition and sex ratio of 2007–2008 *R. longurio* landings differed considerably from those of 1999. Significantly more male (n = 298) than female (n = 231) specimens were observed during 2007–2008 ($\chi^2_{0.05,1}$ = 4.005, P = 0.045). Size composition of landings was bimodal, with a primary peak occurring from 60.0–74.9 cm STL and a secondary peak from 80.0–104.9 cm STL. Females (80.4 ± 13.7 cm STL) were significantly larger than males (75.9 ± 11.8; U =

41,833.50, *P* < 0.001) (Fig. 2b). When compared with 1999 landings, overall size composition of 2007–2008 landings was significantly smaller (*U* = 80,322.00, *P* < 0.001).

Table IV. Size composition (minimum, maximum, and mean size) of elasmobranchs sampled from artisanal fishery landings in Sinaloa during 1998-1999. Only specimens identified to species are included. DW = disc width; PCL = precaudal length; STL= stretched total length, TL = total length.

Group	Species	Sex	n	Measurement	Min (cm)	Max (cm)	Mean (cm)	±1 SD
Shark	*Carcharhinus altimus*	F	1	STL	119	119		
	Carcharhinus leucas	F	1	STL	123	123		
		M	1	STL	182	182		
	Carcharhinus limbatus	F	12	STL	67	146	90.2	29.2
		M	23	STL	57	233	114.1	66.0
	Carcharhinus obscurus	M	2	STL	248	268	258.0	14.1
	Mustelus henlei	M	3	STL	57	67	62.7	5.1
	Nasolamia velox	F	6	STL	97	100	99.2	1.3
		M	2	STL	93	94	93.3	0.4
	Prionace glauca	F	1	PCL	69	69		
	Rhizoprionodon longurio	F	324	STL	30	125	91.6	17.2
		M	266	STL	32	124	89.4	14.5
	Sphyrna lewini	F	832	STL	35	245	85.9	12.0
		M	683	STL	36	242	86.8	12.9
	Sphyrna zygaena	F	46	STL	86	143	115.7	12.3
		M	39	STL	100	155	114.3	13.6
	Squatina californica	F	1	STL	77	77		
		M	5	STL	70	79	75.4	3.5
Batoid	*Aetobatus narinari*	M	1	DW	80	80		
	Dasyatis dipterura	F	97	DW	34	76	54.5	9.1
		M	81	DW	37	63	48.0	4.6
	Dasyatis longa	F	13	DW	39	124	61.5	22.1
		M	3	DW	49	81	60.1	17.7
	Mobula munkiana	F	12	DW	66	89	75.2	7.3
		M	3	DW	107	108	107.7	0.6
	Rhinobatos glaucostigma	F	418	TL	47	89	72.2	7.3
		M	73	TL	48	88	57.4	7.2
	Rhinoptera steindachneri	F	26	DW	58	85	72.3	7.6
		M	105	DW	54	89	72.1	9.7
	Zapteryx exasperata	F	1	TL	59	59		

The great majority of *S. lewini* examined from fishery landings in 1999 measured < 100 cm STL, and only four specimens > 200 cm STL were documented among 1515 measured specimens (Fig. 3a). Female *S. lewini* comprised the largest and smallest individuals recorded for this species, ranging from 35–245 cm STL (Table IV). Females and males averaged 85.9 ± 12.0 cm STL and 86.8 ± 12.9 cm STL, respectively. Size of landed females was significantly smaller than that of males (*U* = 257,789.00, *P* = 0.002). The observed proportion of females and males differed significantly from a 1:1 ratio ($\chi^2_{0.05,1}$= 14.458, *P* < 0.001), with females much more commonly observed.

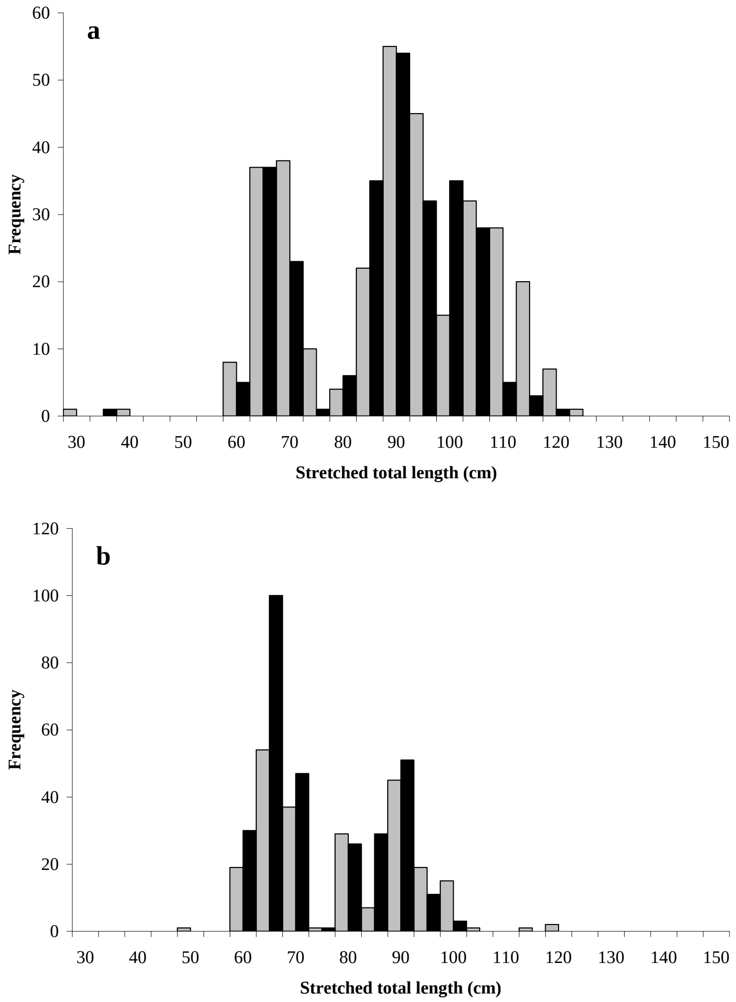

Figure 2. Size compositions of (**a**) female (n = 324) and male (n = 266) Pacific sharpnose sharks, *Rhizoprionodon longurio*, sampled from artisanal fishery landings in Sinaloa during 1999 and (**b**) female (n = 231) and male (n = 298) *R. longurio* sampled during 2007–2008. Females are depicted in gray, males in black. Minimum and maximum values along the x–axis generally reflect size at birth and maximum reported size for each species.

The great majority of inspected *S. lewini* individuals were juveniles. During autumn (n = 8) and winter (n = 571) no other life stages were documented among landings. During March, the inspected catch consisted almost exclusively of juveniles (99.3%, n = 303), with one neonate and one gravid individual observed. By contrast, among a limited number of individuals inspected during June, most were neonates (70.6%, n = 12). In addition, two juveniles, two adults, and one gravid individual were sampled during this time period.

Contemporary *S. lewini* landings were skewed towards small size ranges, with no specimens > 96.5 cm STL observed (Fig. 3b). No mature specimens were documented and neonates comprised 14.7% of the catch (n = 59). Size composition of females (65.9 $\pm$ 10.6 cm STL) and males (65.1 $\pm$ 11.3 cm STL) did not differ significantly (t = 0.727, P = 0.468). In addition, *S. lewini* individuals landed during 2007–2008 were significantly smaller than those landed during 1999 (U = 39,892.00, P < 0.001). The ratio of females (n = 190) to males (n = 211) sampled during 2007–2008 did not differ significantly ($\chi^2_{0.05,1}$ = 0.450, P = 0.500).

Female and male *S. zygaena* landed during 1999 ranged from 86–155 cm STL (Table IV). The majority of the 85 specimens sampled, however, measured 100–120 cm STL (Fig. 3c). No significant difference was found between mean sizes of females and males (t = 0.484, P = 0.630). The proportion of females and males within landings also did not deviate significantly from a 1:1 ratio ($\chi^2_{0.05,1}$= 0.424, P = 0.522). All inspected specimens were juveniles (n = 75).

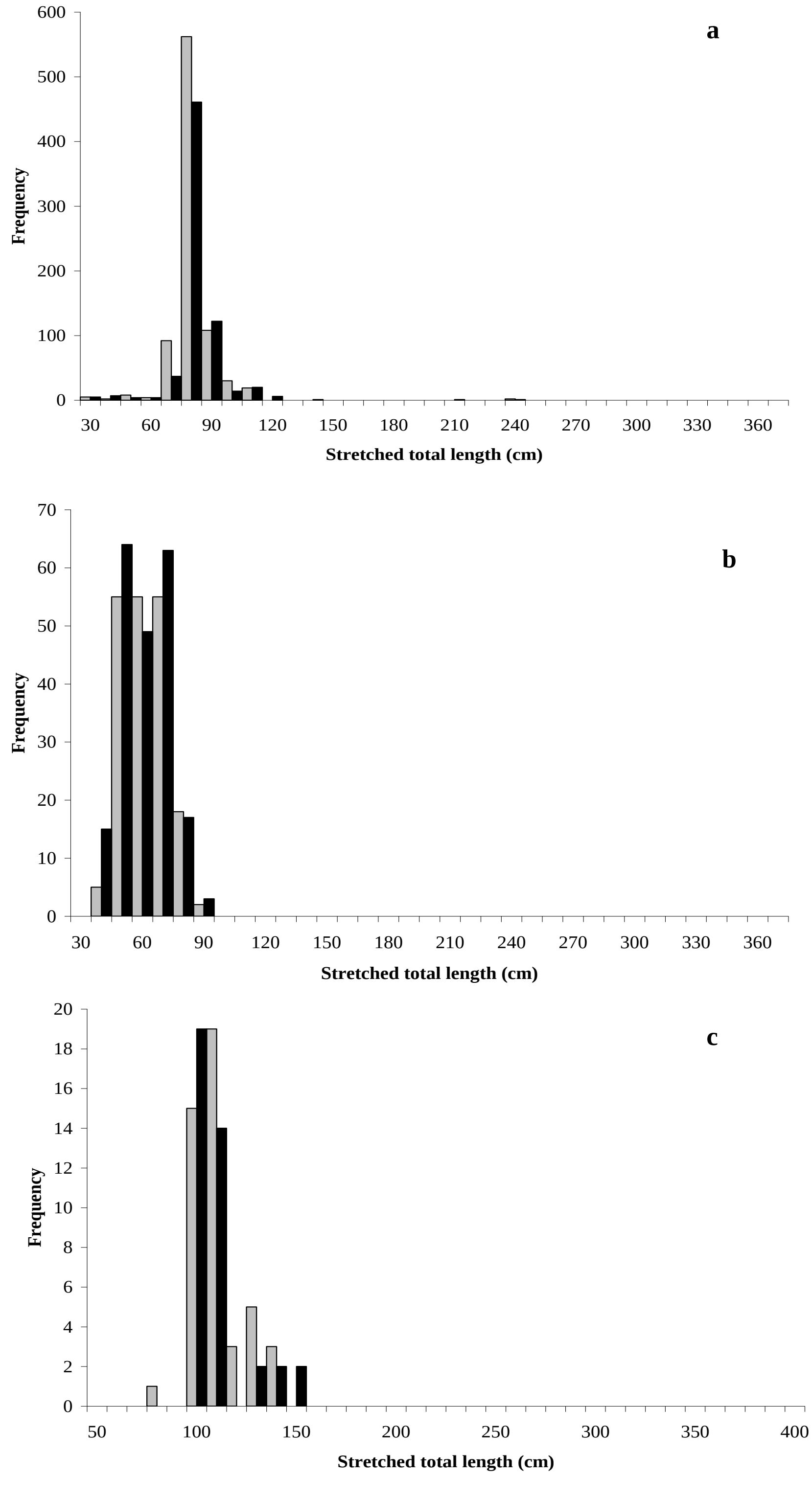

Figure 3. Size compositions of (**a**) female (*n* = 832) and male (*n* = 683) scalloped hammerheads, *Sphyrna lewini*, sampled from artisanal fishery landings in Sinaloa during 1999, (**b**) female (*n* = 190) and male (*n* = 211) *S. lewini* sampled during 2007–2008, and (**c**) female (*n* = 46) and male (*n* =39) smooth hammerheads, *S. zygaena*, sampled during 1999. Females are depicted in gray, males in black. Minimum and maximum values along the x–axis generally reflect size at birth and maximum reported size for each species.

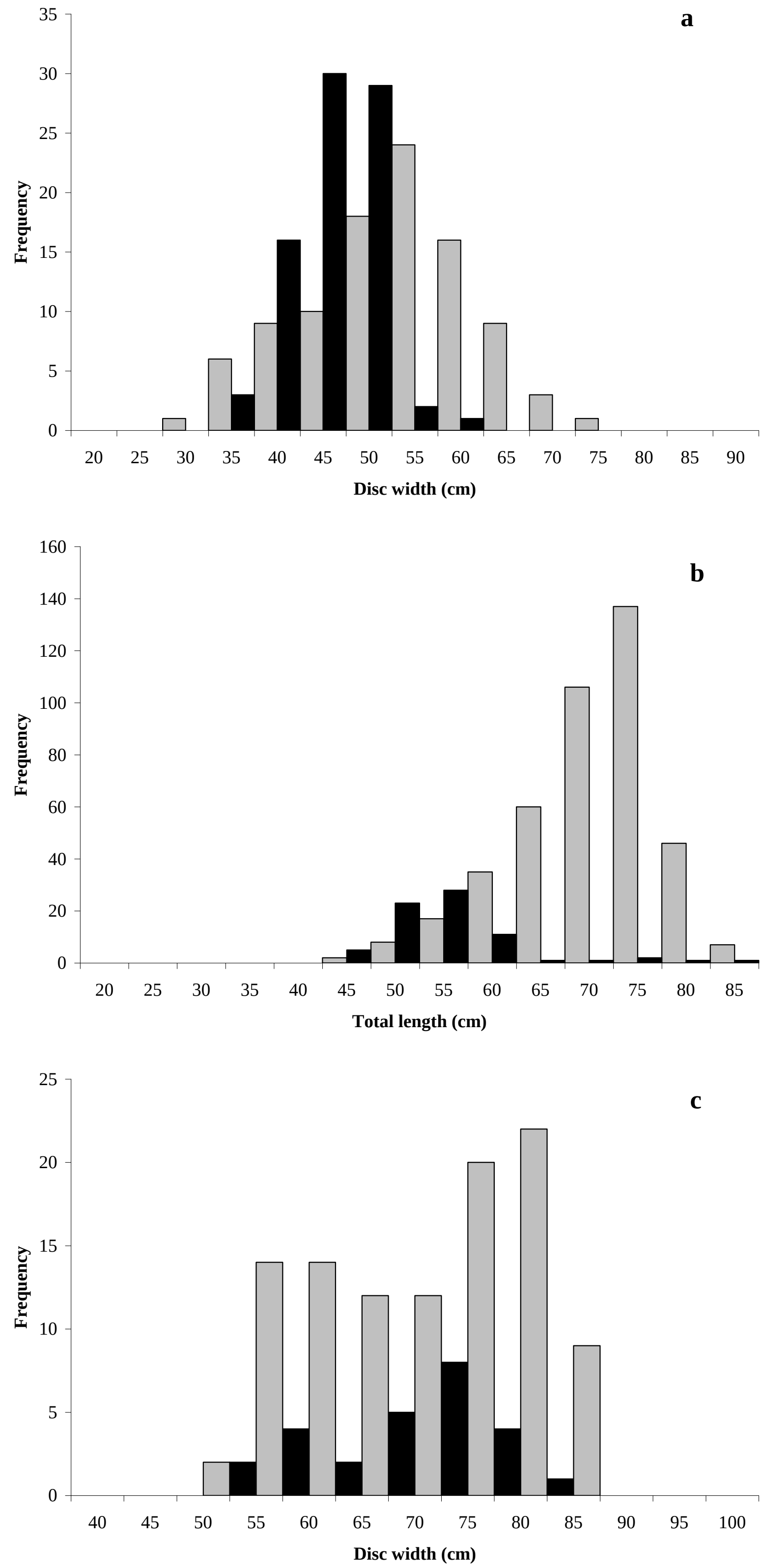

Figure 4. Size compositions of rays sampled from artisanal fishery landings in Sinaloa during 1998–1999. Only species with $\geq$ 50 specimens measured were included: (**a**) female (*n* = 97) and male (*n* = 81) diamond stingrays, *Dasyatis dipterura*, (**b**) female (*n* = 418) and male (*n* = 73) speckled guitarfish, *Rhinobatos glaucostigma*, and (**c**) female (*n* = 26) and male (*n* = 105) male golden cownose rays, *Rhinoptera steindachneri*. Females are depicted in gray, males in black. Minimum and maximum values along the x–axis generally reflect size at birth and maximum reported size for each species.

A total of 178 *D. dipterura* was directly examined from 1999 Sinaloa artisanal fishery landings. These specimens ranged from 34–76 cm DW (Table IV), with individuals > 55 cm DW consisting almost exclusively of females and males dominating smaller size classes (Fig. 4a). Females averaged 54.5 ± 9.1 cm DW, whereas males averaged 48.0 ± 4.6 cm DW. These differences in size were found to be statistically significant (U = 5909.00, P < 0.001). The number of females (n = 97) and males (n = 81) did not differ significantly from a predicted sex ratio of 1:1 ($\chi^2_{0.05,1}$= 1.264, P = 0.267).

The great majority of *D. dipterura* sampled during the winter were adults (76.7%, n = 66), and two gravid specimens were observed (2.3%). The remaining inspected specimens in winter were juveniles (n = 18, 20.9%). Insufficient data were available for other seasons to facilitate comparisons.

Female *R. glaucostigma* were considerably larger than males in 1999 artisanal fishery landings (Table IV, Fig. 4b). Mean DW of males was 57.4 ± 7.2 cm, whereas female DW averaged 72.2 ± 7.3 cm. Females were much more prevalent among sampled landings, comprising 418 of the 491 specimens measured. A significant difference was found in mean STL between sexes (t = 1.965, P < 0.001). The observed (5.7:1.0) and expected (1.0:1.0) ratio of females to males also differed significantly ($\chi^2_{0.05,1}$= 241.010, P < 0.001). Most inspected *R. glaucostigma* were juveniles (n = 17, 77.3%), but two gravid specimens were observed during June.

More male (n = 105) than female (n = 26) *R. steindachneri* were reported from fishery landings sampled during 1999, resulting in a sex ratio that differed significantly from 1:1 ($\chi^2_{0.05,1}$= 46.443, P < 0.001). However, observed mean sizes were similar between the sexes, with females averaging 72.3 ± 7.6 cm DW and males averaging 72.1 ± 9.7 cm DW (t = 1.978, P = 0.896) (Fig. 4c). Individuals of combined sexes ranged from 54–89 cm DW (Table IV). All specimens inspected during summer 1999 were adults (n = 12).

Discussion

Most fishing camps in Sinaloa were associated with urban or suburban centers and active throughout the year. Coincidentally, fishing effort was considerable at most sites, especially when compared to camps on the Baja California Peninsula (Smith *et al.* 2009a, Bizzarro *et al.* 2009b). Most fishing sites were concentrated in the northern part of the state, with considerably fewer camps and less effort in southern Sinaloa. Among the primary state–wide fisheries during 1998–1999, an extensive artisanal shrimp fishery was noted during autumn. However, artisanal landings of tunas and sardines were not observed (CONAPESCA 2006).

In addition to being direct artisanal fishery targets in Sinaloa, elasmobranchs are commonly caught incidentally in industrial teleost fisheries and often retained for sale. Large pelagic sharks are typical bycatch of a pure–seine fishery for yellowfin tuna (*Thunnus albacares*) that operates off Sinaloa (Mendizábal & Oriza *et al.* 2000, CONAPESCA 2006). Large coastal and pelagic sharks were also observed as incidental landings of drift gillnet and drift longline fisheries for tunas and billfishes during the course of this study.

Incidental capture in shrimp fisheries represents a considerable source of mortality for coastal elasmobranchs in tropical and subtropical regions (Ruffino & Castello 1993, Stobutzki *et al.* 2002; Zhou & Griffiths 2008), including Sinaloa. The shrimp fishery of Sinaloa, centered in Mazatlan, is most productive in Mexico (CONAPESCA 2006, Meltzer & Chang 2006). Both industrial and artisanal shrimp fisheries are active, with an average yearly production of 37,104 t since 1996 (CONAPESCA 2006). Rays (e.g., *N. vermiculatus*, *Urobatis halleri*, *Urotrygon chilensis*, *Urotrygon nana*) and to a lesser extent, small sharks are captured incidentally in these fisheries (Flores *et al.* 1995, Garcia–Caudillo *et al.* 2000), with mortality levels possibly exceeding those from directed fisheries (Márquez–Farías 2002). Shrimp trawling in Sinaloa often occurs on nursery areas for rays and sharks, and may therefore represent a considerable source of mortality for early life stages. Given its long history and magnitude, mortality due to the Sinaloa shrimp fishery has almost certainly impacted the structure and relative abundance of exploited elasmobranch populations. Detailed catch records of elasmobranchs in Mexican shrimp fisheries are necessary to determine the composition and magnitude of the incidental catch but are currently unavailable. Any effective management plan to sustain or rebuild populations of rays and small sharks in Sinaloa and the broader GOC must mitigate the impact of shrimp trawling on exploited populations, especially on nursery and breeding grounds.

Although catch composition of landings could not be precisely determined for all seasons, sampling was adequate to formulate reliable inferences about the faunal characteristics of Sinaloa during winter and spring. Tropically and subtropically distributed species dominated landings of sharks and rays, with no species of primarily temperate distributions observed (Love *et al.* 2005). Catch composition from this region was comparable to that of Baja California Sur during the same time period (Bizzarro *et al.* 2009b), but differed considerably from that of Baja California (Smith *et al.* 2009a) and Sonora (Bizzarro *et al.* 2009a). Temperature and current patterns are highly variable between the southern and northern Gulf of California (García–Silva & Marinone 1997, Soto–Mardones *et al.* 1999), resulting in a more tropically derived fish fauna in the lower Gulf and a more temperate fauna in the northern Gulf (Thomson *et al.* 2000). Regional patterns in catch composition probably reflect these faunal differences and exemplify the opportunistic nature of the regional artisanal elasmobranch fishery.

Rays were of variable seasonal importance in the Sinaloa artisanal elasmobranch fishery, with their greatest contributions occurring during summer and to a lesser extent, spring. During spring, *R. glaucostigma* was the second most important species in the fishery, whereas landings of the most abundant ray species during the winter (*D. dipterura*) constituted only 8.2% of the catch. During these seasons, ray landings were composed largely of these two species, with little overall diversity evident. As observed in Sonora for *R. productus* (Bizzarro *et al.* 2009a), massive vessel–specific landings of *R. glaucostigma* (≤ 257 individuals/vessel) were documented during spring in association with emigrations of gravid females to nearshore and inshore waters. In contrast to spring and winter fishery characteristics, summer landing of rays far exceeded those of sharks, with *R. steindachneri* comprising more than half of the total catch, and *Gymnura* spp. and *R. glaucostigma* also contributing substantially. During this time, *R. steindachneri* was directly targeted at La Reforma (SIN–15) for use as bait in a portunid crab fishery. Although a summer trend of increased ray landings and catch rates was also documented in Sonora (Bizzarro *et al.* 2009a) and Baja California (Smith *et al.* 2009a), low sample size precludes definitive conclusions from Sinaloa.

Landings from SIN–04 (Playa Sur) comprised the majority of the sampled catch during winter and a substantial portion of the catch during spring. An active winter and spring cazón fishery primarily targeting *S. lewini* and *R. longurio* has been previously documented at Playa Sur (Saucedo–Barrón *et al.* 1982, Rodríguez–García 1986, Castillo–Géniz 1990, Righetty–Rojo & Castro–Morales 1990). The primary targets of this fishery remained consistent, but a greater proportion of *S. lewini* was noted during this study than was generally observed from prior studies. In addition, triakids were absent from observed landings in this study but comprised a minor component of historic landings (Rodriguez–García 1986, Righetty–Rojo & Castro–Morales 1990). The observed species composition of cazón in Sinaloa differed greatly to that of Sonora, where *Mustelus* spp. were the primary targets and *R. longurio* and *S. lewini* contributed a trivial relative proportion of landings. In addition, although catch rates of cazón were the greatest reported for any elasmobranch group, they were considerably less than those reported for cazón in Sonora and Baja California *Mustelus* fisheries (Bizzarro *et al.* 2009a, Smith *et al.* 2009a).

Although species composition of contemporary and historic cazón landings was generally similar, the fishery appears to be landing considerably smaller individuals. Landings of small *S. lewini* and a broad size range of *R. longurio* have been previously documented at Playa Sur (Saucedo–Barrón *et al.* 1982, Rodríguez–García 1986, Castillo–Géniz 1990, Righetty–Rojo & Castro–Morales 1990). The targeted size class of *S. lewini* was substantially smaller during 1999, whereas that of *R. longurio* was comparable (Saucedo–Barrón *et al.* 1982). Contemporary landings of both species reflect a considerable reduction in size composition when compared to those of 1999. Since gear type and sampling location were generally consistent between sampling periods, this trend suggests that the size composition of the local *S. lewini* population may have been truncated. The apparent absence of large *R. longurio* (> 100 cm STL) from recent landings is problematic if reflective of the true population at large and warrants further attention In addition, the current fishery appears to be targeting early life stages on their nursery grounds. In order to sustain or rebuild exploited stocks, *S. lewini* and *R. longurio* populations in the southeastern Gulf of California should be closely monitored and cautiously managed.

Large sharks (tiburón) comprised a very small proportion of overall landings from Sinaloa, with only 12 individuals > 1.5 m documented among 2248 measured sharks. Although large sharks were never a primary component of the artisanal elasmobranch fishery, fishery effort dedicated to tiburón was considerably reduced during summer months of this study when compared to the historic situation. A similar trend has been observed throughout the Gulf of California, where the historic immigration of fishermen from the southern state of Chiapas has been almost entirely curtailed (J.L. Castillo–Géniz & J.F. Márquez–Farías, pers. obs.). Several previously documented shark species (e.g., *C. falciformis*, *G. cuvier*, *I. oxyrinchus*, *S. mokarran*) were not observed among artisanal landings during 1998–1999 and only one individual of *A. pelagicus*, a common commercial species off Mazatlán during 1986–1987 (Mendizábal & Oriza 1995), was reported.

Although it appears likely that populations of some large shark species have declined, results of this study may not be entirely representative of the contribution of large sharks to the artisanal fishery. A lack of temporal replication and the limited number of camps surveyed may have resulted in underestimates of large shark landings and diversity. Even so, the sizeable reported contribution of tiburón to statewide elasmobranch production (> 70%, CONAPESCA 2006), if accurate, is most likely a consequence of the industrialized, offshore fishery and not a sizeable artisanal fishery.

Fisheries for small coastal sharks may be sustainable (Walker 1998), but the targeting of large shark species is not typically advisable (Smith *et al.* 1998). Fisheries for *Rhizoprionodon* spp. have been well documented (e.g., Castillo–Géniz 1990, Castillo–Géniz *et al.* 1998, Henderson *et al.* 2007), and yet all species with sufficient data for assessment are considered to be “widespread and abundant” by the IUCN (IUCN 2009). Accordingly, *R. longurio* is considered among the most resilient of eastern North Pacific sharks to fishing pressure as a result of its high fecundity and relatively early age at maturity (Smith *et al.* 1998). After a long period of heavy exploitation in southern Sinaloa, *R. longurio* still exhibits a size composition that is generally suggestive of a healthy population. However, because contemporary landings indicate a shift towards smaller specimens and a distinct lack of large specimens (> 100 cm STL), targeted populations should be closely monitored for possible changes in population structure. Hammerhead sharks, although fecund, attain large sizes and have relatively late ages at maturity (PSRC 2004). Large species, such as *S. lewini* and *S. zygaena*, may therefore be susceptible to population declines due to overfishing (Smith *et al.* 1998). Such declines have been speculated to occur for *S. lewini* (Klimley *et al.* 2005) and *S. mokarran* (Bizzarro *et al.* 2009a) populations in the Gulf of California, and *Sphyrna lewini* was recently declared globally endangered (Dulvy *et al.* 2008), although supporting data are somewhat lacking. The Sinaloa artisanal fishery targets early life stages of sharks, reducing the productivity, resilience, and sustainability of targeted populations (Kokko *et al.* 2001). Populations of both sphyrnids should therefore be carefully monitored and more rigorously assessed.

Elasmobranch landings from the Sinaloa fishery were composed of medium and large size classes of most cazón and ray species. Size composition of *R. longurio* landings indicated a bimodal distribution consisting primarily of medium and large specimens. In contrast, landings of *S. lewini* and *S. zygaena* were composed of size classes corresponding to early life stages (Compagno *et al.* 1995, Anislado–Tolentino & Robinson–Mendoza 2001). Among rays, *D. dipterura* landings consisted primarily of medium and large specimens. Landings of *R. steindachneri* were similarly distributed, but contained a greater proportion of relatively large individuals. Most *R. glaucostigma* were large females and the previously reported maximum size (85 cm total length; Amezcua–Linares 1996) was exceeded (89 cm TL).

The results of this study have provided the first detailed, quantitative information on the artisanal elasmobranch fisheries of Sinaloa, one of Mexico’s most productive states in terms of elasmobranch landings. Landings of small sharks were substantial during the survey years and probably represent a significant source of mortality for exploited populations. Although catch rates of some ray species were elevated during spring and summer (e.g., *R. glaucostigma*, *R. steindachneri*), the local shrimp fishery is probably the main source of mortality for this group and should be considered in any management plan. Large sharks did not contribute substantially to artisanal fishery landings and many species that were once common have likely been overfished. Using the results of this study as a baseline, it is important that additional research is conducted off Sinaloa to determine any changes in catch rates, species composition, and size composition that may have occurred in the artisanal elasmobranch fishery since 1998–1999. The historic information presented in this manuscript should also be useful for comparison with similar studies conducted in other subtropical and tropical regions of the world.

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