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Standardized catch rates for blue shark (*Prionace glauca*) in the 2006-2015 Mexican Pacific longline fishery based upon a shark scientific observer program[1]

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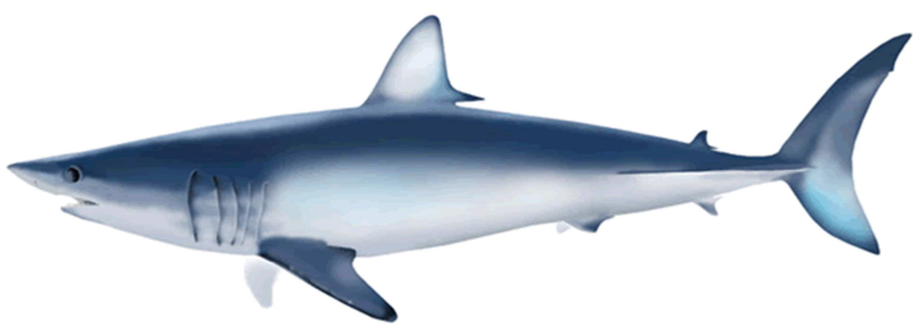

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SUMMARY

Abundance indices for blue shark (*Prionace glauca*) in the northwest Mexican Pacific for the period 2006-2015 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 continental coast and time-area factors. Standardized catch rates were estimated by applying generalized linear models (GLMs). Sea surface temperature, distance to the coast, year, area fished and quarter were all significant factors included in the model. The results of this analysis show a descending trend in the standardized abundance index in the period considered. This trend could be explained in terms of recent oceanographic events like the ENSO of 2014-2015.

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 2014 was 28,248 t, which places Mexico as one of the top shark producer nations in the world according to Musick and Musick (2011). In 2014 the total domestic shark production reached 29,436 t, (2.2% of the total national fisheries production), with a market value of more than three hundred million pesos. The average annual shark production in Mexican Pacific for 1976-2014 was 20,053 t. In 2014 the Pacific shark production reached 24,845 t which comprised 84% of the total Mexican shark production.

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-Ramirez *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). 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-Vazquez (1996), Furlong-Estrada (2000), Reyes-Gonzalez (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 (Federal Register, 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

Recently, 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 mako (*I. oxyrinchus*) 1.7% were the most frequently caught pelagic sharks. With a similar approach, Ortega-Salgado *et al.* (unpublished data) examined the commercial logbooks of 124 fishery trips and 1,404 longline sets from the swordfish and shark fleet of Ensenada conducted during 2001-2013. The logbooks reported a capture of 42,814 sharks belonging to six shark species, with blue (86.5%), mako (11.9%) and thresher (0.73%) 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). 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 BCS with 30% and Sinaloa (10%) (Sosa-Nishizaki 2011).

The Mexican National Aquaculture and Fisheries Commission (CONAPESCA 2015) reported a total catch of blue shark of 25,233 t for the period 2006-2013 for the Mexican Pacific. BC accounted for 44.1% of the total catch, followed by Baja California Sur (BCS, 30.4%) and Sinaloa (16.3%). In 2013 BC reported a total annual blue shark catch of 2,473 t, while BCS and Sinaloa reported 995 and 365 t, respectively. For the period 2006-2013, BC had an annual average of 1,389.5 ± 277 t, BCS 959.2 ± 134.2 t and Sinaloa 586.9 ± 59.5 t. The total annual catch of blue sharks in Mexican Pacific has shown a consistent growth in recent years (Figure 1).

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-Hernandez 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 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 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 2006-2014. 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 2015.

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 (above 24° N) and in the southeastern Mexican Pacific, where no blue sharks were caught in the ten 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.* 2009) criteria was performed. In this way, from an initial total of 5,547 longline sets, 3,942 sets were retained to be used in the analysis. The proportion of zero-catch sets was around 4%, and the probability of obtaining a positive catch being close to 1 (0.96). 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, like mean sea surface temperature (TF as a two level factor, H and L for "high" and "low"), distance to the nearest continental coastline (DF as a two level factor, N for "near" and F for "far" from the coast), and time-area factors such as YEAR, QUARTER and fishing area (ZF, with two levels, Zone1 and Zone2).

Distance (in km) to the nearest point in the continental coast was calculated for the starting point of each fishing set using the raster package in R (Hijmans 2016). Mean sea surface temperature was 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. Mean temperature (TF) levels were defined as L<=20°C and H>20°C, on the basis of the mean sea surface temperature in which all validated sets were performed, and matching approximately the inflexion point of a LOESS smoother on a scatterplot of catch rate against temperature. Two fishing areas were defined, one (Zone1) to the west of the Baja California Peninsula, north of the 22.87° parallel (approximately its southernmost land point at the -110° meridian), and the other (Zone2) south and east from those lines, including the vestibule of the Gulf of California up to a latitude of 24° (Figure 4).

Catch rates were modeled as a function of these factors and several two-way interactions, using Generalized Linear Models in the R environment, version 3.3.0 (R Core Team 2016).

The formula of the maximum (initial) model was:

CTCHRATE~YEAR+QUARTER+TF+DF+ZF+QUARTER:TF+QUARTER:DF+QUARTER:ZF+TF:DF+DF:ZF

Three error structures were considered: Gamma (with log and inverse link functions), lognormal (with log(CTCHRATE) as the response variable) and negative binomial, using only the positive catch sets (96% of the total). The model that best described the data was selected using the Akaike Information Criterion (Burnham and Anderson 2002), followed by an analysis of residuals for validation purposes.

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 (GLMMs) as suggested by Maunder and Punt 2004 and Campbell 2015, could be considered at later stages of the analysis.

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 colinearities, as described by Crawley (2009). The effect of the term was determined to be significant at least at the alpha = 0.05 level based on an F test.

The marginal predicted means and their standard errors for the YEAR factor (the standardized abundance indices) were obtained by using the LSmeans routine contained in the doBy R package (Højsgaard and Halekoh, 2016).

RESULTS AND DISCUSSION

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

CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF + QUARTER:ZF + TF:DF

The results of the standardized relative abundance analyses for the blue shark (2006-2015) from the model are shown in Table 3. Figure 5 show the estimated values of the relative index and their 95% confidence intervals, together with the nominal catch rates for years 2006-2015.

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

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 (Stevens 2010).

The results of this analysis show a reduction of around 50% on the standardized abundance indices in a ten year period (Figure 5). Dulvy and Forrest (2010) quote research results that show a 30% decline in the catch per unit effort of blue shark over the previous 50 years in the North Atlantic, a far less drastic reduction. However, it should be noted that most of this decrease happens in the last two years of the series. The results of our analysis should be considered within the context of the biology of the species and recent oceanographic events in the area where the data used in this analysis originate.

In Figure 6, the standardized abundance indices are shown together with the Multivariate ENSO Index (MEI) from 2006 to 2015 (http://www.esrl.noaa.gov/psd/enso/mei/table.html). It is noticeable that in the last two years the highest values of the MEI coincide with the decrease of the blue shark standardized abundance indices. This decrease 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.

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. Other factors, like moon phase during the fishing set, that could be included in a more detailed analysis, were not considered at this stage due to time constraints.

The present study represents the first attempt 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, and taking into account the size-age structure and sex of the catches.

Variable transformation and use of generalized additive models (GAMs) 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 (GLMMs) could be considered at later stages of the analysis.

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Table 1.- Values of the Akaike Information Criterion for the maximum models tried.

	df	AIC
Gamma (log link)	28	8377.421
Gamma (inverse link)	28	8412.513
Negative binomial (log link)	28	8891.709
Lognormal (identity link)	28	15525.723

Table 2.-Deletion tests for the Gamma (link log) GLM model.

```
> MGLOG2 <- update(MGLOG, . ~ . -DF:ZF)
>
> anova(MGLOG,MGLOG2,test="F")
Analysis of Deviance Table

Model 1: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    QUARTER:ZF + TF:DF + DF:ZF
Model 2: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    QUARTER:ZF + TF:DF
  Resid. Df Resid. Dev Df Deviance      F Pr(>F)
1      3915     2157.4
2      3916     2158.4 -1  -1.0389 2.1209 0.1454
>
> #--------------------------------------
>
> MGLOG3 <- update(MGLOG2, . ~ . -TF:DF)
>
> anova(MGLOG2,MGLOG3,test="F")
Analysis of Deviance Table

Model 1: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    QUARTER:ZF + TF:DF
Model 2: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    QUARTER:ZF
  Resid. Df Resid. Dev Df Deviance      F    Pr(>F)
1      3916     2158.4
2      3917     2167.1 -1  -8.7131 17.794 2.517e-05 ***
>
> #--------------------------------------
>
> MGLOG3 <- update(MGLOG2, . ~ . -QUARTER:ZF)
>
> anova(MGLOG2,MGLOG3,test="F")
Analysis of Deviance Table

Model 1: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    QUARTER:ZF + TF:DF
Model 2: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    TF:DF
  Resid. Df Resid. Dev Df Deviance      F    Pr(>F)
1      3916     2158.4
2      3919     2171.7 -3  -13.321 9.0683 5.572e-06 ***
>
> #--------------------------------------
>
> MGLOG3 <- update(MGLOG2, . ~ . -QUARTER:DF)
>
> anova(MGLOG2,MGLOG3,test="F")
Analysis of Deviance Table

Model 1: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    QUARTER:ZF + TF:DF
Model 2: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:ZF +
    TF:DF
  Resid. Df Resid. Dev Df Deviance      F   Pr(>F)
1      3916     2158.4
2      3919     2165.2 -3  -6.7712 4.6095 0.003182 **
>
> #--------------------------------------
>
> MGLOG3 <- update(MGLOG2, . ~ . -QUARTER:TF)
>
> anova(MGLOG2,MGLOG3,test="F")
Analysis of Deviance Table

Model 1: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:TF + QUARTER:DF +
    QUARTER:ZF + TF:DF
Model 2: CTCHRATE ~ YEAR + QUARTER + TF + DF + ZF + QUARTER:DF + QUARTER:ZF +
    TF:DF
  Resid. Df Resid. Dev Df Deviance      F    Pr(>F)
1      3916     2158.4
2      3919     2172.9 -3  -14.473 9.8526 1.801e-06 ***
```

Table 3.- Standardized relative abundance indices (marginal predicted means for the YEAR factor) from the Gamma model fit.

YEAR	estimate	se	df	t.stat	p.value
2006	3.606712	0.2238804	3916	20.665847	3.86E-90
2007	3.42204	0.1683211	3916	25.011252	3.26E-128
2008	4.345794	0.2337917	3916	27.310107	1.79E-150
2009	3.200324	0.2262534	3916	16.454043	7.12E-59
2010	2.443151	0.141675	3916	15.404542	4.98E-52
2011	1.94669	0.1093551	3916	11.858148	6.82E-32
2012	2.381189	0.2495576	3916	8.278327	1.69E-16
2013	3.557693	0.2111149	3916	21.386993	4.53E-96
2014	2.416524	0.1401802	3916	15.210212	8.34E-51
2015	1.870345	0.1365152	3916	8.57828	1.37E-17

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

	Estimated index	**LCI***	**UCI***
2006	1.235578937	1.085253949	1.385903924
2007	1.172314436	1.059294863	1.285334009
2008	1.488771915	1.331791963	1.645751866
2009	1.096359489	0.944441145	1.248277833
2010	0.836968939	0.741840948	0.932096929
2011	0.666892494	0.593465771	0.740319217
2012	0.815742142	0.648176142	0.983308142
2013	1.218786123	1.077032558	1.360539687
2014	0.827847123	0.733722819	0.921971428
2015	0.640738403	0.549074971	0.732401835

*Approximate 95% lower and upper confidence intervals.

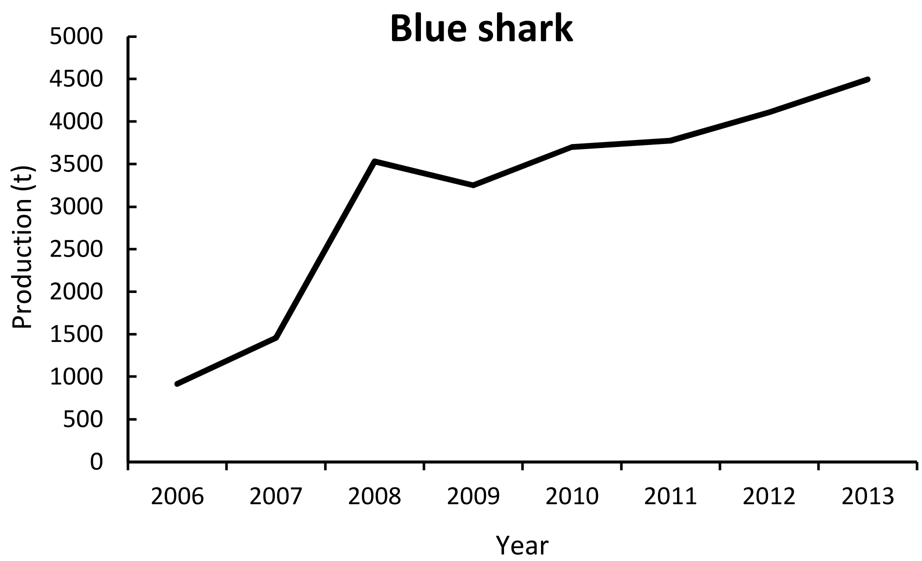

Figure 1. Total annual catch of blue shark from the Mexican Pacific, 2006-2013. Source: CONAPESCA Fisheries Statistics Database (see text).

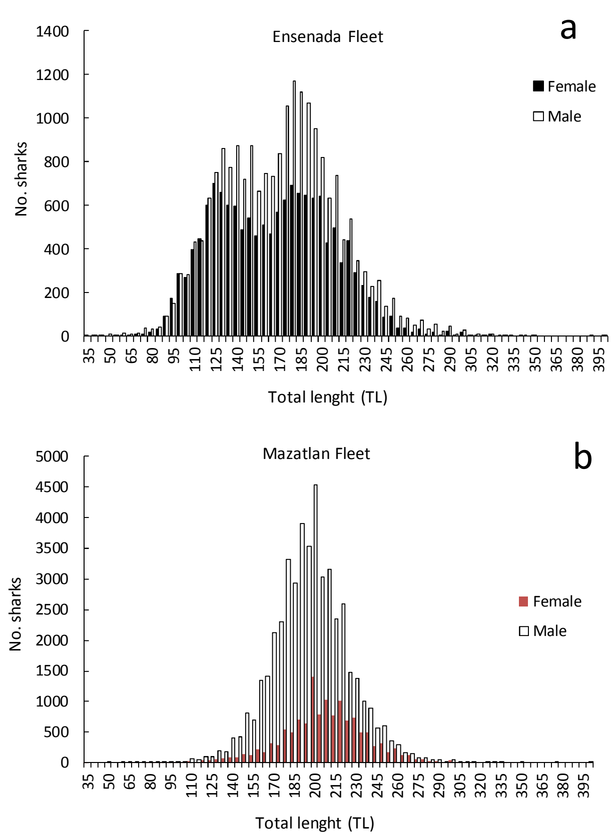

Figure 2. Size frequency structure of blue shark longline catches by sex and fleet in the northern Mexican Pacific in 2006-2014.

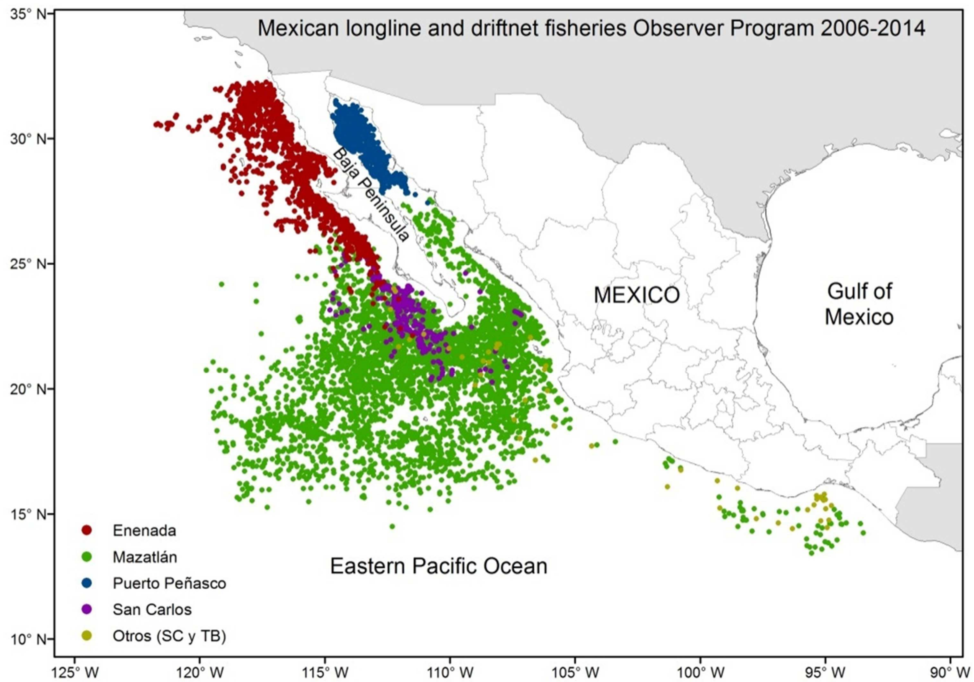

Figure 3. Observer effort in the different Mexican shark pelagic fisheries during 2006-2014.

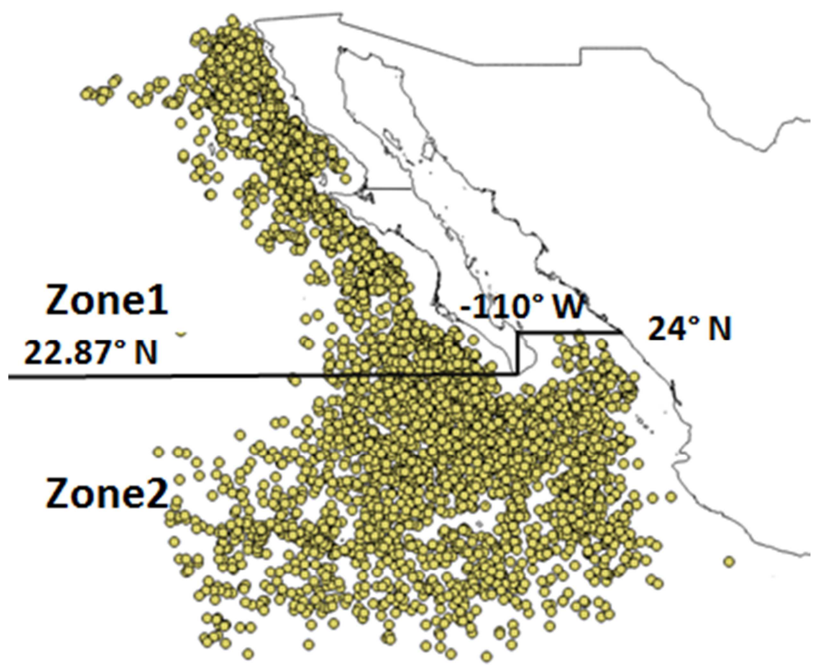

Figure 4.- The zones used in the analyses.

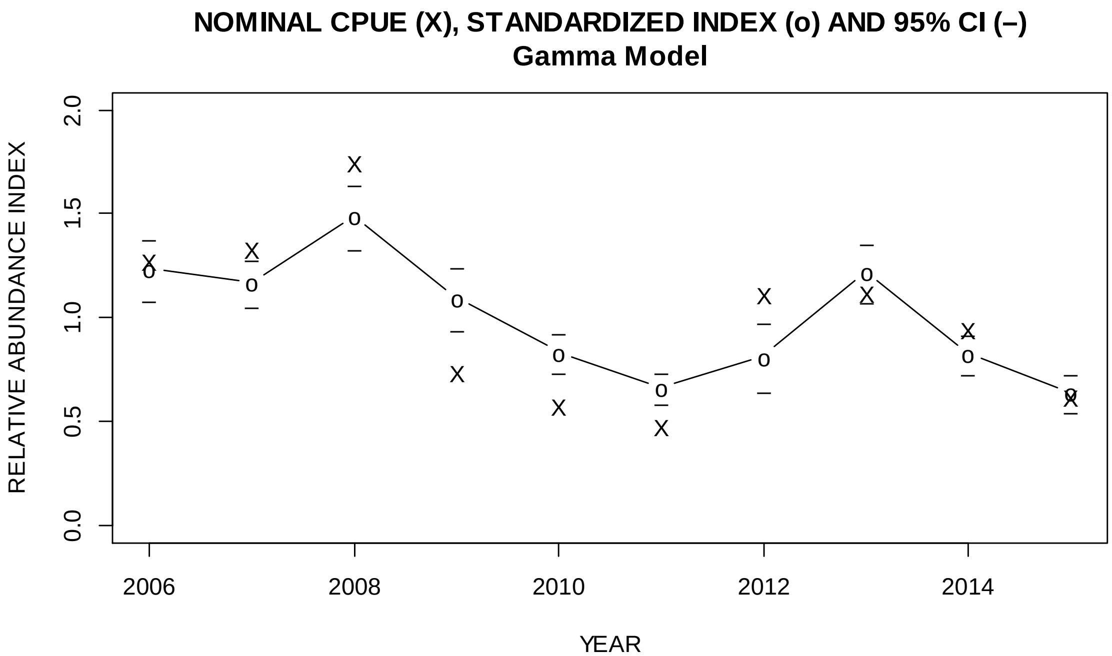

Figure 5.- Relative abundance indices for the blue shark with approximate 95% confidence intervals. Gamma model for years 2006-2015.

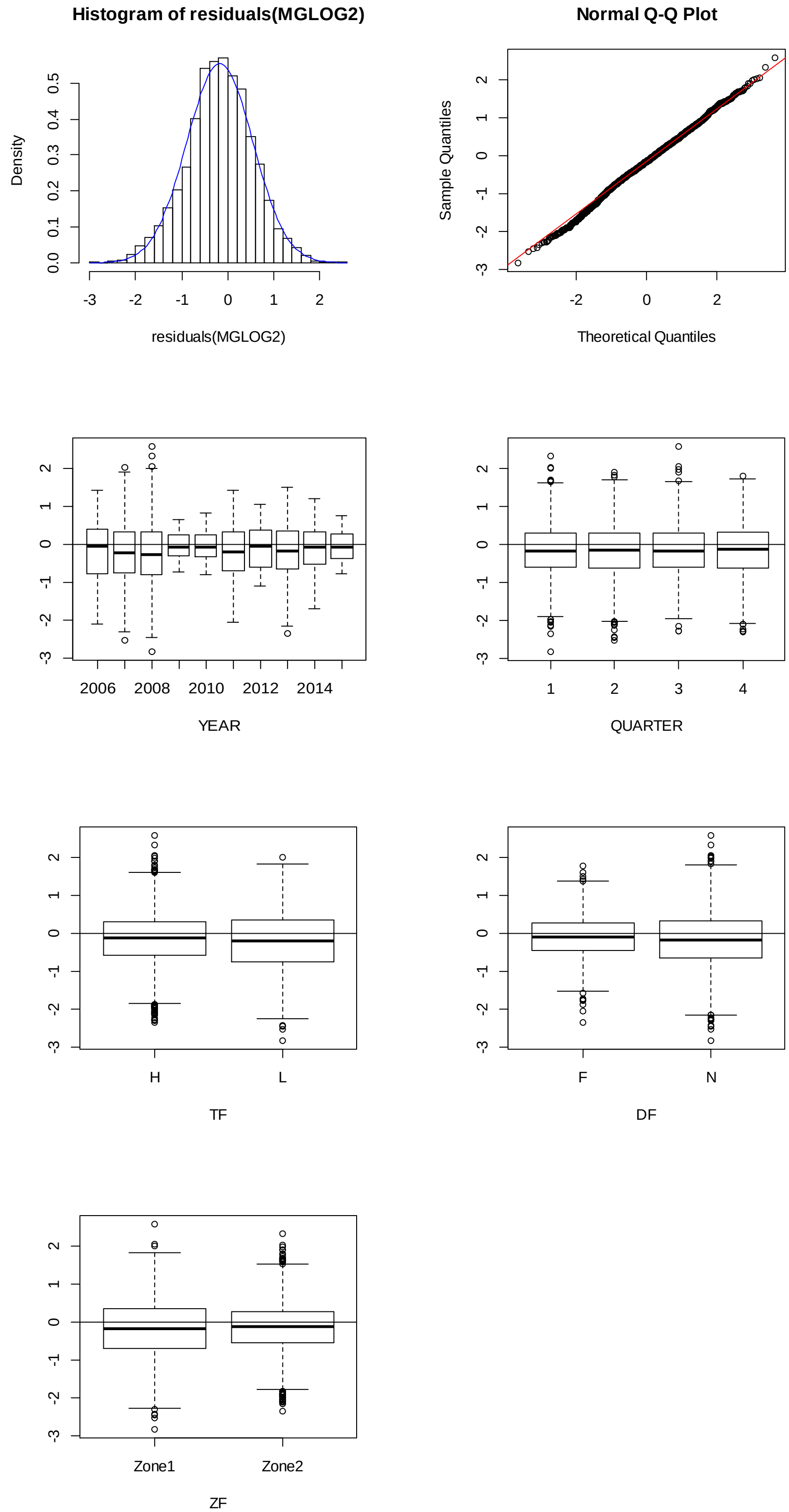

Figure 6.- Residuals and Marginal-model plots of the Gamma GLM.

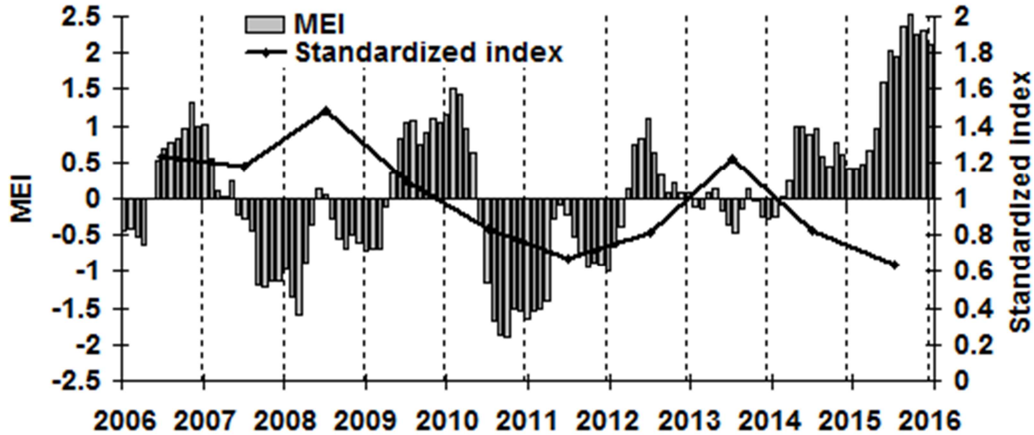

Figure 7.- Multivariate ENSO Index (MEI) and standardized abundance index of blue shark, 2006-2015.