HOOKING MORTALITY OF OCEANIC WHITETIP SHARKS CAUGHT IN A PELAGIC LONGLINE TARGETTING SWORDFISH IN THE SW INDIAN OCEAN: COMMENTS ON THE EFICIENTCY OF NO-RETENTION MEASURES.

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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, but in the more recent period has also expanded to the southeast. Pelagic sharks are an important component of this fishery, with some species, such as oceanic whitetip, discarded due to management recommendations. This working document revises data on the hooking (at-haulback) mortality of oceanic whitetip sharks captured and discarded by this fishery. The overall at-haulback mortality for oceanic whitetip sharks was 50.0%, which is higher than the estimates for the Atlantic (34.2%). The specimen size is significant for the odds of at-haulback mortality, with mortality decreasing as specimen size increases. Caveats of this study are the limited sample size, the fact that it focuses only in one fishery and fleet, with data restricted mainly to the temperate southwest Indian Ocean. Additionally, this study focuses only on the short term immediately mortality, while the overall mortality might be higher due to the potential post-release mortality, that is still currently unknown. In conclusion, and even though preliminary, this work presents new and important information on the potential efficiently of the no-retention measures currently in place for oceanic whitetip sharks in the Indian Ocean.

KEYWORDS: Hooking (at-haulback) mortality; discards, Indian Ocean; mitigation measures; oceanic whitetip shark, pelagic longlines.

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1. Introduction

The Portuguese pelagic longline fishery in the Indian Ocean started in the late 1990's. This fishery traditionally sets shallow sets during the night targeting swordfish (SWO, *Xiphias gladius*) even though in certain areas and seasons it can also catch relatively high quantities of sharks, particularly blue shark (BSH, *Prionace glauca*) (Santos et al., 2013, 2014; Coelho et al., 2014). Other shark species can also be important components of this fishery is particular areas and seasons.

The Portuguese fishing vessels operating in the IOTC area of competence consist only of pelagic longliners, ranging in size from 35 to about 50m. 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 (between 2009 and 2012), with an increase again in the more recent years of in 2013, 2014 and 2015. The reasons behind the decrease in 2009-2012 of active fishing units in the IOTC convention area were related with the increase of exploitation costs (particularly fuel in the late 2000's), but also due to piracy related problems in the SW Indian Ocean, which has been traditionally the fishing area for the Portuguese fleet. More recently, with the reduction of the fuel costs and the higher control in the piracy related problems, several vessels have returned to the Indian Ocean.

The oceanic whitetip shark (OCS, *Carcharhinus longimanus*) has been a no-retention species in the IOTC area of competence since 2013 (Resolution 13/06; IOTC, 2013). However, very little is known about the real efficiency of such mitigation measure, as both the immediate (hooking or at-haulback) mortality rates, as well as the post-release mortality of the released specimens, are largely unknown. Coelho et al. (2011) revised at-haulback mortality rates of several pelagic shark species captured in pelagic longline fisheries of the Indian Ocean. At the time, the data available for the oceanic whitetip shark was very scarce, so no analysis could be carried out for that particular species. In the Atlantic Ocean, Coelho et al (2012) carried out a similar study and concluded that the at-haulback mortality rate of OCS was 34.2%.

Given the current lack of information on the at-haulback mortality rates of OCS captured in pelagic longline fisheries in the Indian Ocean, and the current IOTC Commission request to assess the efficiency of the mitigation currently in place for the oceanic whitetip, the objectives of this paper were to provide information on the at-haulback condition for OCS captured by the Portuguese pelagic longline fishery in the Indian Ocean.

2. Materials and methods

2.1. Data collection

Data for this study comes from the Portuguese pelagic longline fishery observer program maintained by IPMA (*Instituto Português do Mar e da Atmosfera*). Specific data for this species was available and was analysed for the period between 2011 and 2015, the period on which the oberver program has been in operation. The total fishing effort by the Portuguese fleet in the Indian Ocean for that period (2011-2015) is estimated at 4624 longline sets. For this work we use information from 446 sets that were carried out with onboard fishery observers during that period, therefore comprising 9.6% of the total effort (**Figure 1**). The observer effort covers, in general, then main same areas of operation of the fleet.

For elasmobranch specimens captured the onboard fishery observer recorded the species, the specimen size (FL – fork length, taken to the lower 1cm size class), the at-haulback condition (alive or dead at time of fishing gear retrieval), the fate (retained or discarded), and the condition if discarded (alive or dead at time of discarding). For each longline fishing set carried out, additional information was recorded including date, location (latitude and longitude), number of hooks used in the set, etc.

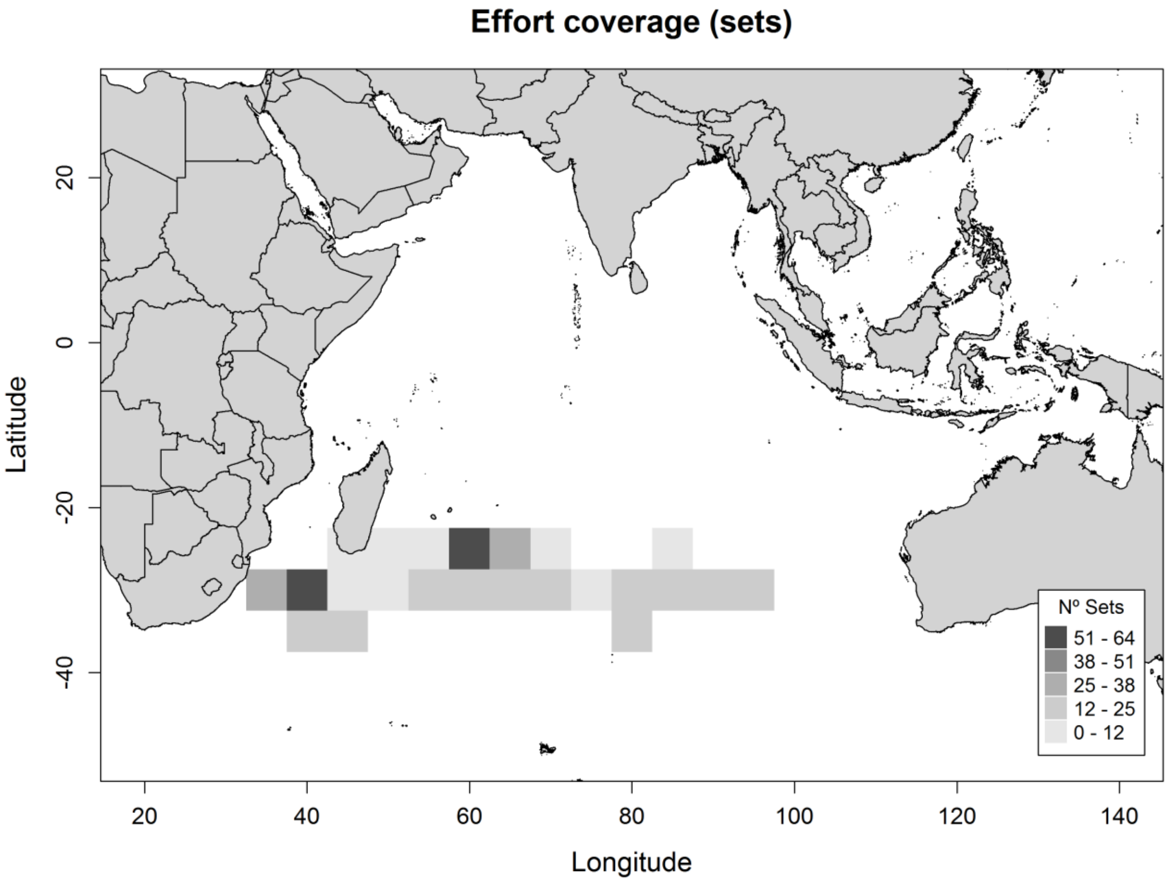

Figure 1: Map with the location (5x5 degrees) of the longline fishing sets analysed for this study.

2.2. Data analysis

The numbers of alive and dead specimens at time of capture was recorded, and the respective percentages calculated.

The effect of potential explanatory variables in the odds of mortality was determined with Generalized Linear Models (GLM) with binomial error distribution and logit link function (logistic model). The response variable was coded as a binary variable in which: 1 = specimen dead at-haulback and 0 = specimen alive at-haulback. Potential explanatory variables tested were specimen size, sex, bait, gangion, average soaking time and SST. Those variables were considered at the 10% significance level, determined by the Wald statistic, and by likelihood ratio tests comparing each univariate model with the null model. The GLM assumption of linearity of the continuous explanatory variables (in this case the size) with the linear predictor was assessed with Generalized Additive Models (GAM) plots. After fitting each model for the significant variables, the odds-ratios of the explanatory variable with the respective 90% confidence intervals were calculated.

All statistical analysis was carried out with the R Project for Statistical Computing version 3.2.0 (R Core Team, 2015). GAM models and plots that were created with library "mgcv" (Wood, 2011).

3. Results and Discussion

3.1. At-haulback fishing mortality of oceanic whitetip sharks

During this study that comprised 446 fishing sets (635,380 hooks), 28 oceanic whitetip sharks were captured (**Figure 2**). Of those specimens, information regarding the at-haulback condition (dead/alive) was recorded for all, size information was available for 25 specimens (89.3%) and the sex was recorded for 18 (64.3%). The mean size was 144.6 cm FL (SD = 42.1; range = 63-206 FL cm).

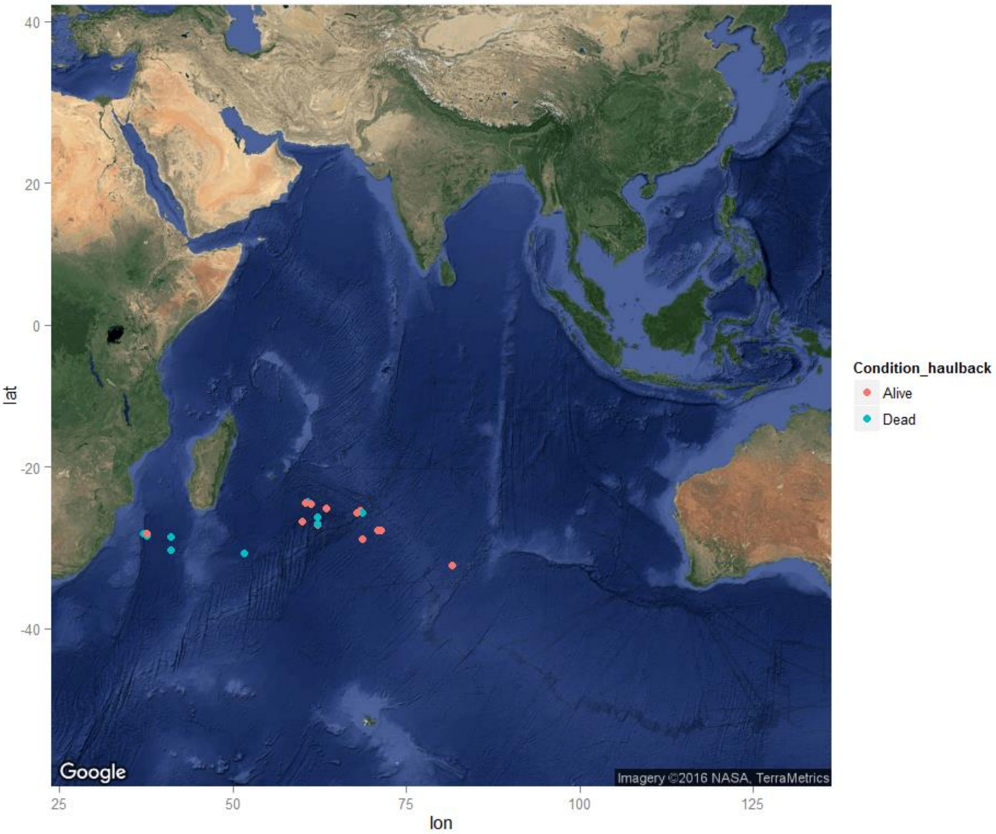

Figure 2: Map with the location of the oceanic whitetip sharks sample analyzed for this study, with the indication of the at-haulback condition.

Of the 28 specimens captured, 13 were dead at-haulback and one additional shark died during the releasing process (i.e., was captured alive but discarded dead). This means that the overall at-haulback and discard mortality was 50.0%. These values are slightly higher than what has been estimated for the Atlantic, specifically 34.2% at-haulback mortality based on a sample of 281 specimens (Coelho et al., 2012).

3.2. Modelling the at-haulback mortality

Of the several potential explanatory variables tested, only size of the oceanic whitetip shark specimens was significant for the odds of at-haulback mortality, with the at-haulback mortality decreasing as specimen size increased (**Figure 3**).

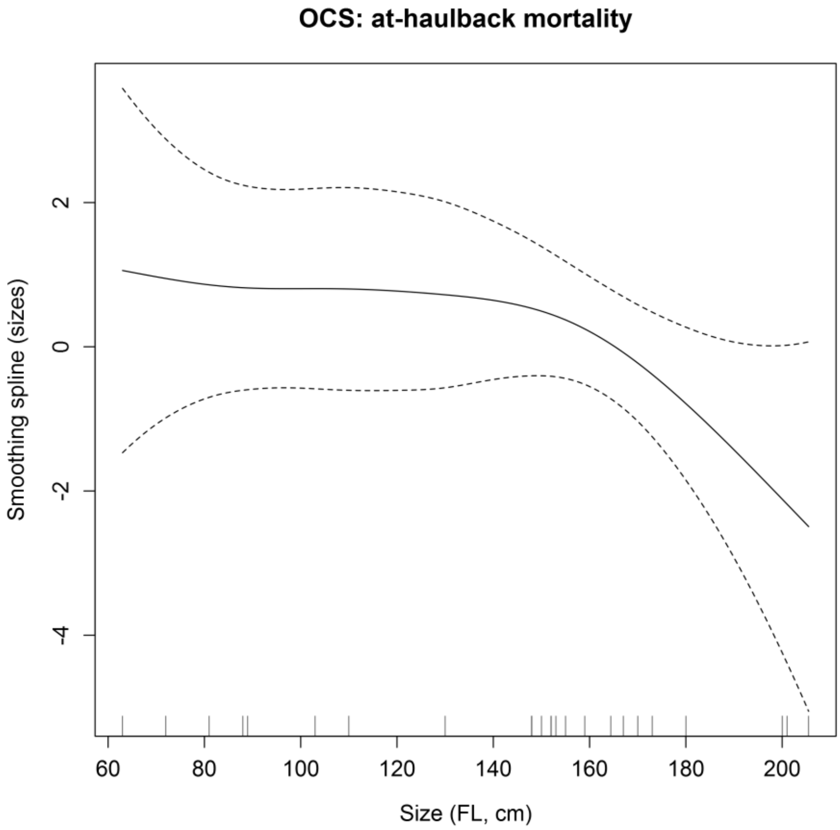

Figure 3: GAM plot with the at-haulback mortality of oceanic whitetip in the Indian Ocean in terms of specimen size (FL). The solid line represents the GAM fit while the dotted lines represent the confidence bands. The vertical bars in the bottom represent samples.

The results of the logistic model using size as explanatory variable are significant, with the variable size significant at the 10% level (estimate = -0.0194, p-value = 0.09). In terms of the odds ratios calculated with the GLM, it was possible to estimate that for each 10 cm FL increase in the size of the sharks, the odds of being dead at time of haulback decreased 17.6%, with 90% confidence intervals varying between 31.8% and 0.5%.

3.3. Comparison of results between the Indian and the Atlantic Ocean

When comparing the results now presented for the Indian Ocean to results previously obtained for the Atlantic (Coelho et al., 2012), the proportions were higher for the Indian

Ocean. Specifically, in the Atlantic Coelho et al (2012) reported an at-haulback mortality rate of 34.2% using a larger sample size with N = 281, while the estimates now reported for the Indian Ocean are 50%, but with a much smaller sample size with N = 28.

Similar decreasing odds of mortality with increasing shark sizes had been previously recorded for other species, such as for the blue shark (Campana et al. 2009; Coelho et al. 2012). As such, it seems that depending on the region and the specific size ranges of the captures, the at-haulback mortality rates will be different.

It should be noted that the present study is only considering the short term mortality that results from the actual capture and discarding process. Some specimens may be discarded still alive but with internal trauma that may result in longer term post-release mortality. For measuring such effects the use of pop-up tags (satellite telemetry) would be needed, given that those tags allow tracking the sharks' vertical and horizontal movements for several weeks after being discarded. Therefore, the values presented in this paper should be regarded as the minimum mortality values due to the fishing and discarding process, and those values may increase due to longer term mortality that was not accounted for in this study. A study by Campana et al. (2009) using satellite telemetry tags looked into blue shark long-term survivorship after being discarded in pelagic longline fisheries in the Atlantic Ocean and concluded that all blue sharks discarded in healthy conditions survived, while 33% of those that were badly injured (or gut hooked) died. Further, Campana et al. (2009) also concluded that 95% of the mortality occurred within 11 days after being released.

Besides pelagic longline, purse seines can also catch and discard relatively high numbers of oceanic whitetip sharks (Amandè et al. 2012). However, the post-release mortality of oceanic whitetip sharks from purse seiners is still unknown (Romanov et al., 2015).

It should be noted that the dataset available for the Indian Ocean is still limited, and with data from only 5 years of fishery observers (2011-2015) and referring mainly to the SW temperate region. As more data from fishery observers becomes available, other covariates that are not significant at thsi stage might become important, as the effects of year, season location, water temperature and fishing gear soaking time. Other potentially important variables that were not recorded in this study and woudl require a dedicated project would be to test the effects of the time spent in the longlines by the specimens, with the use of hook timers.

In conclusion, this paper presents important new information on the impacts of the longline fisheries on oceanic whitetip shark populations, and the efficiency of the no-retention measures currently in place. The minimum estimated mortality rates for the Indian Ocean whitetip sharks captured and discarded by pelagic longlines is 50%, so the efficiency of the no-retention measures is questioned. Additionally, the mortality rates on other fisheries that can also contribute with high catches of oceanic whitetip, such as purse seine and gillnets, is still unknown. Future work should look into ways of minimizing the captures of this species or to improve the operation of the fishing gears and discarding practices to increase survivorship.

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