Received: 18 October, 2011

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PRELIMINARY OBSERVATIONS ON THE BY-CATCH OF ELASMOBRANCHS CAUGHT BY THE PORTUGUESE LONGLINE FISHERY IN THE INDIAN OCEAN: BIOLOGY, ECOLOGY AND FISHERY.

Miguel N. Santos[1,*], Pedro G. Lino[1], Joana Fernandez-Carvalho[1] & Rui Coelho[1,2]

SUMMARY

This paper provides an overview of the elasmobranch by-catch in the Portuguese longline fishery targeting swordfish that operates in the Indian Ocean. Several elasmobranch species are captured by this fishery, the blue shark (*Prionace glauca*) and the shortfin mako (*Isurus oxyrinchus*) being the most commonly captured species. The analysis for this paper was based on data from historical fishery information that has been recently recovered by *IPIMAR*, since the early 2000's to the present date, which included landing data and skipper logbooks. Geographical location is available from VMS data between 2006 and 2010 that was also integrated in the analysis. The trends in the catch rates and sizes of the mako and blue shark were analyzed and compared in terms of location and seasonality, allowing spatial-temporal comparisons. In terms of location, blue shark catch rates tend to be higher towards southern latitudes, while shortfin mako is more widely spread in the region. The sizes of shortfin mako also vary considerably in terms of seasonally and location, with larger specimens tending to be captured in January-February towards eastern longitudes of the Indian Ocean.

KEYWORDS: By-catch, longline fisheries, pelagic elasmobranchs, spatial-temporal trends.

1: Instituto de Investigação das Pescas e do Mar (IPIMAR), Av. 5 de Outubro s/n, 8700-305 Olhão, PORTUGAL
2: Centro de Ciências do Mar (CCMAR), Univ. Algarve, Campus de Gambelas Ed 7, 8005-139 Faro, PORTUGAL
*: Corresponding author e-mail: mnsantos@ipimar.pt

1. Introduction

Pelagic shark species are commonly by-catch in pelagic longline fisheries (e.g. Buencuerpo et al. 1998; Petersen et al. 2009; Simpfendorfer et al. 2002) but still, information on their life history, population parameters and the effects of fisheries on these populations is limited. Elasmobranchs in general have K-strategy life cycles, characterized by slow growth rates and long lives, and reduced reproductive potential with few offspring and late maturity. The natural mortality rates are usually low, and increased fishing mortality may have severe consequences on these populations (Smith et al., 1998; Stevens et al., 2000).

The Portuguese pelagic longline fishery in the Indian Ocean started in the late 1990's and has traditionally targeted swordfish, even though it also catches relatively high quantities of sharks as by-catch. The aims of this paper are therefore to present preliminary observations regarding the by-catch of elasmobranchs caught by this fleet in the Indian Ocean.

2. Material and methods

2.1. Data collection

Currently, several catch and effort databases are being reconstructed and analyzed from the Portuguese fisheries vessels targeting swordfish in the Indian Ocean. These include: 1) landing data recorded by the Portuguese Fisheries authorities (official logbooks); 2) historical and current skipper logbooks (self reporting); and 3) fishery observer data. Additionally, a Vessel Monitoring System (VMS) was implemented in this fleet in the early 2000's, and the data is currently being processed.

Landings data is available between 1998 and 2010, with the major targeted species recorded for total weight per fishing set. For elasmobranchs, information is mainly available for the blue shark (BSH, *Prionace glauca*) and the shortfin mako (SMA, *Isurus oxyrinchus*). Effort information is usually available (number of hooks), and the location of the fishing sets is categorized in FAO statistical regions. The precise location of the fishing sets was accessed by integrating VMS data, filtered and processed for 4,004 sets that took place between 2006 and 2010 (representing 82.2% of the fishing sets with catch and effort data during those years).

Logbook data was recorded and reported voluntarily by vessel skippers. These logbooks have usually more detailed information regarding the catch, effort and location than official logbooks. For some species (such as the shortfin mako within the elasmobranchs) detailed individual specimen information is usually recorded. This historical fishery information is currently being recovered and compiled by *IPIMAR*, and currently comprises information from 1,941 longline sets that took place between

2001 and 2010, representing 20.3% of the total fishing sets carried out by the Portuguese fleet in the Indian Ocean during those years.

The fishery observer program in the Indian Ocean started recently, and currently has information from one trip that took place between May and September 2011, where a total of 103 sets were carried out. In terms of biological information, the fishery observers collect detailed information on the species, sizes, weight, sex, maturity, condition (captured alive or dead) and fate (retained, discarded alive or discarded dead) of most elasmobranchs caught per fishing set. Additional information recorded on each set included the date, effort (number of hooks) and location.

2.2. Data analysis

The records of the numbers of Portuguese fishing vessels licensed to operate with longlines in the Indian Ocean, as well the number of active vessels per year are presented. The total fishing effort in terms of the hooks deployed by the fishery was analyzed by year and fishing area. For this analysis the VMS data currently available between 2006 and 2010 was used. A 5x5 grid was created for the region, and the evolution of the effort during those years was plotted and analyzed in ArcGIS.

For the mako and the blue sharks the mean nominal catch rate (biomass) in each cell of the 5x5 grid was calculated and plotted. The effects of seasonality on the catch rates were analyzed, and compared with non-parametric Kruskal-Wallis rank sum tests. Data was tested for normality with a Kolmogorov–Smirnov test (with Lilliefors correction) and for homogeneity of variances between groups with Levene tests.

For the shortfin mako, individual specimens recorded by the skipper logbooks were analyzed. The individual specimens are usually recorded in trunk weight (TW in kg, corresponding to the cleaned weight of the sharks without the head, viscera, belly and fins), that were then converted into round weight (RW, kg) and then to fork length (FL, cm) using the following equations:

TW=(a)*RW; a=0.71 (IPIMAR, *unpublished data*).

$RW = (a)*FL^{(b)}$; $a = 5.2432*10^{-6}$; $b = 3.1407$ (Kohler *et al.*, 1995).

The mean sizes captured per month were plotted and compared with a Kruskal-Wallis non-parametric rank sum test. The data was tested for normality with a Kolmogorov–Smirnov test (with Lilliefors correction) and for homogeneity of variances with Levene tests. Univariate Generalized Additive Models (GAMs) were created to analyze and plot non-linear effects of both latitude and longitude in the sizes of the captured specimens. For these models the response variable considered was the log-transformed size of the specimen, and the explanatory variables were the latitude and longitude. The errors distribution was assumed to be normal with an identity link function, which seems adequate as the response variable was log-transformed prior to the analysis.

Statistical analysis for this paper was carried out with the R Project for Statistical Computing version 2.13.0 (R Development Core Team 2011). Most analysis carried out is available under the core R program, except the Levene tests for homogeneity of variances that used library "car" (Fox & Weisberg 2011), and the GAM plots that were created with library "gam" (Hastie 2011).

3. Results and Discussion

3.1. Fishing effort in the Indian Ocean

The Portuguese fishing fleet operating in the Indian Ocean consists only of pelagic longliners. The number of fishing licenses increased during the 2000's, having reached a maximum of 24 vessels in 2009 (**Figure 1**). However, only a minor fraction of the fleet was active in the Indian Ocean, the years 2006 and 2007 being those with the higher number of active vessels (**Figure 1**).

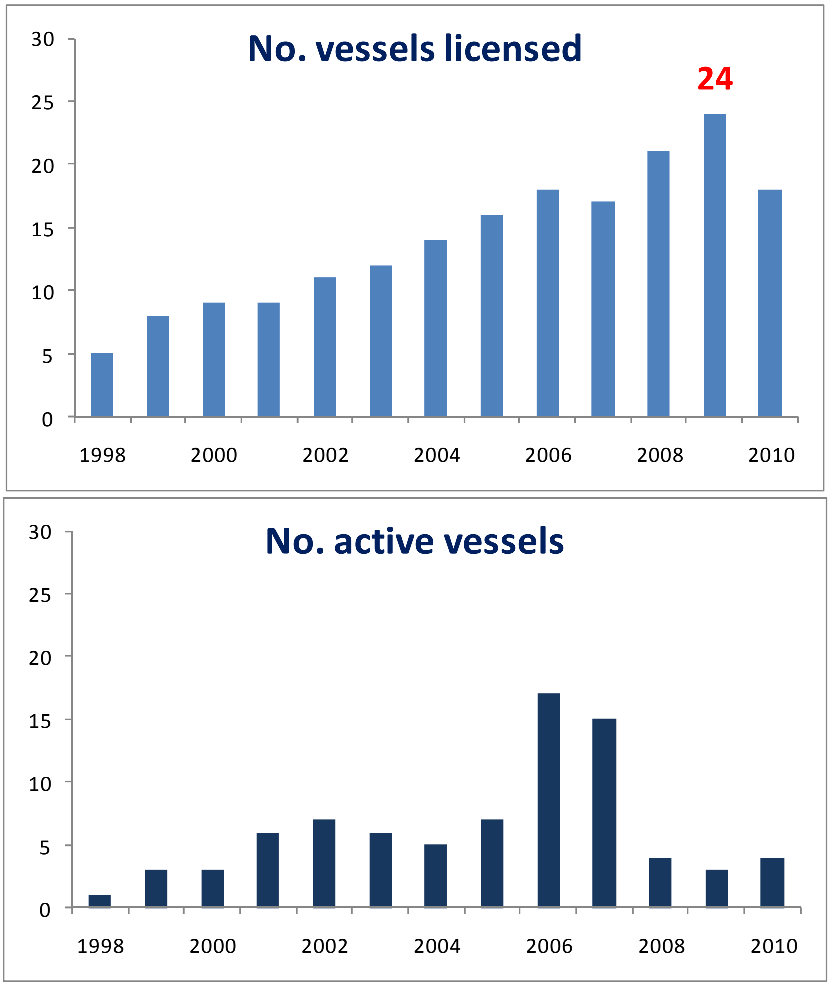

Figure 1: Number of Portuguese longline fishing vessels licensed to operate in the Indian Ocean (top) and number of active vessels (bottom) between 1998 and 2010.

In terms of location of the fishing effort, and using fishing sets with VMS location incorporated in the catch and effort data (analysis between 2006-2010, see paper IOTC–2011–WPEB07–36 for more details on VMS data processing), it is noticeable that there has been some significant changes in the location of the effort. Overall, most sets carried out by the Portuguese longline fleet took place in the western area of the Indian Ocean, even though there was a wide longitudinal dispersion (**Figure 2**). When a yearly specific analysis was carried out, it was interesting to note that during 2006 and 2007 the effort was more widely spread in terms of longitude, but then during 2008, 2009 and particularly 2010 it was noticeable a concentration of effort in the Western region (**Annex I**). This shift in effort observed in the recent years was due to increasing fuel costs and increasing concerns with safety (high seas piracy). It is worth note that these effort data should be considered as preliminary, as the catch and effort databases are not fully completed and are currently being updated with additional information.

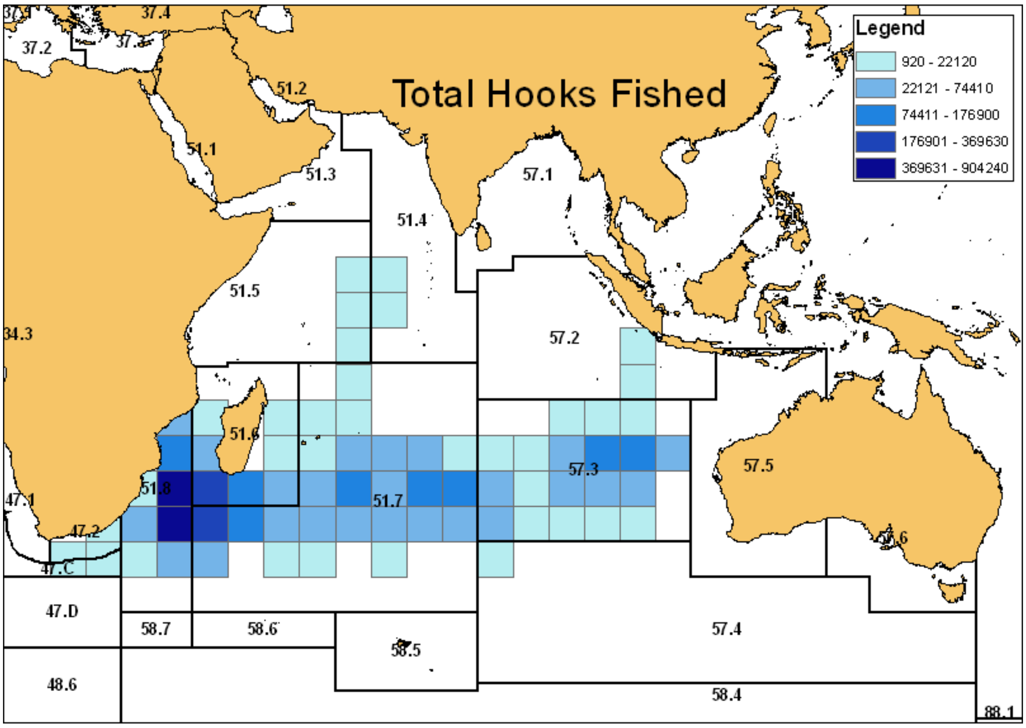

Figure 2: Distribution of the effort (number of hooks) carried out by the Portuguese pelagic longline fishery in the Indian Ocean between 2006 and 2010.

3.2. Effect of location in the catch rates of mako and blue shark

There seem to be important spatial differences in the catch rates of both shortfin mako and blue shark in the Indian Ocean. For the blue shark there seems to be higher catch rates towards southern latitudes and two peaks in terms of longitude (**Figure 3**), while for the shortfin mako the catch rates seem to be more widely spread across the region (**Figure 4**).

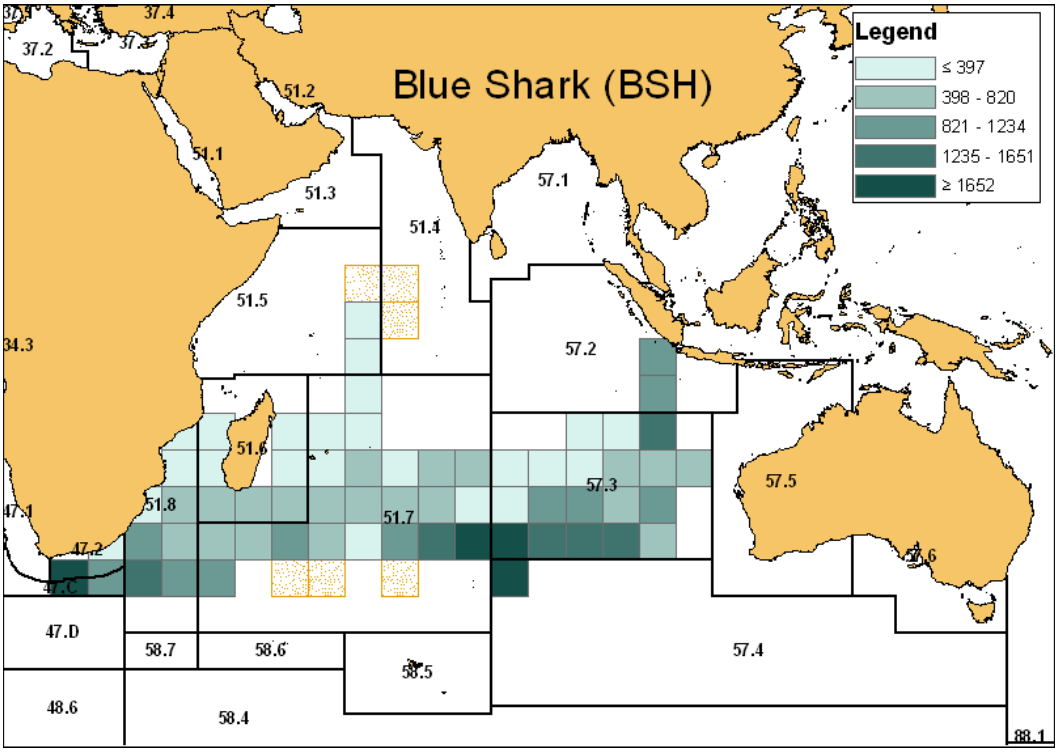

Figure 3: Catch rates (kg/1000 hooks) of blue shark captured by the Portuguese longline fishery in the Indian Ocean between 2006 and 2010. Grid cells with yellow dots represent areas with no catches for this species.

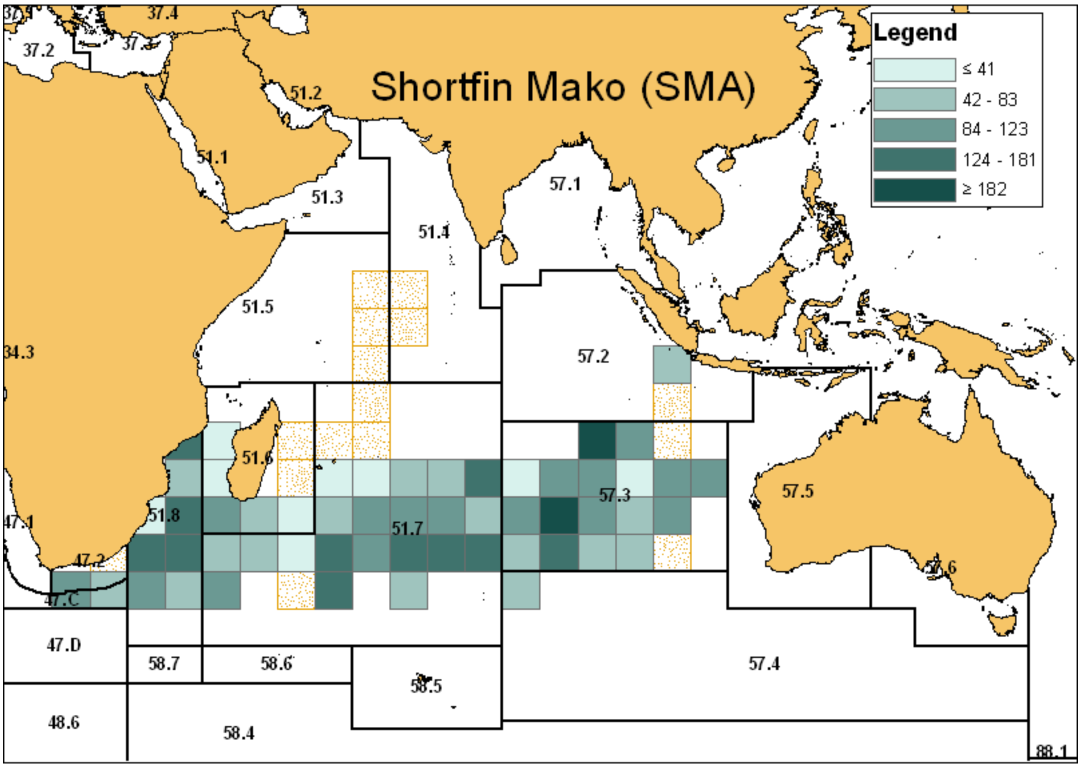

Figure 4: Catch rates (kg/1000 hooks) of shortfin mako shark captured by the Portuguese longline fishery in the Indian Ocean between 2006 and 2010. Grid cells with yellow dots represent areas with no catches for this species.

3.3. Effects of seasonality on the catch rates of mako and blue shark

There was a significant seasonal (monthly) variation in the catch rates of both shark species. Blue sharks tend to be captured in higher catch rates in January, followed by a progressive decrease until October, followed again by an increase until December (**Figure 5**). For the shortfin mako, there seems to be two annual peaks in the catch rates, with higher catch rates in May-June, and then again later in the year during December (**Figure 5**). It is interesting to compare these results to a prior analysis carried out for the blue shark in the North Atlantic, where blue shark dominates the catches for most of the time (from December to August), showing an increase from September to May (Santos *et al.*, 2002).

For both species the observed differences were statistically significant (Kruskal-Wallis: BSH: $Chi^2 = 770.2$, df = 11, p-value < 0.001; SMA: $Chi^2 = 79.8$, df = 11, p-value < 0.001). Non-parametric Kruskal-Wallis tests were used because the data was not normally distributed (Lilliefors: BSH: D = 0.169, p-value < 0.001; SMA: D = 0.227, p-value < 0.001), and the variances were heterogeneous (Levene test: BSH: F = 41.84, df = 11, p-value < 0.001; SMA: F = 4.92, df = 11, p-value < 0.001).

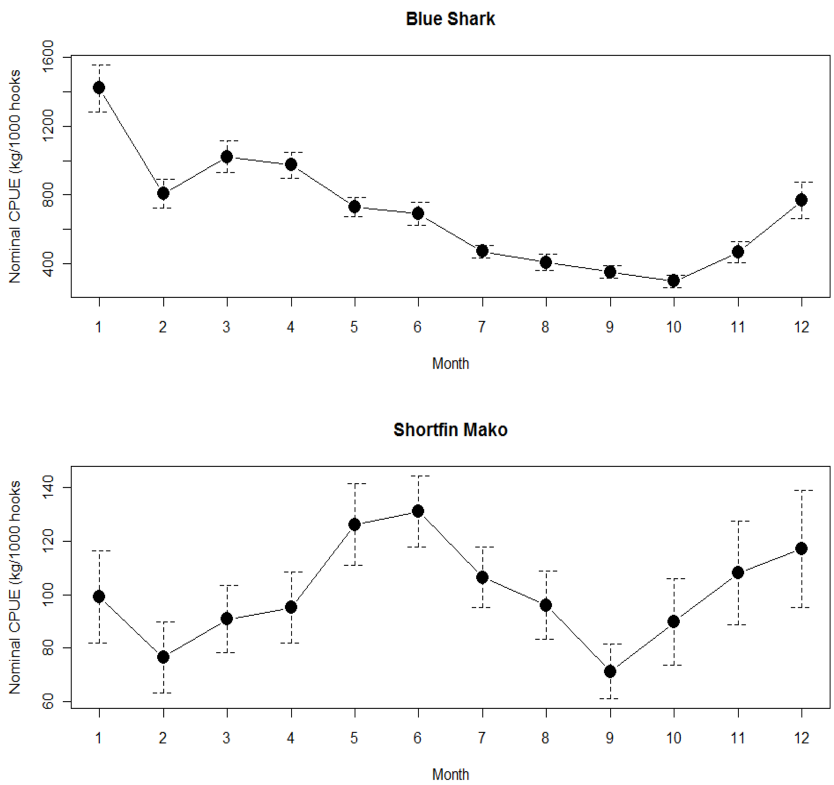

Figure 5: Monthly variations in the mean catch rate (nominal CPUE, kg/1000 hooks) of blue shark and shortfin mako captured by the Portuguese longline fleet in the Indian Ocean between 2006 and 2010.

3.4. Effect of seasonality and location on the sizes of mako sharks

There are significant seasonal variations in the sizes of the shortfin mako sharks captured by the Portuguese fleet in the Indian Ocean. Smaller sizes tend to be captured mainly during July and September, while the larger specimens were captured mainly in January and February (**Figure 6**). The observed differences in the monthly sizes were significant (Kruskal-Wallis: $Chi^2 = 388.7$, df = 11, p-value < 0.001). Non parametric Kruskal-Wallis tests were used because the data was not normally distributed (Lilliefors: D = 0.0808, p-value < 0.001) and the variances were heterogeneous (Levene test: F = 4.39, df = 11, p-value < 0.001).

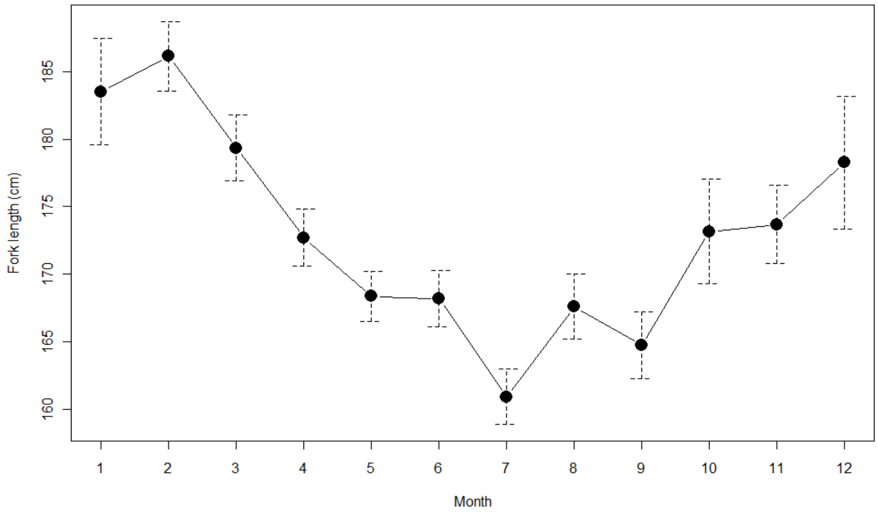

Figure 6: Monthly variations in the mean size of shortfin mako sharks captured by the Portuguese longline fleet in the Indian Ocean.

It was also interesting to note that the shortfin mako sizes varied considerably with the fishing location in terms of latitude and longitude. The relationship with longitude was almost linear, with a tendency for decreasing specimen sizes towards western longitudes (**Figure 7**). With regards to the latitude, larger specimens were captured both at higher latitudes and towards the tropics, with smaller specimens caught around the 30ºdegrees S latitude (**Figure 7**).

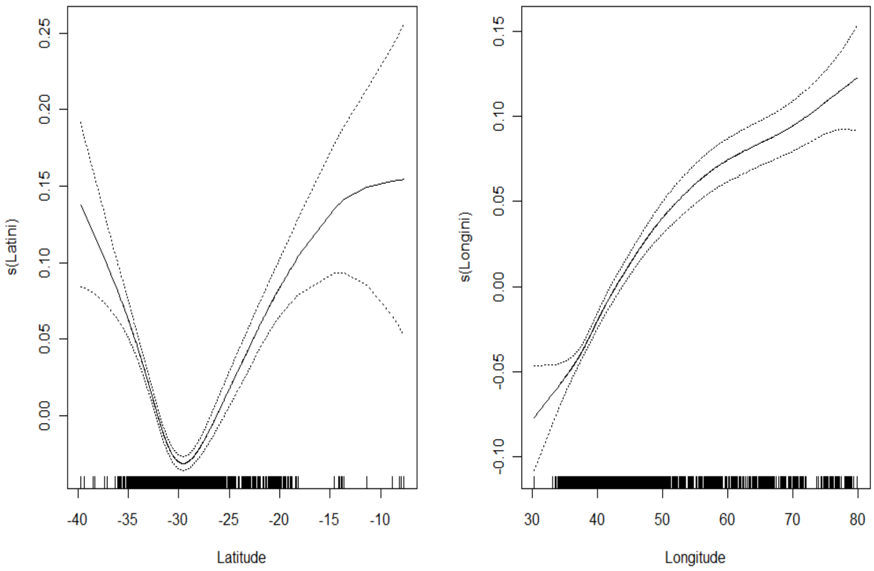

Figure 7: GAM plots with the univariate non-linear effects of latitude and longitude on shortfin mako sizes captured by the Portuguese longline fleet in the Indian Ocean. The error lines represent the standard errors. Vertical bars in the bottom represent number of observations.

4. Acknowledgments

Data was collected within the EU Data Collection Framework. VMS data was collected by the "Sistema integrado de informação e apoio à vigilância, fiscalização e controlo da actividade da pesca - DGPA/SIFICAP-MONICAP". Joana Fernandez-Carvalho was supported by a grant from FCT, the Portuguese Foundation for Science and Technology (Ref: BD 60624 /2009). Rui Coelho was partially supported with a grant from FCT (Ref: BDP 40523 / 2007) co-funded by "POCI-2010 - Programa Operacional Ciência e Inovação 2010" and "FSE - Fundo Social Europeu". Rui Coelho would like to acknowledge the EU Commission (DG MARE) for supporting his attendance at the Working Party on Ecosystem and By-catch meeting to present this paper.

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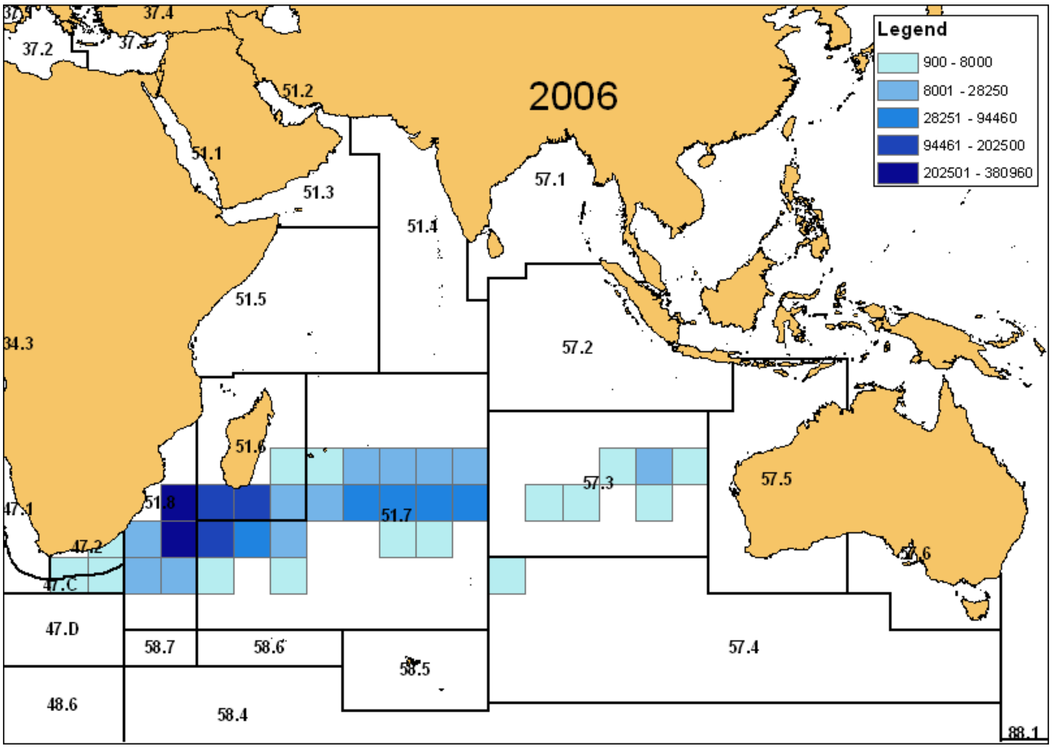
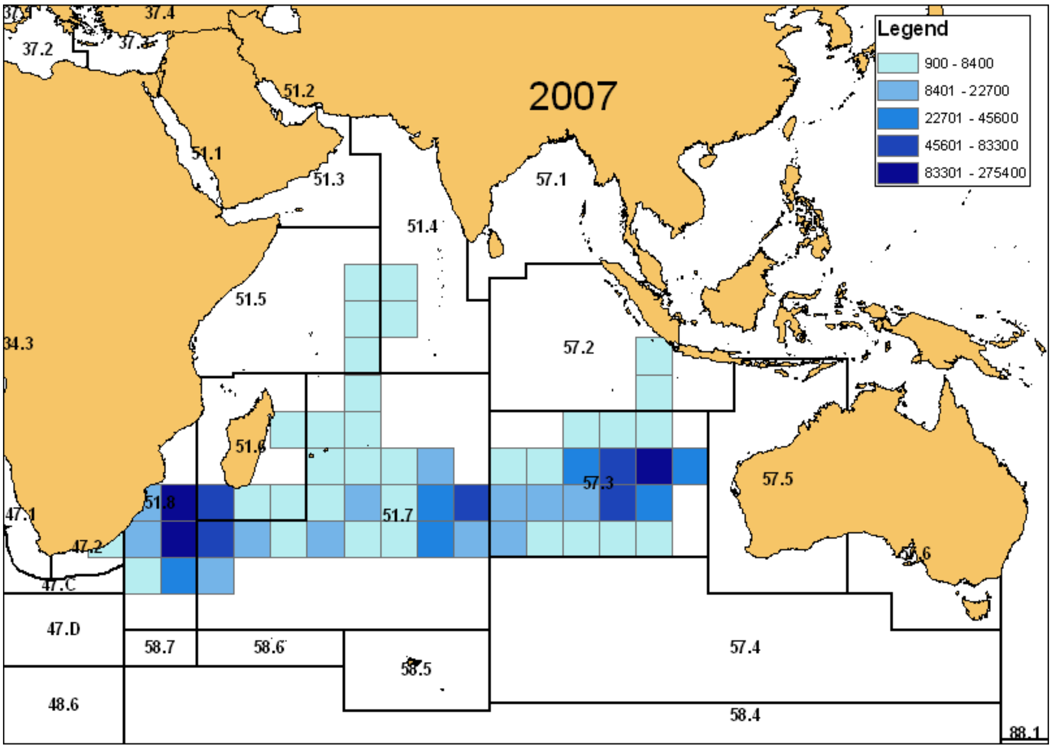
Annex I: Provisional maps with the relative effort (hooks by year) of the Portuguese pelagic longline fishery in the Indian Ocean between 2006 and 2010. A grid of 5x5 degrees was created and the yearly relative effort was plotted using Jenks natural breaks, with darker colors representing higher fishing effort.





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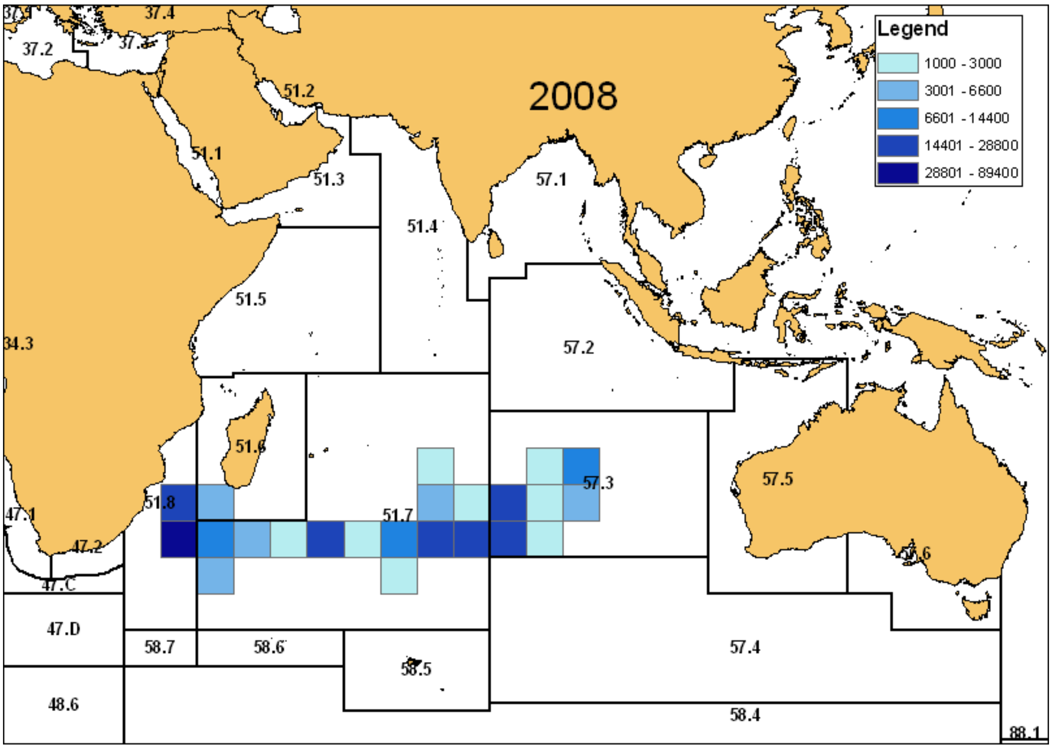

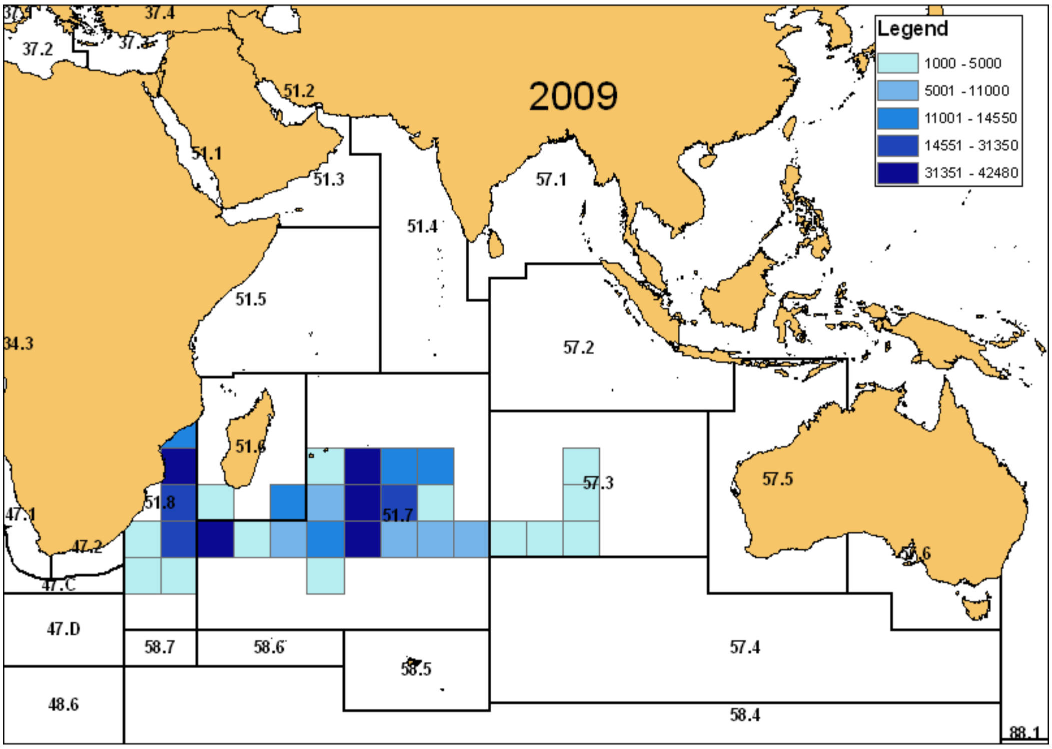

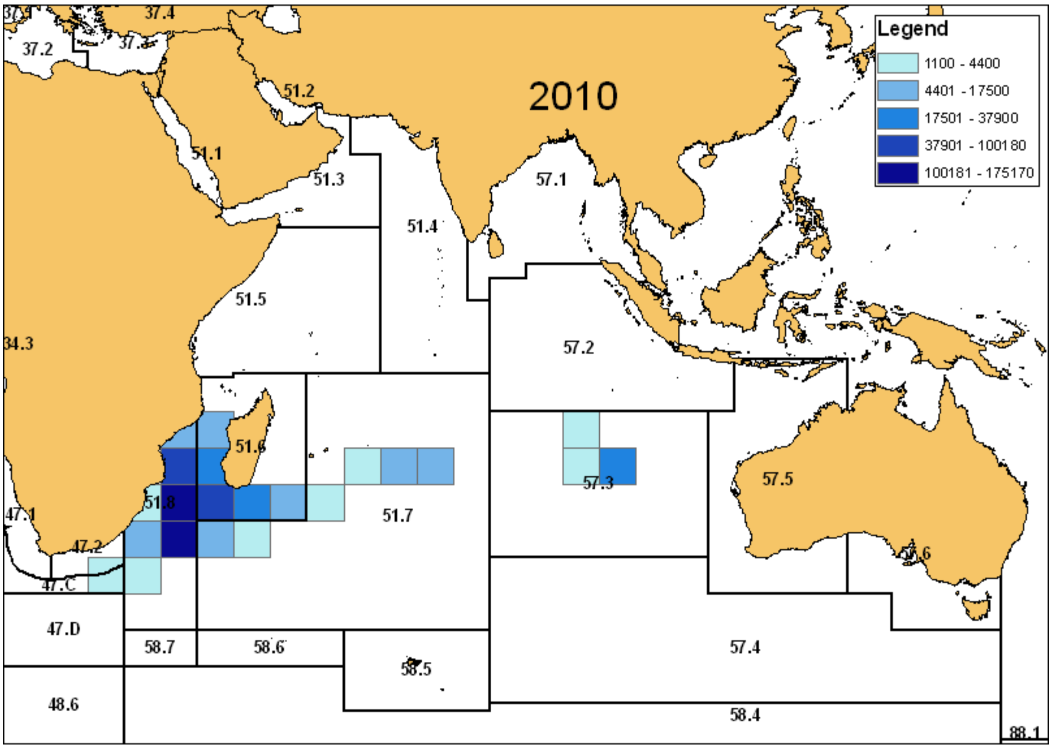
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