METHODS FOR ESTIMATING DISCARDS OF SHORTFIN MAKO (*ISURUS OXYRINCHUS*) BY THE PORTUGUESE LONGLINE FLEET IN THE NORTH ATLANTIC

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SUMMARY

*This document presents preliminary information to start addressing the ICCAT Commission request for estimation of discards of shortfin mako (*Isurus oxyrinchus*) (ICCAT Rec 21-09), with a view to eventually allow for a possible future retention allowance in the North Atlantic. The intent of this paper is to provide an example of a possible approach for estimation of discards of shortfin mako in the Portuguese pelagic longline fleet, with known effort data, including date and location. The estimation is based on GAM models that modelled both total catches and discards of shortfin mako from fishery observer data between 2019 and 2022. With those models, and as an example, we then provide predictions for the dead discards and live releases in years 2020 and 2021.*

RÉSUMÉ

*Ce document présente des informations préliminaires pour commencer à répondre à la demande de la Commission de l'ICCAT concernant l'estimation des rejets de requin-taupe bleu (*Isurus oxyrinchus*) (Rec. 21-09), en vue de permettre à l'avenir une éventuelle tolérance de rétention dans l'Atlantique Nord. L'objectif de ce document est de fournir un exemple d'approche possible pour l'estimation des rejets de requins-taupes bleus dans la flottille palangrière pélagique portugaise, avec des données d'effort connues, y compris la date et la localisation. L'estimation est basée sur des modèles GAM qui modélisent à la fois les captures totales et les rejets de requins-taupes bleus à partir des données des observateurs des pêcheries entre 2019 et 2022. À l'aide de ces modèles, et à titre d'exemple, nous fournissons ensuite des prévisions pour les rejets de poissons morts et les remises à l'eau de spécimens vivants pour les années 2020 et 2021.*

RESUMEN

*Este documento presenta información preliminar para comenzar a abordar la petición de la Comisión de ICCAT de estimar los descartes de marrajo dientuso (*Isurus oxyrinchus*) (Rec. 21-09), con vistas a permitir en el futuro una posible tolerancia de retención en el Atlántico norte. El objetivo de este documento es presentar un ejemplo de un posible enfoque para la estimación de los descartes de marrajo dientuso en la flota de palangre pelágico portuguesa, con datos de esfuerzo conocidos, lo que incluye fecha y ubicación. La estimación se basa en modelos GAM que modelaron tanto las capturas totales como los descartes de marrajo dientuso a partir de los datos de observadores pesqueros entre 2019 y 2022. Con esos modelos, y a modo de ejemplo, se presentan predicciones para los descartes de ejemplares muertos y las liberaciones de ejemplares vivos en los años 2020 y 2021.*

KEYWORDS

Discards, longline fisheries, shortfin mako, North Atlantic, Task 1 data

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Introduction

ICCAT Recommendation 21-09 requests the following in paragraph 13: "…, *CPCs that reported annual average catches (landings and dead discards) of North Atlantic shortfin mako over 1 t between 2018-2020 shall present to the SCRS the statistical methodology used to estimate dead discards and live releases*".

Given that Portugal has reported catches of shortfin mako (FAO code: SMA) of over 1t between 2018-2020, the objective of this paper is to provide a preliminary discussion on possible methods that could be used to address the Commission Request on a methodology to estimate possible dead discards and live releases from this fleet.

Methods

Data

A total of 467 fishing sets with onboard observers carried out between 2019 and 2022 were used in the analysis. The data used was mostly from the North Atlantic stock, but in order to also include data from the equatorial zone that could also be of individuals from the North Atlantic stock, the data used included all sets that were located in latitudes northern than 5º South. **Figure 1** provides the map with the distribution of the effort covered by observers in the 2019-2022 period, while **Figure 2** provides the SMA CPUE distribution.

Analysis

Statistical models were used to model the expected CPUEs and respective discards (in numbers). The initial models were carried out using Poisson GLMs with the effort used as a model offset in log(effort). The dispersion parameter within the Poisson model was calculated and used in the models, to allow the interpretation of the models with Poisson distribution even with slightly over-dispersed data, as was the case.

The explanatory variables tested included categorical variables (month or season) and continuous variables (location: latitudes and longitudes). The catch of blue shark (BSH) and swordfish (SWO) were also tested as model covariates, as there are relationships between the catches of those species in pelagic longlines. Some variables such as year and vessel (or trip) were tested as random variables to generalize the models and the respective predictions. However, there were convergence problems when using random effects and therefore those were not used in the final models. Interactions between model covariates were also tested and used if significant and if the models improved in terms of deviance explained.

The continuous variables (latitude and longitude) were tested for the assumption of linearity. Given that both failed linearity with the predictor, alternative models using Generalized Additive Models (GAMs) were carried out.

The models were used, as a trial, to make predictions for 2020 and 2021 SMA discards given the reported effort for the Portuguese fleet operating in the North Atlantic, with known location and date (month or season). Given that the models used for the estimates were in numbers (N/1000 hooks) and ICCAT Task 1 data is to be reported in weight, for the final calculation the average size of SMA in the area was calculated, and the respective mean weight was used to convert overall estimated N to overall estimated weight.

With regards to the split of those total estimated discards into the dead discards and live releases, given that there is currently insufficient data to make specific models for each of those components, we used the value of hooking mortality by Coelho et al. (2011) as a proxy for the percentage of the dead discards, with the remaining being assumed to have been live releases. Therefore, from the total estimated discards, the specific percentage assumed to be dead discards was 35.6%.

The analysis was carried out in R language for statistical computing version 4.0.5 (R Core Team, 2021). Several plots were build using package "ggplot2" (Wickham, 2016). GAM models were carried out using package "mgcv" (Wood, 2017). Other packages used included "nortest" (Gorss and Ligges, 2015), "car" (Fox and Weisberg, 2019), "MASS" (Venables and Ripley, 2002.), "mfp" (Ambler and Benner, 2022), "boot" (Davison and Hinkley, 1997; Canty and Ripley, 2021), "cvTools" (Alfons, 2012), "tidyverse" (Wickham et al., 2019) and "lubridate" (Grolemund and Wickham, 2011).

Results

3.1 Data characteristics

The majority of sets analysed had either zero or one shortfin mako catches. Specifically, the CPUE was zero in 52.7% of the sets and one in 26.8% of the sets (**Figure 3**).

The effects of seasonality and location were tested. For seasonality, the month (or quarter) variable was used as a categorical variable and the observed effects are represented in **Figure 4**. In terms of location, both the latitude and longitude had non-linear effects (**Figure 5**) and therefore the model type used were GAMs. Specifically, in terms of longitude catches of SMA were higher towards the east, while in terms of latitude higher catches were observed in sub-tropical waters of the NE Atlantic.

3.2 Models

The model predictors were the smooth terms for location (latitude and longitude) and the season effect used as a categorical variable. Several models using various options in terms of covariates were tested. The use of BSH and SWO CPUEs were tested as covariates, and the model goodness-of-fit was also generally good. However, those models were not used in the final analysis, as in the data used for estimations (logbook data) there are a few outliers sets with extremely high BSH catches, and those were resulting in unrealistically high SMA estimations.

In terms of distribution family, we tested both Poisson and Negative Binomial models. The data is only slightly over-dispersed, with the dispersion parameter estimated at 1.27. As such, the use of Poisson models was preferred.

The final GAMs used had a Poisson distribution and a log link, with the following specification:

- SMA catches ~ Season + s(Long, Lat) + offset(log(Hooks))
- SMA discards ~ Season + s(Long, Lat) + offset(log(Hooks))

For the catches, the final model explained 41.5% of the deviance, while for the discards it explained 32.6% of the deviance. The model summaries are shown in **Table 1** and **Table 2**. The residuals are shown in **Figure 6** and **Figure 7**, noting that especially for the discards model there are some clear outliers in the residuals. This might be improved in the future as more discards data is included in the models, but at this stage does not seem to have any immediate solution.

3.3 Model predictions

At this preliminary stage, we carried out an example for possible discards estimation considering the known total effort in the North Atlantic by the Portuguese fleet during 2020 and 2021.

For comparison purposes, we first carried out predictions of the total catches using the catch model, and compared it to the reported catches. The Portuguese longline fleet in the North Atlantic reported SMA catches of 342 tons for 2020, and 202 tons for 2021, while the model predicted a total catch of 203,675.6 Kg (approx. 204 tons) in 2020 and 307,015.9 Kg (approx. 307 tons) in 2021. **Figure 8** represents the distribution of the observed versus predicted catches.

For the discards, the frequency distribution of the predicted discards for 2020 and 2021 in the North Atlantic is represented in **Figure 9**. This estimation resulted in a total estimated SMA discard value of 31,888 Kg (i.e, approximately 32 tons) in 2020, and 38,207Kg (i.e., approximately 38 tons) in 2021.

From those total estimated SMA discards, the values estimated for each component in 2020 are 11.5 tons of dead discards and 20.4 tons of live releases, while for 2021 it is estimated a total of 13.8 tons of dead discards and 24.4 tons of live releases.

Final remarks

This paper provides a first approach to a possible method for estimating discards of shortfin mako for the Portuguese longline fleet operating in the North Atlantic. The method is based on statistical models, using fishery observer data to make estimations of discards for the entire fishing effort, with known operation location and date (season).

The results presented in the paper are preliminary, and mostly provided for discussion and input at the ICCAT Sharks Species Group. We note that especially the discards model has some possibly problematic patterns in the model residuals. Those might improve as more discards data is collected and added to the models.

One important possible source of bias is that the models are based on data from observers, and according to the SMA regulation in place between 2019-2021 there were some limits for SMA retention, with one exception being when the fish was dead and there were onboard observers present. As such, it is possible that the data source from that period is reflective of the part of the fleet that was carrying observers, and the remaining of the fleet might have different discarding rate patterns.

At this point we only estimated catches and discards until 2021, and the 2022 logbook effort data is not yet available. However, one difficulty with these specific models will be the future estimation of discarded data after 2021. Since 2022 the retention of shortfin mako in the North Atlantic has been forbidden (ICCAT Rec 21-09), and the current models still does not have sufficient information on the new discarding patterns that are now mandatory for the entire fleet. As such, there is the need to collect additional observer data from several years subsequent to 2021, and include those in updated future models, so that the estimations for future years include those patterns and can provide more reliable estimations of discards of shortfin mako sharks in future years.

5. Acknowledgments

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Table 1. Summary of the final model (GAM Poisson with log link) used for SMA catches in the NE Atlantic, using observer data from the Portuguese longline fleet between 2019-2022.

```
Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -7.45076    0.24225 -30.756   <2e-16 ***
Season2      0.46121    0.27511   1.676   0.0936 .
Season3     -0.19593    0.37342  -0.525   0.5998
Season4      0.04712    0.28721   0.164   0.8697
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                          edf Ref.df Chi.sq p-value
s(Long_media,Lat_media) 23.17     29  434.7  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.468   Deviance explained = 41.5%
UBRE = 0.41526  Scale est. = 1.271     n = 467
```

Table 2. Summary of the final model (GAM Poisson with log link) used for SMA discards in the NE Atlantic, using observer data from the Portuguese longline fleet between 2019-2022.

```
Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -10.1123     0.5971 -16.936   <2e-16 ***
Season2       0.2475     0.6606   0.375    0.708
Season3      -0.5892     0.9782  -0.602    0.547
Season4       0.5418     0.6461   0.838    0.402
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                          edf Ref.df Chi.sq p-value
s(Long_media,Lat_media) 8.221     29  47.69  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.167   Deviance explained = 32.6%
UBRE = -0.53385  Scale est. = 1.1247    n = 467
```

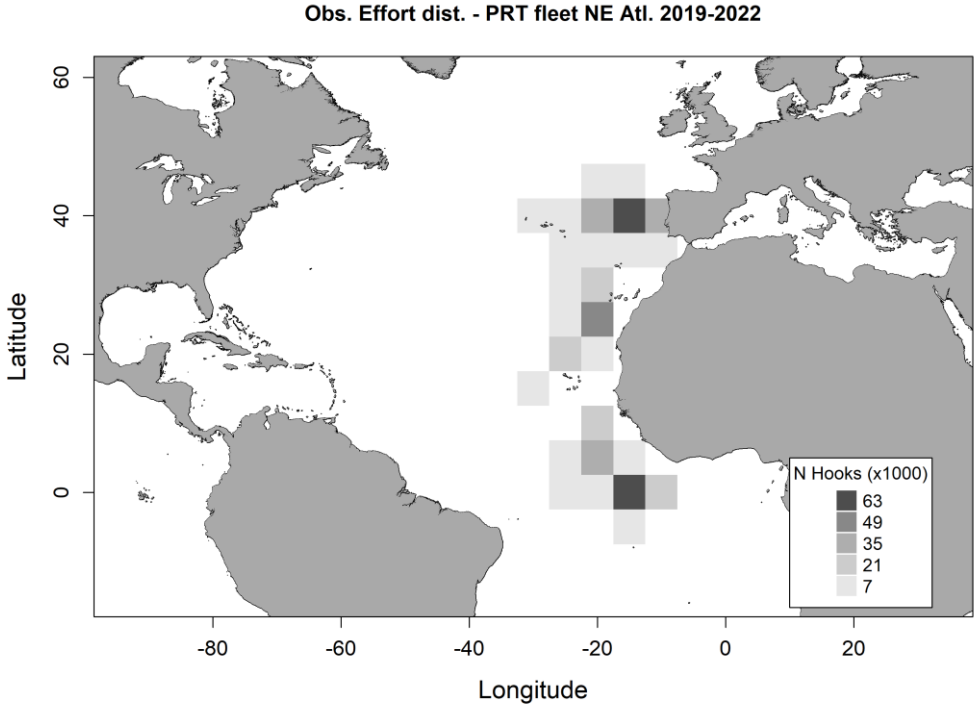

Figure 1. Effort distribution covered by onboard observers for the Portuguese pelagic longline fleet sampled in the NE Atlantic used in this study, for the period 2019-2022. The effort is represented in numbers of hooks (x1000) in 5x5 degree grids.

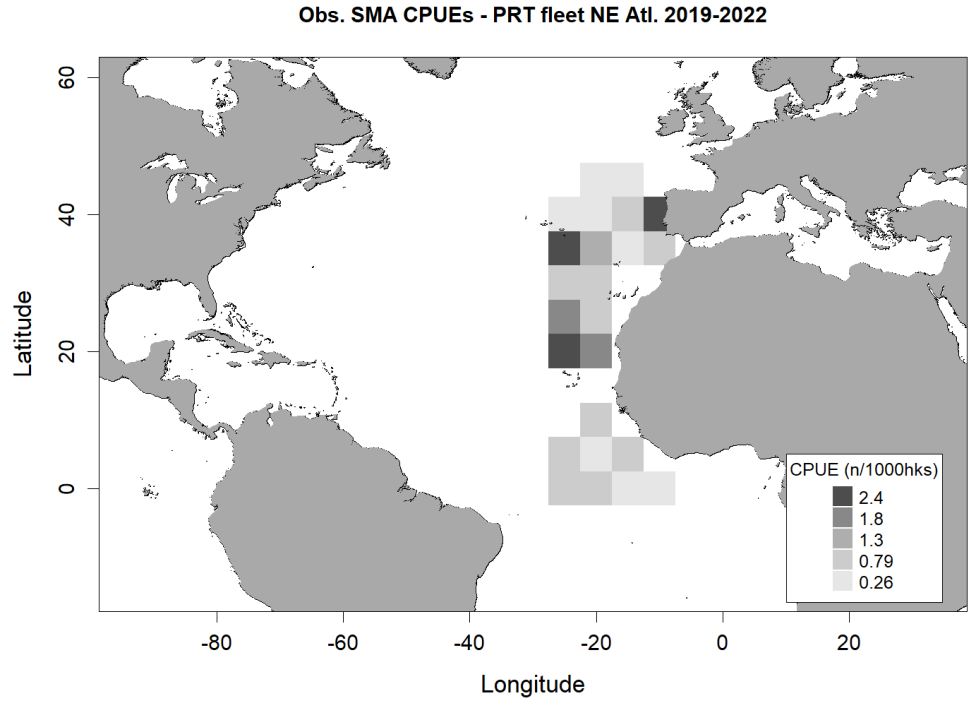

Figure 2. Shortfin mako CPUE distribution observed with onboard observers for the Portuguese pelagic longline fleet sampled in the NE Atlantic used in this study, for the period 1999-2022. The CPUE data is represented in number of SMA captured per 1000 hooks in 5x5 degree grids.

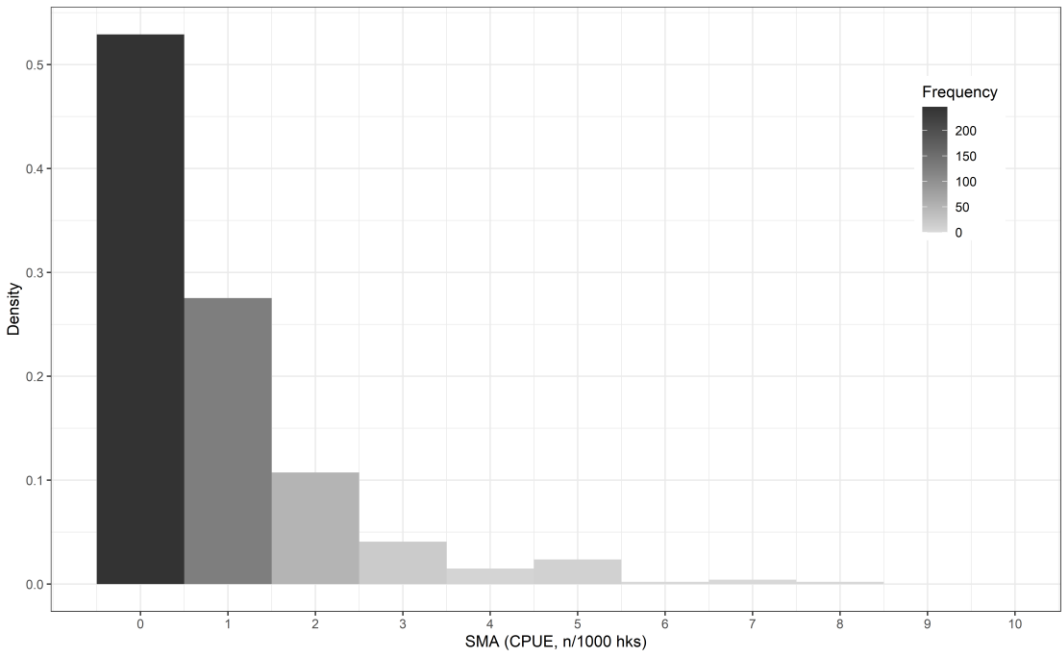

Figure 3. Density and frequency distribution of shortfin mako CPUE in the NE Atlantic, using data from observers in Portuguese pelagic longlines between 2019-2022.

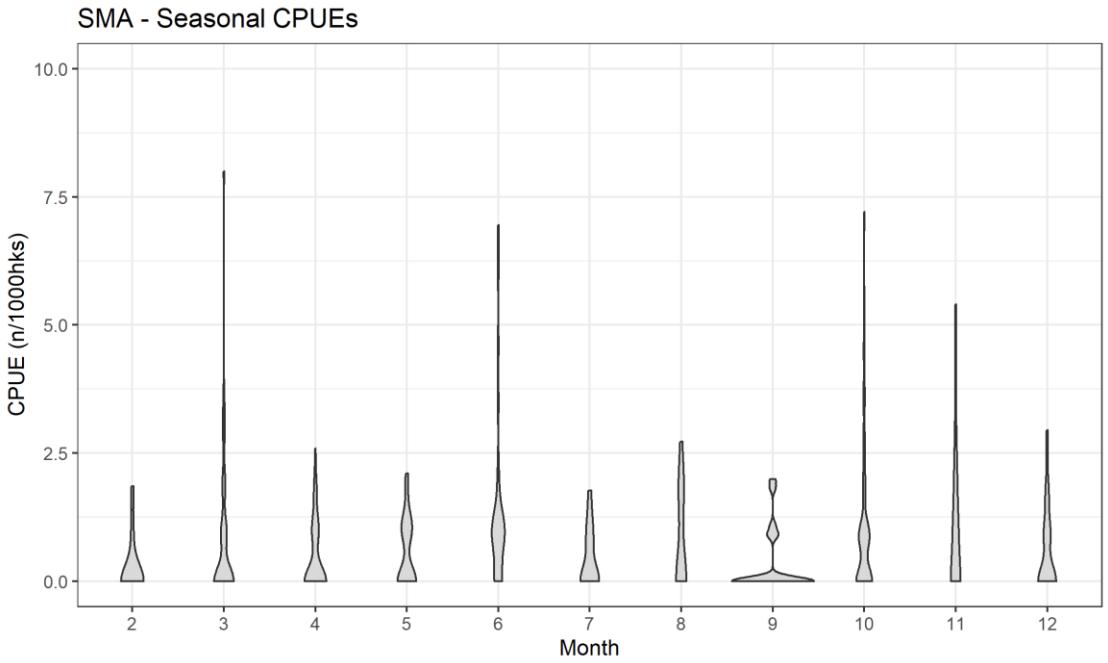

Figure 4. Effect of seasonality (represented by month) in the catch rates of shortfin mako in the NE Atlantic.

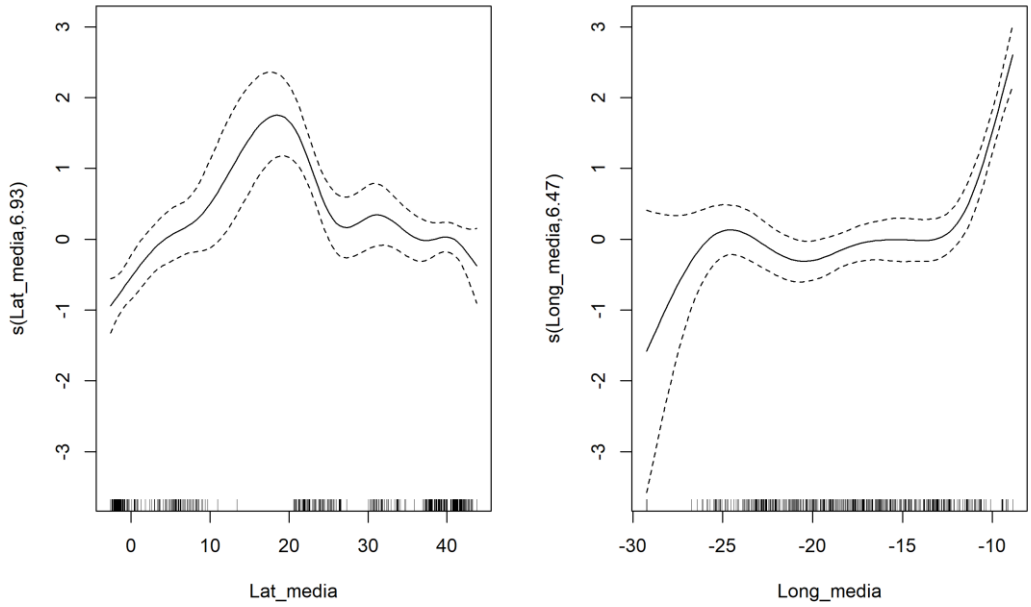

Figure 5. Effects of latitude and longitude in the catch rates of shortfin mako in the NE Atlantic, using data from observers in Portuguese pelagic longliners between 2019-2022.

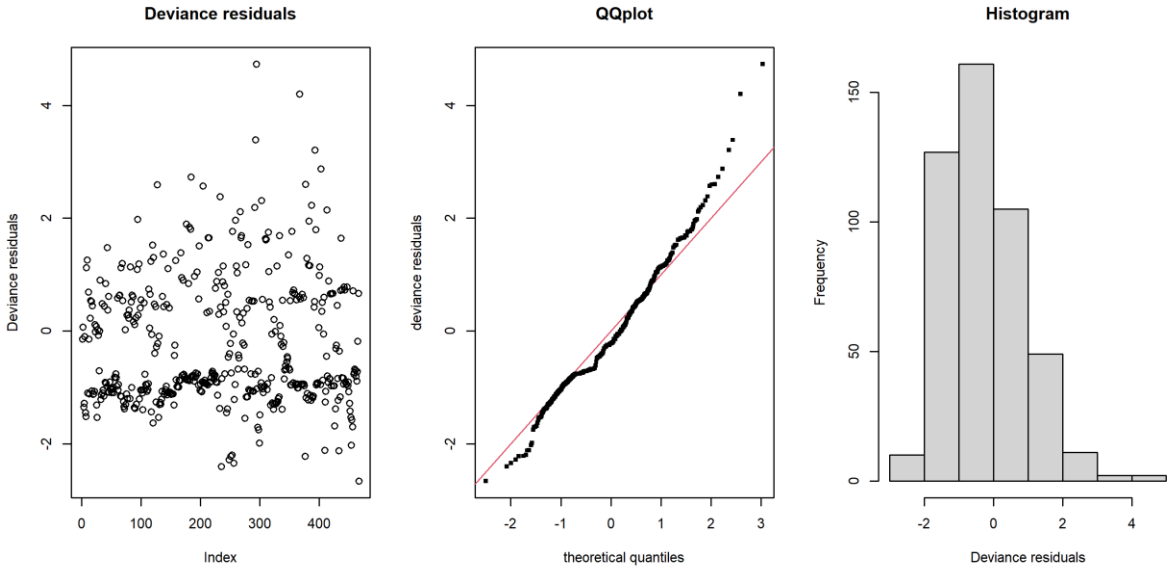

Figure 6. Residual analysis (deviance residuals) for the shortfin mako catch final model (Poisson GAM), for the Portuguese longline fleet in the NE Atlantic. The plot on the left represents the residuals along the time series, the plot in the middle represents the QQ Plot, and the plot on the right represents the frequency distribution (histogram) of the residuals.

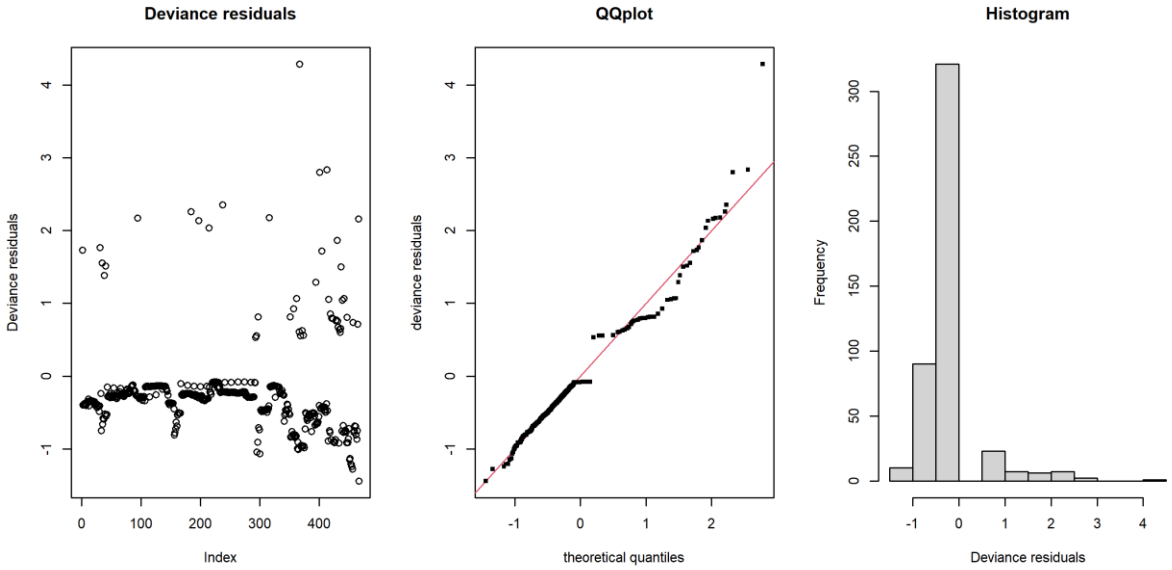

Figure 7. Residual analysis (deviance residuals) for the shortfin mako discards final model (Poisson GAM), for the Portuguese longline fleet in the NE Atlantic. The plot on the left represents the residuals along the time series, the plot in the middle represents the QQ Plot, and the plot on the right represents the frequency distribution (histogram) of the residuals.

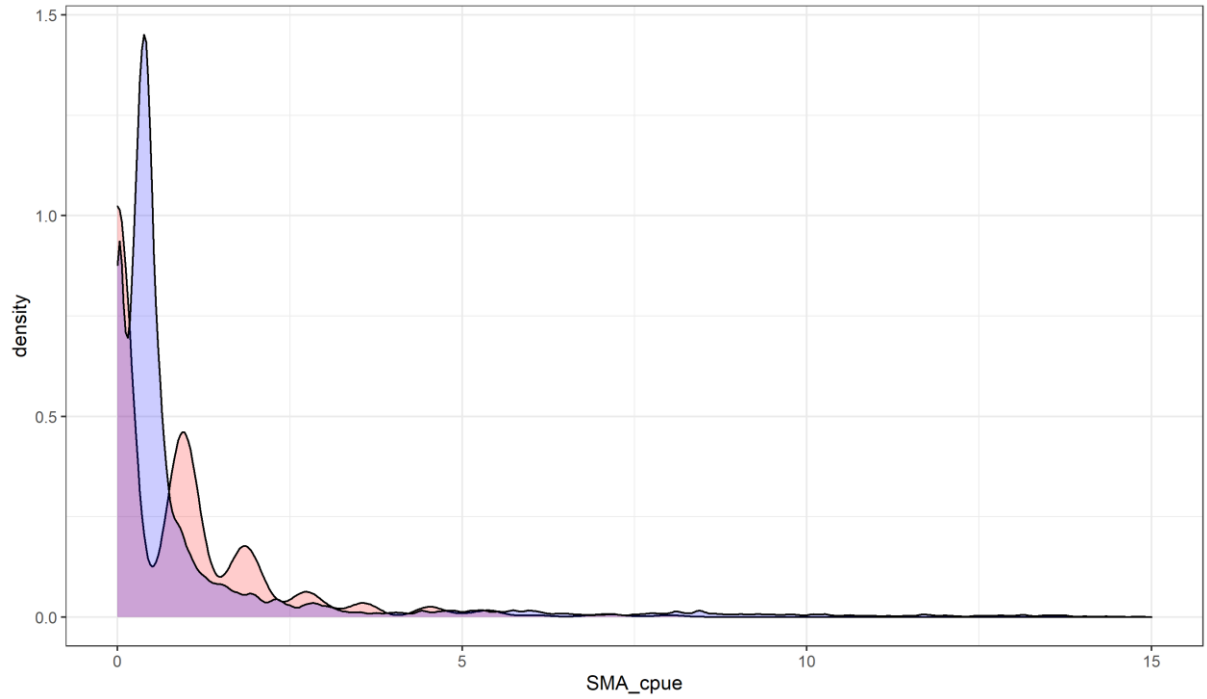

Figure 8. Distribution of the observed versus predicted catches of shortfin mako for the Portuguese pelagic longline fleet in the North Atlantic for the years 2020 and 2021. In red the observed data and in blue the model predictions.

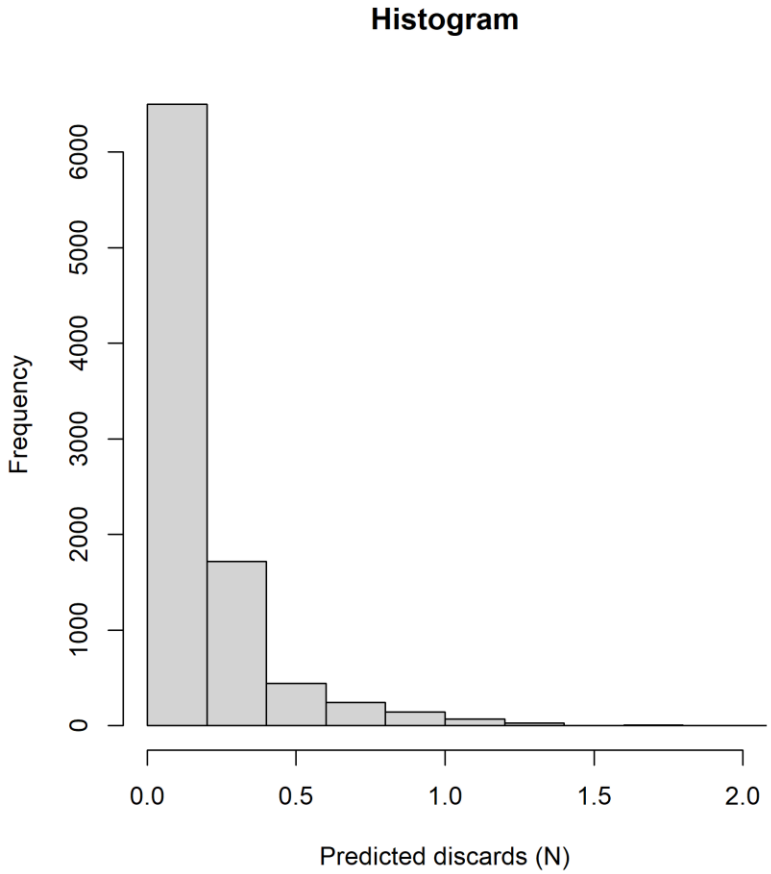

Figure 9. Distribution of the predicted discards of shortfin mako for the Portuguese pelagic longline fleet in the North Atlantic during 2020 and 2021.