Long-term monitoring of the biology of tropical tunas through routine sampling at the cannery of Victoria, Seychelles

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SUMMARY

More than 35,000 fishes have been sampled at the Seychelles cannery during 1987-2014 to collect morphometric data and information on the reproduction of the principal market tropical tunas harvested in the Indian Ocean. Samples are largely predominated by large yellowfin tuna but sampling operations have included juveniles of yellowfin as well as skipjack and bigeye since January 2014. Information on the dates of origin and fishing grounds has been retrieved from the purse seiner logbooks for most fish sampled. Data collected are useful for deriving conversion keys between lengths and weights, identifying spawning grounds and fishes in sexual activity, and monitoring long-term changes in condition. A generic database is currently in development to host different types of biological data and provide free open-access to the data so as to promote comparative analyses between populations, species, and areas.

KEYWORDS: bigeye, fish condition, sex-ratio, skipjack, yellowfin

1. Introduction

Basic biological data (length, weight, sex, etc.) constitute essential information for the analysis of fisheries data and inputs of stock assessment models. For purse seine fisheries, length-length and length-weight relationships are used in the data processing aimed at estimating the species composition (in biomass) of the catch through the conversion of fish sizes measured onboard the vessels at landing. Indeed, the use of weighing scales as well as long calipers (>1 m) is difficult in lower decks of purse seiners. In addition, morphometric measurements such as thorax perimeter, parameters of the length-weight relationships as well as weight measurements of organs (e.g. liver, stomach) can be used to compute individual fish condition indices that are useful for monitoring seasonal and interannual changes in energy reserves. Finally, data collected on sex, macroscopic maturity stage and gonad weight can be used to monitor the reproductive cycle of tunas and derive metrics of the reproductive potential of the stocks (i.e. maturity ogive and sex-ratio) for assessment models.

Samples of the three principal market tunas – yellowfin (*Thunnus albacares*; YFT), skipjack (*Katsuwonus pelamis*; SKJ), and bigeye (*Thunnus obesus*; BET) – have been collected at the cannery of

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Seychelles since its opening in early June 1987 during 2 distinct periods: 1987-1991 and 2003-2014. The sampling protocol as well as results derived from the data collected during the first period have been presented during IPTP (Indo-Pacific Tuna Development and Management Programme) meetings through several reports (Karpinski and Hallier, 1988; Hassani and Stéquert, 1991; de Montaudoin et al., 1990). More recently, data obtained from yellowfin sampled at the cannery were combined with size data collected at sea by observers during 1984-1987 to update the relationship between predorsal length and fork length, fork length and weight, male proportion and length (Marsac et al., 2006). In addition, stomach samples collected at the cannery and at-sea were used to describe the feeding habits of yellowfin and identify areas characterized by dominant preys.

In the present article, we describe the different data sets that have been collected at the IOT Ltd. cannery of the Seychelles (originally Indian Ocean cannery) during 1987-2014 and how we established a link between these biological data and information on fishing grounds and dates. We then provide some information on the morphometric measurements of YFT, SKJ, and BET and observed annual and seasonal patterns in gonadic index, changes in sex-ratio with length, and seasonal changes in maturity for yellowfin. We finally discuss the perspectives of the work in conjunction with ongoing research projects on tuna biology in the Indian Ocean and interest of routine sampling programs to study the reproductive strategy of tunas and monitor long-term changes in open-sea ecosystems through their individual condition.

2. Materials & Methods

2.1 Sampling at the cannery

A total of 35,533 tunas have been sampled at the Seychelles cannery since 1987, YFT representing 94% of the samples. The predominance of YFT (>60 cm) in the samples is mainly explained by the historical major commercial interest of this species for purse seine fisheries and the easy access to the raw-pack processing line at the cannery where the tunas are defrosted before being processed. By contrast, skipack and juveniles of YFT and BET are cooked whole without being defrosted at a precook processing line, which has limited for some time their sampling. Since January 2014, a new agreement has been made with IOT Ltd. and the sampling now includes fishes from the precook processing line through a defrosting period.

2.2 Fish traceability

Information on the fishing trip of origin of the tunas processed at the cannery has been collected for a large majority of the tunas sampled. The traceability is made possible through the information collected on the vessel and date of purchase by the cannery. No information on the brine-freezing wells of origin of the fish is available as most purse seiners unload the tunas from several wells at the same time and tunas can then be mixed in the cannery scows before being sorted and stored in the cold storage rooms of the cannery. Information on the vessel name and date of unloading were then inferred from the information provided by the cannery and used to establish the link with the databases of IRD, IEO, and SFA so as to associate the dates and positions of all fishing sets made during each fishing trip to each fish sampled. The information could not be gathered when the tunas processed came from reefers (which might come from the Indian Ocean but from other oceans) as well as from groups of vessels or purse seiners not flying the European and associated flags, i.e.. Korea, Thailand, and Soviet Union.

2.3 Sampling protocol

The sampling protocol has varied over time and the sampling was mainly opportunistic until 2014, with all tunas being sampled at the raw-pack processing line through operations that would occur each month of the year depending on the availability of tunas and work priorities of the sampling team. Since january 2014, a sampling design has been implemented for the three species based on quarter, size-range, and sex (Table 1).

Table 1: Sampling design (target) for each quarter. Values of fork length (F_L) and size classes are given in cm. M = Male ; F = Female ; I = Indeterminate

Species	L_F min.	L_F max.	Size class	N by quarter		
				I	M	F
Yellowfin	<30	>159	2	50	105	105
Skipjack	<30	>59	1	25	70	70
Bigeye	<30	>159	2	50	105	105

The current sampling includes morphometric measurements, sex identification, and macroscopic evaluation of the maturity stage following the ICCAT reference table (Table 2). Although visual exams to determine maturity stage have been shown to poorly perform for yellowfin (Albaret, 1977), the data are available and have been used to estimate the size of first maturity and size at which 50% of the females are mature (Hassani and Stéquert, 1991). In addition to maturity stage, historical samples mainly focused on F_L, L_{D1}, T_W and sex while the recent sampling aims to collect information on the weight of each organ that can play a role in energy storage and allocation.

Table 2: Summary of data to be collected for each individual

Notation	Definition	Precision	Tool
F_L	Fork length	1 cm	Caliper
L_{D1}	Predorsal length	1/2 cm	Caliper
T_P	Thorax perimeter	1 cm	Tape measure
W_T	Whole fish weight	10 g	150 kg scale
W_{gon}	Gonad weight	1 g	6 kg scale
W_{liv}	Liver weight	1 g	6 kg scale
W_{stom0}	Whole stomach weight	1 g	6 kg scale
W_{stom1}	Empty stomach weight	1 g	6 kg scale
W_{visc}	Rest of the viscera weight	1 g	6 kg scale
S	Sex	-	-
M	Maturity stage	-	ICCAT table

3. Results

A total of 34,203 YFT, 821 SKJ and 1,427 have been sampled during 1987-2014 at the cannery of the Seychelles. The level of sampling effort varied between years and SKJ have only been sampled from 2014

(Appendix 1). The sampling covers the main size range of the tunas that are harvested by purse seiners in the Indian Ocean but it appears to be unbalanced for YFT and BET, with very few large individuals (>70 cm) for BET while the sampling of YFT is predominated by fishes >90 cm F_L (Fig. 1). The length-weight relationships are shown in figure 2. Preliminary analyses showed that the length-weight relationship did not vary significantly between males and females for the 3 species. Length measurements at the cannery have been used to derive a key giving the proportions of individuals by L_{D1} size class into F_L classes (Fig. 3). The key that enables to account for the variability between L_{D1} and F_L is updated each year to improve the conversions in the purse seine data processing.

Sampling operations conducted at the cannery provide information on the reproductive cycle of tunas. Data collected on the sex of YFT show that the proportion of males increases from 130 cm F_L to reach almost 1 from 150 cm (Fig. 4). In addition, information on maturity stages derived from visual exams reveal seasonal patterns in YFT reproduction. Females and males in stage 4 are more abundant in the population during the months of Nov-Jan while the months of Jun-Aug seem characterized by very few females in reproductive stage (Figs 5-6). Finally, condition indices for large females (>90 cm) were computed from observed weights and lengths (Le Cren 1951) and suggest that some major changes in YFT condition occurred over the last decade (Fig. 7). In particular, the overall condition of females fished during 2005-2009 appear to be lower than 1, suggesting some potential changes in food quantity and/or quality that affected the population at this time.

4. Discussion

4.1 Ongoing work

The relationships between fork length (F_L) and total weight (W_T) for SKJ and BET will be updated on a yearly basis in the future through the collection of data on SKJ and juveniles of BET and YFT that has been made possible since January 2014 through access to tunas at the precook processing line. The updating of the historical key used to convert predorsal length (L_{D1}) into fork length (F_L) for BET is more difficult as very few large BET (>90 cm) are processed at the cannery. Large BET are currently collected through opportunistic sampling through an agreement with the French fishing companies as well as through ongoing research projects in the Indian Ocean.

The increased proportion of females observed in the size-class 120-125 (>56%) might reflect an accumulation of females that could be due to lower asymptotic length than males (Eveson et al. in press). Analysis of the spatial changes in male proportion should be investigated and accounted for when deriving a vector of sex ratio for stock assessment models (Farley et al. 2014). Finally, the comparison of indicators of fish condition (i.e. GI and GSI) based on morphometric data with biochemical information derived from stable isotopes of Carbon and Nitrogen, lipid classes and fatty acid profiles is currently ongoing to determine how well morphometric indicators of condition perform for monitoring the good physiological state of the tunas.

4.2 Towards an open database for biological data

Biological data on tuna and tuna-like species are currently spread between RFMOs and research institutes although they do not hold any confidentiality issue as compared to some fisheries data (e.g. vessel name). Such data are however of major importance for data processing procedures (e.g. conversions) as well as for comparisons between populations, species, areas, or time periods. In addition, such data might be valuable for describing the resistance of some species to fishing such as derived from Ecological Risk Assessment analyses. For instance, maximum observations of length or weight have been used to derive expected life span. We are currently developing a generic database for biological data, including morphometric measurements, data on reproduction (e.g. maturity stage derived from histology, batch fecundity) as well as data derived from biochemical analyses (stable isotopes, fatty acid profiles, contaminant profiles, lipid classes). The final objective is to propose to the different RFMOs a tool to host any type of biological data (geo-referenced or not) coming from different institutions through the definition of standard protocols and formats to promote comparative analyses and archive such valuable data that can generally be lost over time.

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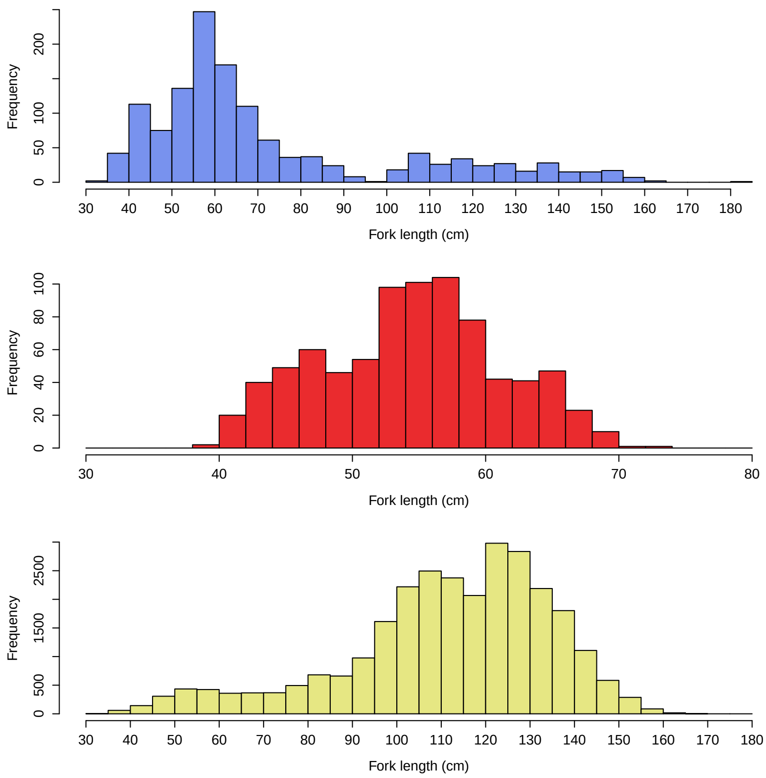

Figure 1: Size frequency histograms of tunas sampled at the Seychelles cannery during 1987-2014

Figures

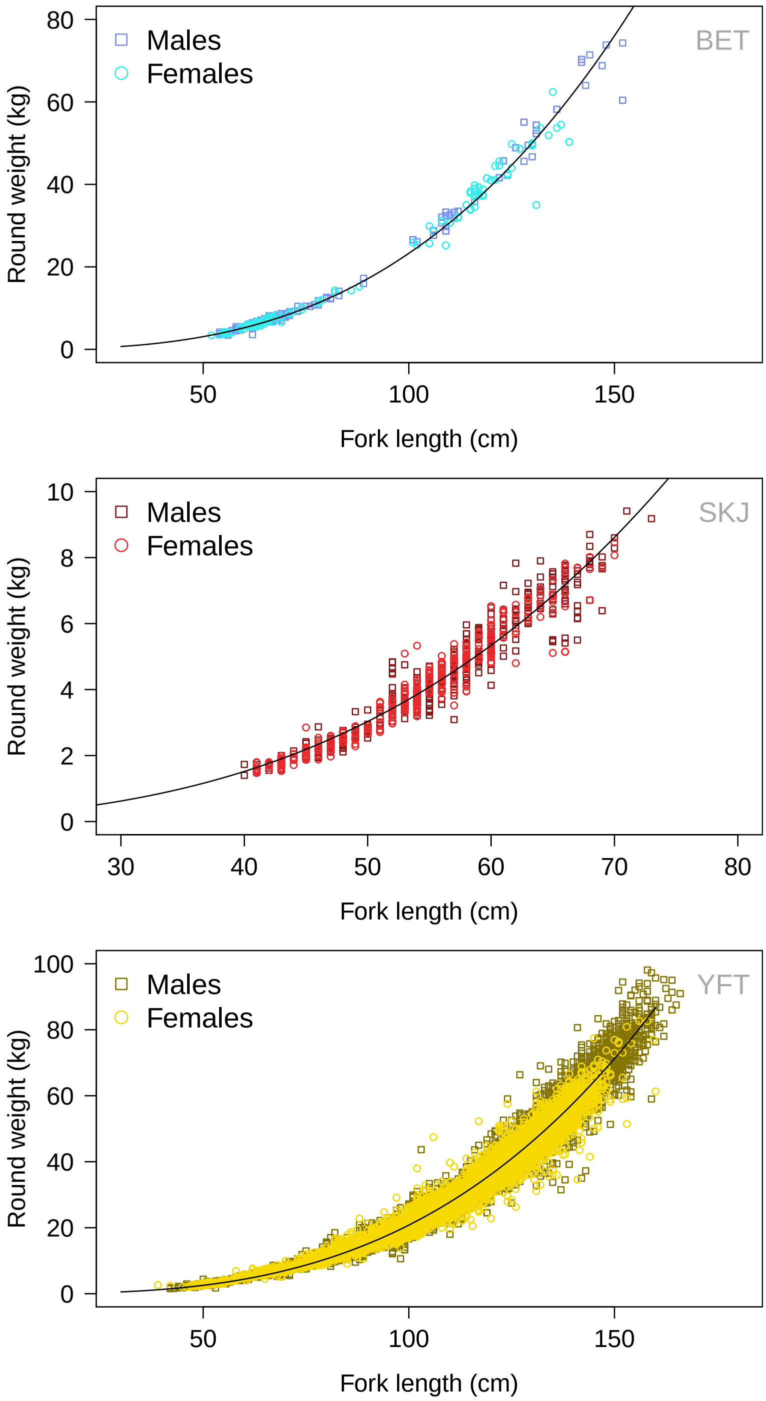

Figure 2: Length-weight data of tunas sampled at the Seychelles cannery during 1987-2014. Solid line indicates fitted regression models

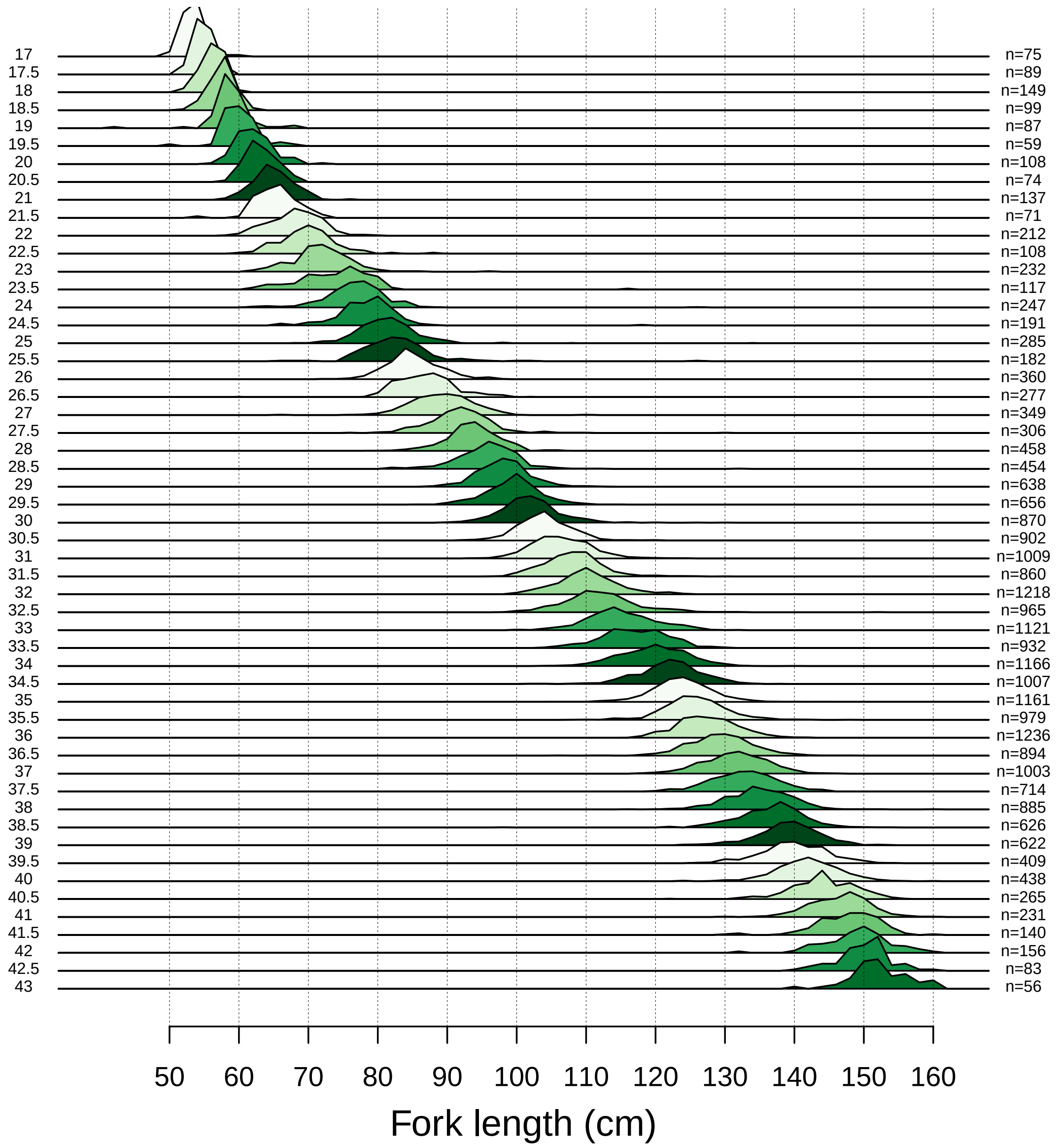

Figure 3: Key between predorsal length (L_{D1}) and fork length (F_L) for YFT based on tunas sampled at the Seychelles cannery during 1987-2014

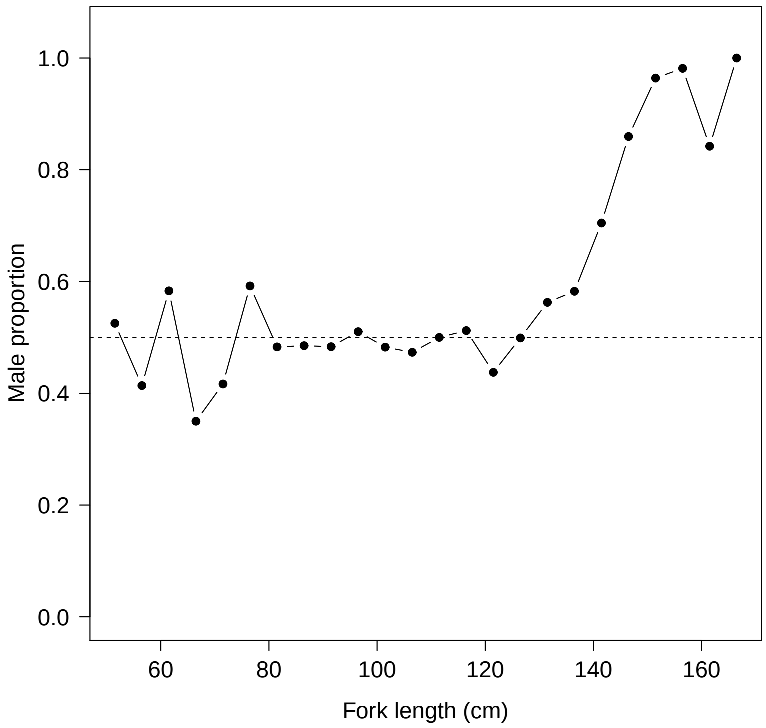

Figure 4: Proportion of males as a function of fork length (F_L) for yellowfin tuna. Fishes were aggregated by 5-cm size classes

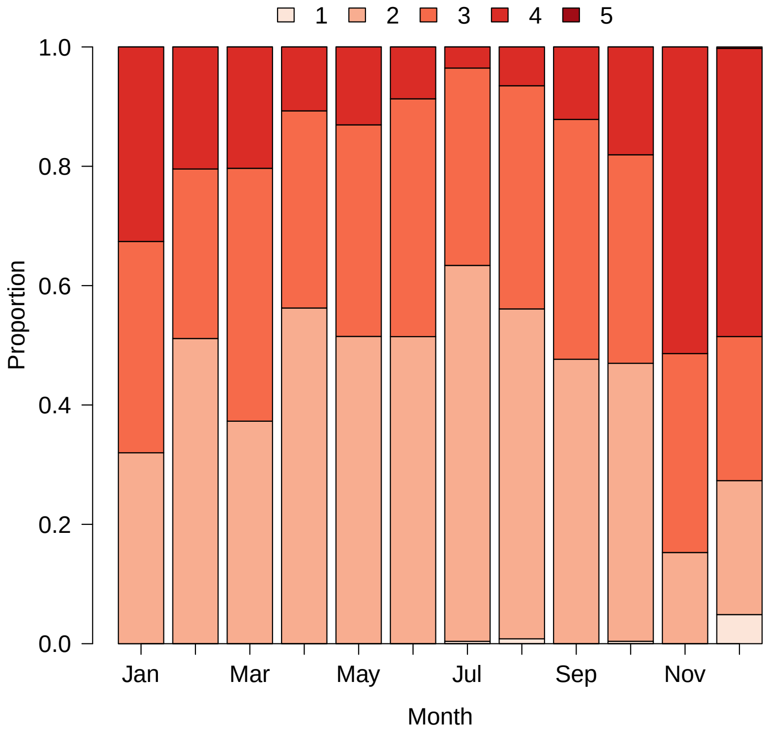

Figure 5: Monthly changes in the proportion of yellowfin females in each maturity stage. All data were aggregated to derive a mean seasonal pattern in the reproductive cycle over 1987-2014. The month corresponds to the month of 'average' date of the fising sets made during the trip

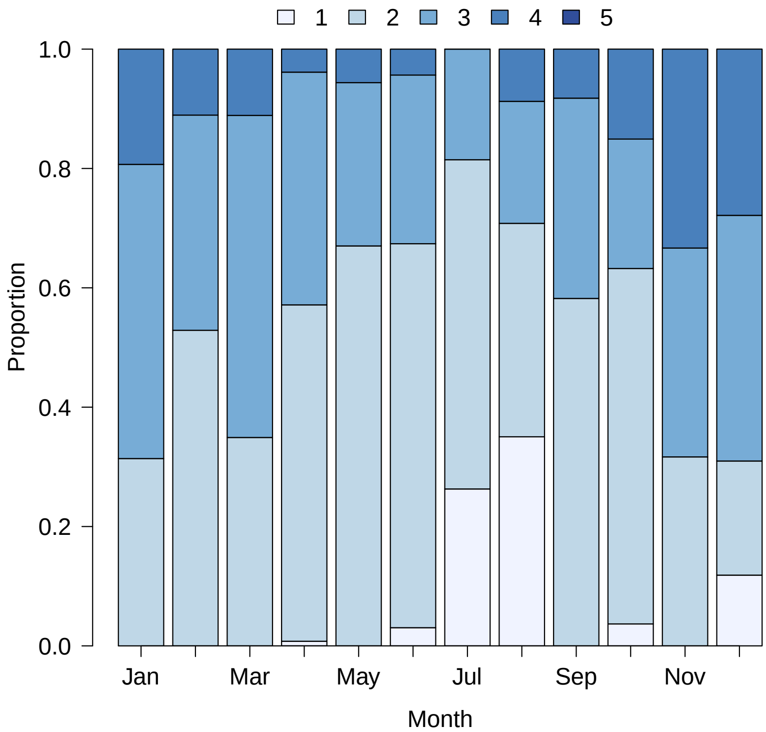

Figure 6: Monthly changes in the proportion of yellowfin males in each maturity stage. All data were aggregated to derive a mean seasonal pattern in the reproductive cycle over 1987-2014. The month corresponds to the month of 'average' date of the fising sets made during the trip

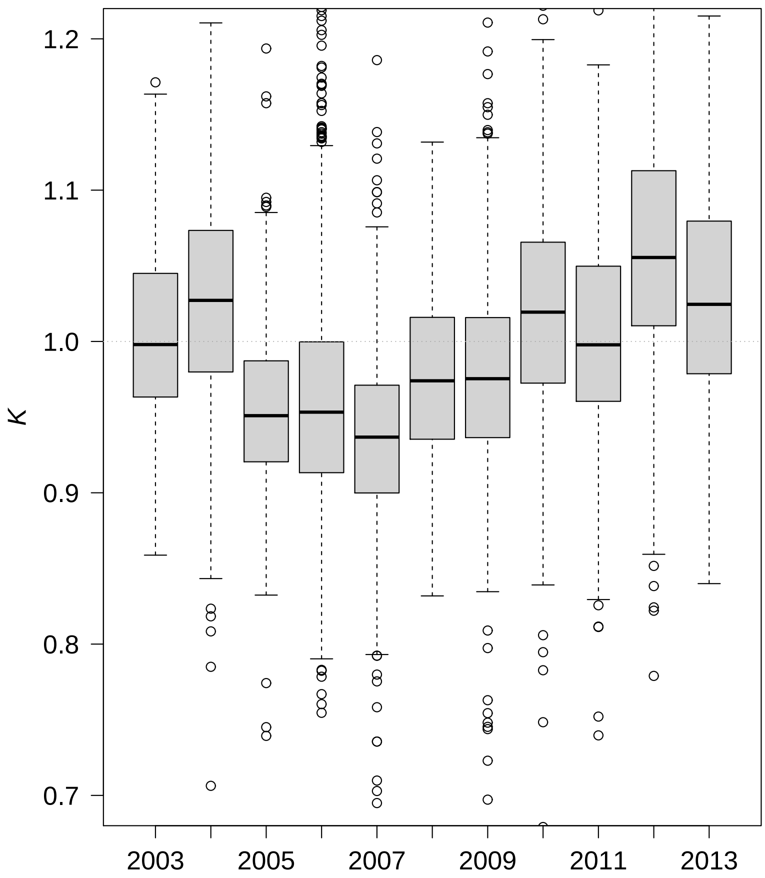

Figure 7: Annual changes in the condition index of large yellowfin females

Appendix 1

Species	1987	1988	1989	1990	1991
BET	23	240	68	625	5
YFT	615	707	481	899	32
SKJ	0	0	0	0	0

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
BET	0	0	0	40	95	31	0	2	0	1	0	241	1371
YFT	311	1152	2413	4512	2227	2924	3712	4186	2874	3615	1635	1046	33341
SKJ	0	0	0	0	0	0	0	0	0	0	0	821	821