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UPDATE OF BLUE SHARK CATCHES AND STANDARDIZED CPUE FOR THE PORTUGUESE PELAGIC LONGLINE FLEET IN THE INDIAN OCEAN: EXPLORING THE EFFECTS OF TARGETING.

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SUMMARY

The Portuguese pelagic longline fishery in the Indian Ocean started in the late 1990's, targeting mainly swordfish in the southwest region. A effort has been made by the Portuguese Institute for the Ocean and Atmosphere (IPMA) over the last years to collect of historical catch and effort data on this fishery since it started in the late 1990's to the present date, as well as vessel monitoring system (VMS) data. This working document analyses the catch, effort, nominal and standardized CPUE trends for blue shark captured by this fishery, and explores the use of targeting effects in the CPUE standardization process. Nominal annual CPUEs were calculated in biomass (kg/1000 hooks), and were standardized with Generalized Linear Mixed Models (GLMMs) using year, quarter, season, targeting, and area:season interactions as fixed effects, and vessel as random effects. Model goodness-of-fit and comparison was carried out with the Akaike Information Criteria (AIC), and model validation with residual analysis. The use of targeting effects was tested in a sensitivity analysis comparing: 1) using blue shark/swordfish ratios; 2) using targeting defined by cluster analysis and 3) removing the targeting effects. The final selected model used target based on ratios. The standardized CPUE trends shows a general decrease in the initial years between 2000 and 2005, followed by an increase until 2008, and then another general decrease in the more recent years until 2014. These results present an updated annual index of abundance for the blue shark captured by the Portuguese pelagic longline fleet in the Indian Ocean, that can now be used in stock assessment models.

KEYWORDS: Blue shark, CPUE standardization, generalized linear mixed models (GLMM), Indian Ocean, pelagic longline fisheries, targeting effects.

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1. Introduction

The Portuguese pelagic longline fishery in the Indian Ocean started in the late 1990's in the southwest area (SW-IO) and has traditionally targeted swordfish (*Xiphias gladius*, SWO). However, in certain areas and seasons this fishery also catches relatively high quantities of sharks, particularly blue shark (*Prionace glauca,* BSH) (Santos et al., 2013, 2014; Coelho et al., 2014).

The Portuguese fishing vessels operating in the IOTC area consist only of pelagic longliners setting shallow night sets targeting swordfish, traditionally ranging in size from 35 to about 50m. On recent years the mean vessel size was 40 m of total length. The number of vessels licensed increased from the beginning of the fishery in 1998 (five vessels) until 2009 (24 vessels). The number of active vessels followed a similar trend, with a peak in 2006 (17 vessels). However, during the last 5 years, the active vessels in the convention area decreased to as low as three (in 2009, 2012), with another increase in 2013 and 2014 (Santos et al., 2013, 2014). The reasons behind this decrease of active fishing vessels in the IOTC area is related mainly with an increase of the exploitation costs, particularly the increase in fuel prices in the late 2000's, but also to piracy related problems in the SW Indian Ocean, which has traditionally been the fishing area for the Portuguese fleet (Santos et al., 2013, 2014).

Preliminary standardized blue shark CPUE indices for EU.Portugal were presented to the IOTC Working Party on Ecosystems and Bycatch (WPEB) in 2011, 2012 and 2013 (Coelho et al., 2011, 2012, 2013). In 2014, a thorough revision was made on the modeling approach, including sensitivity analyses for the model type, using the ratio factor as a proxy for targeting, and the definition of areas in the Indian Ocean (Coelho et al., 2014).

In this work, we update the standardized BSH CPUE index using the best case as defined by Coelho et al. (2014) and, as recommended by the WPEB in 2014 (IOTC WPEB, 2014), we conduct an additional sensitivity analysis for the use of targeting effects. Specifically, we compare the use of ratios as has been done in the past for this fleet (Coelho et al., 2013, 2014) with a new definition based on multivariate classification methods (i.e., cluster analysis). The objectives of this study were therefore to provide an updated description of the BSH catches by the Portuguese pelagic longline fishery operating in the Indian Ocean between 1998 and 2014, including information on the catch, effort and CPUE trends (nominal and standardized) that can contribute for the 2015 BSH stock assessment in the Indian Ocean.

2. Material and methods

2.1. Catch and effort

A continuous effort over the last years has been made by the *Portuguese Institute for the Ocean and Atmosphere* (*IPMA)* to collect current and historical catch and effort data from the Portuguese longliners targeting swordfish in the Indian Ocean. This includes information on the catches, fishing effort in number of hooks per set and geographical location integrated from VMS data (**Table 1**). This data mining effort allowed us to recover most of the time series for the Portuguese pelagic longline fleet operating in Indian Ocean, which can now be used in this work. It should be noted that thanks to this effort, the overall coverage available and used for the BSH CPUE analysis has increased from 39.1% in 2011 (Coelho et al., 2011) to 99.6% in this work (**Table 1**).

Table 1: Number of fishing sets with catch, effort and location information carried out by the Portuguese pelagic longline fleet in the Indian Ocean between 1998 and 2014. The percentage of sets per year analyzed for this paper is also indicated. Note that the 2 first years of the series (1998 and 1999) were not used for the CPUE standardization analysis.

Year	No. sets (n)	No. sets with effort (Hooks)	No. sets with location (VMS)	Sets used for analysis (%)
1998	113	113	113	100.0
1999	147	147	147	100.0
2000	275	275	275	100.0
2001	631	631	631	100.0
2002	687	687	647	94.2
2003	575	575	575	100.0
2004	370	370	370	100.0
2005	143	143	143	100.0
2006	1801	1801	1801	100.0
2007	1325	1325	1325	100.0
2008	238	238	238	100.0
2009	482	482	482	100.0
2010	457	457	457	100.0
2011	633	633	633	100.0
2012	516	516	516	100.0
2013	1312	1312	1312	100.0
2014	863	863	863	100.0
Total	**10455**	**10455**	**10415**	**99.6**

2.3. CPUE standardization

The CPUE analysis was carried out using the official fisheries statistics collected by the Portuguese Fisheries authorities (DGRM), to which VMS and skippers logbook data was added. Operational data at the fishing set level was used, with the catch data referring to the total (round) weight of blue shark captured per fishing set. The available catch data started in 1998 and was available until 2014. However, the first 2 years of the series (1998 and 1999) were not used for the models because there was more limited information in those initial years of the fisheries. For the CPUE standardization, the response variable considered for this study was catch per unit of effort (CPUE), measured as biomass of live fish (kg) per 1000 hooks deployed. The standardized CPUEs were estimated with Generalized Linear Mixed Models (GLMMs).

Coelho et al (2014) tested 10 sensitivity runs in BSH CPUE standardization models, including sensitivities to the model type, the use of ratio factor and the definition of the area effects. The base case used for the present work is based on the best model selected in that work. There were some fishing sets with zero blue shark catches that result in a response variable of CPUE=0. As these zeros can cause mathematical problems for fitting the models, Coelho et al. (2014) tested three different methodologies, specifically tweedie, gamma and lognormal models. The best fit was achieved using lognormal models with the response variable defined as the nominal CPUE + constant (*c*), with *c* set to 10% of the overall mean catch rate (as recommended by Campbell, 2004), as that is the value that seems to minimize the bias for this type of adjustments. Further, and in a comparative study, Shono (2008) showed that when the percentage of zeros in the dataset is low (<10%, as is the case in this dataset), the method of adding a constant to the response variable performs relatively well.

Based on the sensitivities and tests reported by Coelho et al (2014), the covariates considered and tested in the base case models for this work were:

- Year: analyzed between 2000 and 2014;
- Quarter of the year: 4 categories: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December;
- Area: Based on sea temperature at 50m depth, as defined by Mejuto et al. (2008) (see **Annex 1** for a map with the definition of the areas used);
- Ratio: based on the SWO/SWO+BSH ratio of captures;
- Quarter:Area interactions;
- Vessel ID: used as a random variable in the GLMM.

The significance of the explanatory variables was assessed with likelihood ratio tests comparing each univariate model to the null model (considering a significance level of 5%), and by analyzing the deviance explained by each covariate. Goodness-of-fit and model comparison was carried out with the Akaike Information Criteria (AIC). Model validation was carried out with a residual analysis. The final estimated indexes of abundance were calculated by Least Square Means (marginal means), that for comparison purposes were scaled by the mean standardized CPUE in the time series.

The ratio factor was defined as the percentage of swordfish catches related to combined swordfish and blue shark catches. This ratio is in general considered a good proxy indicator of target criteria more clearly directed at swordfish *versus* a more diffuse fishing strategy aimed at the two main species (SWO and BSH). Moreover, it has been consistently applied to other fleets that have a similar method of operation, such as the Spanish fleet, with applications both to the Atlantic and the Indian Ocean (e.g., Ramos-Cartelle et al., 2011; Mejuto et al., 2012; Santos et al., 2013). The ratio factor was calculated for each set and then divided into ten categories using the 0.1 quantiles. However, recent works have also suggested the use of cluster analysis to define target effects as explanatory variables in the standardization models (He et al., 1997). This approach has been used with success in the Indian Ocean by Wang and Nishida (2014) for swordfish, and has also been tested in blue shark in the North Atlantic by Coelho et al. (2015). However, in this later study, this approach was tested as a sensitivity analysis but not selected in the final model as the EU.Portugal fleet consistently targets SWO and to a less extent BSH, and as such the information obtained with the cluster analysis is very similar to using SWO/BSH ratios. However, and because this approach was not tested yet for the Indian Ocean, a new sensitivity analysis was carried out comparing the use of targeting effects estimated with ratios *versus* clusters, as well as by removing the target effects. The various model specification and characteristics considered in this comparative approach are listed in detail in **Table 2**.

All statistical analysis for this paper was carried out with the R Project for Statistical Computing version 3.2.0 (R Core Team, 2015) using several additional libraries (Wickham, 2007, 2009; Fox and Weisberg, 2011; Højsgaard and Halekoh, 2012; Bivand and Lewin-Koh, 2013; Bates et al., 2014; Lenth, 2014).

Table 2: Specifications of the candidate models run for the blue shark CPUE standardization for the Indian Ocean by the Portuguese pelagic longline fleet. The model types, specifications and explanatory variables are described, as well as some additional comments including the number of estimated parameters (pars) are also indicated.

	Model	**Model type**	**Explanatory variables**	**Comments**
Base case	Mod1	GLMM Lognormal	Year + Quarter + Area + Ratio + Quarter:Area + random(vessel)	Model with area:season interaction; targeting based on ratios; vessel as random effect (46 pars). Based on the best case from Coelho et al. (2014).
Sensitivity to targeting	Sens1	GLMM Lognormal	Year + Quarter + Area + Cluster + Quarter:Area + random(vessel)	Similar to Mod1 but with targeting based on cluster analysis (40 pars).
	Sens2	GLMM Lognormal	Year + Quarter + Area + Quarter:Area + random(vessel)	Model without targeting effects (37 pars).

3. Results and Discussion

3.1. Catch and effort

3.1.1. Spatial distribution of the catch and effort

The area of operation in the Indian Ocean in terms of fishing effort for the Portuguese pelagic longline fleet, for the period between 1998 and 2014, is shown in **Figure 1**, where it is possible to see that most of the effort took place in the southwest region of the Indian Ocean. The yearly effort plots are presented in **Annex 2**.

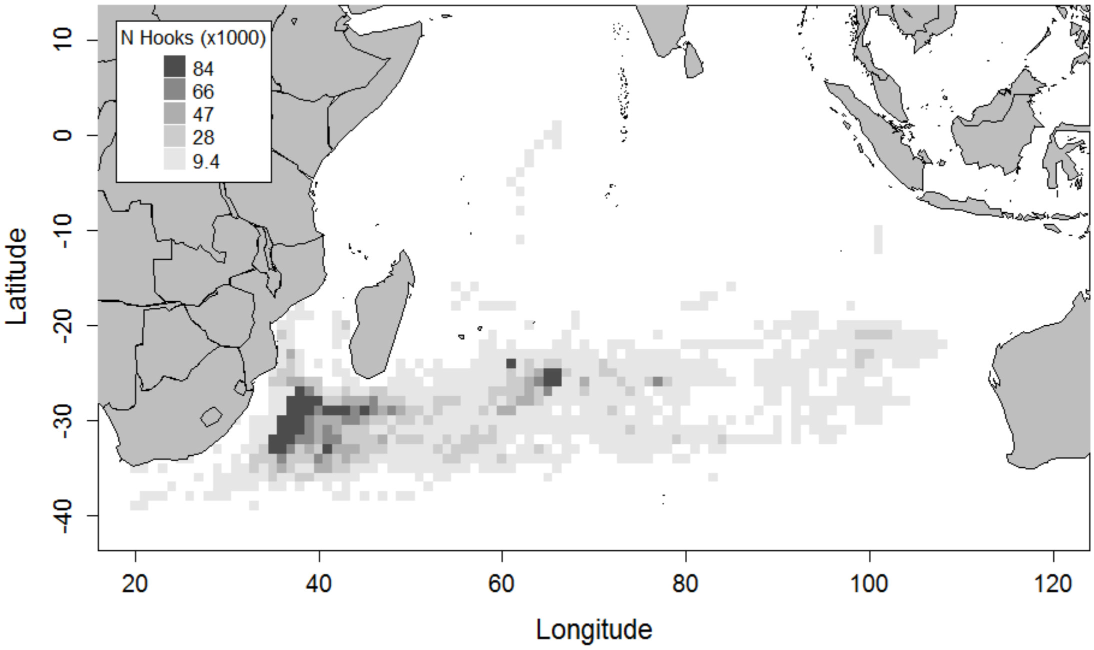

Figure 1. Effort distribution of the Portuguese pelagic longline fleet for the 1998-2014 period in the Indian Ocean. The effort is represented in 1°x1° grids with darker and lighter colors representing respectively to areas with more and less effort in number of hooks.

The BSH catches are also spread throughout the Indian Ocean region, but also follow this general trend of a higher concentration in the southwest region, south of Madagascar Island and closer to South Africa and south Mozambique (**Figure 2**).

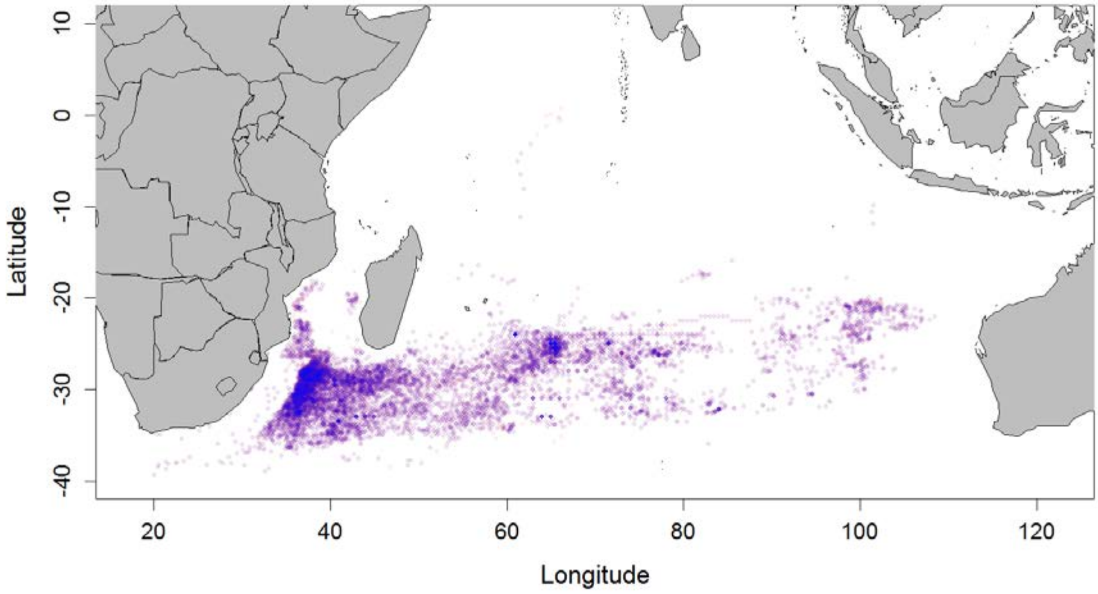

Figure 2. Location of the Portuguese pelagic longline sets between 1998 and 2014 for the entire Indian Ocean. Full color saturation indicates higher blue shark CPUE while the lighter red color represents sets with zero BSH catches.

3.1.2. Yearly and seasonal variability in the catch and effort

The total effort of the Portuguese longline fleet in the Indian Ocean remained relatively constant between 1999 and 2004, followed by an increase during 2006-2007 and then a sharp decrease in 2008 (**Figure 3**). Since then, and for the more recent years (2009 to 2014) the effort has been increasing again to values higher than in the early 2000's and closer to the 2006-2007 period (**Figure 3**).

The total blue shark catches also tended to follow this general trend, with a peak during 2006-2007, followed by a sharp decrease in 2008, and then a more steady and progressive increase for the more recent period (**Figure 3**). In terms of ratios of swordfish compared to the swordfish + blue shark catches, the ratios were higher in the first 2 years of the time series, then tended to be lower between 2000 and 2005, followed by a higher period between 2005 and 2013, and then a decrease in 2014 (**Figure 3**).

The increase after 2005 might be a result of a change in the fishery, namely in terms of gear material, i.e. the replacement of the traditional multifilament by nylon monofilament gear which provides higher swordfish catches. Whereas, the slight decrease after 2008 is probably related by another change in the fishing gear (nylon monofilament replaced by wire leaders) and bait (mackerel alternating with squid, or instead of, in areas/periods of higher shark abundance). Several authors have demonstrated that higher blue shark catch rates are obtained when wire leaders are used (e.g., Ward et al., 2009; Vega and Licandeo, 2009; Afonso et al., 2012).

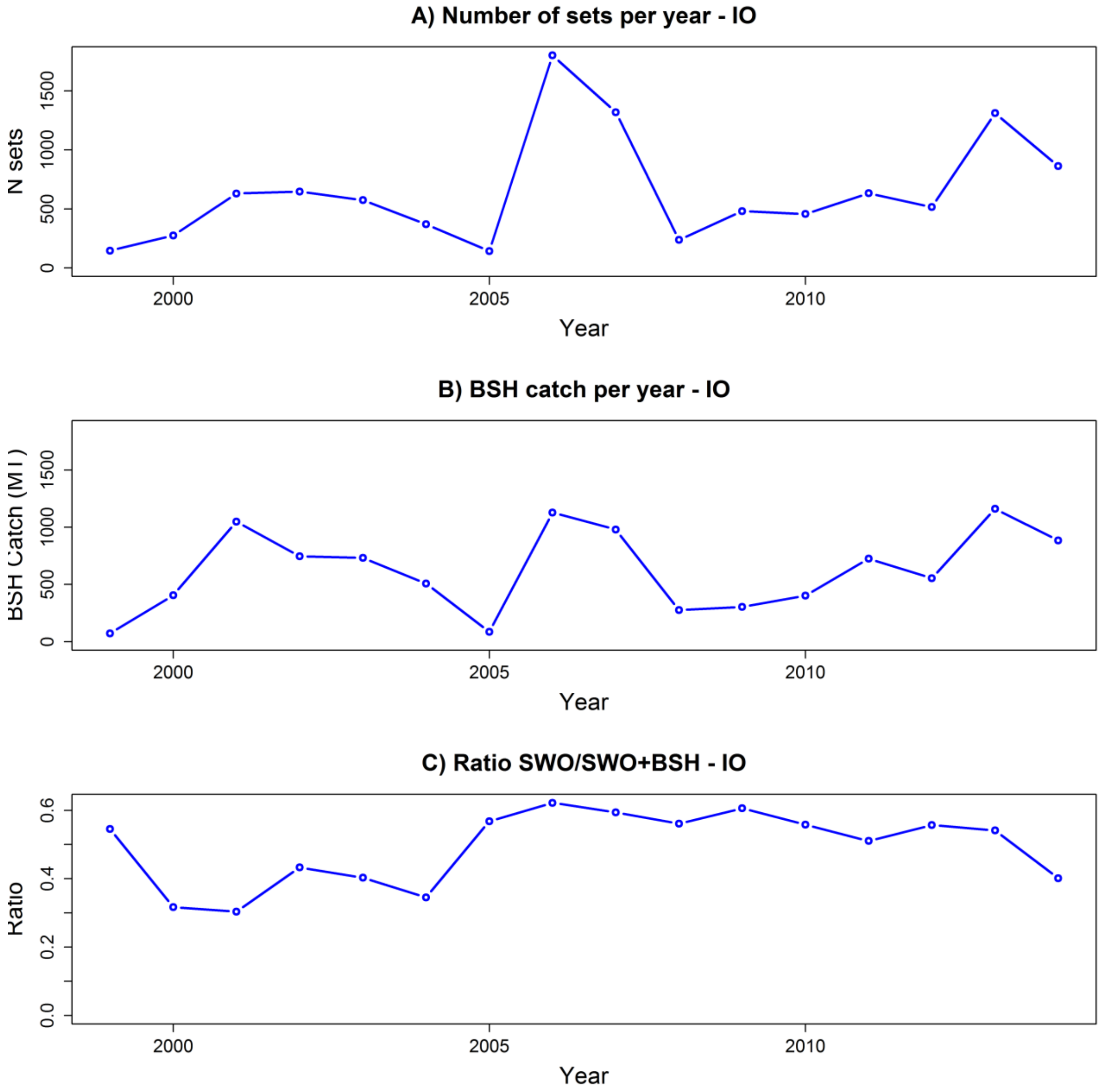

Figure 3. Descriptive plots of the total effort in sets (A), the total catch of blue shark (B), and the ratio of swordfish compared to the swordfish and blue shark catches (C), for the Portuguese longline fleet operating in the Indian Ocean.

In terms of seasonality in the CPUE, and even though there was some considerable inter-annual variability, it was possible to observe a general trend of higher CPUEs in the 1st half of the year followed by lower CPUEs towards the middle of the year, and then higher CPUEs again later in the year (**Figure 4**). Santos et al. (2002) reported a similar trend for the Portuguese pelagic longline blue shark catches in the North Atlantic, with a peak occurring in May-June.

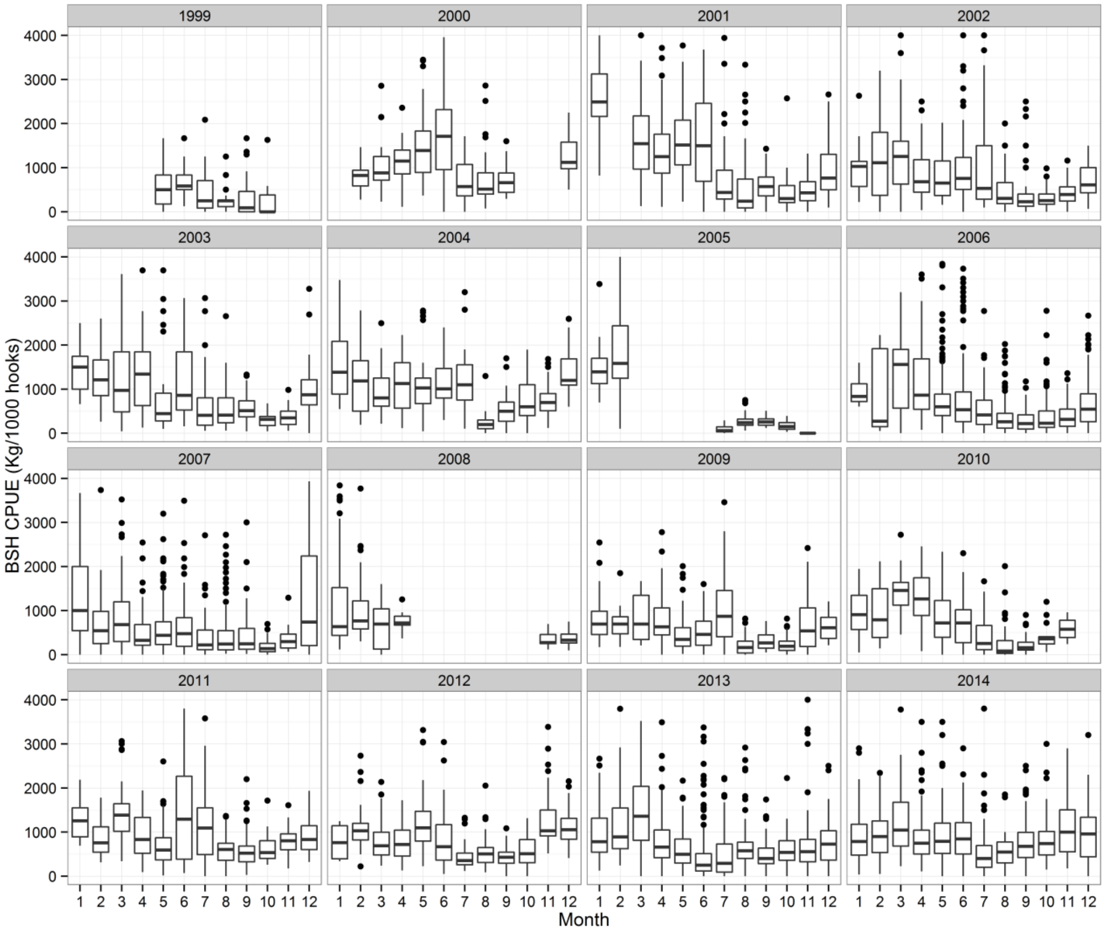

Figure 4. Monthly blue shark CPUE (kg/1000 hooks) by the Portuguese pelagic longline fleet in the Indian Ocean, per year. In the boxplots the middle lines represents the median, the box the quartiles, the whiskers the non-outlier range and the points the outliers.

3.2. CPUE standardization

3.2.1. CPUE data characteristics

The nominal time series of the blue shark CPUE for the Portuguese pelagic longline fleet operating in the Indian Ocean is presented in **Figure 5**. In general there was a decreasing tendency between the initial and final years of the series, even though several peaks were recorded in several years along the series, especially in 2000, 2004, 2008 and 2011 (**Figure 5**). In the more recent year, there was an increasing trend (**Figure 5**).

The percentage of fishing sets with zero catches of BSH in the Indian Ocean was low, specifically 3.45%. The nominal blue shark CPUE distribution was highly skewed to the right and become more normal shaped in the log-transformed scale (**Figure 6**).

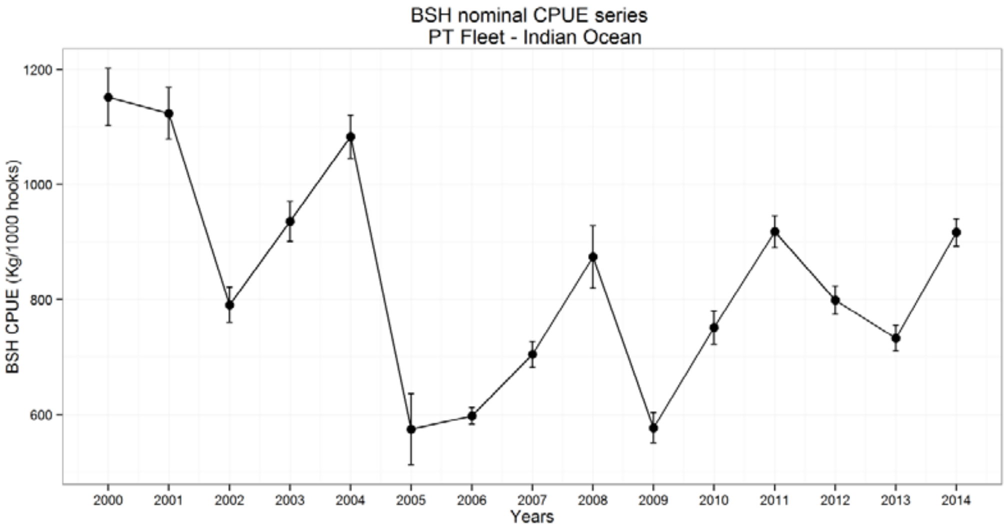

Figure 5. Nominal CPUE series (kg/1000 hooks) for blue shark caught by the Portuguese pelagic longline fishery in the Indian Ocean, between 2000 and 2014. The error bars refer to the standard errors.

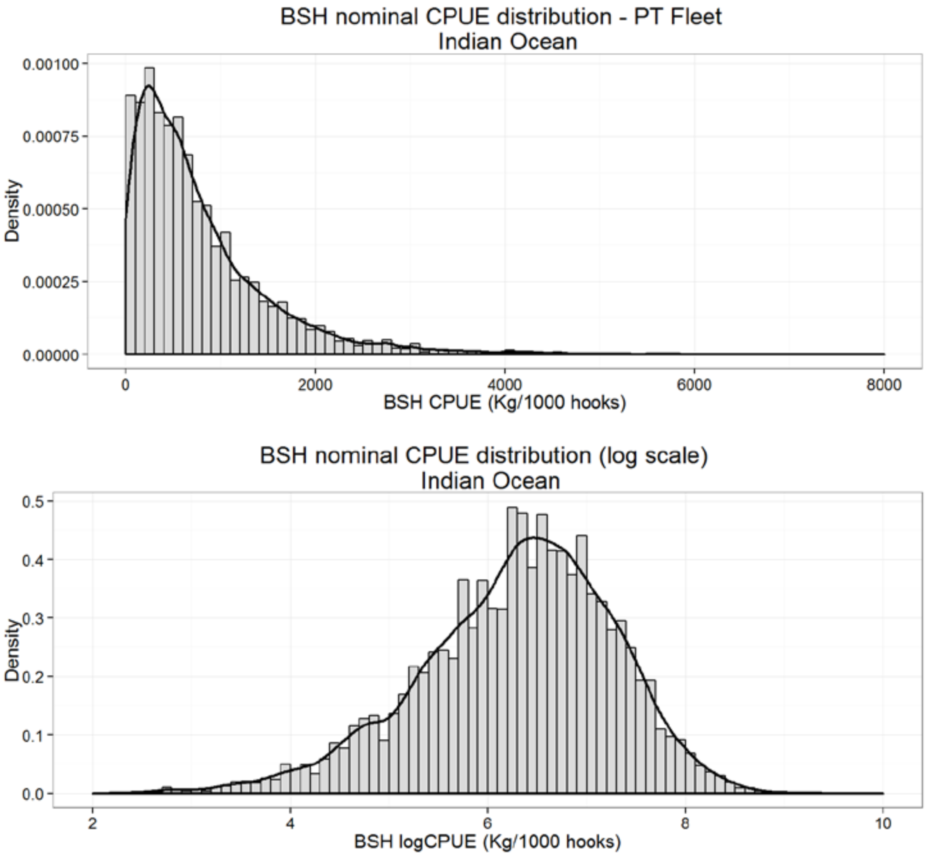

Figure 6: Distribution of the nominal blue shark CPUE captured by the Portuguese longline fleet in the Indian Ocean in non-transformed (top) and log-transformed (bottom) scales.

3.2.2. Base case model

The base case model was based on the best case as tested by Coelho et al (2014) using the explanatory variables that were selected then. For this base case, a lognormal model was used and all explanatory variables contributed significantly for explaining part of the deviance. The factors that contributed most for the deviance explanation were the ratio, followed by the quarter, year, area and the quarter:area interaction (**Table 3**). The residual analysis showed no major problems, with the histogram of the residuals distribution very close to a normal shape, even thought it was evident the presence of some outliers along the fitted values (**Figure 7**).

On this base case model using a lognormal error distribution with the season:area interaction and considering the vessel as a random effect, the relative index of abundance showed a decrease in the initial years between 2000 and 2005, then followed by an increase until 2008, and finally another general decrease in the more recent years until 2014 (**Figure 8**).

Table 3. Deviance table (type II Anova) of the parameters used for the blue shark CPUE standardization in the base model for the Indian Ocean. For each parameter it is indicated the degrees of freedom used (Df), the sum of squares (Sum sq.), the mean squares (Mean sq.) the F statistic (F-stat) and the significance (p-value). The goodness-of-fit (AIC) of the model is also provided.

Model	**Variables**	**Df**	**Sum sq.**	**Mean sq.**	**F-stat.**	***p-value***
Mod 1: Base case (AIC=12131)	Intersept only					
	Year	14	377.8	26.99	147.28	< 0.001
	Year + Quarter	3	632.6	210.87	1150.70	< 0.001
	Year + Quarter + Area	5	185.4	37.08	202.36	< 0.001
	Year + Quarter + Area + Ratio	9	3246.9	360.76	1968.67	< 0.001
	Year + Quarter + Area + Ratio + Quarter:Area	15	36.6	2.44	13.30	< 0.001

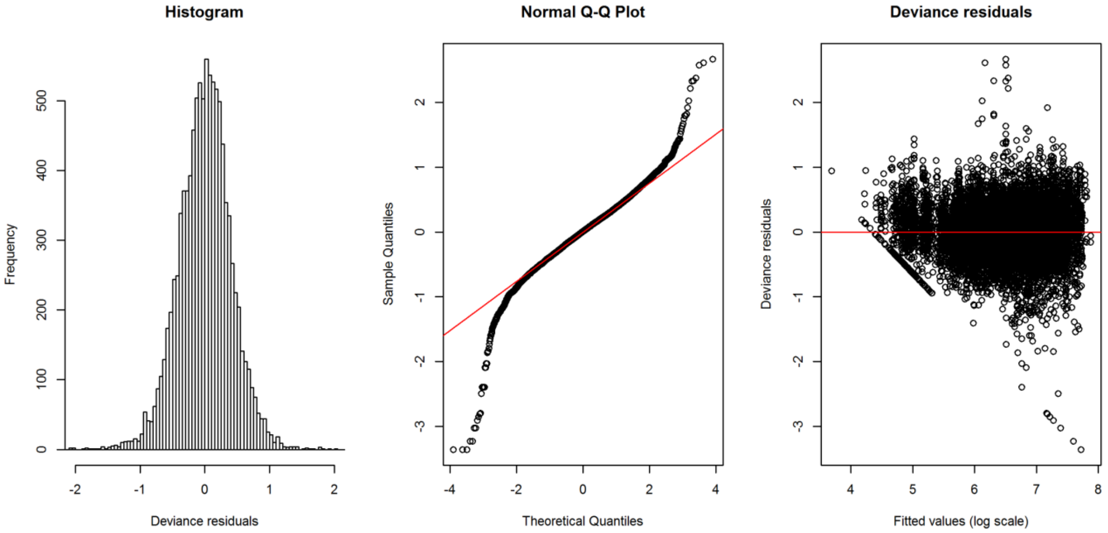

Figure 7. Residual analysis for the base case lognormal GLMM model for the blue shark CPUE standardization in the Indian Ocean. In the plot it is presented the histogram of the distribution of the residuals (left), the QQPlot (middle) and the residuals along the fitted values on the log scale (right).

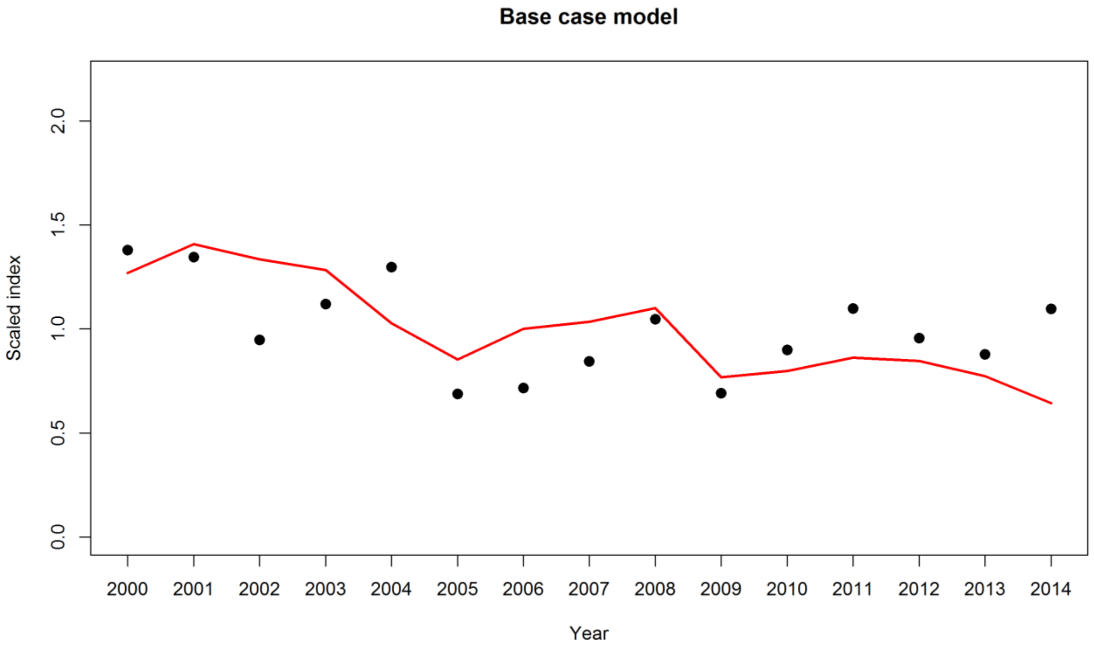

Figure 8. Standardized CPUE series for blue shark captured by the Portuguese pelagic longline fleet in the Indian Ocean using a lognormal GLMM based on the base case model. The solid line refers to the standardized index and the black dots to the nominal CPUE series.

3.2.3. Cluster analysis to define targets

A sensitivity analysis was run for testing the influence of the targeting effects. This was carried out by comparing the base case using ratios (swordfish / swordfish + blue shark) with a model using targets effects based on cluster analysis, and with a model without considering target effects.

In terms of species composition it is noteworthy that the two dominant species in the catches of the Portuguese fleet for the entire time series were SWO and BSH, with some inter-annual variability (**Figure 9**). He et al. (1997) and Wang and Nishida (2014) noted that the choice for the number of clusters to produce with multivariate statistics was largely subjective, and in the case of the mixed tuna fisheries in the Pacific and Indian Oceans, both mentioned that at least two clusters are expected (from tuna and swordfish sets), and that more may be produced to allow other targeting categories. The case of the Portuguese pelagic longline fishery is different, as it is clear from the catch composition that the major species are SWO and BSH, while the tunas represent a very small component of the catch (**Figure 9**). As such, in the Portuguese fishery the two minimum clusters would represent swordfish or blue shark targeting, while the other clusters would represent either a mixed SWO + BSH targeting, or other target species in a few specific sets. A similar situation was observed for the Portuguese fleet operating in the North Atlantic, where the 2 major clusters also represented the fleet targeting either SWO or BSH (Coelho et al., 2015).

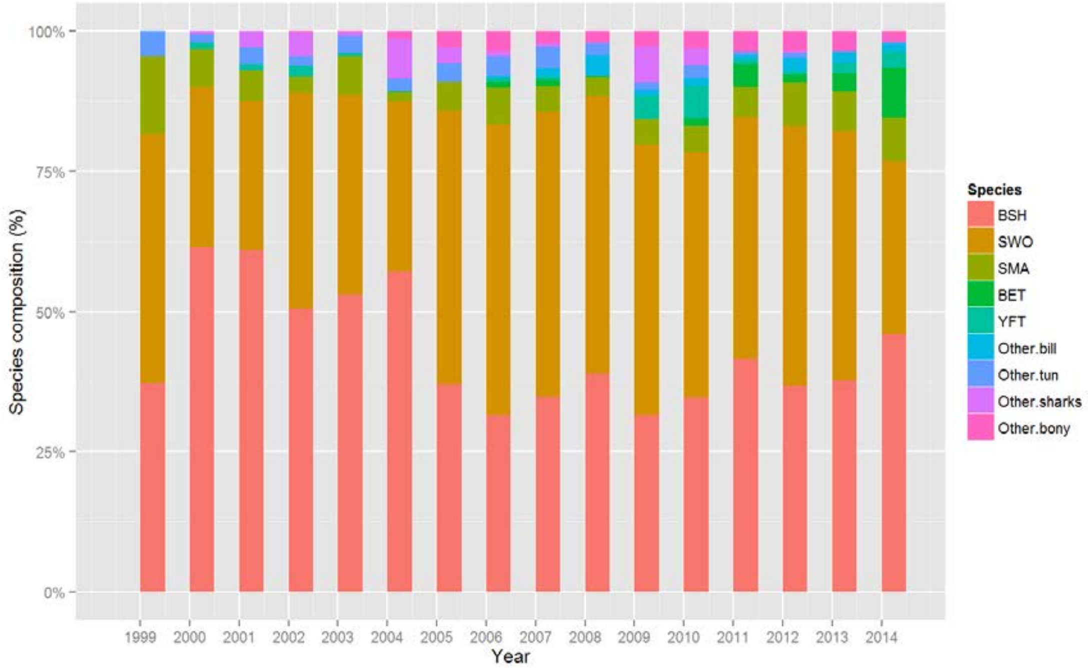

Figure 9. Catch composition of the Portuguese pelagic longline fleet operating in the Indian Ocean between 1999 and 2014.

From the non-hierarchical cluster analysis (k-means) it was possible to reduce the overall number of trips or sub-trips into 36 groups, which were then clustered in the hierarchical analysis (**Figure 10**). The selection of clusters for the hierarchical analysis followed He et al. (1997) and Wang and Nishida (2014) suggestion of reducing the number until the smallest cluster contained less than 10% of the observations.

In the case of the Portuguese fleet this was achieved with four clusters. The catch composition of those four clusters, representing targeting strategies of the fleet is presented in **Figure 11**, and is summarized as: 1) targeting mainly BSH (18.7% of the sets), 2) mixed strategy targeting both BSH and SWO (44.8% of the sets), 3) targeting mainly SWO (32.4% of the sets) and 4) mixed strategy targeting SWO and other fishes mainly tunas (4.0%).

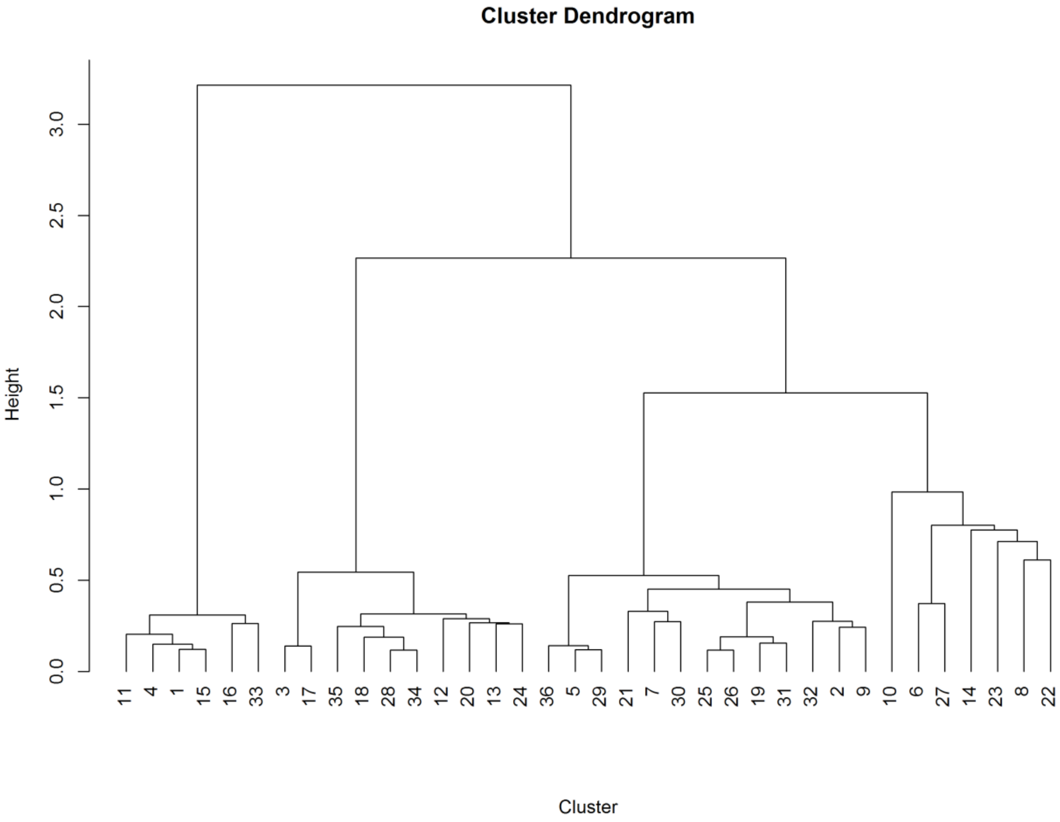

Figure 10. Hierarchical cluster analysis classifying the groups formed with the non-hierarchical analysis (k-means) for the Portuguese pelagic longline fleet operating in the Indian Ocean.

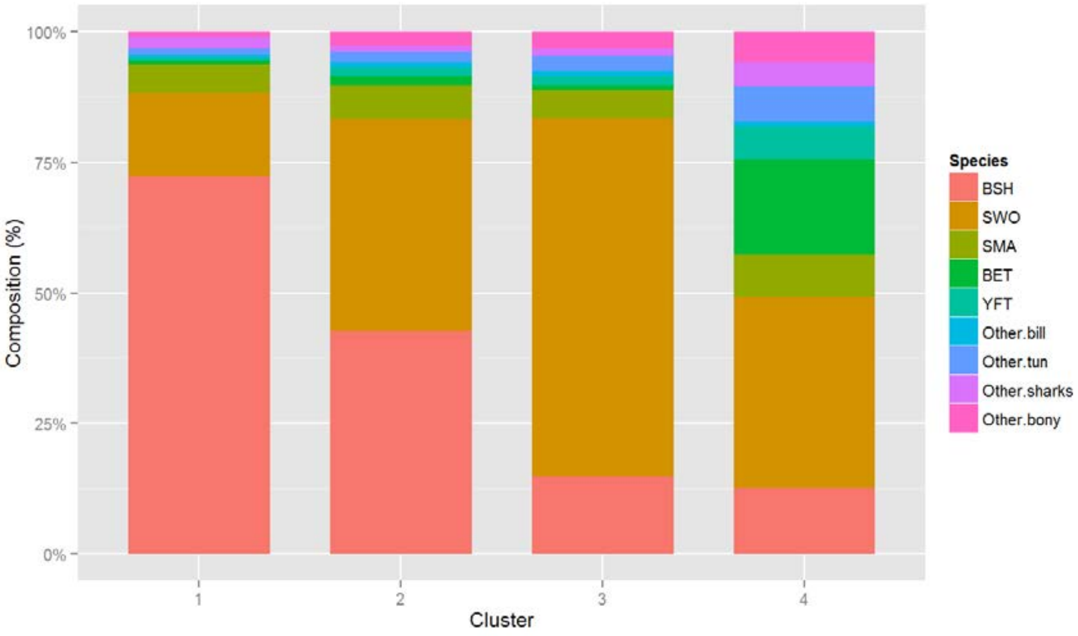

Figure 11. Catch composition of the four clusters defined for the Portuguese pelagic longline fleet operating in the Indian Ocean.

3.2.4. Sensitivity to targeting effects

This sensitivity analysis revealed some differences in the standardized BSH CPUE series, but the general trends remained very similar for all tested scenarios (**Figure 12**). In terms of goodness-of-fit, the best fitted model was the original base case using the SWO/BSH ratios. Using clusters produced a slightly worse fit with a higher AIC, and by removing the target effects the fit was much worse with a much higher AIC (**Table 4**).

In terms of residual analysis there were no major differences in the models using ratios, using clusters or when removing the targeting effects, even though a larger dispersion in the residuals was observed when the ratio factor was removed (**Figure 13**).

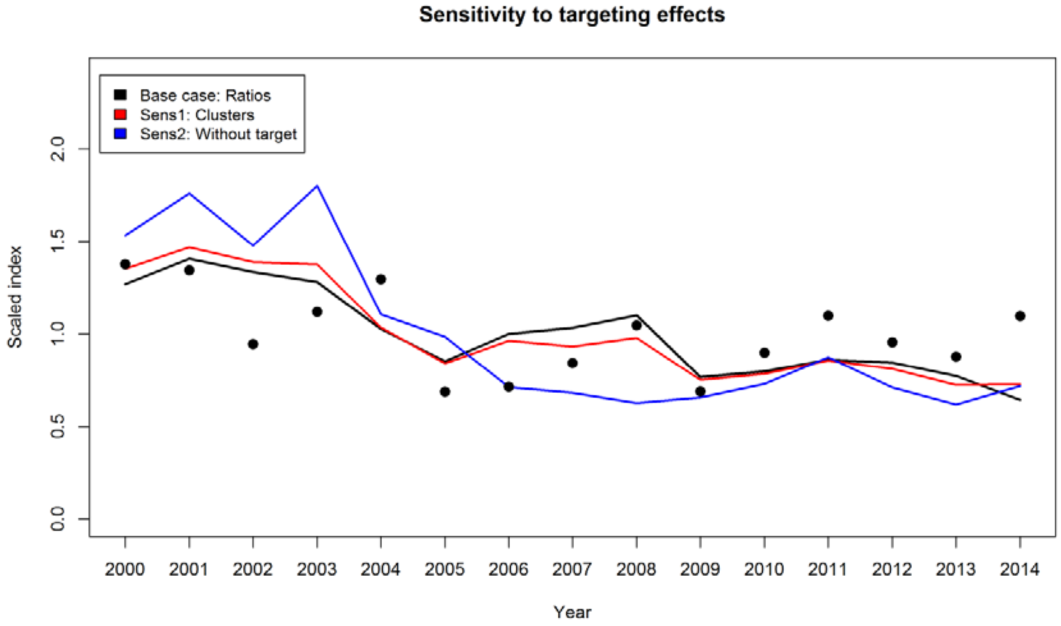

Figure 12. Model sensitivity to targeting effect in the BSH standardization from the Portuguese pelagic longline fleet in the Indian Ocean. The scaled annual indexes of abundance of the base case model (using ratios) is represented in black, the model using the clusters from the multivariate classification analysis is represented in red, and the model without target effects is represented in blue.

Table 4. Deviance table (type II Anova) of the parameters used for the blue shark CPUE standardization in the sensitivity analysis for the Indian Ocean. For each parameter it is indicated the degrees of freedom used (Df), the sum of squares (Sum sq.), the mean squares (Mean sq.) the F statistic (F-stat) and the significance (p-value). The goodness-of-fit (AIC) of the model is also provided.

Model	**Variables**	**Df**	**Sum sq.**	**Mean Sq.**	**F-stat.**	***p-value***
Sens1: Using clusters (AIC=15863)	Year	14	377.5	26.96	102	< 0.001
	Year + Quarter	3	633.2	211.08	795	< 0.001
	Year + Quarter + Area	5	185.3	37.07	140	< 0.001
	Year + Quarter + Area + Cluster	9	2419.2	806.4	3037	< 0.001
	Year + Quarter + Area + Cluster + Quarter:Area	15	27.8	1.86	7	< 0.001
Sens2: Removing target (AIC=22282)	Year	14	377.6	26.97	54.12	< 0.001
	Year + Quarter	3	633.0	211.01	423.38	< 0.001
	Year + Quarter + Area	5	185.4	37.07	74.38	< 0.001
	Year + Quarter + Area + Quarter:Area	15	63.9	4.26	8.54	< 0.001

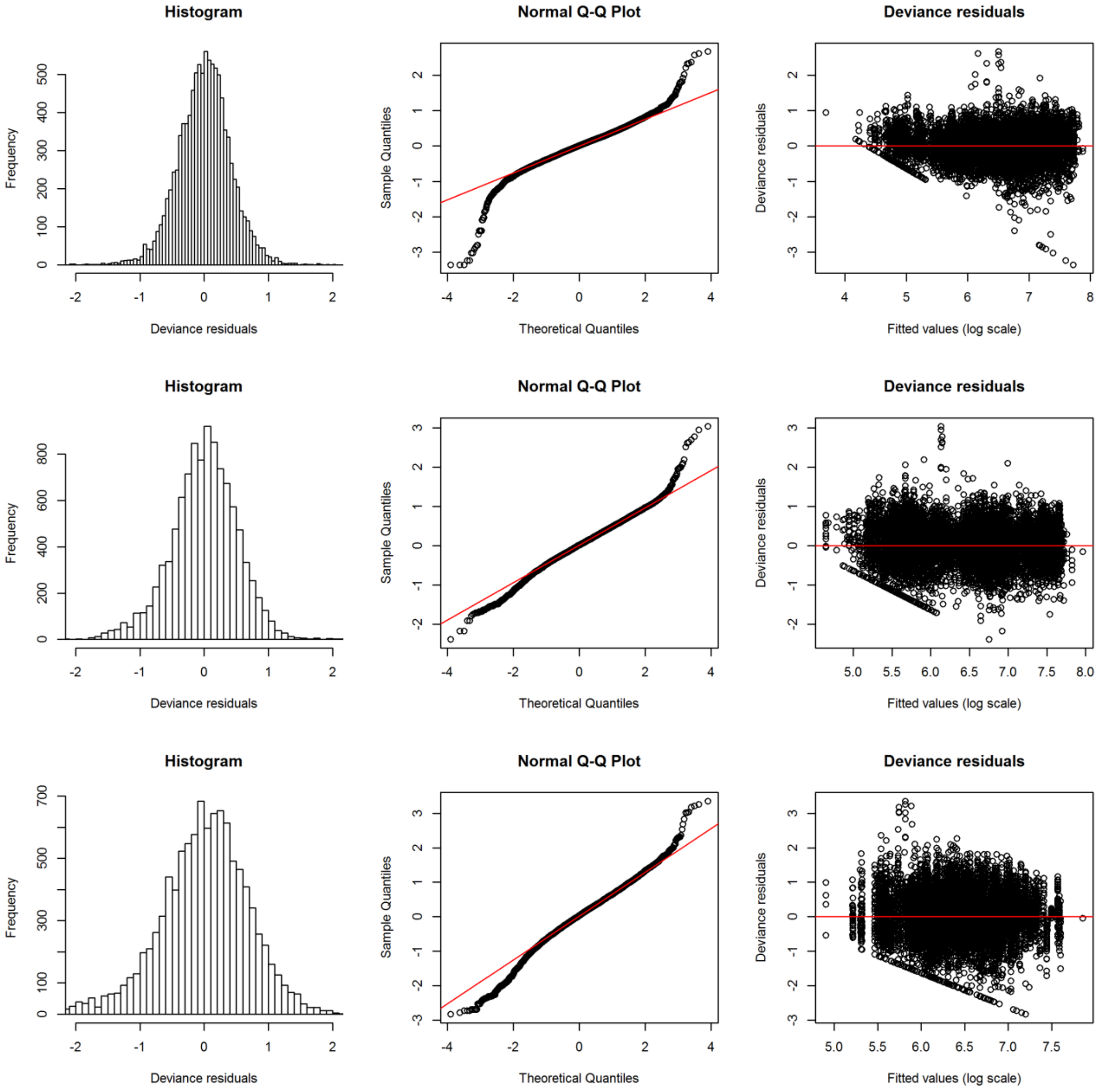

Figure 13. Residual analysis for the various model tested for the sensitivity to the target effects for the blue shark CPUE standardization in the Indian Ocean. The upper plots refer to the base case model using ratios, the middle plots refer to the models using clusters, and the bottom plots refer to the model not considering targeting effects. For each model it is presented the histogram of the distribution of the residuals (left), the QQPlot (middle) and the residuals along the fitted values on the log scale (right).

3.3. Final standardized CPUE series

Given the goodness-of-fit of the various candidate models and the comparisons from the sensitivity analysis for the target effects, as well as the previous sensitivity runs described by Coelho *et al.* (2014), the final standardized CPUE series recommended to be used in the blue shark stock assessment derives from the base case model (Mod1) in this paper.

Besides the main simple effects Year, Quarter, Area and Ratio, this model also accounts for a Quarter:Area interaction allowing for different seasonal effects in the CPUEs to take place within each of the areas considered. Additionally, this model incorporates a random vessel effect, allowing the variability inherent to the different vessels to be considered in the models.

The final standardized blue shark CPUE index (in kg/1000 hooks) for the Portuguese pelagic longline fishery in the Indian Ocean between 2000-2013, suggested to be used in the blue shark stock assessments is presented in **Table 5**.

Table 5. Standardized BSH CPUE index (kg/1000 hooks) for the Portuguese pelagic longline fleet in the Indian Ocean between 2000 and 2014, suggested to be used in the 2015 stock assessment models. The table includes the standardized index value, the 95% confidence intervals (CI) and the coefficient of variation (CV, %).

Year	Estimate	Upper CI (95%)	Lower CI (95%)	CV (%)
2000	655.4	799.8	534.7	2.29
2001	727.0	882.6	596.6	3.40
2002	689.3	837.1	565.4	3.43
2003	662.0	805.8	541.6	3.27
2004	530.2	648.0	431.4	2.61
2005	440.6	548.8	351.1	1.76
2006	516.5	628.1	422.5	5.56
2007	533.6	648.2	437.1	4.75
2008	568.2	695.7	461.7	2.14
2009	396.7	489.5	319.0	3.01
2010	412.3	508.0	332.2	2.93
2011	444.8	545.8	360.2	3.40
2012	436.4	537.1	352.2	3.12
2013	399.4	490.4	322.9	4.83
2014	331.8	411.5	265.1	4.00

4. Acknowledgments

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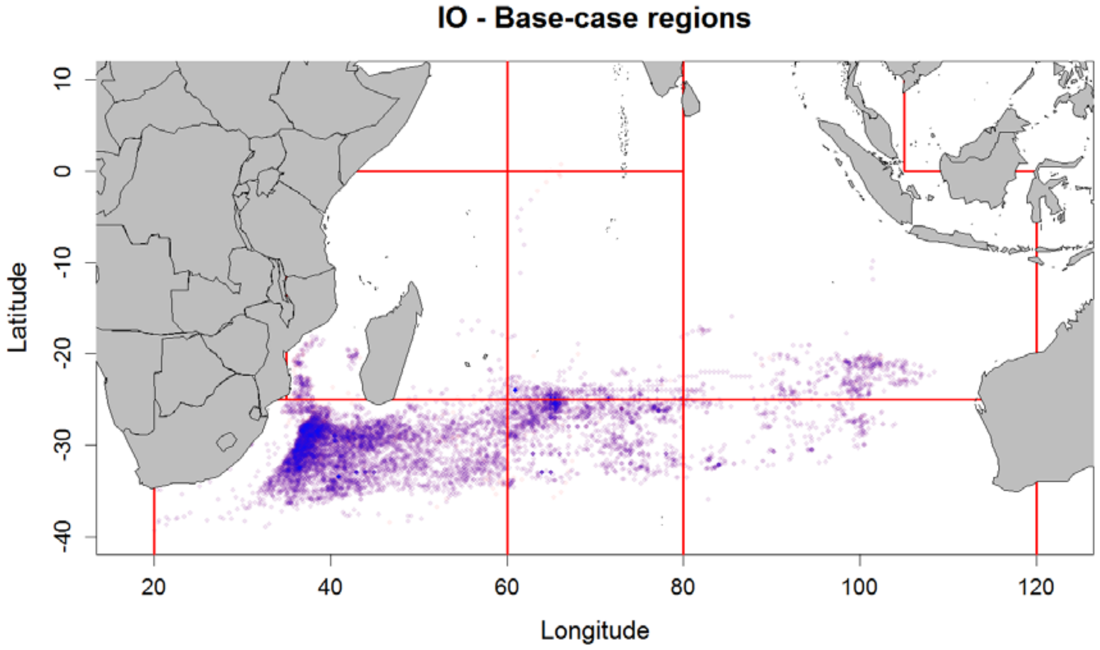
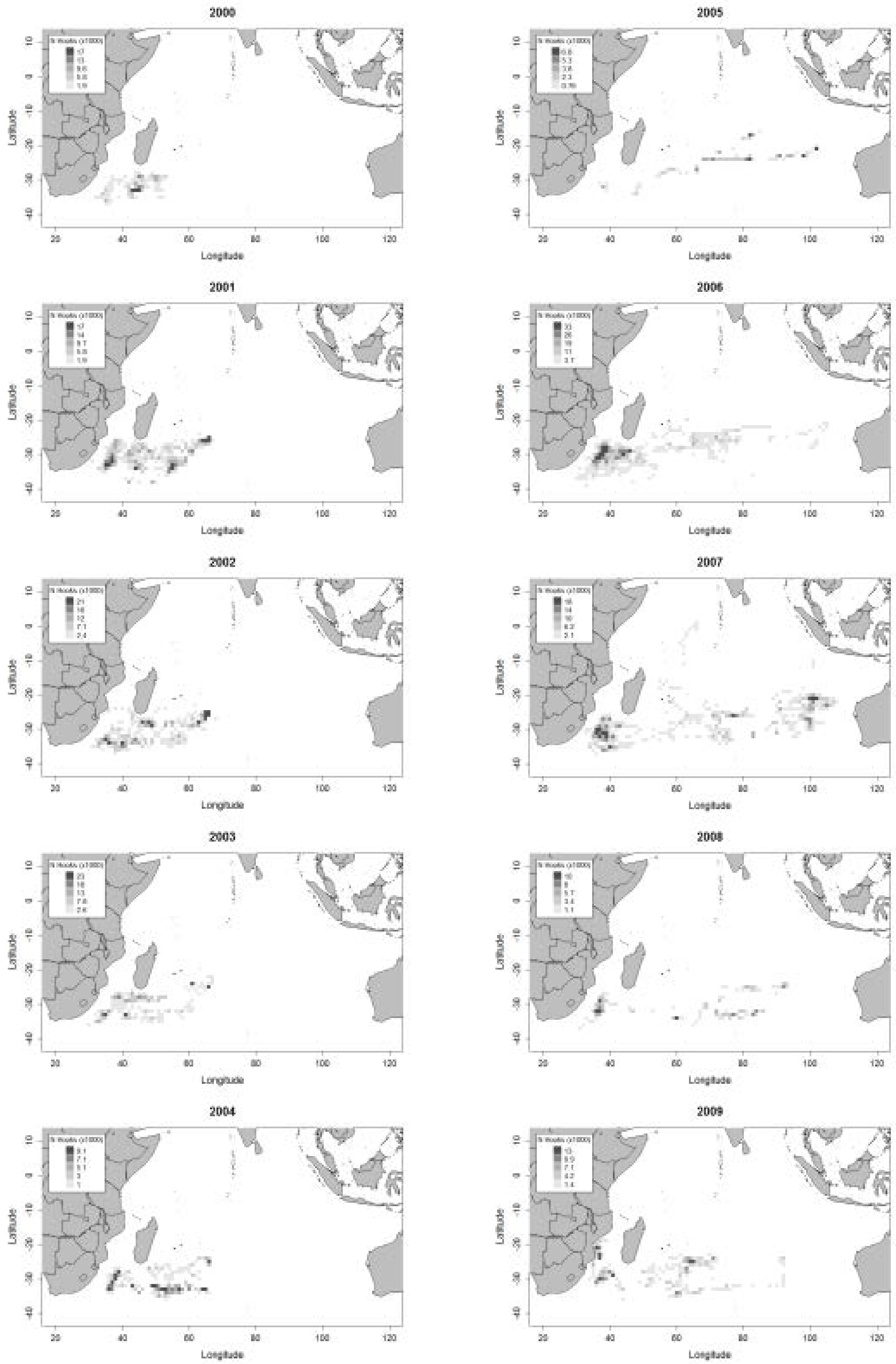
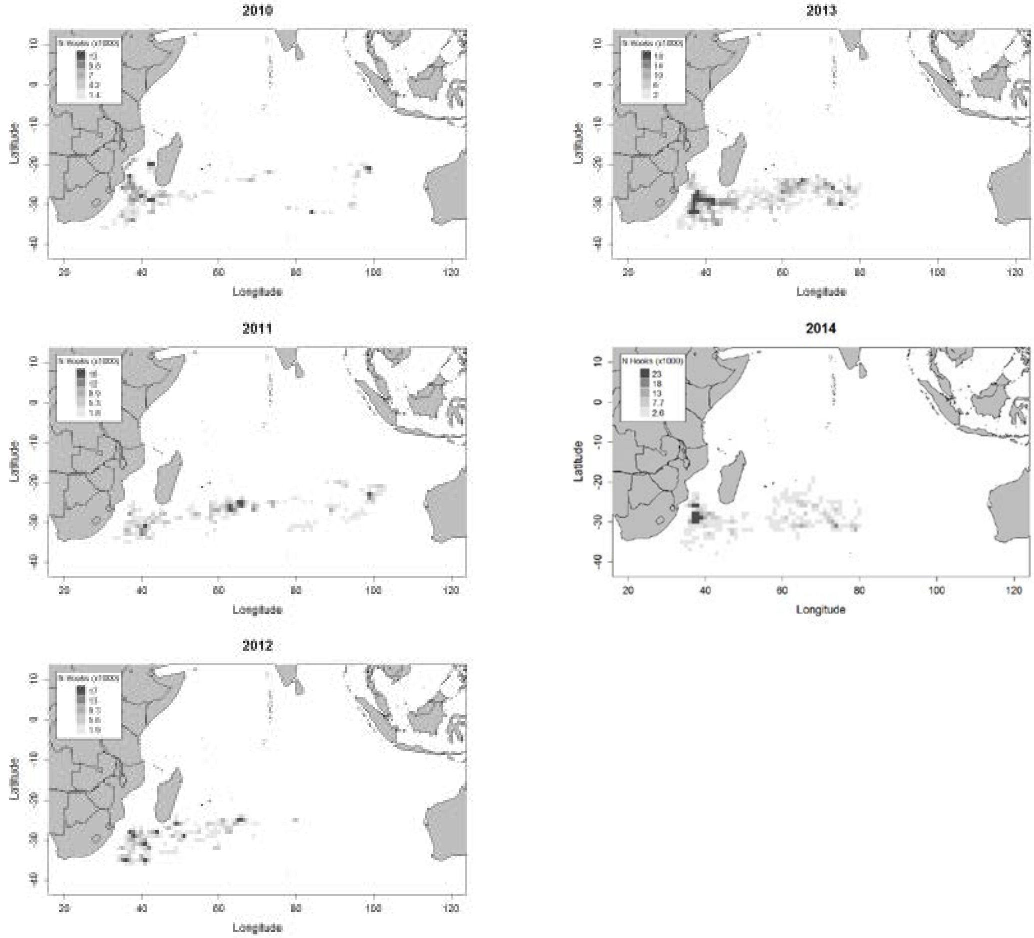
Annexes



Annex 1. Area stratification in the Indian Ocean as defined in Mejuto et al. (2008) based on sea temperature at 50m depth, with the location of the Portuguese pelagic longline sets reported by the fleet with logbooks between 1998 and 2014. Full color saturation indicates higher blue shark CPUE while the lighter red color represents sets with zero BSH catches.



Annex 2. Effort distribution of the Portuguese pelagic longline fleet in the Indian Ocean between 2000 and 2014. The effort is represented in 1°x1° grids with darker and lighter colors representing respectively to areas with more and less effort in number of hooks *(continues on next page)*.



Annex 2. *Continued*.