REVIEW OF THE SIZE-FREQUENCY DATA COLLECTED FROM SEYCHELLES INDUSTRIAL LONGLINERS DURING 2007-2015

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SUMMARY

A large set of size data for yellowfin and bigeye tunas has been collected aboard Seychelles industrial longliners since 2007 and carefully checked and managed by the Seychelles Fishing Authority. Analysis of the data at the scale of the fishing operation shows that size frequency data collected at sea by fishermen are consistent with logbook information in several vessels while some data appear to be spurious. We also show that changes in spatial distribution of the longline fleet in relation with piracy threat might explain some changes in average weight in the catch observed in the early 2010s within the large areas used for assessing the status of the stocks. Future work will aim (i) to improve data collection from the identification of vessels that appear to report size data of poor quality and (ii) to select the good size data sets to be used in the future assessments of Indian Ocean yellowfin and bigeye tuna. The availability of operational data is key to determine the causes of discrepancy between data sources of tuna size and eventually improve the overall quality of management advice.

KEYWORDS: bigeye, size structure, stock assessment, yellowfin

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1. Introduction

The status of the stocks of yellowfin (*Thunnus albacares*; YFT) and bigeye (*Thunnus obesus*; BET) tuna in the Indian Ocean is assessed with integrated statistical age-structured stock assessment models. Length-frequency data, which indicate the sizes selected by the different tuna fisheries, contribute to parameter inference through the multinomial likelihood component of such models (Langley 2016). Length measurements available from the Taiwanese distant-water longline fishery now predominate in the description of the size patterns in the catches of the overall Indian Ocean longline fleet following increased sampling rates and reduced collection of size data from Japan (Geehan and Hoyle 2013). Recent analysis of Taiwanese of size-frequency data however showed some substantial increase in average weight of YFT and BET in the 2000s as well as discrepancies between logbook data and size data which may be due to changes in sampling and/or processing protocol (Geehan and Hoyle 2013). Consequently, the length frequency data from the Taiwanese longline fleet during 1997-2015 were excluded from the final length frequency data sets incorporated in the 2016 bigeye and yellowfin tuna assessments.

Since the late 1990s, Seychelles have been flagging Taiwanese deepwater longliners as part of their national fishery policy. Logbook data have been collected and managed by the Seychelles Fishing Authority (SFA) since 1999, while length data have been collected from 2007. Over the recent years, the mean annual catch of bigeye and yellowfin tuna by Seychelles industrial longliners was around 6,000 and 1,500 metric tons, respectively. Here, we review the information available for the Seychelles industrial longline fishery and investigate the data quality for stock assessment.

2. Materials

2.1 Seychelles industrial longline fishery

During 2007-2015, the Seychelles industrial longline fishing fleet was composed of around 30 active longliners each year. The length overall of the longliners was comprised between 36 and 60 m, with a mean length of around 50 m. The vessels operated throughout the Indian Ocean, with the main fishing grounds located in the equatorial area between 15°S and 10°N (**Fig. 1**). Bigeye tuna was the principal target of the fishery and represented about 65% of the total catch in the western part of the equatorial area, while the percentage increased to an average of 75% east of 70°E (**Fig. 2**). Longliners operating south of 20°S mainly targeted swordfish (*Xiphias gladius*) and albacore tuna (*Thunnus alalunga*).

2.2 Size frequency data

The size sampling protocol was set up by SFA in collaboration with Deep-Sea Fisheries of Taiwan in June 2007. The sampling is carried out on Seychelles flagged longliners by crew members who are expected to measure the first 20 fish per each set haul and record on a sampling form. The number of fish measured can be smaller than 20 since about 20% of the fishing sets reported during 2007-2015 included less than 20 fish caught on the longline. The form is then submitted to SFA via email. The data recorded are: vessel details, date, position, and size measurement for the first 20 fish by species, in dorsal fork length (L_F) for tuna species, lower maxillary fork length (L_{MFL}) for swordfish and marlins, and total length (L_T) for sharks. Minimum and maximum size thresholds are used to flag anomalous values in the data.

The link between logbooks and length-frequency forms was made through vessel name and date of fishing operation and could not be achieved for 0.1% of the fishing operations recorded during 2007-2015 because of missing logbook, resulting in the loss of about 11,000 size measurements. Also, some discrepancies were found between the two sources of information for about 5% of all size samples. Information in the sampling form corresponded to a different activity than fishing operation, i.e. no fishing (1,657 fish), cruising (1,902 fish), at port (974), or to a position significantly different than reported in the logbook (38,642 fish).

2.3 Analysis of size-sample data

In a first step, the annual time series of mean length of yellowfin and bigeye were used to assess the temporal consistency in size data available within the areas used in the most recent stock assessment models during 2007-2014. The year 2015 was not considered because of missing data. To remove any auto-correlation due to fish caught on a same longline operation (e.g. school effect), the mean length was computed as the arithmetic average of mean lengths of bigeye or yellowfin in each sample. Only samples including at least 10 fish for bigeye and at least 5 fish for yellowfin were used to reduce high variability inherent to small sized samples.

In a second step, average weights derived from catch data were compared with weights derived from size-samples at the scale of the fishing set. Average weights of bigeye and yellowfin were computed at the scale of fishing set as the ratio between the total weight in metric tonnes and the total number of fish reported in the logbooks. Catch weight reported in the logbooks was assumed to be measured by fishermen with a spring scale after the fish was processed, i.e. gilled and gutted with removal of operculum and tail (Ren-Fen, *pers. com*). A fixed correction factor of 1.13 was considered for converting processed weight to total weight (IOTC-2016-WPTT18-DATA10-Equations) although data from the Pacific Ocean suggest that such conversion factor should be size-dependent (Langley et al. 2006). . Fork length was converted to weight through the IOTC official allometric length-weight relationships, i.e. power function with a = 0.0000159207 and b = 3.0415414023 for BET and a = 0.0000094007 and b = 3.126843987 for YFT (IOTC-2016-WPTT18-DATA10-Equations). The adjusted Pearson's correlation coefficient was used to identify the vessels and fishing trips for which there were some inconsistencies between logbooks and size samples.

3. Results

3.1 Sampling

More than 33,000 sampling operations have been conducted onboard from Seychelles industrial longline vessels between 2007-2015. With the exception of 2010 and 2015, for which sampling data are still in the process of database entry and checking, between 3,000 to 6,000 samples have been collected annually. The number of fish measured in each sample suggests that the protocol has been respected for most sampling operations with regards to the target number of measurements. About 70% of all the samples include 20 fish measurements and this percentage increased to 80% when one considered 15 measurements and more (**Fig. 3**). While the median number of fish sampled per set is 20, the range of number of fish however shows some inter-annual variability with a few samples composed of less than 5 fish but the 25% quantile varying between 11 in 2013 to 20 in 2012 (**Fig. 3**).

In total, more than 430,000 BET and YFT tunas were sampled aboard Seychelles industrial longliners during 2007-2015 (**Fig. 4**). Samples collected for 2010 and 2015 are expected to increase this overall number to more than 500,000 tuna measurements over the same period. Bigeye represents annually more than 70% of the tunas measured, which is consistent with the percentage of bigeye catch declared in the total catch of the fishery (**Table 1**). Excluding 2010 and 2015, the sampling coverage was high and varied between 24-57% for bigeye and 16-40% for yellowfin (**Table 2**). Conversion of fish measured into weight indicated that around 40% and 28% of the total catch of bigeye and yellowfin, respectively, or 9 bigeye and 8 yellowfin per tonne of catch. This level of sampling is well above the minimum sampling of 1 fish per tonne of catch recommended by the IOTC.

Mean length of bigeye caught by Seychelles longliners was around 130 cm F_L with some temporal variability over time and space (**Fig. 5**). Bigeye length was found to be higher in area R1N in relation with the observed spatial gradient of increased length from the centre of the Indian Ocean to the west and north along the coasts of Tanzania and Somali (**Fig. 6**). The decrease in mean length of bigeye in 2009-2011 seemed linked to the contraction of the distribution of the fleet in the southeastern part of area R1S due to piracy threat. The temporal trend in the time series and spatial gradient in mean length in yellowfin were opposed to that of bigeye, i.e. decrease in the recent years in relation with smaller fish along the coasts of east-African countries where the fleet returned from 2012 (**Figs. 7, 8**). There was an apparent issue in size data in the 4th quarter of 2011 in region 1N for both yellowfin and bigeye with very small values which should be checked (**Figs. 6, 8**).

3.2 Comparison between logbooks and samples

A total of 50,009 fishing operations with catch in both numbers and weights were recorded during 2007-2015 for bigeye and yellowfin tuna, respectively. Comparison between logbook and size data showed some large discrepancy between data sources of tuna weight in the Seychelles longline fishery. Although an underlying increasing linear pattern could be inferred from the relationship between average weights derived from size samples and logbooks at set scale, the scatterplot showed that the weights were inconsistent in many cases (**Fig. 9**). We found that the 2 data sources were very consistent in several vessels (Pearson's r > 0.8) and that the data quality was stable over time (i.e. different fishing trips) for a vessel identified as 'good' (**Fig. 10**). By contrast, no linear relationship was found between weights in several longliners. In such cases, it is difficult to identify if the errors come from the logbook or the size frequency data. For some vessels, size data were however clearly showing some issues, i.e. most fish measured were had the same size (**Fig. 10**).

4. Conclusions

A large set of size data for yellowfin and bigeye tunas has been collected aboard Seychelles industrial longliners since 2007 and carefully checked and managed by the Seychelles Fishing Authority. Analysis of these data indicates that there are some spatial patterns in the size distribution of large yellowfin and bigeye caught with longline in the Indian Ocean. Changes in spatial distribution of the longline fleet in relation with piracy threat might explain some changes in average weight in the catch observed in the early 2010s within the large areas used for assessing the status of the stocks. Our results also show that size frequency data collected at sea by fishermen are consistent with logbook information in several vessels while some data available from some vessels are spurious. Next steps will consist in (i) working with the fishing companies to improve future data collection from the identification of vessels that appear to report size data of poor quality and (ii) working with the IOTC Secretariat to select the good size data sets to be used in the future assessments of Indian Ocean yellowfin and bigeye tuna.

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Figures

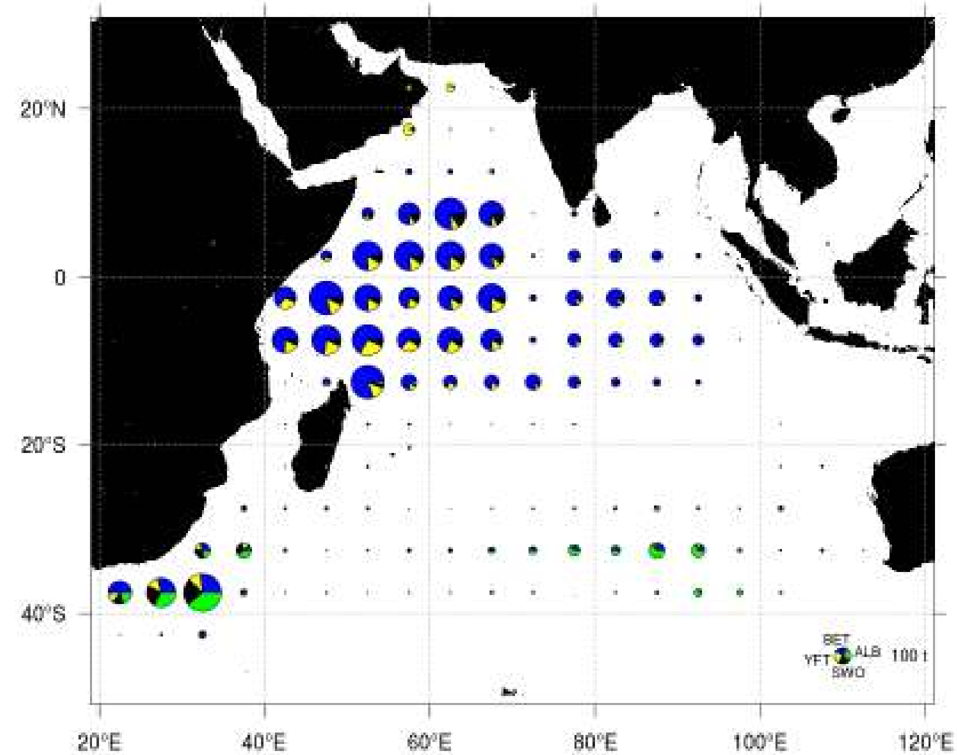

Fig. 1. Mean spatial distribution of the annual catch for the main species caught by Seychelles industrial longline fishery during 2007-2015. ALB = albacore tuna; BET = bigeye tuna; SWO = swordfish; YFT = yellowfin tuna

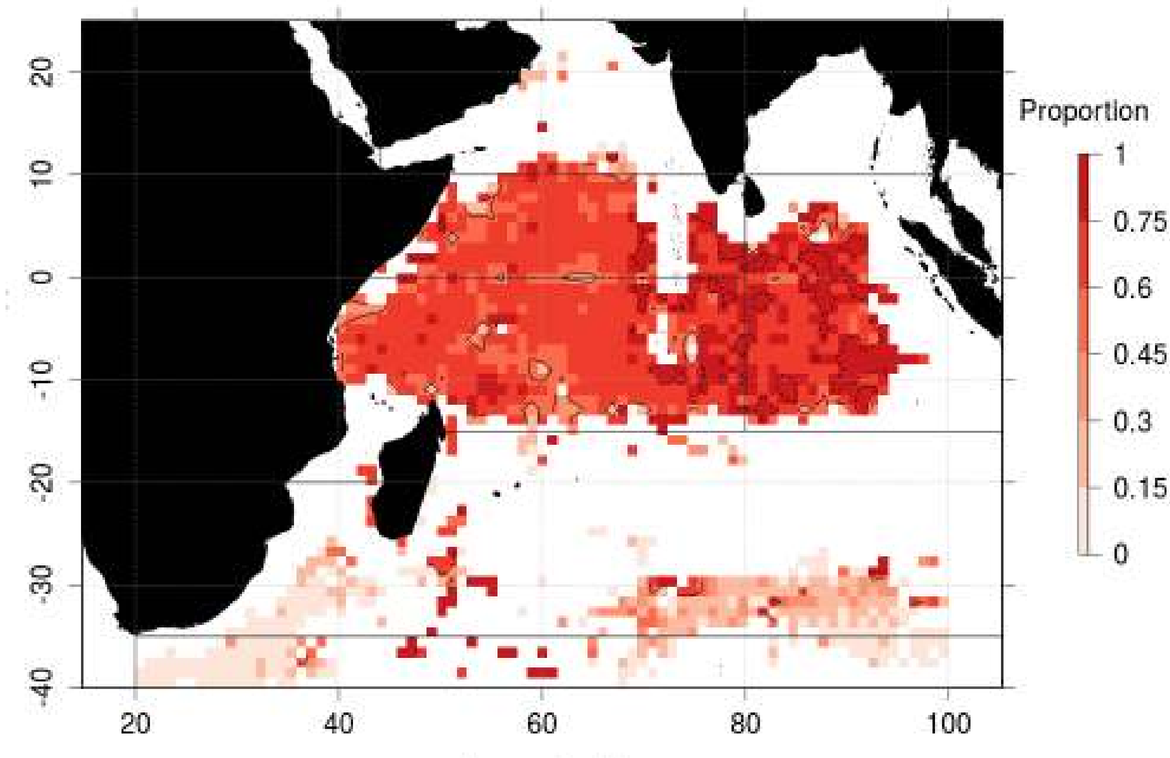

Fig. 2. Spatial distribution of the proportion of bigeye tuna in the total catch recorded for each fishing set of the Seychelles industrial longline fishery during 2007-2015

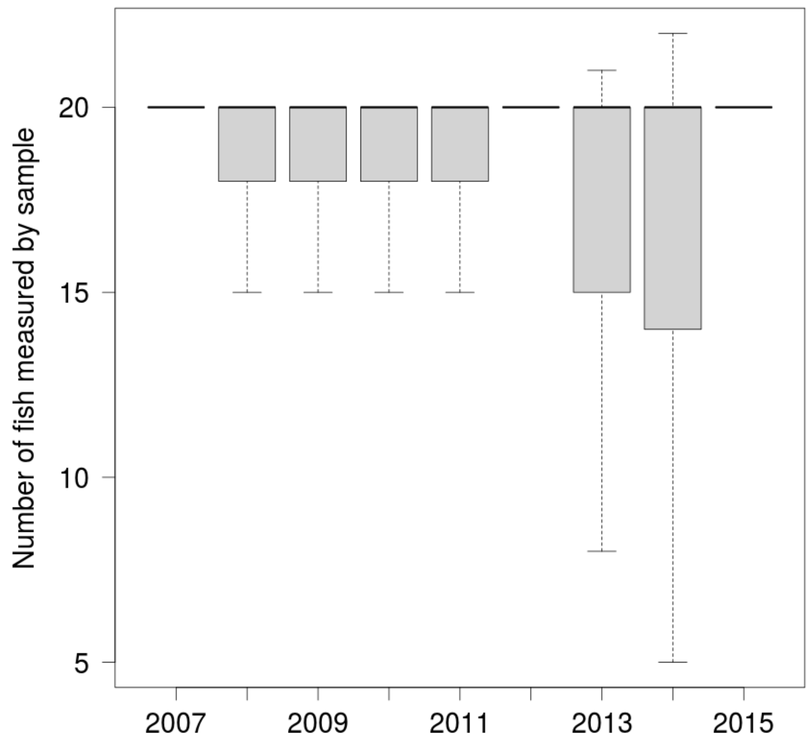

Fig. 3. Annual distribution of the number of fish (all species) measured by sample aboard Seychelles industrial longliners during 2007-2015

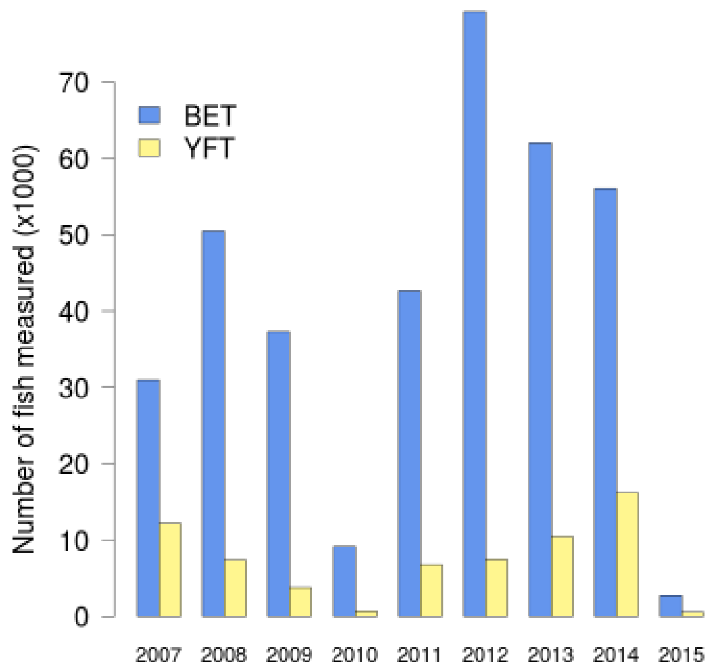

Fig. 4. Annual number of bigeye (BET) and yellowfin (YFT) tuna measured by species aboard Seychelles industrial longliners during 2007-2015 and recorded in the SFA database

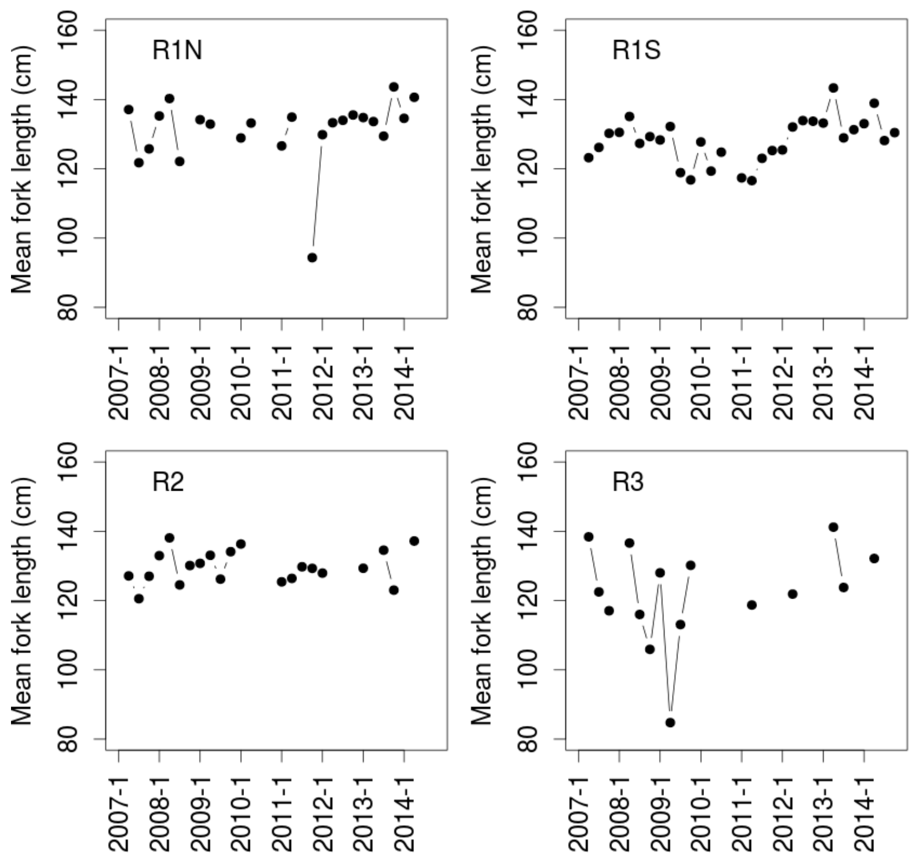

Fig. 5. Quarterly distribution of mean length of bigeye in the 2016 assessment areas estimated from the size samples collected aboard Seychelles industrial longliners during 2007-2014.

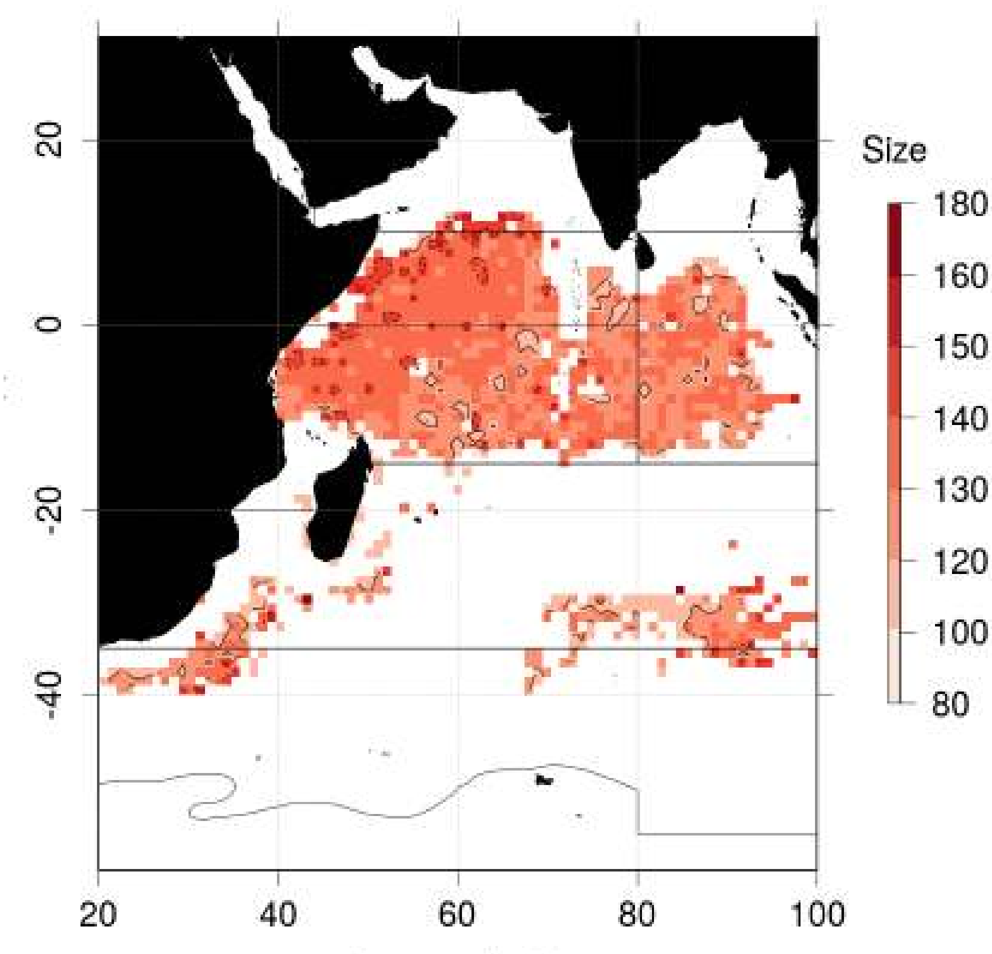

Fig. 6. Spatial distribution of bigeye fork length (cm; F_L) available from size samples collected aboard Seychelles industrial longliners during 2007-2015. Solid and dashed lines indicate 120 and 140 cm F_L contour lines, respectively.

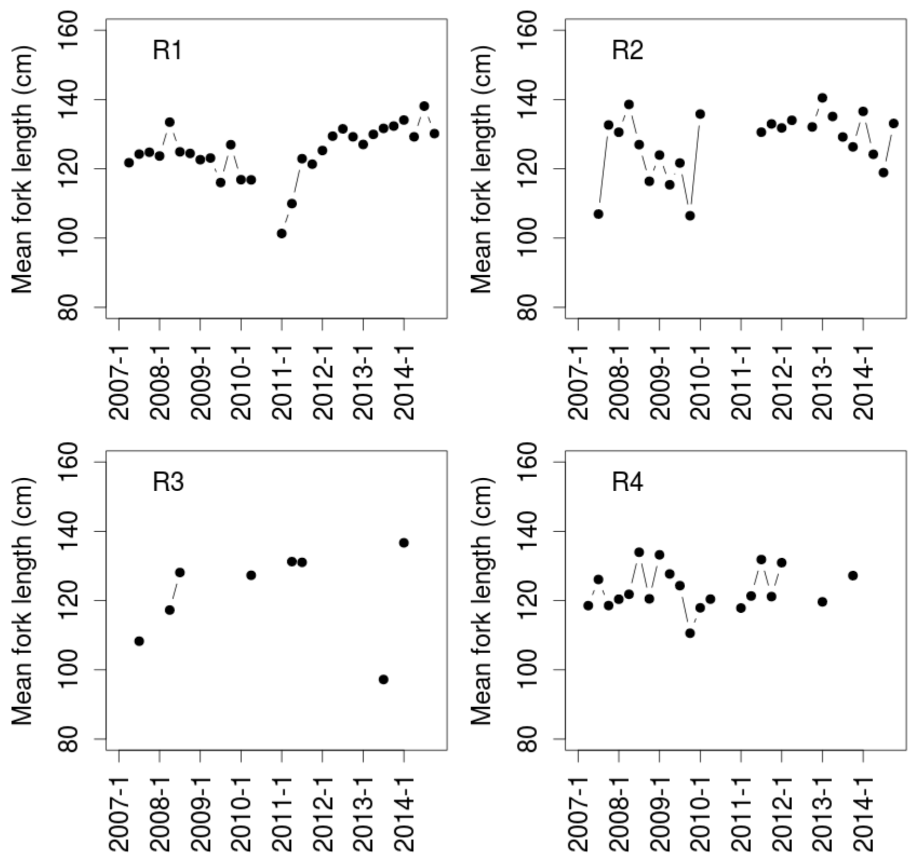

Fig. 7. Quarterly distribution of mean length of yellowfin in the 2015 assessment areas estimated from the size samples collected aboard Seychelles industrial longliners during 2007-2014.

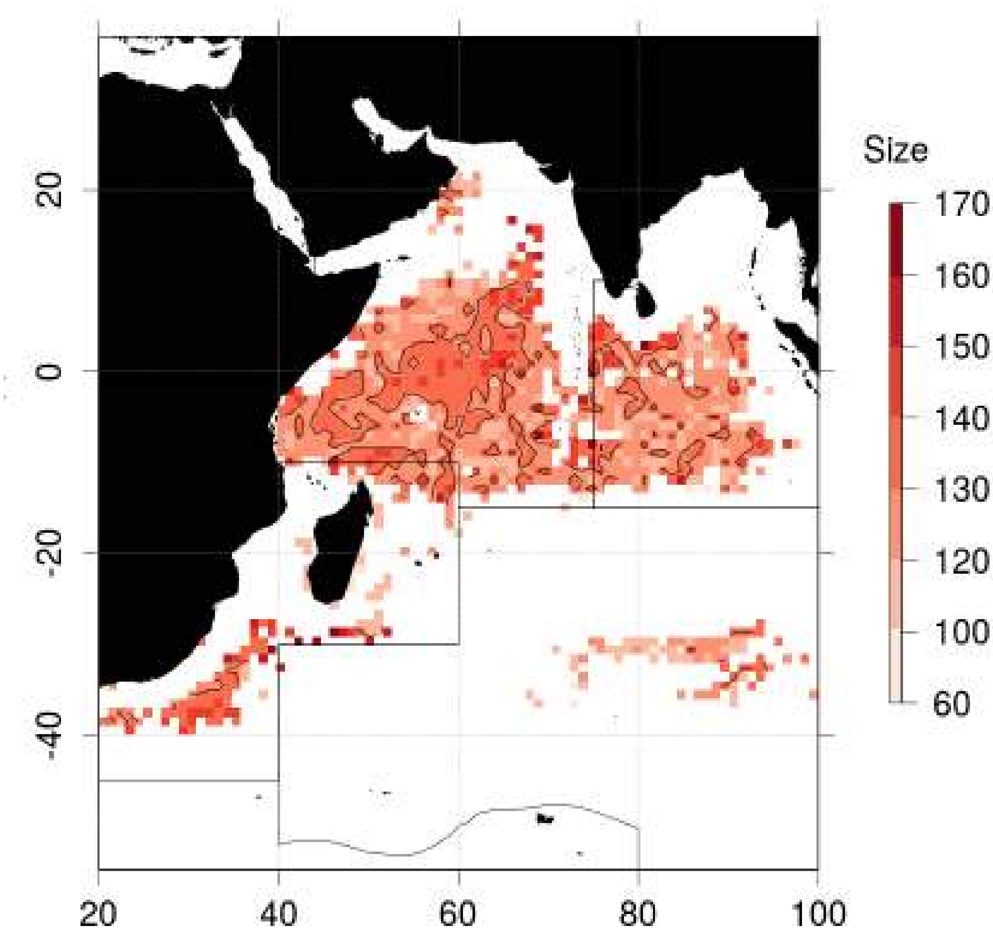

Fig. 8. Spatial distribution of yellowfin fork length (cm; F_L) available from size samples collected aboard Seychelles industrial longliners during 2007-2015. Solid line indicates 130 cm F_L contour line.

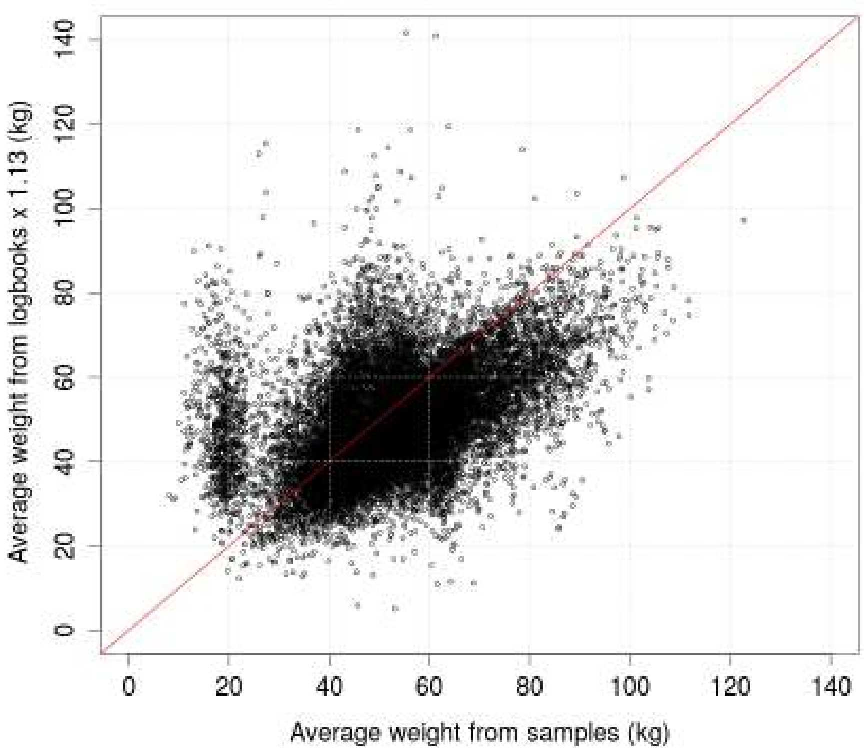

Fig. 9. Comparison between average weights for bigeye derived from logbook and size-frequency data at the fishing set level for the Seychelles industrial longline fishery during 2007-2015. Red solid line indicates the 1:1 line

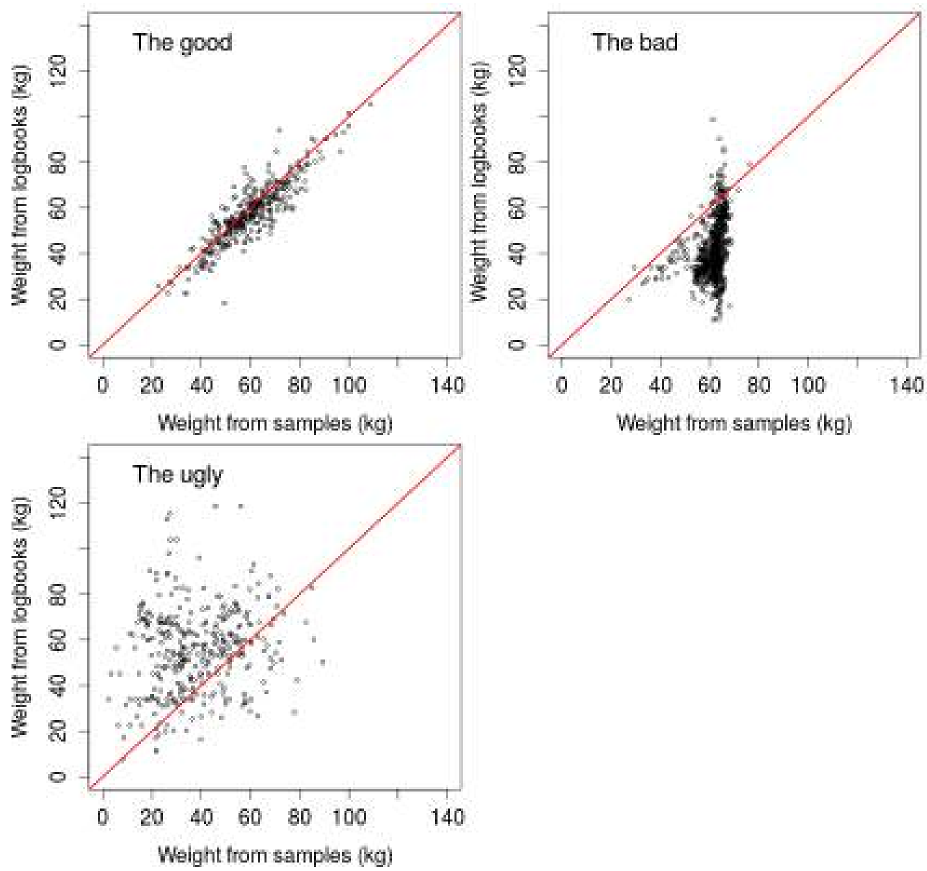

Fig. 10. Three case studies of relationship between average weights (kg) of bigeye derived from size-frequency samples and logbooks

5. Tables

Table 1. Total annual number of bigeye (BET) and yellowfin (YFT) tunas measured aboard Seychelles industrial longliners during 2007-2015

	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOTAL
BET	30950	50449	37265	9149	42671	79225	62047	56046	2747	370549
YFT	12185	7415	3809	716	6802	7484	10478	16208	603	65700
TOTAL	43135	57864	41074	9865	49473	86709	72525	72254	3350	436249

Table 2. Sampling coverage computed as the percentage of fish measured over reported in the logbooks. Sampling coverage does account for the proportion of missing monthly logbooks.

	% logbooks available	CE-No		SF-N0		% SF coverage	
		BET	YFT	BET	YFT	BET	YFT
2007	82	105344	60941	30944	12194	24%	16%
2008	89	90127	16325	50432	7424	50%	40%
2009	95	95877	13231	37235	3864	37%	28%
2010	84	90088	14828	9147	718	9%	4%
2011	97	102357	33671	42664	6802	40%	20%
2012	96	209081	30342	79192	7499	36%	24%
2013	100	126385	28716	62007	10501	49%	37%
2014	95	93884	39817	56020	14924	57%	36%
2015	88	87953	50129	2747	571	3%	1%