An application of length-based assessment methods to Indian Ocean fisheries for yellowfin tuna (*Thunnus albacores*) between 1955 and 2015: implications for sustainable fisheries management

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Abstract

Conventional stock assessment methods require a lot of scientific knowledge and a large quantity of catch and effort data to assess the status of a simple fishery. The Indian Ocean yellowfin tuna (*Thunnus albacores*) fishery is not a simple 'fishery'; it is an assemblage of fisheries. The complexity, uncertainty and data deficiencies inherent in these fisheries makes it is difficult to predict the impact of a fishery on the stock. Five length-based assessment methods were applied to size frequency data for *T. albacores* caught using five fishing methods every five years between 1955 and 2015. The results suggest that different fisheries are likely to have different impacts on the stock. Longline, hand line and trolling lines fisheries most closely corresponded to the target reference points for sustainable fishing. Pole and line and purse seine fisheries generated the least favourable results for all five assessment methods. Equipped with such knowledge fishery managers can formulate locally appropriate harvest control management measures to reduce a fishery's impact on the stock. Extrapolating from the results suggests that 207,170 MT of the *T. albacares* harvested in 2015 (407,573 MT) were immature and only 47,147 MT were caught at optimum length. The annual yield of YFT in 2015 was numerically similar to the IOTC's estimate of MSY (403,000 MT), but given the composition of the catch (*i.e.* 52% immature / 12% optimum length) it is unlikely that this yield was sustainable. The results cast doubt on whether the harvest control management measures proposed by analysts and lobbyists to rebuild the stock and achieve MSY (*i.e.* catch reductions of 5% - 25) will be effective if the assemblage of fisheries that harvest IO YFT remains unchanged.

1. Introduction

Conventional stock assessment methods require a lot of scientific knowledge and a large quantity of catch and effort data to assess the status of a simple - one species, one gear, one vessel, one nation – fishery (FAO UN, 2006). The Indian Ocean (IO) yellowfin tuna (YFT - *Thunnus albacores*) fishery is not a simple fishery. Many types of gear are used to harvest YFT. Gear is operated by a variety of - artisanal, semi-industrial and or industrial – fishing vessels. Vessels operate within exclusive economic zones (EEZ) and or beyond EEZ (BEEZ). Fishermen from more than 30 countries harvest YFT from the IO[1]. The IO YFT fishery is not '*a fishery*'; it is an assemblage of fisheries defined by gear and vessel type, area of operation and fishing nation.

IOTC's stock analysts advise the IOTC on the management of YFT fisheries. In 2018 analysts noted *that the quantified uncertainty in stock status is likely underestimating the underlying uncertainty of the assessment.*

[1] https://iotc.org/about-iotc/structure-commission

The assessors concluded by saying that *the projections shown in Kobe II Strategy Matric results do not adequately reflect known sources of uncertainty due to a series of issues with data and model performance, and should be taken with caution given the issues identified by the Committee* (IOTC, 2018). The availability of data and the quality of the data available is also a concern. In their management advice in 2018, the IOTC's analysts acknowledged that *the assessment results were only based on a grid of 24 Stock Synthesis III model runs which are recognized as insufficient to explore the spectrum of uncertainties and scenarios, noting the large uncertainty associated with data quality (e.g., spatial representativeness of CPUE coverage, estimation of catch and inconsistency in length-frequency) and lack of considering model statistical uncertainty (IOTC, 2018).* The complexity, uncertainty and data deficiencies inherent in IO fisheries for *T. albacares* means that the impact of fishing on the stock is extremely difficult to predict using conventional methods and mathematical models.

In this paper we applied five length-based assessment methods to size frequency data from five IO YFT fisheries every five years between 1955 and 2015. Our immediate objective was not to estimate the status of the stock at five yearly intervals, but to investigate what – *if anything* - these methods could tell fishery managers about the likely impact of these fisheries on the stock? Our longer term objective is to inform decision-making about each fishery and the harvest control management measures necessary to ensure that the impact of fishing on the IO YFT stock is sustainable.

2. Methodology

Length frequency data: Fork length (FL) frequency data collected by CPC and Scientific Observers on behalf of the IOTC's Working Party on Tropical Tunas (WPTT) was downloaded from the IOTC database released on 14th September 2019[2]. Data was extracted every five years between 1955 and 2015 for five YFT fisheries.

1) Handline and trolling line fisheries - *IOTC codes HAND (handline), HATR (handline trolling), HLOF (handline offshore) and HOOK (hook and line)*
2) Pole and line fisheries - *IOTC codes BB (bait boat) and BBOF (bait boat offshore)*
3) Longline fisheries - *IOTC codes FLL (fresh longline), LL (longline), LLCO (longline coastal), LLEX (longline exploratory) and LLOB (longline observer onboard)*
4) Gillnet fisheries - *IOTC codes GILL (gillnet) and GIOFF (gillnet offshore)*
5) Purse seine fisheries - *IOTC codes PS (purse seine), PSOB (purse seine observer onboard) and PSS (purse seine small).*

Assessment methods: Five length-based assessment methods were applied to the data to assess the likely impact of each fishery on the stock

(1) ***Change in average length*** of the catch over time indicates whether the average length of the fished population is constant or increasing. The Target Reference Point (TRP) for sustainable fishing is a constant or increasing trajectory, indicating a positive outcome. A decreasing trajectory indicates a negative outcome (Fairtrade USA, 2014).

(2) ***Percentage of mature fish*** in the catch is a measure of the percentage of fish greater than the average size on first maturity (L_m) in the catch (Froese, 2004). The TRP for sustainability is zero percent (0%) immature fish in the catch, whereby 100% of the population would spawn at least once before they are caught to rebuild and or maintain a healthy spawning stock (Froese, 2004).

[2] https://www.iotc.org/WPTT/21/Data/11-SFYFT

(3) ***Percentage of fish caught at optimum length*** is measured as the percentage of fish caught at optimum length, *i.e.* the length where the number of fish in a given unfished year class multiplied with their mean individual weight is maximum and where thus the maximum yield and revenue can be obtained (Froese, 2004). The TRP for sustainable fishing is for all fish in the catch (100%) to fall within ±10% of optimum length (Froese, 2004).

(4) ***Percentage of mega-spawners*** in the catch is measured as the percentage of old, large fish in the catch *i.e.* fish of a size larger than optimum length + 10% (Froese, 2004). The TRP for sustainable fishing depends on the management regime: the aim is to implement a fishing strategy that results in no (0%) mega-spawners being caught. If no such strategy is in place and thus the catch reflects the age and size structure of the stock, values of 30% - 40% mega-spawners represent a healthy age structure and are desirable, whereas less than 20% will be a matter of concern (Froese, 2004).

(5) **Length-based spawning potential ratio** (*LB-SPR*). Spawning potential ratio (SPR) is the ratio of the fished to the unfished reproductive potential and is a measure of the impact of fishing on the potential productivity of a stock (Goodyear, 1993). The length-based approach to SPR (LB-SPR) uses the length composition of the catch and key life history parameters of the target species to calculate the residual spawning potential (SP) of the exploited stock (Hordyk, A. *et. al* 2015a, 2015b and 2016). The TRP for sustainable fishing is a spawning potential of 30% to 40% (Mace and Sissenwine, 1993)

Average length (av. FL), the percentage of mature fish in the catch (% > L_m); the percentage of fish caught at optimum length (% L_{opt} +/- 10%) and the percentage of mega-spawners (M-S) in the catch (% > L_{opt} + 10%) were calculated using Microsoft Excel. The LB-SPR of YFT aggregations targeted by each fishery was calculated using an application in the Barefoot Ecologist's Toolbox[3]

Life history parameters: Eight life history parameters (LHP) *i.e.* maximum length (L_{max}), asymptotic length (L_{inf}), length on first maturity (L_m), length on 50% maturity (L_{m50}), length on 95% maturity (L_{m95})., natural mortality (M) and growth (K) were required to run one or more of the five assessment methods

LHP estimates were extracted from a global study of scombrid life histories by Juan-Jordá *et al* (2013) and other published studies. A soft copy of the global scombrid life histories database was kindly made available by the author (Juan-Jordá *et al* 2016). No values were available in the literature describing L_{m95}. Values for L_{m95} were calculated based on the relationship $L_{m95} = L_{m50} + (L_{m50} \times .1)$[4]. A formula in Microsoft Excel (L_{opt} =3/(3+B1)*B3) was used to calculate the length at which the total biomass of a year-class reaches a maximum value (L_{opt}). The formula is based on the equation $L_{opt}=3L_{inf}(3+MK^{-1})^{-1}$ after Beverton (1992)[5].

[3] http://barefootecologist.com.au/
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3. Results

Life history parameters: Four sets of average values for each LHP were calculated using values in the literature. The first set of average values was based on estimates from all studies conducted in three major ocean basins *i.e.* the Atlantic Ocean (AO), Indian Ocean (IO) and Pacific Ocean (PO) (C1 in Table 1). The second set of values was derived from the same studies, edited to exclude 'improbable' estimates of L_{inf} and L_{max} (C2 in Table 1).

One estimate of L_{inf} (272.7 cm see Stícquert 1996 in Juan-Jordá *et a*l 2016) was excluded for being greater than the probable $L_{inf} \approx L_{max}$ /0.95; based on the rule of thumb suggested by Pauly (1984*a*) where L_{max} = 239 cm (FishBase) in all oceans. Six estimates of L_{max} (92 cm to 126 cm) were excluded for being either less than the estimated average value for L_{m50} or less than the average value for L_{opt} +10% in all oceans.

A third set of LHP was calculated using only estimates from the IO (C3 in Table 1). The fourth set of key LHP was derived from the same studies, edited to exclude 'improbable' estimates of L_{inf} and L_{max} (C4 in Table 1). Four estimates of L_{inf} (197 cm - 273 cm) were excluded for being greater than the probable $L_{inf} \approx L_{max}$ /0.95 (Pauly 1984*a*), where L_{max} = 186 cm in the IO (see Rohit *et al* 2012 in in Juan-Jordá *et al* 2016). One estimate of L_{max} (125 cm) was excluded for being less than the estimated average value for L_{opt} +10% in the IO.

L_{max} ranged from 161 cm (all oceans / 61 studies) to 165 cm (IO - edited / 18 studies). L_{inf} ranged from 177 cm (IO - edited / 05 studies) to 195 cm (IO / 49 studies). L_m, L_{m50}, and L_{m95} were estimated to be 82 cm, 104 cm and 115 cm in all oceans (23 studies) compared to 92 cm, 110 cm and 121 cm in the IO (11 studies). Only three estimates of M have been published for YFT in the all oceans, one of which was in the IO. The average value of M in all oceans was 0.62 compared to 0.48 in the IO. The average value for K in all oceans was 0.44 (48 studies) compared to 0.33 for IO (09 studies). The value of M/K calculated using the average estimates of M and K in all oceans was 1.39 compared to 1.48 for the IO. The average M/K ratio derived from three studies in all oceans was 1.29. No studies have been published estimating the ratio of M/K in the IO. Average values for L_{opt} ranged from 119 cm (IO - edited) to 130 cm (IO). The corresponding optimum size range (+/- 10%) ranged from 131 cm (IO - edited) to 143 cm (IO).

The average LHP calculated from studies in all oceans, edited to remove 'improbable' estimates (C2 in Table 1) together with the estimated value of M/K calculated from the ratio of published estimates of M and K (1.39) were judged by the authors to be the 'best fit' of the four sets of possible average LHP. The LHP values in C2 (Table 1) were used to generate the results presented in Tables 2 and 3 and Figures 1 to 11, described below.

Change in average length (∆ FL): The average length of YFT caught by handline and trolling line fisheries increased from a very small size in the 1980s (≈ 50 cm) to ≈ 115 cm between 2005 and 2015. The trajectory of average length of YFT caught using handline and trolling line was positive after 2010 (Figure 1). The average length of fish harvested by pole and line fisheries declined from 52.67 cm in 1985 to 46.15 cm in 2015. The trajectory of average length was negative for pole and line catch YFT after 2005. The average length of YFT harvested by longline fisheries was constant between 1965 and 1990. Since 2000 the average length of YFT caught using longline has increased. The trajectory of change in average length for fish harvested by gillnet fisheries was positive after 2000 (69.98 cm), increasing to 80.31 cm in 2015. The trend in average length of YFT harvested by purse seine fisheries was negative after 2005 (72.07 cm); declining to 59.63 cm in 2015.

Handline and trolling line fisheries: No mature fish, no YFT caught at optimum length and no mega-spawners were observed in the handline and trolling line catch in the 1980s. The SP of YFT aggregations targeted by handline and trolling line was zero in the 1980s (Figure 2). In 2005 the percentage of mature fish in the handline and trolling line catch increased to more than 70% and more than half the catch was harvested at the optimum length (55%). However by 2015 the percentage of YFT caught at optimum length had decreased to 24%. At the same time, the percentage of mega-spawners in the catch increased from 10% in 2005 to 50% by 2015 (Figure 2 and 3). The SP of aggregations of YF targeted by handline and trolling lines fisheries in 2015 was 53% (Figure 2).

Pole and line fisheries: Mature fish were rarely caught (12%) or absent entirely (0%) in the pole and line catch after 1995 (Figure 4). After 2005 only three percent (3%) of YFT harvested using pole and line were mature. Less than 2% of the pole and line catch was harvested at optimum length between 1995 and 2015. Mega-spawners were rarely seen in the pole and line catch between 1985 and 2005 (maximum 0.7%). No mega-spawners were observed in the pole and line catch in 2015 (Figure 5). The maximum SP of YFT aggregations targeted by pole and line fisheries was 7% in 1990. Since 2000, the SP of YFT aggregations targeted by pole and line fisheries was zero (Figure 4).

Longline fisheries: The percentage of mature fish in the longline catch remained above 84% between 1955 and 2015 (Figure 6). Since 2005 the percentage of mature YFT caught using longline remained at or above 95%. The percentage of fish harvested at optimum length by longline fisheries fluctuated around 50% between 1955 and 2015, ranging from 32% in 1995 to 75% in 2005. 50% of the fish harvested using longline in 1955 were mega-spawners. This value fell to 9% in 1965 before increasing to 27% in 1975 and averaging 20% thereafter. Since 2005 the percentage of mega-spawners in the catch from the longline fishery increased steadily, reaching 34% in 2015 (Figure 6 and 7). YFT aggregations targeted by longline fisheries had an average SP of 28% between 1955 and 2015, ranging from 22% in 2005 to 37% in 2015 (Figure 6).

Gillnet fisheries: The percentage of mature fish in gillnet fisheries peaked at 48% in 1995 before declining to 14% in 2000 (Figure 8). The percentage of mature fish harvested using gillnet increased from 15% in 2000 to 38% in 2015. The highest percentage of fish harvested at optimum length using gillnet was 20% in 1995. The percentage of optimum sized fish in the gillnet catch declined to 3% by 2015. Mega-spawners were rarely harvested using gillnet (maximum 3% in 1995). 0.3% of the fish caught by gillnet fisheries were mega-spawners in 2015 (Figure 8 and 9). The SP of YFT aggregations targeted by gillnet fisheries did not exceeded 10% between 1975 and 2015 (Figure 8).

Purse seine fisheries: The percentage of mature YFT harvested by purse seine fisheries also peaked in 1995 (33%), then declined steady to its lowest value of 8% in 2010 (Figure 10). Only 12% of the fish harvested by purse seine fisheries were mature in 2015. The percentage of fish caught at optimum length in the purse seine catch declined to 5% by 2015. Mega-spawners were rarely harvested using purse seine (maximum 7% in 1985). Only 2% of the fish harvested using purse seine were mega-spawners in 2015 (Figure 10 and 11). The SP of YFT aggregations targeted by purse seine fisheries did not exceed 15% between 1985 and 2015 (Figure 10).

The application of length-based assessment methods to Indian Ocean fisheries for T. *albacores* between 1955 and 2015 using size frequency data published by the IOTC and estimates of life history parameters available in the literature was completed in about a month at nominal cost. A summary of the results for each fishery against the TRP for each assessment method is presented in Table 2.

4. Discussion

Length-based assessment methods

Length frequency data for IO YFT harvested by longline fisheries most closely corresponded with the TRPs for sustainable fishing prescribed by Fairtrade (2014), Froese (2004) and Mace and Sissenwine (1993). The average length of fish harvested using longline (≈ 120 cm) increased after 2000 and was well above L_m for the past 60 years. The percentage of mature fish in the catch fluctuated around 90% during the same period (TRP = 100%). Half the YFT caught by longline fisheries were harvested at optimum length (TRP 100%). The percentage of mega-spawners in the catch and the SP of the aggregations targeted by longline fisheries increased from 12% and 34% in 2005 to 22% and 37% in 2015 respectively.

The Length frequency data for YFT caught by handline and trolling line fisheries also corresponded reasonable well with TRPs for change in average length (*positive trajectory*), percentage of mature fish in the catch *(≈ 80%*) and percentage of YFT caught at optimum length *(≈ 35%*) after 2005. The percentage of mega-spawners and the SP of YFT aggregations targeted by handline and trolling line fisheries increased from 10% and 20% in 2005 to 50% and 53% in 2015 respectively.

The Length frequency data for YFT harvested by pole and line fisheries generated the least favourable results for all five length-based assessment methods. The average length of fish harvested by pole and line fisheries decreased from 52.67 cm in 1985 to 46.15 cm in 2015. The average length of YFT caught using pole and line over the last 35 years (≈ 46 cm) was considerable lower than L_m. Less than 5% of the YFT caught by pole and line fisheries were mature after 1995 and few if any YFT were harvested at optimum length. Mega-spawners were absent from the pole and line catch after 2005. The SP of YFT aggregations targeted by pole and line fisheries was zero after 1995.

The average length of YFT harvested by IO purse seine fisheries declined (*negative trajectory*) from 72.07 cm in 2005 to 59.63 cm in 2015. The average length of fish harvested using purse seine since 1985 (≈ 60 cm) was less than $L_{m.}$ The percentage of mature fish harvested by purse seine fisheries also declined after 2005, from 27% to 12% in 2015. Only 5% of YFT caught by purse seine fisheries were harvested at optimum length. Very few mega-spawners were present in the purse seine catch in 2015 (2%). The SP of YFT aggregations targeted by purse seine fisheries was 1% in 2015.

The length frequency data for YFT harvested by gillnet fisheries generated results between those for longline, handline and trolling line fisheries and pole and line and purse seine fisheries. The average length of fish caught using gillnet was less than L_m, but increased from 67.21 cm in 1975 to 80.31 cm in 2015. The percentage of mature YFT in the catch was 38% in 2015, but only 8% were caught at optimum length. Very few mega-spawners were harvested using gillnets (0.3%). The SP of YFT aggregations targeted by gillnet fisheries was 1%.

A yield or the maximum sustainable yield?

The on-going debate between the IOTC and environmental lobbyists (BET, 2019; GTA, 2020) about the status of IO YFT stock revolves almost exclusively around the yield in 2017 (409,567 mt) compared to the estimated maximum sustainable yield (MSY = 403,000 mt); and the degree to which the stock is *overfished* and subject to *overfishing (*IOTC, 2018, IOTC, 2018a). Neither the IOTC nor lobbyists have taken into account what is being caught, as opposed to how much.

407,573 mt of YFT were caught in 2015 (IOTC 2018b). 25% of the total catch was caught by handlines and trolling lines, 4% by pole and lines, 18% by longlines, 17% by gillnet s and 35% by purse seines (IOTC 2018b and see Table 3).

Extrapolating from the results generated by the application of five length-based assessment methods to these fisheries suggests that more than half the YFT caught in 2015 were immature (207,170 MT) and only 47,146 MT of the total catch was harvested at optimum length. The annual yield of 407,573 mt of YFT in 2015 was numerically similar to the IOTC's estimate of MSY (403,000 MT), but the composition of the catch (*i.e.* 52% immature / 12% optimum length) suggests that this yield was not sustainable.

5. Conclusion

Length-based assessment methods proposed by Fairtrade USA (2014), Froese (2004) and Hordyck (2015a, 2015b and 2016) are relatively easy, quick and low or 'no-cost' to use. Length frequency data is simple and cheap to collect from a fishery. New length data is collected and published annually by the IOTC for all IO fisheries. Sufficient research has been published to inform (*and dispute*) estimates of LHPs for IO YFT. However more research into the basic biology (*i.e.* growth, mortality, maturity) of IO YFT is necessary, before LHPs can be generated from studies conducted exclusively on the IO stock.

Length-based assessment methods generate immediate insights into the likely impact of a fishery on the IO YFT stock. These insights can be used by fishery managers to formulate and implement appropriate harvest control management measures to ensure that the impact of each national YFT fishery on the IO stock is likely to be sustainable. The results suggest that different fisheries have different impacts on the YFT stock. The immediate insights generated by these length-based assessment methods question whether the gear-wise catch reductions of 5% to 25% proposed by IOTC (IOTC, 2018b) and by lobbyists (BMF, 2019; GTA 2020) to rebuild the YFT stock and achieve MSY (*i.e.* catch reductions of 5% - 25) will be effective, if the assemblage of fisheries that harvest IO YFT remains unchanged

Stepping down from the regional IOTC level to the national level, then down again to the level of a local fishery; limiting the number of variables to one (length); using a handful of relatively easy to estimate LHPs, then looking for patterns among the results does not lessen the complexity of the IO YFT 'fishery'. But what it will do is enable across the region fishery managers to better understand and manage the complexity, uncertainty and data deficiencies inherent in their local / national fisheries enabling them to mitigate the negative impacts these fisheries may have on the IO YFT stock. The status of the YFT stock at the regional level will only begin to improve when effective harvest control management measures are implemented at the local / national level.

As the debate over the status of the IO YFT stock goes on, four years after the stock was assessed and two years after the results were announced, IOTC analysts and lobbyists are increasingly guilty of missing the wood for the trees. Analysts by building ever more elaborate mathematical models to simulate the complexities – ecological, biological, economic and social – of YFT fisheries' impacts on the IO stock; lobbyist for failing to question whether increasing mathematical complexity is an appropriate response to the unpredictability and uncertainty inherent in the multi-gear, multi-vessel, multi-nation fisheries that harvest YFT within and beyond IO EEZs? While the debate meanders on, thousands of vessels crewed by tens of thousands of fishermen continue to harvest hundreds of thousands of metric tonnes of YFT, by means of an assemblage of fisheries that appears to be detrimental to the present and future status of the IO YFT stock.

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Tables

LHPs	**Atlantic / Indian / Pacific Oceans**					**Indian Ocean**				
	C1	**Studies**		**C2**	Studies	**C3**	**Studies**		**C4**	**Studies**
L_{max}	161 cm	61		**165** cm	55	163 cm	19		165 cm	18
L_{inf}	185 cm	49		**183** cm	48	195 cm	9		177 cm	5
L_m	82 cm	23		**82** cm	23	92 cm	11		92 cm	11
L_{m50}	104 cm	23		**104** cm	23	110 cm	10		110 cm	10
L_{m95}	115 cm	0		**115** cm	0	121 cm	0		121 cm	0
M	0.62	3		**0.62**	3	0.48	1		0.48	1
K	0.44	48		**0.44**	48	0.33	9		0.33	9
M/K	1.39			**1.39**		1.48			1.48	
M/K	1.26	3		**1.26**	3	-	0		-	0
L_{opt}	126 cm			**125** cm		130 cm			119 cm	
-10%	113 cm			**112** cm		117 cm			107 cm	
+10%	139 cm			**137** cm		143 cm			131 cm	

Table 1 Average values for YFT LHP estimated from studies conducted in the Atlantic, Indian and Pacific oceans

Fisheries	**Δ av. L**	**% > L_m**	**% L_{opt}**	**% M-S**	**LB-SP**
	2000 - 2015	2015	2015	2015	2015
Handline and trolling	Increasing	83.3%	24.3%	49.6%	53.0%
Pole and line	Decreasing	0.2%	0.1%	0.0%	0.0%
Longline	Increasing	94.9%	49.8%	33.9%	37.0%
Gillnet	Increasing	38.2%	2.9%	0.3%	1.0%
Purse seine	Decreasing	12.5%	5.1%	2.2%	1.0%
TRP	**Constant / Increasing**	**100%**	**100%**	**30 – 40%**	**30%**

Table 2 Summary of the results for each fishery and TRPs for each fishery assessment method

Fisheries	Total[6]			< L_m			L_{opt}	
	%	mt		%	mt		%	mt
Handline & trolling	25%	103,721		17%	17,633		23.0%	23,856
Pole & line	4%	17,790		100%	17,790		0.1%	142
Longline	18%	75,132		5%	3,757		50.0%	37,566
Gillnets	16%	67,797		62%	42,034		2.9%	1,953
Purse seine	35%	143,133		88%	125,957		5.2%	7,486
Totals		**407,573**		**51%**	**207,170**		**12%**	**47,147**

Table 3 The likely impacts of five fisheries on the 2015 YFT catch.

Figures

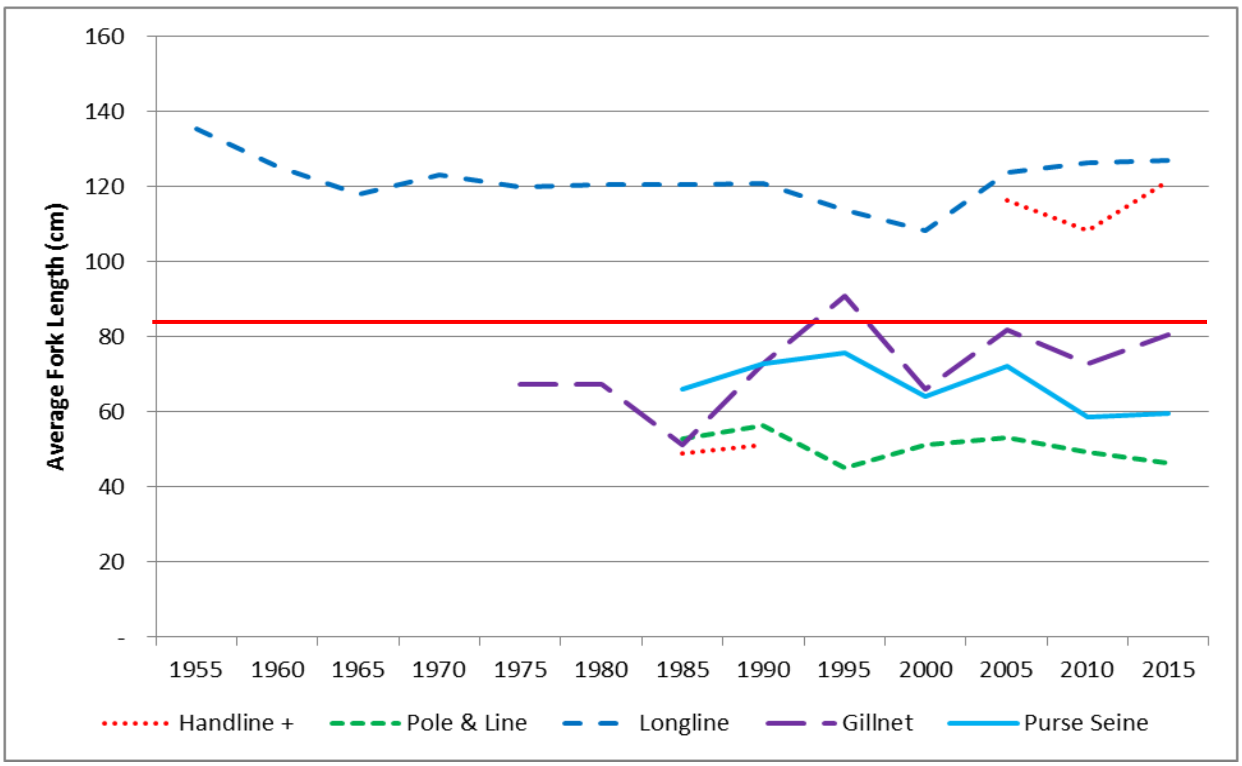

Figure 1 Average fork length (cm) of YFT caught using five fisheries between 1955 and 2015, where L_m = 82 cm (Horizontal Solid Line).

[6] IOTC 2018b

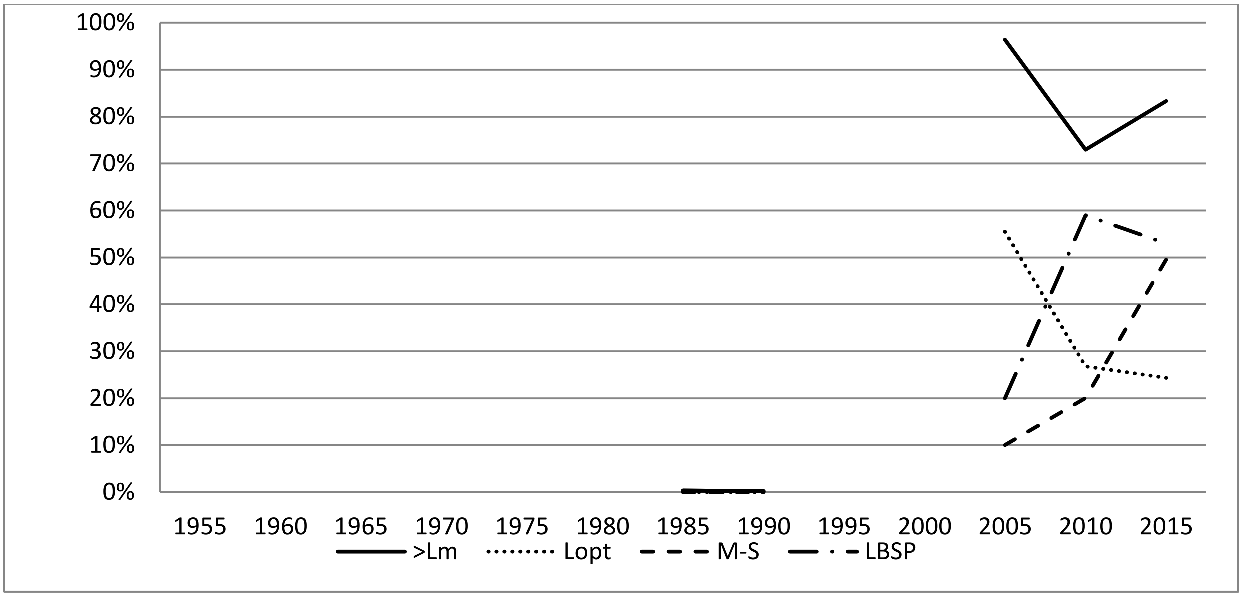

Figure 2 *%>L_m, %L_{opt}, %M-S and LB-SP for YFT caught using handline and trolling line between YFT 1955 and 2015.*

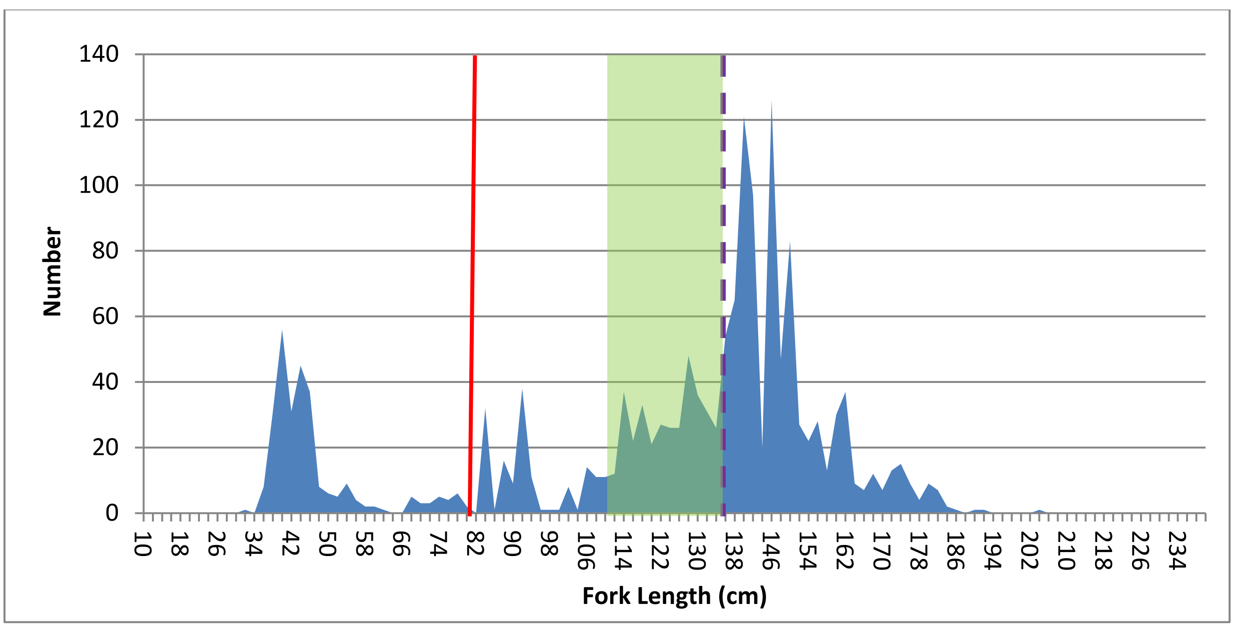

Figure 3 *Size frequency of YFT caught using* ***handline and trolling*** *in 2015 relative to L_m L_{opt} and M-S.*

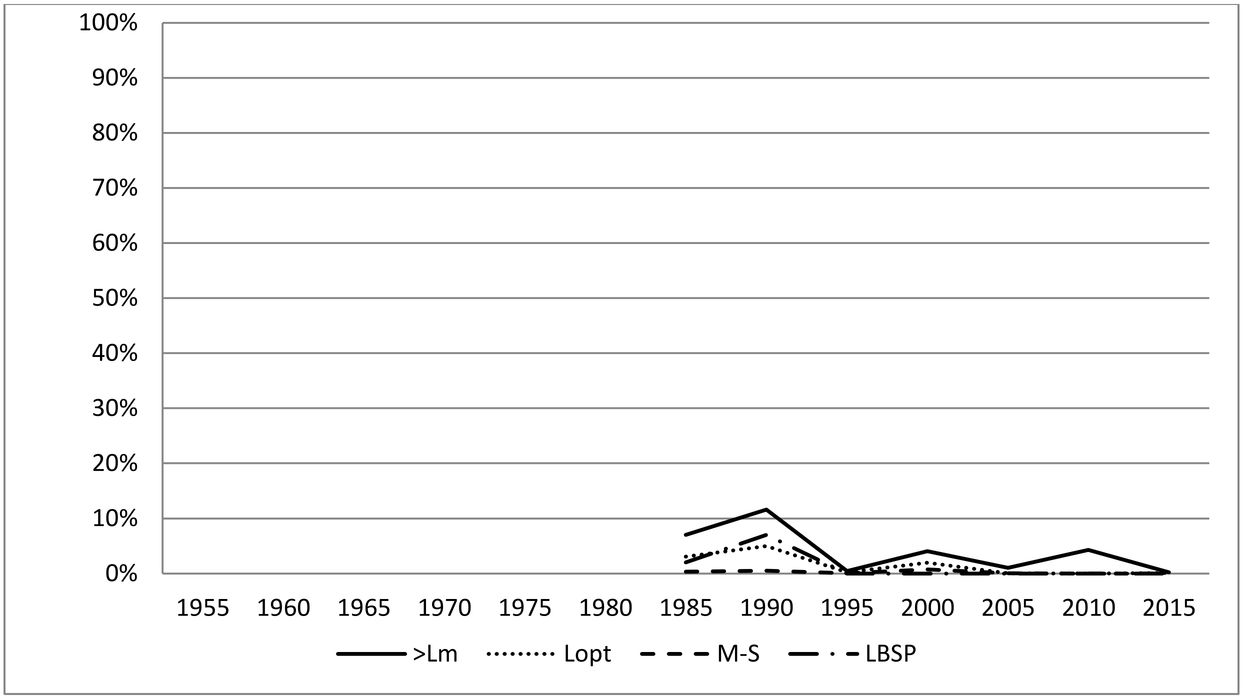

Figure 4 *%>L_m, %L_{opt}, %M-S and LB-SP for YFT caught using pole and line between 1955 and 2015.*

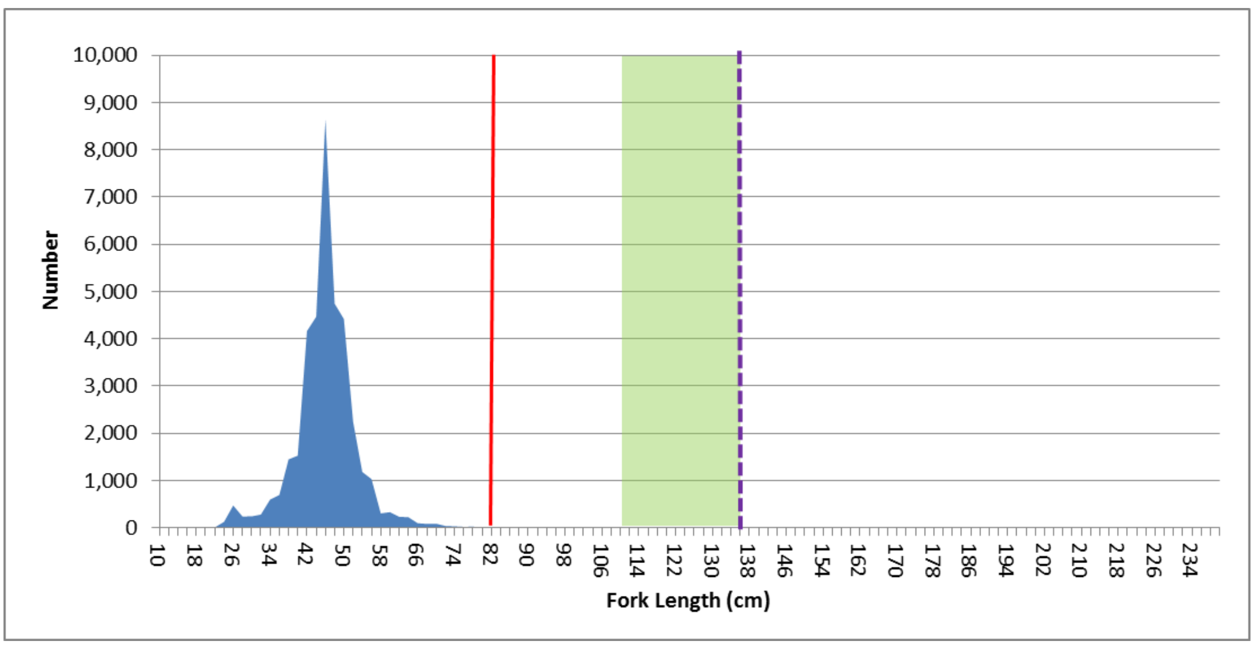

Figure 5 *Size frequency of YFT caught using* ***pole and line*** *in 2015 relative to L_m L_{opt} and M-S.*

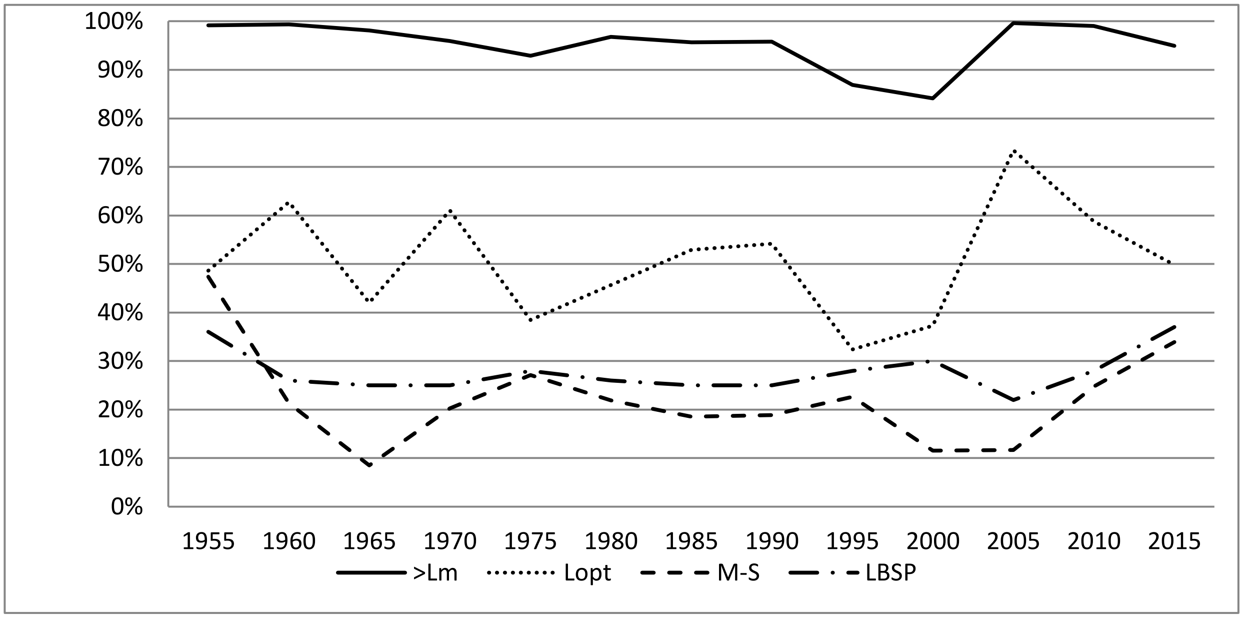

Figure 6 *% > L_m, %L_{opt}, %M-S and LB-SP for YFT caught using longline between 1955and- 2015.*

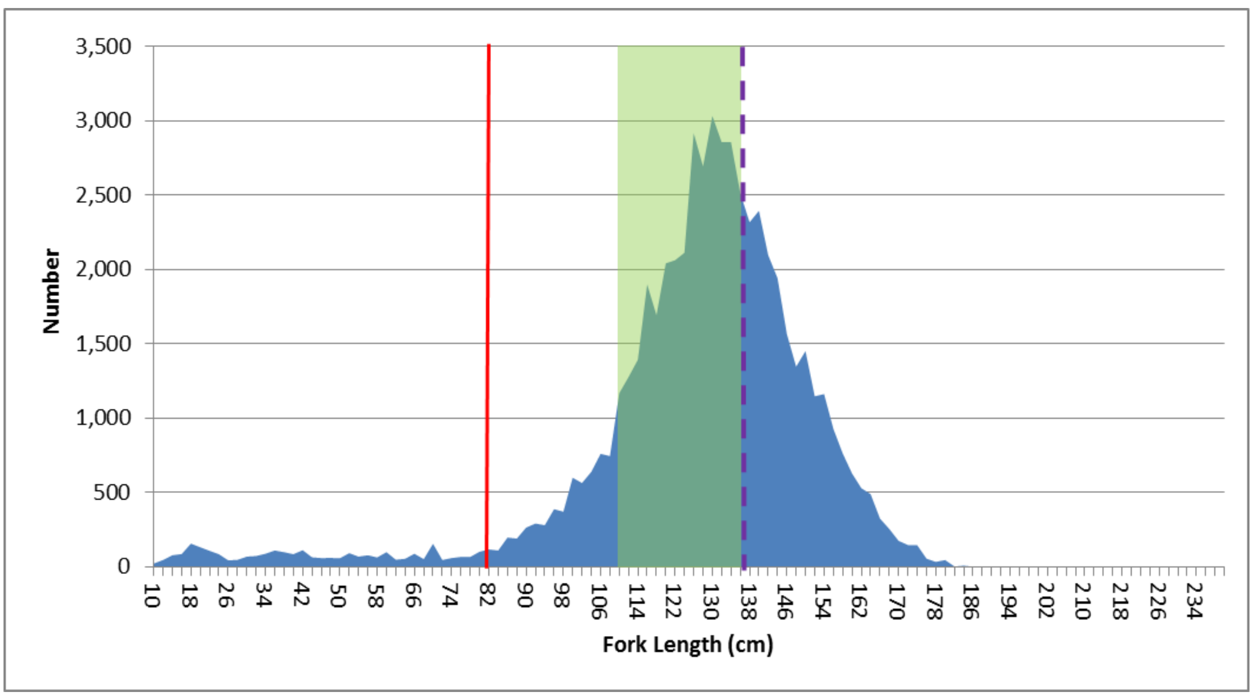

Figure 7 *Size frequency of YFT caught using longline in 2015 relative to L_m L_{opt} and M-S.*

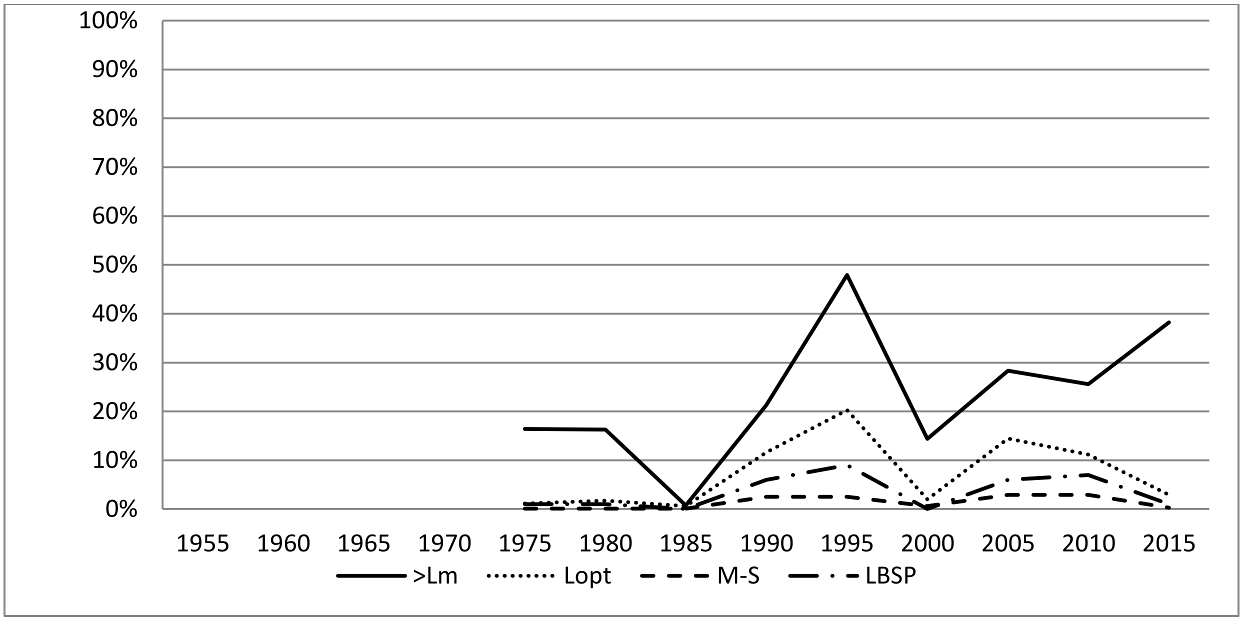

Figure 8 % > L_m, %L_{opt}, %M-S and LBSP for YFT caught using gillnet between 1955 and 2015.

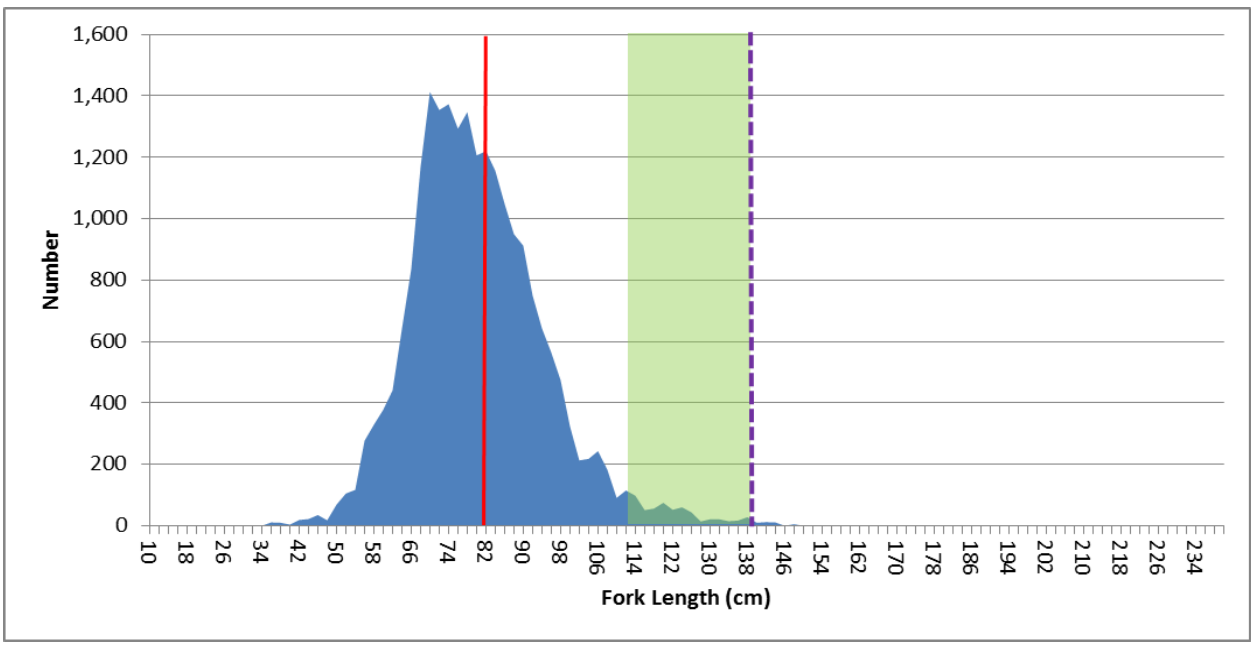

Figure 9 Size frequency of YFT caught using gillnet in 2015 relative to L_m L_{opt} and M-S.

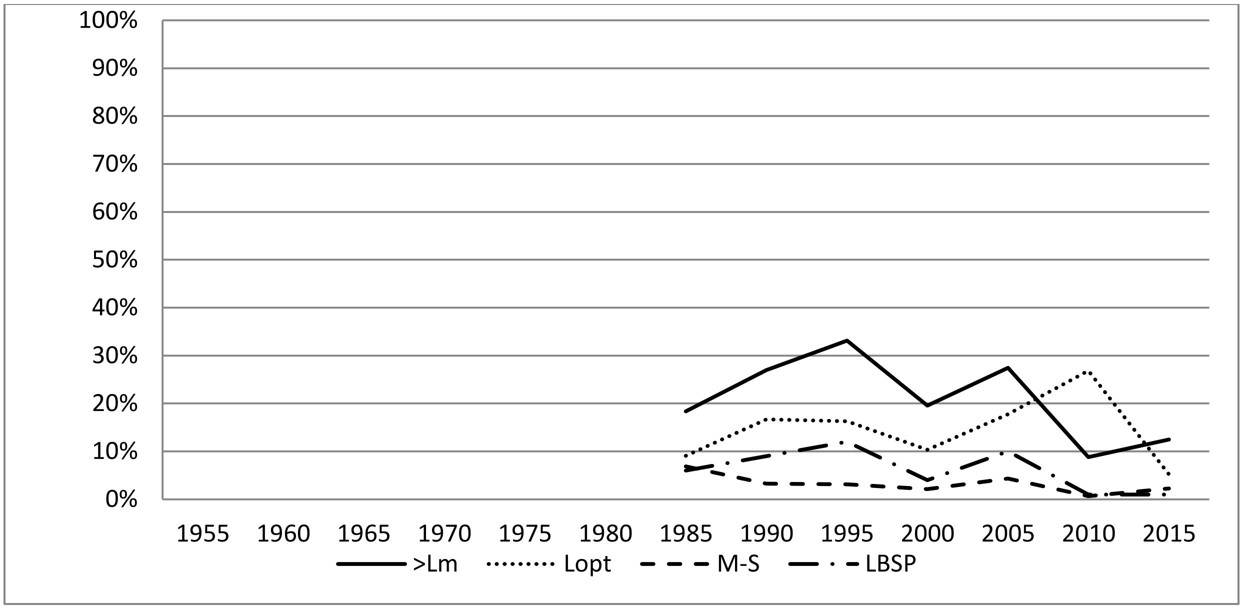

Figure 10 *% > L_m, %L_{opt}, %M-S and LBSP for YFT caught using purse seine 1955 - 2015.*

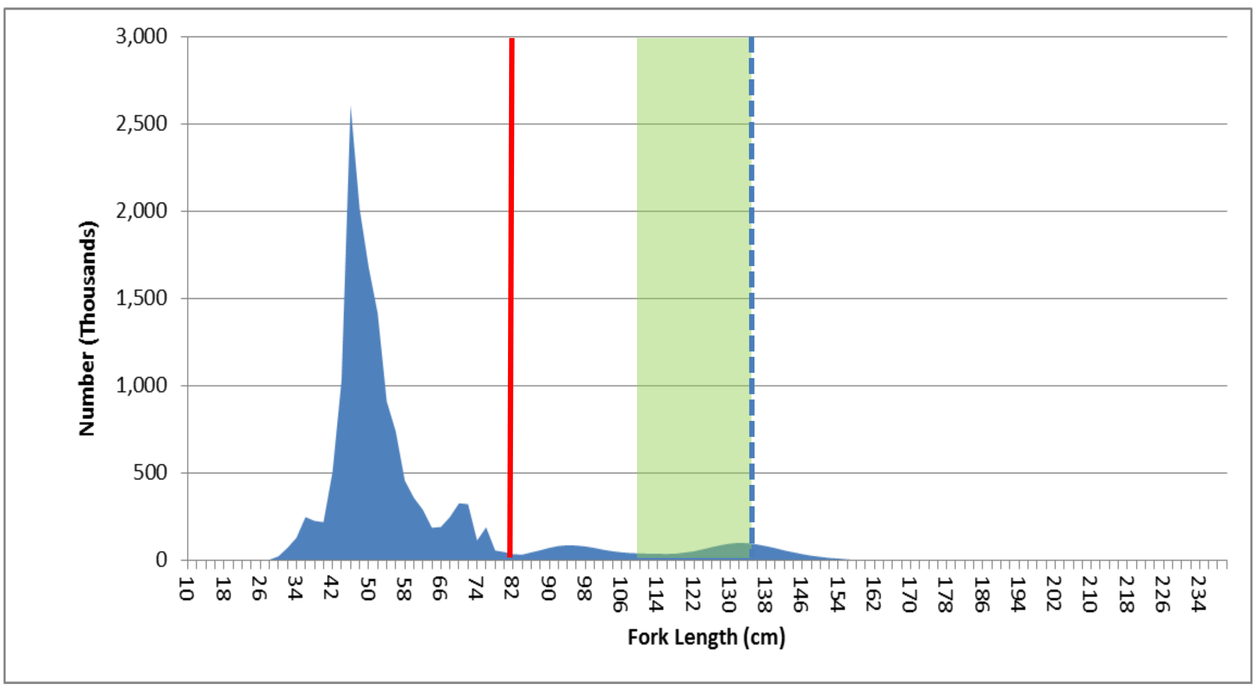

Figure 11 *Size frequency of YFT caught using purse seine in 2015 relative to L_m L_{opt} and M-S.*