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A POTENTIAL INDICATOR FOR NON-RETAINED SHARKS IN SUPPORT OF AN ICCAT ECOSYSTEM REPORT CARD

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SUMMARY

This work follows the requests and ongoing work from the ICCAT Sub-Committee on Ecosystems to develop an Ecosystem report card, in this case related with non-retained sharks. As a starting point, the bigeye thresher shark was used given its low productivity and susceptibility to longline fisheries, determined in the latest sharks ERA. The preliminary indicator developed now is based on a standardized CPUE from operational level fishery observer data, from the Portuguese pelagic longline fleet (2008-2016). This indicator should be considered preliminary, at this stage provided mostly as a starting point for discussion at the SC-ECO, since it only has data from one fleet. If there is an interest to progress the development of these types of indicator, then it is recommended that detailed observer data from other fleets should be incorporated, especially fleets from CPCs that interact more with those pelagic shark species.

KEYWORD

Atlantic Ocean, ecosystem indicators, pelagic fisheries, sharks

1. Introduction

Some initial thoughts on possible indicators for non-retained sharks in support of an ICCAT Ecosystem Report card were provided by Cortés et al. (2018). It was noted that ICCAT Task I-NC and Task II-CE data for non-retained sharks is very incomplete and most likely underestimate true catches. Additionally, very few CPCs report dead discard estimates for non-retained sharks. As such, Cortes et al (2018) concluded that for providing indicators for non-retained sharks there would be the need for concerted efforts by all CPCs to report all catches in ICCAT fisheries and produce joint analysis, preferably using detailed operational data from fishery observers. Examples of possible indicators that could experimentally be used included trends in catch per unit of effort, that once standardized could be used as indices of relative abundance.

Furthermore, the SC-ECO in 2018 during its inter-sessional meeting, discussed whether it was possible for a single species to represent the fishery impacts experienced by non-retained sharks in general. The SC-ECO mentioned that it might not be appropriate as different species have different biology (productivity) and are susceptible to different fleets/gears and therefore subject to different selectivities. However, and as a starting point, the SC-ECO agreed that the latest sharks ERA (Cortés, et al., 2015) could be used to determine the most vulnerable species. And as a starting point, the focus could therefore be concentrated on the bigeye thresher shark (BTH - *Alopias superciliosus*) for longline fleets and silky shark (FAL - *Carcharhinus falciformis*) for purse seine fleets (ICCAT, 2018).

The bigeye thresher shark is an oceanic, pelagic and highly migratory species, with a wide distribution in the Atlantic, Indian and Pacific Oceans. The bigeye thresher has some particular distribution patterns in the Atlantic, with mean sizes tending to be smaller in the tropical regions, and with pregnant females also

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recorded mostly in the tropical NE and SW Atlantic, with these two regions possibly corresponding to nursery areas for this species in the Atlantic (Fernandez-Carvalho et al., 2015).

Given the discussions and agreements from the 2018 SC-ECO meeting (ICCAT, 2018), the main objective of this paper is now to provide a preliminary indicator for non-retained sharks, in this case based on a relative index of abundance for the bigeye thresher shark from ICCAT pelagic longline fisheries.

2. Materials and methods

2.1. Data collection

The data used for this work refers to captures of bigeye thresher shark in the Atlantic Ocean. Bigeye thresher is currently a no-retention species in ICCAT fisheries, but it is still occasionally captured as bycatch and therefore recorded by onboard scientific fishery observers.

For this preliminary work only data collected by the scientific fishery observers from the Portuguese Institute for the Ocean and Atmosphere (IPMA) onboard the EU.Portugal pelagic longline fleet was used. . This fleet operates throughout a wide area of the Atlantic Ocean, with spots of higher fishing effort around the temperate Northeast and Equatorial regions (**Figure 1**). The spatial distribution of the fishing effort is mostly associated with the target species swordfish, *Xiphias gladius*, and, to a lesser extent, blue shark, *Prionace glauca* (Coelho et al., 2012).

Fishery observers regularly collect data for all specimens caught, including target species, bycatch and interactions with vulnerable fauna. The observers collect and record data on the species, size (typically fork length - FL for shark) and sex, as well as other details such as hooking location, condition at hauling and condition if discarded/released. The fishing set data is also recorded, including location (latitude and longitude), date and effort in terms of the number of hooks. Finally, some detailed operational level data is also recorded, such as hook types, bait used and gangion line materials.

The data used for this work covered the years 2008 to 2016. Data from a total of 1,777 fishing sets was available and used, varying between 149 and 275 fishing sets per year, and representing around 3% of the total fleet effort in the period.

2.2. Data analysis

Catch per unit effort (CPUE) was calculated as the number (N) of BTH specimens per 1000 hooks. The preliminary indicator provided in this work refers to a standardization of those CPUEs, where the response variable is the set-level nominal CPUEs and is modeled by Generalized Linear Models (GLM).

As the bigeye thresher is an occasional and relatively rare species captured in the fishery, there are many fishing sets with zero catches that results in a response variable of CPUE=0. To deal with those zeros, a Tweedie GLM was used, following models used for example in previous shortfin mako CPUE standardizations (Coelho et al., 2013; 2017). This model uses an approach where only one model is fitted to the data, with that model handling this mixture of continuous positive values with a discrete mass of zeros. The Tweedie distribution is part of the exponential family of distributions, and is defined by a mean (μ) and a variance ($\varphi\mu p$), in which φ is the dispersion parameter and p is an index parameter. In this study, the index parameter (p-index) was calculated by maximum likelihood estimation (MLE).

The covariates considered and tested in the models were:

- Year: analyzed between 2008 and 2016;
- Month of the year;
- Areas: Using 4 areas defined with a GLM-tree area stratification (based on the approach of Ichinokawa and Brodziak, 2010) (**Figure 2**);
- Leader material: wire or monofilament leaders.

Interactions were considered and tested in the analysis but not used in the final models. This was due to the fact that as BTH is only captured occasionally and therefore the percentage of zeros is very high. As such, when interactions are tested most often there is not sufficient contrasting information for all combinations (positive and negative sets), which does not allow the estimation of interaction parameters. As such, the final models used only involved simple effects.

The significance of the explanatory variables in the CPUE standardization models 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) and the pseudo coefficient of determination (R2). Model validation was carried out with a residual analysis. The final estimated indexes of abundance were calculated by least square means (LSMeans or Marginal Means), that for comparison purposes were scaled by the mean standardized CPUE in the time series.

Data analysis for this paper was carried out in the R language for statistical computing 3.5.1 (R Core Team, 2018).

3. Results

3.1. Data description and characteristics

The bigeye thresher shark nominal CPUEs in the Atlantic, considering only the Portuguese fleet distribution, were mainly concentrated in tropical waters of the NE Atlantic (**Figure 3**).

The distribution of the BTH CPUE data was highly asymmetrical and skewed to the right (**Figure 4**). The data contained 70.8% of zeros, with variations between 55.6% and 93.9% by year (**Figure 5**). Overall, the nominal CPUEs showed a decreasing trend between 2008 and 2013, followed by an increasing trend between 2013 and 2016 (**Figure 6**).

3.2. Indicator - Bigeye thresher CPUE standardization

The Tweedie GLM used in the CPUE standardization explained 41% of the variability. The index parameter estimated for the Tweedie distribution was 1.173 and resulted in a distribution that expects 69.6% of zeros, compared to the 70.8% observed in the bigeye thresher shark data.

All explanatory variables tested (year, month, area and gangion line material) contributed significantly for explaining part of the deviance. The year effects were responsible for most of the variability, followed by area, month and finally gangion line material (**Table 1**).

In terms of model validation, the residual analysis, including the residuals distribution along the fitted values, the QQ plots and the residuals histograms, showed that the model was adequate with no major outliers or trends identified in the residuals (**Figure 7**).

The final relative index of abundance showed an increasing trend in the 1st year, followed by a general decreasing trend for the rest of the period (**Figure 8**). Similarly to the nominal series, the standardized CPUE also showed an increase in the more recent years, but not as noticeable as in the nominal series (**Figure 9**).

4. Discussion

This work presents a standardized CPUE series for the bigeye thresher shark, a no-retention shark in ICCAT fisheries and that could therefore be considered as an indicator for this category within a future ICCAT Ecosystem report card. The species was selected as it has a very low productivity and was determined to be the most vulnerable to longline fisheries in the last sharks ERA (Cortés et al., 2015).

The current analysis provided here is limited as it only takes into account one fishing fleet (EU.Portugal). As such, if the SC-ECO wishes to continue and progress this work, it would be advisable to incorporate fishery observer data from more fleets, especially surface longline fleets that more frequently interact with shark species such as the bigeye thresher shark.

Other potential future indicators that have been discussed by the SC-ECO in the past and can also be considered are: 1) other species-specific relative indices of abundance and/or trends in size by sex from observer data and 2) estimates of species-specific total mortality, taking into account dead discards and any known post-release mortality.

Given that at this point the data available at the ICCAT Secretariat from Task I and II are limited and not usable to provide informative time series indicators for non-retained sharks, continuing the work would require the joint efforts from national scientists from the various CPCs, with the use of detailed fishery observer data.

5. Recommendations and considerations for future work

- Advance this standardized CPUE index for the bigeye thresher shark by incorporation detailed observer data from other fleets/CPCs. It would be especially important to cover fleets from CPCs that interact more with this shark species;

- Consider other alternative indicators, such as CPUE series from other species or try to estimate trends of species-specific total mortality, taking into account dead discards and post-release mortality.

- Other ideas to be discussed at the SC-ECO...

6. Acknowledgements

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Tables

Table 1. Deviance table for the Tweedie GLM used for the BTH CPUE standardization. The analysis is based on a type II Anova test.

Variable	Sum Sq.	Df	F	P-value
Year	213.38	8	11.7144	4.14E-16
Month	145.57	11	5.8122	3.27E-09
Area	181.35	3	26.5501	2.20E-16
Gangion	66.28	1	29.111	8.33E-08

Figures

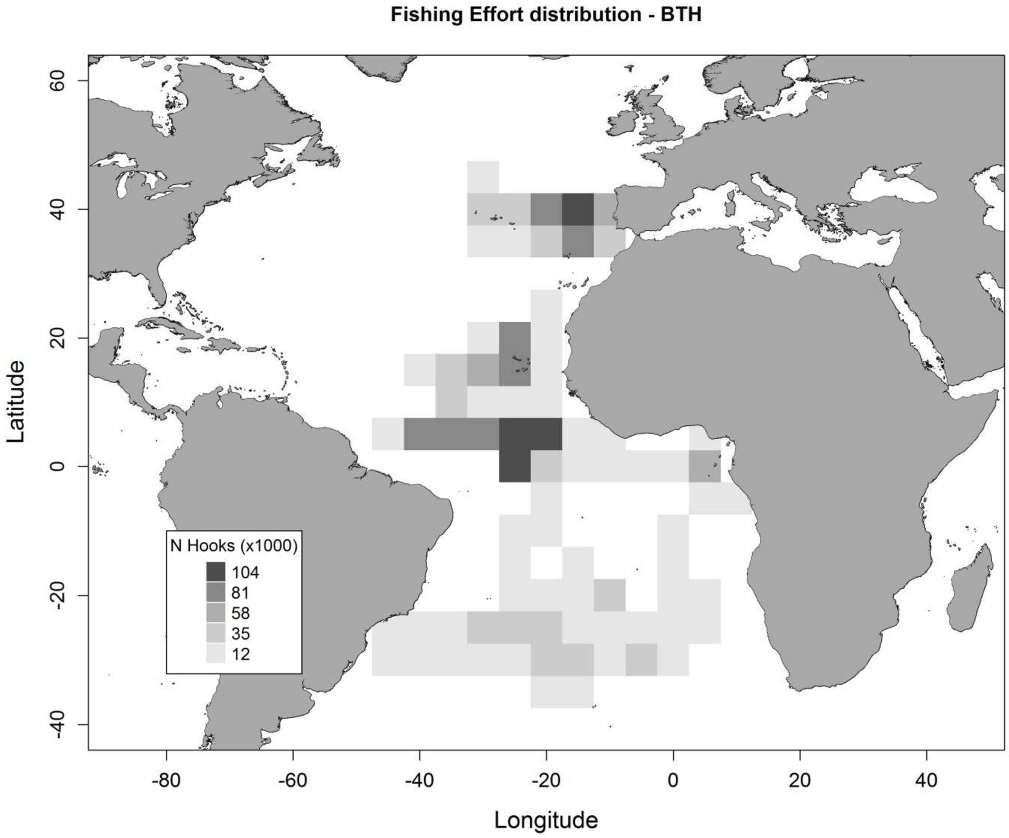

Figure 1: Effort distribution, measured in number (N) of hooks covered by fishery observers, represented in 5*5 squares. The data represented covers the years 2008 to 2016.

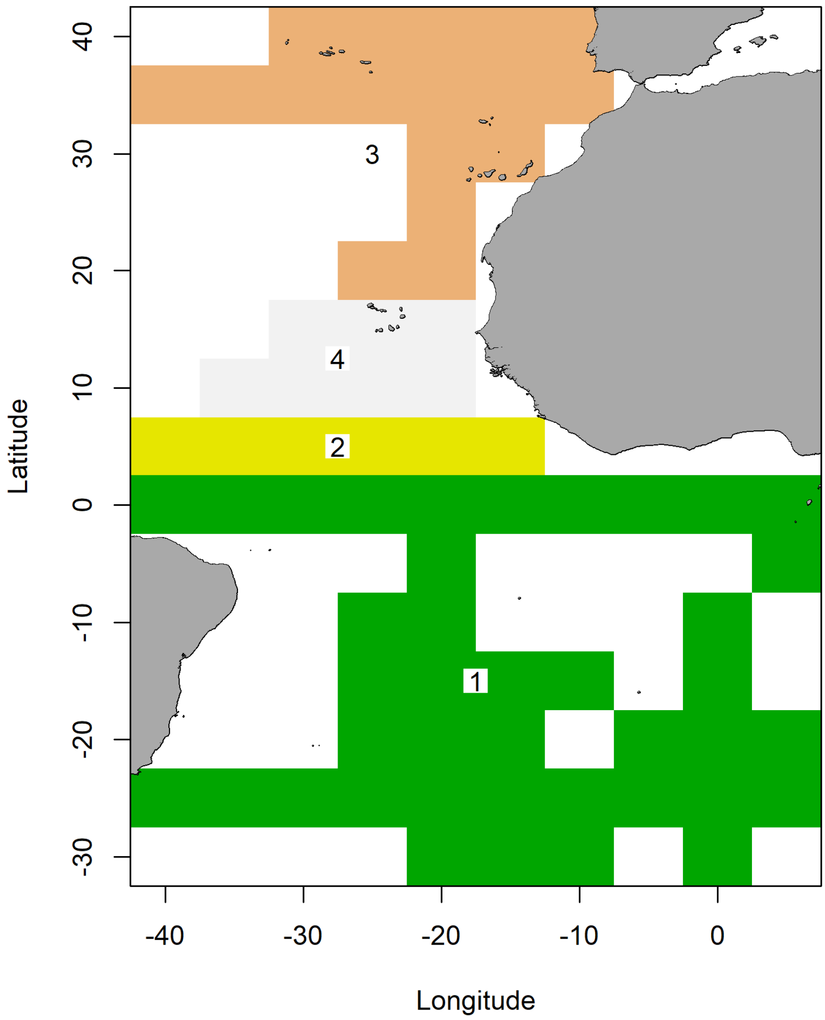

Figure 2: Four (4) area solution for the distribution of BTH nominal CPUEs, using a GLM-Tree approach as described by Ichinokawa and Brodziak (2010).

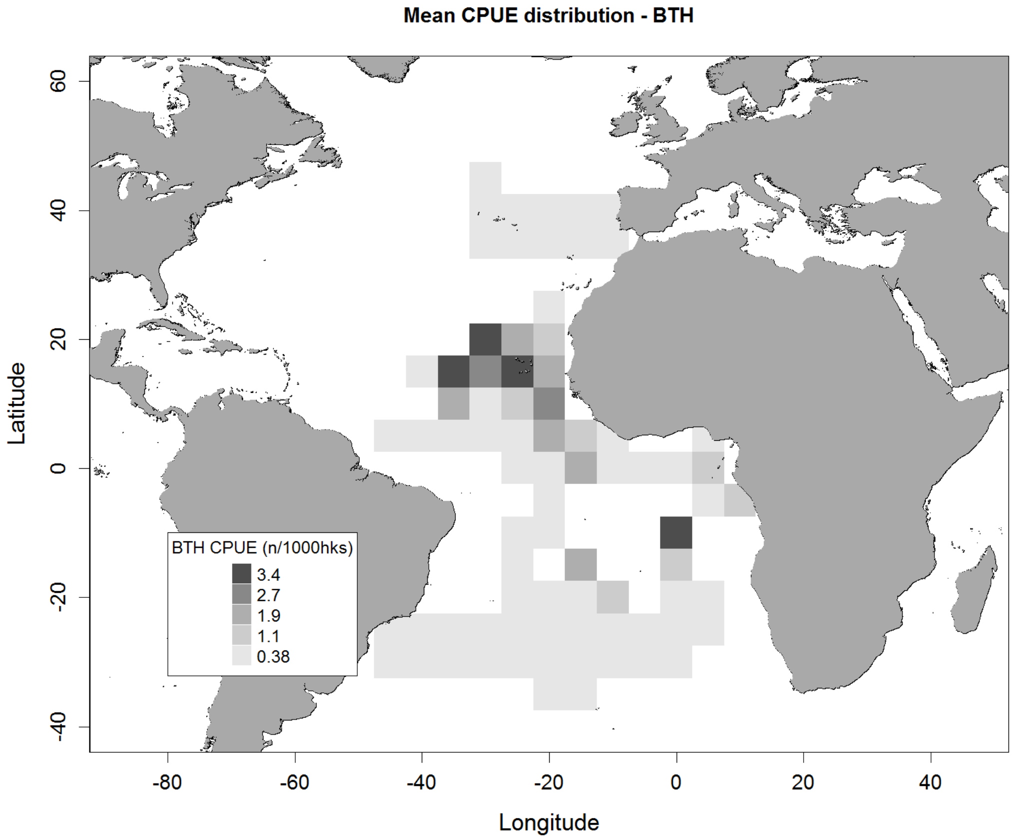

Figure 3: Bigeye thresher shark (BTH) distribution measured in CPUE (N/1000 hooks), represented in 5*5 squares. The data covers the years 2008 to 2016.

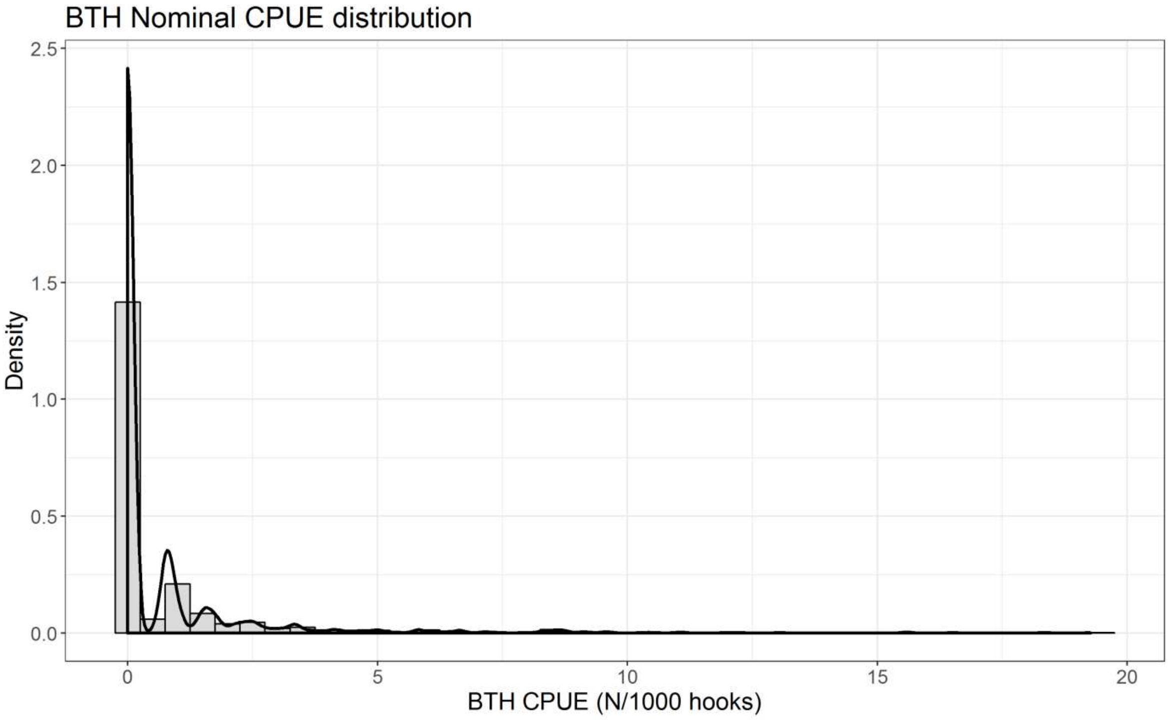

Figure 4. Shape of the distribution of the nominal BTH CPUE data.

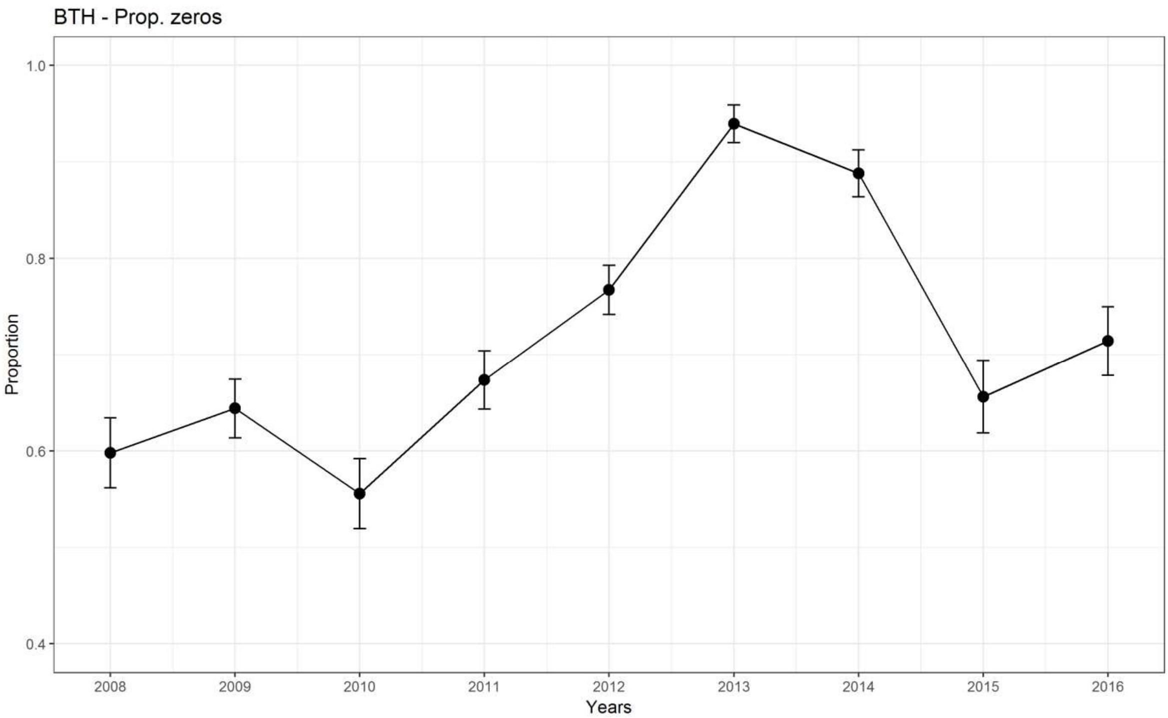

Figure 5. Proportion of zeros in the BTH CPUE data by year. Error bars represent standard errors.

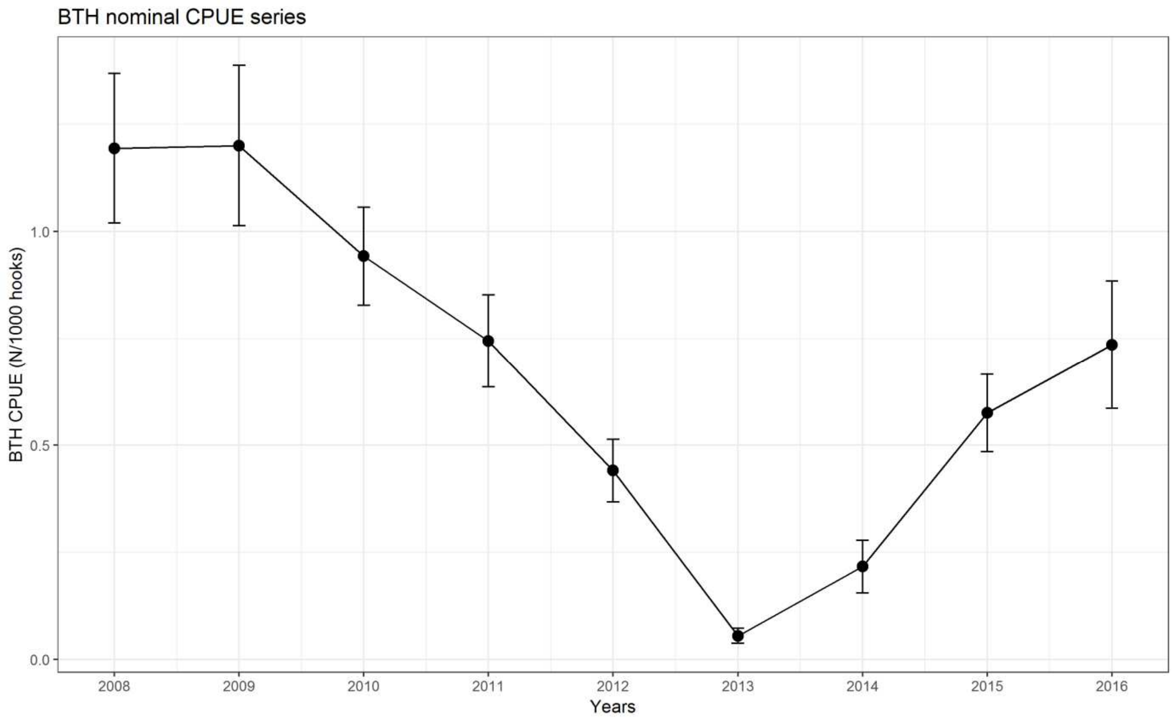

Figure 6: Time series of the nominal BTH CPUEs (N/1000 hooks), between 2008 and 2016. The error bars represent standard errors.

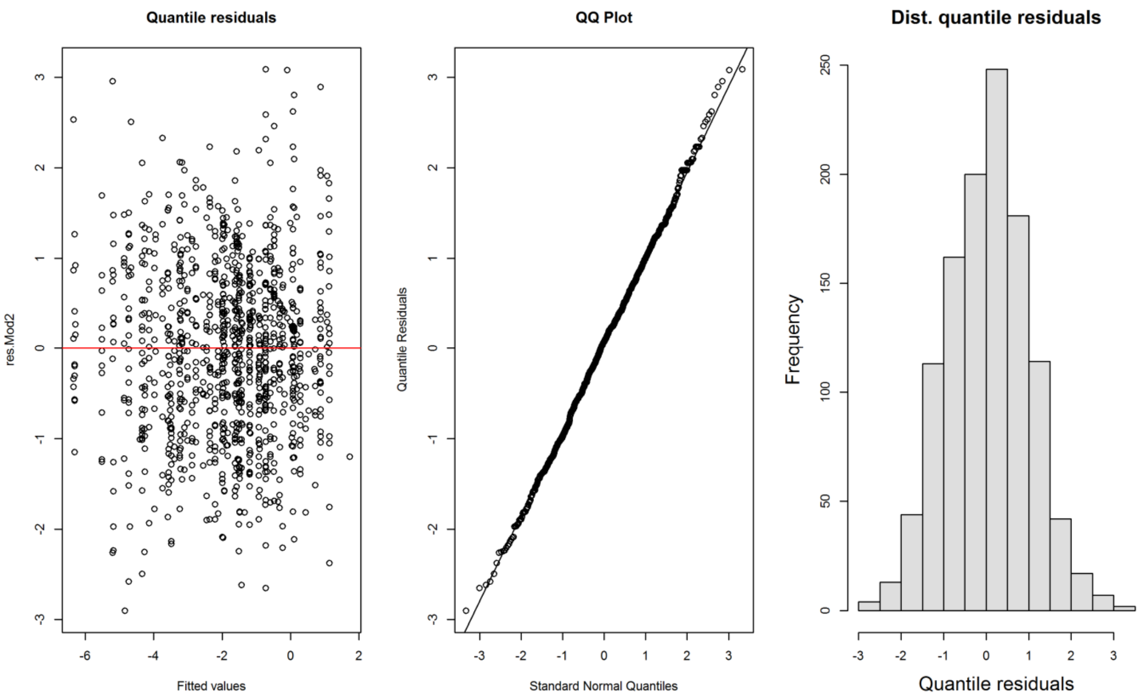

Figure 7: Residual analysis (quantile residuals) for the Tweedie GLM for the standardization of BTH CPUEs.

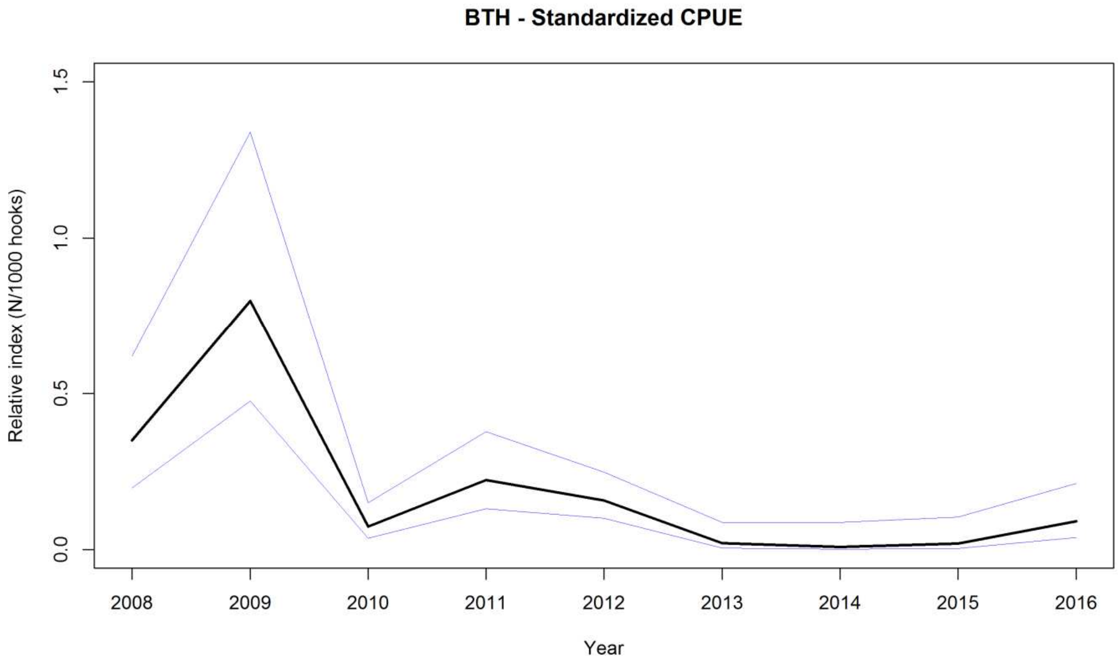

Figure 8: Bigeye thresher standardized CPUE series between 2008 and 2016, with the respective confidence intervals. The series in this plot is represented in the original scale.

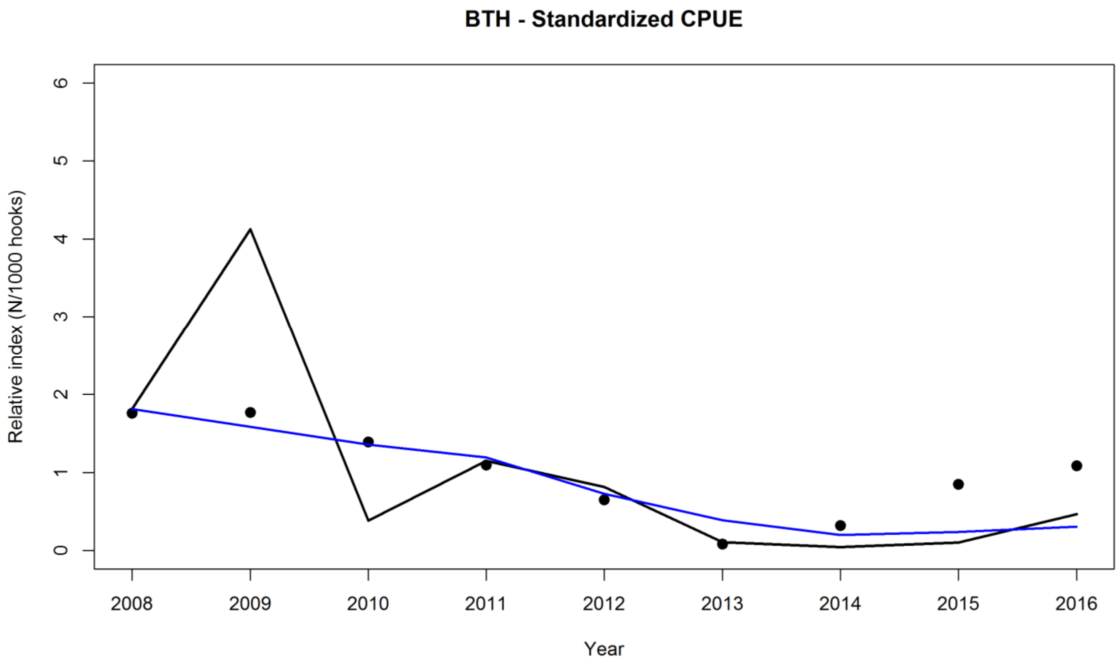

Figure 9: Bigeye thresher standardized CPUE series between 2006 and 2018. The black line represents the standardized CPUE series and the blue line represents a lowess smooth line fitted to the standardized CPUE series. The nominal CPUEs are represented by the black dots. For comparative purposes, all series are scaled by their mean values.