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**Hooking mortality of swordfish in pelagic longlines: Comments on the efficiency of
minimum retention sizes.**

Rui Coelho^{1,*} & Rubén Muñoz-Lechuga¹

¹: IPMA- Portuguese Institute for the Ocean and Atmosphere. Av. 5 de Outubro s/n,
8700-305 Olhão, Portugal.

*: Corresponding author: R. Coelho. Tel: +(351)289700504; E-mail: rpcoelho@ipma.pt

Rui Coelho ORCID: 0000-0003-3813-5157

Rubén Muñoz-Lechuga ORCID: 0000-0001-8148-872X

Abstract

This paper revises detailed data on hooking (at-haulback) mortality of swordfish captured and discarded by pelagic longlines, using as a case study the shallow night setting Portuguese pelagic longline fishery that targets mainly swordfish, in the Atlantic Ocean. The overall at-haulback mortality for swordfish was very high, specifically 85.2% for all sample/sizes combined, and even higher for the smaller sizes classes. Specifically, observed at-haulback mortality was 87.8% for specimens smaller than 125 cm LJFL (lower jaw fork length) and 88.1% for specimens smaller than 119 cm LJFL, corresponding to the minimum landing size options currently in place in the Atlantic Ocean. The mortality was modeled with logistic GLMs (Generalized Linear Models), showing that specimen size, SST (sea surface temperature) and mode of operation were significant variables, and with the hooking mortality decreasing with specimen size while increasing with SST. Even though this study only focuses on one fishery, the data is widespread and covers a wide Atlantic area, being representative of most modern shallow setting longlines targeting swordfish, and including both fresh and freezer operating vessels. Additionally, this study only focuses on hooking mortality, with a note that the overall mortality rates are likely higher due to post-release mortality of released specimens. Overall, this work presents new and important information on swordfish mortality and opens the discussion on the efficiency of the minimum landing sizes for swordfish currently in place in the Atlantic that were established mainly to protect juvenile swordfish.

Keywords: Discards; hooking mortality; longline fisheries; management measures; minimum landing size; swordfish.

Introduction

The Portuguese pelagic longline fishery in the Atlantic Ocean started in the late 1970's. In the North Atlantic area the fishery started to develop mainly after 1986, while in the South Atlantic it gained importance after 1989 (Santos et al. 2001). The fishery traditionally sets shallow sets during the night targeting mainly swordfish (SWO, *Xiphias gladius*). Still, it is a multi-species fishery where some other bony fishes as well as pelagic sharks are captured. In certain areas and seasons, the catch of pelagic sharks can be of relatively high quantities, particularly blue shark (BSH, *Prionace glauca*) (Coelho et al. 2012a, b). This fleet can in general be separated in two main components: the "*fresh fleet*" composed by vessels without freezing capacity that only refrigerate the catch, and usually make shorter trips up to 10-15 sets mainly in the temperate NE Atlantic, and the "*freezer fleet*" composed by vessels with freezing capacity that make much longer trips, usually with 30-100 sets and operate mostly in the tropical NE, Equatorial and Southern Atlantic.

Management regulations for swordfish started to be established in the Atlantic Ocean back in 1991 by ICCAT (International Commission for the Conservation of Atlantic Tunas), the inter-governmental RFMO (Regional Fishery Management Organization) responsible for the conservation of tunas and tuna-like species in the Atlantic. The establishment of Minimum Landing Sizes (MLS) with the aim of protecting smaller swordfish, are included in those earlier regulations (ICCAT, 1990). Over time the regulations changed, but the MLS regulations have remained in effect. Currently, ICCAT manages Atlantic swordfish with a TAC system, specifically 13,200 t in the North Atlantic stock and 14,000 t in the South Atlantic (ICCAT 2017a, b). And in order to protect small swordfish, there are still MLS measures in place, specifically with a prohibitions to retain and land swordfish weighing less than 25 kg live weight (or 125 cm LJFL - lower jaw fork length) with a 15% tolerance in number of swordfish or, as an alternative, a prohibition to retain and land swordfish with less than 119 cm LJFL (or 15 kg live weight) in this case with no tolerance. Those minimum landing sizes apply to both North and South Atlantic (ICCAT 2017a, b).

Still with regards to the established MLS, both ICCAT Recommendations (ICCAT 2017a, b) also state that "*the SCRS should continue to monitor and analyze the effects of this measure on the mortality of immature swordfish*", noting that the SCRS (Standing Committee on Research and Statistics), is the scientific body responsible for

providing scientific advice and management options to the ICCAT Commission. This means that there is an interest by the ICCAT Commission for the scientific community to continue to analyze and discuss the effects of MLS as a management measure created mainly for the protection of small swordfish.

From a biological perspective it is not clear why the values of 125 cm LJFL (or 119 as an alternative) were chosen. In the Atlantic, Mejuto and García-Cortés (2014) estimated size at first maturity (L_{50}) for female swordfish at 146.5 cm LJFL, using data covering a wide Atlantic area of both hemispheres. More specifically for the Northwest Atlantic region, Arocha and Lee (1996) estimated L_{50} at 179 cm LJFL for females and 129 cm LJFL for males. In other Oceans, specifically in the southwest Indian Ocean, swordfish L_{50} was estimated at 170 cm LJFL for females and 120 cm LJFL for males (Poisson and Fauvel, 2009). As such, it seems that there is a discrepancy between the currently adopted MLS and the biological L_{50} values for swordfish. In addition, there is a high perception by fishers, fishery observers and fisheries scientists that the hooking (at-haulback) mortality of swordfish is very high in pelagic longline fisheries (Afonso et al. 2012), therefore hindering the effectiveness of such minimum landing sizes as a measure to protect juvenile swordfish (Cramer 1996). However, there is currently still limited information on the actual mortality rates and any relationships with the specimen sizes.

Considering the interest to monitor and analyze the effects of this minimum landing size on the mortality of swordfish, and consequently its effectiveness as a management measure aimed primarily for the protection of small specimens, the objective of this work is to provide information on at-haulback condition and mortality of swordfish captured in surface drifting pelagic longlines in the Atlantic Ocean. A secondary objective is to analyze the effects of other variables, such as specimen size and sex, catch location and fishing gear specifications in the mortality rates. The case study focused is the Portuguese pelagic longline fishery, a shallow night setting pelagic longline that targets mainly swordfish and operates over Atlantic wide areas both in the North and South Atlantic, and whose results can be largely generalized to the most modern style shallow night setting pelagic surface longline fisheries.

Materials and methods

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 swordfish, including the at-haulback condition, was available and was analyzed for the period between 2008 and 2016, representing 1,731 fishing sets covered by fishery observers over that period (Fig. 1). The observer effort covers in general the main areas of operation of the fleet, particularly in the temperate northeast Atlantic between mainland Portugal and the Azores islands, in the tropical northeast Atlantic off the Cabo Verde islands, and along the equatorial area. Other areas, such as the South Atlantic, are also covered to a lower extent, as the fleet effort in those regions is also lower.

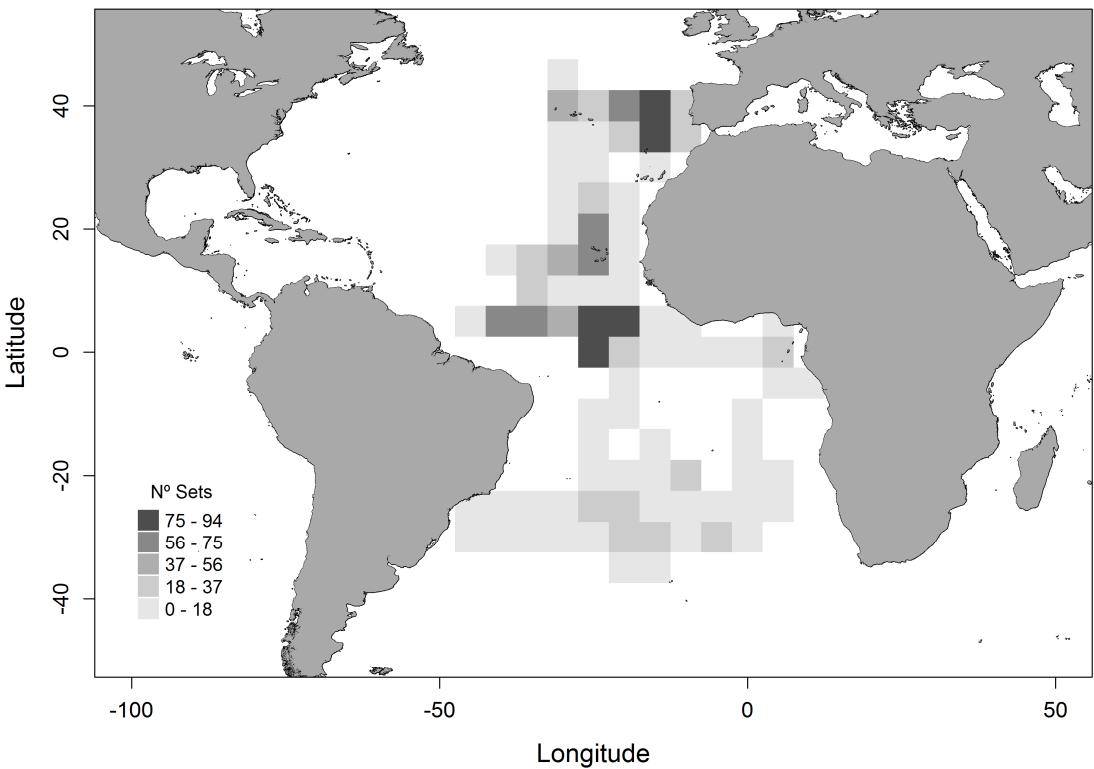


Fig. 1 Spatial location (5x5 degrees) of the longline fishing sets analyzed for this study, between 2008 and 2016 from the Portuguese fishery observer program.

The two main components for the fleet, as described in the Introduction section, were analyzed in this study. Those are denoted by two separate fleets in the models, and specify the "*fresh fleet*" composed by vessels without freezing capacity that make shorter trips (up to 10-12 sets in general) and the "*freezer fleet*" composed by larger vessels with freezing capacity that tend to make much larger trips (30-100 sets). Those larger vessels with freezing capacity have the capacity to operate in more remote areas, such as the tropical, equatorial and south Atlantic, and as such this variable was used mainly as a proxy for the general location of the fishing operations. Even though the vessels from those two components of the fleet are different mainly in size and in the freezing capacity, on both types of fleets/vessels the gear used and mode of operation is relatively similar. Specifically, on both cases the gear is composed by modern style (Florida style) shallow night setting pelagic longlines targeting swordfish. The Portuguese fleet introduced this semi-automatic mode of operation between 2000 and 2004, and the gear consists of a standard monofilament polyamide mainline (usually 3.6 mm in diameter), in this case using typically 6 branch lines between floats, and with the branch lines having around 18-20 m in length. The branch lines are attached to the main line by a snap and are composed of 2.2-2.5-mm nylon monofilament. The last section (leader) can also be made from nylon monofilament (usually 2.5 mm) or from stainless steel (usually 1.2-mm multifilament). At the end of the leader there is a hook in the terminal tackle, with the most commonly used type the "*J-style hooks*", usually stainless steel hooks with 10° offset. Either squid (*Illex* spp.) or finfish can be used as bait as bait, with the most common fish being mackerel (*Scomber* spp.) but other species can be used. A battery flashlight is usually attached close to the hook, usually between the second and third sections of the branch line. For fleets such as this that target mainly swordfish, the fishing depth of the hooks is set at approximately 20–50 m and the gear operates at night, with gear deployment beginning traditionally at around 18:00 h and haulback starting the next day at about 06:00 h.

For all specimens captured the onboard fishery observers recorded the species, the specimen size (LJFL for billfishes, as is the case of swordfish), 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 set specific information was also recorded, including date, location (latitude and longitude), time of setting and hauling, effort

(number of hooks), and fishing gear characteristics, including hook style and size, bait type and leader material.

Data analysis

The number of swordfish specimens recorded alive or dead at time of capture were analyzed and the respective percentages calculated. The sample size distribution was also analyzed and compared between males and females using non-parametric permutation tests (Manly 2007). The proportion of dead versus alive specimens by size class (categorized by the deciles) was compared with contingency tables and chi-square statistics.

The effect of potential explanatory variables in the odds of mortality was determined with 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 biological characteristics as specimen size and sex, spatial characteristics as fishing set location (coordinates) and SST, and operational characteristics as vessel type (termed fleet in the models, and representing either the fresh vs. freezer vessels), leader line material and bait type used. The soaking time of the fishing gear was also tested in the models, calculated as the difference between the mean setting and mean hauling time for each fishing set.

The details of all variables considered are shown in Table 1. Each explanatory variable was considered and selected at the 5% significance level, determined by the Wald statistic, and by likelihood ratio tests comparing each univariate model with the null model (Hosmer and Lemeshow 2000). The GLM assumption of linearity of the continuous explanatory variables with the linear predictor was assessed with GAM (Generalized Additive Models) plots, and if needed fractional polynomials transformations were used (Royston and Altman 1994). Within this approach, a backward elimination process was carried out, starting from the most complex fractional polynomial model and simplifying by reducing the degrees of freedom. After fitting each model for the significant variables, the probabilities of dying at-haulback were calculated (inverse-logit function) as well as the odds-ratios, with their respective 95% confidence intervals.

Table 1 Variables considered within this study, with their respective type and levels or range.

Variable	Variable name	Type	Levels/Range
Response variable	Mortality	Binomial	Levels: 1= dead or 0=alive
Explanatory variables tested	Size	Continuous	Size range: 45-312 (cm, LJFL)
	Sex	Categorical	Levels: male or female
	Location	Continuous	Latitude and Longitude (decimal degrees)
	SST	Continuous	SST range: 13.9-30.3 (°C)
	Fleet type	Categorical	Levels: fresh or freezer type vessels
	Leader material	Categorical	Levels: monofilament or wire
	Bait type	Categorical	Levels: squid or mackarel
	Soaking time	Continuous	Range: 11.6-20.9 (decimal hours)

For model validation, a residual analysis was carried out using Deviance residuals to search for outliers, and the Cooks distances were used to identify eventual values with influence in the estimated parameters. The discriminative capacity of the models was determined by the Area Under the Curve (AUC) from the Receiver Operating Characteristic Curves (ROC), with the calculation of model sensitivity (capacity to correctly detect at-haulback mortality events) and model specificity (capacity to correctly exclude swordfish not dead at-haulback). A cross validation analysis was also carried out with a k-fold cross validation procedure (using k = 10) to estimate the expected level of fit of the models to new data. This procedure was used to estimate the misclassification error rate, with a random partition the original dataset into k-subsamples, followed by using one subsample as the validation dataset and the remaining k-1 subsamples as training datasets to build new models. This cross-validation procedure was repeated k times, with each of the k subsamples used one time as the validation dataset. The use of k = 10 was chosen as this seems to be an adequate value for models using large datasets (Fushiki 2011).

Predictions of at-haulback mortality under various scenarios were calculated, mainly for interpretation and comparison purposes of the model results. The specific

scenarios created cover the entire range of the specimen sizes, for each fleet and considering different SST values, specifically the minimum, maximum, quartiles and median SST. Additionally, predictions for at-haulback mortality specific to the two currently established minimum landing sizes options in the Atlantic (i.e., 119 or 125cm LJFL) were also calculated and are provided.

All statistical analysis was carried out with the R Project for Statistical Computing version 3.3.2. (R Core Team 2016). GAM models and plots that were created with library “mgcv” (Wood 2011), and fractional polynomials with library “mfp” (Ambler, G., & Benner 2015). Other libraries used in R for the analysis and plots were “ggplot2” (Wickham 2009), “reshape2” (Wickham 2007), “maps”(Becker et al. 2016), “mapplots” (Hans Gerritsen 2014), “car” (Fox and Weisberg 2011), “perm” (Fay and Shaw 2010) and “boot” (Canty and Ripley 2017, Davison and Hinkley, 1997).

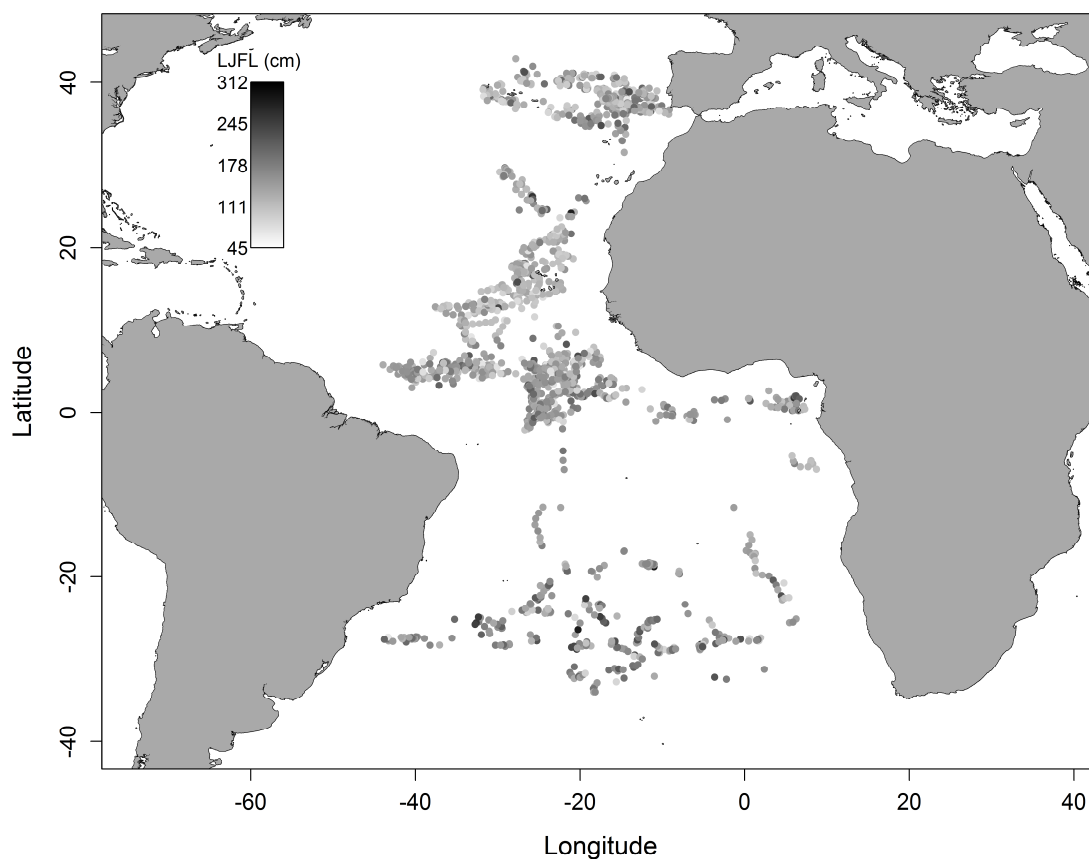
Results

At-haulback mortality of swordfish

During this study that comprised 1,731 fishing sets (2,078,228 hooks), a total of 27,869 swordfish were captured (Fig. 2). Of those specimens, information regarding the at-haulback condition (dead/alive) was recorded for 26,490 (95.1%), size information (LJFL) was available for 27,172 specimens (97.5%) and the sex was recorded for 14,892 (53.4%). The mean size of the sample was 142.7 cm LJFL (SD = 34.2) (Fig. 3). There were differences in the size distribution of male and female swordfish specimens, specifically with mean sizes of 157.1 cm LJFL (SD = 41.6) and 141.3 cm LJFL (SD = 25.3) for females and males, respectively (Fig. 3). Those differences were statistically significant (permutation test: $\text{diffs} = 15.9$; $p\text{-value} < 0.001$).

Of the 26,490 swordfish specimens captured during this study with haulback mortality information recorded, 22,577 were dead at-haulback while the remaining 3,913 were captured alive. This means that the overall at-haulback mortality of swordfish was 85.2%. There is a relation between mortality and specimen size (Fig. 4), with significant differences detected in the proportions of dead specimens by size class, specifically with the smaller swordfish having higher mortality rates (chi-square = 184.4, $df = 9$, $p\text{-value} < 0.001$). When analyzing only specimens smaller than 125 cm

268 LJFL the at-haulback mortality increased to 87.8%, and for specimens smaller than 119
269 cm LJFL it increased even more to 88.1%.



270
271 **Fig. 2** Location of the swordfish samples analyzed for this study, with the indication of
272 the size (LJFL, cm) spatial distribution.
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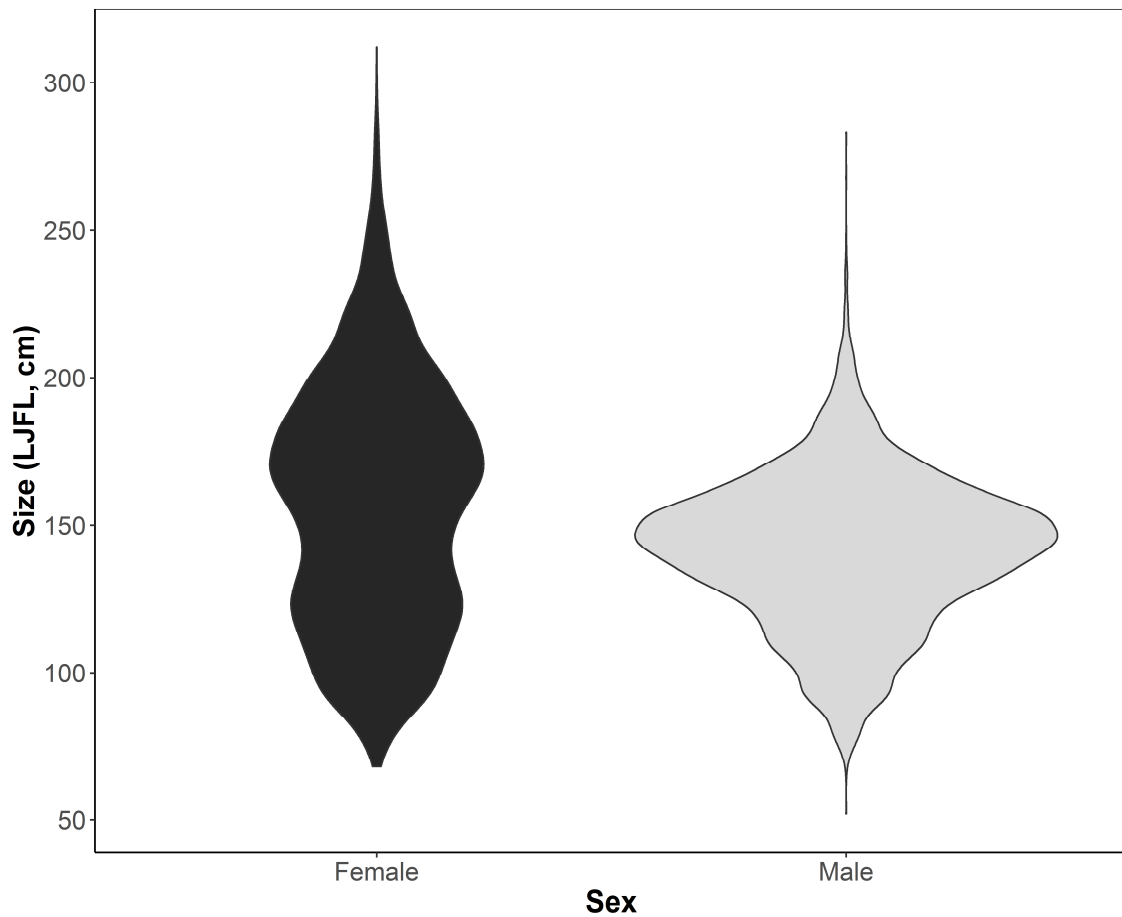


Fig. 3 Size distribution of the male and female swordfish sample analyzed in this study, in the Atlantic Ocean between 2008 and 2016.

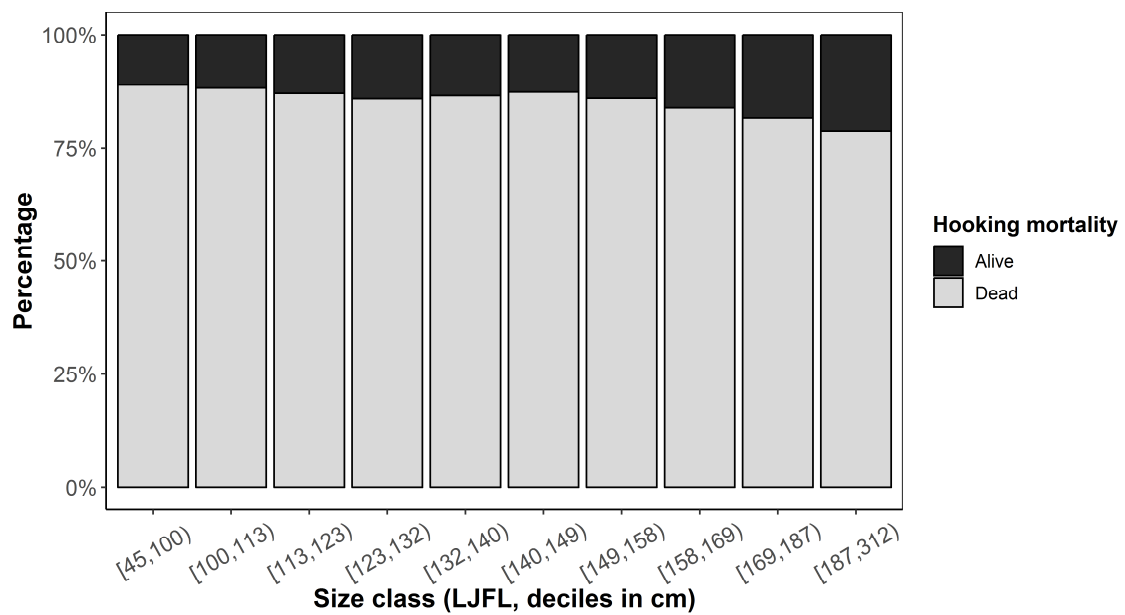


Fig. 4 Proportion of swordfish condition (alive vs. dead, at-haulback) by size class (categorized by the deciles).

Relation between mortality and size

The results of the univariate logistic model using size as explanatory variable were significant, with the variable size significant at the 5% level ($p\text{-value} < 0.001$). The probabilities of dying at haulback vary with specimen size, ranging on average between 92% for the smaller sizes to 67% for the larger swordfish (Fig. 5). In terms of odds ratios calculated with the GLM, it was possible to estimate that for each 10 cm LJFL increase in the size of swordfish, the odds of being dead at time of haulback decreased by 6.2%, with 95% confidence intervals varying between 5.3% and 7.2%.

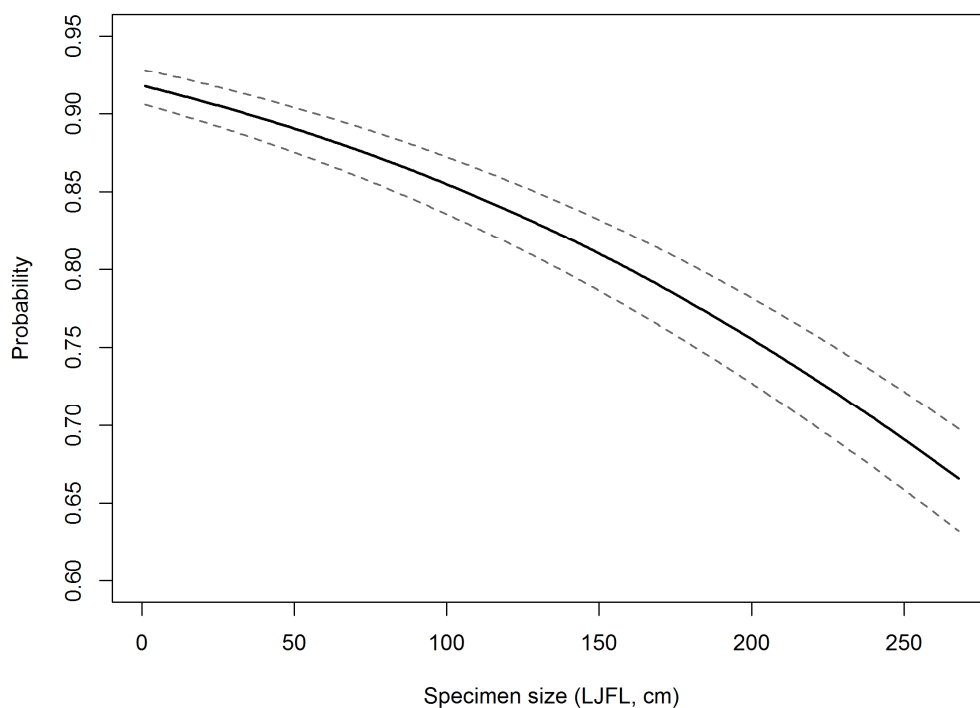


Fig. 5 Probabilities (inverse-logit) of at haulback mortality of swordfish in the Atlantic in function of specimen size (univariate logistic GLM). The solid black line represents the point estimate and the dashed grey lines the 95% confidence intervals.

Relation between mortality and other variables

Of the additional variables tested to explain swordfish mortality, sex, latitude, SST, fleet and leader material were significant at the 5% level in univariate tests. Other variables tested, such as bait or soaking time were not significant. When building the multivariate model, the leader material lost significance and there were correlations between some pairs of variables such as latitude with SST.

Regarding the continuous variables, while size had mostly a linear response with the predictor and was used directly in the GLM, the SST was non-linear (Fig. 6) and as such transformed with fractional polynomials as indicated in the equation:

$$SST.t = \left(\frac{SST}{10}\right)^{-0.5} + \log\left(\frac{SST}{10}\right) \quad (1)$$

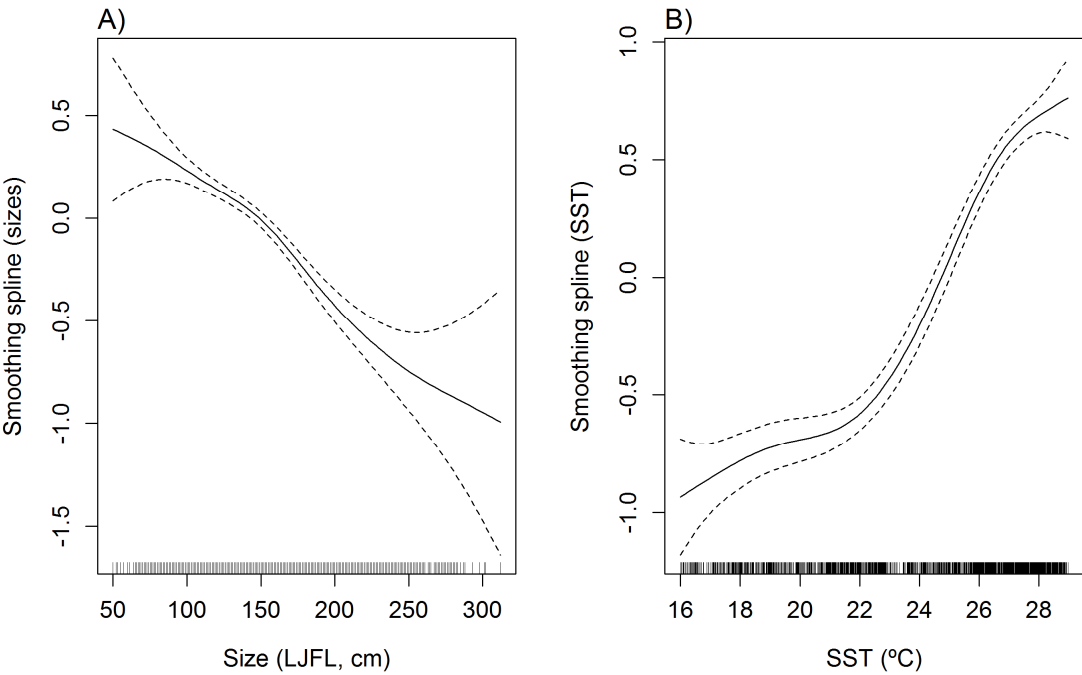


Fig. 6 GAM plot with the at-haulback mortality of swordfish in the Atlantic in terms of A) specimen size and B) SST. The solid line represents the GAM fits while the dotted lines represent the confidence bands. The vertical bars in the bottom represent samples distribution.

The final most parsimonious model using only significant variables therefore included specimen size, SST (transformed) and fleet, as well as interactions between SST (transformed) and fleet (Table 2).

Table 2 Deviance table for the GLM for the binomial response (alive or dead) status of swordfish at-haulback, in function of specimen size and SST. "Df" are the degrees of freedom, "Resid.Df" are the residual degrees of freedom and "Resid.Dev" is the residual deviance. Significance is given by the p-values of the Chi-square test. The ".t" notation after SST represents the use of variable transformed with fractional polynomials.

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
Null			25739	21415	
LJFL	1	166.07	25738	21249	< 0.001
SST.t	1	169.264	25737	21079	< 0.001
Fleet	1	229.251	25736	20850	< 0.001
Fleet:SST.t	1	74.317	25735	20776	< 0.001

On this final model, the residual analysis did not show any values that could be significant outliers. The Cooks distances identified a few data points with values relatively higher than the remaining, but they did not have an impact in the estimated parameters and therefore were not removed. The discriminative capacity of the model had an AUC of 0.622, with a sensitivity of 64.8% and a specificity of 53.2%, for a cut point of 0.859. The 10-fold cross validation procedure resulted in an estimated prediction error of 14.6%. Both the residual analysis and goodness-of-fit measures estimated indicate the validity of the final model and its adequacy for predictions.

On all scenarios considered with varying fleets and SSTs, the probabilities of dying decreased with specimen size. Additionally, the probabilities of dying also increased with SST (Fig. 7). Some examples were considered taking into account the minimum landing sizes in place in the Atlantic, showing that for a swordfish at the undersize limit of 125 cm LJFL, the probabilities of being dead at haulback would mostly range between 85.6% and 87.6% for the fresh operating fleet and between 84.5% and 90.3% for the freezer vessels. For swordfish with 119 LJFL, the other option in terms of minimum landing sizes, the probabilities of being dead at haulback would be higher, ranging mainly between 85.9% and 87.8% for the fresh operating fleet and between 85.2% and 90.6% for the freezer vessels (Table 3).

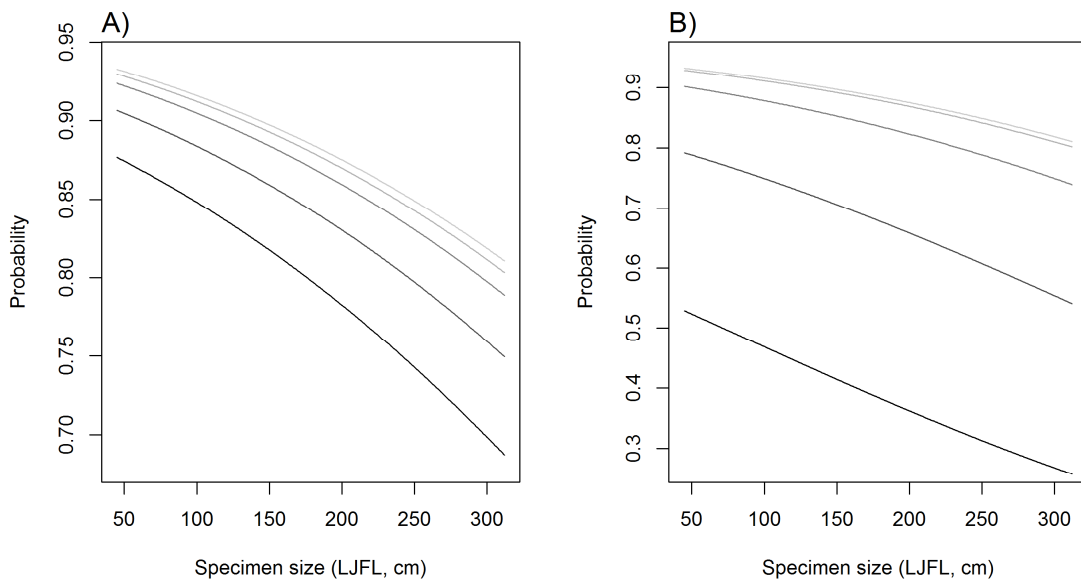


Fig. 7 Probabilities (inverse-logit) of at haulback mortality of swordfish in the Atlantic in function of specimen size for the A) fresh and B) frozen pelagic longline fleets, operating in various environmental (SST) conditions. The colors represent different SST values, ranging from maximum to lower SST (darker and lighter grey), while the intermediate shades represent the quartiles and median SST.

Table 3 Probabilities of a swordfish being dead at-haulback for the two minimum size limits in place in the Atlantic, for two swordfish targeting fleets (fresh and freezer vessels) and for various scenarios of SST, specifically the quartiles (25%, 50% and 75%) of the SST registered in the areas of operation of each fleet.

Fleet	SST (°C)	LJFL (cm)	
		119	125
Fresh fleet	17.6 (Q1)	0.859	0.856
	19.3 (Q2)	0.870	0.867
	21.0 (Q3)	0.878	0.876
Frozen fleet	24.5 (Q1)	0.852	0.848
	26.6 (Q2)	0.889	0.886
	27.8 (Q3)	0.906	0.903

Discussion

This study revealed that the at-haulback mortality of swordfish captured in surface pelagic drifting longlines in the Atlantic is high, with 85.2% of the overall specimens captured dead. For the smaller specimens, this overall observed value was higher, specifically 87.8% when considering specimens smaller than 125 cm LJFL and 88.1% for specimens smaller than 119 cm LJFL. These results are similar to those obtained previously in another study in the North Atlantic (Afonso et al. 2012). The study also revealed a significant relationship between mortality and specimen size, as described above, with the smaller swordfish specimens having higher probabilities of dying compared to the larger specimens.

Compared to other pelagic species previously studied in the Atlantic Ocean, including both bony fishes and elasmobranchs, the swordfish exhibited hooking mortality values that tended to be in the higher range of values, similar to what has been described for some sharks. Specifically, hooking mortality for dusky sharks (DUS, *Carcharhinus obscurus*) less than 110 cm FL was 79% and for the 110–169 cm FL range was 71% (Romine et al. 2009). Other sharks species also showed high hooking mortality rates, as the blacktip shark (CCL, *Carcharhinus limbatus*) (90% < 115 cm FL), scalloped hammerhead (SPL, *Sphyrna lewini*) (93% < 137 cm FL) and great hammerhead (SPK, *Sphyrna mokarran*) (93% < 189 cm FL) (Morgan and Burgess 2007). By the contrary, the sandbar shark (CCP, *Carcharhinus plumbeus*) (42% < 150 cm FL) or billfishes of the family Istiophoridae, which includes blue marlin, *Makaira nigricans*, white marlin, *Tetrapturus albidus*, sailfish, *Istiophorus platypterus*, and spearfish, *Tetrapturus angustirostris*, showed some of the lowest hooking mortality rates (approximately 10%). However, for those billfishes, it was also noted that the mortality rates increase to 65% after 12 hours of being hooked on the fishing lines (Erickson and Berkeley 2008).

In our study we tested soaking time and found that it was not significant as an explanatory variable to the mortality models. The reason may be related with the fact that soaking time is not necessarily related with the time the specimens actually spend hooked in the fishing gear, as different specimens will be hooked at different times. As such, future studies should further explore this issue and consider the use of hook timers in the longline gear to have a measure of the actual time each specimen spends hooked in the fishing gear and how that relates with hooking mortality.

By the contrary, specimen size, SST and fleet type were significant variables in the mortality models. In terms of sizes, this type of relation with increasing mortality for

smaller specimens had been previously described, including for example for some pelagic sharks (Coelho et al. 2012a, 2013). The effects of SST, in this case with increasing mortality rates for warmer water temperatures, may be related mostly with physiological characteristics of the species. Finally, the fleet effects, as well as the interactions between SST and fleet, will be mostly related with the types of vessels and their general areas of operation, noting that the larger vessels with freezer capabilities have the possibility to operate for much longer periods and travel to more distant areas.

Since the implementation of minimum landing sizes for swordfish in the North Atlantic, the estimated percentage of swordfish reported landed with less than 125 cm LJFL (in numbers) has been generally decreasing; specifically, this value was 33% of the catch in 2000 and decreased to 23% in 2015 (Anon. 2017). In the South Atlantic, the estimate of landed specimens smaller than 125 cm LJFL was 18% in 2000, had a maximum of 19% in 2006 and decreased to 13% in 2015 (Anon. 2017). From our study, a first conclusion is that the very high hooking mortalities seem to indicate a large inefficiency of the minimum landing sizes as a measure to protect small swordfish. However, the shifts in the catch-at-size as described before, especially the ones observed in the North Atlantic, raise the possibility of the fleets having increasingly started to avoid hotspot areas of concentrations of juvenile swordfish, in which case the minimum landing sizes would to some extent be efficient in protecting those specimens. However, as the catch-at-size estimates by ICCAT refer only to landed catch (not total catch), this possibility of a changing pattern in the fleets may be confounded with a possible increase of discards for the smaller specimens, in which case the currently established minimal landing sizes would not be efficient to protect juvenile swordfish, as intended by the regulations. For clarifying those possibilities, there would be the need to calculate overall catch-at-size for the entire Atlantic area representative of the total catch, including both landings and discards, which is not currently possible due to the general lack of data on discards in the official statistics (Anon. 2017).

Finally, it should be noted that the present study only considers the short term mortality that results from the actual capture, and eventually the discarding process. Some specimens may be discarded still alive but with internal trauma that may result in longer term post-release mortality (Skomal 2007). For measuring such effects the use of pop-up tags (satellite telemetry) would be needed, given that those tags allow tracking the specimens 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 process, and those values may increase due to longer term post-release mortality not accounted for in this study.

Conclusions

In conclusion, this paper presents important new information on the impacts of the longline fisheries on swordfish in the Atlantic, which can contribute to the discussion on the efficiency of mitigation measures as minimum landing sizes (i.e., mandatory discards of specimens smaller than a certain size). The overall minimum estimated mortality rate is 85.2% and there is a relationship with specimen size, meaning that smaller specimens tend to suffer higher mortality rates than the larger specimens. As such, the efficiency of the minimum size limits as a measure to protect small and immature swordfish is questioned. There is a possibility for such measure to work if such minimum size regulations would lead to avoidance of areas of high concentration of small swordfish by the fleets, which is currently unknown. Future work should look into ways of minimizing the captures of small immature swordfish, as for example options for spatial/seasonal closures in areas of high aggregations of small swordfish, as well as to analyze detailed multi-fleet catch and effort to understand the extent of the fleets displacements to avoid such hotspot areas.

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