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Size And Sex of the Blue Sharks Caught by the Mexican Longline Industrial Fleets Recorded by on board Observers in the Pacific 2006-2015†

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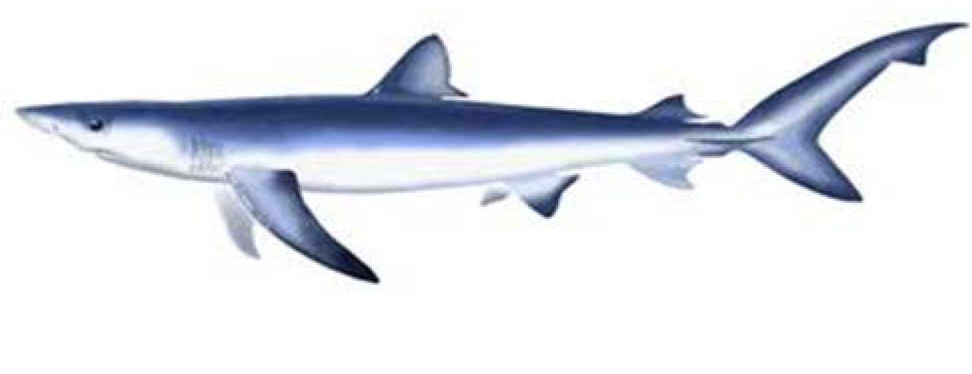

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Abstract

This aim of this working paper is to contribute to the knowledge of the spatially and temporal length and sex structure of the blue shark in the North Pacific Ocean with recent information from the Mexican longlines fleets which operate in the west coast of the Mexican Pacific. Data on 71,803 blue sharks measured on board by observers from two principal fleets (Ensenada and Mazatlan) during 2006-2016 were used to describe the size composition of the blue shark catches in two regions: the west coast of the Peninsula of Baja California and the central Mexican Pacific. Results indicate significant differences in sizes and maturity condition of the blue sharks in terms of season (quarter) and zone. Immature or juveniles blue sharks of both sexes compose principally (76.8%) the observed catches along the west coast of the Peninsula of BC. Mature blue sharks were predominant (59.8%) in the southern catches of the Mazatlan fleet. The present work detected a “hot spot” area with a significant aggregation of blue shark gravid females in oceanic waters just in front of the tip of the Peninsula of Baja California.

Introduction

The blue shark, *Prionace glauca* (Linnaeus, 1758) is the most common and widely distributed shark in subtropical and temperate oceanic waters (Castro, 2011). Because of its cosmopolitan distribution large numbers are caught by several fisheries around the world, principally as bycatch but also as a target species in diverse pelagic fisheries (Nakano and Stevens, 2008). The species is highly migratory with complex movement patterns related to its life history. Blue sharks prefer temperatures between 12°C and 20°C and its relative abundance is generally low in equatorial waters and increase with latitude (Strasburg, 1958; Last and Stevens, 1994). In 1994 Nakano published one of the most comprehensive and extended studies of the movement patterns of *P. glauca* in the North Pacific. This author proposed a movement model that explained the complex migrations between different blue shark ground stages (mating, parturition and nursery grounds), suggesting that the pupping grounds (sub-adults) are located mainly in the North at 35-45°N, whereas adults commonly occur in southern waters. Because of the large numbers of blue sharks removed by fisheries the IUCN has assessed *P. glauca* as a species Near Threatened species (Stevens, 2009).

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Blue sharks represent a valuable source of food (meat), employment and business for diverse fishery communities along the northern and central west coast of Mexico. It is recorded as the most abundant shark species in the landings of the Mexican industrial longline fleets (vessels longer than 10 m in length) which operate in Northern and Central Mexican Pacific waters (Tovar-Avila *et al*., 2011 ISC/11/SHARKWG-1/8; Vögler *et al*. 2012); as well as in the landings of the artisanal shark fishery along the west coast of the Peninsula of Baja California (PBC) (Cartamil *et al*. 2011; Sosa-Nishizaki *et al*., 2002 and 2008). Blue shark catches increased from less than 500 t in the 1970s to around 1,000 in the 1990s, and 4,000 t in the second half of the 2000s, reaching the highest catch reported in 2014 (5,500 t)(Sosa-Nishizaki, 2011; Sosa-Nishizaki and Castillo-Geniz, 2014).

The management of sharks fisheries in Mexican waters from both littorals, including the blue shark catches, is conducted through commercial permits and diverse regulations contained in the Mexican Official Standard NOM-029-PESC-2006, Shark and Rays Responsible Fisheries. This law was published in February 14, 2007 in the Federal Gazzete (SAGARPA, 2007). Regulations in the NOM-029-PESC-2006 include several important measures like the permanent ban since 2007 for new shark commercial permits, specific shark fishery areas exclusion by fleets, prohibition of use driftnets in all commercial shark vessels longer than 10 m length, mandatory use of VMS in all the industrial vessels, and the total prohibition for shark finning practices in Mexican waters. Another important contribution of the NOM-029-PESC-2006 was the establishment of a shark observer program (POT) which operates onboard the industrial fleets. A general description of the POT operations is provided by Castillo-Geniz *et al*. (2014). It is important to mention that the POT operates in a voluntary basis for vessels participation.

The present work provides the first analysis of size and sex composition for the blue sharks catches of longline vessels based in the ports of Ensenada (north Mexican Pacific) and Mazatlan (Central Mexican Pacific) collected through the POT during 2006-2015. Vessels based in the port of Ensenada operate along the west coast of the PBC, in temperate waters with influence of the California Current, whereas vessels based in the port of Mazatlan operate in warmer waters of the Central Mexican Pacific.

Material and Methods

Two different sources were consulted to determine the percentage of coverage of the POT through the period 2006-2015: 1) The notice of arrival ("Aviso de Arribo") and 2) The commercial shark fishery logbooks ("Bitácora de Pesca commercial de Tiburon en Embarcaciones de Mediana Altura"). Both documents are mandatory for all industrial shark fishing vessels and represent the main instruments to collect statistical information of the fishery. Table 1 shows the total number of trips and sets observed by year in the longline fishery industrial fleet which has operated in the Mexican northern and central Pacific during 2006-2016. It also includes the observed coverage percentage per year, 8.7% out of a total of 58,759 fishing sets conducted were observed during eleven years. Data on length, sex and maturity condition of blue sharks were documented on board by certified observers participating in the POT. The morphometric measurements (Total Length TL, Furcal Length FL and Precaudal Length PCL) were obtained following Compagno (1984). FL was used as the standard measurement to determine the size of the sharks in the present study. Length and sex data were separated by year quarters of the year and fishing zone (North and South) considering the fishery grounds of Ensenada and Mazatlan fleets respectively. To assess possible differences in FL of the blue sharks (combined sexes) caught in difference zones and seasons a Generalized Linear Model (GLM) in function of the quarter, the zone and the interaction effect of both variables were applied (McCullagn and Nelder, 1989) was applied. The GLM was performed in the R environment, version 3.3.2 (R Core Team, 2016). GLM with several probability distributions of error were applied and compared with the Akaike information criterion (Akaike, 1974).

For the special and temporal distribution of blue shark catches maps were built using the software ArgGIS® 10.3 (ESRI, 2014). Length and sex data were agglutinated in 1x1° (lon x lat) spatial bins because this resolution fits better to the spatial scale of the fishery grounds of the longline industrial fleet. The estimated length at 50% maturity (193 cm TL or 145 cm PCL for both sexes according to Sippel *et al*. (2016 ISC/16/SHARKWG-1) was used to separate immature from mature measured blue sharks. Gravid females were identified on board by the presence of embryos in their uteri. Spatially explicit size and sex data were available through the POT operating on board the Ensenada and Mazatlan longline fleets.

Results

The POT observed 5,435 longline sets during 2006-2016 for both fleets, Ensenada and Mazatlan (Fig. 1A). Blue sharks were caught in 94% of the total observed sets (Fig. 1.B)(Table 1). The proportion of sets with capture of blue sharks observed in the Ensenada and Mazatlan fleets was 96.7% and 92.2%, respectively (Table 2). A total of 71,803 blue sharks were measured on board of vessels from both fleets. Females accounted for 29.6% of the recorded blue sharks whereas males up to 70.4%. Males size ranged of 46-333.7 cm FL (155.9 ± 0.1 cm FL), similar to the females range 47-333.7 cm FL (150.1 ± 0.3 cm FL).

The numbers by fleet were: Ensenada with 24,644 sharks, 55.7% was males and 44.3% females. The proportion of immature and mature males was 74% and 26%, respectively. Females 80.4% immature and 19.6% mature. In Mazatlan fleet were measured 47,159 blue sharks, which 78.1% was males and 21.9% females. Males showed an almost equal proportion of immature (43.1%) and mature (56.9%) Large number of females was mature (70.2%) and 29.8% was immature.

On board Ensenada vessels 24,644 blue sharks were measured (55.6% males and 44.4% females) with a size range 50-333.7 cm FL (136.8 ± 03 cm FL) for males and 47 - 333.7 cm FL (130.5 ± 0.3 cm FL) for females (Fig. 2A). On board Mazatlan vessels 47,159 blue sharks were measured, with a significant different sex ratio (78.1% males and only 21.9% females). The size of males caught by this fleet ranged 46-333.7 cm FL (163.0 ± 0.1 cm FL) whereas females ranged 60 - 333.7 cm FL (170.9 ± 0.3 cm FL) (Fig. 2B). In Table 3 is presented the mean and standard deviation, including sample size of the blue sharks measured by sex, quarter, year by fleet during 2006-2016.

Statistical analysis of blue shark length (FL) spatial distribution

The model with Gamma distribution of the errors with reverse link function (1/ mu) presented the lowest AIC value (-41015.09) (Table 4). The effect of quarter, zone and the interaction between both variables were significant and thus included in the GLM model:

glm(LF ~ Quarter + Zone + Quarter:Zone, family = Gamma(link = inv))

Figure 3 shows the shark FL in the North zone (Ensenada fleet) have much more dispersed distribution and are more visibly different between quarters (Q), especially Q3 with mean 140.4 cm FL (SD 38.9) (Fig. 3C), which was larger than in other zones. In the Southern zone (Mazatlan fleet) the sizes are distributed quite symmetrically (normal distribution type), with similar average size among the four quarters and considerably larger than the total average size of the North zone (Table 3). The ANOVA test of the GLM showed that the bue shark FL was significantly different between zones (deviance residual 669.1521, (Table 5) and also between quarters. The largest mean FL of blue shark for the North region was estimated for the Q3 (140.4 cm FL), whereas the lowest was estimated for the Q2 (130.cm FL). The blue sharks captured in Southern waters presented the largest means size during Q2 (166 cm FL) and the lowest during.

All three terms in the models were highly significant for combined sexes, males and females (Table 3), indicating statistical differences in mean FL between north and south, and among quarters within each zone, small differences in the last resulting significant because of the high sample sizes (in the order of thousands).

The Akaike information criterion (AIC) also presented the lowest values for Gamma models with inverse link function used for the analyses of both males and females FL. The best model indicated all three terms: quarter, zone, and the interaction of both, are significant in the variation of blue shark FL along quarters and zones for each sex. The results of these 2 GLMs conducted for FL of males and females of *P. glauca* show similar pattern to those in the model of combined sexes. Females showed the largest FL means in the southern region with lower dispersion in contrast with females caught in the northern region (Fig. 2 and Fig. 3) (Table 3). In the northern zone off the west coast of BC, quarterly FL averages for males were very similar, although in Q3 a larger mean was observed. In the case of blue shark males caught by the Mazatlan longline fleet in the southern zone, those presented larger sizes but the mean was quite similar and stable through quarters during 2006-2015 (Table 3; Fig. 3).

In the three models applied (combined sexes, males and females), the "zone" factor explained the largest variation in FL, followed by the "quarter" factor (Table 5).

Blue shark catches distribution by size and sex

The statistical analysis of the size structure of the blue shark catches observed resulted in significant difference between the fishery grounds of both longline fleets. Fernandez-Mendez *et al.* (2016, ISC/16/SHARKWG-1/25) used 22.87° N as the arbitrary latitudinal limit that separates the principal fishery grounds of the Ensenada and Mazatlan fleets. Mapping quarterly the proportion of immature and mature blue sharks catches it is clear that the catches obtained north to 23° N along the west coast of PBC were dominated with small immature individuals < 193 cm TL during Q1,Q2 and Q4. In Q3 was observed an extensive presence of mature sharks in the southern region between 108° and 118°W (Fig. 4). The sex ratio of observed blue shark catches was also mapped showing that there is an apparent sexual segregation with females being dominant the northern region and males outnumbered in the central Pacific of the Mexican coast (Fig. 5). Only in Q1 and Q4 females were more frequent in the catches along the northern PBC. Although the annually closure fishery season since 2012 (May 1 – July

31) has affected the collection of data in the last five years, numerical samples of blue sharks are still high and consistent to demonstrate such seasonal pattern.

Finally it was examined roughly the spatial distribution and relative abundance of 1,874 blue shark gravid females caught during 2006-2015 by the Mexican longline industrial fleets. All gravid females ranged 143-333.7 cm FL. The Ensenada fleet fished 577 gravid females (143-304 cm FL) along the west coast of the PBC. A larger number of pregnant females was caught southern in the central Mexican Pacific, 1,297 (143-333.7 cm FL) (Fig 6A). There was a significant aggregation ("hot spot") in term of numbers of females with embryos in oceanic waters just in front of tip of the PBC, especially in winter months (Fig. 6B).

Discussion

Due to its wide geographic distribution and abundance *P. glauca* is the shark species that provides the largest catches and landings in terms of individuals in the Mexican Pacific (Sosa-Nishizaki and Castillo-Geniz, 2016). Several industrial and artisanal fleets have fished for blue sharks along the Mexico's EEZ, in open and coastal waters respectively. It is also probably one of the most shark species studied in Mexico (Sosa-Nishizaki *et al*. 2002, Sosa-Nishizaki *et al*. 2008, Carrera-Fernandez *et al*. 2010, Cartamil *et al*. 2011, Cruz-Ramirez *et al*., 2011 and 2012, Vögler *et al*. 2012, Ramirez-Amado *et al*. 2013 and Santana-Hernández and Valdez-Flores, 2014). Along the west coast of the PCB (23° N – 33° N) blue sharks are caught all year around by both fisheries and the size and sex data obtained by the POT suggested that catches are dominated by juvenile sharks (quarter mean FL interval 130.8 – 140.5 cm) with an almost equal sex ratio. In contrast, the size structure of catches observed in southern waters at the central Pacific (16°N – 23° N) presented larger sizes (quarter mean FL interval 161.6 – 166.7 cm) and sex ratio was dominated extensively by males. The results of the GLMs and ANOVAs for combined sexes, males and females demonstrated the statistical differences between both groups of blue sharks caught in terms of zone and season. Casey (1985) reported a spatial size and sex segregation of the blue shark based in the temperate region of the north-eastern Atlantic. The spatial segregation showed by the blue sharks catches in Mexican waters followed roughly the movement model proposed BY Nakano in 1994. This author suggested that the pupping grounds in the Central Pacific are located between 35° N – 45° N, thought our data indicated juveniles can be distributed further south reaching the 23° N along the west coast of the PBC. Sosa-Nishizaki *et al.* (2002) reported for blue shark caught as by catch in the swordfish fishery a size range of 69 – 250 cm TL but with a notorious mode of 100-109 cm TL, which corresponded to juvenile and immature individuals, smaller to those reported in the present study (males 136.8 ± 0.3 cm FL and females 130.5 ± 0.3 cm FL). Litvinov (2006) using the data of several survey cruises by the Soviet fishery and research vessels in oceanic waters during 1960-1980, observed juveniles aggregations of *P. glauca* distributed in northwestern Africa and other regions with range sizes between 70-116 cm TL, and 60-110 cm TL with almost equally sex ratio. Litvinov (2006) denominated those areas as "kindergartens" for blue sharks. This author also detected aggregations of adult males with similar size composition in oceanic waters as well as in coastal waters which called "males clubs" particularly located near seamounts. The author considered the function or role of those aggregations of blue shark males oriented to the mating. Litvinov (2006) accordingly to the reported by other authors about the presence of small sized blue sharks along the west coast of Mexico, assumed the presence of "kindergartens" in the entire coastal region of the country. Vögler *et al*. (2012) analyzed blue shark catches obtained from two different fishing grounds, the oceanic (1994-1996 and 2000-2002) and coastal-oceanic waters (2003-2009) of the eastern tropical Pacific off Mexico. The blue shark catch size structure data from oceanic waters was dominated by juveniles (63.9%) (n= 2,552) between 2000 and 2002 whereas in coastal waters during the seven years blue shark catches were dominated by adults (n=1,025, 64.9%). The size class 188-202 cm TL was the most representative (males). In their study on the reproductive biology of the blue shark in the west coast of BCS, Carrera-Fernández *et al*. (2010) sampled 1,033 sharks from the coastal artisanal shark fishery, which 41.8% were juvenile males (80 -203 cm TL). The most abundant size class observed in that study was 131-140 cm TL, which correspond to juveniles as well. Thus, the size structure data reported by these authors coincide in general terms with the size data presented in the present study. Sippel *et al.* (2016) conducted a first analysis to understand the stock structure and fleet dynamics using blue shark spatially explicit size and sex data reported by several fleets along the North Pacific Ocean (NPO), including information from the blue shark fished and measured on board the Ensenada longline fleet from 2006-2014. They found that equal female/male proportions of blue sharks in the Central Pacific Ocean (CPO) in Q1, Q2 and Q4 combined with the mean size of both sexes in the NPO being at or above the 50% maturity could be consistent with the mating grounds proposed by Nakano (1994). Also the observations of small individuals through all seasons in the northern Western Pacific Ocean (WPO) and EPO are consistent with parturition. The mean size was smaller in the EPO (~100 cm PCL) than in the northern WPO (~145 cm PCL). The data examined in the present working paper corroborated the results of Sippel *et al.* (2016) in relation with the high proportions of juveniles of both sexes in north EPO and with the presence of larger sharks (mature) during three quarters in CPO. Larger groups of mature males were observed in the catches in the central Mexican Pacific.

The west coast of the PBC (Baja California and Baja California Sur states) is highly influenced by the oceanographic conditions of the California Current, which is considerated as one of the most productive ecosystems in the world (Durazo *et al*. 2010). Hot spots of high biological productivity as Sebastian Vizcaino Bay and the Gulf of Ulloa characterized by the presence of intense seasonally upwellings (Martinez-Fuentes *et al*., 2016; González-Rodríguez et al., 2012) could represented ideal nursery and fast growth areas for blue sharks. According to Vögler *et al*. (2012) the horizontal distribution of blue sharks in the Eastern Tropical Pacific exhibited latitudinal changes that were coupled to the forward and backward movement of subarctic waters, and also with the forward and backward displacements of subtropical waters and tropical waters. The quarterly analysis of the length and sex data of the present study did not show a clearly migration pattern in the blue sharks caught and reported by the observers, but in general the results of the present study coincide with the observations and suggestions of Litvinov (2006) and Vögler *et al*. (2012) on the presence of juveniles aggregations of both sexes in coastal waters (in front of the PBC) and the presence of adult males groups towards oceanic waters. The larger sample size of this study confirmed the year-round presence of those immature and juvenile blue sharks along the PBC. Carvalho *et al.* (2011) in their study on the spatial predictions of blue sharks catch rate and catch probability of juveniles in the southwest Atlantic found that the proportion of juvenile sharks has a positively association with higher latitude, particularly south of 30° S. So the evidence from various sources suggested that blue shark juveniles of both sexes dominate the cooler and highly productive waters of the eastern Pacific.

Eighteen hundred seventy four gravid female blue sharks were caught and documented by observers on board the Ensenada and Mazatlan industrial longline fleets. The general area where those females were fished was between 15° N - 32° N and 106° W – 122° W, which corresponded roughly to the latitude range of the mating grounds proposed by Nakano (1994) in the central North Pacific. Two studies on the blue shark reproductive biology in the west coast of Mexico have been published. The first was conducted by Carrera-Fernández *et al*. (2010) during the period August 2000 – March 2003, and recorded 1,033 sharks landed by the artisanal commercial fishery in the west coast of BCS from which 101 females were identified as mature. They examined 37 gravid females, being the smallest pregnant female of 172 cm TL. Size at maturity was calculated at 196 cm TL. Gravid females were caught apparently year-round although the authors did not provide data spatially explicit of those females the coastal fishery grounds of the small artisanal boats are relative near of the "hot spot" area of blue shark gravid females detected in the present work. During April 2006 and April 2007, Cruz-Ramírez *et al.* (2012) sampled on board of the semi-industrial longline fleet of Manzanillo, in central Mexican Pacific, in coast front Colima, 36 blue shark pregnant females, which ranged 175-274 cm TL. They observed gravid females in May-August. Vögler *et al*. (2012) confirmed the annually presence of pregnant females in the commercial catches within western coastal waters off PBC (22.0° N – 28° N, 111° W – 116° W) and off Colima (16° N – 20°N, 104°W – 107° W). The data provided by the POT indicated that mating occurred in along the northern and central Mexican Pacific coast, but the high aggregation of gravid females at the southern zone of the PBC (21° N – 24° N and 113° W – 114° W) coincide with an area historically characterized as an exceptionally persistent in high concentration of temperature fronts in Mexico's Pacific EEZ (Etnoyer *et al*. 2004).

Blue sharks has a complex and extended migratory pattern around its cosmopolite worldwide spatial distribution, and in the west coast of Mexican Pacific it is not the exception. This work is the first approximation to understand the dynamics and structure of *P. glauca* observed in the catches of the Mexican industrial longline fleets.

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Table 1. Number of commercial fishery trips and sets observed by the Mexican shark observer program that operated onboard of the longline industrial fleets during 2006-2016, along the northern and central Mexican Pacific coast.

Year	No. Trips	No. Sets	No. Trips Obser	No. Sets Obser	% Sets Obser
2006	462	6316	46	326	5.2
2007	191	2138	88	885	41.4
2008	445	6086	72	706	11.6
2009	271	3034	37	447	14.7
2010	401	5356	51	884	16.5
2011	428	5815	30	480	8.3
2012	419	5665	5	99	1.7
2013	422	5784	21	342	5.9
2014	444	5936	34	574	9.7
2015	535	7196	24	314	4.4
2016	425	5433	11	38	0.7

Table 2. Number of commercial fishery trips and sets observed by the Mexican shark observer program that operate onboard of the longline industrial fleets during 2006-2016, along the northern and central Pacific coast.

Año	Ensenada Fleet			Mazatlan Fleet		
	Total No. Sets	Total No. Sets blue shark	% Sets Blue shark	Total No. Sets	Total No. Sets blue shark	% Sets Blue shark
2006	116	112	96.6	215	183	85.1
2007	474	463	97.7	569	530	93.1
2008	319	297	93.1	454	439	96.7
2009	124	113	91.1	333	320	96.1
2010	149	146	98.0	749	695	92.8
2011	128	125	97.7	414	364	87.9
2012	34	34	100.0	65	65	100.0
2013	181	178	98.3	212	196	92.5
2014	276	270	97.8	302	267	88.4
2015	243	234	96.3	74	66	89.2

Table 3. Means quarterly estimated of the size of the blue sharks caught and measured in both longline industrial fleets which operated along the north and central Mexican Pacific during 2006-2015, from data reported by observers (POT).

	North zone			South zone		
Combined sexes	Mean	SD	n	Mean	SD	n
Quarter 1	132.5	33.6	7369	161.6	22.4	14111
Quarter 2	130.8	40.3	5788	166.7	23.4	14815
Quarter 3	140.5	39.0	3450	164.9	24.0	6413
Quarter 4	134.9	30.6	8037	165.8	23.5	11820
Males						
Quarter 1	135.3	33.6	3304	160.5	21.5	11469
Quarter 2	133.9	40.7	3678	166.1	21.6	11346
Quarter 3	145.2	37.4	2578	161.9	21.3	4900
Quarter 4	135.2	31.0	4162	162.9	22.4	9131
Females						
Quarter 1	130.2	33.5	4065	166.7	25.0	2642
Quarter 2	125.3	38.9	2110	168.7	28.2	3469
Quarter 3	126.5	40.1	872	174.8	29.0	1513
Quarter 4	134.7	30.1	3875	175.8	24.7	2689

Table 4. Values of the Akaike Information Criterion (AIC) for the GLM models tried (combined sexes, males and females).

Sex	Error distributions and (link functions)	df	AIC
Combined sexes	Gamma (inverse)	9	-41,015.09
	Gamma (log)	9	-33,717.27
	Poisson (log)	9	319,547.16
	Gaussian(identity)	9	681,724.62
Males	Gamma (inverse)	9	-36,068.52
	Gamma (log)	9	-31,289.16
	Poisson (log)	9	218,440.19
	Gaussian(identity)	9	474,013.46
Females	Gamma (inverse)	9	-6,836.719
	Gamma (log)	9	-4,819.287
	Poisson (log)	9	99,142.875
	Gaussian(identity)	9	205,656.40

Table 5. Analysis of Deviance (ANOVA) of GLM models for FL of combined sexes, males and females.

Sex	Terms	Df	Deviance	Resid. Df.	Resid. Dev.	F value	Pr (F)
Combined sexes	Null			71,802	3,321.524		
	Quarter	3	13.5314	71,799	3,307.993	122.86	0
	Zone	1	669.1521	71,798	2,638.841	18,226.96	0
	Quarter: Zone	3	10.8534	71,795	2,627.987	98.54	0
Males	Null			50,567	1,912.526		
	Quarter	3	5.5476	50,564	1,906.979	58.811	0
	Zone	1	300.1866	50,563	1,606.792	9,546.993	0
	Quarter: Zone	3	12.6564	50,560	1,594.136	134.173	0
Females	Null			21,234	1,388.350		
	Quarter	3	16.2065	21,231	1,372.144	114.296	0
	Zone	1	378.3833	21,230	993.760	8,005.655	0
	Quarter: Zone	3	3.7345	21,227	990.026	26.338	0

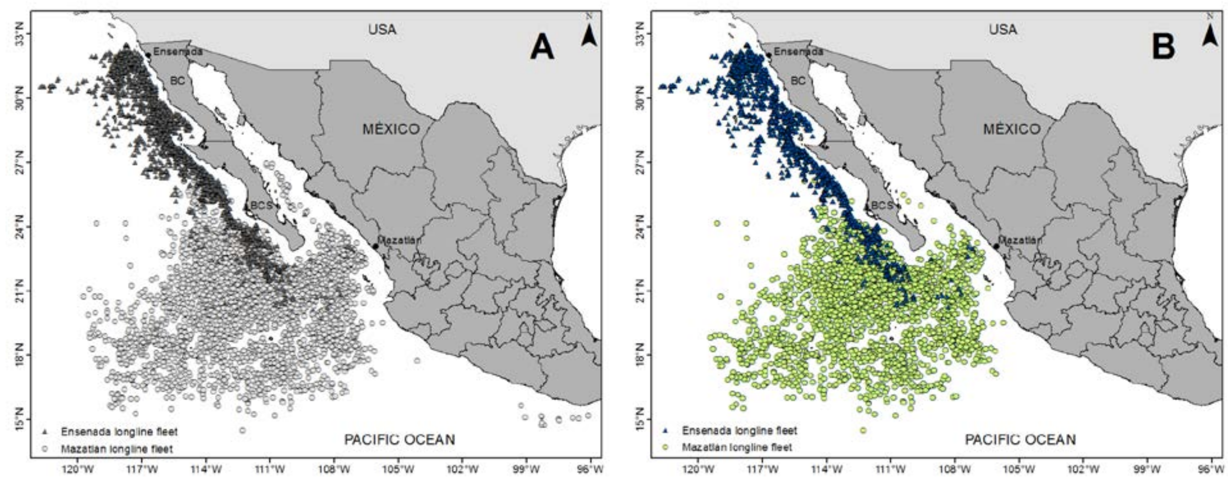

Figure 1. A) Fishing sets conducted by the industrial longline fleets in the Mexican Pacific registered by on board observers during 2006-2015; B) Sets with blue shark catches by fleet (Dark triangles representing Ensenada port-based fleet sets and green circles Mazatlan port-based fleet sets).

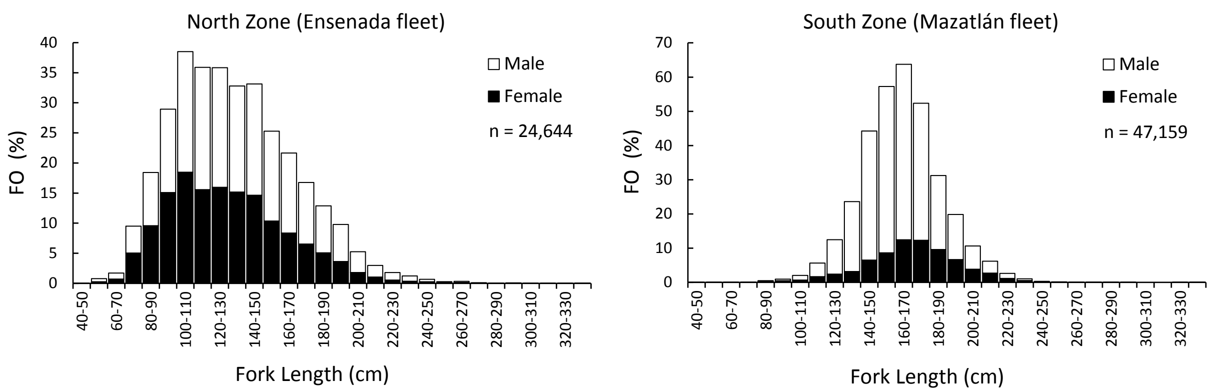

Figure 2. Sex-length frequency distributions of blue sharks caught in the Mexican Pacific; A) Ensenada, BC port-based fleet; B) Mazatlan, Sinaloa port-based fleet.

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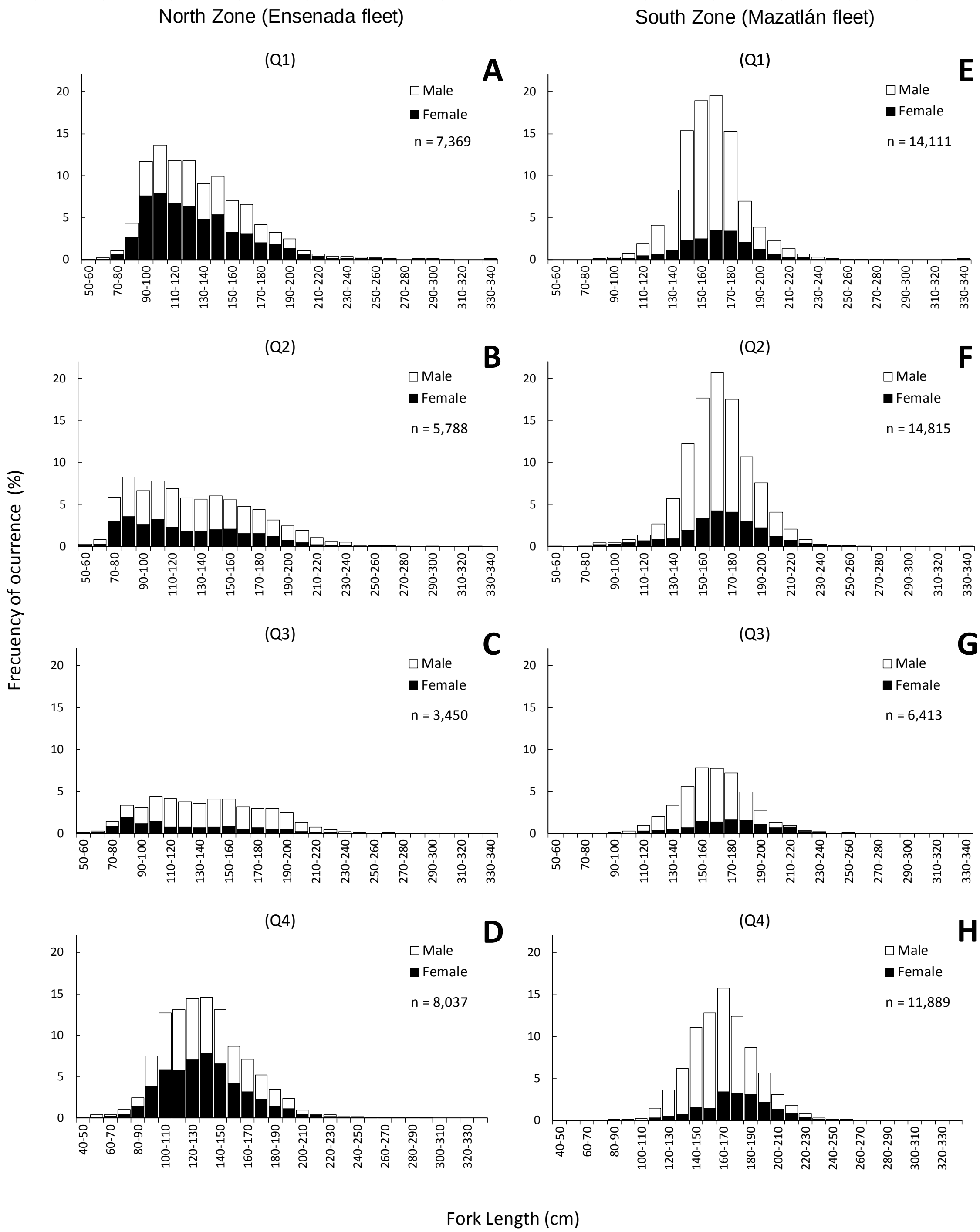

Figure 3. Sex-length frequency distribution of blue sharks caught during each quarter of 2006-2015 by the Ensenada port-based fleet in the north region (A-D) and the Mazatlan port-based fleet in the southern region (E-H).

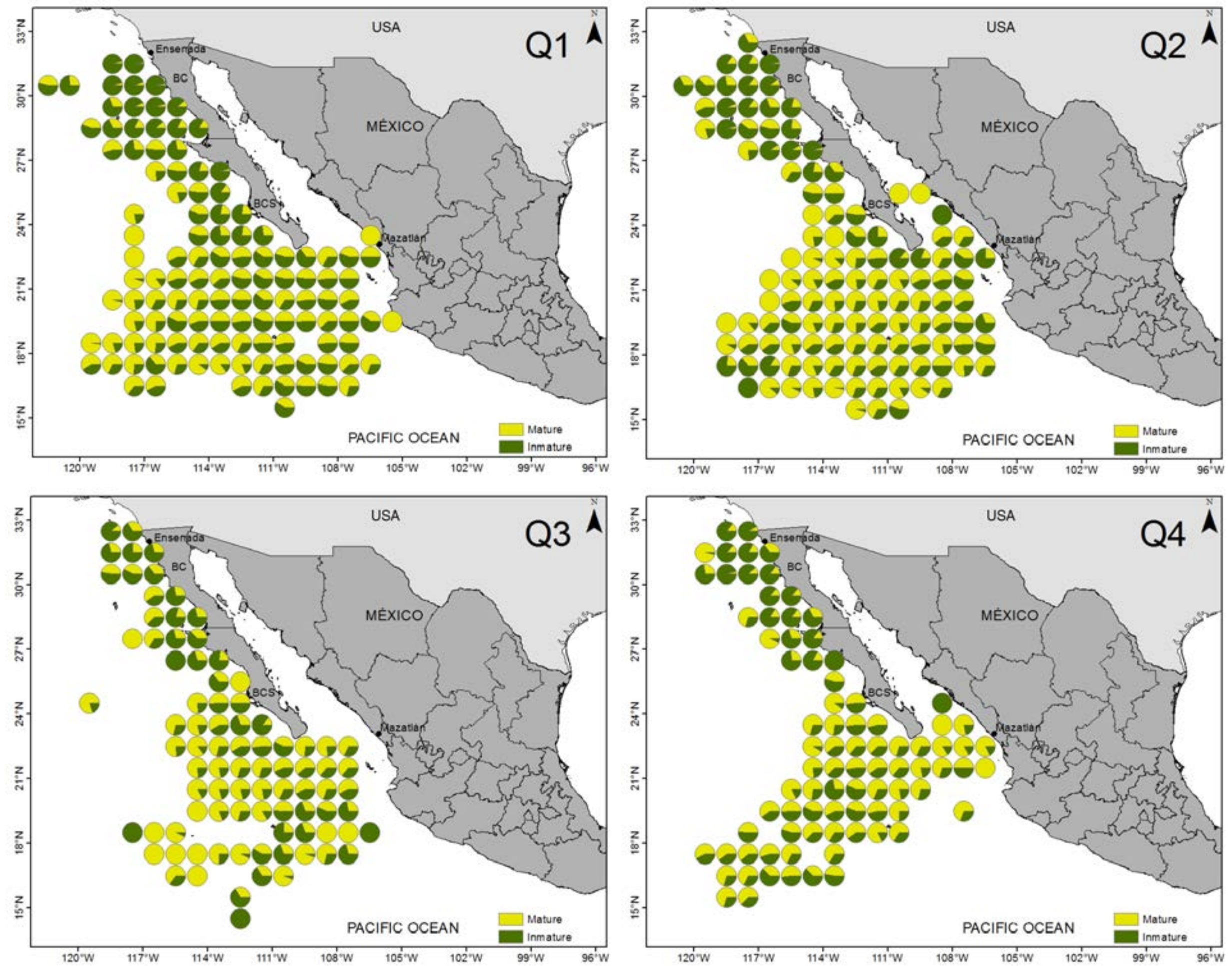

Figure 4. Blue shark quarterly mature and immature proportions (combined sexes) from north (Ensenada longline fleet) and south (Mazatlan longline fleet) fisheries regions (2006-2015).

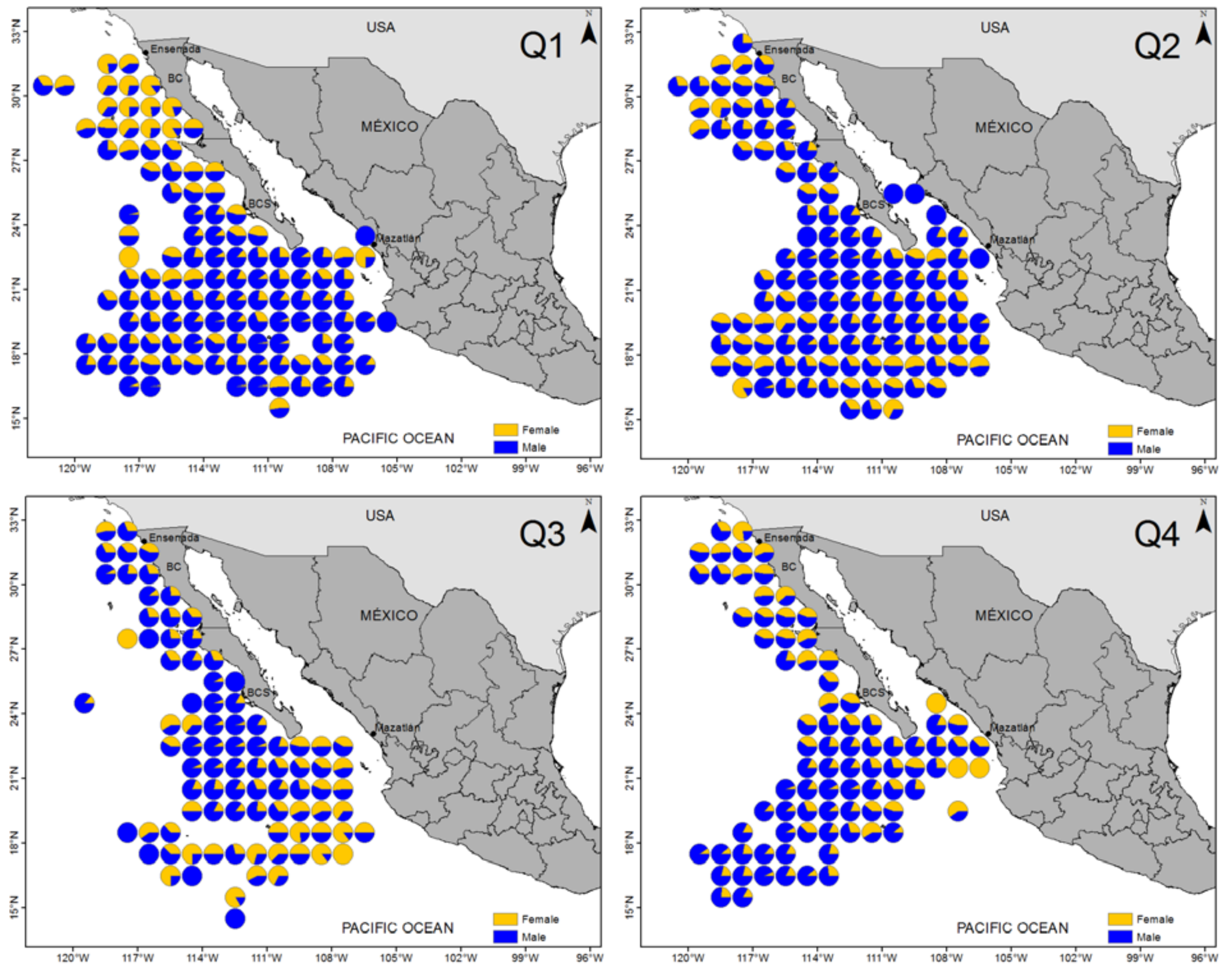

Figure 5. Blue shark quarterly males and females proportions from northern (Ensenada longline fleet) and southern (Mazatlan longline fleet) fisheries regions (2006-2015).

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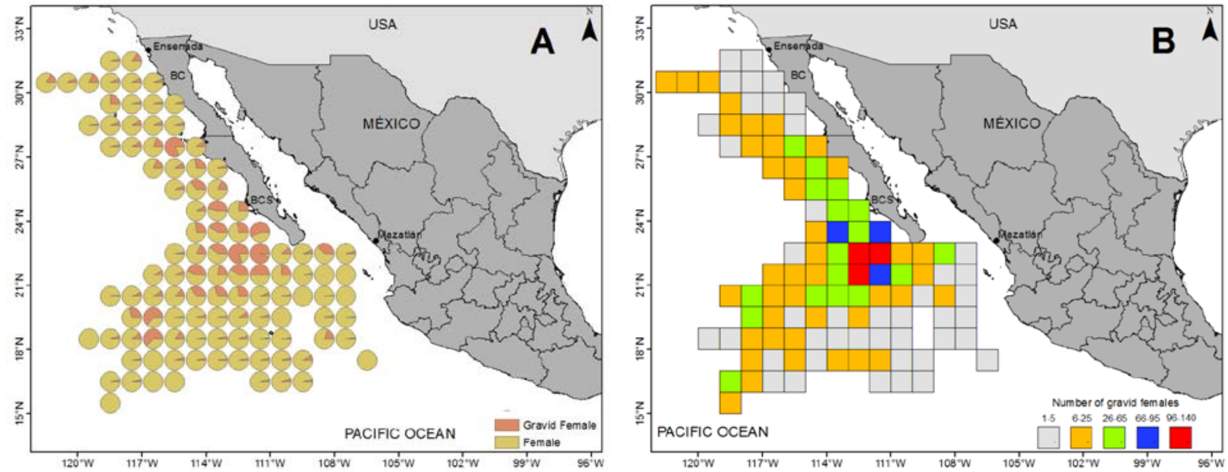

Figure 6. Spatial distribution of blue shark gravid females caught by the industrial longline fishery in the Mexican Pacific observed during 2006-2015. A) Proportion of gravid females and B) relative abundance of gravid females caught in the observed longline fishery operations.