UPDATED BLUE SHARK CATCHES AND STANDARDIZED CPUE FOR THE PORTUGUESE PELAGIC LONGLINE FLEET IN THE INDIAN OCEAN, BETWEEN 1998 AND 2019.

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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. This working document analyses catch, effort and standardized CPUE trends for blue shark captured by this fishery. Nominal annual CPUEs were calculated in biomass (kg/1000 hooks), and were standardized with Generalized Linear Mixed Models (GLMMs) using year, quarter, season and targeting as fixed effects, and vessel as random effects. The standardized CPUE trends shows a general decrease in the initial years between 2000 and 2005, followed by a more stable period with some oscillations until 2019. 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 consider3d for utilization in the 2021 IOTC blue shark stock assessment.

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

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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 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 2015 an updated index was created for use in the 2015 BSH stock assessment, which also explored the effects of targeting based on ratios *versus* clustering analysis (Coelho et al., 2015a). Finally, and update was produced in 2017, that was used in the 2017 stock assessment (Coelho et al., 2017).

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 also take into consideration the recommendations from the targeting effects study by Coelho et al. (2015a). 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 2019, including information on the catch, effort and CPUE trends (nominal and standardized) that can contribute for the 2021 IOTC 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.

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 2019. 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 due to lower effort in the Indian Ocean.

Year	Number of sets (N)
1998	113
1999	147
2000	275
2001	631
2002	687
2003	575
2004	370
2005	143
2006	1801
2007	1325
2008	238
2009	482
2010	457
2011	633
2012	516
2013	1312
2014	978
2015	1415
2016	1699
2017	1618
2018	893
2019	809
Total	**17117**

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 2016. 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. Additionally, Coelho et al. (2015a) tested targeting effects to this fleet by using ratios and cluster analysis, demonstrating that both had very similar behaviors in this particular fleet (fleet targeting mainly SWO but with BSH as a secondary target). Therefore, this update of the BSH CPUE is based on the base case from those previous studies.

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) and the standardization carried out by Coelho et al. (2017), the covariates considered and tested in the base case models for this work were:

- Year: analyzed between 2000 and 2019;
- Quarter of the year: 4 categories: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December;
- Area: Using a GLM Tree area stratification based on Ichinokawa & Brodziak (2010) approach;
- Ratio: based on the SWO/SWO+BSH ratio of captures;
- Interactions: first order interactions were tested and would be used if significant with the AIC criteria;
- 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; Coelho et al., 2015a). 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 both in the North Atlantic by Coelho et al. (2015b) and Indian Ocean by Coelho et al. (2015a). In those later studies, 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.

All statistical analysis for this paper was carried out with the R Project for Statistical Computing version 3.6.1 (R Core Team, 2019) 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).

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 2019, 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. However, part of the effort also takes place in more eastern areas of the South Indian Ocean.

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**).

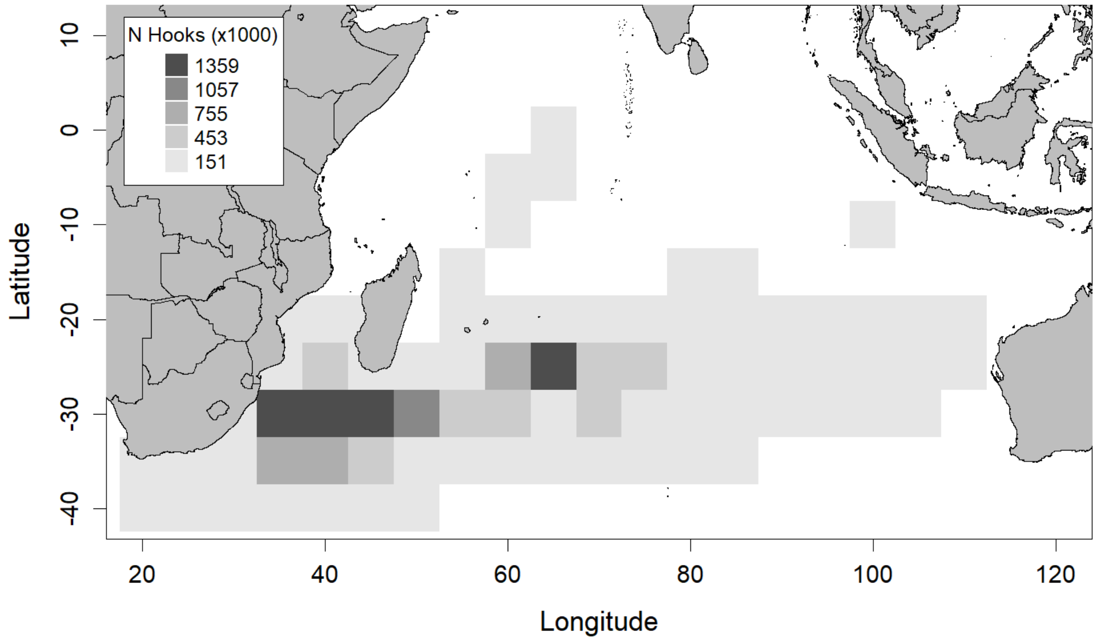

Figure 1. Effort distribution of the Portuguese pelagic longline fleet for the 1998-2019 period in the Indian Ocean. The effort is represented in 1°x1° grids with darker and lighter colors representing respectively areas with more and less effort in number of hooks.

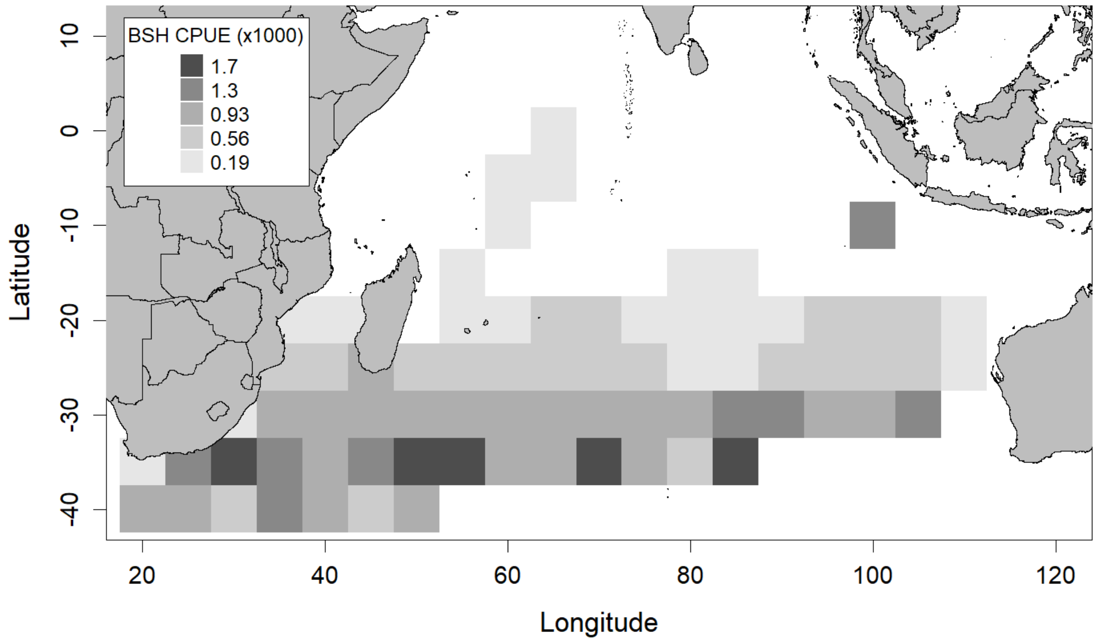

Figure 2. Catch distribution of BSH CPUEs in the Portuguese pelagic longline fleet for the 1998-2019 period in the Indian Ocean. The effort is represented in 5°x5° grids with darker and lighter colors representing respectively areas with more and less BSH CPUEs in biomass (kg/1000 hooks).

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 2005, followed by an increase during 2006-2007 and then a sharp decrease in 2008 (**Figure 3**). Since then, and for the most recent years (2009 to 2019) the effort has been increasing to values higher than in the early 2000's (**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, that has in fact represented the highest values in the time series (**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 since then, even though there has been a progressive slight decrease until the recent years (**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).

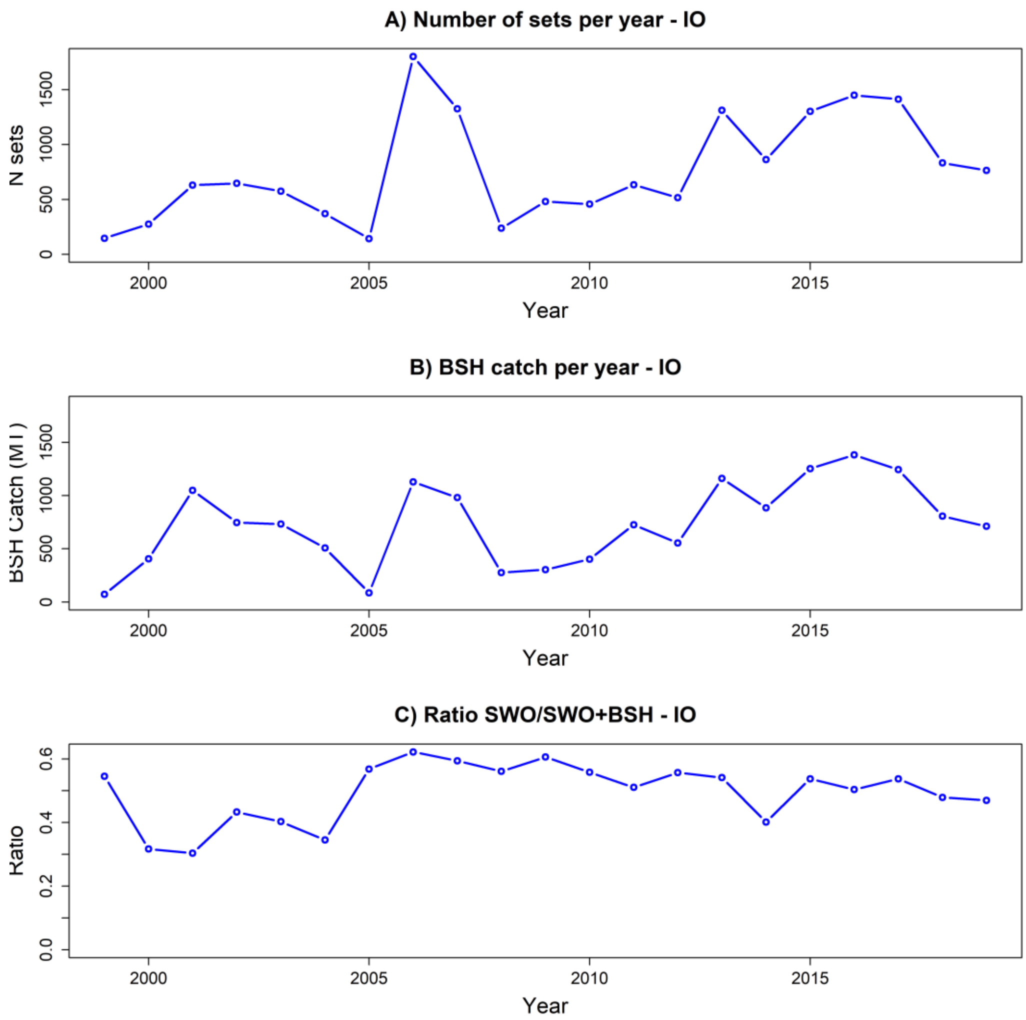

Figure 3. Descriptive plots of the total effort in sets (A), the total catch of blue shark (B), and the ratio of swordfish compared to the swordfish and blue shark catches (C), for the Portuguese longline fleet operating in the Indian Ocean.

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.

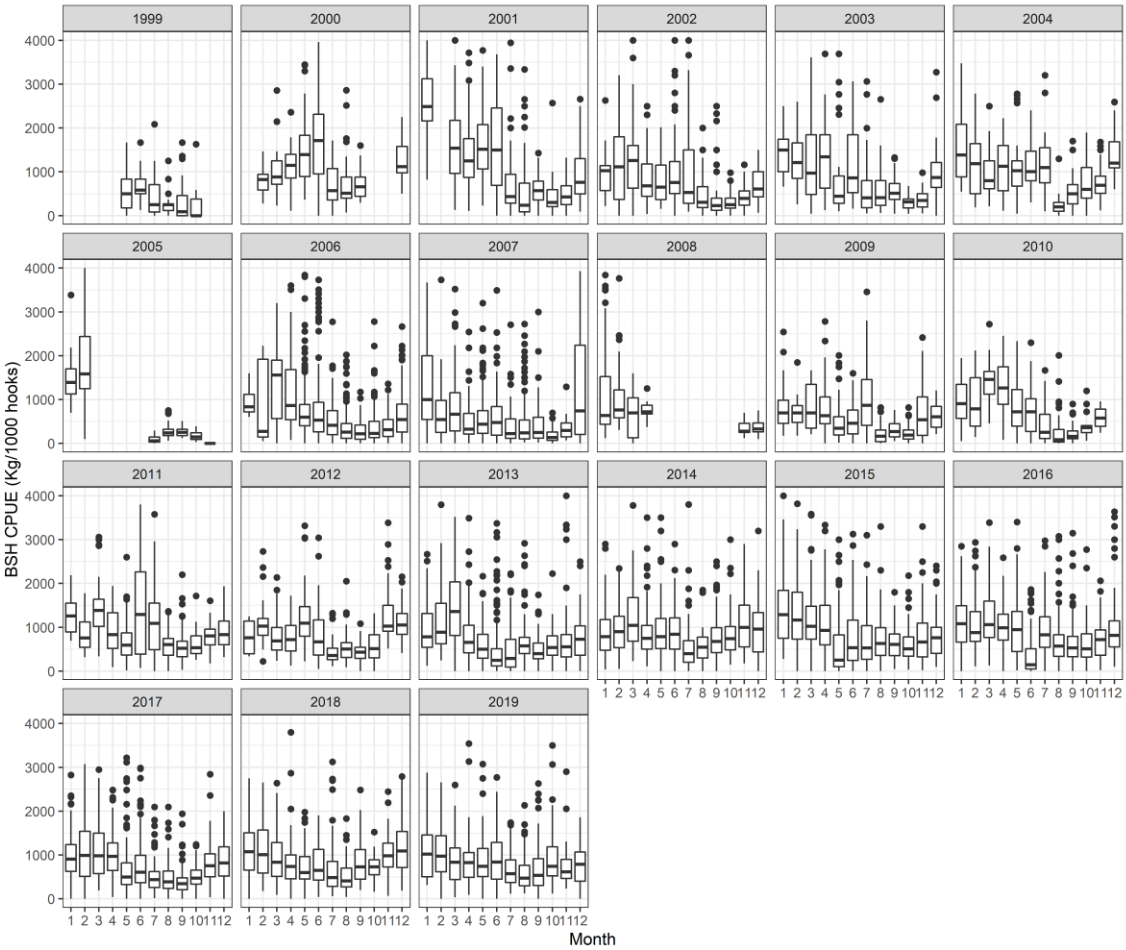

Figure 4. Monthly blue shark CPUE (kg/1000 hooks) by the Portuguese pelagic longline fleet in the Indian Ocean, per year. In the boxplots the middle lines represents the median, the box the quartiles, the whiskers the non-outlier range and the points the outliers.

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, 2011 and 2014 (**Figure 5**). In the most recent years there was an increasing trend in 2018 and 2019 (**Figure 5**).

The percentage of fishing sets with zero catches of BSH in the Indian Ocean was low, specifically 2.7%. The nominal blue shark CPUE distribution was highly skewed to the right and became more normal shaped in the log-transformed scale (**Figure 6**).

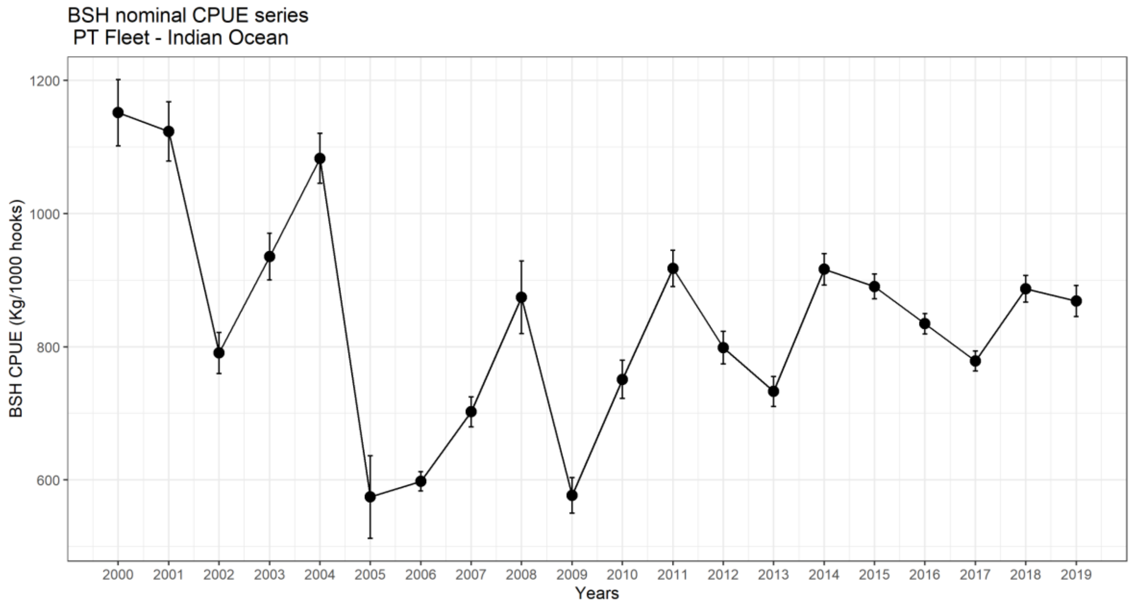

Figure 5. Nominal CPUE series (kg/1000 hooks) for BSH caught by the Portuguese pelagic longline fishery in the Indian Ocean between 2000 and 2019. The error bars refer to the standard errors.

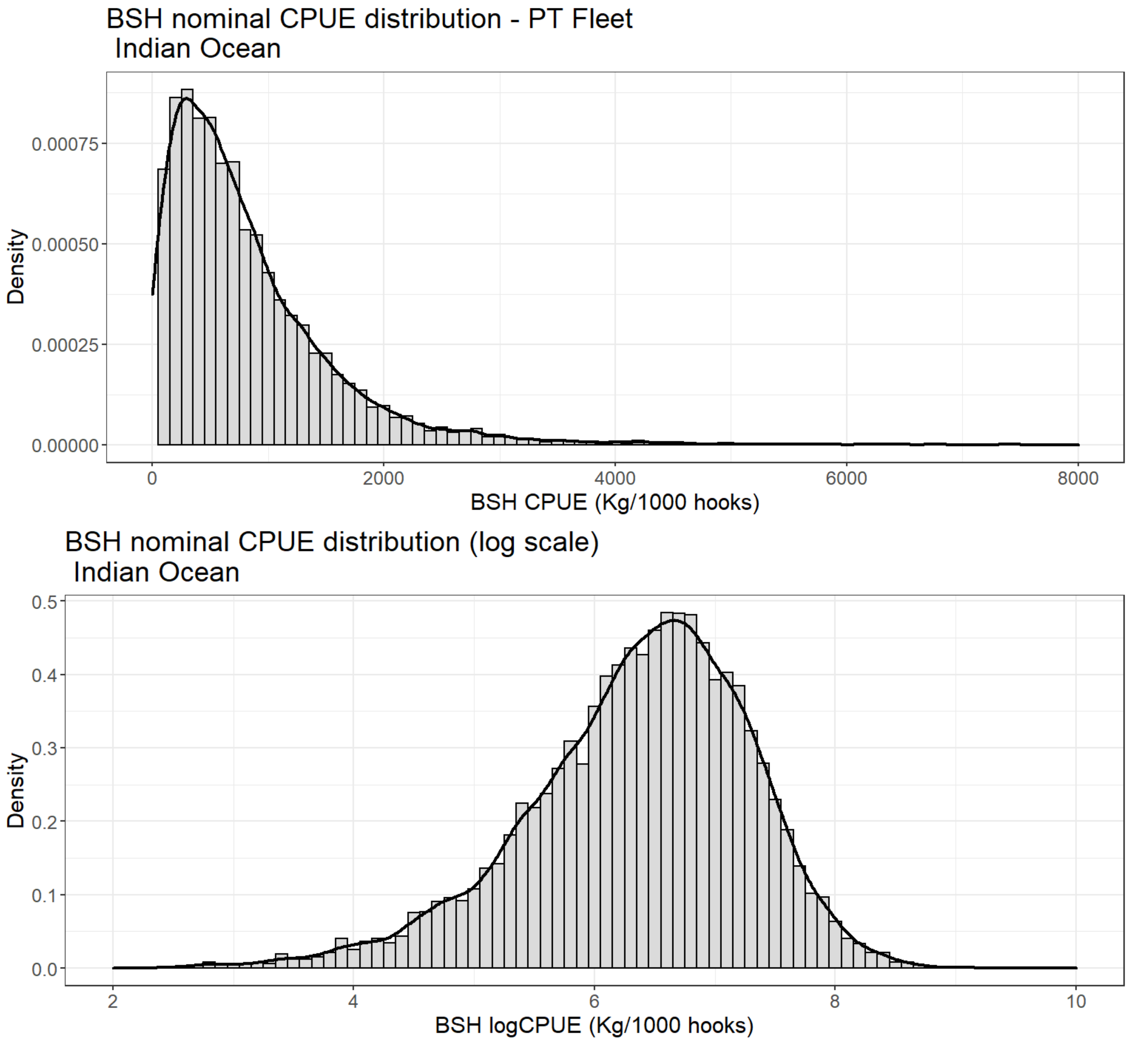

Figure 6: Distribution of the nominal blue shark CPUE captured by the Portuguese longline fleet in the Indian Ocean in non-transformed (top) and log-transformed (bottom) scales.

3.2.3. CPUE standardization 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. The area stratifications followed a GLM tree approach for optimization based on the AIC drop. The final areas selected (7 areas) are shown in **Figure 7**.

The factors that contributed most for the deviance explanation were the ratio, followed by the quarter, year and area (**Table 2**). The residual analysis showed no major problems, with the histogram of the residuals distribution being very close to a normal shape, even thought it was evident the presence of some outliers along the fitted values (**Figure 8**).

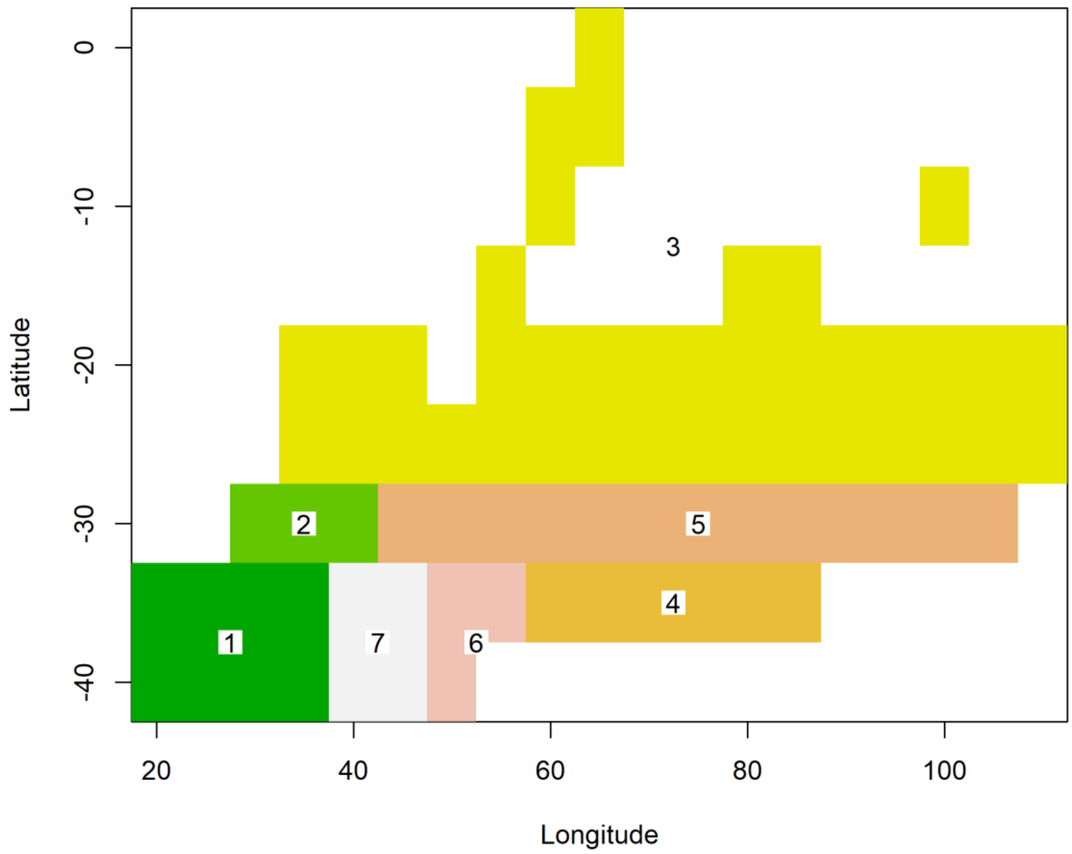

Figure 7: Spatial area stratification for the BSH CPUE captured by the Portuguese longline fleet in the Indian Ocean.

Table 2. Deviance table (type II Anova) of the parameters used for the BSH CPUE standardization in the Indian Ocean from the Portuguese pelagic longline fleet. 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).

Analysis of Variance Table

	Df	Sum Sq	Mean Sq	F value
Year	19	384.0	20.21	112.73
Quarter	3	797.2	265.74	1482.25
AreaCat7	6	255.8	42.63	237.79
RatioFac	9	4733.8	525.98	2933.83

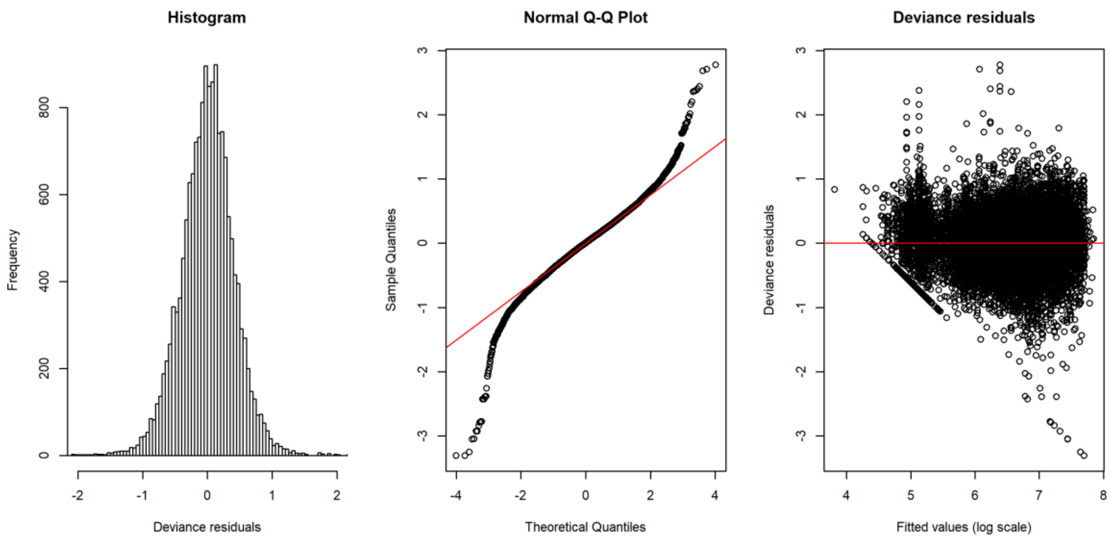

Figure 8. Residual analysis for the final lognormal GLMM model for the BSH CPUE standardization in the Indian Ocean. In the plot it is presented the histogram of the distribution of the residuals (left), the QQPlot (middle) and the residuals along the fitted values on the log scale (right).

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) and standardization carried out by Coelho et al. (2017), the final standardized CPUE series recommended to be used in the blue shark stock assessment derives from the base case model in those papers. This model accounts for the main simple effects Year, Quarter, Area and Ratio. Additionally, this model incorporates a random vessel effect, allowing the variability inherent to the different vessels to be considered in the models.

On this final model, the relative index of abundance showed a decrease in the initial years between 2000 and 2005, followed by an more stable period with some oscillations until 2019 (**Figure 9**). The final standardized blue shark CPUE index (in kg/1000 hooks) for the Portuguese pelagic longline fishery in the Indian Ocean between 2000-2019, suggested to be used in the blue shark stock assessments is presented in **Table 3**.

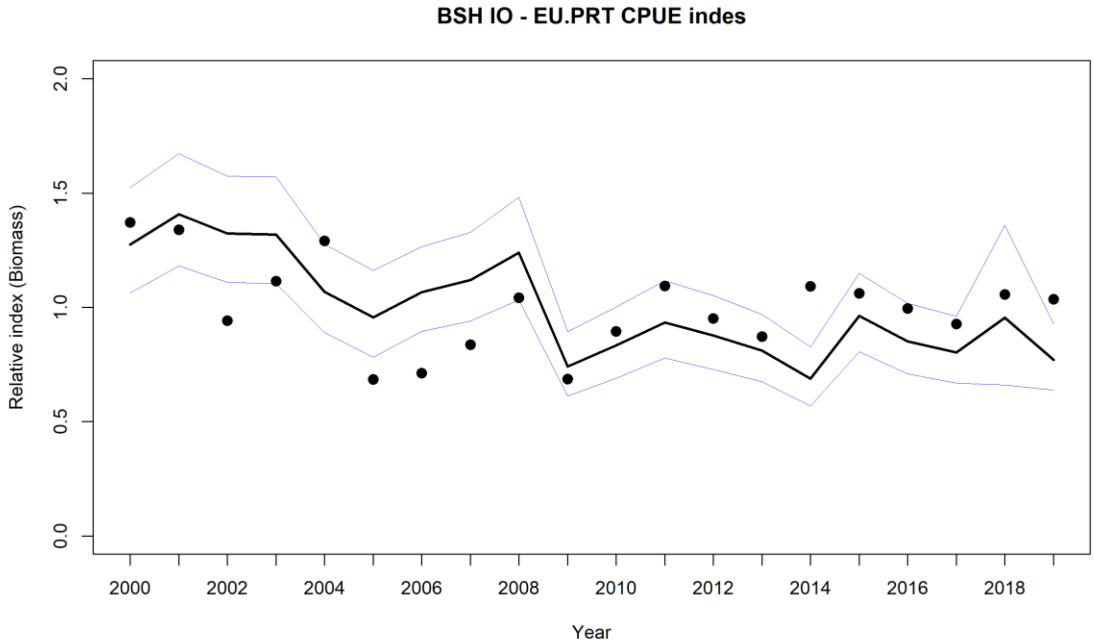

Figure 9. Standardized CPUE series for BSH captured by the Portuguese pelagic longline fleet in the Indian Ocean using a lognormal GLMM for the final selected model. The solid line refers to the standardized index and the black dots to the nominal CPUE series.

Table 3. Standardized BSH CPUE index (kg/1000 hooks) for the Portuguese pelagic longline fleet in the Indian Ocean between 2000 and 2019, for consideration to use in the 2021 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	726.1	868.0	605.4	21.2
2001	801.9	952.6	673.1	31.3
2002	754.4	896.6	632.8	31.6
2003	751.1	894.7	628.7	30.1
2004	608.4	727.2	507.1	24.2
2005	544.7	661.8	446.1	16.2
2006	607.6	721.3	510.1	51.2
2007	637.9	756.9	535.8	44.0
2008	706.0	844.3	588.4	19.7
2009	423.1	509.5	349.3	27.4
2010	475.3	571.0	393.6	26.8
2011	532.3	636.2	443.4	31.1
2012	499.9	599.1	415.2	28.3
2013	462.0	552.4	384.5	44.1

2014	392.1	471.8	324.0	36.1
2015	549.2	654.4	459.1	44.0
2016	485.4	579.7	404.5	46.3
2017	458.0	547.6	381.1	45.7
2018	544.5	774.4	376.4	71.3
2019	439.6	528.2	363.8	34.3

4. Acknowledgments

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5. References

Afonso, A.S., Hazin, F.H.V., Carvalho, F., Pacheco, J.C., Hazin, H., Kerstetter, D,W,, Murie, D., Burgess, G.H. 2011. Fishing gear modifications to reduce elasmobranch mortality in pelagic and bottom longline fisheries off Northeast Brazil. *Fisheries Research*, 108: 336–343.

Bates, D., Maechler, M., Bolker, B., Walker, S. 2014. lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1-7, URL: http://CRAN.R-project.org/package=lme4.

Bivand, R., Lewin-Koh, N. 2013. maptools: Tools for reading and handling spatial objects. R package version 0.8-27. http://CRAN.R-project.org/package=maptools.

Campbell, R.A. 2004. CPUE standardisation and the construction of indices of stock abundance in a spatially varying fishery using general linear models. *Fisheries Research*, 70: 209–227.

Coelho, R., Lino, P.G., Santos, M.N. 2011. Standardized CPUE of major shark species caught by the Portuguese longline fishery in the Indian Ocean. *IOTC Working Document*. OTC–2011–WPEB07–36.

Coelho, R., Santos, M.N., Lino, P.G. 2012. Update of the standardized CPUE series for major shark species caught by the Portuguese pelagic longline fishery in the Indian Ocean. *IOTC Working Document*. IOTC–2012–WPEB08–29.

Coelho, R., Santos, M.N., Lino, P.G. 2013. Standardized CPUE series for blue and shortfin mako sharks caught by the Portuguese pelagic longline fishery in the Indian Ocean between 1999 and 2012. *IOTC Working Document*. IOTC–2013–WPEB09–22.

Coelho, R., Santos, M.N., Lino, P.G. 2014. Blue shark catches by the Portuguese pelagic longline fleet between 1998-2013 in the Indian Ocean: Catch, effort and standardized CPUE. *IOTC Working Document*: IOTC–2014–WPEB10–24.

Coelho, R., Lino, P.G., Rosa, D., Santos, M.N. 2015a. Update of blue shark catches and standardized CPUE for the Portuguese pelagic longline fleet in the Indian Ocean: exploring the effects of targeting. *IOTC Working Document*: IOTC–2015–WPEB11–26.

Coelho, R., Santos, M.N., Lino, P.G. 2015b. Standardized CPUE of blue shark in the Portuguese pelagic longline fleet operating in the North Atlantic. ICCAT blue shark data preparatory meeting. *ICCAT Working Document*: SCRS/2015/037.

Coelho, R., Lino, P.G., Rosa, D. 2017. Blue shark catches and standardized CPUE for the Portuguese pelagic longline fleet in the Indian Ocean. 13th Working Party on Ecosystems and Bycatch, 4-8 September, San Sebastian, Spain. IOTC Document, IOTC–2017–WPEB13–24. 17pp.

Fox, J., Weisberg, S. 2011. An R Companion to Applied Regression, 2nd Edition. Sage, Thousand Oaks CA.

He, X., Bigelow, K.A., Boggs, C.H. 1997. Cluster analysis of longline sets and fishing strategies within the Hawaii-based fishery. *Fisheries Research*, 31: 147-158.

Højsgaard, S., Halekoh, U. 2012. doBy: Groupwise summary statistics, general linear contrasts, population means (least-squares-means), and other utilities. R package version 4.5.0. http://CRAN.R-project.org/package=doBy.

Ichinokawa, M., Brodziak, J. 2010. Using adaptive area stratification to standardize catch rates with application to North Pacific swordfish (*Xiphias gladius*). *Fisheries Research*, 106: 249-260.

IOTC–WPEB10 2014. Report of the 10th Session of the IOTC Working Party on Ecosystems and Bycatch. Yokohama, Japan, 27–30 October 2014. IOTC–2014–WPEB10–R[E]: 94 pp.

Lenth, R.V. 2014. lsmeans: Least-Squares Means. R package version 2.11. http://CRAN.R-project.org/package=lsmeans.

Mejuto, J., García-Cortés, B., Ramos-Cartelle, A. 2008. Standardized catch rates in biomass for the swordfish (Xiphias gladius) caught by the Spanish longline fleet in the Indian Ocean for the period 1993-2007. *IOTC Working Document*. IOTC-2008-WPB-06.

Mejuto, J., García-Cortés, B., Ramos-Cartelle, A., De la Serna, J.M., González-González, I. 2012. Standardized catch rates of shortfin mako (Isurus oxyrinchus) caught by the Spanish surface longline fishery targeting swordfish in the Atlantic Ocean during the period 1990-2010. *ICCAT Working Document*. SCRS/2012/046. 12pp.

Ramos-Cartelle, A., García-Cortés, B., Fernández-Costa, J., Mejuto, J. 2011. Standardized catch rates for the swordfish (Xiphias gladius) caught by the Spanish longline in the Indian Ocean during the period 2011-2012. *IOTC Working Document*. IOTC-2011-WPB09-23. 19pp.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Santos, M.N., Garcia, A., Pereira, J.G. 2002. A historical review of the by-catch from the Portuguese surface long-line swordfish fishery: observations on blue shark (*Prionace glauca*) and short-fin mako (*Isurus oxyrinchus*). *Col. Vol. Sci. Pap., ICCAT*, Madrid, 54(4): 1333-1340.

Santos, M.N., Coelho, R., Lino, P.G. 2013. Updated overview of the swordfish catches by the Portuguese pelagic longline fishery in the Indian Ocean: catch, effort, CPUE and catch-at-size. *IOTC Working Document*: IOTC–2013–WPB11–31.

Santos, M.N., Coelho, R., Lino, P.G. 2014. Swordfish catches by the Portuguese pelagic longline fleet between 1998-2013 in the southwest Indian Ocean: Effort, standardized CPUE and catch-at-size. *IOTC Working Document*: IOTC–2014–WPB12–19.

Shono, H. 2008. Application of the Tweedie distribution to zero-catch data in CPUE analysis. *Fisheries Research*, 93: 154–162.

Vega, R., Licandeo, R. 2009. The effect of American and Spanish longline systems on target and non-target species in the eastern South Pacific swordfish fishery. *Fisheries Research*, 98: 22-32.

Wang, S-P., Nishida. T. 2014. CPUE standardization with targeting analysis for swordfish (*Xiphias gladius*) caught by Taiwanese longline fishery in the Indian Ocean. *IOTC Working Document*: IOTC–2014–WPB12–22.

Ward, P., Lawrence, E., Darbyshire, R., Hindmarsh, S. 2008. Large-scale experiment shows that nylon leaders reduce shark bycatch and benefit pelagic longline fishers. *Fisheries Research*, 90: 100-108.

Wickham, H. 2007. Reshaping data with the reshape package. *Journal of Statistical Software*, 21 (12): 20pp.

Wickham, H. 2009. ggplot2: elegant graphics for data analysis. Springer, New York.