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Update on standardized catch rates for blue shark (*Prionace glauca*) in the 2006-2020 Mexican Pacific longline fishery based upon a shark scientific observer program

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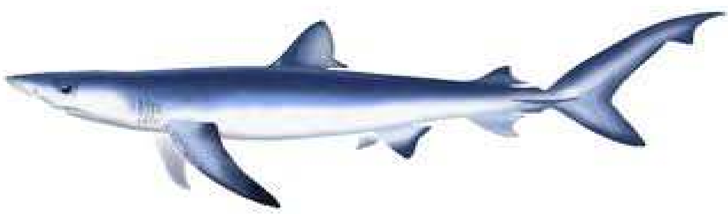

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SUMMARY

Abundance indices for blue shark (*Prionace glauca*) in the northwest Mexican Pacific for the period 2006-2020 were estimated using data obtained through a pelagic longline observer program. Individual longline set catch per unit effort data, collected by scientific observers, were analyzed to assess effects of environmental factors such as sea surface temperature, distance to the nearest point on the coast and time-area factors. Standardized catch rates were estimated by applying generalized linear models (GLM). Sea surface temperature, mean SST anomalies, distance to the coast, year, area fished, quarter and fraction of night hours in the fishing set were all significant factors included in the model. The results of this analysis show a relatively stable trend with a sharp descent in the last year of the time series in the standardized abundance index in the period considered. This trend could be explained in terms of recent oceanographic events and possible recent changes in fishing strategy of the fleets involved.

INTRODUCTION

The presence of more than 100 species of sharks in Mexican waters has allowed the historical development of commercial fisheries in both coastal and oceanic waters (Castillo-Géniz *et al.* 1998). The main Mexican shark fisheries are the coastal artisanal fishery (along the coasts of both Pacific and Gulf of Mexico coastlines) and the pelagic longline fisheries using medium size vessels in the northern Pacific region (Castillo-Géniz *et al*. 2008).

The Mexican average annual shark production (including small sharks, "cazones") from 1976 to 2018 was 25,784.16 t, which places Mexico as one of the top shark producer nations in the world according to Musick and Musick (2011). In 2018 the total domestic shark production reached 44,656 t, with a market value of more than six hundred million pesos. The average annual shark production in Mexican Pacific for 1976-2018 was 21,658 t. In 2018 the Pacific shark production reached 31,304 t which comprised 85.4% of the total Mexican shark production (CONAPESCA 2018).

Pelagic shark fisheries in the Mexican Northwest Pacific began in the mid 80's with the creation of an industrial fishing fleet. Stimulated by the successful driftnet fishery in California, in 1986 a small fleet of driftnet vessels appeared in northern Baja California, Mexico. This fishery was stimulated both by the reduction in longline permits and by the local abundance of swordfish and other marketable by-catch products, including several species of large pelagic sharks. These vessels were fiberglass or steel built, with an overall length of 18-25 m and a fish hold capacity of 50-70 t.

From twenty medium size vessels in 1990, the fleet expanded to 31 vessels in 1993 (Sosa-Nishizaki *et al.* 1993). This fleet targets sharks, swordfish, tuna, and other pelagic fish. Sosa-Nishizaki *et al.* (1993), Holts *et al*. (1998), Ulloa-Ramírez *et al.* (2000), and Sosa-Nishizaki *et al*. (2002) described in detail the origin and growth of swordfish and sharks fishery along the west coast of Baja California (BC).

During the first 20 years, this fleet used surface gillnets as its primary fishing gear. The Mexican Official Standard NOM-029-PESC-2006 banned driftnets in medium-size vessels (10-27 m length).

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By the end of 2009, all vessels switched to longlines and the operational dynamics of the fleet changed drastically. The main shark species caught were blue (*Prionace glauca*), short-fin mako (*Isurus oxyrinchus*) and thresher (*Alopias vulpinus*) sharks.

Among the studies conducted on shark fisheries in the West BC coast, included studies focused in blue shark catches and biology, are the works of Miranda-Vázquez (1996), Furlong-Estrada (2000), Reyes-González (2001) and Guerrero-Maldonado (2005).

Shark fisheries management

Shark fisheries in Mexican waters are managed mainly through three instruments: 1) The Mexican Official Standard NOM-029-PESC-2006. Shark and Ray Responsible Fisheries. Specifications for Their Exploitation; 2) The National Fisheries Chart (Carta Nacional Pesquera, CNP) and 3) The Shark and Ray Fishery Closure Agreements for both coastlines. The NOM-029 established numerous regulations for shark and ray fisheries in order to achieve sustainability, among them the establishment of specific fishing zones according to vessel characteristics, refuge zones, specifications for fishing gears, mandatory participation in the satellite vessel tracking program (Vessel Monitoring System, VMS), the banning of gillnets on medium size boats and the implementation of a scientific observer program on a voluntary basis.

The CNP includes the description and the current status of shark populations as well as their availability in Mexican waters. At present, all shark fisheries are considered to be fully exploited (Diario Oficial de la Federación, DOF 2010). Finally, the fisheries authority has established closed seasons for shark and ray fisheries in the Pacific and for sharks only in the Gulf of Mexico, with the aim of protecting the main reproductive season for most species (DOF 2012 and 2014). Those closed periods include shark by-catch in other fisheries. The closed season in the Mexican Pacific was established between May 1st and July 31st.

Blue shark Pacific catches

Corro-Espinosa (unpublished data) conducted an analysis of the commercial logbooks from the Mazatlan longline fleet for years 2009-2012. Corro-Espinosa documented a total catch of 182,482 sharks from 11 species, caught in 8,447 sets. Blue shark (*P. glauca*) 64.6%, thresher (*A. vulpinus)* 9.4%, bigeye thresher (*A. superciliosus*) 9.3%, pelagic thresher (*A. pelagicus*) 7.7% and shortfin mako (*I. oxyrinchus*) 1.7% were the most frequently caught pelagic sharks. Godinez-Padilla *et al*. (2016) examined the commercial logbooks of 683 fishery trips and 6,371 longline sets from the swordfish and shark fleet of Ensenada conducted during 2011-2015. The logbooks reported a capture of 642,052 sharks belonging to eighteen shark species, with blue (89.25%), mako (7.77%) and thresher (1.06%) sharks being the most abundant species.

The blue shark, *P. glauca,* is the most abundant shark species in pelagic longline catches in the Northwestern Mexican Pacific (Sosa-Nishizaki *et al*. 2008, Vögler *et al.* 2012, Godínez-Padilla *et al*. 2016). Sosa-Nishizaki (2011) estimated the Pacific total blue shark landings in 66,221 t for the years 1976-2011. The largest catches were reported by BC (43.4%), followed by Baja California Sur (BCS) with 30% and Sinaloa (10%).

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The Mexican National Aquaculture and Fisheries Commission (internal report) reported a total catch of blue shark of 59,658 t for the period 2006-2020 for the Mexican Pacific. BC accounted for 48.79% of the total catch, followed by BCS (21.34%) and Sinaloa (19.57%). In 2020 BC reported a total annual blue shark catch of 1,565 t, while BCS and Sinaloa reported 756 and 865 t, respectively. For the period 2006-2020, BC had an annual average of 1,940.5 ± 378 t, BCS 849 ± 388 t and Sinaloa 778.6 ± 377.5 t. The total annual catch of blue shark in Mexican Pacific showed a consistent growth until 2014, and from that year a downward trend (Figure 1). The commercial longline fishing sector in northwestern Mexico faced a severe decline in domestic demand for blue shark meat, forcing vessels to reduce the number of fishing trips made in 2020. The cancellation of the subsidy for the marine diesel for the fishing industry and the low cost of blue shark meat also influenced the decrease in fishing activity, which was reflected in low levels of blue shark production (Miguel Chaidez, representative of the Mexican National Chamber of the Fishing and Aquaculture Industry, pers. comm., October 2021).

The blue shark is caught all year long on the west coast of the Baja California Peninsula and in the central Pacific (off Colima and Nayarit states) (Guerrero-Maldonado 2005, Cartamil *et al*. 2011, Santana-Hernández and Valdez-Flores 2014). *P. glauca* individuals of a relatively young age (0-3 years) were reported in the catch of the shark fisheries in BC (Guerrero-Maldonado 2005).

In artisanal fisheries blue sharks are fully recruited at age 1, while in the offshore fishery, using medium size boats, individuals are recruited at the age of 2 and 3 years. In BCS artisanal fisheries, blue shark individuals were caught at relatively older ages (4 years and older on the west coast and 5 years and older on the east coast), compared to blue sharks fished in similar vessels landed at San Carlos, in Western BCS (0-7 years old). Guerrero-Maldonado (2005) also reviewed catches of blue shark landed by the Manzanillo longline fleet in Colima. This fleet caught *P. glauca* in areas off BCS at ages between one to six years old but this author reports that individuals were recruited to the fishery at age three in that region.

In the Ensenada longline fleet, female blue shark catches range 35-400 cm in total length (TL) with an average of 165.1 ± 0.3 cm TL (n = 14,822 females), while range in males is 40-400 cm TL with an average of 169.3 ± 0.3 cm TL (n = 20,857 males). The female blue shark catches from the Mazatlán fleet were comprised by individuals with a range of 30-400 cm TL and an average of 207.1 ± 0.3 cm TL (n = 13,064 females). Males showed a length interval of 50-400 cm TL with a mean of 195.5 ± 0.1 cm TL (n = 47,003 males). Apparently, both fleets catch immature individuals with a small proportion of adults (Figure 2).

Shark Observer Program (Programa de Observadores de Tiburón, POT)

The shark observer program (POT) began operations on several shark fishing fleets along the Northern West coast of Mexico in August 2006 (as established in the NOM-029-PESC-2006 official standard). Participation in the POT is voluntary so fishing trips with observer onboard are conducted according to the availability and willingness of fishing companies. The POT is one of the most important research tools in Mexico’s shark fisheries, providing data for monitoring the main shark species caught on the Mexican Pacific coast (Tovar-Ávila *et al.* 2011). Observers gather data

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during a fishing trip, including catches by set or haul, species composition and size and sex of a sample of individuals.

Detailed POT operating statistics for the period 2006-2014 have been described previously by Castillo-Géniz *et al.* 2014 (ISC/14/SHARWG-3/02). Figure 3 shows the fishing effort recorded for different shark fishing fleets that operated during 2006-2020. Currently, the POT continues operating on board of the longline fleets of Ensenada (BC) and Mazatlán (Sinaloa), which represent the largest pelagic longline fishing effort in the northwest Mexican Pacific.

Catch rate standardization

Stock assessments may involve the use of several indices of stock abundance derived from commercial fisheries data, observer data from fisheries, and scientific surveys (McDonald *et al.* 2001). The primary indices of abundance for many of the world's valuable and vulnerable species are based on catch and effort. These indices, however, should be used with care because changes over space and time in catch rates can occur because of factors other than real changes in abundance (Gavaris 1980, Walters 2003, Maunder and Punt 2004, Campbell 2015). Nominal catch rates obtained from fishery statistics or observer programs require standardization to correct for the effect of factors not related to regional fish abundance but assumed to affect fish availability and vulnerability, usually by using statistical regression methods (Bigelow *et al.* 1999, Ortiz and Arocha 2004).

Generalized Linear Models (GLM, Nelder and Wedderburn 1972, McCullagh and Nelder 1989) are the most common method for standardizing catch and effort data and their use has become standard practice because this approach allows identification of the factors that influence catch rates and calculation of standardized abundance indices, through the estimation of the year effect (Goñi *et al*. 1999, Maunder and Punt 2004, Brodziak and Walsh 2013). GLMs are defined mainly by the statistical distribution for the response variable (in this case, catch rate) and the relationship of a linear combination of a set of explanatory variables with the expected value of the response variable. Its use is based upon the assumption that the relationship between a function of the expected value of the response variable and the explanatory variables is linear. A variety of error distributions of catch rate data have been assumed in GLM analyses (Lo *et al.* 1992, Bigelow *et al.* 1999, Punt *et al.* 2000, Goñi *et al.* 2004, Maunder and Punt 2004).

MATERIAL AND METHODS

As commented above, driftnet operations were banned in 2009, while longline fishing has prevailed through the years of operation of the scientific observer program. This study is focused on the longline component of the shark fishery with medium size vessels in the northwest region of the Mexican Pacific from June 2006 to December 2020.

Data were subjected to a preliminary analysis, looking for missing values, incomplete information and inconsistencies. Original data contained fishing sets from within the Gulf of California and in the southeastern Mexican Pacific, where no blue sharks were caught in the years contained in the time series. Data from these zones were excluded from the analysis. An exploratory analysis, looking for extreme and highly influential values using leverage and Cook's distance (Zuur *et al.*

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2009) criteria was performed. In this way, from an initial total of 7,153 longline sets, 6,408 sets were retained to be used in the analysis. The proportion of zero-catch sets was around 4.8%, and the probability of obtaining a positive catch being close to 1 (0.95). For this reason, it was not considered necessary to use a Delta model in this analysis, modeling separately the probability of obtaining a positive catch and the catch rate, given that the catch is non-zero, using a standard distribution defined for positive values (Pennington 1983, as proposed by Lo *et al.* 1992).

After an initial exploratory analysis, factors which were considered as having a possible influence on the RESPONSE variable, catch rate (CTCHRATE), were selected to be included in a "maximum model" for the analyses.

The factors selected for inclusion in the analysis were the following: Mean Sea Surface Temperature (MEANTEMP as a three level factor, H, M and L for "high", "medium" and "low"), calculated for each set as the average of temperature data measured *in situ*, at the beginning and the end of both gear setting and retrieval. MEANTEMP levels were defined as L<=21°C, 21<M<=25, and H>25°C, on the basis of the mean sea surface temperature in all validated sets.

Mean Sea Surface Temperature Anomaly (MEANSSTANOM) was defined as a three level factor, MSSTANL (<=-1), MSSTANM (>-1,<+1), MSSTANH (>=+1) for "low", medium and "high" mean SST anomaly. Data on this factor were obtained from the Multi-scale Ultra-high Resolution (MUR) SST Analysis Anomaly fv04.1, Global, 0.01°, 2002-present, Daily, Lon0360 data base, available in the ERDDAP data server:
(https://coastwatch.pfeg.noaa.gov/erddap/griddap/jplMURSST41anom1day_Lon0360.html)
using the rerddapXtracto R package (Mendelssohn 2021).

The proportion of night hours in the fishing set for sets being carried out mostly in daylight or at night (PNH, a two level factor, "DAY" < 0.5 and "NIGHT" >=0.5) was calculated using the data from each fishing set and calculating the time of dawn and sunset for the corresponding dates and coordinates, using the suncalc R package (Thieurmel and Achraf 2019).

Fraction of the Moon Illuminated (MP, a three level factor, "NEW"<0.3, "PART">=0.3 <=0.7, and "FULL" >0.7), were obtained for the dates of the fishing sets from the Naval Oceanography Portal (https://www.usno.navy.mil/USNO/astronomical-applications/astronomical-information-center/phases-percent-m).

Distance to the nearest coastline, including islands, (DIST as a two level factor, N for "near" for distances less than 200 km and F for "far" from the coast for distances above that number), was calculated using the raster R package (Hijmans 2019).

Time-area factors such as YEAR, QUARTER and fishing area were included. Three fishing areas (LATF) were defined, NORTH above the 25° parallel, CENTRAL between 21° and 25° of latitude and SOUTH below 21° (Figure 4).

The levels of the above mentioned factors were selected matching approximately the inflexion points of a LOESS smoother on a scatterplot of catch rate against the values of the corresponding

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variable. The fishing areas were defined based on that LOESS – scatterplot procedure and on observed fleet operations patterns.

Catch rates were modeled as a function of these factors and several two-way interactions, LATF:PNH, PNH:MP, MEANSSTANOM:MEANTEMP, LATF:DIST, QUARTER:DIST.

Although we are conscious that inter annual variations in spatial or temporal patterns could occur (*v. gr.* the species and/or effort distribution, seasonal changes in temperature or other factors among years), we preferred not including interactions involving the factor YEAR at this stage of the analysis with fixed effects models. Including interactions involving the factor YEAR, as well as treating it as a random factor by using Generalized Linear Mixed Effects Models (GLMM) as suggested by Maunder and Punt (2004) and Campbell (2015), could be considered at later stages of the analysis.

The formula of the maximum (initial) model was:

CTCHRATE~YEAR+QUARTER+LATF+DIST+MEANTEMP+MEANSSTANOM+PNH+MP+QUARTER:DIST+LATF:DIST+MEANTEMP:MEANSSTANOM+PNH:MP+LATF:PNH

Two error structures were considered: Poisson (with log and inverse link functions) and negative binomial. The model that best described the data was selected using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Burnham and Anderson 2002), followed by an analysis of residuals for validation purposes.

The significance of the included variables and interactions was assessed through tests of hypothesis, using one-term deletion tests in order to prevent the potential effects of collinearities, as described by Crawley (2007) The effect of the term was determined to be significant at least at the alpha = 0.05 level based on an F test. The K-fold Cross Validation procedure (James *et al.* 2021) was used as an additional criterion of model simplification using the boot R package (Canty and Ripley 2020).

The estimated marginal means and their standard errors for the YEAR factor (the standardized abundance indices) were obtained by using the emmeans routine contained in the emmeans R package (Lenth 2021).

RESULTS AND DISCUSSION

Table 1 shows the values of the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) for the maximum models tried. Table 2 shows the results of the model simplification process. Based on the AIC and BIC, the model with the Negative Binomial error distribution and the log link was selected for simplification with one-term deletion and Cross Validation tests. The final ("minimum adequate") model was:

CTCHRATE ~ YEAR + QUARTER + LATF + DIST + MEANTEMP + MEANSSTANOM + PNH + QUARTER:DIST + LATF:DIST + MEANTEMP:MEANSSTANOM + LATF:PNH

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The results of estimated marginal means procedure, the standardized abundance indices for the blue shark (2006-2020) from the model are shown in Table 3. The re-scaled values of the estimated indices are shown in table 4. Figure 5 show the estimated values of the relative index and their 95% confidence intervals, together with the nominal catch rates for years 2006-2020.

Figure 6 shows the residuals of the Negative Binomial GLM as well as the marginal-model plots for each factor. The residuals for the Negative Binomial GLM are close to normal. Diagnostic plots showed good agreement with model assumptions and there were no clear systematic patterns in the residuals.

Figure 7 shows the effects graphs for the terms included in the final model.

Spatial-temporal heterogeneity in the marine environment is believed to greatly affect the biology, dynamics, and availability of fish stocks, as well as their vulnerability to fishing gear, thus introducing a source of variability in nominal catch rates (Bigelow *et al.* 1999). Sea surface temperature is one of the most important physical factors because it modifies the geographical and vertical aggregation patterns of fishes, through its effect on feeding, reproductive and migratory behavior, and body thermoregulation (Fonteneau 1998). The blue shark is highly migratory, with complex movement patterns related to water temperature, reproduction, and the distribution of prey (Nakano 1994, Nakano and Seki 2003, Stevens 2010).

The results of this analysis show a relatively low dispersion (cv = 0.23) and stable trend of the standardized abundance indices from 2006 to 2020, with somehow lower levels after 2014 and a noticeable reduction in the latter year (Figure 5).

It should be noted that the period after that year registered the occurrence of two unusual and consecutive warming events known as The Blob (TB2013–2015) and the 2015–2016 El Niño (Jiménez-Quiroz *et al*. 2019). The observed decrease in CPUE in the years after 2014 could be caused by the blue shark leaving the area included in this analysis or moving to deeper waters, rather than by an actual decrease in local abundance. It is suggested to compare the results of this analysis with those performed on the contiguous colder zone off California.

Adams *et al.* (2016) report lower blue shark CPUEs at positive values of the MEI off the coast of Peru. Cavole *et al.* (2016) comment that research surveys during the summer of 2015 reported unusual sightings of blue shark in the Gulf of Alaska and that those reports suggested that tropical invertebrates such as tuna crabs were followed northward by their predators, tuna, which were in turn followed by their predators, sharks. According to Compagno (1984), in the tropics the blue shark shows submergence and occurs at greater depths there. In the tropical Indian Ocean the greatest abundance of blue sharks occurs at depths of 80 to 220 m, with temperatures about 12° to 25° C.

In our results, lower levels of CPUE seem to be related with high values of the Mean SST Anomalies (Figure 7), like those occurring in the study area in the last years. Birkmanis *et al*. (2020) predict shifts in suitable habitat for blue and mako sharks, related with higher SST anomalies in the Southern Hemisphere.

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Variability in nominal catch rates can also be related to other physical, chemical, and biological processes or factors in the ocean (e.g. water transparency, circulation patterns, frontal zones, salinity, plankton, nekton), which together with temperature define the identity, structure, and interaction of water masses and can affect the availability of potential prey and the capture efficiency of predatory fishes (Laurs *et al.* 1984, Bigelow *et al.* 1999).

Fishery-related factors like hook size and type, fishing depth or bait type were not included in this analysis, as data on these factors were not available in the data set we used but could be available in the observer data base. However, the inclusion in the model of the interaction of latitude with the fraction of night hours in the fishing set (LATF:PNH) was aimed at assessing the effect of an apparent shift to night sets in some specific areas where the participating fleets operate. This change in fishing strategy is apparently related to fishermen looking for species other than sharks, like swordfish (*Xiphias gladius*). Figure 8 shows a graph containing the fraction of fishing sets with zero catch of swordfish and blue shark by year in the available data set. A clear negative trend in the fraction of zero swordfish catch coincides with a rise in the one for blue shark. A shift in the target species, with the possible corresponding change in blue shark CPUE, could not be excluded at this time and should be attentively evaluated in future analysis.

The present study represents part of the initial stages of attempting to merge fishery and environmental information from the distribution range of the blue shark in the Mexican Pacific, estimate the best available relative abundance indices, and model recent trends in CPUE. Results may be improved by adding other predictor variables to the model, extending the time series, analyzing the data at lower spatial scales (particular areas and characteristics and operation of particular fleets) and taking into account the size-age structure and sex of the catches.

Variable transformation and use of generalized additive models (GAM) may also increase the explanatory power of the model, due to the likely nonlinearity of many of the functional relationships between catch rate and the predictor variables. As mentioned before, using Generalized Linear Mixed Effects Models (GLMM) could be considered at later stages of the analysis.

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Table 1. Values of the Akaike and Bayesian Information Criterions for the maximum models tried.

	df	**AIC**	**BIC**
Poisson (log link)	41	214,665.83	214,943.21
Negative binomial (log link)	42	56,827.28	57,111.43

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Table 2. p values and Cross Validation MSE obtained in the model simplification process (*covariate retained in the model).

Term	p (anova test)	Model	CV
LATF:PNH *	0.002867007	MNB	1985.905
		MNB2	1990.319
PNH:MP	0.3147707	MNB	1985.905
		MNB2	1983.174
MEANSSTANOM:MEANTEMP *	8.98E-06	MNB2	1983.174
		MNB3	1995.063
LATF:DIST *	2.62E-05	MNB2	1983.174
		MNB3	1986.711
QUARTER:DIST *	2.27E-10	MNB2	1983.174
		MNB3	2007.317
MP	0.01685487	MNB2	1983.174
		MNB3	1977.972
YEAR *	< 1.00 E-10	MNB3	1971.344
		MNB4	2025.018

Table 3. Standardized abundance indices (estimated marginal means for the YEAR factor) from the Negative Binomial model fit, their standard errors (se), coefficient of variation (cv) and lower and upper asymptotic 95% confidence intervals.

YEAR	Index	se	cv	L CI 95%	U CI 95%
2006	43.7	2.92	0.067	38.3	49.8
2007	35.5	1.54	0.043	32.6	38.6
2008	41.6	2.03	0.049	37.8	45.8
2009	32.8	1.87	0.057	29.3	36.7
2010	27.5	1.27	0.046	25.2	30.1
2011	24.9	1.38	0.055	22.4	27.8
2012	40.5	4.27	0.105	32.9	49.8
2013	42.4	2.57	0.061	37.6	47.7
2014	36.3	2.01	0.055	32.6	40.5
2015	25.8	1.77	0.069	22.6	29.5
2016	34.6	2.4	0.069	30.2	39.6
2017	24.5	1.48	0.060	21.8	27.6
2018	30	2.16	0.072	26	34.5
2019	36.5	2.68	0.073	31.6	42.1
2020	18.7	1.68	0.090	15.7	22.3

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Table 4. Re-scaled values of the estimated abundance indices for the Negative Binomial model and their 95% confidence intervals.

YEAR	Re-scaled abundance index	L CI 95%	U CI 95%
2006	1.323	1.149	1.496
2007	1.074	0.983	1.165
2008	1.261	1.140	1.381
2009	0.994	0.883	1.105
2010	0.834	0.758	0.910
2011	0.756	0.673	0.838
2012	1.225	0.972	1.479
2013	1.284	1.131	1.436
2014	1.100	0.981	1.219
2015	0.782	0.677	0.887
2016	1.047	0.904	1.190
2017	0.743	0.655	0.831
2018	0.908	0.780	1.036
2019	1.105	0.945	1.264
2020	0.566	0.466	0.666

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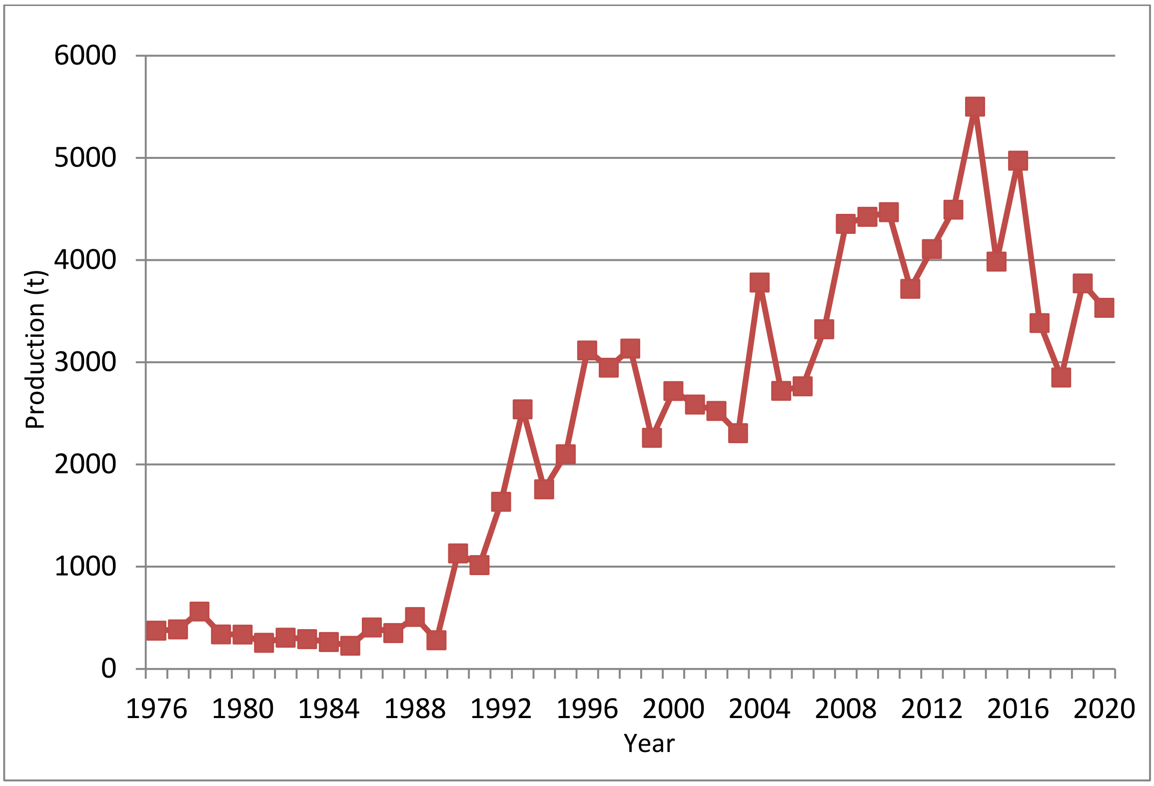

Figure 1. Total annual catch of blue shark from the Mexican Pacific, 1976-2020.

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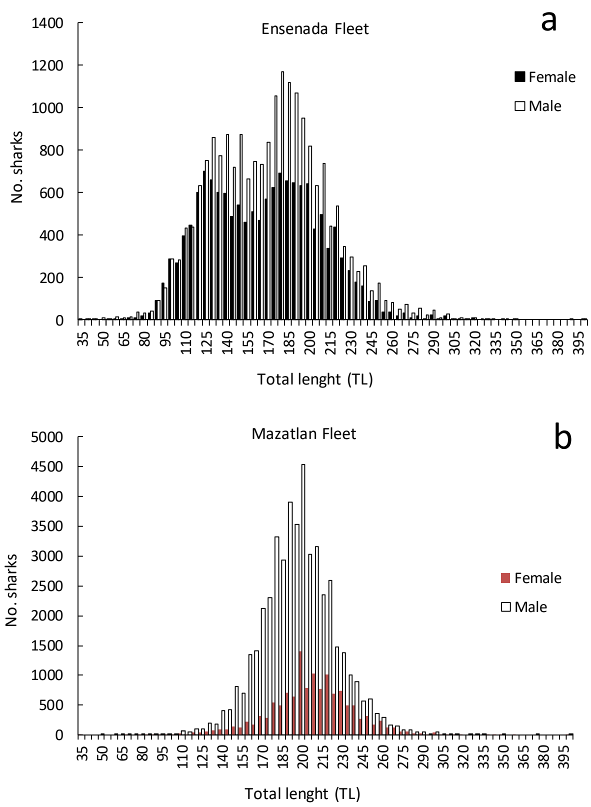

Figure 2. Size frequency structure of blue shark longline catches by sex and fleet in the northern Mexican Pacific in 2006-2014.

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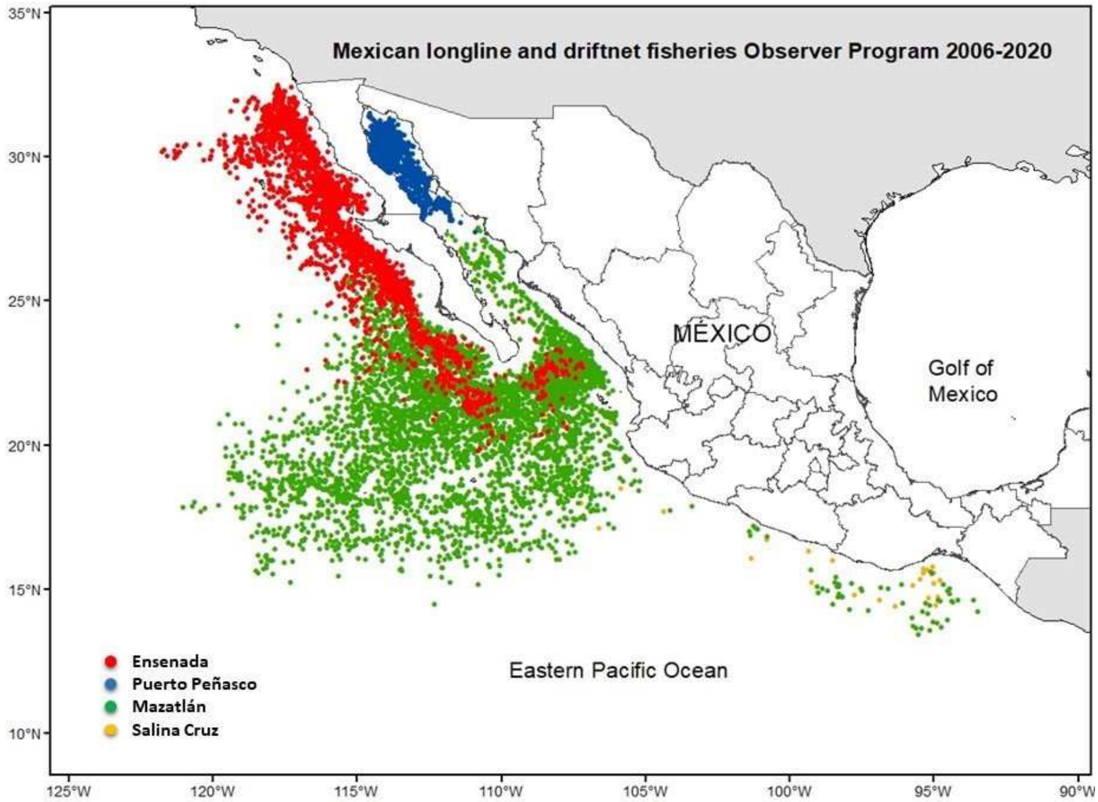

Figure 3. Observer effort in the different Mexican shark pelagic fisheries during 2006-2020.

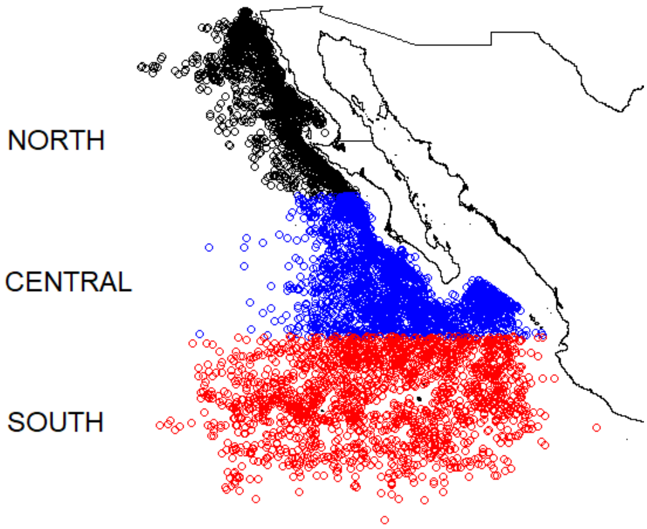

Figure 4. The zones used in the analyses (see text for details).

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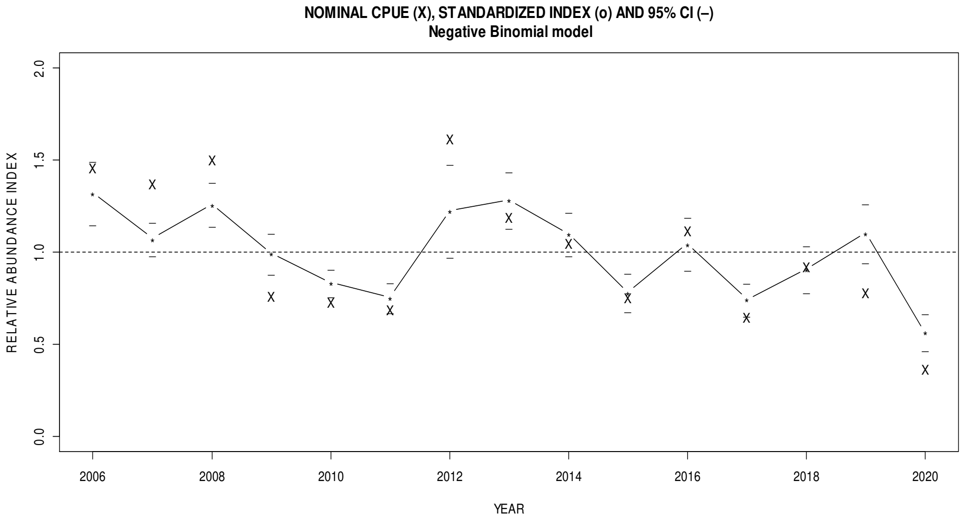

Figure 5. Relative abundance indices for the blue shark with approximate 95% confidence intervals. Negative Binomial model for years 2006-2020.

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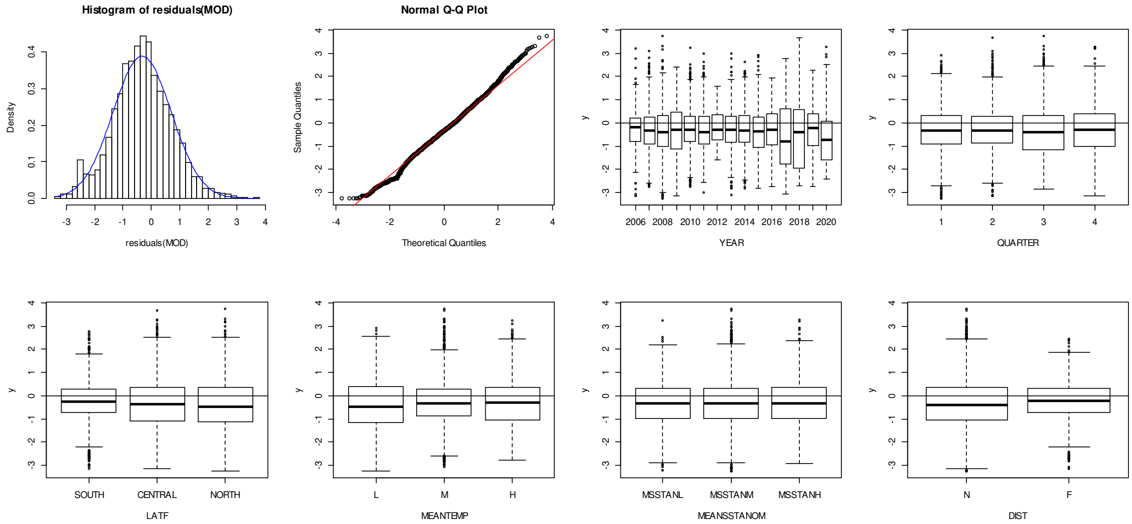

Figure 6. Residuals and Marginal-model plots of the Negative Binomial GLM.

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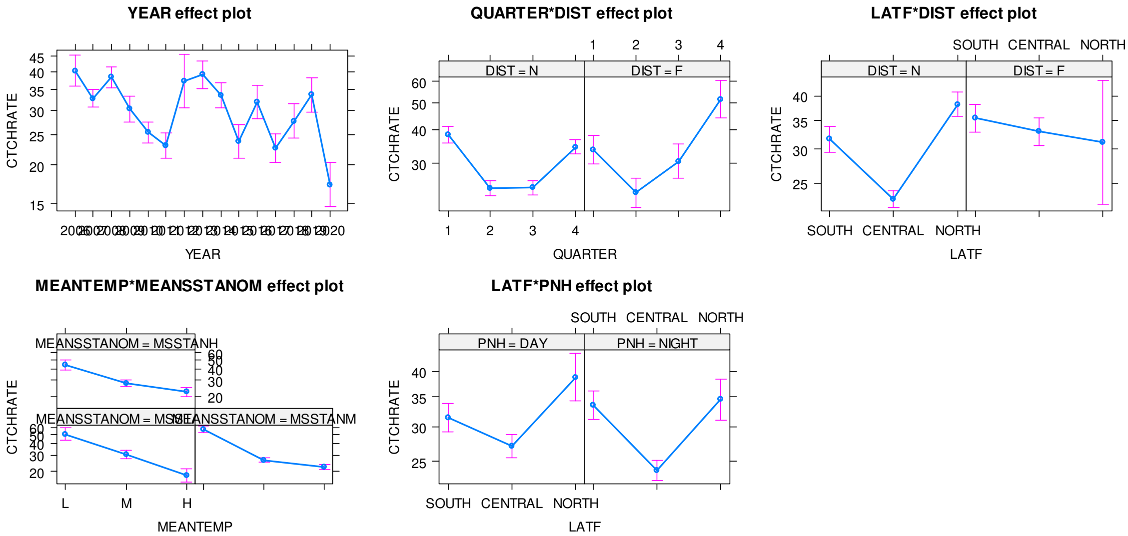

Figure 7. Effects plot for the terms included in the final model.

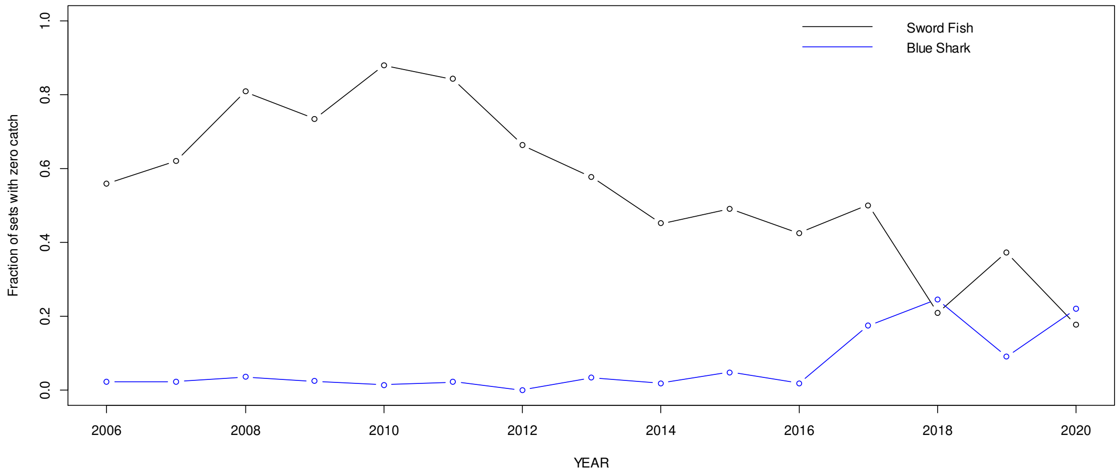

Figure 8. Fraction of fishing sets with zero catch of swordfish and blue shark by year in the available data set.

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