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The artisanal elasmobranch fishery of the Pacific coast of Baja California Sur, Mexico, management implications

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SUMMARY: Artisanal fisheries in Mexico account for approximately 40% of the total national catch. In 2009, Baja California Sur (BCS) had the second largest catch of elasmobranchs on the Mexican Pacific coast. This paper characterizes and describes the artisanal elasmobranch fishery of Pacific coast of BCS from 2000 to 2010. Sixty artisanal camps were documented, of which 45 targeted elasmobranchs, using primarily gillnets and longlines. We identified 52 elasmobranch species. Gillnetting accounted for 73.5% of the fishing effort and most frequently captured *Rhinobatos productus, Mustelus henlei* and *Myliobatis californica*. Longline fishing accounted for 26.5% of effort, most frequently capturing *Prionace glauca* and *Isurus oxyrinchus*. The prevalence of juveniles of several species (e.g., *Cephaloscyllium ventriosum*, *Galeorhinus galeus*, *Isurus oxyrinchus*, and *Myliobatis californica*) within landings suggests that fishing effort may be opportunistically directed at breeding or nursery areas. Despite the dominance of species with wide distributions, we observed a significant biogeographic pattern in the abundance of some species relative to Bahia Magdalena. Results of the present study will be useful to detect changes in the structure of commercially exploited elasmobranch populations, and to provide useful indications for management purposes.

Keywords: biogeographic pattern, elasmobranchs richness, fishing effort, Mexican coast, nursery areas, small-scale fishery.

RESUMEN: PESQUERÍA ARTESANAL DE ELASMOBRANQUIOS EN LA COSTA PACIFICO DE BAJA CALIFORNIA SUR, MÉXICO, IMPLICACIONES PARA SU GESTIÓN. – La pesquería artesanal en México soporta aproximadamente el 40% de la captura total nacional. En 2009 Baja California Sur (BCS) fue el segundo estado con mayor registro de captura de elasmobranquios de todo el Pacifico Mexicano. En el presente trabajo se realizó la caracterización y descripción de la pesquería artesanal de elasmobranquios en la costa Pacífico de BCS del 2000 al 2010. Se registraron 60 campos artesanales, de los cuales en 45 se capturaron elasmobranquios usando como artes de pesca redes y palangres. Se identificaron 52 especies de elasmobranquios. Las redes representaron el 73.5% del esfuerzo pesquero, las especies que se capturaron con mayor frecuencia fueron *Rhinobatos productus*, *Mustelus henlei* y *Myliobatis californica*. Por otra parte los palangres representaron el 26.5% del esfuerzo pesquero, las especies capturadas con mayor frecuencia fueron, *Prionace glauca* e *Isurus oxyrinchus*. La presencia de especímenes juveniles de varias especies en los desembarques (p. ej. *Cephaloscyllium ventriosum*, *Galeorhinus galeus*, *Isurus oxyrinchus*, *Myliobatis californica*) sugiere que el esfuerzo pesquero podría ser oportunista dirigido a las zonas de crianza o de reproducción. A pesar del dominio de especies con distribuciones amplias, se observó un patrón biogeográfico significativo en la abundancia de algunas especies al sur y al norte de Bahía Magdalena. Los resultados del presente estudio serán de utilidad para poder detectar los posibles cambios en la estructura poblacional de los elasmobranquios explotados comercialmente.

Palabras clave: patrón biogeográfico, riqueza de elasmobranquios, esfuerzo pesquero, costa mexicana, zona de crianza, pesquería de pequeña escala.

INTRODUCTION

Artisanal fisheries are generally characterized as small-scale traditional fisheries using small amounts of capital and energy and small fishing vessels, which make short fishing trips close to shore, primarily for local consumption. These fisheries often take place in remote areas of developing countries. With the widespread adoption of motorization, artisanal fisheries have grown significantly over the past two decades, contributing more than 25% of the world catch and accounting for half of the fish used for direct human consumption. The rapid expansion of artisanal fishing capacity under open access regimes has begun to exert overfishing pressures on coastal fisheries resources (Mathew 2001).

Elasmobranchs (i.e. sharks and rays) are currently one of the resources of greatest concern in artisanal fisheries. Worldwide overfishing of several species has caused population declines of their populations, mainly because they are *k*-selected fishes with slow growth and low reproductive rates (Bonfil 1994, Camhi 1998, Walker 1998, Musick 1999).

In Mexico, artisanal fisheries account for approximately 40% of the total national catch and comprise up to 80% of the elasmobranch fishing effort (Arreguin-Sanchez *et al*. 2004). Mexico has been one of the most important elasmobranch fishing nations in the world; in 2007 it had the sixth largest catch of elasmobranchs, representing 4.3% of total world catch, with approximately 34638 t (Sosa-Nishizaki *et al*. 2008, FAO 2009). In 2008, 102807 vessels were recorded in Mexican artisanal fisheries, exploiting mainly coastal finfish, sharks, crustaceans, mollusks and echinoderms (Ramirez-Rodriguez 2011). This fishery represents an important source of employment, providing both sustenance and income for some of the poorest sectors of Mexican society (Arreguin-Sanchez *et al*. 2004, Ponce-Diaz *et al*. 2009, Cartamil *et al*. 2011).

The management of sustainable elasmobranch fisheries in Mexico has been hampered by a lack of reliable data. For example, official records of elasmobranchs recognize only three categories: sharks (sharks larger than 150 cm total length [TL]), *cazones* (sharks smaller than 150 cm TL) and rays (all batoids) (Bonfil 1997, Castillo–Geniz *et al*. 1998, Galvan-Magaña 2009). Detailed quantitative information on the specific composition of the catch is a basic requirement to determine possible effects of fishing on populations of target species and to establish baselines for comparison of biological diversity (Bonfil 1997, Marquez–Farias 2002).

In recent years the artisanal elasmobranch fisheries have been described in several regions of northwestern Mexico, including Sonora (Bizzarro *et al*. 2009a), the east coast of Baja California (BC) (Smith *et al*. 2009), the east coast of Baja California Sur (BCS) (Bizzarro *et al*. 2009b), Sinaloa (Bizzarro *et al*. 2009c) and the Pacific coast of BC (Cartamil *et al*. 2011). In 2009 BCS was the state with the second largest catch of elasmobranchs, representing 17% (4004 t) of the total catch on the Mexican Pacific coast (SAGARPA 2009). However, there have been no studies describing elasmobranch artisanal fisheries on the highly productive Pacific coast of BCS.

The objectives of the present study were to identify and describe the Pacific coast BCS artisanal elasmobranch fishery, to determine elasmobranch species composition and catch rates, and to provide biological information (size, sex, seasonality) for the most abundant species captured in BCS.

MATERIALS AND METHODS

Study area

BCS has an area of 73677 km^2, representing 3.8% of the land mass of Mexico and comprising the southern half of the Baja California Peninsula. It has 2220 km of coastline: 1400 km of which corresponds to the Pacific coast (between 28°16' and 22°33'N) (Fig.1). In 2010, the population of BCS was 637027, indicating a relatively low population density (Cortes-Ortiz *et al*. 2006, INEGI 2011).

The Pacific coast of BCS is characterized by a narrow continental shelf that is generally less than 37 km wide with a peak width of approximately 68.5 km between Laguna San Ignacio and the area north of the Bahia Magdalena lagoon complex (Fig. 1). This region is affected by the California Current System, which dominates during the cool part of the year, and by the northward intrusion of a branch of the tropical North Equatorial Current during the warm part. It has a high primary productivity driven by coastal upwelling (Alvarez-Borrego 1983, Espinoza-Carreon *et al*. 2001, Zaytsev *et al*. 2003).

Artisanal fishery survey

The artisanal elasmobranch fishery on the Pacific coast of BCS was surveyed during the period 2000-2010. The location of each camp was determined with a global positioning system (GPS) unit. Sites supporting artisanal fishing activities were characterized based on the level of infrastructure (Bizzarro *et al*. 2009a): A, little to no infrastructure; B, moderate infrastructure; and C, significant infrastructure. We determined whether camps were permanent (P) or temporary (T), and the number of active artisanal fishing vessels.

Elasmobranch sampling was conducted at 16 artisanal camps. Elasmobranchs landed at the camps were identified to the lowest possible taxon and enumerated. Sharks of the genus *Mustelus* were sometimes grouped into the category *Mustelus* spp. due to the difficulty of identifying them to species level. In addition, species-specific size and sex composition data were collected. Standard measurements used were total length (TL; using the natural extension of the caudal fin) and disc width (DW), recorded to the nearest 0.5 cm (Compagno 2001).

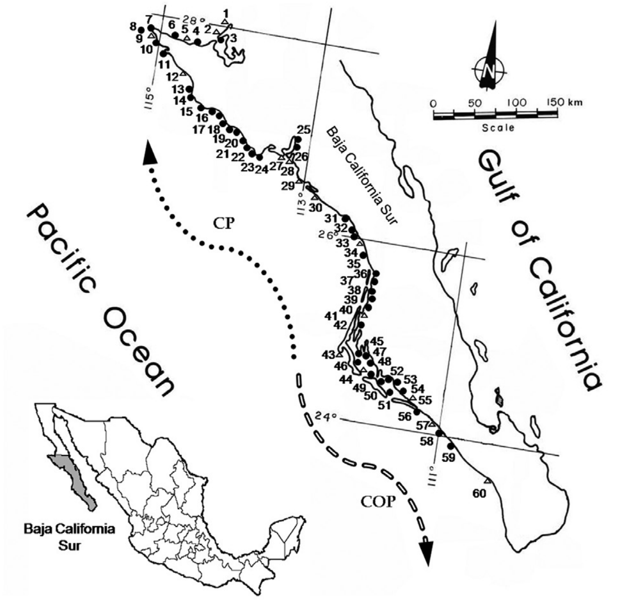

FIG. 1. – Locations of artisanal camps along the Pacific coast of Baja California Sur, Mexico. Open triangles (△) indicate sites where biological data were collected. Numbers refer to codes in Table 1. Biogeographical zones: CP, California province; COP, Cortez province.

Total elasmobranch landings by season were assessed according to species composition. Catch per unit effort (CPUE) was defined as the number of individuals per vessel per trip, and was calculated for each species within each major gear type and for each season surveyed. Measured specimens were used to determine size composition and sex ratio of landings. Sex-specific size composition data were evaluated for normality (Kolmogorov-Smirnov test) and homoscedasticity (F test) and compared using a t-test or Mann-Whitney U test, as appropriate. As a result, differences in the size composition between the sexes were compared using raw size data in all cases. The sex ratio among landings was evaluated using chi-square analysis with Yates correction for continuity for specimens directly examined (Zar 1996). Histograms of size and sex composition of each species with ≥50 measured individuals were computed and compared with size at maturity (taken from several scientific literature sources: Villavicencio-Garayzar *et al.* 1994, Villavicencio-Garyazar 1995, 1996a,b, Compagno 2001, Ebert 2003, Villavicencio-Garayzar and Bizzarro 2004, Perez-Jimenez *et al.* 2005, Shoou-Jeng and Hua-Hsun 2005, Castillo-Geniz *et al.* 2007, Bizzarro *et al.* 2007a, Bejarano-Alvarez *et al.* 2010, Carrera-Fernandez *et al.* 2010, Hoyos-Padilla *et al.* 2012).

Sample size-sufficiency for each fishing gear and each seasonal catch composition was verified using cumulative taxon curves (Gotelli and Cowell 2001). Seasons were defined as follows: spring (22 March–21 June), summer (22 June–21 September), autumn (22 September–21 December) and winter (22 December–21 March). To determine whether the sampled landings were adequate to describe the catch composition, the average curve of accumulated number of elasmobranch taxa present in each vessel was plotted against the number of vessels grouped at random (Ferry and Cailliet 1996). Catch composition of 1000 randomly selected vessels was re-sampled (EstimateS 8.2.0.), and used to calculate a mean and standard deviation estimate for each sample (Colwell 2009). Linear regression was used to determine quantitatively whether the curve reached an asymptote, signifying an adequate number of samples (Bizzarro *et al.* 2007b).

The Shannon-Wiener index (H') was used to evaluate the levels of elasmobranch diversity within the study area, using the equation:

$$H = -\sum_{i=1}^{S} p_i \log_2 p_i$$

where S is the number of species in the sample, p_i is the proportion that the ith species contributes to the total abundance of the sample ($p_i = N_i/N$), N_i the number of individuals of the ith species, and N the number of individuals in the sample. Nonparametric permutation and bootstrap statistical methods (Manly 2007) were applied to estimate the mean and variance of the diversity index of the Pacific coast of BCS.

Elasmobranch dominance within the study area was further tested using the Simpson index (D) with the equation

$$D = \sum \left(\frac{n_i}{n} \right)^2$$

where n_i is the number of organisms of a particular species and n the total number of organisms of all species.

Zoogeographic affinity analysis was done according to the biogeographical divisions suggested for the Pacific coast of BC Peninsula by several authors (Briggs 1974, Walker 1960, Hastings 2000, Horn *et al.* 2006, Spalding *et al.* 2007, Robertson and Cramer 2009). The following divisions were considered: Californian Province (corresponding to temperate waters) from Point Conception, California to Bahia Magdalena, BCS, and the Cortez Province (corresponding to tropical waters), which extends south from Bahia Magdalena to the Gulf of California (Fig. 1). Based on these studies we divided the study area into north and south zones (relative to Bahia Magdalena). We calculated the diversity index for each zone and made comparisons between zones using a t-test. The Jaccard index (Jac) was calculated as a measure of similarity of species composition for each zone. This presence-absence index takes into account the relationship between the number of common species and total species found in the samples being compared, and is calculated as

$$Jac_{ij} = \frac{a}{a+b+c}$$

where a is number of shared species (present in both zones, i and j), b is the number of species present only in zone i and c is the number of species present only in zone j.

Table 1. – Characteristics of the surveyed artisanal camps. "Type" refers to infrastructure: A, little to no infrastructure; B, moderate infrastructure; C, significant infrastructure. "Perm" refers to whether a camp is permanent (P) or temporary (T). "Target" refers to the fishery typology : EG, elasmobranch gillnet; EL, elasmobranch longline; T, teleosts; I, invertebrates (A, abalone; L, lobster; C, crab; G, gastropod; B, bivalve; H, sea cucumber; O, octopus; S, shrimp). FV = number of fishing vessels present during the surveys (or minimum/maximum in case of seasonal fluctuations in effort). Asterisks denote artisanal camps where elasmobranch biological data were sampled.

Map	Camp Name	N. Lat	W. Long	Type	Perm	Target	FV
1	La Isla*	28.211	114.078	A	T	I (B), EG	3/7
2	Las Casitas*	27.851	114.158	A	P	I (B, C, G), T, EG, EL	15/80
3	Campo El Datil	27.796	114.176	A	T	NA	NA
4	Campo Queen	27.801	114.720	A	P	I (A, L, B, H, O), T, EG	4/6
5	Malarrimo*	27.822	114.852	B	P	I (A, L, B, H, G, O), T, EG, EL	9
6	Campito	27.800	114.518	A	P	I (L,O), T, EG	6/8
7	Chester	27.859	115.052	A	T	I (A, L) EG	4/7
8	Isla Natividad	27.853	115.169	C	P	I (A, L, G), T, EL	45
9	Punta Eugenia*	27.848	115.078	B	P	I (A, L, B, H), T, EG	12
10	Lobera	27.831	115.064	A	T	I (A, L) EG	3/6
11	Punta Quebrada	27.727	114.994	A	T	I (A, L, H, G, B)	3/5
12	Bahia Tortugas*	27.690	114.894	C	P	I (A, L, G, B, H), T, EL, EG	23/85
13	El Rincon	27.645	114.864	A	T	I (A, L, G), T, EG	3
14	Clambey	27.619	114.844	A	T	I (A, L, G), T, EG	3
15	Puerto Escondido	27.534	114.741	A	P	I (A, L, G), T, EG, EL	7/9
16	Puerto Nuevo	27.477	114.599	B	P	I (L, A, H), T, EL	8
17	San Cristobal	27.446	114.557	B	P	I (A, L, H),T, EG	12
18	San Pablo	27.219	114.470	A	P	I (A, L, H, B), T, EL	6/9
19	San Roque	27.181	114.398	B	P	I (A, L, H) T, EG	8/10
20	Bahía Asuncion	27.141	114.295	C	P	I (A, L, B) T, EG, EL	18/69
21	Punta Prieta	27.015	114.042	B	P	I (A, L, B) T, EG	16/24
22	San Hipolito	26.988	113.979	B	P	I (A, L, B), T, EG, EL	18
23	La Bocana	26.796	113.712	C	P	I (A, L, B, G, H), EG	19/51
24	Punta Abreojos	26.710	113.574	C	P	I (A, L, B, G), T, EG	54
25	Campo Pachico	26.874	113.135	A	T	I(B), T, EG	2/4
26	La Base	26.863	113.137	A	T	I(B), T, EG	3
27	La Freidera*	26.830	113.167	A	T	T, I (B), EG	2
28	El Cardon*	26.799	113.149	B	P	EG, T, I (B,)	12/19
29	El Delgadito*	26.606	113.058	B	P	EG, T, I (B)	6/12
30	El Datil*	26.532	112.911	B	P	T, EG, I (B,C)	13/22
31	San Juanico	26.253	112.479	C	P	I (A, L, B), T, EG	16/23
32	La Bocana 1	26.062	112.286	A	T	I (A, L, B), T, EG	6/9
33	El Chicharron	26.063	112.273	A	P	EL, EG, T	8/13
34	Las Barrancas*	26.001	112.198	C	P	I (A, L, B), T, EG	15/19
35	San Andresito	25.805	112.119	A	NA	NA	NA
36	Santa Rosa	25.696	112.073	A	T	I (B, L), T	5/9
37	Buena Vista	25.653	112.066	A	T	I (B, L, C), T	6/8
38	Estero San Vicente	25.431	112.066	A	P	T, I, (B,C,S,L)	4/6
39	El Caballo	25.404	112.085	A	NA	NA	NA
40	Las Vacas	25.340	112.074	A	T	T, I (B,C,S)	3/6
41	Adolfo Lopez Mateos*	25.191	112.115	C	P	T,I (B,C), EG, EL	34/113
42	La Florida	25.040	112.121	A	P	T, I (B,C,S)	3/7
43	San Lazaro*	24.796	112.267	B	P	EL, EG, T, I (B)	12
44	Punta Belcher*	24.584	112.072	A	T	EL, EG, T	7/10
45	San Carlos	24.787	112.103	C	P	I (B,S,C,L), T, EG, EL	25/48
46	Bahia Magdalena	24.634	112.139	C	P	I (B,S,C,L,O), T, EG	18/26
47	San Buto	24.777	112.051	A	T	I (S,B,C), T	6/8
48	Paredon Amarillo	24.787	111.968	A	NA	NA	NA
49	Puerto Alcatraz	24.504	111.845	C	P	T, I (B,S,C), EG	12/21
50	Puerto Cortes	24.477	111.822	B	P	T, I (B,C,)	6/8
51	Las Tijeras	24.376	111.705	A	T	T, EG, I (B, C)	4
52	Puerto Cancun	24.548	111.746	B	P	I (S,C,B), T, EG	6/10
53	El Cayuco	24.583	111.683	A	T	I (S,C,B), T, EG	3
54	Puerto Chale	24.422	111.553	B	P	T, I (S,C,B,L) EG	40
55	Puerto Viejo*	24.347	111.471	A	T	T, I (S,C,B,) EG	13
56	Loma Amarilla	24.310	111.395	A	T	T, I (S,C,B,)	4/6
57	El Datilar*	24.132	111.077	A	P	I (L, B), T, EG	7
58	El Conejo	24.077	111.005	A	P	I (L, B), T, EG	5
59	Punta Marquez	23.970	110.882	B	P	T, I (B), EG	15-20
60	Punta Lobos*	23.414	110.230	A	P	EG, EL, T	40-50

RESULTS

Fishing sites and global fishery characteristics

A total of 60 artisanal fishing camps were documented along the Pacific coast of BCS (Fig. 1). High variability was observed in fishing camp size, from small temporary camps to permanent camps with significant infrastructure. Table 1 details the comparative characteristics of the documented camps. Tables 2 and 3 indicate the number of days and trips sampled for each season and fishing gear.

Table 2. – Number of fishing vessels sampled by season and gear type.

Season	Vessels	Gillnets	Longlines
Spring	221	142	79
Summer	302	241	61
Autumn	57	27	30
Winter	55	6	49

Elasmobranchs were targeted at 75% (*n*=45; Table 1) of the artisanal camps, as either the primary (*n*=6) or the secondary target (*n*=39). Most camps contained moderate infrastructure (57%, *n*=34). The artisanal elasmobranch fishery was conducted with small vessels of less than 10.5 m length, locally called "pangas". These fishing vessels were open-hulled fiberglass boats with outboard motors. The number of vessels varied among camps, ranging from two (e.g. La Freidera camp) to 113 (e.g. Adolfo Lopez Mateos camp) (Table 1).

Bottom set gillnets were the most common fishing gear used, and were deployed on the continental shelf (<100 m depth). These nets were monofilament with lengths of 200-800 m, a drop of up to 6 m, and highly variable mesh sizes, ranging from 7.6 to 25.4 cm. On average, two gillnets were used per vessel.

Pelagic sharks were targeted mainly with longlines, which ranged from 1.5 to 3 km in length. The number of hooks per longline was highly variable (range 250-400), and set depths ranged from 5 to 10 m. The hook type commonly used is the "J-style hook" with a 6-8 cm length. On average, two longlines were used per vessel, and fishing time ranged from 10 to 15 hours.

In most artisanal camps, elasmobranchs were dressed, iced and sold fresh to local buyer or cooperatives. However, in some camps elasmobranchs were filleted, dried and salted; this was observed mainly in remote camps with more difficult access. Prices for elasmobranchs varied between seasons by species, size and buyers, but typically ranged between MX$7.00 and $14.00 per kilogram.

Catch composition

Sharks and batoids contributed differentially to total elasmobranch capture, comprising 61% and 39%, respectively. Of the 18192 specimens observed, at least 30 species of sharks and 22 species of batoids were recorded. The catch composition varied according to the gear used. Two fishing gears were registered during the study period: gillnets and longlines. Gillnets were used by 416 of the 635 vessels (65% of the fishing trips) and the primary target was elasmobranchs (13372 individuals from 49 species; Table 4). The most abundant elasmobranchs taken by gillnets were the shovelnose guitarfish (*Rhinobatos productus*; 28.6%; CPUE=9.18), the brown smooth-hound (*Mustelus henlei*; 24.2%; CPUE=7.8), the California bat ray (*Myliobatis californica*; 11%; CPUE=3.5), the banded guitarfish (*Zapteryx exasperata*; 8.3%; CPUE 2.67) and the angel shark (*Squatina californica*; 5.6%; CPUE 1.82) (Table 4).

Longlines were used by 219 of the 635 vessels sampled (35% of fishing trips), and the primary target was elasmobranchs (4820 individuals from 16 species, Table 4). The catches by longline were dominated by sharks (99%). Catch was dominated by two species: blue shark (*Prionace glauca*; 69.75%; CPUE 15.35) and mako shark (*Isurus oxyrinchus*; 22.74%; CPUE 5.01), which accounted for 91% of the total catch (Table 4).

Seasonality

CPUE for sharks and rays differed considerably between seasons (Table 5). In the shark group, the blue shark was captured in all seasons, while among batoids, *R. productus* was the dominant species, though its capture decreased significantly in winter. Overall, the CPUEs were greatest in spring because of high catch rates of *R. productus* (8.34±1.54), *P. glauca* (8.19±1.68) and *M. californica* (5.18±1.95) (Table 5). *Echinorhinus cookei*, *Negaprion brevirostris*, *Squalus acanthias* and *Torpedo californica* were recorded only in summer.

High CPUEs were noted for many species during summer (Table 5). The species that dominated the landings were *M. henlei* (8.87±1.27), *R. productus* (5.94±0.87), *Z. exasperata* (2.64±0.49) and *P. glauca* (2.42±0.4). The species recorded only in summer were *Carcharhinus brachyurus*, *Notorynchus cepedianus*,

Table 3. – Sampling days (D) and number of fishing vessels sampled (V) on the Pacific coast of Baja California Sur for the present study. The numbers represent months of the year from January (1) to December (12) during the period 2000-2010.

Years	1		2		3		4		5		6		7		8		9		10		11		12	
	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V
2000															7	12	2	2	1	2	1	1	2	2
2001	3	3	5	4	4	4	3	4	4	4	1	1	4	5	2	2	2	2						
2002			3	4			3	3	3	6	5	5	2	2	3	5	1	1	4	4	1	1	2	2
2003	2	4	2	6	2	3													3	3				
2004			2	3			1	1	2	2	2	3			2	2	1	1			1	1	1	2
2005									2	3														
2006																								
2007																	2	3			1	1		
2008							7	7	3	4									1	6				
2009	3	3	3	4			7	17	12	29	1	1	24	59	8	39			2	5			4	4
2010			5	7	15	45	16	42	10	16	15	57	13	22	27	93	8	24	12	16	3	4		

Table 4. – List of elasmobranchs collected in Baja California Sur from 2000 to 2010, according to the fishing gear. The number of individuals documented (*n*), their percentage contribution on the total catch (%), and the catch per unit effort (CPUE) with standard error (SE) are indicated.

Species	Gillnet (*n*)	%	CPUE	S.E.	Longline (*n*)	%	CPUE	SE
Sharks								
Alopias pelagicus	15	0.11	0.04	0.02				
Alopias vulpinus	36	0.27	0.09	0.03				
Carcharhinus altimus	12	0.09	0.03	0.01				
Carcharhinus brachyurus	1	0.01	0.00	0.00				
Carcharhinus falciformis	161	1.20	0.39	0.14	97	2.01	0.44	0.13
Carcharhinus leucas	1	0.01	0.00	0.00	1	0.02	0.00	0.00
Carcharhinus limbatus					3	0.06	0.01	0.01
Carcharhinus longimanus	3	0.02	0.01	0.01	4	0.08	0.02	0.01
Carcharhinus obscurus	52	0.39	0.13	0.06	1	0.02	0.00	0.00
Carcharodon carcharias	4	0.03	0.01	0.00				
Cephaloscyllium ventriosum	151	1.13	0.36	0.08				
Echinorhinus cookei	1	0.01	0.00	0.00				
Galeocerdo cuvier					3	0.06	0.01	0.01
Galeorhinus galeus	151	1.13	0.36	0.12	1	0.02	0.00	0.00
Heterodontus francisci	378	2.83	0.91	0.16				
Heterodontus mexicanus	57	0.43	0.14	0.05				
Hexanchus griseus	3	0.02	0.01	0.01				
Isurus oxyrinchus	181	1.35	0.44	0.09	1096	22.74	5.01	1.25
Mustelus californicus	175	1.31	0.42	0.10	17	0.35	0.08	0.08
Mustelus henlei	3233	24.18	7.77	1.07	2	0.04	0.01	0.01
Mustelus lunulatus	72	0.54	0.17	0.10	4	0.08	0.02	0.02
Negaprion brevirostris	1	0.01	0.00	0.00				
Notorhynchus cepedianus	1	0.01	0.00	0.00				
Prionace glauca	93	0.70	0.22	0.05	3362	69.75	15.35	1.78
Rhizoprionodon longurio	3	0.02	0.01	0.01				
Sphyrna lewini	14	0.10	0.03	0.02	12	0.25	0.05	0.04
Sphyrna zygaena	330	2.47	0.79	0.15	197	4.09	0.90	0.21
Squalus acanthias	1	0.01	0.00	0.00				
Squatina californica	755	5.65	1.82	0.26				
Triakis semifasciata	63	0.47	0.15	0.04				
Subtotal	5882				4800			
Batoids								
Bathyraja spinosissima	1	0.01	0.00	0.00				
Dasyatis dipterura	19	0.14	0.05	0.01	1	0.02	0.00	0.00
Dasyatis longa	32	0.24	0.08	0.05				
Gymnura marmorata	245	1.83	0.59	0.10				
Himantura pacifica	4	0.03	0.01	0.00				
Myliobatis californica	1457	10.90	3.50	1.08				
Myliobatis longirostris	29	0.22	0.07	0.02				
Narcine entemedor	40	0.30	0.10	0.04				
Platyrhinoidis triseriata	15	0.11	0.04	0.03				
Pteroplatytrygon violacea					2	0.04	0.01	0.01
Raja inornata	1	0.01	0.00	0.00				
Raja velezi	34	0.25	0.08	0.03				
Rhinobatos glaucostigma	125	0.93	0.30	0.10				
Rhinobatos productus	3820	28.57	9.18	1.30				
Rhinoptera staindachneri	32	0.24	0.08	0.02				
Torpedo californica	1	0.01	0.00	0.00				
Urobatis concentricus	14	0.10	0.03	0.02				
Urobatis halleri	3	0.02	0.01	0.01				
Urotrygon chilensis	1	0.01	0.00	0.00				
Urotrygon nana	2	0.01	0.00	0.00				
Urotrygon rogersi	1	0.01	0.00	0.00				
Zapteryx exasperata	1110	8.30	2.67	0.41				
Subtotal	7052				3			
Undetermined species								
Mustelus spp.	400	2.99	0.96	0.25	4	0.08	0.02	0.01
Myliobatis spp.	11	0.08	0.03	0.02	7	0.15	0.03	0.03
Raja spp.	11	0.08	0.03	0.01				
Rhinobatos spp.	12	0.09	0.03	0.02				
Sphyrna spp.	4	0.03	0.01	0.01	6	0.12	0.03	0.02
Subtotal	438				17			

Bathyraja spinosissima, *Raja inornata*, *Urotrygon chilensis* and *Urotrygon rogersi*.

In autumn the CPUEs were lower than in spring and summer (Table 5). Catches were dominated by sharks, which accounted for 70% of the total catch for this season. The most common species were *P. glauca* (3.6±1.13), *R. productus* (2.79±0.85), *S. californica* (2.42±0.71) and *M. californica* (2.35±1.18). Finally, in winter the lowest CPUE values were recorded (Table 5). Sharks dominated winter catches,

Table 5. – Seasonal catch per unit effort (CPUE) and standard error (SE) for elasmobranch species sampled on the Pacific coast of Baja California Sur during the period 2000-2010.

	Spring (n=7268)			Summer (n=8531)			Autumn (n=1314)			Winter (n=1079)		
Species	n	CPUE	SE	n	CPUE	SE	n	CPUE	SE	n	CPUE	SE
Sharks												
Alopias pelagicus				12	0.04	0.03	3	0.05	0.04			
Alopias vulpinus	13	0.06	0.03	16	0.05	0.02	4	0.07	0.04	3	0.05	0.05
Carcharhinus altimus				12	0.04	0.02						
Carcharhinus brachyurus				1	0.00	0.00						
Carcharhinus falciformis				139	0.46	0.16	118	2.07	0.68	1	0.02	0.02
Carcharhinus leucas	1	0.00	0.00							1	0.02	0.02
Carcharhinus limbatus	1	0.00	0.00							2	0.04	0.04
Carcharhinus longimanus	1	0.00	0.00	6	0.02	0.01						
Carcharhinus obscurus	37	0.17	0.10	16	0.05	0.03						
Carcharodon carcharias	2	0.01	0.01	2	0.01	0.00						
Cephaloscyllium ventriosum	37	0.17	0.05	96	0.32	0.09	18	0.32	0.14			
Echinorhinus cookei	1	0.00	0.00									
Galeocerdo cuvier				1	0.00	0.00				2	0.04	0.04
Galeorhinus galeus	15	0.07	0.04	137	0.45	0.16						
Heterodontus francisci	137	0.62	0.22	183	0.61	0.13	52	0.91	0.32	6	0.11	0.08
Heterodontus mexicanus				56	0.19	0.07				1	0.02	0.02
Hexanchus griseus				3	0.01	0.01						
Isurus oxyrinchus	687	3.11	1.19	276	0.91	0.12	107	1.88	0.62	257	4.67	1.46
Mustelus californicus	111	0.50	0.15	78	0.26	0.09				3	0.05	0.05
Mustelus henlei	442	2.00	0.48	2678	8.87	1.27	115	2.02	0.73			
Mustelus lunulatus	72	0.33	0.14	1	0.00	0.00	3	0.05	0.05			
Mustelus spp.	157	0.71	0.23	213	0.71	0.19	33	0.58	0.51	1	0.02	0.02
Negaprion brevirostris	1	0.00	0.00	0								
Notorynchus cepedianus				1								
Prionace glauca	1810	8.19	1.68	732	2.42	0.40	205	3.60	1.13	708	12.87	1.92
Rhizoprionodon longurio				3	0.01	0.01	0	0.00	0.00			
Sphyrna lewini	3	0.01	0.01	12	0.04	0.02	9	0.16	0.14	2	0.04	0.03
Sphyrna spp.	3	0.01	0.01	6	0.02	0.02	0	0.00	0.00	1	0.02	0.02
Sphyrna zygaena	110	0.50	0.11	228	0.76	0.15	99	1.74	0.54	40	0.73	0.19
Squalus acanthias	1	0.00	0.00									
Squatina californica	205	0.93	0.26	410	1.36	0.23	138	2.42	0.71	2	0.04	0.04
Triakis semifasciata	17	0.08	0.03	24	0.08	0.02	7	0.12	0.06	15	0.27	0.13
Subtotal	3864			5342			911			1045		
Batoids												
Bathyraja spinosissima				1	0.00	0.00						
Dasyatis dipterura	8	0.04	0.02	12	0.04	0.02						
Dasyatis longa	25	0.11	0.09	7	0.02	0.01						
Gymnura marmorata	72	0.33	0.10	173	0.57	0.13						
Himantura pacifica	0	0.00	0.00	3	0.01	0.01	1	0.02	0.02	0	0.00	0.00
Myliobatis californica	1144	5.18	1.95	179	0.59	0.10	134	2.35	1.18	0	0.00	0.00
Myliobatis longirostris	9	0.04	0.03	20	0.07	0.03						
Myliobatis spp.	13	0.06	0.04	5	0.02	0.01						
Narcine entemedor	23	0.10	0.04	15	0.05	0.02	2	0.04	0.04	0	0.00	0.00
Platyrhinoidis triseriata				15	0.05	0.02						
Pteroplatytrygon violacea	1	0.00	0.00	1	0.00	0.00						
Raja inornata				1	0.00	0.00						
Raja spp.	10	0.05	0.02	1	0.00	0.00						
Raja velezi	29	0.13	0.05	5	0.02	0.01						
Rhinobatos glaucostigma	13	0.06	0.03	112	0.37	0.13						
Rhinobatos productus	1842	8.34	1.54	1793	5.94	0.87	159	2.79	0.85	26	0.47	0.18
Rhinobatus spp.	6	0.03	0.03	6	0.02	0.02						
Rhinoptera steindachneri	8	0.04	0.02	24	0.08	0.03						
Torpedo californica	1	0.00	0.00	0	0.00	0.00						
Urobatis concentricus	1	0.00	0.00	13	0.04	0.03						
Urobatis halleri				3	0.01	0.01						
Urotrygon chilensis				1	0.00	0.00						
Urotrygon nana				2	0.01	0.01						
Urotrygon rogersi				1	0.00	0.00						
Zapteryx exasperata	199	0.90	0.24	796	2.64	0.49	107	1.88	0.59	8	0.15	0.11
Subtotal	3404			3189			403			34		

accounting for 95%, mostly because of the frequency of *P. glauca* (12.87±1.92) and *I. oxyrinchus* (4.67±1.46).

Cumulative taxon curves showed sufficient sample sizes for catch composition estimates of vessel using gillnets (t=0.260; P=0.795; n=416) and longlines (t=0.360; P=0.719; n=219). The curves also indicate that sample size was sufficient to estimate the species composition by seasons: spring (t=0.130; P=0.896; n=221), summer (t=0.214; P=0.83; n=302), autumn (t=0.0132; P=0.91; n=57) and winter (t=0.125; P=0.90; n=55).

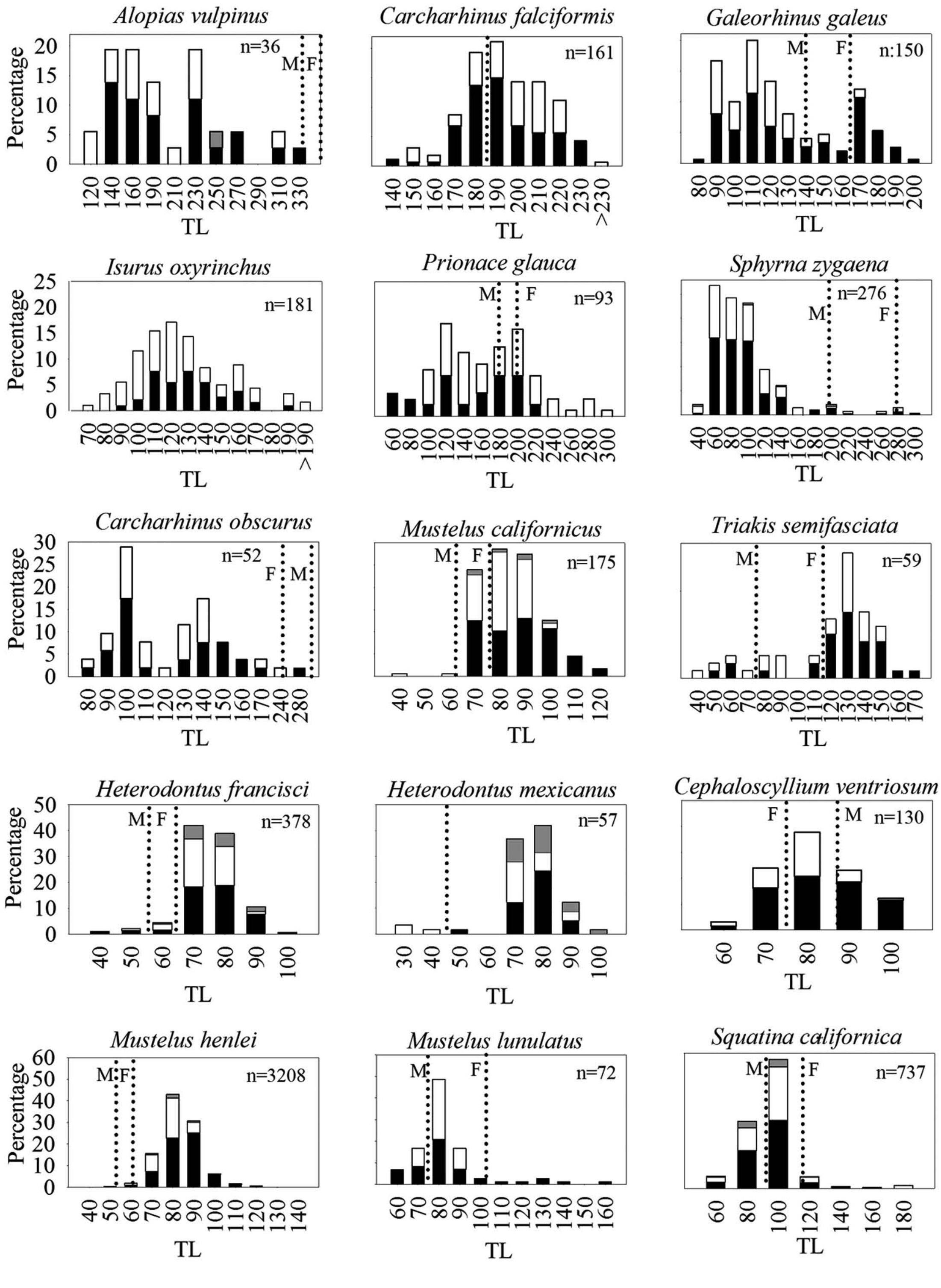

Fig. 2. – Size frequency distributions by sex of shark species captured by gillnets. *n* refers to the number of measured individuals. Females are depicted in black, males in white, unsexed specimens in grey. Dotted lines indicate the size at maturity. In cases in which a substantial difference in size at maturity exists between sexes, lines are labeled M (male) or F (female).

Biological information

For gillnet-captured elasmobranchs, size distribution differed significantly between males and females for *C. ventriosum*, *G. galeus*, *H. francisci*, *I. oxyrhinchus*, *M. californicus*, *M. henlei*, *P. glauca*, *S. californica*, *G. marmorata*, *M. californica, R. glaucostigmata, R. productus* and *Z. exasperata*. In addition, the

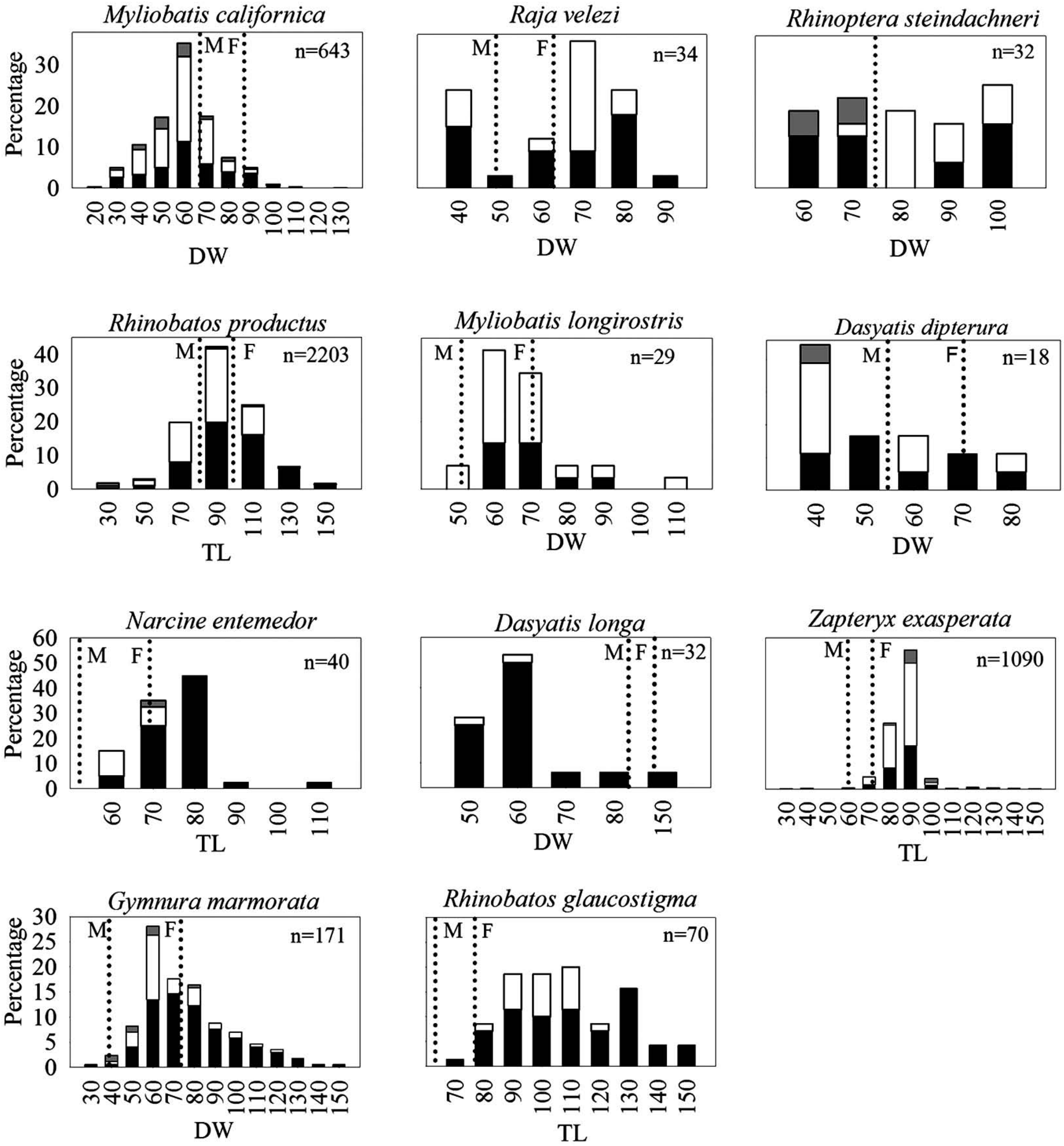

Fig. 3. – Size frequency distributions by sex of batoid species captured by gillnets. *n* refers to the number of measured individuals. Females are depicted in black, males in white, unsexed specimens in grey. Dotted lines indicate the size at maturity. In cases in which a substantial difference in size at maturity exists between sexes, lines are labeled M (male) or F (female).

male-to-female sex ratio differed significantly from the expected 1:1 ratio for the following gillnet-captured elasmobranch species: *C. falciformis*, *C. ventriosum*, *G. galeus*, *H. francisci*, *I. oxyrhinchus*, *M. henlei*, *S. zygaena*, *S. californica*, *G. marmorata*, *M. californica, R. glaucostigmata, R. productus* and *Z. exasperata.* For longline-captured elasmobranchs, size distribution differed significantly between males and females for *C. falciformis*, *P. glauca*, and *S. zygaena*, while sex ratio differed significantly from the expected 1:1 ratio for *I. oxyrhinchus*, *P. glauca* and *S. zygaena*.

Information detailing the size and sex composition of elasmobranchs captured by gillnet and longline is summarized in Figures 2, 3, and 4. Table 6 provides detailed information in sex ratios of all captured elasmobranchs, and Table 7 provides information on the size structure of infrequently captured species.

Diversity index and biogeography

The species richness and diversity recorded in BCS was high with 52 elasmobranch species documented, the Shannon-Wiener index value (*H'*) of 2.34±0.01 SE and the Simpson index (*D*) of 0.86. There was a higher species richness in the north zone (46 species), resulting in a high diversity index (*H'*=2.32±0.02 SE) and dominance index (*D*=0.84), while the south zone (26 species) had lower richness; the diversity index was 2.19 (±0.14),

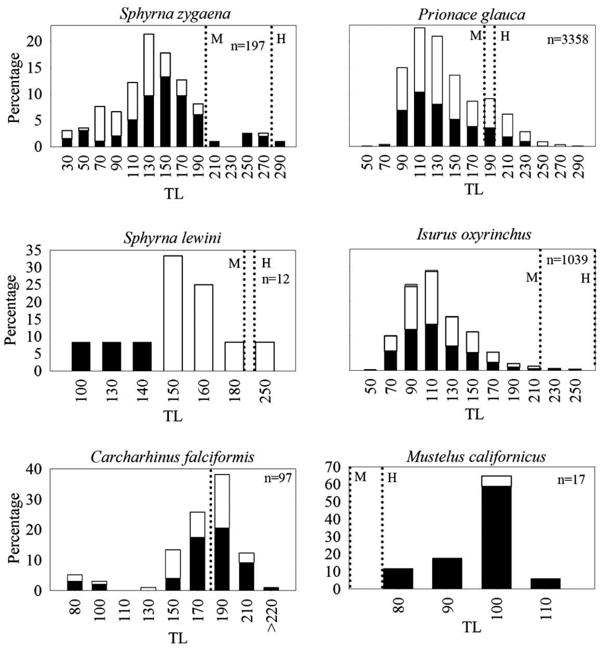

FIG. 4. – Size frequency distributions by sex of shark species captured by longlines. *n* refers to the number of measured individuals. Females are depicted in black, males in white, unsexed specimens in grey. Dotted lines indicate the size at maturity. In cases in which a substantial difference in size at maturity exists among sexes, lines are labeled M (male) or F (female).

but the dominance index was high (D=0.83). Significant differences (t=14.93; p<0.001) were found in the diversity indices estimated between north and south zones. Also, the Jaccard index between the two zones was low (J=0.42), indicating that there is a difference in the species composition of elasmobranchs from the sites studied.

DISCUSSION

Survey of artisanal camps

In conjunction with previous studies (Bizzarro *et al*. 2009a, Smith *et al*. 2009, Bizzarro *et al*. 2009b, Bizzarro *et al*. 2009c and Cartamil *et al*. 2011), the results of the present study allow for the first time a comprehensive characterization of artisanal elasmobranch fisheries throughout the Mexican northwest. In this region, the Pacific coast of BCS represents one of the largest catch regions of elasmobranch artisanal fisheries. A total of 60 artisanal camps were recorded and the area was surpassed in number only by the 83 camps on the east coast of BCS (Bizzarro *et al*. 2009b).

Elasmobranchs were the primary target in relatively few camps (6 camps). This may be due to the economics of this fishery, including high operating costs, fuel, oil, equipment, gear, poor infrastructure, limited marketing channels and consequently lower prices for products (Ponce-Diaz *et al*. 2009). On the Pacific coast of BCS the artisanal elasmobranch fishery was conducted by licensees (concessionaires), free fishers and cooperatives.

Elasmobranchs were often caught incidentally in teleost fisheries, such as the California halibut (*Paralichthys californicus*) gillnet fishery, in which elasmobranch bycatch such as *R. productus* and *M. henlei* was recorded. In addition, fishermen in some camps were opportunistic and focused catch on abundant local fauna, which varied according to the season, due to the low price of elasmobranchs (7-14 pesos kg^{-1}) compared with other fishery resources in the study area [e.g., California halibut (20-40 pesos kg^{-1}), white seabass (*Atractoscion*

TABLE 6. – Sex ratios for the most common species of elasmobranchs captured by the artisanal fishery on the Pacific coast of Baja California Sur during the period 2000-2010.

Fishing gear	Species	Males (*n*)	Females (*n*)	Ratio	χ^2	*P**
Gillnet	Sharks					
	Carcharhinus falciformis	64	97	1.5:1	6.76	<0.001
	Carcharhinus obscurus	25	27	1:1	0.16	>0.68
	Cephaloscyllium ventriosum	41	89	2.1:1	17.72	<0.001
	Galeorhinus galeus	56	94	1.6:1	9.62	<0.001
	Heterodontus francisci	144	186	1.2:1	5.35	<0.01
	Heterodontus mexicanus	18	25	1:1	1.13	0.28
	Isurus oxyrinchus	110	71	1.5:1	8.4	<0.01
	Mustelus californicus	77	92	1:1	1.33	0.24
	Mustelus henlei	1038	2066	2:1	340.46	<0.001
	Mustelus lunulatus	33	39	1:1	0.5	0.48
	Prionace glauca	55	38	1:1	3.1	0.07
	Sphyrna zygaena	106	166	1.5:1	13.23	<0.001
	Squatina californica	298	389	1.3:1	12.05	<0.001
	Triakis semifasciata	26	33	1:1	0.83	0.36
	Batoids					
	Gymnura marmorata	53	118	2.2:1	32.69	<0.001
	Myliobatis californica	338	238	1.4:1	17.36	<0.001
	Rhinobatos glaucostigma	19	51	2.6:1	14.63	<0.001
	Rhinobatos productus	989	1164	1.2:1	14.22	<0.001
	Zapteryx exasperata	645	354	1.8:1	84.76	<0.001
Longline	Sharks					
	Carcharhinus falciformis	41	56	1:1	2.32	0.12
	Isurus oxyrinchus	588	432	1.3:1	23.86	<0.001
	Prionace glauca	1993	1358	1.4:1	120.33	<0.001
	Sphyrna zygaena	83	114	1.3:1	4.88	<0.01

Table 7. – Summary statistics on size parameters for elasmobranch species captured by gillnet (where *n*<16) and longline (where *n*<8). Mean size (MS, in cm) ± standard deviation (SD) is shown for each specified measurement (SM). TL, total length; DW, disc width; AL, alternate length.

Fishing gears	Species	MS	SD	SM	*n*
Gillnet	*Alopias pelagicus*	272.2	14.2	TL	15
	Bathyraja spinosissima	30	------	DW	1
	Carcharhinus altimus	126.74	14.84	TL	12
	Carcharhinus brachyurus	275	------	TL	1
	Carcharhinus leucas	91	------	TL	1
	Carcharhinus longimanus	195	12.16	TL	3
	Carcharodon carcharias	151.5	13.9	TL	4
	Echinorhinus cookei	145	------	TL	1
	Hexanchus griseus	143.5	14.15	TL	3
	Himantura pacifica	44.5	10.4	DW	4
	Myliobatis spp.	60	14	DW	11
	Negaprion brevirostris	67	------	TL	1
	Notorhynchus cepedianus	163	------	TL	1
	Platyrhinoidis triseriata	53.2	8.34	TL	15
	Raja inornata	36	------	DW	1
	Raja spp.	61.4	28.88	DW	11
	Rhinobatos spp.	86.62	9.36	TL	12
	Rhizoprionodon longurio	75.3	21.45	TL	3
	Sphyrna lewini	160.77	65.34	TL	14
	Sphyrna spp.	127.75	62.65	TL	4
	Squalus acanthias	33	------	AL	1
	Torpedo californica	43	------	DW	1
	Urobatis concentricus	37.17	1.89	DW	14
	Urobatis halleri	43.3	2.3	DW	3
	Urotrygon chilensis	33	------	DW	1
	Urotrygon nana	23.75	1.76	DW	2
	Urotrygon rogersi	36	------	DW	1
Longline	*Carcharhinus leucas*	285	-----	TL	1
	Carcharhinus limbatus	162.33	38.39	TL	3
	Carcharhinus longimanus	187.5	23.04	TL	4
	Carcharhinus obscurus	99	-----	TL	1
	Dasyatis dipterura	150	-----	DW	1
	Galeocerdo cuvier	167.33	51.68	TL	3
	Galeorhinus galeus	125	-----	TL	1
	Mustelus henlei	109.5	13.44	TL	2
	Mustelus lunulatus	77	4.6904	TL	4
	Mustelus spp.	76.25	4.79	TL	4
	Myliobatis spp.	86.29	24.27	DW	7
	Pteroplatytrygon violacea	51.5	9.19	DW	2
	Sphyrna spp.	94.33	36.779	TL	6

nobilis; 40-60 pesos kg^{-1}), abalone (300-500 pesos kg^{-1}) and lobster (150-250 pesos kg^{-1})].

Landings in the present study were dominated by sharks (61%). Compared with the shark fishery that began in 1930, batoid fisheries in Mexico are a relatively new activity. In the late 1980s, demand increased as shrimp vessels began to commercialize their batoid bycatch. In the early 1990s, due to a drop in the production of Pacific sharpnose shark (*Rhizoprionodon longurio*) and growing market demand, artisanal fishermen began to engage formally in targeting batoids (Cudney-Bueno and Turk-Boyer 1998). Currently the artisanal batoid fishery is increasing, and official data show that in BCS from 2008 (983 t) to 2009 (1504 t) there was an increase of over 50% (Marquez-Farias and Blanco-Parra 2006, SAGARPA 2009).

Biological data

The prevalence of juveniles of several elasmobranch species (e.g. *G. galeus*, *C. ventriosum* and *M. californica*) throughout the year and the frequency of occurrence of small size classes of several shark species (e.g. *P. glauca* and *I. oxyrinchus*) within landings suggests that considerable fishing effort may be opportunistically directed on breeding or nursery areas. Along the Pacific coast of BCS there are three major coastal lagoon systems (Guerrero Negro-Ojo de Liebre, Laguna San Ignacio and Bahia Magdalena; Fig. 1), which represent highly productive and diverse environments (Ibarra-Obando *et al*. 2001). It has been documented that coastal elasmobranch species use bays, estuaries and lagoons as foraging, resting, mating and nursery grounds (Pratt and Carrier 2001, Heupel and Simpfendorfer 2005, Farrugia *et al*. 2011).

Sexual segregation has been reported in elasmobranchs (Sims 2005) and in the present study several species had a tendency to be caught in same sex grouping, such as *R. productus*, *M. californica*, *Z. exasperata* and species of the *Mustelus* genus. This is a behavior that can occur due to differences in sex, body size, behavior, nutritional requirements and/or habitat selection (Klimley 1987, Magurran and Macias-Garcia 2000, Sims 2005, Wearmouth and Sims 2008).

Table 8. – Arrangement of species according to marine province divisions. The first column represents species distributed along the entire Pacific coast of BCS. The "North of Bahia Magdalena" column represents species restricted to the California Province. The "South of Bahia Magdalena" represents species restricted to the Cortez Province. Species are arranged from highest to lowest relative abundance.

Pacific coast of BCS	N	North of Bahia Magdalena	N	South of Bahia Magdalena	N
Rhinobatos productus	3820	*Squatina californica*	755	*Carcharhinus falciformis*	258
Prionace glauca	3455	*Heterodontus francisci*	378	*Myliobatis* spp.	18
Mustelus henlei	3235	*Galeorhinus galeus*	152	*Alopias pelagicus*	15
Myliobatis californica	1457	*Cephaloscyllium ventriosum*	151	*Carcharhinus longimanus*	7
Isurus oxyrinchus	1327	*Triakis semifasciata*	63	*Carcharhinus limbatus*	3
Zapteryx exasperata	1110	*Heterodontus mexicanus*	57	*Galeocerdo cuvier*	3
Sphyrna zygaena	477	*Carcharhinus obscurus*	53	*Carcharhinus leucas*	2
Mustelus spp.	404	*Alopias vulpinus*	36	*Negaprion brevirostris*	1
Gymnura marmorata	245	*Platyrhinoidis triseriata*	15		
Mustelus californicus	192	*Urobatis concentricus*	14		
Rhinobatos glaucostigma	125	*Carcharhinus altimus*	12		
Mustelus lunulatus	76	*Carcharodon carcharias*	4		
Narcine entemedor	40	*Himantura pacifica*	4		
Raja velezi	34	*Hexanchus griseus*	3		
Rhinoptera steindachneri	32	*Urotrygon chilensis*	3		
Dasyatis longa	32	*Urobatis halleri*	2		
Myliobatis longirostris	29	*Pteroplatytrygon violacea*	2		
Sphyrna lewini	26	*Carcharhinus brachyurus*	1		
Dasyatis dipterura	20	*Bathyraja spinosissima*	1		
Rhinobatos spp.	12	*Notorhynchus cepedianus*	1		
Raja spp.	11	*Echinorhinus cookei*	1		
Sphyrna spp.	10	*Raja inornata*	1		
Rhizoprionodon longurio	3	*Squalus acanthias*	1		
		Urotrygon rogersi	1		
		Torpedo californica	1		
		Urotrygon nana	1		

R. productus and *P. glauca,* the two most abundant elasmobranch species recorded, were also the most important species in landings along the Pacific coast of BC (Cartamil *et al.* 2011). Shovelnose guitarfish was also the species most captured in the upper Gulf of California (Marquez-Farias 2002, Bizzarro *et al.* 2009a, Smith *et al.* 2009). High fishing pressure recorded in this species could cause population declines, so this species should be monitored closely.

Seasonality

Seasonal variation in targeted elasmobranch species was recorded along the Pacific coast of BCS. Several species recorded in the landings could be involved in seasonal migrations (e.g. *R. productus*, *M. californica*) (Bizzarro *et al.* 2007a). Temperature plays an important role in the seasonal migrations of several elasmobranchs species in nearshore waters (Talent 1985, Wallman and Bennett 2006, Wiley and Simpfendorfer 2008).

Fishing effort was greater during the spring and summer seasons than in autumn and winter. This late-year decrease was caused primarily by adverse oceanographic conditions due to the presence of northwesterly winds (Jaramillo *et al.* 2004).

Diversity and biogeography

Estimates of diversity levels in fishery studies can be useful because changes can be detected in the structure of commercially exploited populations (Tavares and Arocha 2008). Further, it has been suggested that managers can use the diversity of species in an area and the presence of foundation species as indicators of marine ecosystem functioning (Bracken *et al.* 2007). The application of diversity indices in elasmobranch fisheries biology is relatively recent, and few studies using this technique have been reported (e.g. Worm *et al.* 2003, Tavares and Arocha 2008).

The Shannon-Wiener index estimated for the study area suggests high levels of elasmobranch diversity. The number of elasmobranch species (52) recorded on the Pacific coast of BCS is higher than that reported in any other region of northwestern Mexico. This high richness and diversity included species of different affinities and ecological requirements; this finding can be attributed to the convergence of currents found in the study area, as well as topography and bathymetry. Currents converging on the Pacific coast of BCS are the cold-temperate California current, and the North Equatorial Current with warm tropical characteristics (Hickey 1979, Lynn and Simpson 1987). These currents influence elasmobranch species composition (e.g. tropical species such as *R. glaucostigma* and *N. brevirostris* and temperate species such as *T. californica* and *Alopias vulpinus*) (Hubbs 1960, Walker 1960, Lluch-Belda *et al.* 2003, Dawson *et al.* 2006).

We observed a significant change in the abundance of some species to the south and north of Punta San Lazaro, Bahia Magdalena (Table 8). Bahia Magdalena is located at the confluence of several water masses and is therefore considered a transition zone (Brinton and Reid 1986). Our results also suggest that from Laguna San Ignacio to Bahia Magdalena there exists a transition zone between the Californian Province and Cortez Province; this is corroborated by the mixed tropical-temperate species found in this study. This transition zone is a possible boundary for the distribution of some elasmobranchs (e.g. *Rhinoptera steindachneri, Rhinobatos glaucostigma* and *Myliobatis longirostris*).

Management implications

Despite the importance of elasmobranch fishing in Mexico, few regulations have been instituted for this fishery. The first step for management was taken by the Mexican National Institute of Fisheries, which recommended a moratorium on issuing new shark-fishing permits beginning in 1993 (Castillo-Geniz *et al*. 1998), which was carried out in 1998 (Sosa-Nishizaki *et al*. 2008). This was followed by the development of a National Action Plan for the Conservation and Management of sharks, rays and related species in Mexico in 2004 by the Comision Nacional de Agricultura y Pesca (CONAPESCA-INP 2004). Finally, a regulation known as NOM-029-PESCA-2006 (DOF 2007) instituted in 2007 aimed to protect and ensure proper fisheries management and conservation for elasmobranchs (DOF 2007).

Our results will serve as a baseline for determining future changes in the artisanal fishery. For proper management in Mexico it is necessary to improve fishery statistics and there is a need for a continued monitoring programme to obtain specific information about captures by sites and seasons. It is also important to incorporate an ecosystem approach to fisheries management, which represents a substantial change in perspective and poses equally substantial challenges (Bracken *et al*. 2007). In addition, our survey indicates that considerable fishing pressure is occurring upon juvenile elasmobranchs, likely within their nursery habitat. Further research into the determination and protection of these nursery areas is critical for the sustainability of elasmobranch populations (Branstetter 1990).

After decades of elasmobranch exploitation in waters of the Pacific coast of BCS, there have likely been decreases in populations and changes in size structure among less fecund species (Stevens *et al*. 2000). A specific case that was observed in the present study is that of the angel shark, which was exploited significantly in Laguna San Ignacio and Bahia Magdalena many years ago (Villavicencio-Garayzar and Abitia-Cardenas 1994). In the present study this species was not recorded in either zone; its catch was restricted only to the zone north of Laguna San Ignacio. This suggests that fishing pressure has caused the decline of its populations. Genetic studies suggest that the angel shark captured on the Pacific coast of the BC Peninsula is going through a "bottleneck" process caused by overfishing (Ramirez-Amaro *et al*. 2011), so particular attention should be paid to the protection of this species.

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