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UPDATE ON THE VENEZUELAN CATCH AND SPATIAL-TEMPORAL DISTRIBUTION OF SHORTFIN MAKO SHARK (*ISURUS OXYRINCHUS*) AND OTHER COMMON SHARK SPECIES CAUGHT IN THE CARIBBEAN SEA AND ADJACENT WATERS OF THE NORTH ATLANTIC OCEAN

Arocha, F[1]., J.H. Marcano[2], M. Narváez[1], X. Gutiérrez[2], L. Marcano[3]

SUMMARY

*Venezuelan shortfin mako shark (*Isurus oxyrinchus*) catch estimates commenced to be recorded separately and reported to ICCAT in 2004, previously was recorded under the shark category (SHX or SHK). In this document statistical data from various sources, official statistics, publications, grey literature, expert opinion, and several ICCAT monitoring projects for data improvement in Venezuela were used to reconstruct the specific shortfin mako shark catch for the period of 1986-2015 caught by the industrial longline fishery and the artisanal drift-gillnet fishery for the period 1991-2014. Information on size, and sex ratio of shortfin mako shark from the Venezuelan pelagic longline fishery and the artisanal drift-gillnet fishery is presented for the period 1994-2014. The document updates the analyses of spatial and temporal distribution of shortfin mako shark, and other common shark species of concern to ICCAT, including* Carcharhinus falciformis, C. longimanus, Alopias spp.*, and* Sphyrna spp. *from both fisheries.*

RÉSUMÉ

*Les estimations des prises de requin-taupe bleu (*Isurus oxyrinchus*) du Venezuela ont commencé à être enregistrées séparément et déclarées à l'ICCAT en 2004. Auparavant, elles étaient consignées dans la catégorie des requins (SHX ou SHK). Dans le présent document, les données statistiques issues de diverses sources (statistiques officielles, publications, littérature grise, opinion d'expert et plusieurs projets de suivi de l'ICCAT destinés à l'amélioration des données au Venezuela) ont été utilisées pour reconstruire la capture spécifique du requin-taupe bleu réalisée par la pêcherie palangrière industrielle entre 1986 et 2015 et la pêcherie artisanale utilisant le filet maillant dérivant entre 1991 et 2014. Des informations sur la taille et le sex ratio du requin-taupe bleu provenant des pêcheries palangrières pélagiques et des pêcheries artisanales de filet maillant dérivant du Venezuela sont présentées pour la période comprise entre 1994 et 2014. Le document met à jour les analyses de la distribution spatiale et temporelle du requin-taupe bleu et d'autres espèces communes de requin d'intérêt pour l'ICCAT, y compris* Carcharhinus falciformis, C. longimanus, Alopias spp. *et* Sphyrna spp. *dans les deux pêcheries.*

RESUMEN

Las estimaciones de la captura de marrajo dientuso (Isurus oxyrinchus) de Venezuela empezaron a consignarse por separado y a comunicarse a ICCAT en 2004, anteriormente se consignaban en la categoría de tiburones (SHX o SHK). En este documento, se utilizaron datos estadísticos procedentes de varias fuentes, estadísticas oficiales, publicaciones, documentación gris, opiniones de expertos y varios proyectos de seguimiento de ICCAT para la mejora de los datos en Venezuela, para reconstruir la captura específica del marrajo dientuso para el periodo de 1986-2015 capturado por la pesquería de palangre industrial y la pesquería de redes de enmalle artesanal para el periodo 1991-2014. Se presenta información sobre la ratio de sexos y tallas del marrajo dientuso de la pesquería de palangre pelágico y de la pesquería

[1] Instituto Oceanográfico de Venezuela, Universidad de Oriente, Cumaná 6101, Venezuela; *Corresponding author: farocha@udo.edu.ve / farochap@gmail.com
[2] INSOPESCA-Sucre, Cumaná 6101, Venezuela
[3] Instituto Nacional de Investigaciones Agrícolas, Cumaná 6101, Venezuela.

artesanal de redes de enmalle de deriva de Venezuela para el periodo 1994-2014. El documento actualiza los análisis de la distribución espacial y temporal del marrajo dientuso y de otras especies comunes de tiburón de interés para ICCAT, lo que incluye: Carcharhinus falciformis, C. longimanus, Alopias spp., y Sphyrna spp. de ambas pesquerías.

KEYWORDS

Isurus oxyrinchus, spatial distribution, size composition, sex ratios, Caribbean Sea, Venezuela

Introduction

Shortfin mako sharks (*Isurus oxyrinchus*) have been part of the shark landings in Venezuela coming from the large pelagic fisheries operating in the Caribbean Sea and adjacent waters of the North Atlantic (Arocha et al., 2002). In this part of the southwestern North Atlantic, Venezuelan fisheries targeting tropical tunas (*Thunnus albacares, T. obsesus*) and swordfish (*Xiphias gladius*) have had an important retention of sharks in which shortfin mako sharks represented about 6 % of the shark species caught by the pelagic longline fleet (Tavares and Arocha, 2008). Shortfin mako sharks are also caught and landed by Venezuelan artisanal fisheries targeting large pelagics, like the small drift-gillnet fishery operating from Playa Verde-La Guaira (Marcano et al., 2014) and the Venezuelan Artisanal Off-Shore pelagic longline fishery (Arocha et al., 2015), both targeting billfishes. Observations made on landing sites by personnel of ICCAT's Enhanced Program for Billfish Research (EPBR) in Venezuela and reports of Captains to the same personnel noted that the landed catch of shortfin mako sharks from the pelagic longline fishery consists of the finned trunks (gutted and headed), and fins; where the trunk is sold in the local market and the fins are to be commercialized in the international market. In the artisanal drift-gillnet fishery, the sharks are landed whole, gutted and finned on site; while in the artisanal pelagic longline fishery, shortfin mako sharks are landed headed and gutted with fins attached, and sharks from both fisheries are sold to the local market.

Venezuela has reported shark catch data to ICCAT as sharks unclassified since the late 1990's, and shortfin mako shark specific catch data since 2004 most of which came from the pelagic longline fishery. Presently, the national agency responsible for collecting fishery statistical data in Venezuela is the Instituto Socialista de la Pesca y Acuicultura (INSOPESCA), while the official fisheries research conducted by the Instituto Nacional de Investigaciones Agropecuarias (INIA) contributes to provide catch estimates of species or taxonomic group from on-site sampling programs to enhance and correct INSOPESCA's fishery statistics. Over the years, sharks species have been included in the national statistics as *cazón tintorera (Galeocerdo cuvieri)*, *cazón viuda (Mustelus spp.)*, *cazón tiburón*, *cazón varios*, and rays. Shortfin mako shark catches are likely reported as *cazón tiburon* and/or *cazón varios*, and in some occasions as *tiburón carite*. Under this classification it would be complicated if not impossible to separate the shark catch that would include shortfin mako shark from the national statistics. Recognizing the need to have better estimates of the shortfin mako shark catch in the Atlantic, an effort was made to reconstruct the shortfin mako shark catch data from Venezuela since 1986, when the data collection programs for large pelagics were initiated (Marcano et al., 2004). The first part of the present document reports on the historical estimation of the shortfin mako shark catch data from Venezuela.

In addition, noting that a recent document on shortfin mako shark demographics in the southwestern North Atlantic by Arocha et al. (2013) provided information contributing to understand and characterize the demographics of shortfin mako shark in the area; the second part of the present document offers an update on the temporal and spatial composition of catch rates, size and sex ratio of shortfin mako shark (SMA), and those of silky shark (FAL), *Carcharhinus falciformis,* oceanic whitetip shark (OCS), *C. longimanus,* thresher sharks (THR), *Alopias spp.,* and hammerhead shark (SPN), *Sphyrna spp* caught by the Venezuelan large pelagic fisheries.

Material and Methods

Data sources

The shortfin mako shark catch data was reconstructed from various sources, official statistics, publications, grey literature, expert opinion, ICCAT's Enhanced Program for Billfish Research (EPBR) in Venezuela for the period of 1991-2013, and the Venezuela National Observer Program (INSOPESCA) for the period of 2012-2014. The shark catch data from the pelagic longline fishery reported for the first time in Marcano et al. (2004) was utilized to reconstruct the Venezuelan shortfin mako shark catch. Additional unclassified shark catch data from the pelagic longline fishery used in the reconstruction came from the Venezuelan National Report to ICCAT during 1999 and 2000 and from TASK I data of sharks unclassified for the period 2001-2003. The shark catch from the artisanal drift-gillnet fishery targeting billfishes off Playa Verde-La Guaira was included in the reconstruction of the Venezuelan shortfin mako shark catch from data collected by ICCAT's-EPBR in Venezuela since 1991. The shark catch from the Venezuelan Artisanal Off-Shore pelagic longline fishery was not included because a recent study indicated that the shortfin mako shark catch from that fishery was of very low volume (Arocha et al., 2015), and would not impact the total catch of shortfin mako shark from Venezuela.

Disaggregation of the shortfin mako catch

The aggregated shark catch data from the Venezuelan large pelagic catch statistics was disaggregated to extract shortfin mako shark using species specific proportion in weight by year obtained from a couple of sources; 1, ICCAT's EPBR at-sea sampling of the Venezuelan pelagic longline fishery (1994-2011); 2, ICCAT's EPBR port sampling of the artisanal drift-gillnet fishery from Playa Verde-La Guaira (1991-2014). In addition, the mean of the ICCAT Task I data for the period 2001, 2004-2006 was used to estimate proportion of shortfin mako shark for 2002-2003.

Spatial and temporal distribution of catch rates, sizes, and sex ratio

The spatial and temporal data used in this document came from the database of the ICCAT sponsored EPBR Venezuelan Pelagic Longline Observer Program (VPLOP) for the period 1994-2011(Arocha et al., 2013), from INSOPESCA's National Observer Program for the period 2012-2015 (Gassman et al., 2014), from the Venezuelan Artisanal Off-Shore pelagic longline fishery for the period of 2011-2014 (Arocha et al., 2015), and the shark data collected by ICCAT's-EPBR port sampling in Playa Verde (off LaGuaira) during 2012 and 2013. Shark species catch rates were calculated as number of sharks caught per 1000 hooks. The fishing grounds for the Venezuelan longline fleet extend from northwest of Puerto Rico (22°N-68°W) to off the coast of northeastern Brazil (4°N-44°W), and the western Caribbean Sea (up to ~70°W). In the present document two geographical areas for longline fishing were used for the analysis, namely, the Caribbean (CAR) area, and the Atlantic (ATL) area which represented the area of the Atlantic east of 61°W.

All shark specimens captured were sexed and the fork length (FL) and/or total length (TL) were measured to the nearest cm. TL were converted to FL using Kohler et al. (1995) length conversion factors for shortfin mako, thresher sharks, and silky shark, Piercy et al. (2010) for great hammerhead, and Travassos et al. (2013) for oceanic whitetip shark. The size and sex data was collected from two different types of gear and different areas. For the analysis, the size data collected from the same gear (pelagic longline) were separated in two areas, CAR and ATL; while the size and sex data collected from artisanal drift-gillnet fishery came from the Billfish hot-spot in La Guaira Bank, and was included in CAR area.

Size data were tested for normality with Shapiro-Wilk W test (for n<2000), and Welch's ANOVA was used to compare size distribution data when variances are heterogeneous, otherwise ANOVA, and Student's *t* were used. Sex ratios were calculated and compared with contingency tables and Likelihood ratio χ^2 tests. Sex ratios were also compared between months taking into account the two areas using Cochran-Mantel-Haenszel (CMH) χ^2 test. All statistical test were conducted using JMP v.12 (2016).

Results and Discussion

Shortfin mako shark (SMA), *Isurus oxyrinchus*

Catch estimates

The reported shark unclassified catch and the estimated shortfin mako shark (*Isurus oxyrinchus*) from the Venezuelan large pelagic fisheries are shown in **Table 1**. The analysis of all the available statistical data on shark catches resulted in substitutions, corrections, and estimations when values were unlikely plausible knowing the source originating the value and the fleet operating during the time the value was recorded. The shark catch from the pelagic longline fishery was obtained from the study of Marcano et al. (2004), which came from fishing logbooks of pelagic longline vessels for the period of 1986-2000. However, the data for 1999-2000 was substituted with the shark catch data reported to ICCAT in the National Report from Venezuela which provided a higher and more realistic estimate of the shark catch for that period of time. The rest of the shark catch data used was from the one reported as Task I data. The shark catch from the artisanal drift-gillnet fishery from Playa Verde-La Guaira was obtained directly from daily recordings during the port sampling operations of the EPBR personnel for the period of 1991-2014.

The EPBR sampling programs in Venezuela started in 1991, it included the port sampling program at Playa Verde-La Guaira of the artisanal drift-gillnet fishery there, and the at-sea sampling program in the pelagic longline fishery which resulted in the VPLOP for the period of 1991-2011. Shark catches were recorded regularly on a daily basis along with the specific billfish and tuna catch from the artisanal drift-gillnet fishery. However, specific shark data, including catch in weight, was recorded by the VPLOP starting in 1994. It included specific catch data of the most important shark species (shortfin mako shark among them). The estimated proportion of shortfin mako shark with respect to the total shark catch is shown in **Table 2** for the artisanal drift-gillnet fishery, and in **Table 3** for the pelagic longline fishery catch data. Given that the VPLOP started to record shark specific catch data in 1994, the estimated annual proportions of shortfin mako shark used for the earlier period was the mean of the annual shortfin mako shark proportions for the period of 1994-1999 recorded by the VPLOP. Considering that shark catch reported as Task I data to ICCAT started in 2001 and the specific shortfin mako shark data in 2004, the proportion of shortfin mako shark used for the period of 2002-2003 was the mean of the annual proportion of shortfin mako shark for 2001 and 2004-2006 (**Table 3**). In the artisanal drift-gillnet fishery, the specific shortfin mako shark catch was only available for 2011-2014, therefore, the mean value of the proportions for 2011-2014 was used for the earlier period (**Table 2**). It became evident that the proportion of shortfin mako shark between the two fisheries is different, in the artisanal drift-gillnet fishery it can reach up to 40% of the total shark catch, with an average of about 35%; while in the pelagic longline fishery it has been under 20% in recent years.

The total estimated shortfin mako shark catch (t) of the pelagic longline and artisanal drift-gillnet fishery for the period of 1986-2014 is shown in **Table 1**. The total shortfin mako shark catch show an uneven increasing trend that peaked in 2004 (**Figure 1**), with a high catch of ~63 t. Thereafter, high catches of shortfin mako shark appear for a period of 4 consecutive years and then drop to low levels. It is not clear if this is a commercial strategy of the pelagic longline fishery or a seasonal variation in the availability of shortfin mako shark in the fishing grounds. These new shortfin mako shark catches from Venezuela represents the most accurate catch estimate for the time series analyzed.

Spatial and temporal distribution of catch rates

The overall spatial distribution of the total relative abundance of SMA (numbers of sharks/ hooks×1000) observed by the pelagic longline observer programs for the period of 1994-2015 indicated high concentrations (>1.1 SMA/hooks×1000) in the Caribbean Sea off the central coast of Venezuela and around the off-shore islands, and off Guyana, the catch rates were low in the rest of the fishing area (**Figure 2**). Seasonally, the highest catch rates were observed during the 1st quarter of the year, where important catch rates were observed in both areas, and followed by those observed during the 3rd quarter (**Figure 2**), during the 2nd and 4th quarters catch rates were relatively low throughout the fishing areas.

Size distribution

A total of 427 SMA were sampled and measured during the collection time period of the present document, SMA sampled were between 73 and 280 cm FL (**Table 4)**. Of the 427 SMA measured, 189 were females ($\bar{x}=$ 174.6 cm FL, ±2.57) and 238 were males ($\bar{x}=$ 177.9 cm FL, ±2.05).

Size data was normally distributed (Shapiro-Will test, $W = 0.993$, $p = 0.0710$) (**Figure 3**), and Student's *t* test revealed that SMA size data were significantly different between areas (Student's *t* test, $t = 2.653$, $p < 0.0105$), but was not different between sexes (Welch's test, $F = 0.965$, $df = 1$, $p = 0.3264$).

Seasonal trend in the sex specific size distributions of SMA show minor variations throughout the fishing area. The ANOVA test revealed that sex specific SMA size data were significantly different between quarters for all years combined ($ANOVA_{females}$, $F = 3.0403$, $df = 3$, $p = 0.0303$; $ANOVA_{males}$, $F = 4.5963$, $df = 3$, $p = 0.0038$). During the 1^{st} quarter was where most of the SMA appeared in the catches, and females sizes appeared close the female mean size; while most males were below the male mean size (**Figure 4**). In the 2^{nd} quarter, SMA sizes were above the mean size in both sexes; but during the 3^{rd} quarter the trend was reversed in female sizes where most of the females were below its mean size. In the 4^{th} quarter, the number of male SMA increased but SMA sizes for both sexes were around their mean values.

Sex ratio

The overall sex ratio among the two areas did not depart from the 1:1 ratio (Likelihood Ratio: $\chi^2 = 0.238$, $p = 0.6258$). In contrast, there were significant differences in sex ratios among quarters, even when compared conditionally within each of the different areas (CMH test: $\chi^2 = 35.1142$, $df = 3$, $p < 0.0001$; $\chi^2 = 11.4759$, $df = 1$, $p < 0.0007$). The mosaic plot indicated that seasonal sex ratio was even during the 1^{st} quarter, in the 2^{nd} and 3^{rd} quarters the sex ratio increased favoring the females, but during the 4^{th} quarter the female sex ratio dropped to below 25% (**Figure 5**).

The variations in SMA sex specific sizes are most likely attributed to sampling effects and the fisheries operations and gears. In the area of the Caribbean (CAR), where most of the SMA were caught and sampled, came from pelagic longline (LL) and artisanal drift-gillnet (GN) operations (**Figure 6**). The size distribution of SMA between the two fisheries was evident, females sizes were larger in the GN fishery than those from the LL fishery; while male sizes were evenly distributed between gears, but those from the GN fishery were concentrated between 160 and 200 cm FL. In the ATL area, female sizes were similar to those of the CAR area caught by the LL fishery; while the male sizes from the ATL area consisted of smaller individuals (<160 cm FL).

Other Sharks

Silky shark (FAL), *Carcharhinus falciformis*

The overall spatial distribution of the total relative abundance of FAL (numbers of sharks/ hooks×1000) observed by the pelagic longline observer programs for the period of 1994-2015 indicated high concentrations (>3 FAL/hooks×1000) in the Caribbean Sea off the central coast of Venezuela and around the off-shore islands (**Figure 7**); while important catches (1-3 FAL/hooks×1000) were common in the ATL area off the northern shelf of South America. Catch rates were low in the central areas of the Caribbean Sea.

A total of 568 FAL were sampled and measured during the collection time period of the present document, FAL sampled were between 25 and 280 cm FL (**Table 4)**. Of the 568 FAL measured, 271 were females ($\bar{x} =$ 96.1 cm FL, ±2.83), 159 were males ($\bar{x} =$ 123.7 cm FL, ±3.85), and 138 were of unknown sex ($\bar{x} =$ 85.8 cm FL, ±3.12).

Size data was not normally distributed (Shapiro-Will test, $W = 0.846$, $p < 0.0001$) (**Figure 8**), and Welch's ANOVA revealed that FAL size data were significantly different between areas (Welch's test, $F = 124.094$, $df = 1$, $p < 0.0001$), and Student's *t* test indicated that size data was significantly different between sexes (Student's *t* test, $t = 5.824$, $p < 0.0001$).

Seasonal trend in the sex specific size distributions of FAL show small variations throughout the fishing area. The ANOVA test revealed that sex specific FAL size data was significantly different for females between quarters for all years combined ($ANOVA_{females}$, $F = 10.170$, $df = 3$, $p < 0.0001$), but not for males (Welch's $ANOVA_{males}$, $F = 1.260$, $df = 3$, $p = 0.293$). In females FAL, quarterly sizes were below or around the mean vales, with the exception of the 3^{rd} quarter where most of the females consisted of individuals larger than the mean size (**Figure 9**); while male quarterly sizes appear to increase steadily across the seasons.

The overall sex ratio was significantly different between the two areas (Likelihood Ratio: χ^2 = 23.661, p<0.0001), with females in the ATL area reaching up to 75% (**Figure 10**). In contrast, there were significant differences in sex ratios among quarters (Likelihood Ratio: χ^2= 8.832, $p=0.0316$), but not when compared conditionally within each of the different areas (CMH test: χ^2 = 5.0294, df = 3, p = 0.1697; χ^2 = 2.0858, df = 1, p = 0.1487). The seasonal sex ratio was relatively even between the 1st and 3rd quarter, but changed during the 4th quarter favoring females (**Figure 10**).

Similar to SMA, FAL the variability in sex specific sizes was most likely attributed to sampling effects and the gears utilized in the fisheries operations. In FAL was mostly attributed to how the pelagic longline sets were operated by the fisheries, i.e., the artisanal vs. the industrial. The artisanal fishery catches smaller size shark of both sexes than the industrial fishery (**Figure 11**). Most of the sharks caught by the artisanal fishery are <100 cm FL; while the sharks caught by the industrial PLL fishery are >100 cm FL. The difference is basically attributed to the depth of the longline set and the target species between the two fisheries; the VAOS fishery targets dolphinfish and billfishes and sets are shallower than those of the industrial PLL fishery, which targets tropical tunas, mostly YFT (Arocha et al., 2015).

Oceanic whitetip shark (OCS), *Carcharhinus longimanus*

The overall spatial distribution of the total relative abundance of OCS (numbers of sharks/ hooks×1000) observed by the pelagic longline observer programs for the period of 1994-2015 indicated high concentrations (>3 OCS/hooks×1000) in the Caribbean Sea off the northeast coast of Venezuela and around the eastern off-shore islands (**Figure 12**); while important catches (1.6-3 OCS/hooks×1000) were more common in the ATL area off the northern shelf of South America. In general, catch rates were low in the central areas of the Caribbean Sea.

A total of 101 OCS were sampled and measured during the collection time period of the present document, OCS sampled were between 52 and 260 cm FL (**Table 4**). Of the OCS measured, 51 were females ($\bar{x} =$ 134.2 cm FL, ±7.61), 46 were males ($\bar{x} =$ 122.7 cm FL, ±6.03), and 4 were of unknown sex ($\bar{x} =$ 115.8 cm FL, ±14.31).

Size data was not normally distributed (Shapiro-Will test, W = 0.933, p < 0.0001) (**Figure 13**), and Welch's ANOVA revealed that OCS size data were significantly different between areas (Welch's test, F = 24.724, df = 1, p < 0.0001), and Student's t test indicated that size data was not different between sexes (Student's t test, t = 1.1824, p= 0.2401).

Seasonal trend in the sex specific size distributions of OCS showed small variations throughout the fishing area. The Welch's ANOVA test revealed that sex specific OCS size data showed no significant differences for females and males between quarters for all years combined (Welch's $\text{ANOVA}_{\text{females}}$, F = 2.7054, df = 3, p= 0.0761), but not for males (Welch's $\text{ANOVA}_{\text{males}}$, F = 2.5828, df = 3, p = 0.0858). However, in female OCS, quarterly sizes appeared to increase steadily across the seasons but drop to very low sizes during the 4th quarter (**Figure 14**). In males, with the exception of the 3rd quarter which the size data was higher than the mean size, most of the size data observed was around the mean sizes during the rest of the quarters (**Figure 14**).

The overall sex ratio among the two areas did not depart from the 1:1 ratio (Likelihood Ratio: χ^2 = 1.682, p=0.1946), although the mosaic plot showed that in the CAR area female sex ratio was slightly higher (**Figure 15**). Similarly, no significant differences were observed in sex ratios among quarters (Likelihood Ratio: χ^2= 1.808, $p=0.6131$), even when compared conditionally within each of the different areas (CMH test: χ^2 = 0.6870, df = 3, p = 0.8763; χ^2 = 0.0058, df = 1, p = 0.9393). The mosaic plot for the seasonal sex ratio show that it was relatively even during the 1st and 4th quarter, but increased slightly during the 2nd and 3rd quarter favoring females (**Figure 15**).

Unlike SMA and FAL, OCS variability in sex specific sizes appears to be attributed to area, as most of the catches (94%) came from the pelagic longline observer programs in the industrial PLL fishery. OCS caught in the ATL area displayed a more grouped distribution around 80-140 cm FL, in contrast to those caught in the Caribbean where the size distribution was more spread out over sizes in both sexes (**Figure 16**).

Thresher sharks (THR)

A total of 219 thresher sharks were recorded by the programs covering the large pelagic fisheries, and most of the caught specimens (84%) were from the VPLOP (1994-2011), the rest were from the artisanal drift-gillnet fishery (16%) off La Guaira, in central Venezuela. For the purpose of the overall spatial distribution of catch rates, THR were considered as a species group. THR showed high concentrations (>2.1 THR/hooks×1000) in the Caribbean Sea off the coast of Venezuela and around the off-shore islands (**Figure 17**); while important catches (1.1-5 THR/hooks×1000) were more common in the ATL area off the northern shelf of South America. In general, THR catch rates were low in the central areas of the Caribbean Sea.

The 219 THR sampled consisted of 90 bigeye thresher sharks (BTH) of 87-280 cm FL, 94 common thresher shark (ALV) of 86-231 cm FL, and 35 *Alopias sp.* (THR) of 110-230 cm FL (**Table 4)**. Of the 90 BTH measured, 32 were females ($\bar{x} =$ 159.3 cm FL, ±7.23), 58 were males ($\bar{x} =$ 163.4 cm FL, ±5.73). Of the 94 ALV, 30 were females ($\bar{x} =$ 137.2 cm FL, ±7.22), 64 were males ($\bar{x} =$ 142.0 cm FL, ±4.37). Non-specific thresher (THR) had an average size of 186.6 cm FL, of which for females was 198.4 cm FL and males 177.8 cm FL.

Size data was not normally distributed (Shapiro-Will test, $W = 0.961$, $p < 0.0001$) (**Figure 18**). Most of the ALV and all THR specimens were from the Caribbean Sea, only BTH had sufficient sample size to test for difference between areas. The Student's *t* test indicated that significant differences were found between areas for BTH, but there were not significant differences in the size data between sexes (Student's *t* test, $t = 0.4489$, $p = 0.6549$).

Seasonal trend in the sex specific size distributions of THR indicated that only BTH showed significant differences between quarters in both sexes ($ANOVA_{females}$, $F = 3.6523$, $df = 3$, $p < 0.0244$; Welch's $ANOVA_{males}$, $F = 4.4432$, $df = 3$, $p < 0.0108$), the other two species groups showed no significant differences between quarters for either sex. During the 2nd and 3rd quarters BTH females displayed smaller sizes that the rest of the season; while males caught during the 3rd quarter displayed smaller sizes than the rest of the quarters (**Figure 19**).

Overall THR sex ratio among the two areas did not depart from the 1:1 ratio, nor did it depart from the 1:1 ratio for specific species (ALV, BTH). Similarly, it did not depart from the 1:1 ratio between quarters; therefore no further tests were pursued.

Hammerhead sharks (SPN)

A total of 560 hammerhead sharks were recorded by the programs covering the large pelagic fisheries, and most of the caught specimens (65%) were from the VPLOP&PNOB (1994-2015), the rest were from the artisanal drift-gillnet fishery (19%) off La Guaira in central Venezuela, and the artisanal off-shore pelagic longline fishery (16%). For the purpose of the overall spatial distribution of catch rates, SPN were considered a species group that included: great hammerhead (SPK, *Sphyrna mokarran*), smooth hammerhead (*S. zigaena*, SPZ), scalloped hammerhead (*S. lewini*, SPL), and other hammerhead sharks (*Sphyrna sp*., SPN). SPN showed high concentrations (>2.1 SPN/hooks×1000) in the Caribbean Sea off the northeastern coast of Venezuela and around the off-shore island in the area (**Figure 20**); while in the ATL area few important catches (>2 SPN/hooks×1000) were observed in a single area off the northern shelf of South America. In general, catch rates were low in the central areas of the Caribbean Sea.

The 560 SPN sampled, 191 consisted of great hammerhead sharks of 74-193 cm FL, 114 scalloped hammerhead sharks of 20-230 cm FL, 66 smooth hammerhead sharks of 66-212 cm FL, and 207 *Sphyrna sp*. sharks of 70-320 cm FL (**Table 4)**. Of the 191 SPK measured, 59 were females ($\bar{x} =$ 131.3 cm FL, ±2.43), 128 were males ($\bar{x} =$ 129.3 cm FL, ±1.40). Of the 114 SPL, 46 were females ($\bar{x} =$ 127.1 cm FL, ±7.05), 54 were males ($\bar{x} =$ 117.7 cm FL, ±4.77). Of the 66 SPZ, 25 were females ($\bar{x} =$ 161.8 cm FL, ±3.65), 23 were males ($\bar{x} =$ 148.3 cm FL, ±6.24). 207 *Sphyrna sp*. (SPN) had an average size of 149.7 cm FL, of which for females was 161.5 cm FL and males 146.6 cm FL. 48 specimens of the 560 SPN had no sex information.

Size data was not normally distributed (Shapiro-Will test, $W = 0.968$, $p < 0.0001$) (**Figure 21**). Only SPK showed significant differences between areas (Student's *t* test, $t = -2.349$, $p = 0.0295$); SPL and SPZ did not, and SPN were mostly recorded from the CAR area. Only SPK and SPL were tested for seasonal variations by sex; results indicated that neither SPK nor SPL showed significant differences between quarters for either sex (all $p > 0.05$) (**Figure 22**).

SPK and SPL sex ratio among the two areas did not show significant differences, nor when tested seasonally ($p>0.05$). Mosaic plots by area show the sex ratio favoring the males in both areas for SPK, and for SPL only in the Caribbean area but at a much reduced level, in the ATL area sex ratios are close to the expected 1:1 ratio (**Figure 23**). The mosaic plots of the seasonal trend in SPK reflects a similar trend as it did between areas, a high proportion of males across all quarters (>60%); while in SPL most of the sex ratio was around the 1:1 ratio except during the 3rd quarter where the proportion males was substantially increased (87%).

Similar to the other shark species variability in sex specific sizes appears to be attributed to fishing operations. Comparing sex specific size data by species *vs* gears, a pattern appears, most of the larger specimens of either sex are SPN and caught by the artisanal drift-gillnet fishery (**Figure 24**); most likely the species caught by this fishery were SPK and SPL but the proportions are unknown. In SPL, specimens caught consisted of smaller sizes, more in females than males, and is mostly attributed to high catches of juveniles from the VAOS fishery (Arocha et al., 2015).

References

Arocha F., O. Arocha, L.A. Marcano. 2002. Observed shark by-catch from the Venezuelan tuna and swordfish longline fishery from 1994 through 2000. ICCAT Col. Vol. Sci. Pap., 54:1123-1131.

Arocha F., J. Silva, L.A. Marcano. 2013. Shortfin mako shark (*Isurus oxyrinchus*) in the catch from the Venezuelan pelagic longline fleet in the Caribbean Sea and adjacent waters: Period 1994-2011. ICCAT Col. Vol. Sci. Pap., 69:1571-1577.

Arocha, F., L.A. Marcano, J. Silva. 2013. Description of the Venezuelan pelagic longline observer program (VPLOP) sponsored by the ICCAT Enhanced Research Program for Billfish. ICCAT, Col. Vol. Sci. Pap., 69: 1333-1342.

Arocha, F., A. Pazos, A. Larez, J. Marcano, X. Gutierrez. 2015. Enhanced monitoring of large pelagic fishes caught by the Venezuela artisanal off-shore fleet targeting tuna and tuna-like species in the Caribbean Sea and adjacent northwestern Atlantic waters: Final analysis. ICCAT Coll. Vol. Sci. Pap. 71:2316-2333.

Gassman, J., C. Laurent, J.H. Marcano. 2014. Ejecución del programa nacional de observadores a bordo de la flota industrial atunera venezolana del mar caribe y océano atlántico año 2012. ICCAT Col. Vol. Sci. Pap.,70:2207-2216.

JMP® 12 Basic Analysis. 2016. Cary, NC: SAS Institute Inc.

Kohler, N., J. Casey, P. Turner. 1995. Length-weight relationships for 13 species of sharks from the western North Atlantic. Fish. Bull. 93, 412-418.

Marcano, J.S., A. Lárez, X. Gutiérrez, J. J. Alió, H. Salazar, M. Márquez. 2004. Captura incidental de agujas y otras especies por palangreros venezolanos en el Mar Caribe y Océano Atlántico occidental: Periodo 1986-2000. Ciencias Marinas, 30(1B): 201–217.

Marcano, L.A., F. Arocha, J. Alío, I. Marcano, X. Gutiérrez. 2015. Actividades desarrolladas en el Programa de Investigacion Intensiva sobre Marlines en Venezuela. Período 2012-2013. ICCAT Col. Vol. Sci. Pap., 71:2302-2315

Piercy, A.N., J.K. Carlson, M.S. Passerotti. 2010. Age and growth of the great hammerhead shark, Sphyrna mokarran, in the north-western Atlantic Ocean and Gulf of Mexico. Marine and Freshwater Research, 61:992-998.

Tavares, R., F. Arocha. 2008. Species diversity, relative abundance and length structure of oceanic sharks caught by the Venezuelan longline fishery in the Caribbean Sea and western-central Atlantic. Zootecnia Tropical, 26 (4):489-503.

Travassos Tolotti, P. Travassos, F.L. Frédou, C. Wor, H.A. Andrade, F. Hazin. 2013. Size, distribution and catch rates of the oceanic whitetip shark caught by the Brazilian tuna longline fleet. Fisheries Research, 143: 136-142.

Table 1. Venezuelan pelagic longline and artisanal drift-gillnet total shark unclassified catch for the period of 1986-2010, specific shortfin mako shark (*Isurus oxyrinchus*) catch reported from the pelagic longline and artisanal drift-gillnet, and total shortfin mako shark (*I. oxyrinchus*) estimated catch for the Venezuelan pelagic longline and artisanal drift-gillnet fisheries. Weights are expressed as dressed weight (no head, no entrails, no fins).

	Pelagic longline fishery				***Artisanal drift-gillnet fishery***			
Year	***SHK Unclass. (t)***	***SMA (t)***	***Source***	***SMA Total catch (t)***	***SHK Unclass. (t)***	***SMA (t)***	***Source***	***SMA Total catch (t)***
1986	28,2		Marcano *et al.* (2004)	2,8	-	-		-
1987	39,3			1,7	-	-		-
1988	21,8			2,6	-	-		-
1989	22,9			8,1	-	-		-
1990	24,4			1,5	-	-		-
1991	17,0			2,1	9,7	-	Vzla. EPBR	3,5
1992	61,3			0,7	11,3	-		4,0
1993	60,2			0,6	2,4	-		0,8
1994	56,5			3,5	11,0	-		3,9
1995	46,4			4,2	9,1	-		3,2
1996	40,7			11,7	16,2	-		5,7
1997	65,3			3,4	16,1	-		5,7
1998	10,1			0,8	21,4	-		7,6
1999	83,0			2,0	11,0	-		3,9
2000	106,3		Ven. National Report LL	2,2	19,3	-		6,9
2001	96,7			20,3	10,7	-		3,8
2002	37,3		ICCAT Task I LL	16	13,2	-		4,7
2003	51,0			22	16,0	-		5,7
2004	-	58,0			18,1	-		6,4
2005	-	19,6			20,8	-		7,4
2006	-	6,3			22,7	-		8,1
2007	-	11,1			22,3	-		7,9
2008	-	1,8			18,3	-		6,5
2009	-	35,1			17,7	-		6,3
2010	-	21,9			13,9	-		4,9
2011	-	18,0			20,6	9,7	Vzla. EPBR/ICCAT	
2012	-	24,3			26,8	8,6		
2013	-	5,8			9,6	3,2		
2014	-	7,5			14,1	5,6		

Table 2. Proportion of shortfin mako shark (*Isurus oxyrinchus*) in the shark unclassified catch in weight of the Venezuelan pelagic longline recorded by ICCAT's EPBR port sampling at Playa Verde-La Guaira.
Note: † Represents mean value of the period 2011-2013.

Year	**prop.SMA_LL**	**Source**
1991-2010	0,355†	Vzla EPBR mean
2011	0,365	Vzla EPBR
2012	0,322	Vzla EPBR
2013	0,334	Vzla EPBR
2014	0,401	Vzla EPBR

Table 3. Proportion of shorfin mako shark (*Isurus oxyrinchus*) in the shark unclassified catch in weight of the Venezuelan pelagic longline recorded by ICCAT's EPBR Venezuelan Pelagic Longline Observer Program (VPLOP) and from ICCAT Task I data.

Note: † Represents mean value of the period 1994-1999. †† Represents mean value of the period 2001, 2004-2006.

Year	prop.SMA_LL	Source
1986-1993	0,098†	VPLOP mean 94-99
1994	0,062	VPLOP
1995	0,091	VPLOP
1996	0,288	VPLOP
1997	0,052	VPLOP
1998	0,075	VPLOP
1999	0,024	VPLOP
2000	0,021	VPLOP
2001	0,210	VPLOP
2002-2003	0,430††	VPLOP/ICCAT mean
2004	0,839	ICCAT
2005	0,429	ICCAT
2006	0,243	ICCAT
2007	0,147	ICCAT
2008	0,063	ICCAT
2009	0,126	ICCAT
2010	0,167	ICCAT
2011	0,133	ICCAT
2012	0,198	ICCAT
2013	0,091	ICCAT
2014	0,054	ICCAT

Table 4. Descriptive statistics of shortfin mako and other common shark species caught by the Venezuelan large pelagic fisheries during the period of 1994-2015.

ICCAT Code	*Species*	*N*	*Mean FL (cm)*	*s.e.*	*Range FL (cm)*
SMA	*Isurus oxyrinchus*	427	176.5	1.61	73-280
FAL	*Carcharhinus falciformis*	568	101.4	1.98	25-280
OCS	*Carcharhinus longimanus*	101	128.2	4.76	52-260
THR	*Alopias superciliosus*	90	161.9	4.48	87-280
	Alopias vulpinus	94	140.5	3.75	86-231
	Alopias sp.	35	186.6	4.61	110-230
SPN	*Sphyrna mokarran*	191	129.9	1.21	74-193
	Sphyrna lewini	114	117.9	3.79	20-230
	Sphyrna zigaena	48	155.3	3.64	66-212
	Sphyrna sp.	207	149.7	3.00	70-320

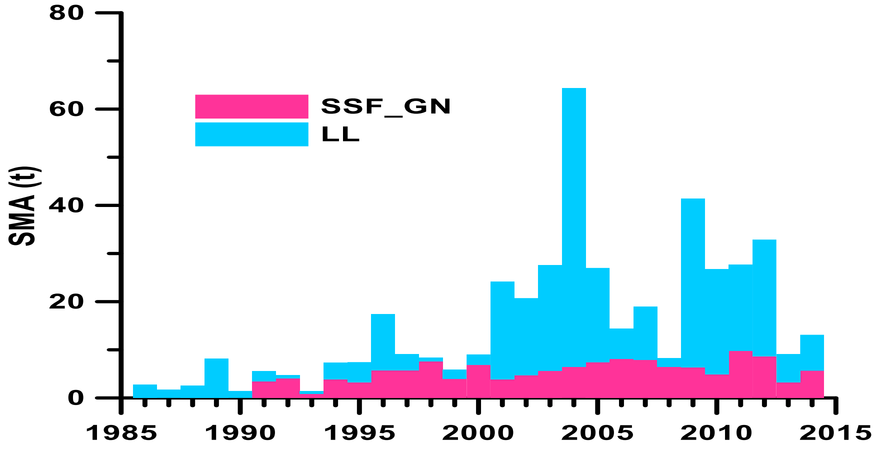

Figure 1. Estimated shortfin mako shark (*Isurus oxyrinchus*) catch from Venezuelan large pelagic fisheries.

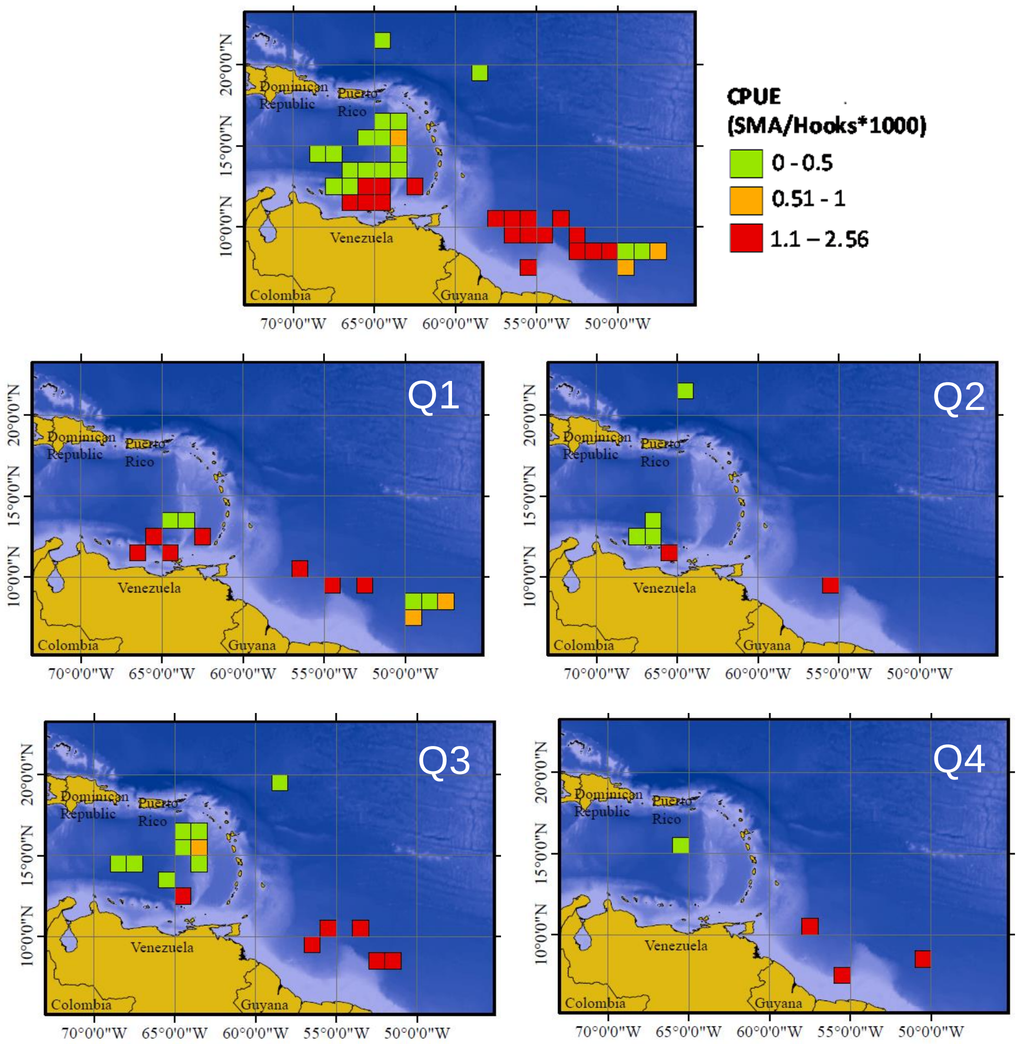

Figure 2. Overall and seasonal spatial distribution of shortfin mako shark (*Isurus oxyrinchus*) nominal catch rates during 1994-2015, from observed sets.

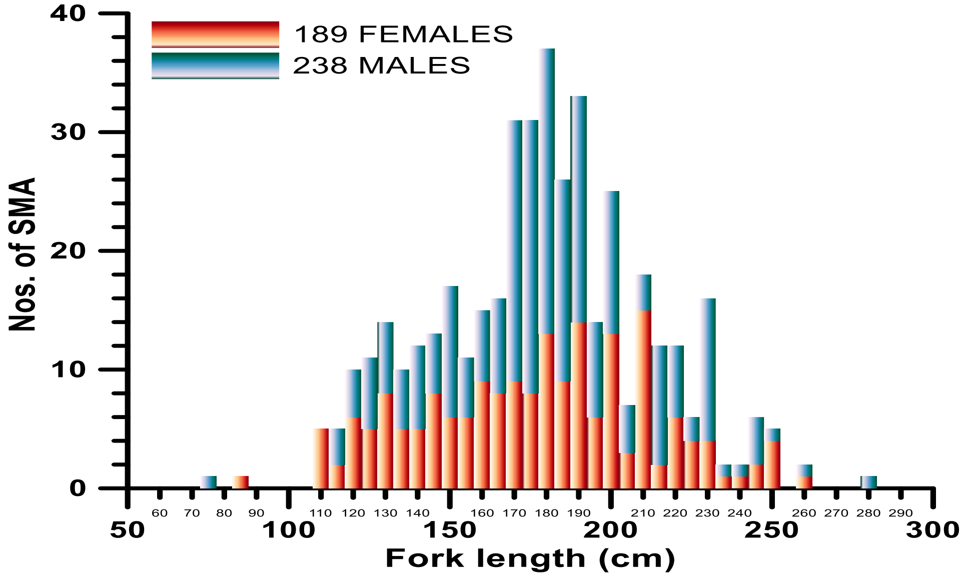

Figure 3. Size frequency distribution shortfin mako shark (*Isurus oxyrinchus*) caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

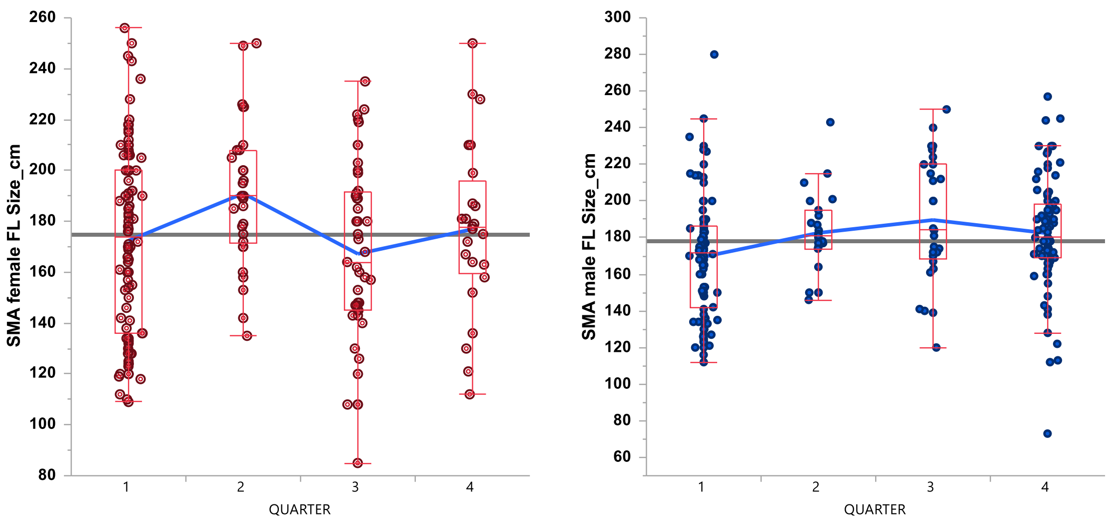

Figure 4. Seasonal time series for all years combined of female (left) and male (right) shortfin mako shark (*Isurus oxyrinchus*) size (FL) expressed as a median with the interquartile range (25% qt–75% qt) from individuals caught during the period of study. The grey line represents the grand mean and the blue line connects the quarterly means.

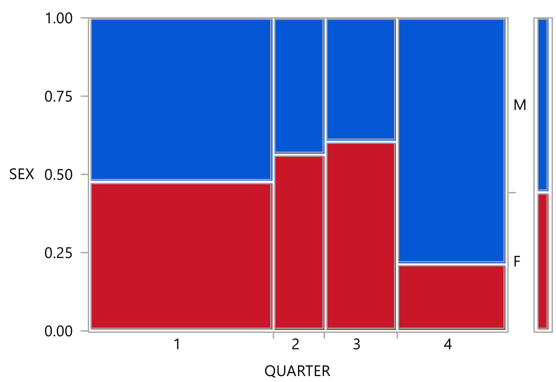

Figure 5. Seasonal sex ratio of shortfin mako shark (*Isurus oxyrinchus*) during the study period. Male (blue) and female (red).

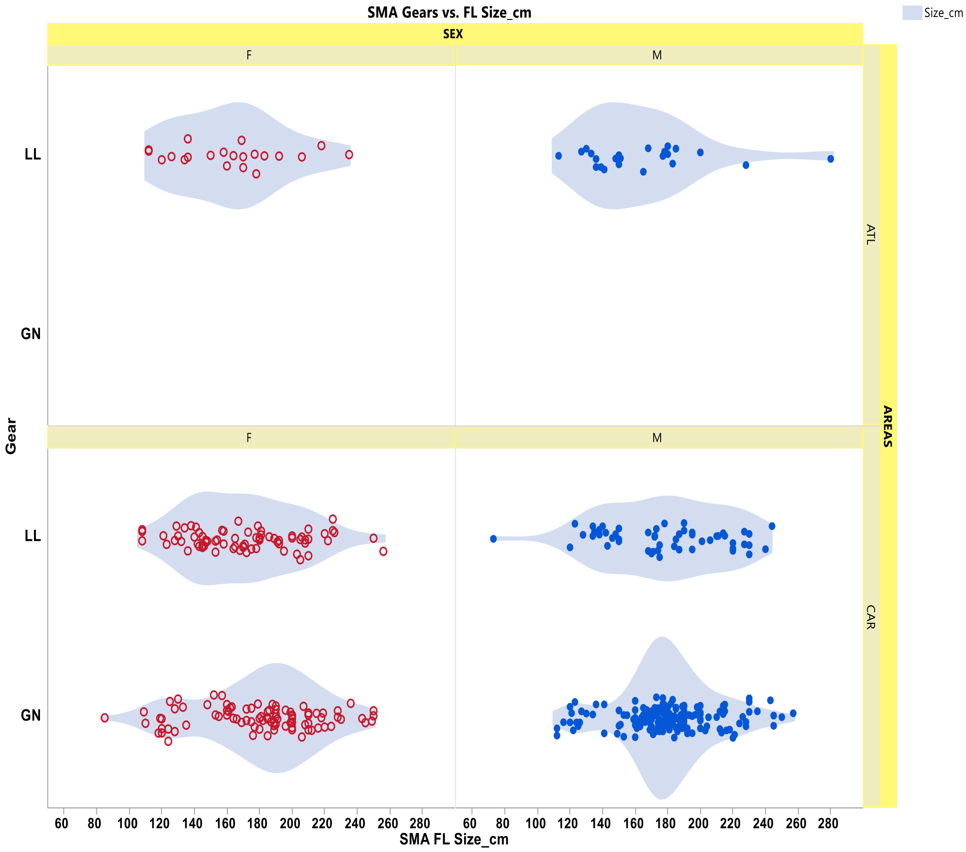

Figure 6. Sex specific size distribution of shortfin mako shark (*Isurus oxyrinchus*) by areas and gears caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

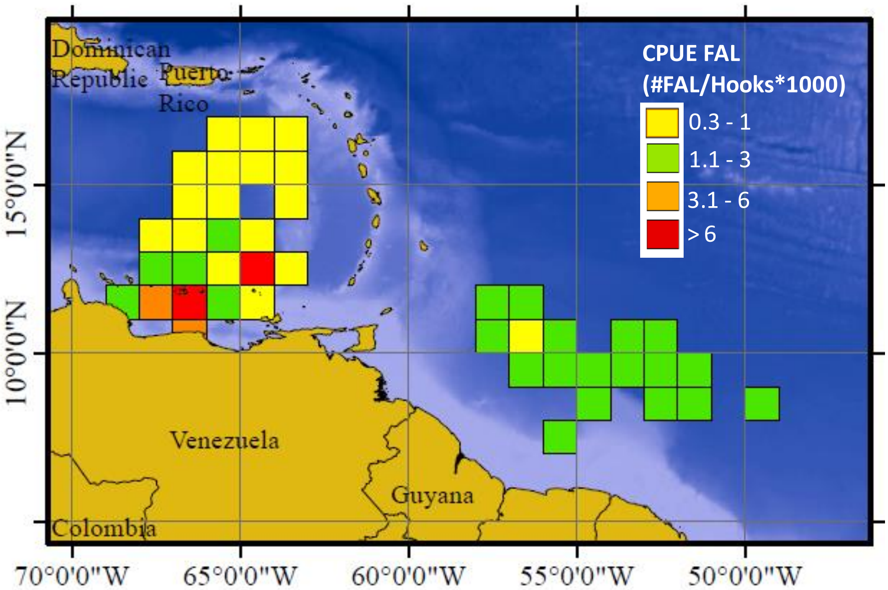

Figure 7. Overall spatial distribution of silky shark (*Carcharhinus falciformis*) nominal catch rates during 1994-2015, from observed sets.

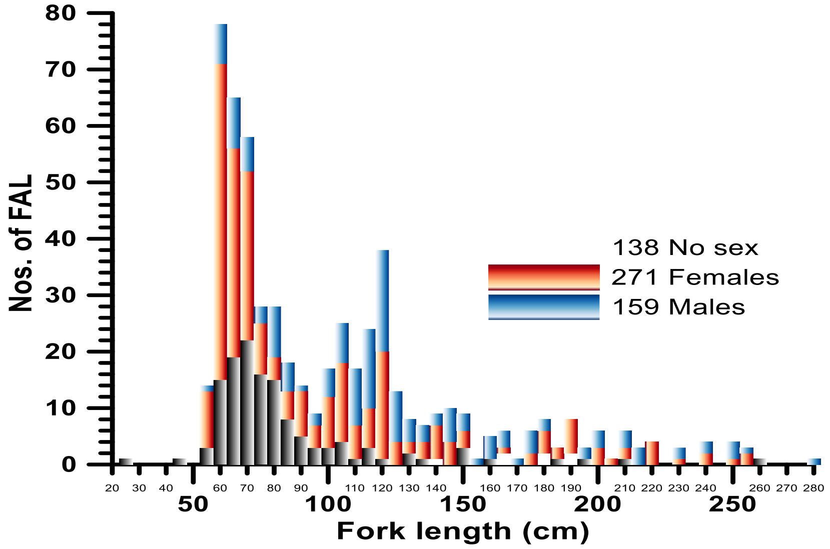

Figure 8. Size frequency distribution of silky shark (*Carcharhinus falciformis*) caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

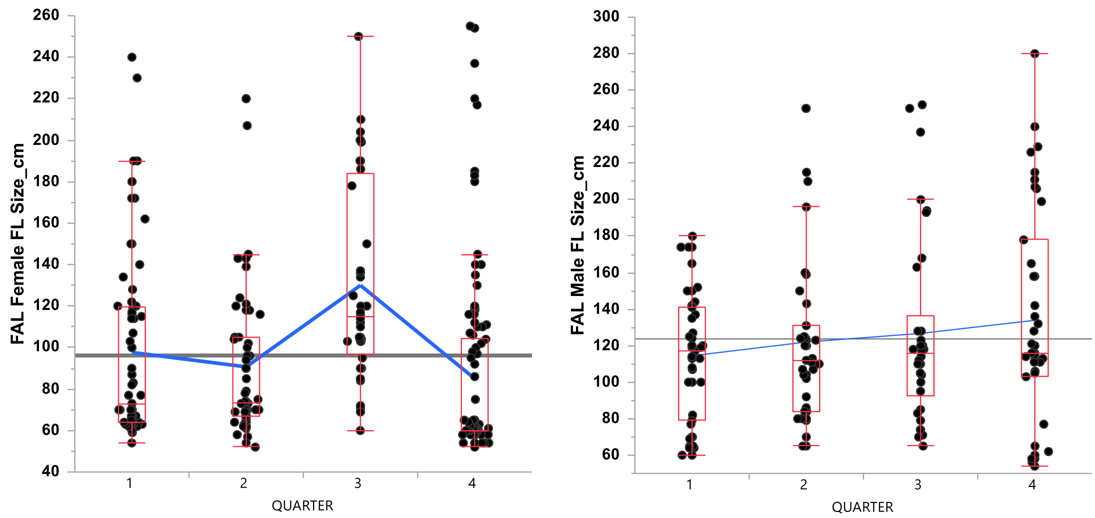

Figure 9. Seasonal time series for all years combined of female (left) and male (right) silky shark (*Carcharhinus falciformis*) size (FL) expressed as a median with the interquartile range (25% qt–75% qt) from individuals caught during the period of study. The grey line represents the grand mean and the blue line connects the quarterly means.

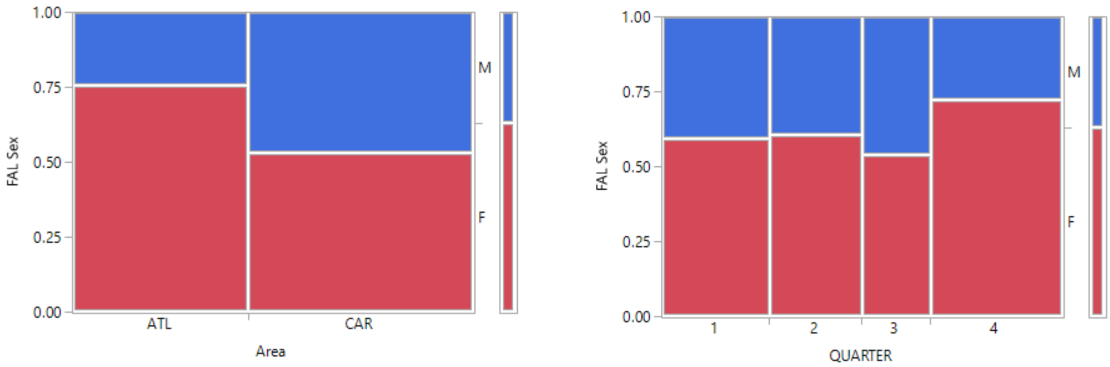

Figure 10. Sex ratio by area, and season of silky shark (*Carcharhinus falciformis*) during the study period. Male (blue) and female (red).

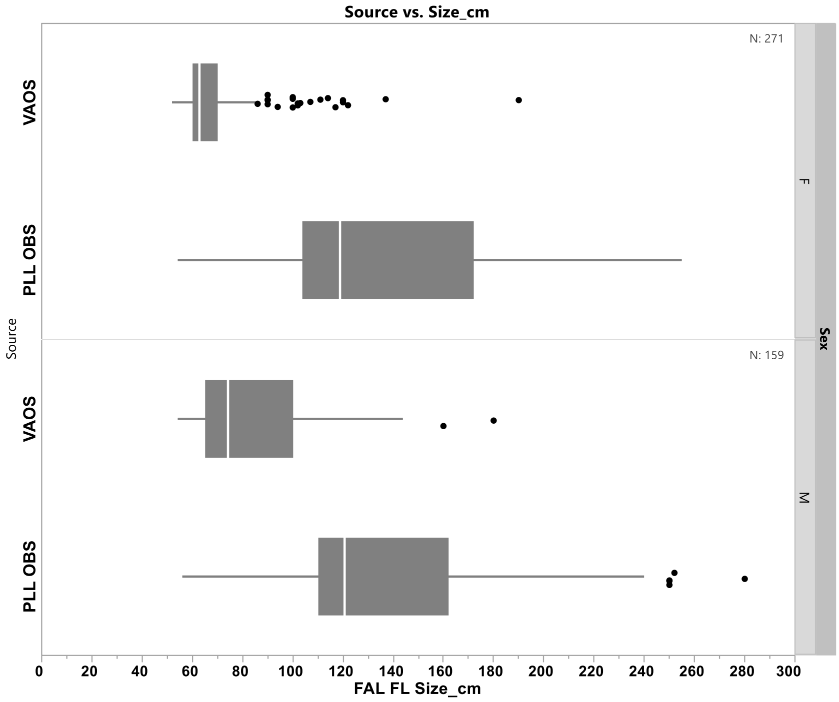

Figure 11. Sex specific size distribution of silky shark (*Carcharhinus falciformis*) by fisheries (industrial *vs* artisanal) caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

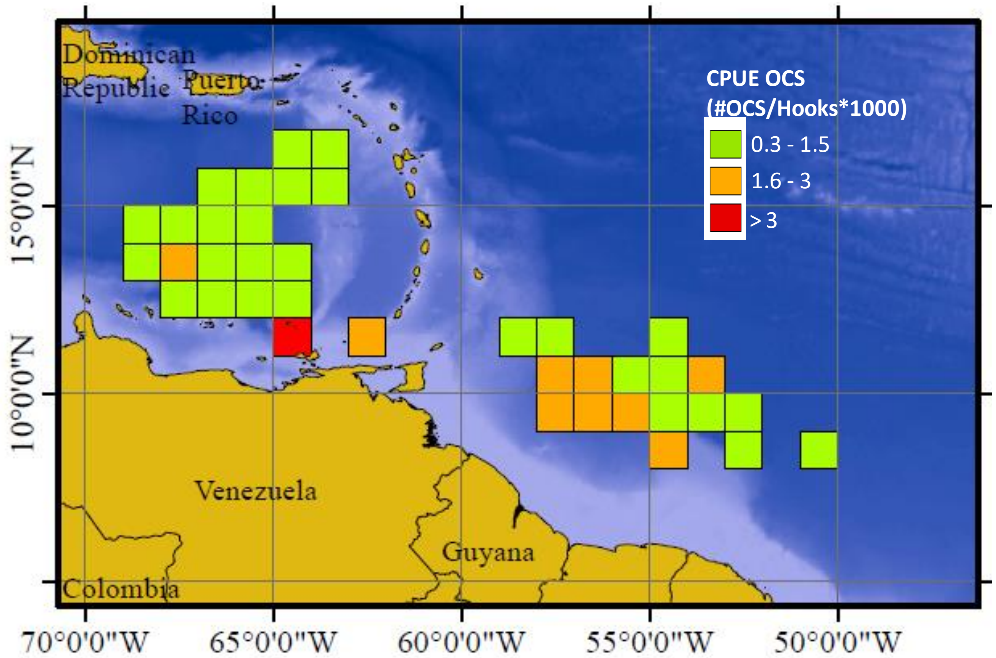

Figure 12. Overall spatial distribution of oceanic whitetip shark (*Carcharhinus longimanus*) nominal catch rates during 1994-2015, from observed sets.

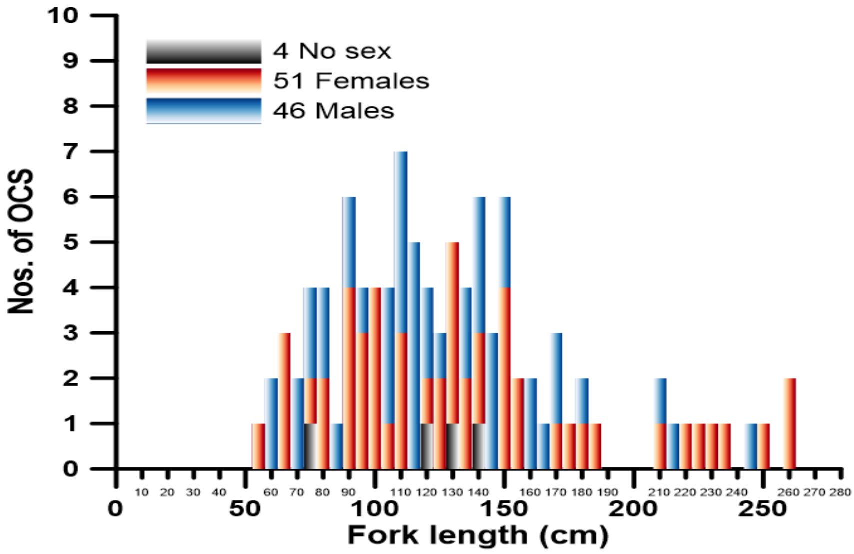

Figure 13. Size frequency distribution of oceanic whitetip shark (*Carcharhinus longimanus*) caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

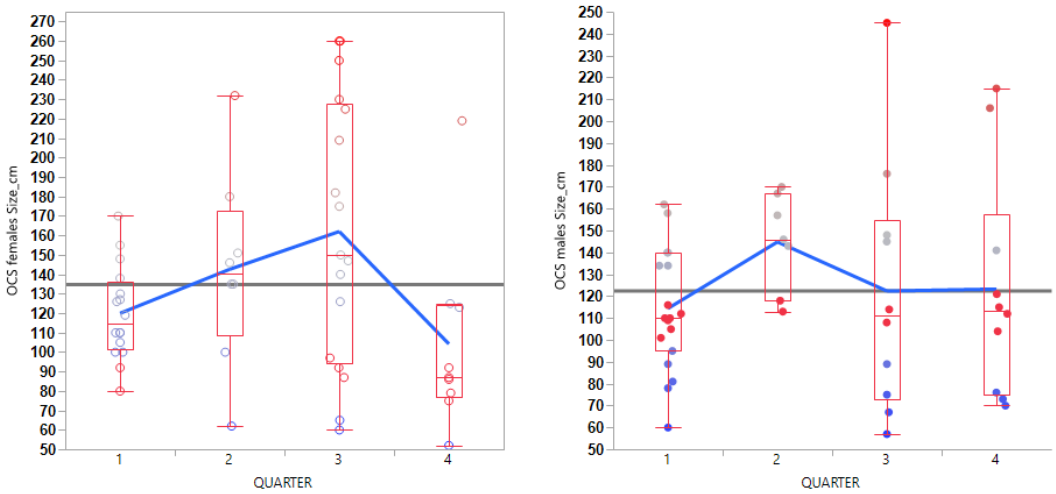

Figure 14. Seasonal time series for all years combined of female (left) and male (right) oceanic whitetip shark (*Carcharhinus longimanus*) size (FL) expressed as a median with the interquartile range (25% qt–75% qt) from individuals caught during the period of study. The grey line represents the grand mean and the blue line connects the quarterly means.

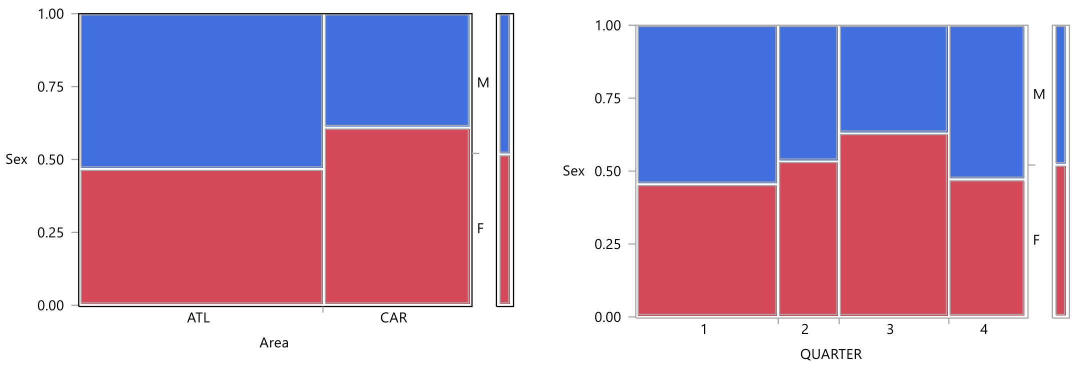

Figure 15. Sex ratio by area, and season of oceanic whitetip shark (*Carcharhinus longimanus*) during the study period. Male (blue) and female (red).

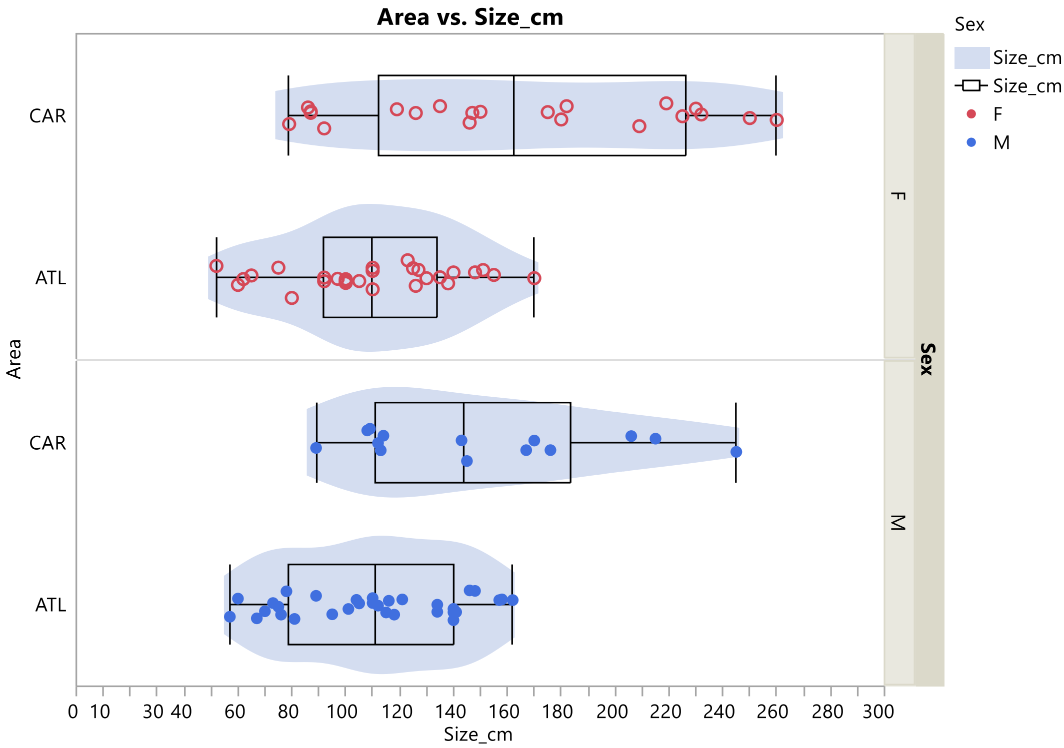

Figure 16. Sex specific size distribution of oceanic whitetip shark (*Carcharhinus longimanus*) by areas caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

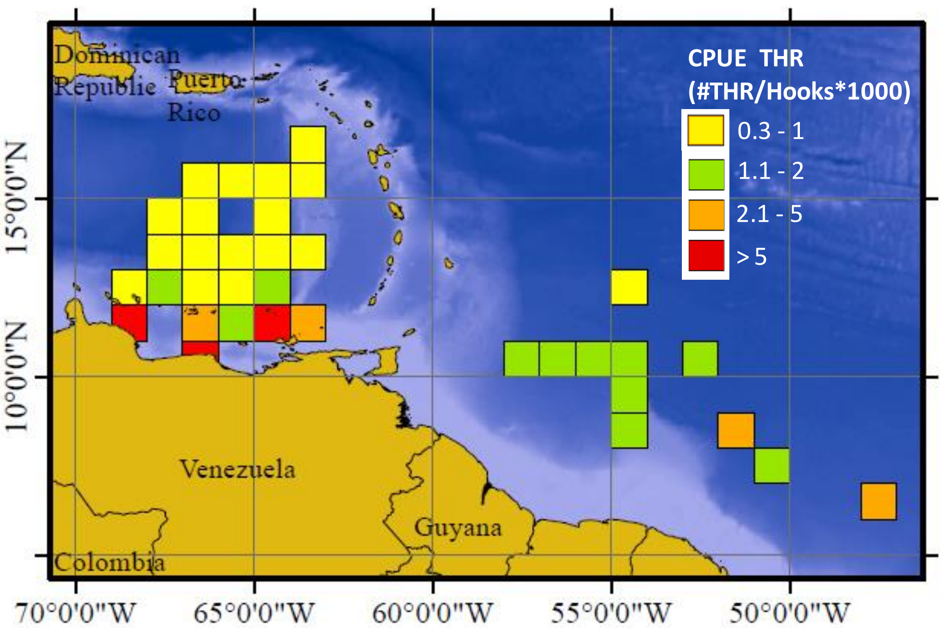

Figure 17. Overall spatial distribution of thresher sharks (*Alopias spp.*) nominal catch rates during 1994-2015, from observed sets.

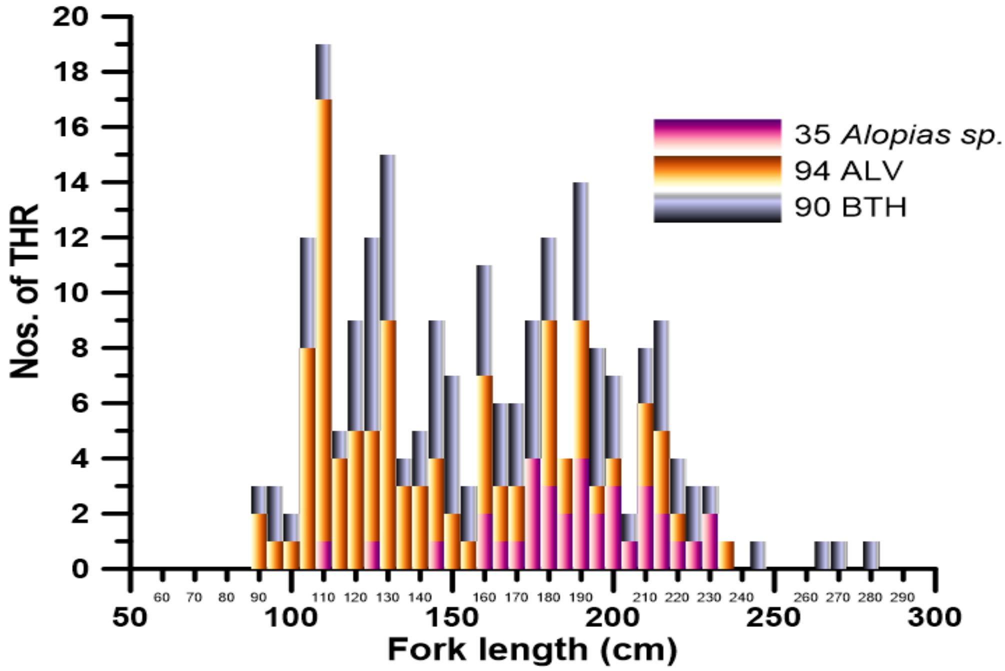

Figure 18. Size frequency distribution of thresher sharks caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

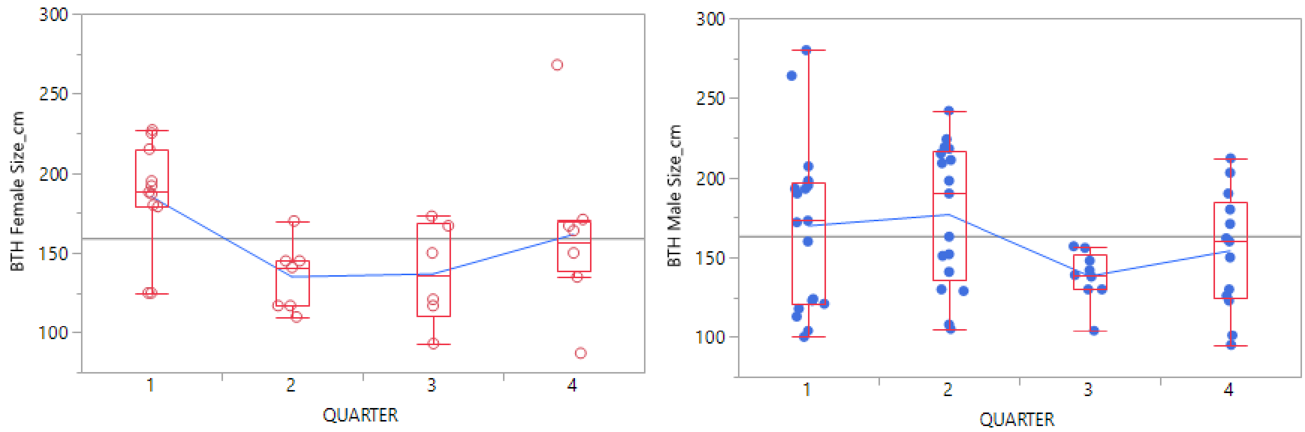

Figure 19. Seasonal time series for all years combined of female (left) and male (right) bigeye thresher sharks (*Alopias superciliosus*) size (FL) expressed as a median with the interquartile range (25% qt–75% qt) from individuals caught during the period of study. The grey line represents the grand mean and the blue line connects the quarterly means.

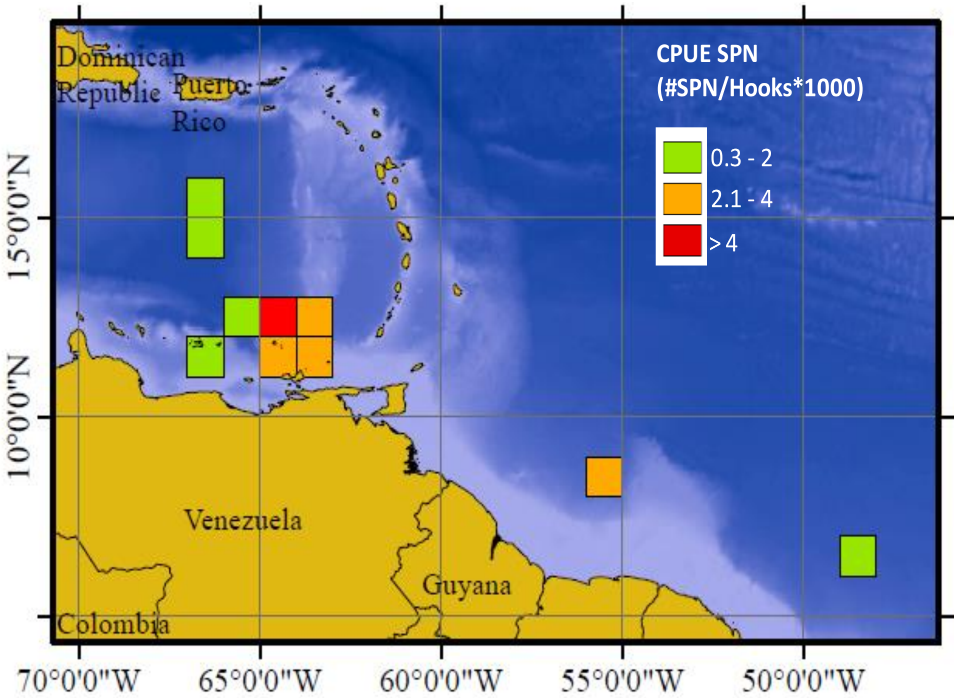

Figure 20. Overall spatial distribution of hammerhead sharks (*Sphyrna spp.*) nominal catch rates during 1994-2015, from observed sets.

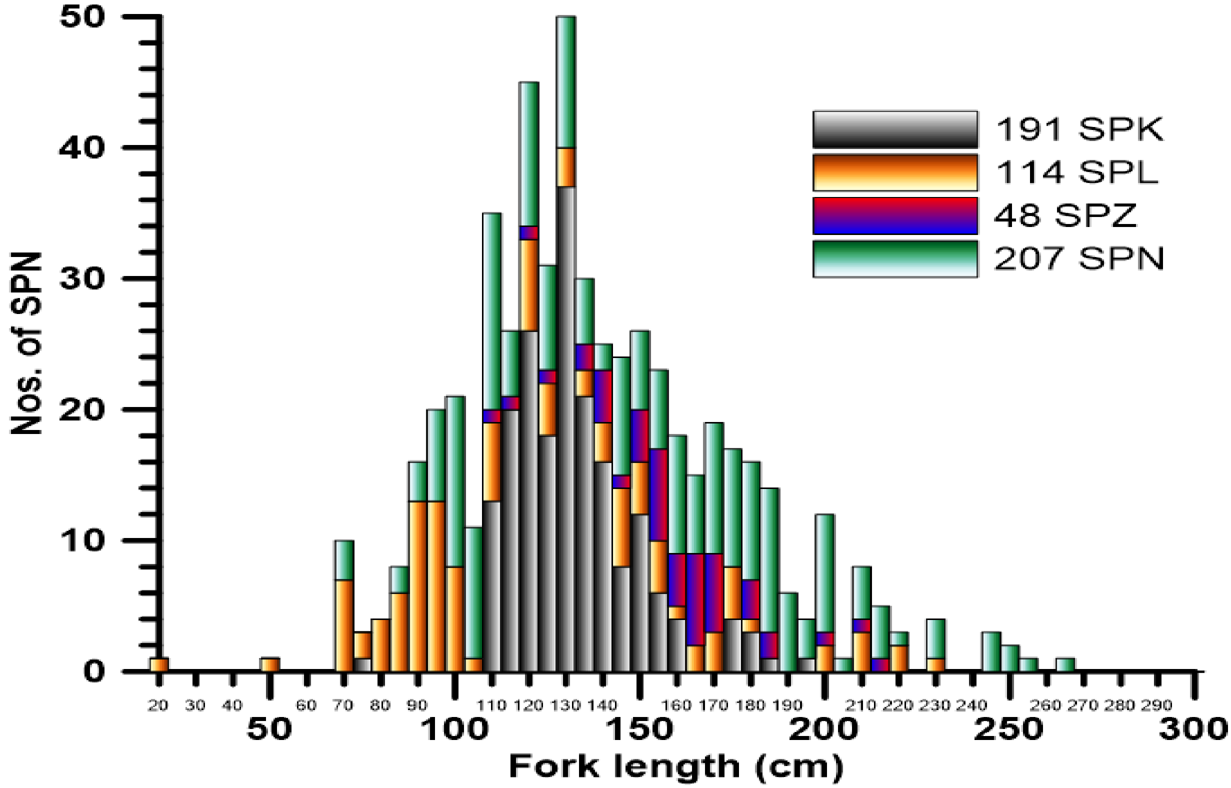

Figure 21. Size frequency distribution of hammerhead sharks caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.

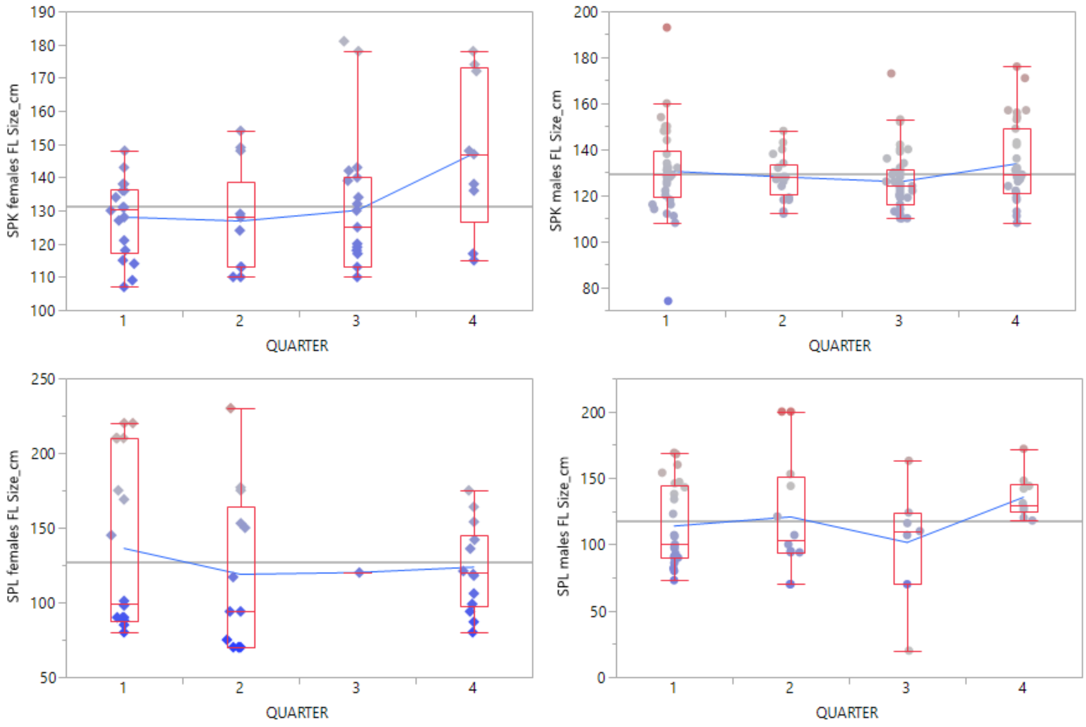

Figure 22. Seasonal time series for all years combined of female (left) and male (right) SPK (*S. mokarran*) and SPL (*S. lewini*) size (FL) expressed as a median with the interquartile range (25% qt–75% qt) from individuals caught during the period of study. The grey line represents the grand mean and the blue line connects the quarterly means.

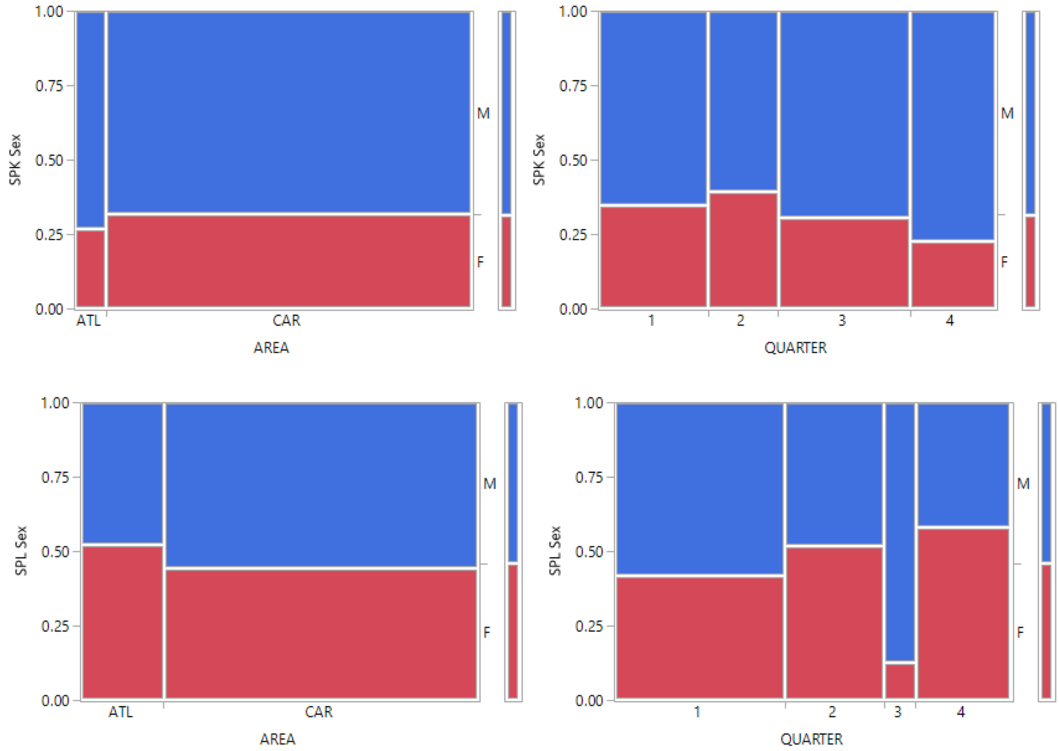

Figure 23. Sex ratio by area, and season of SPK (*S. mokarran*) and SPL (*S. lewini*) during the study period. Male (blue) and female (red).

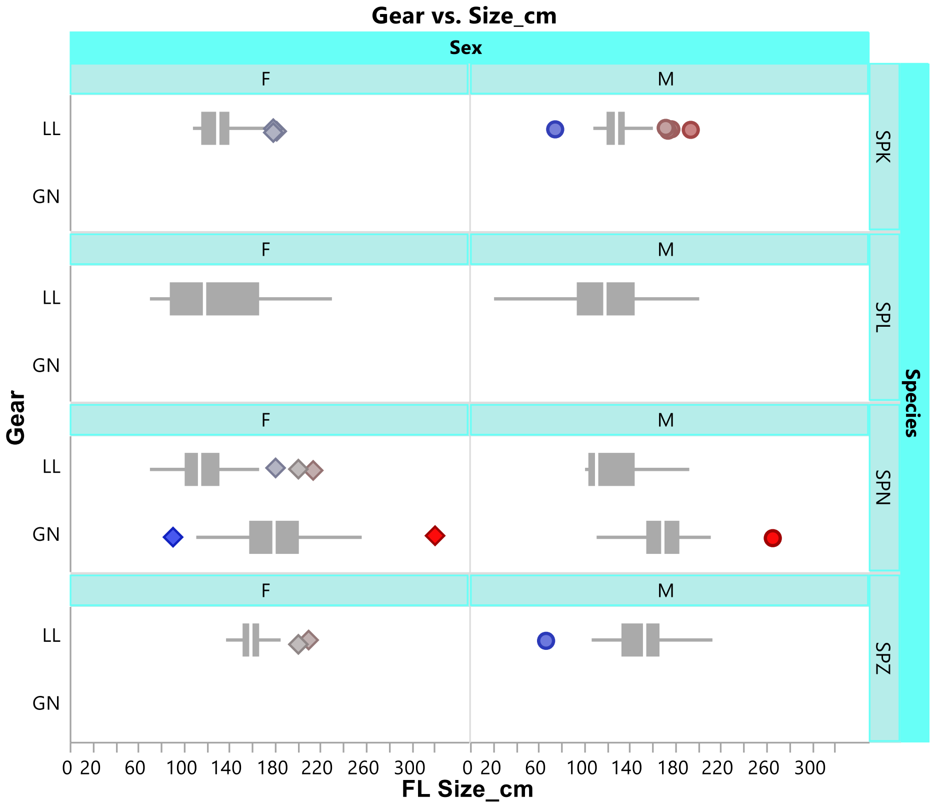

Figure 24. Sex specific size distribution of hammerhead sharks by gears and species caught by the observed Venezuelan large pelagic fisheries in the Caribbean Sea and adjacent Atlantic waters during 1994-2015.