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OBSERVATIONS ON THE INDO-PACIFIC SAILFISH, *Istiophorus platypterus*, FROM THE PORTUGUESE PELAGIC LONGLINE FLEET IN THE SOUTHWEST INDIAN OCEAN.

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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, for the first time, the catch, nominal CPUE trends, size distribution, sex-ratios and at-haulback mortality for the Indo-Pacific sailfish (Istiophorus platypterus) occasionally captured as bycatch in this fishery. The data was recorded by fishery observers and skippers logbooks, and was analysed between 2011 and 2014. The nominal CPUEs were calculated in n/1000 hooks and were analysed both spatially and in a yearly time series, showing an increase in 2012 and a decrease for the more recent years. The spatial size distribution of the catches seems to indicate that smaller individuals occur mostly in more coastal waters while the larger specimens prefer offshore waters. Overall, there were more females than males in the catch, with a trend of increasing female proportions with increasing specimen sizes. The overall at-haulback mortality of this species is high, with 69.6% of the specimens recorded dead at haulback. Even though preliminary, the results presented in this paper provide the first fisheries indicators of this species captured by the shallow setting pelagic longline fleet in the Southwest Indian Ocean.

KEYWORDS: Indo-pacific sailfish, pelagic longline fisheries, fishery indicators, Southwest Indian Ocean (SWIO).

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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).

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 a slight increase in 2013 and 2014. The reasons behind such decrease 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.

Very little information currently exists and/or is available about the Indo-Pacific sailfish (SFA, *Istiophorus platypterus*) catches, distribution and trends in the Indian Ocean. Given that SFA is a priority species for the 2015 IOTC Working Party on Billfishes (WPB), the objectives of this paper were to provide, for the first time, information on the CPUEs, distribution, sizes, sex-ratios and at-haulback condition for SFA captured by the Portuguese pelagic longline fishery in the Southwest 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*), and from skippers logbooks voluntarily provided to IPMA. Specific data for this species was available and was analysed for the period between 2011 and 2014. The total fishing effort by the Portuguese fleet in the Indian Ocean for that period (2011-2014) is estimated at 3324 longline sets, and for this work we use information from 947 sets, comprising therefore 28.5% of the total effort.

2.2. Data analysis

The CPUEs were calculated as n/1000 hooks with a set level resolution. The CPUEs were mapped in 5*5 degrees to provide an overview of the catch locations of SFA by this fleet. The nominal CPUE trends were calculated and the time series plotted.

The ranges of the sizes of SFA caught per year and per month were explored with boxplots and plots of means with the respective standard errors. For all years partial data was available for the separate sexes. However, the sex specific data was not available for all captured specimens. Specifically it was available for 98 specimens which represent 28.4% of the available data. Size data was tested for normality with Kolmogorov-Smirnov tests (with Lilliefors correction) and for homogeneity of variances with Levene tests. Catch sizes were then compared between years and between months with non-parametric Kruskal-Wallis tests, given that the data was not normally distributed and the variances were heterogeneous. The sex-ratios were calculated and compared between years and the size classes (10 cm LJFL) with contingency tables and Pearson's Chi-squared tests. At-haulback mortality was calculated and compared between sexes with contingency tables and Pearson's Chi-squared tests.

Data analysis for this paper was carried out in the R language for statistical computing 3.2.0 (R Core Team, 2015). The plots designed using library ggplot2 (Wickham, 2009) and the maps using libraries maps (Richard *et al*., 2014), maptools (Bivand and Lewin-Koh, 2013) and mapplots (Gerritsen, 2014).

3. Results and Discussion

3.1. CPUE analysis

The SFA catches were mainly concentrated in the SW Indian Ocean, in the areas of the main operation of the Portuguese pelagic longline fleet (**Figure 1**). When the CPUEs spatial distribution were analyzed by year, the higher SFA values were consistently recorded in areas to the East and Southeast of Madagascar (**Figure 2**), but there were also some differences. Such yearly differences might in part be related to the species spatial trends, but also with the spatial dynamics of the fishing fleet.

The CPUEs of SFA in the Portuguese pelagic longline fishery are in general low. There was an increase in the nominal CPUE time series between 2011 and 2012, followed by a decrease for the more recent years until 2014 (**Figure 3)**. The percentage of fishing sets with zero catches of SFA in the Indian Ocean was very high, specifically with an overall 78.0% of the sets not capturing SFA. There were some yearly differences in those percentages of sets with zero SFA catches that in general followed the nominal CPUEs trends. Specifically, the sets with zero SFA varied between 72.3% in 2012 and 93.9% in 2014 (**Figure 4**). The interpretation of this nominal series and trends should be careful. Moreover, this CPUE series is not standardized and as such depends on the spatial and seasonal patterns of the fleet, as well as other fishery-dependant factors, that can change between years.

3.2. Size structure of the catches

Size data was available for 345 specimens. In 2014 only 4 specimens are available, so results from this year must be taken with caution. Mapping of catch by 10 cm LJFL size classes seems to indicate that smaller individuals' distribution occurs mostly in coastal waters while larger specimens are more commonly caught offshore (**Figure 5**).

The ranges of sizes of SFA caught were larger in 2011 and 2012 than in 2013 and 2014. Mean size was slightly lower in 2011 and 2012, increasing in 2013 and 2014 (**Figure 6**). The length frequency distributions shown in **Figure 7** denote that in 2013 and 2014 no individuals smaller than 160 cm were caught, while in previous years these were present in the catch.

Significant differences between years were detected (Kruskal-Wallis: $Chi^2 = 24.34$; df = 3; p-value < 0.001). This test was used instead of a parametric ANOVA due to the lack of normality in the data (Lilliefors test: D =0.15 and p-value < 0.001) and heterogeneity of variances (Levene: F = 2.77; df = 3; p-value=0.04).

For the sex-specific size distributions, and even though data is only partially available, a slight increase in the mean sizes was observed for males between 2011 and 2013. During the same period females mean size decreased in 2012, but increased in 2013 and 2014 (**Figure 8**). These differences were not statistically significant (Kruskal-Wallis: $Chi^2 = 4.18$; df = 3; p-value = 0.24 for females and Kruskal-Wallis: $Chi^2 = 3.81$; df = 3; p-value = 0.28 for males).

Mean size-per-month was roughly the same throughout the year except for May where the caught individuals were smaller than in the remaining months (**Figure 9**). The sizes of SFA caught in the different months were significantly different (Kruskal-Wallis: $Chi^2=88.56$; df = 11; p-value < 0.001).

3.3. Sex-ratios

The sex-specific data showed that more females than males were captured, with an overall sex-ratio of 73.5% females and 26.5% males. These differences in the sex ratios were similar for 2011, 2013 and 2014, while in 2012 the proportion of males was higher than females (**Figure 10**), and significant differences were detected when comparing the sex-ratios between the years ($Chi^2= 19.00$; df = 3, p-value < 0.001).

Sex-ratios by quarter show that females proportion is higher in the first and third quarter, while in the second and fourth quarters the relationship between males and females is nearly 1:1 (**Figure 11**), and that these overall differences are significant ($Chi^2= 12.67$; df = 3, p-value =0.005). Hernández-Herrera and Ramírez-Rodriguez (1998) found differences in the sex-ratio between seasons and attributed these differences to the spawning season.

Sex-ratios by size class show an increasing proportion of females with increasing size, although these differences are not significant ($Chi^2= 6.85$; df = 4, p-value =0.144, **Figure 12**). Several authors have also reported that females attain a larger size than males and that the proportion of males decreases with increasing size (Jolley 1974; Chiang *et al*., 2004; Chiang *et al*. 2006; Hoolihan, 2006).

3.4. At-haulback mortality

The at-haulback status of the specimens (alive/dead) was recorded and available for 112 specimens, which represent 32.5% of the available data. The overall at-haulback mortality was 69.6%.

It was not possible to study mortality by size classes because of low sample size. The mortality by sex showed that a slightly lower percentage of males were dead at-haulback than females, specifically 65.4% for males *versus* 70.8% for females, although this difference was not statistically significant (chi-square = 0.27; df = 1, p-value = 0.605, **Figure 13**).

4. Acknowledgements

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Figures

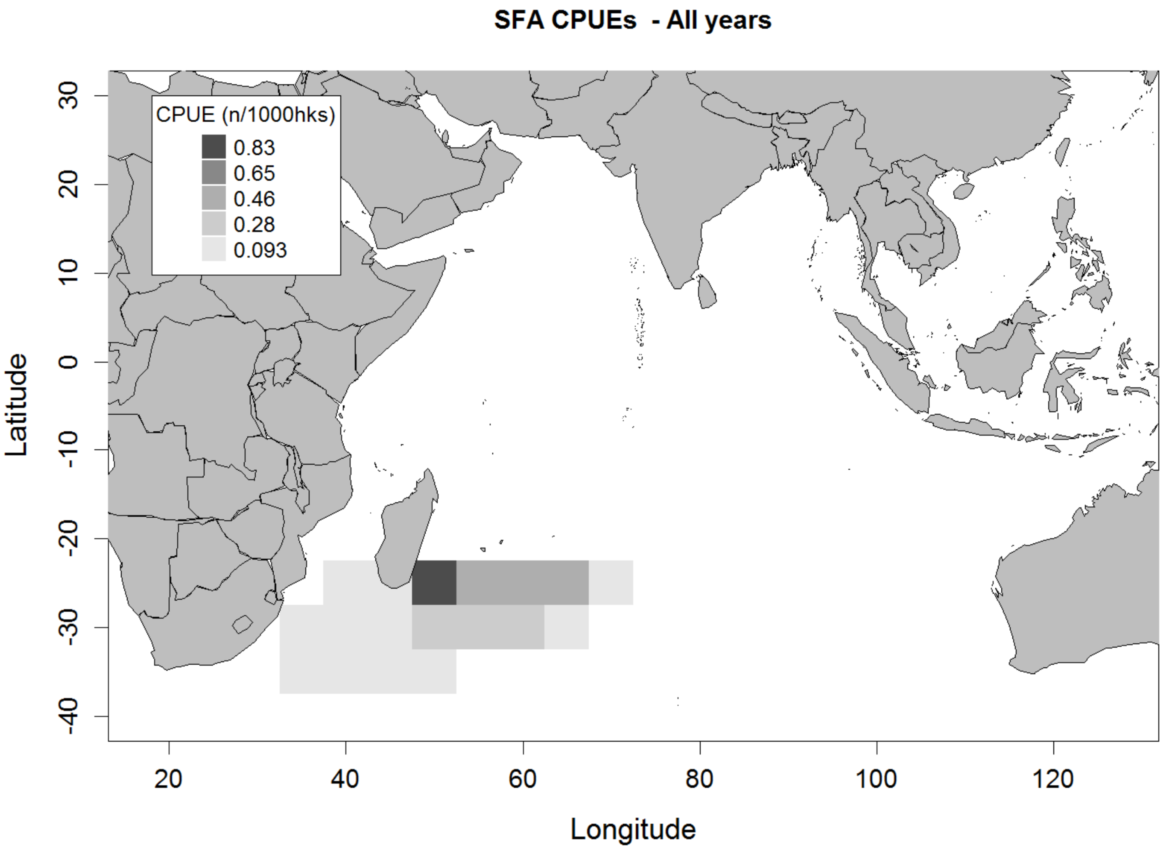

Figure 1 - Map of the Indian Ocean with the *Istiophorus platypterus* CPUEs (all years combined data between 2011 and 2014) in areas of operation of the Portuguese pelagic longline fleet. The squares are in 5*5º and the CPUEs are in n/1000 hooks.

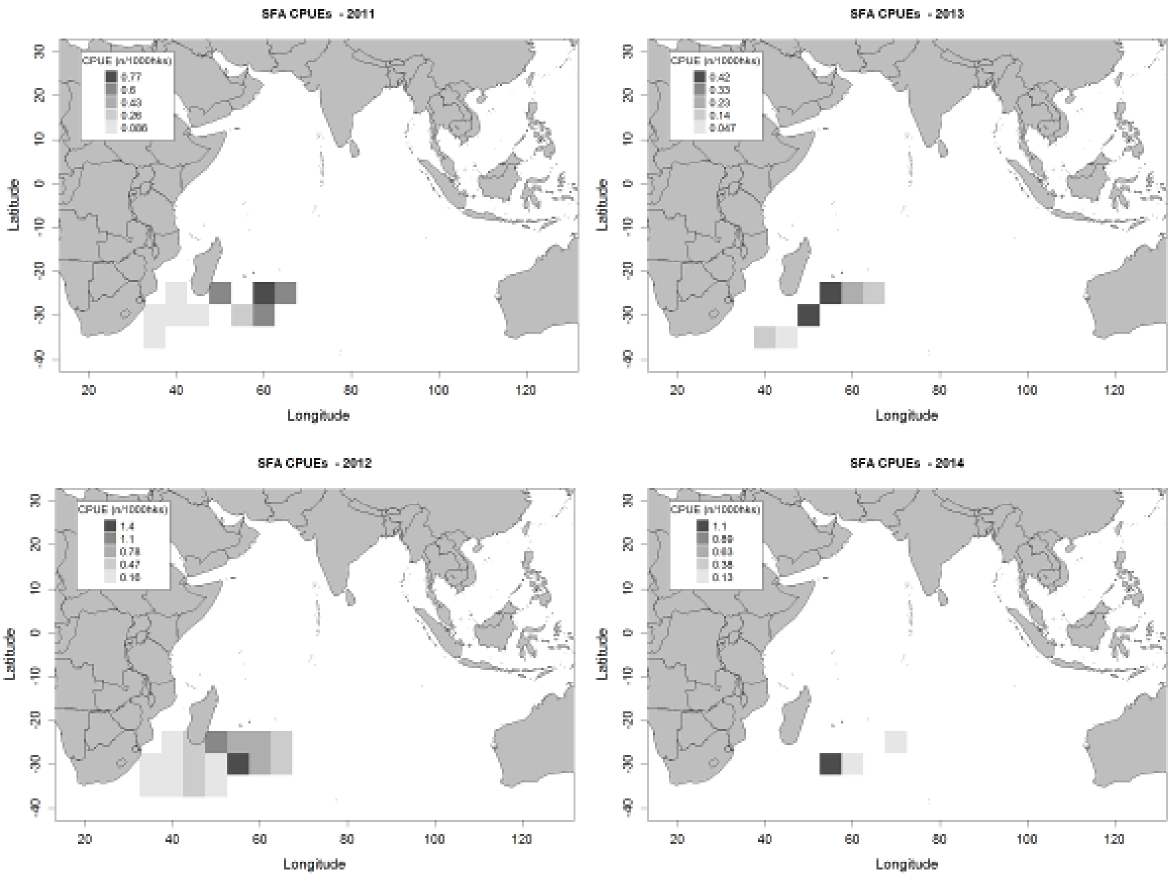

Figure 2 - Map of the Indian Ocean with the *Istiophorus platypterus* CPUEs by year (between 2011 and 2014) in areas of operation of the Portuguese pelagic longline fleet. The squares are in 5*5º and the CPUEs are in n/1000 hooks.

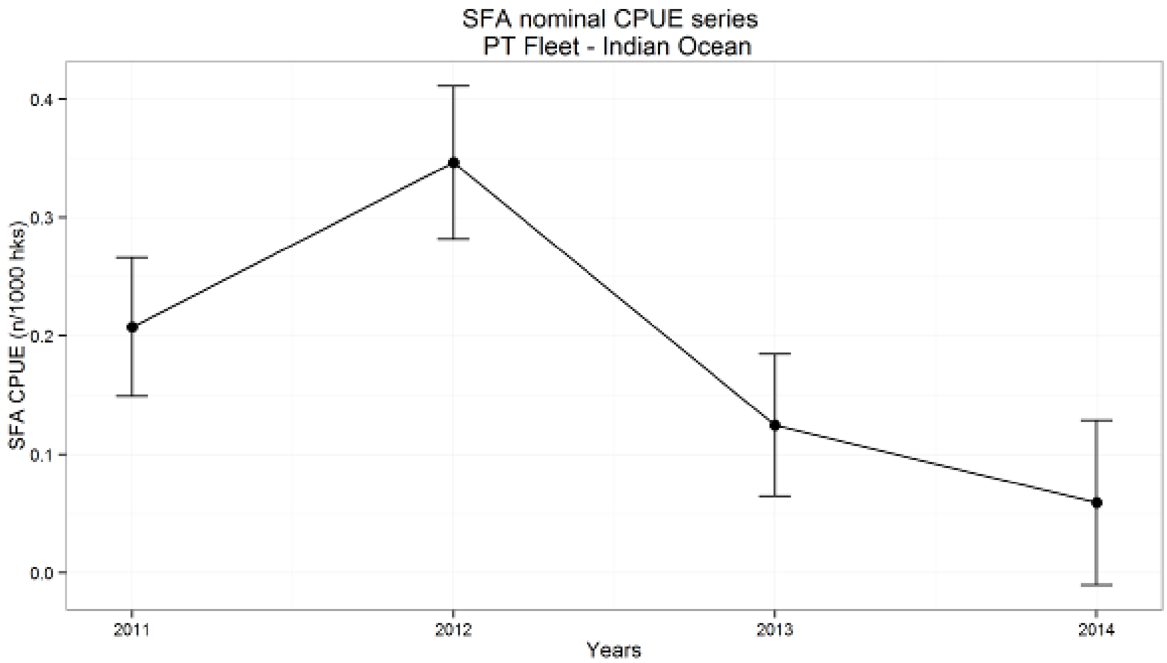

Figure 3 - Nominal CPUE series (n/1000 hooks) for *Istiophorus platypterus* caught by the Portuguese pelagic longline fishery in the Indian Ocean, between 2011 and 2014. The error bars are the 95% confidence intervals.

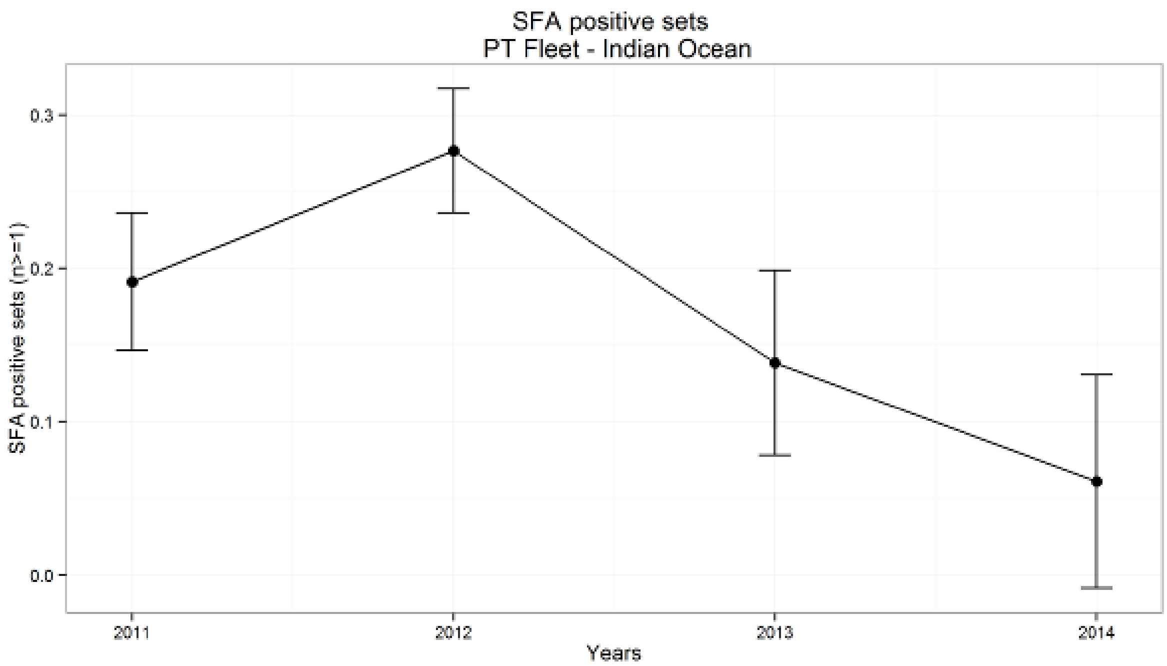

Figure 4 - Positive fishing sets with SFA catches for the Portuguese pelagic longline fishery in the Indian Ocean, between 2011 and 2014. The error bars are the 95% confidence intervals.

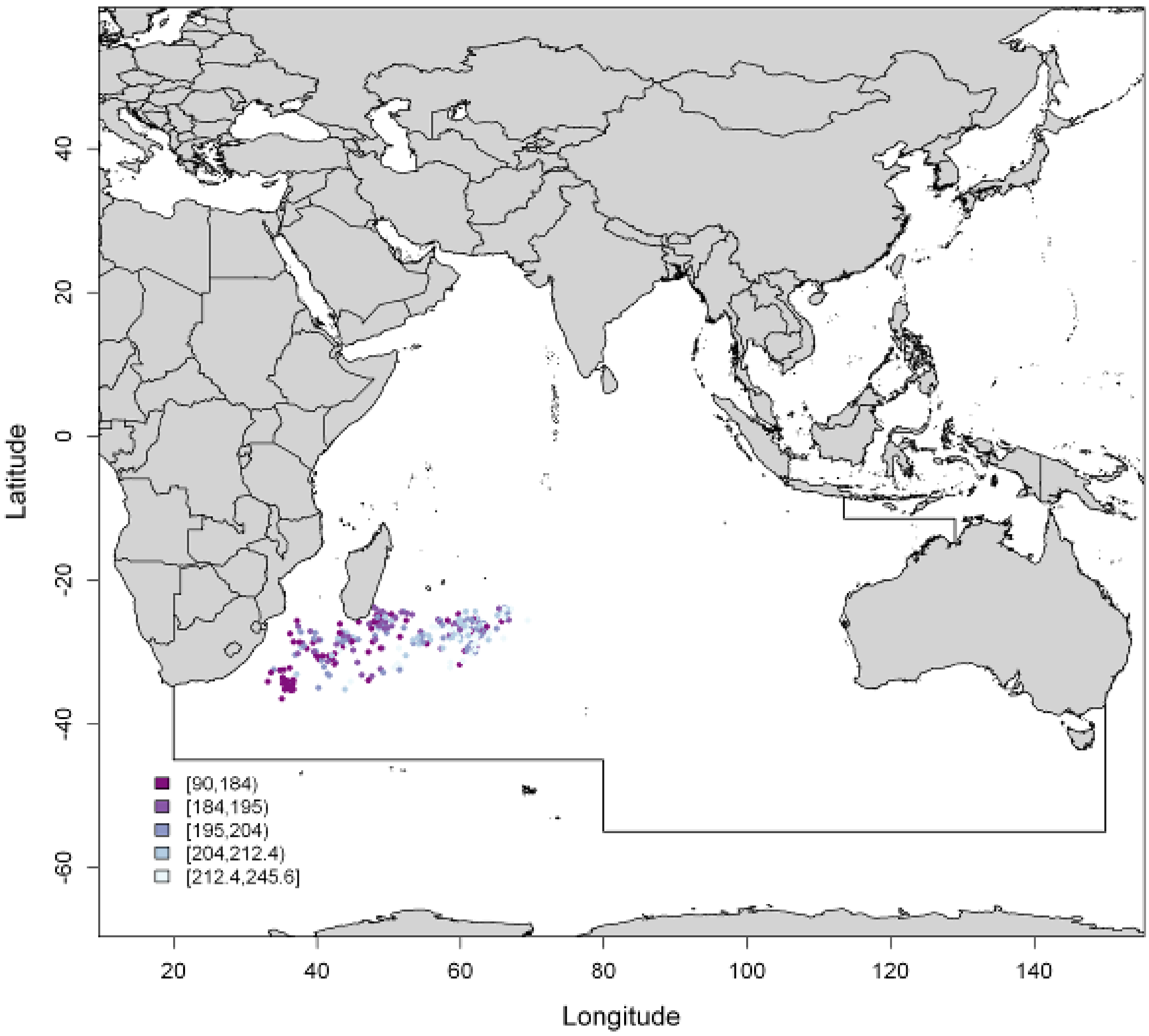

Figure 5 - Map of the Indian Ocean with the location of the *Istiophorus platypterus* samples. Black line represents the IOTC area. Coloured circles represent different size classes (LJFL, cm), colour coded with the darker colours representing smaller size classes.

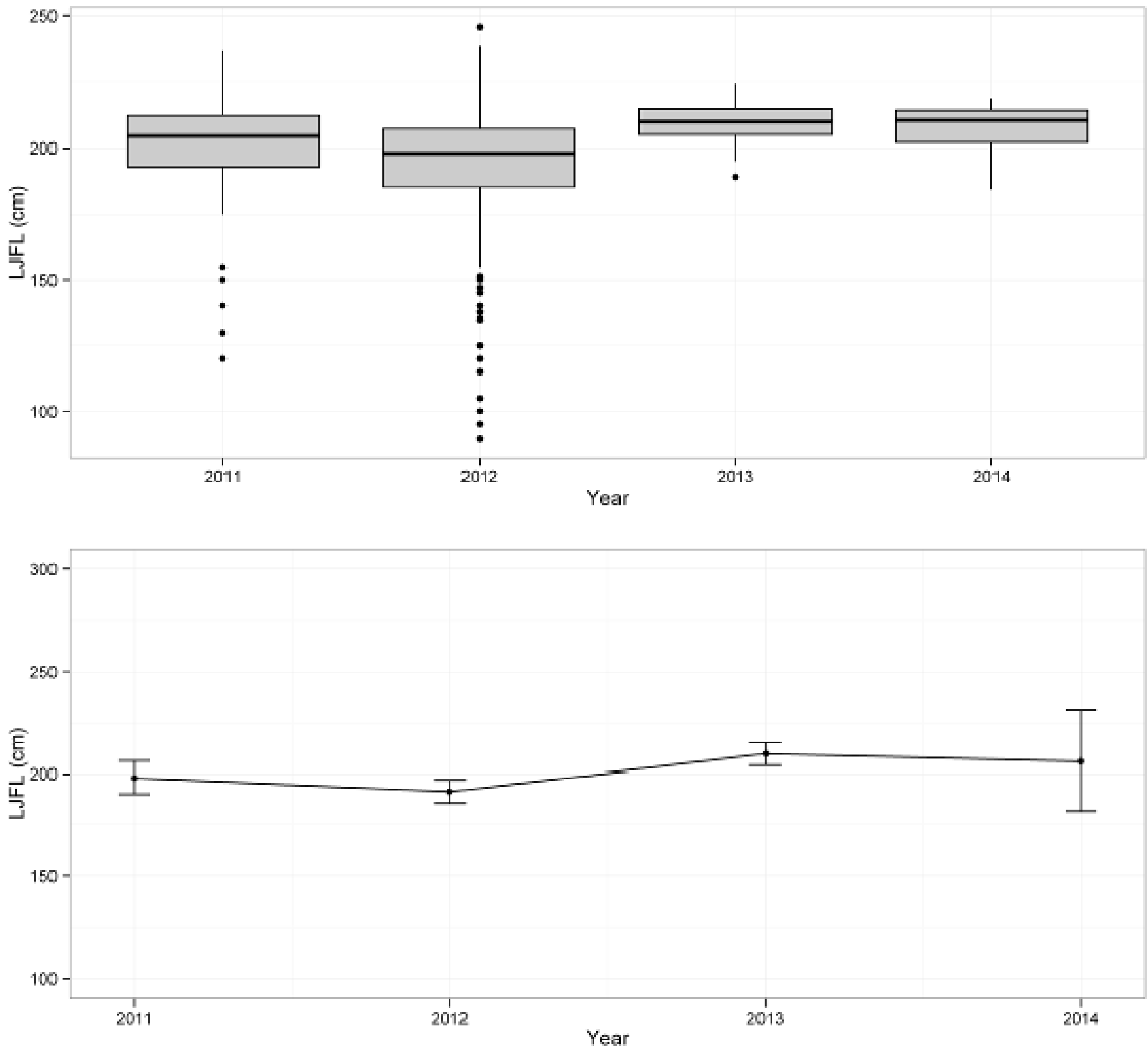

Figure 6 - Yearly catch-at-size of SFA caught between 2011 and 2014, represented as boxplots with the median, inter-quartile range and range (upper panel) and as the yearly averages with ± 95% confidence intervals (lower panel).

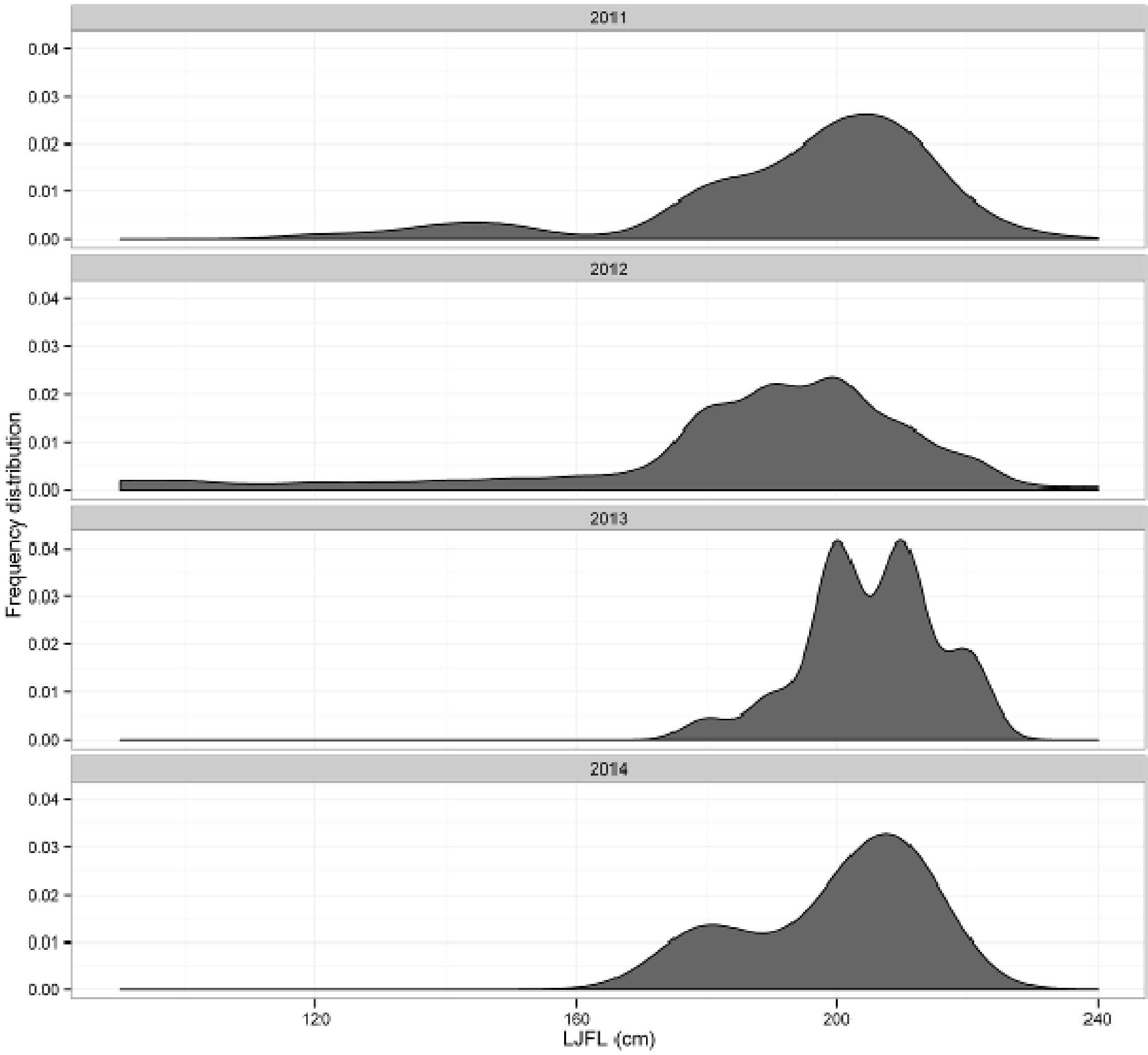

Figure 7 - Yearly size frequency distribution of SFA caught between 2011 and 2014.

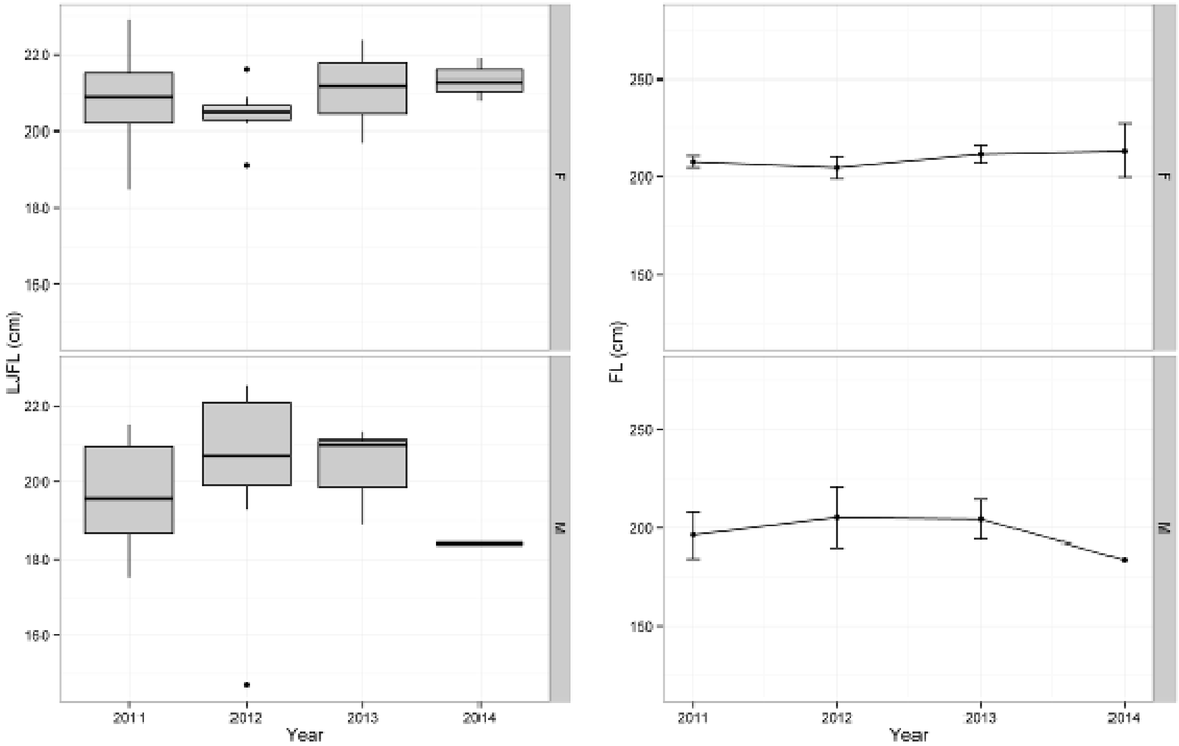

Figure 8 - Sex-specific yearly catch-at-size of SFA caught between 2011 and 2014, represented as boxplots with the median, inter-quartile range and range (left) and as the yearly averages with ± 95%confidence intervals (right). The sex specific sample size was of 98 specimens and represented 28.4% of the available data.

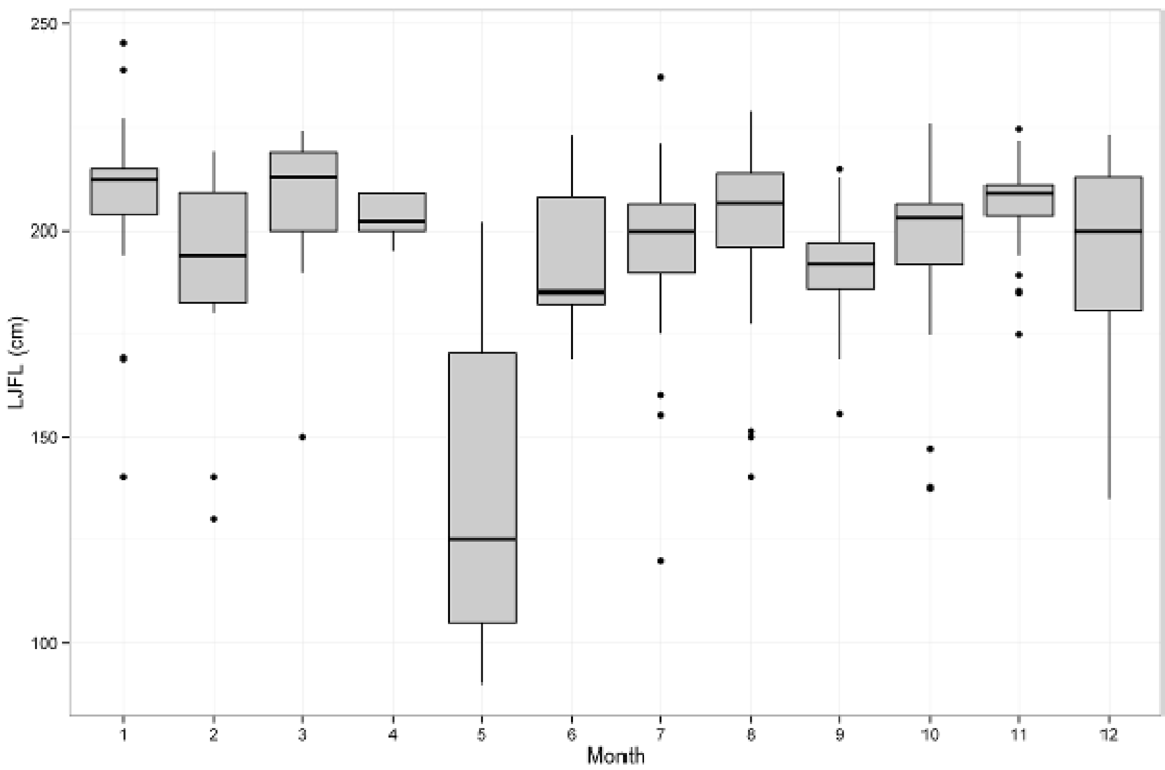

Figure 9 - Monthly sizes of SFA represented as boxplots with the median, inter-quartile range. Data between the years of 2011 and 2014 was pooled per month.

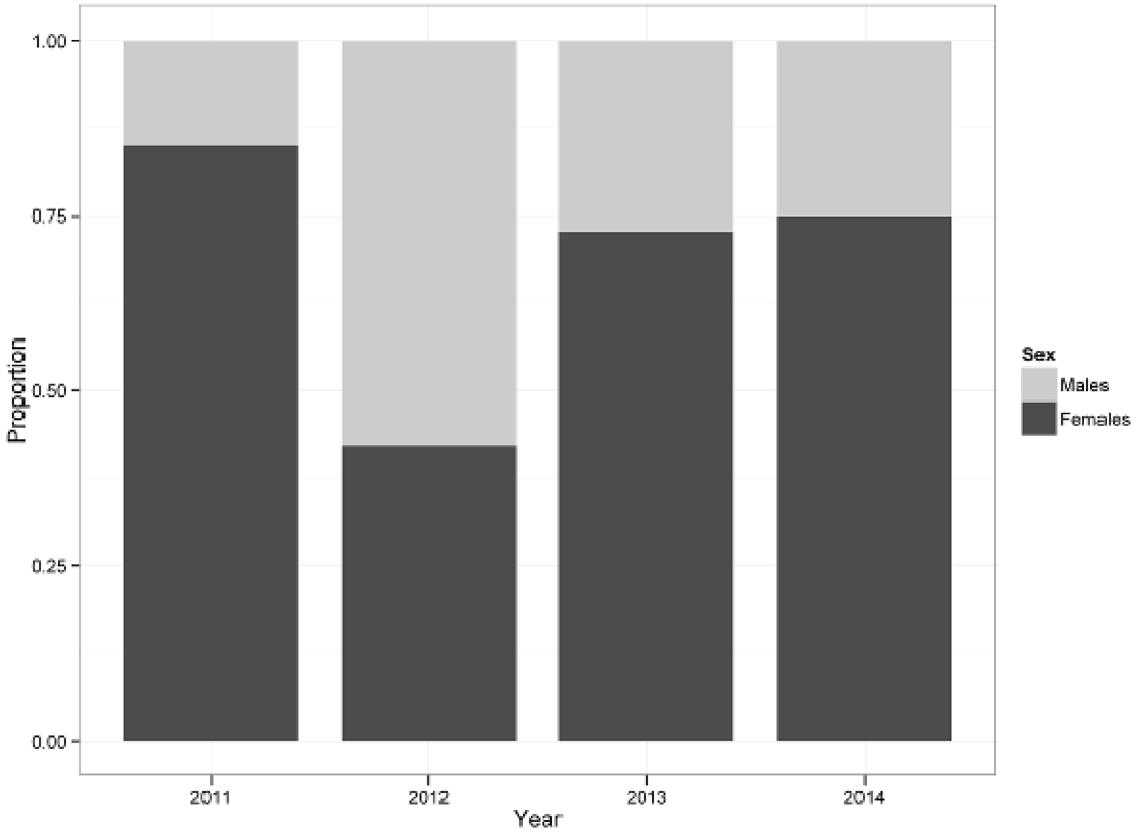

Figure 10 - Yearly sex-ratios of SFA captured between 2011 and 2014. The sex specific sample size was of 98 specimens and represented 28.4% of the available data.

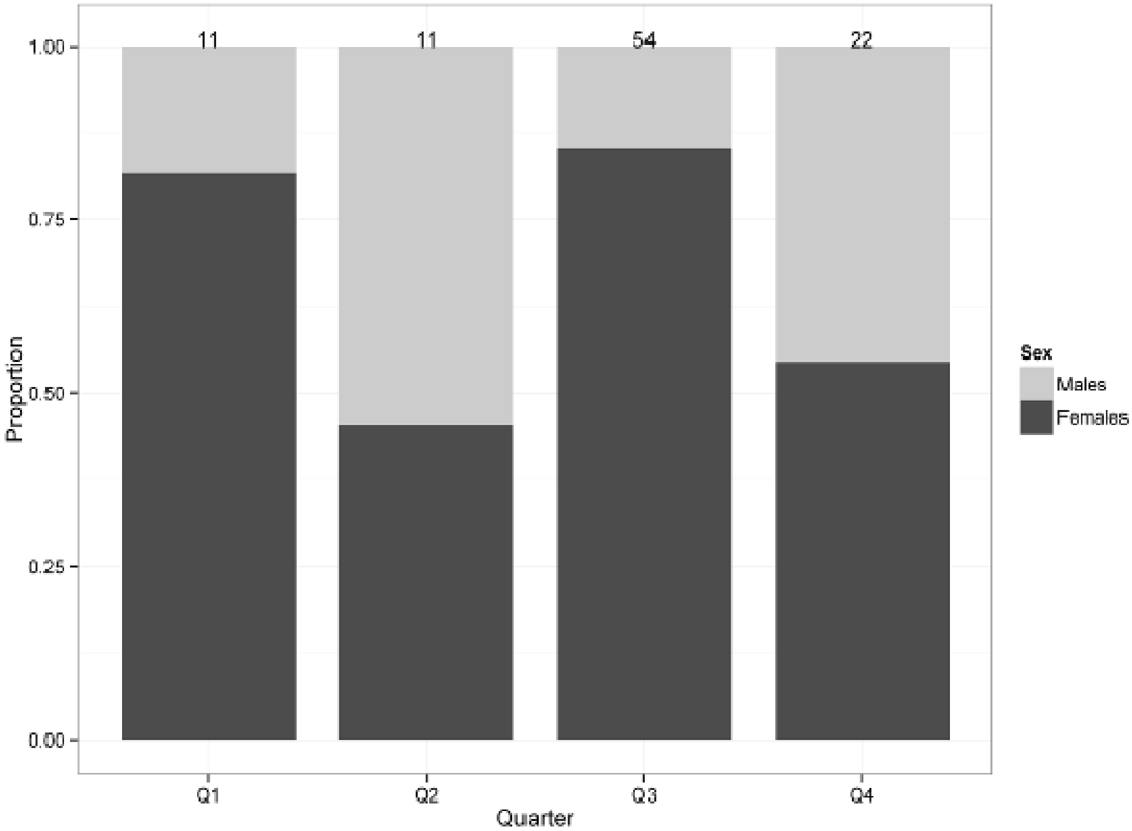

Figure 11 - Sex-ratios by quarter of SFA captured between 2011 and 2014. The sex specific sample size was of 98 specimens and represented 28.4% of the available data. The figures at the top represent the number of specimens sampled per quarter.

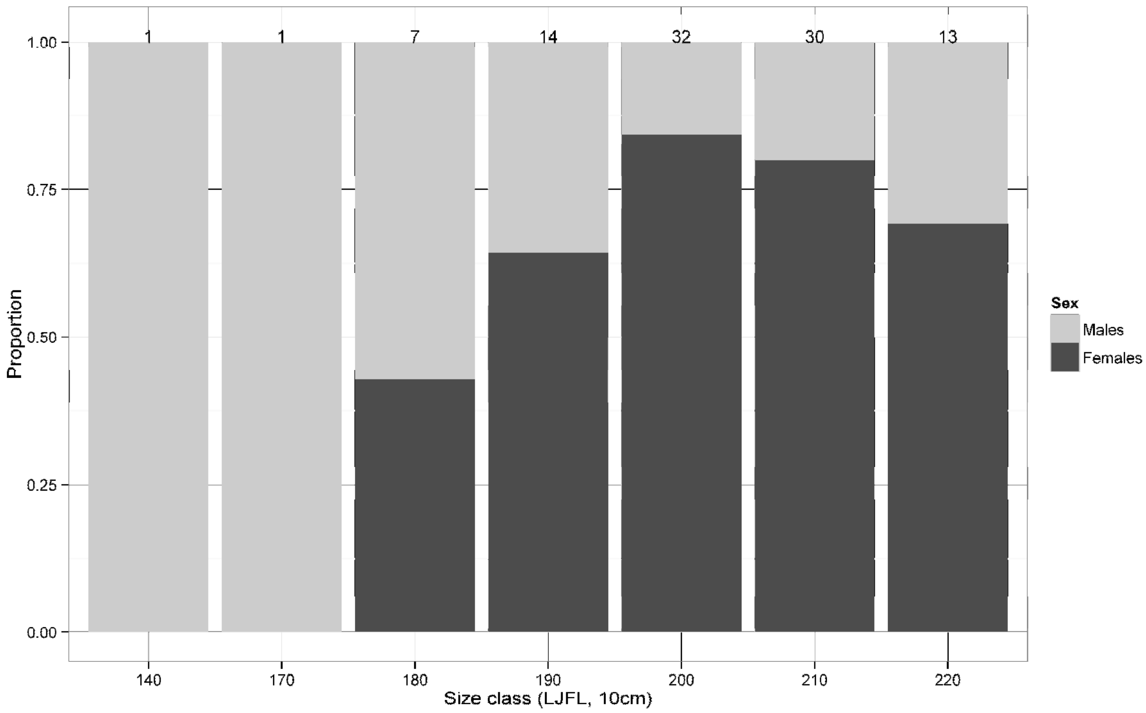

Figure 12 - Sex-ratios by size classes (10 cm LJFL) of the SFA captured between 2011 and 2014. The sex specific sample size was of 98 specimens and represented 28.4% of the available data. The figures at the top represent the number of specimens sampled per size class.

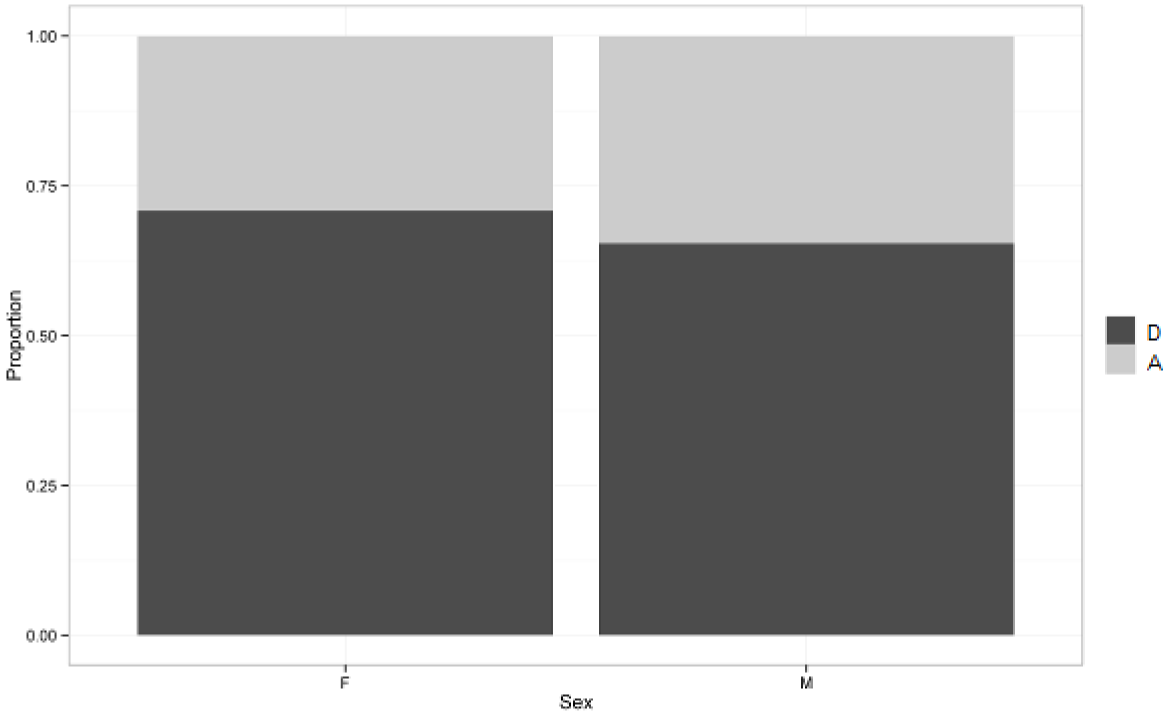

Figure 13 - At-haulback mortality by sex in SFA captured between 2011 and 2014. Sex-specific haul mortality was available for 98 specimens and represented 28.4% of the available data. In the legend A=alive and D=dead at haulback.