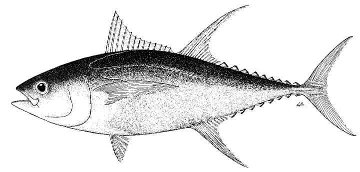
DRAFT EXECUTIVE SUMMARY: YELLOWFIN TUNA

Indian Ocean Tuna Commission
Commission des Thons de l'Océan Indien
iotc ctoi



Status of the Indian Ocean yellowfin tuna (YFT: *Thunnus albacares*) resource

TABLE 1. Yellowfin tuna: Status of yellowfin tuna (*Thunnus albacares*) in the Indian Ocean.

Area[1]	**Indicators**		**2015 stock status determination**
Indian Ocean	Catch 2014: Average catch 2010–2014:	430,327 t 373,824 t	**94%***
	MSY (1000 t) (80% CI): F_{MSY} (80% CI): SB_{MSY} (1,000 t) (80% CI): F_{2014}/F_{MSY} (80% CI): SB_{2014}/SB_{MSY} (80% CI): SB_{2014}/SB_0 (80% CI):	421 (404–439) 0.165 (0.162–0.168) 1,217 (1,165–1,268) 1.34 (1.02–1.67) 0.66 (0.58–0.74) 0.23 (0.21–0.36)	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
*Estimated probability that the stock is in the respective quadrant of the Kobe plot (shown below), derived from the confidence intervals associated with the current stock status.

Colour key	Stock overfished (SB_{year}/SB_{MSY}< 1)	Stock not overfished ($SB_{year}/SB_{MSY}\geq$ 1)
Stock subject to overfishing(F_{year}/F_{MSY}> 1)	**94%**	**0%**
Stock not subject to overfishing ($F_{year}/F_{MSY}\leq$ 1)	**6%**	**0%**
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. In 2015, three models were applied to the yellowfin tuna stock in the IOTC area of competence, a BBPM, SCAA and Stock Synthesis III model, all of which give qualitatively similar results. Stock status is based on the SS3 model formulation. Spawning stock biomass in 2014 was estimated to be 23% (21–36%) of the unfished levels (Table 1) and 66% (58–74%) of the level which can support MSY. The low level of stock biomass in 2014 is consistent with the long-term decline in the primary stock abundance indices (longline CPUE indices) and recent trends are attributable to increased catch levels. Total catch has continued to increase with 430,327 t taken in 2014, up from 407,633 t in 2013 and 400,322 t in 2012, in comparison to 329,184 t landed in 2011, 301,655 in 2010 and 266,848 t landed in 2009. The assessment is more pessimistic that the 2012 assessment due to the increase in catches and the changes in assessment assumptions regarding the recruitment processes. Fishing mortality estimates for 2014 was 34% (2–67%) higher than the corresponding fishing mortality rate that would produce MSY. Thus, on the weight-of-evidence available in 2015, the yellowfin tuna stock is determined to be **overfished** and **subject to overfishing** (Table 1 and Fig. 1).

Outlook. The substantial increase in longline, gillnet, handline and purse seine effort and associated catches in recent years has substantially increased the pressure on the Indian Ocean stock as a whole, with recent fishing mortality exceeding the MSY-related levels. The current assessment estimates that the stock biomass is below the level that will support the MSY and current levels of catch. There is a very high risk of continuing to exceed the biomass MSY-based reference point if catches increase further or are maintained at current levels (2014) until 2017 (>99% risk that $SB_{2017} < SB_{MSY}$), and similarly a very high risk that $F_{2017} > F_{MSY}$ (≈100% if maintained) (Table 2). The modeled probabilities of the stock achieving levels consistent with the Commission's current management objective (e.g. $SB > SB_{MSY}$) are 50% for a future constant catch at 80% of current catch levels by 2024. Higher probabilities of rebuilding require longer timeframes and/or larger reduction of current catches (Table 2). The K2MSM provides the Commission with a range of options for reducing catches and the probabilities of the yellowfin tuna stock recovering to the MSY target levels (Table 2).

Management advice. The stock status determination changed in 2015 as a direct result of the large and unsustainable catches of yellowfin tuna taken over the last three (3) years, and the relatively low recruitment levels estimated by the model in recent years. The Commission does not currently have any Conservation and Management Measures in place, other than the FAD limitation measure (Resolution 15/08, which is yet to be evaluated) to regulate the fisheries for yellowfin tuna. Given the short term projected decline in stock status if catches are maintained or increased from 2014 levels, catches should be reduced in conformity with the decision framework described in Resolution 15/10 (Table 2).

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY):** estimate for the whole Indian Ocean is 421,000 t with a range between 404,000–439,000 t for SS3 (Table 1). The average catches (357,000 t) since 2006 were below the MSY level.
- **Interim reference points**: Noting that the Commission in 2015 agreed to Resolution 15/10 *on target and limit reference points and a decision framework*, the following should be noted:
    - **Fishing mortality**: Current fishing mortality is considered to be well above the interim target reference point of F_{MSY}, and at or just under the interim limit reference point of $1.4*F_{MSY}$ (Fig. 1).
    - **Biomass**: Current spawning biomass is considered to be well below the interim target reference point of SB_{MSY}, however above the interim limit reference point of $0.4*SB_{MSY}$ (Fig. 1).
- **Main fishing gear** (Average catch 2011–14): Purse seine ≈33.8% (FAD associated school ≈21.7%; free swimming school ≈12.1%); Longline ≈18.7% (frozen ≈4.6%, fresh ≈14.1%); Handline ≈18.6%; Gillnet ≈15.1%; Trolling ≈6.8%; Pole-and-line ≈4.9%; ≈Other 2.1%).
- **Main fleets** (Average catch 2011–14): European Union ≈26% (EU,Spain ≈15%; EU,France ≈11%); Maldives ≈11%; Indonesia ≈10%; I.R. Iran ≈9%; Sri Lanka ≈9%; Yemen ≈8%; India ≈8%.

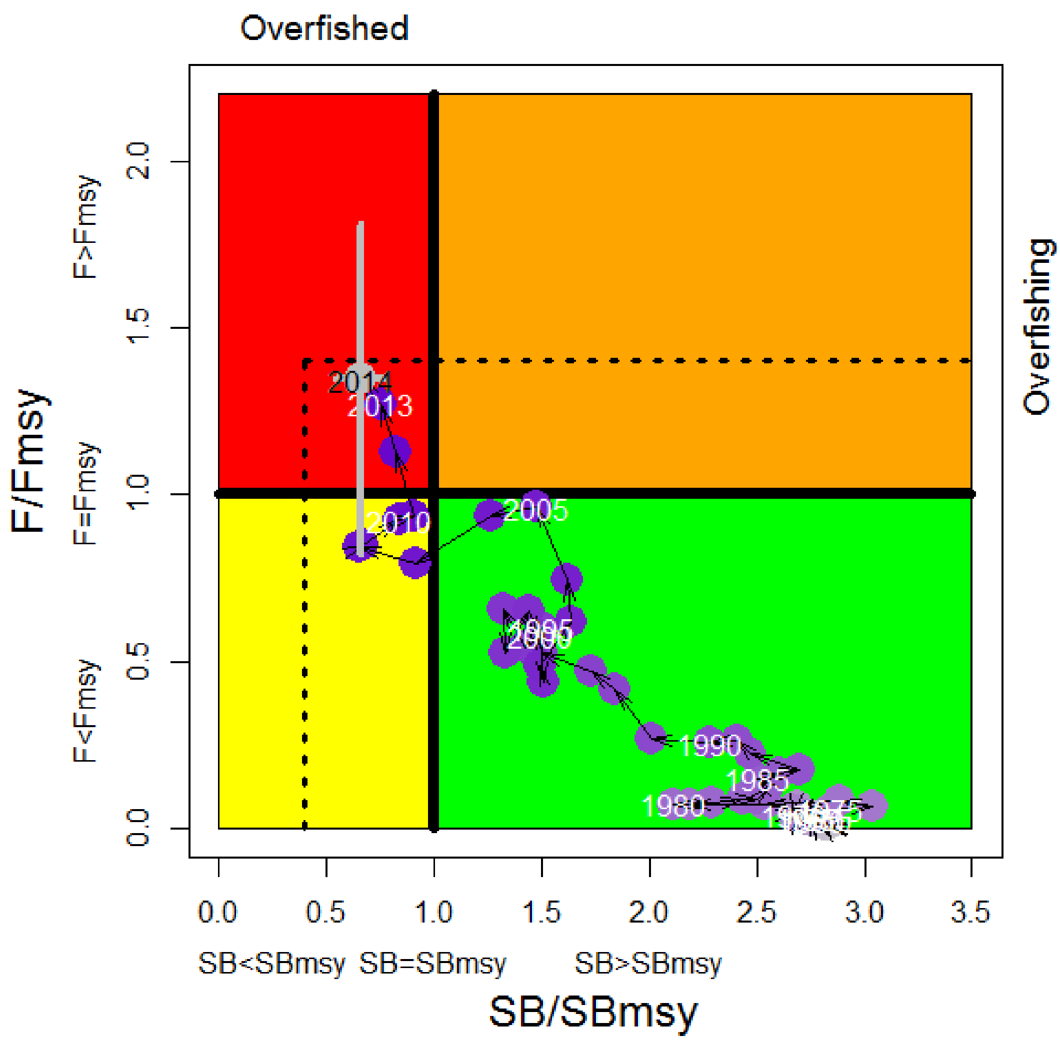


Fig. 1. Yellowfin tuna: SS3 Aggregated Indian Ocean assessment Kobe plot. Blue circles indicate the trajectory of the point estimates for the SB/SB_0 ratio and F proxy ratio for each year 1950–2014 for the base model. The grey lines represent the 95% confidence interval associated with the 2014 stock status. Dotted black lines are the interim limit reference points adopted by the Commission via Resolution 15/10.

Table 2. Yellowfin tuna: SS3 base case aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for nine constant catch projections (average catch level from 2014 (427,440 t), ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2014) and probability (%) of violating MSY-based target reference points ($SB_{targ} = SB_{MSY}$; $F_{targ} = F_{MSY}$)**								
	60% (256,464t)	**70%** (299,208)	**80%** (341,952t)	**90%** (384,696t)	**100%** (427,440t)	**110%** (470,184t)	**120%** (512,928t)	**130%** (555,672t)	**140%** (598,416)
$SB_{2017} < SB_{MSY}$	69	95	91	99	99	100	100	100	100
$F_{2017} > F_{MSY}$	2	54	60	79	100	100	100	100	100
$SB_{2024} < SB_{MSY}$	4	36	50	100	100	100	100	100	100
$F_{2024} > F_{MSY}$	0	22	49	100	100	100	100	100	100
Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2014) and probability (%) of violating MSY-based limit reference points ($SB_{lim} = 0.4\ SB_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	60% (256,464t)	**70%** (299,208)	**80%** (341,952t)	**90%** (384,696t)	**100%** (427,440t)	**110%** (470,184t)	**120%** (512,928t)	**130%** (555,672t)	**140%** (598,416)
$SB_{2017} < SB_{Lim}$	2	15	12	44	33	n.a.	n.a.	n.a.	n.a.
$F_{2017} > F_{Lim}$	0	13	19	70	100	100	100	100	100
$SB_{2024} < SB_{Lim}$	<1	8	15	51	100	100	100	100	100
$F_{2024} > F_{Lim}$	0	2	21	100	100	100	100	100	100

APPENDIX I

SUPPORTING INFORMATION

(Information collated from reports of the Working Party on Tropical Tunas and other sources as cited)

CONSERVATION AND MANAGEMENT MEASURES

Yellowfin tuna (*Thunnus albacares*) in the Indian Ocean is currently subject to a number of Conservation and Management Measures adopted by the Commission:

- Resolution 15/01 *on the recording of catch and effort by fishing vessels in the IOTC area of competence*
- Resolution 15/02 *mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPC's)*
- Resolution 15/06 *On a ban on discards of bigeye tuna, skipjack tuna, yellowfin tuna and a recommendation for non-targeted species caught by purse seine vessels in the IOTC area of competence*
- Resolution 15/10 *On target and limit reference points and a decision framework*
- Resolution 15/11 *on the implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties*
- Resolution 14/02 *for the conservation and management of tropical tunas stocks in the IOTC area of competence*.
- Resolution 14/05 *concerning a record of licensed foreign vessels fishing for IOTC species in the IOTC area of competence and access agreement information*
- Resolution 10/08 *concerning a record of active vessels fishing for tunas and swordfish in the IOTC area*

FISHERIES INDICATORS

Yellowfin tuna: General

Yellowfin tuna *(Thunnus albacares)* is a cosmopolitan species distributed mainly in the tropical and subtropical oceanic waters of the three major oceans, where it forms large schools. **Table 3** outlines some of the key life history traits of yellowfin tuna relevant for management.

TABLE 3. Yellowfin tuna: Biology of Indian Ocean yellowfin tuna (*Thunnus albacares*).

Parameter	Description
Range and stock structure	A cosmopolitan species distributed mainly in the tropical and subtropical oceanic waters of the three major oceans, where it forms large schools. Feeding behaviour has been extensively studied and it is largely opportunistic, with a variety of prey species being consumed, including large concentrations of crustaceans that have occurred recently in the tropical areas and small mesopelagic fishes which are abundant in the Arabian Sea. It has also been observed that large individuals can feed on very small prey, thus increasing the availability of food for this species. Archival tagging of yellowfin tuna has shown that this species can dive very deep (over 1000 m) probably to feed on meso-pelagic prey. Longline catch data indicates that yellowfin tuna are distributed throughout the entire tropical Indian Ocean. The tag recoveries of the RTTP-IO provide evidence of large movements of yellowfin tuna, thus supporting the assumption of a single stock for the Indian Ocean. The average distance travelled by yellowfin between being tagging and recovered is 710 nautical miles, and showing increasing distances as a function of time at sea.
Longevity	9 years
Maturity (50%)	Age: females and males 3–5 years. Size: females and males 100 cm.
Spawning season	Spawning occurs mainly from December to March in the equatorial area (0-10°S), with the main spawning grounds west of 75°E. Secondary spawning grounds exist off Sri Lanka and the Mozambique Channel and in the eastern Indian Ocean off Australia.
Size (length and weight)	Maximum length: 240 cm FL; Maximum weight: 200 kg. Newly recruited fish are primarily caught by the purse seine fishery on floating objects. Males are predominant in the catches of larger fish at sizes than 140 cm (this is also the case in other oceans). The sizes exploited in the Indian Ocean range from 30 cm to 180 cm fork length. Smaller fish (juveniles) form mixed schools with skipjack tuna and juvenile bigeye tuna and are mainly limited to surface tropical waters, while larger fish are found in surface and sub-surface waters. Intermediate age yellowfin tuna are seldom taken in the industrial fisheries, but are abundant in some artisanal fisheries, mainly in the Arabian Sea.

Sources: Froese & Pauly 2009

Yellowfin tuna: Fisheries and main catch trends

- Main fishing gear (2011–14): In recent years catches have been evenly split between industrial and artisanal fisheries. Purse seiners (free and associated schools) and longline fisheries still account for around 50% of total catches, while catches from artisanal gears – namely handline, gillnet, and pole-and-line – have steadily increased since the 1980s (**Table 4**; **Fig. 2**).

  Contrary to other oceans, the artisanal fishery component of yellowfin catches in the Indian Ocean are substantial, accounting for catches of over 200,000 t per annum since 2012. Moreover, the proportion of yellowfin catches from artisanal fisheries has increased from around 30% in 2000 to nearly 50% in recent years.

- Main fleets (and primary gear associated with catches): percentage of total catches (2011–14):
  EU-Spain (purse seine): 15%; Maldives (handline, pole-andline): 11%; EU-France (purse seine): 10%; Indonesia (fresh longline, handline): 10%; I.R. Iran (gillnet): 9% (**Fig. 4**).

- Main fishing areas: Primary: Western Indian Ocean, around Seychelles and waters off Somalia (Area R2), and Mozambique Channel (Area R3) (**Table 5**; **Fig. 3**).

- Retained catch trends:
  Catches of yellowfin tuna remained stable between the mid-1950s and the early-1980s, ranging between 30,000 t and 70,000 t, with longliners and gillnetters the main fisheries. Catches increased rapidly in the early-1980s with the arrival of the purse seiners and increased activity of longliners and other fleets, reaching over 400,000 t by 1993.

  Exceptionally high catches were recorded between 2003 and 2006 – with the highest catches ever recorded in 2004 at over 525,000 t – while catches of bigeye tuna which are generally associated with the same fishing grounds as yellowfin tuna remained at average levels.

  Between 2007 and 2011 catches dropped considerably (around ≈40% compared to 2004) as longline fishing effort in the western Indian Ocean have been displaced eastwards or reduced due to the threat of piracy. Catches by purse seiners also declined over the same period – albeit not to the same extent as longliners – due to the presence of security personnel onboard purse seine vessels of the EU and Seychelles which has enabled fishing operations to continue.

  Since 2012 catches have once again been increasing, with catches over 400,000 t recorded.

  Purse seine fishery:

  Although some Japanese purse seiners have fished in the Indian Ocean since 1977, the purse seine fishery developed rapidly with the arrival of European vessels between 1982 and 1984. Since then, there has been an increasing number of yellowfin tuna caught, with a larger proportion of the catches consisting of adult fish, as opposed to catches of bigeye tuna, which are mostly composed of juvenile fish.

  The purse seine fishery is characterized by the use of two different fishing modes. The fishery on floating objects (FADs) catches large numbers of small yellowfin tuna in association with skipjack tuna and juvenile bigeye tuna, compared to the fishery on free swimming schools, which catches larger yellowfin tuna on multi-specific or mono-specific sets.

  Longline fishery:

  The longline fishery started in the early 1950's and expanded rapidly over throughout the Indian Ocean. The longline fishery targets several tuna species in different parts of the Indian Ocean, with yellowfin tuna and bigeye tuna being the main target species in tropical waters. The longline fishery can be subdivided into a deep-freezing longline component (i.e., large scale deep-freezing longliners operating on the high seas from Japan, Korea and Taiwan,China) and a fresh-tuna longline component (i.e., small to medium scale fresh tuna longliners from Indonesia and Taiwan,China).

- Discard levels: Low, although estimates of discards are unknown for most industrial fisheries, excluding industrial purse seiners flagged in EU countries for the period 2003–07.

  ***Changes to the catch series*:** no major changes to the catch series since the WPTT meeting in 2014.

Table 4. Yellowfin tuna: Best scientific estimates of the catches of yellowfin tuna (*Thunnus albacares*) by gear and main fleets [or type of fishery] by decade (1950–2009) and year (2005–2014), in tonnes. Catches by decade represent the average annual catch, noting that some gears were not used since the beginning of the fishery. Data as of November 2015.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
FS	-	-	18	31,552	64,938	89,204	123,997	85,039	53,527	74,986	36,047	32,136	36,453	64,594	34,457	53,916
LS	-	-	17	17,597	56,278	61,890	69,879	74,601	43,777	41,539	51,351	73,382	76,658	66,165	101,907	95,081
LL	21,990	41,351	29,588	33,968	66,318	56,758	117,341	70,397	51,224	25,937	19,917	18,661	20,550	19,499	16,124	15,675
LF	141	1,214	2,281	7,721	58,525	55,539	57,523	57,139	55,619	58,102	49,883	50,485	43,455	54,643	59,044	63,984
BB	2,110	2,318	5,809	8,295	12,803	16,072	16,822	18,021	16,327	18,279	16,827	14,106	14,009	15,512	24,047	23,598
GI	1,566	4,109	7,928	11,993	39,540	49,393	61,379	62,579	43,510	47,872	41,906	51,121	50,964	63,458	56,570	65,783
HD	558	552	2,956	7,630	19,471	34,768	40,938	34,678	34,636	31,371	28,945	35,003	60,492	79,687	73,923	77,787
TR	1,092	1,957	4,293	7,331	12,271	16,145	17,888	17,371	19,052	16,514	14,611	19,056	18,730	28,550	32,699	26,326
OT	80	193	454	1,871	3,378	5,402	5,829	5,800	6,703	6,556	7,361	7,705	7,872	8,214	8,861	8,176
Total	**27,538**	**51,694**	**53,344**	**127,959**	**333,524**	**385,171**	**511,596**	**425,624**	**324,377**	**321,156**	**266,848**	**301,655**	**329,184**	**400,322**	**407,633**	**430,327**

Gears: Purse seine free-school (**FS**); Purse seine associated school (**LS**); Deep-freezing longline (**LL**); Fresh-tuna longline (**FL**); Pole-and-Line (**BB**); Gillnet (**GI**); Hand line (**HD**); Trolling (**TR**); Other gears nei (**OT**).

Table 5. Yellowfin tuna: Best scientific estimates of the catches of yellowfin tuna (*Thunnus albacares*) by area by decade (1950–2009) and year (2005–2014), in tonnes. Catches by decade represent the average annual catch. The areas are presented in Fig. 20(a). Data as of November 2015.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
R1	1,931	4,395	8,670	8,670	75,066	85,358	130,875	101,328	78,580	72,086	60,230	71,819	103,546	131,944	122,971	135,948
R2	12,259	24,035	22,127	22,127	142,282	180,618	248,558	201,688	123,016	134,759	99,646	115,041	121,442	145,391	155,526	179,964
R3	724	7,449	4,282	4,282	21,818	23,626	24,353	23,836	23,568	19,925	18,542	18,195	18,911	17,059	20,830	10,127
R4	918	1,799	1,356	1,356	3,414	2,508	3,697	1,904	1,027	587	895	1,406	530	601	859	529
R5	11,706	14,016	16,909	16,909	90,944	93,060	104,113	96,868	98,186	93,799	87,536	95,194	84,754	105,327	107,448	103,759
Total	**27,538**	**51,694**	**53,344**	**53,344**	**333,524**	**385,171**	**511,596**	**425,624**	**324,377**	**321,156**	**266,848**	**301,655**	**329,184**	**400,322**	**407,633**	**430,327**

Areas: Arabian Sea (**R1**); Off Somalia (**R2**); Mozambique Channel including southern (**R3**); South Indian Ocean including southern (**R4**); East Indian Ocean including Bay of Bengal (**R5**).

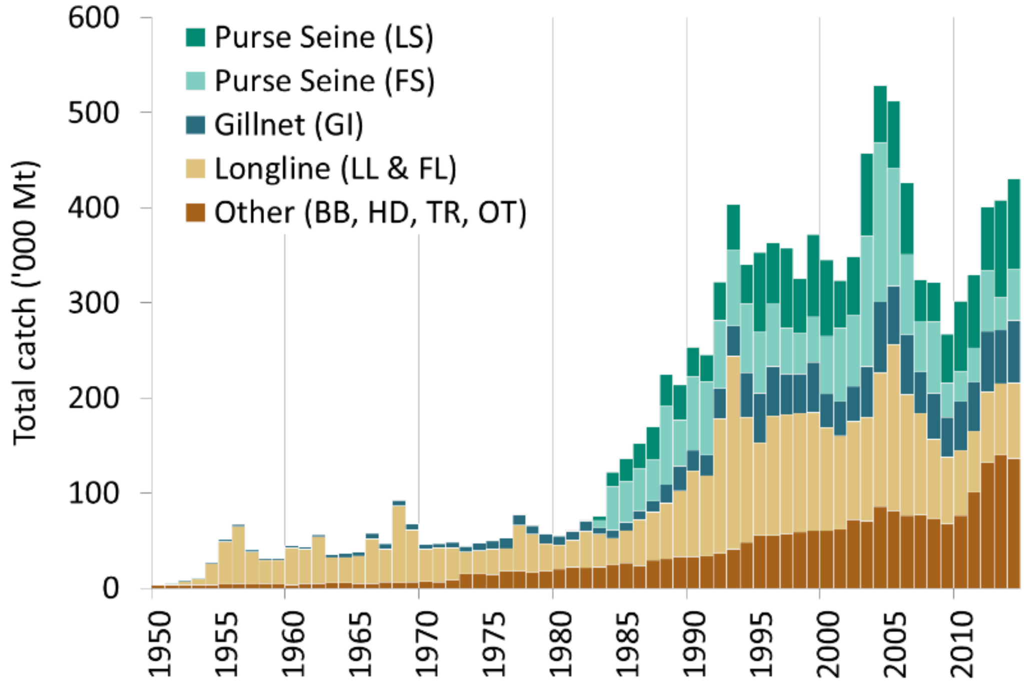
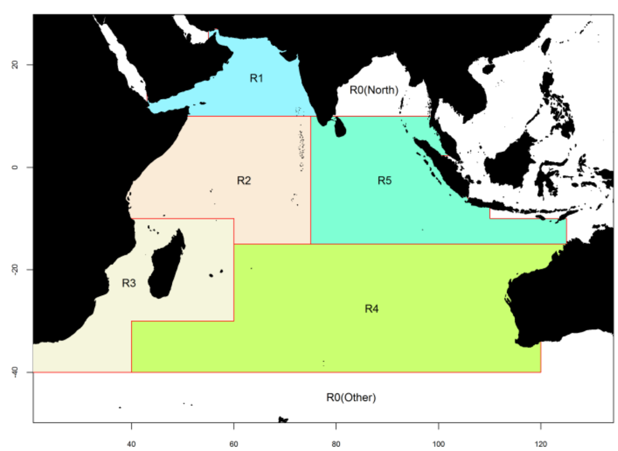


Fig. 2. Annual catches of yellowfin tuna by gear (1950–2014). Data as of November 2015.



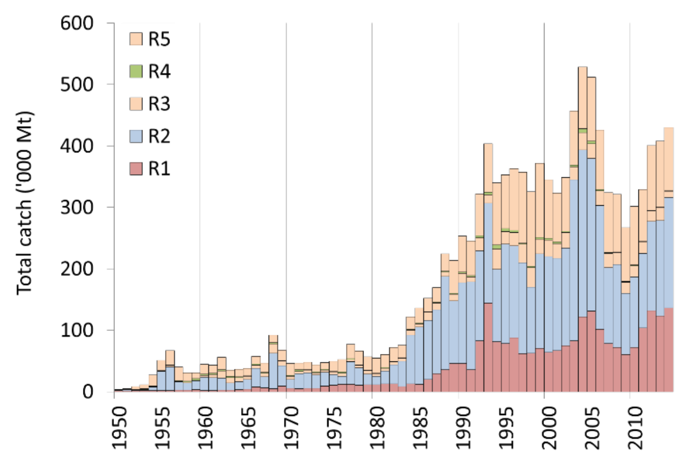


Fig. 3(a-b). Yellowfin tuna: Catches of yellowfin tuna by area by year estimated for the WPTT (1950–2014). Catches in areas R0 were assigned to the closest neighbouring area for the assessment. Data as of November 2015.

Areas: Arabian Sea (**R1**); Off Somalia (**R2**); Mozambique Channel, including southern (**R3**); South Indian Ocean including southern (**R4**); East Indian Ocean, including Bay of Bengal(**R5**).

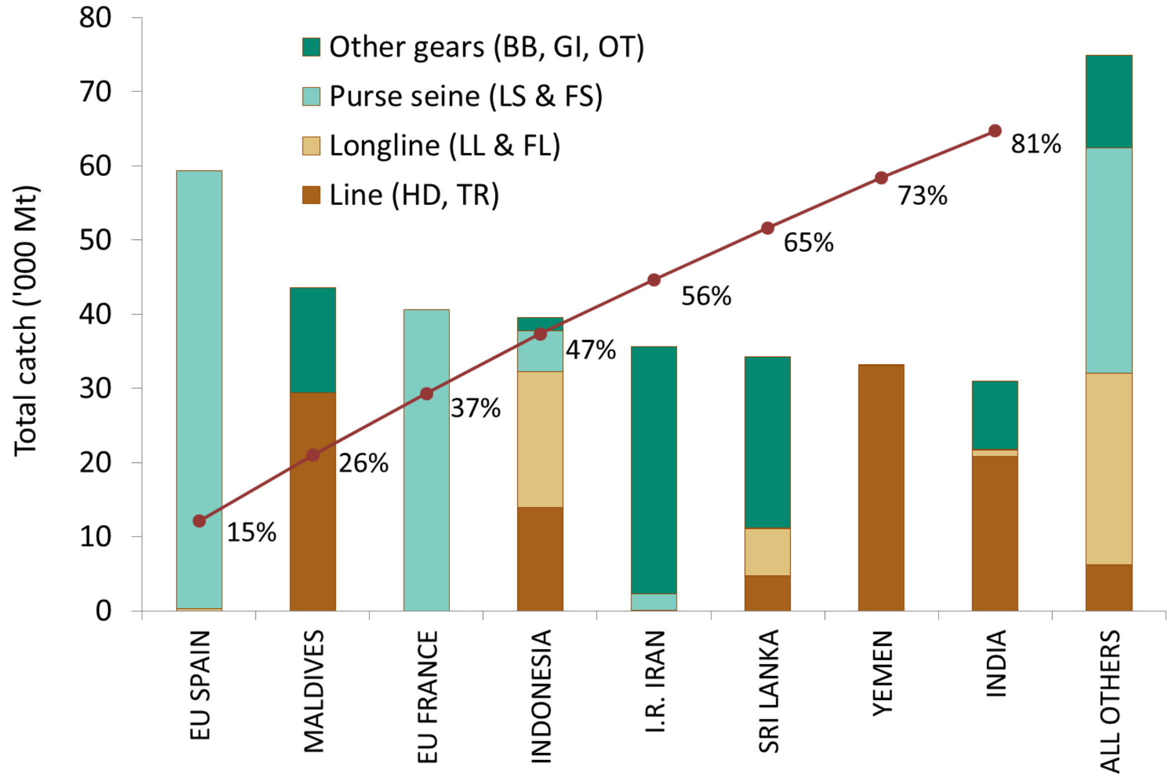


Fig. 4. Yellowfin tuna: average catches in the Indian Ocean over the period 2011–14, by country. Countries are ordered from left to right, according to the importance of catches of yellowfin reported. The red line indicates the (cumulative) proportion of catches of yellowfin for the countries concerned, over the total combined catches of this species reported from all countries and fisheries. Data as of November 2015.

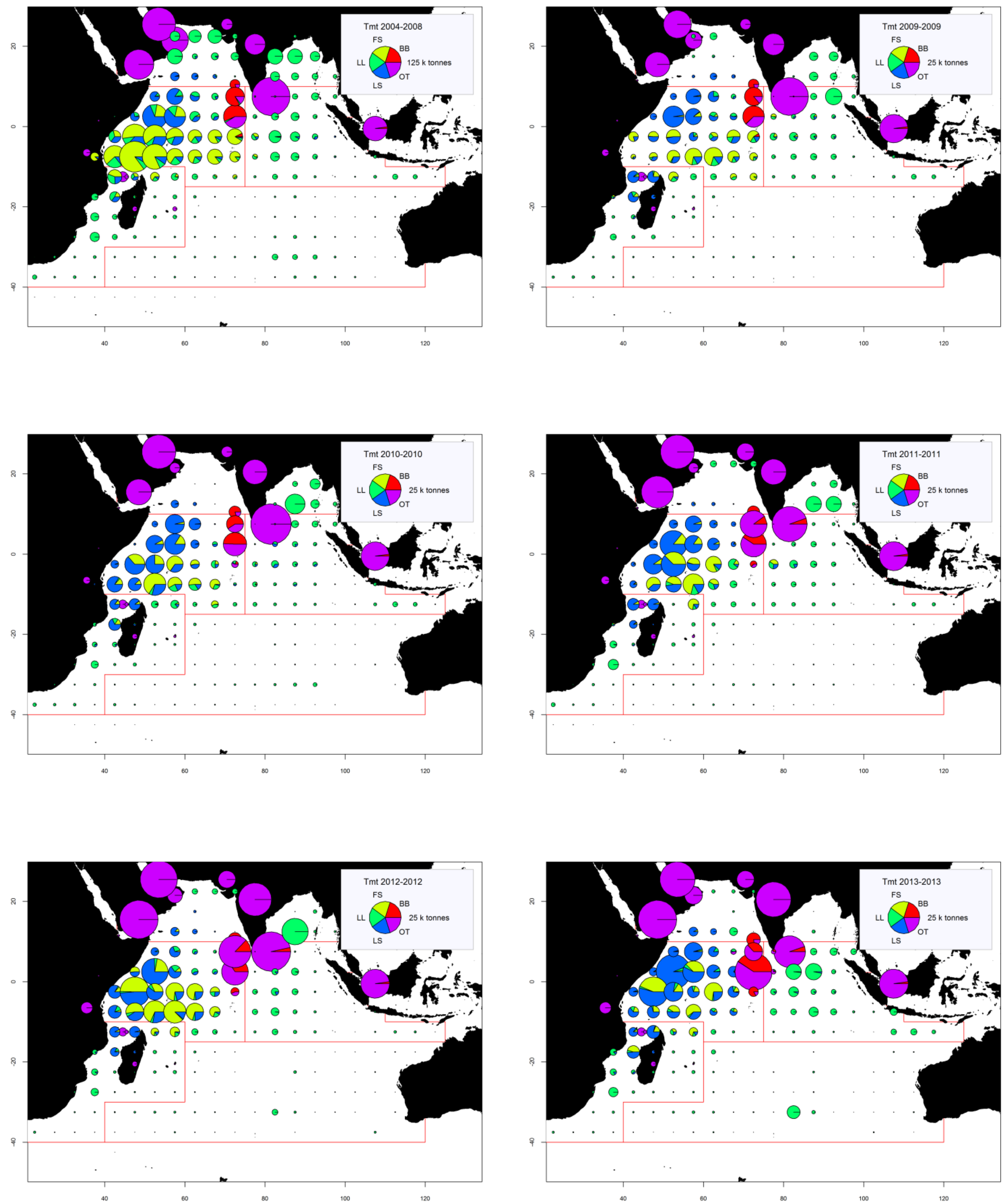


Fig. 5(a-f). Time-area catches (total combined in tonnes) of yellowfin tuna estimated for the period 2004–2008 by type of gear and for 2009–2013, by year and type of gear. Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including drifting gillnets, and various coastal fisheries. Catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded within the area of the countries concerned, in particular driftnets from I.R. Iran and Pakistan, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Yemen, Oman, Comoros, Indonesia and India.

Yellowfin tuna: data availability and related data quality issues

Retained catches

- Data are considered to be generally well known for the major industrial fisheries, with the proportion of catches estimated, or adjusted, by the IOTC Secretariat relatively low (**Fig. 5a**). Catches are less certain for the following fisheries/fleets:
  - many coastal fisheries, notably those from Indonesia, Sri Lanka, Yemen, and Madagascar;
  - gillnet fishery of Pakistan;
  - Non-reporting industrial purse seiners and longliners (NEI), and longliners of India.

Catch-per-unit-effort (CPUE) trends

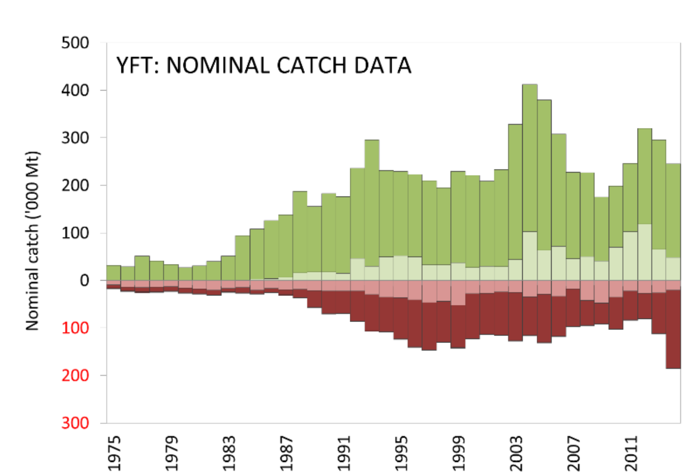
- <u>Availability</u>: Catch-and-effort series are available for the major industrial and artisanal fisheries (e.g., Japan longline, Taiwan,China) (**Fig. 6b**).

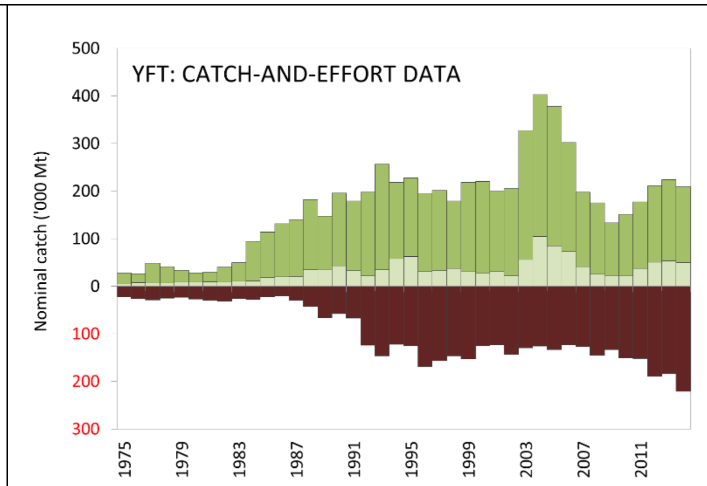
  However, for other important fisheries catch-and-effort are either not available, or are considered to be of poor quality for the following reasons:
  - no data are available for the fresh-tuna longline fishery of Indonesia, over the entire time series, and data for the fresh-tuna longline fishery of Taiwan,China are only available since 2006;
  - insufficient data for the gillnet fisheries of I.R., Iran and Pakistan;
  - poor quality effort data for the significant gillnet-longline fishery of Sri Lanka;
  - no data are available from important coastal fisheries using hand and/or troll lines, in particular Yemen, Indonesia, and Madagascar.

Fish size or age trends (e.g., by length, weight, sex and/or maturity)

- <u>Average fish weight</u>: trends in average weight can be assessed for several industrial fisheries but they are very incomplete or of poor quality for some fisheries (**Fig. 6c**), namely hand lines (Yemen, Comoros, Madagascar), troll lines (Indonesia) and many gillnet fisheries (**Fig. 7**).
  - ➢ Purse seine vessels typically take fish ranging from 40 to 140 cm fork length (FL), while smaller fish are more common in catches taken north of the equator.
  - ➢ Longline gear mainly catches large fish, from 80 to 160 cm FL, although smaller fish in the size range 60 cm – 100 cm (FL) have been taken by longliners from Taiwan,China since 1989 in the Arabian Sea.

- <u>Catch-at-Size (Age) table</u>: data are available, although the estimates are more uncertain in some years and some fisheries due to:
  - size data not being available from important fisheries, notably Yemen, Pakistan, Sri Lanka and Indonesia (lines and gillnets) and Comoros and Madagascar (lines)
  - the paucity of size data available from industrial longliners from the late-1960s up to the mid-1980s, and in recent years (Japan and Taiwan,China)
  - the paucity of catch by area data available for some industrial fleets (NEI fleets, I.R. Iran, India, Indonesia, Malaysia).
- <u>Catch at length trends:</u> Purse seine free swimming school (**Fig 9a**), purse seine FAD associated school (**Fig 9b**) and longline (**Fig. 10**) length frequency distributions and total number of specimens sampled for lengths (raised to total catch).





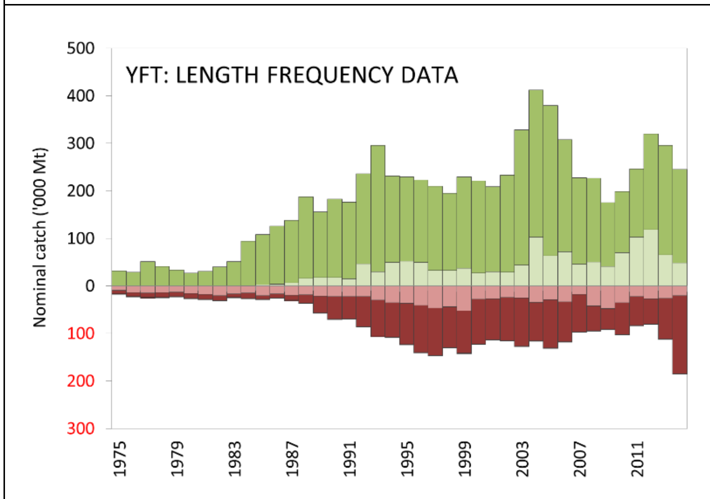
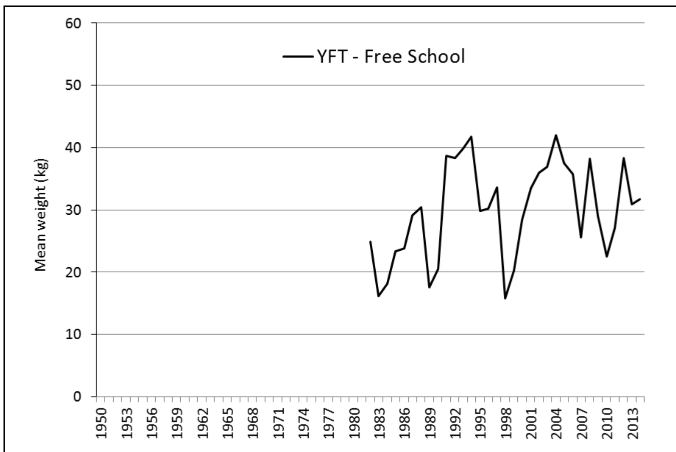
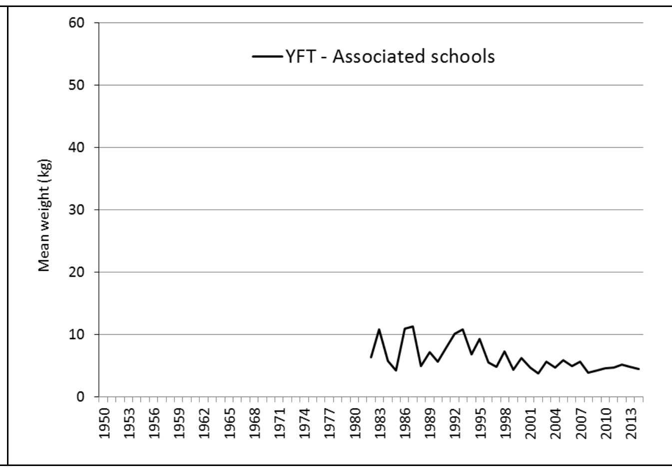


Fig. 6a-c. Yellowfin tuna: data reporting coverage (1975–2014).

Each IOTC dataset (nominal catch, catch-and-effort, and length frequency) are assessed against IOTC reporting standards, where: a score of 0 indicates the amount of nominal catch associated with each dataset that is fully reported according to IOTC standards; a score of between 2 – 6 refers to the amount of nominal catch associated with each dataset that is partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat) or any of the other reasons provided in the document; a score of 8 refers to the amount of nominal catch associated with catch-and-effort data that is not available. Data as of November 2015.





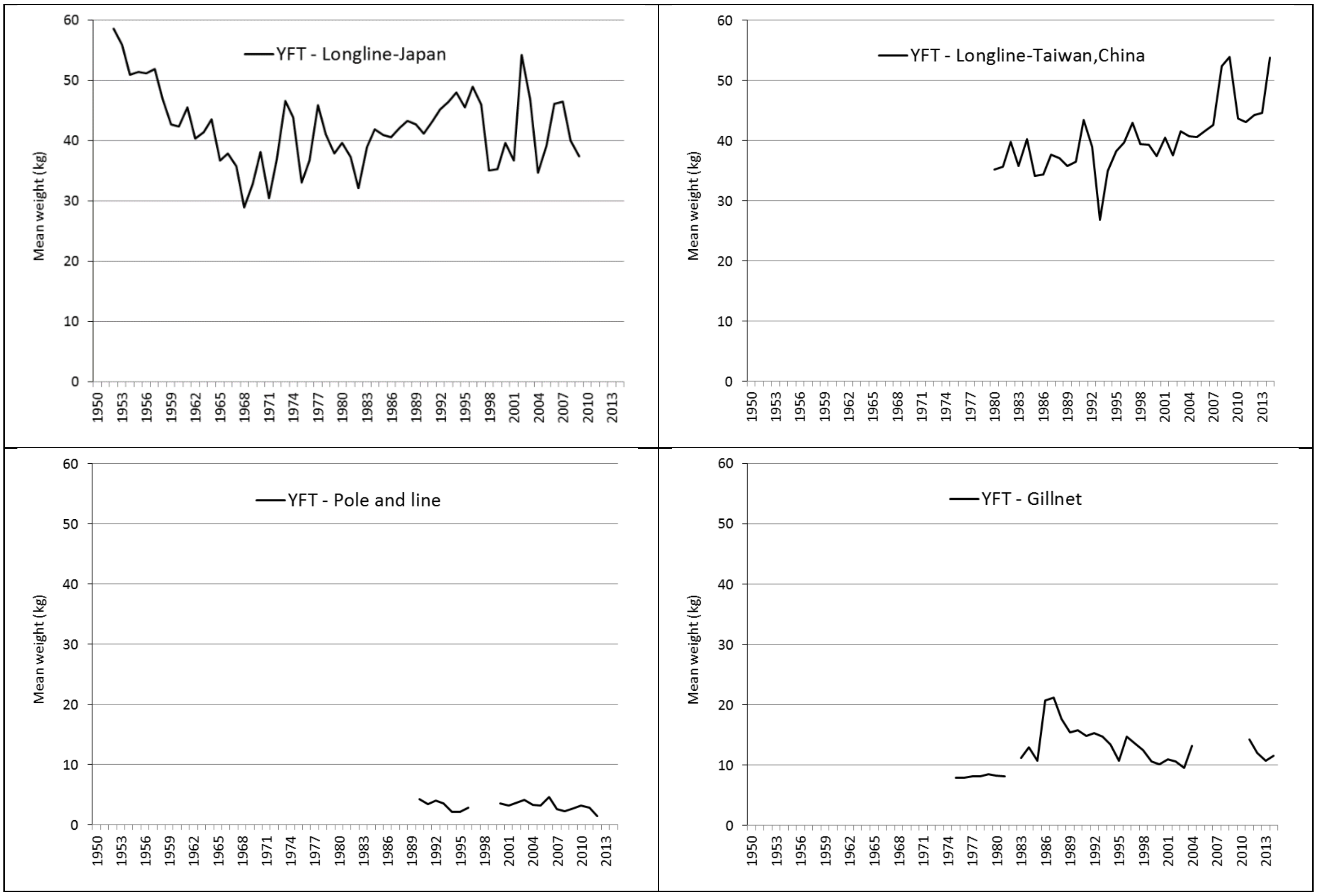


Fig. 7 Average weight of yellowfin tuna (YFT) taken by purse seine on free (top left) and associated (top right) schools; longlines from Japan (mid left) and Taiwan,China (mid right); pole-and-line from Maldives and India (bottom left); gillnets from Sri Lanka, Iran, and other countries (bottom right).

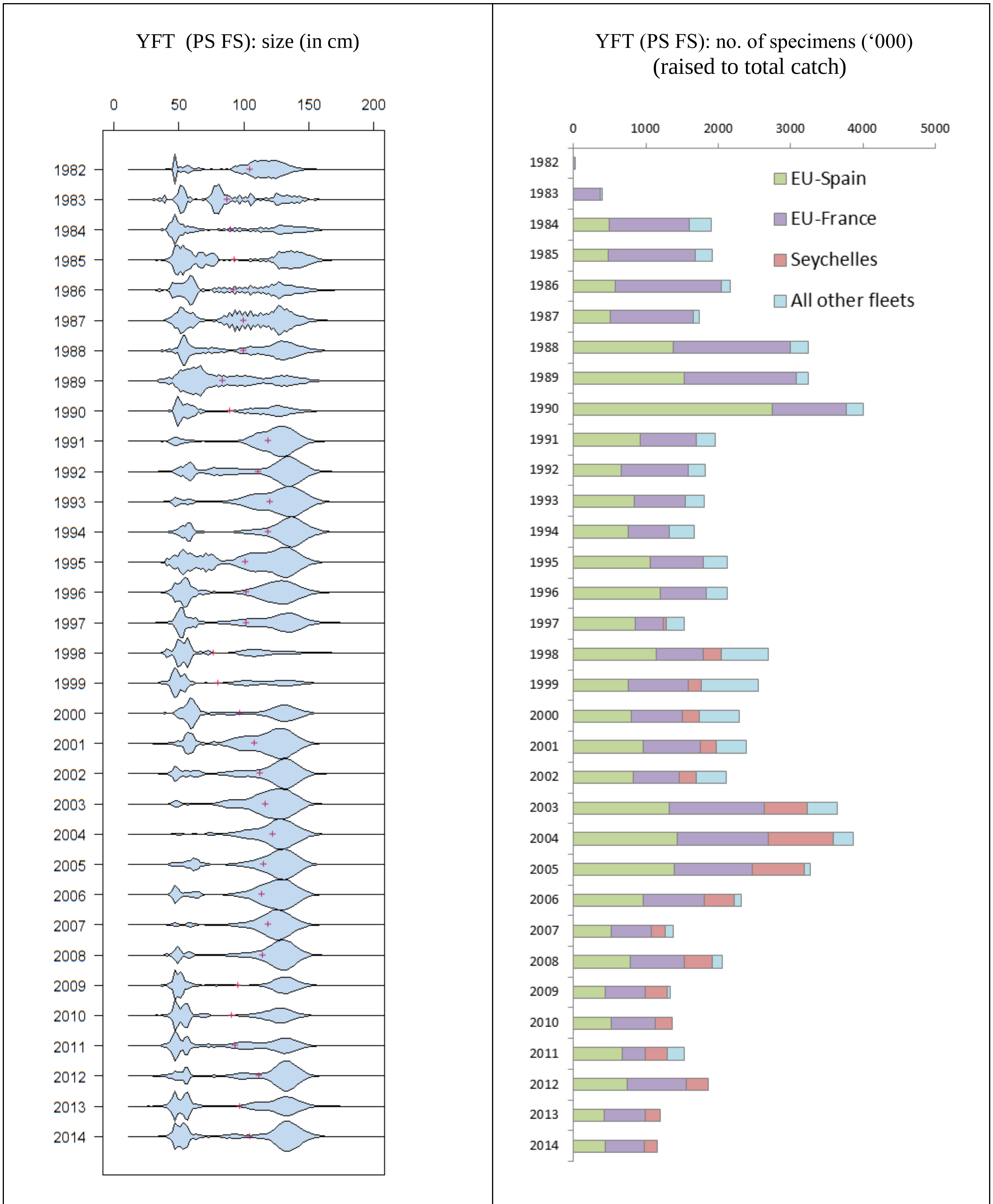


Fig. 8a Yellowfin tuna (PS Free school): **Left:** length frequency distributions for PS Free school fisheries (total amount of fish measured by 2 cm length class) derived from data available at the IOTC Secretariat. **Right**: Number of yellowfin tuna specimens sampled for lengths (raised to total catch), by fleet (PS Free school only).

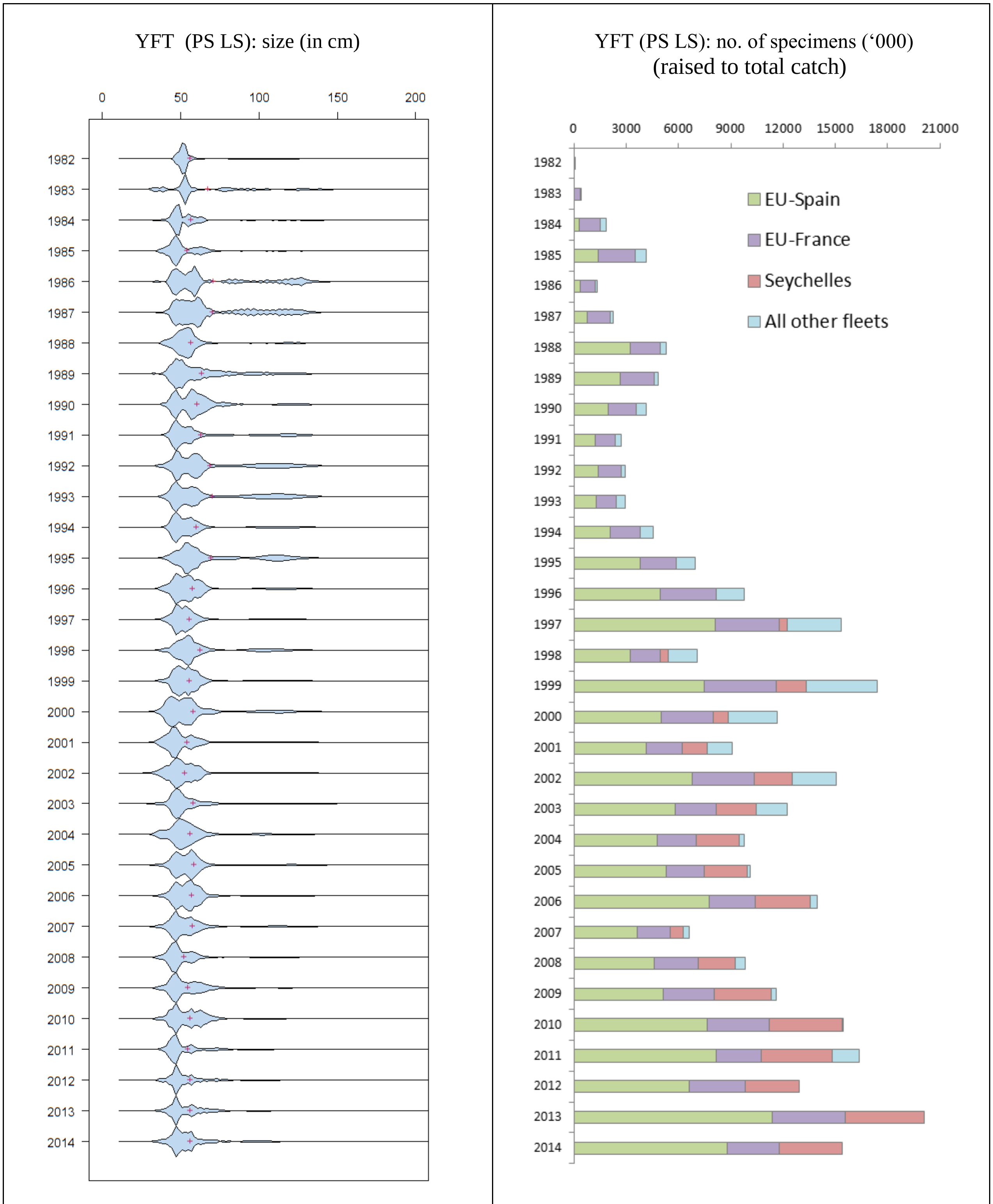


Fig. 8b. Yellowfin tuna (PS Associated school): **Left:** length frequency distributions for PS Associated school fisheries (total amount of fish measured by 2 cm length class) derived from data available at the IOTC Secretariat. **Right**: Number of yellowfin tuna specimens sampled for lengths (raised to total catch), by fleet (PS Associated school only).

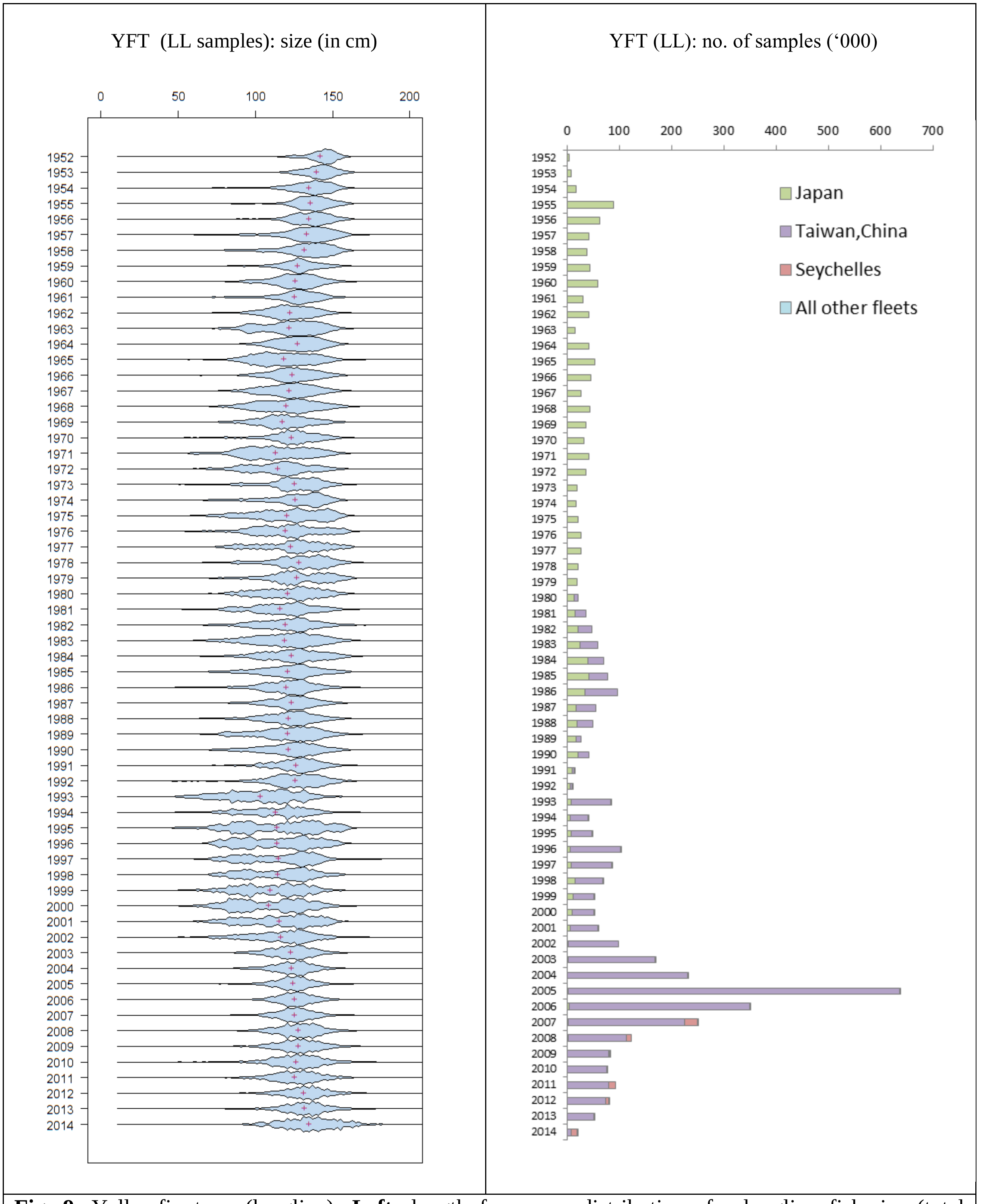


Fig. 9. Yellowfin tuna (longline): **Left:** length frequency distributions for longline fisheries (total amount of fish measured by 2 cm length class) derived from data available at the IOTC Secretariat. **Right**: Number of yellowfin tuna specimens sampled for lengths, by fleet (longline only).

Yellowfin tuna: tagging data

- A total of 63,328 yellowfin tuna (representing 31.4% of the total number of specimens tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP). Most of them (86.4%) were released during the main Regional

Tuna Tagging Project-Indian Ocean (RTTP-IO) and were released around Seychelles, in the Mozambique Channel, along the coast of Oman and off the coast of Tanzania, between May 2005 and September 2007 (**Fig. 10**). The remaining were tagged during small-scale tagging projects, and by other institutions with the support of IOTC Secretariat, in Maldives, India, and in the south west and the eastern Indian Ocean.

- To date, 10,842 specimens (17.1%), have been recovered and reported to the IOTC Secretariat. More than 85.9% of these recoveries we made by the purse seine fleets operating in the Indian Ocean, while around 9.1% were made by pole-and-line and less than 1% by longline vessels. The addition of the data from the past projects in the Maldives (in 1990s) added 3,211 tagged yellowfin tuna to the databases, or which 151 were recovered, mainly from the Maldives.

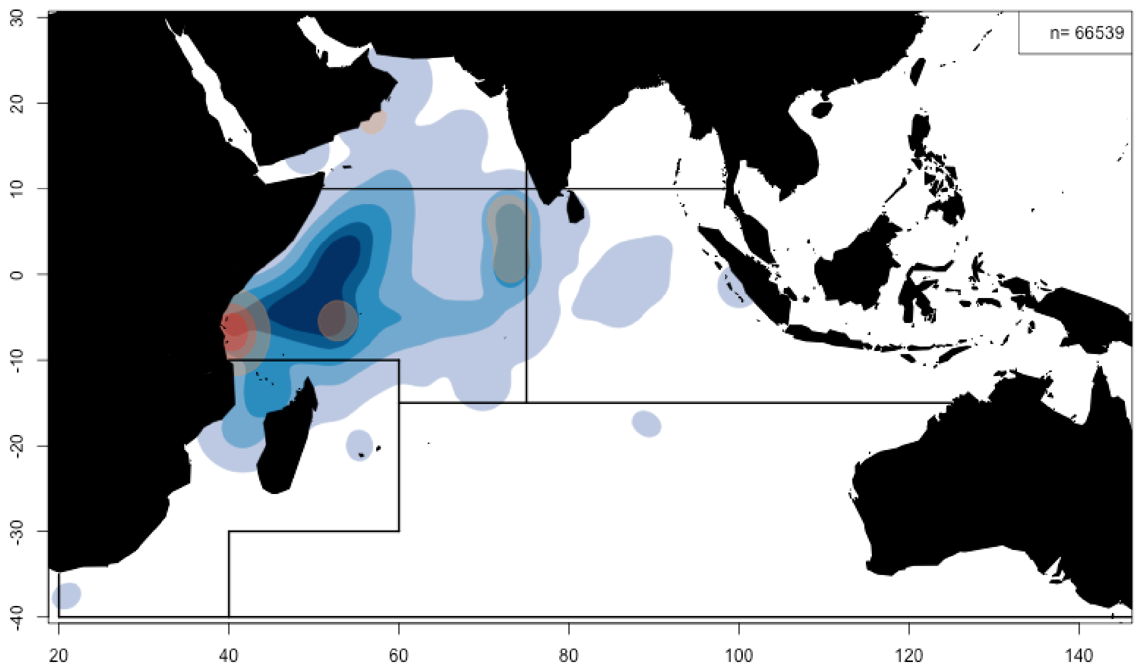


Fig. 10. Yellowfin tuna: Densities of releases (in red) and recoveries (in blue). The black line represents the stock assessment areas. Includes specimens tagged during the IOTTP and also Indian Ocean (Maldivian) tagging programmes during the 1990s. Data as of September 2012.

Yellowfin tuna: Effort trends

Total effort from longline vessels flagged to Japan, Taiwan,China and EU,Spain by five degree square grid in 2013 and 2014 are provided in **Fig. 11**, and total effort from purse seine vessels flagged to the EU and Seychelles (operating under flags of EU countries, Seychelles and other flags), and others, by five degree square grid and main fleets, for the years 2013 and 2014 are provided in **Fig. 12**. Total effort exerted by pole-and-line fleets in the Indian Ocean for the years 2013 and 2014 are provided in **Fig. 13**.

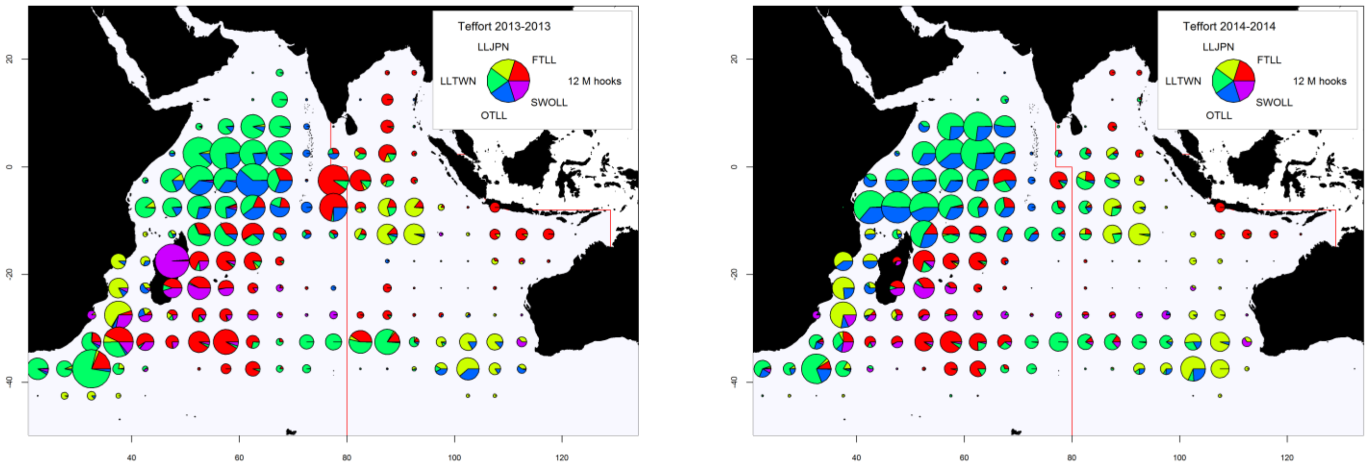


Fig. 11. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2013 (left) and 2014 (right) (Data as of October 2015). **LLJP** (light green): deep-freezing longliners from Japan LLTW (dark green): deep-freezing longliners from Taiwan,China; **SWLL** (turquoise): swordfish longliners (Australia, EU, Mauritius, Seychelles and other fleets); **FTLL** (red) : fresh-tuna longliners (China, Taiwan,China and other fleets); **OTLL** (blue): Longliners from other fleets (includes Belize, China, Philippines, Seychelles, South Africa, Rep. of Korea and various other fleets).

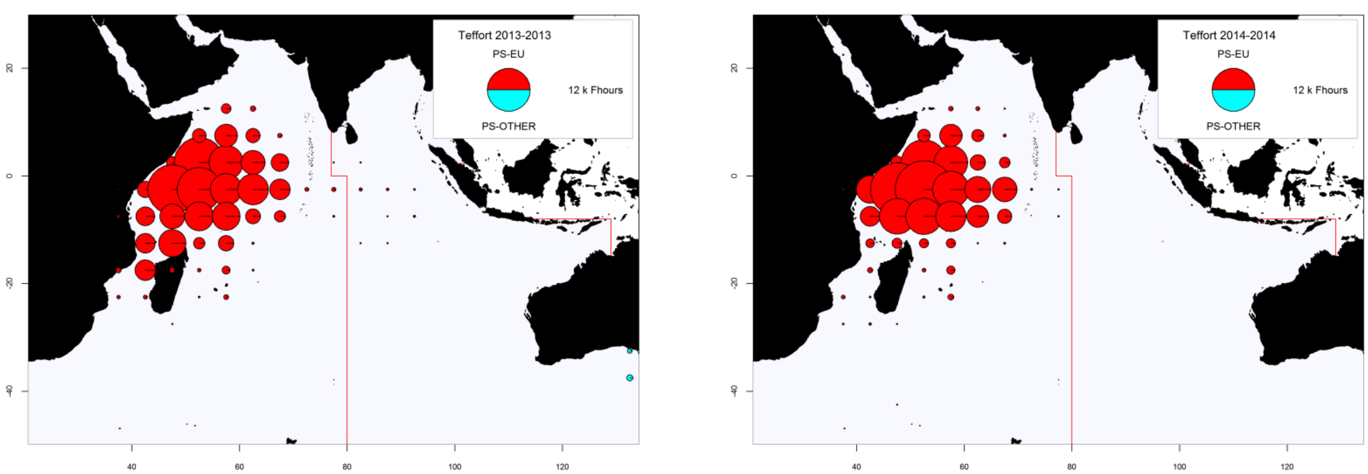
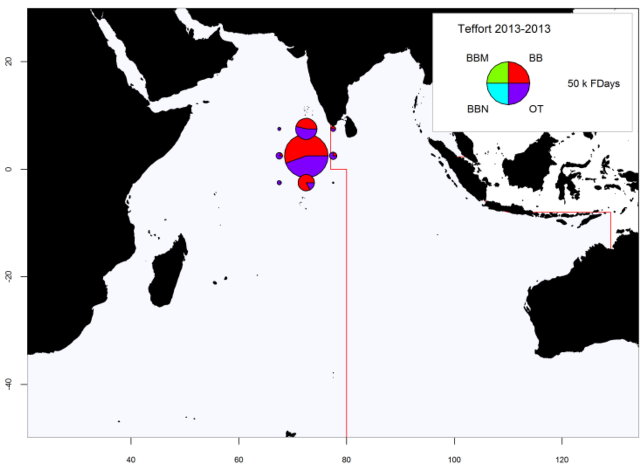


Fig. 12. Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2013 (left) and 2014 (right) (Data as of October 2015). **PS-EU** (red): Industrial purse seiners monitored by the EU and Seychelles (operating under flags of EU countries, Seychelles and other flags); **PS-OTHER** (green): Industrial purse seiners from other fleets (includes Japan, Mauritius and purse seiners of Soviet origin) (excludes effort data for purse seiners of Iran and Thailand).



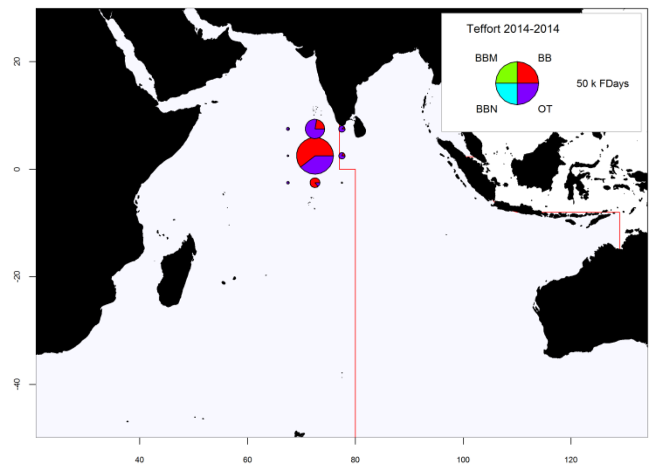


Fig. 13. Effort exerted by pole-and-line fleets in the Indian Ocean, in thousands (k) of trips (equivalent to fishing days), for the years 2013 (left) and 2014 (right) (data as of November 2015). **BBM** (green): Pole-and-line (mechanized baitboats); **BBN** (blue): Pole-and-line (non-mechanized baitboats); **BB** (red): Pole-and-line (all types of baitboat, especially mechanized); **OT** (purple): Pole-and-line and other gears unidentified (effort not available by gear).

Note that the above maps were derived using the available catch-and-effort data in the IOTC database, which is limited to the number of baitboat calls (trips) by atoll by month for Maldivian baitboats for the period concerned. Note that some trips may be fully devoted to handlining, trolling, or other activities (data by gear type are not available since 2002). No data are available for the pole-and-line fisheries of India (Lakshadweep) and Indonesia.

Yellowfin tuna – Standardised catch–per–unit–effort (CPUE) trends

The following points in relation to the longline CPUE discussions in 2015 should be noted:

- The latest yellowfin tuna CPUE series were relatively consistent with each other and with the Indian survey (as evident in **Fig. 14** despite the inconsistency in spatial definitions for the series shown).
- The Japan longline CPUE series were given the primary emphasis in the stock assessments. The SS3 assessment also included sensitivity trials using the combined fleet data that included individual vessel effects, the Indian longline CPUE and the European Union purse seine CPUE.
- The effects of piracy increased the uncertainty of Japanese CPUE indices in the western equatorial Indian Ocean region since 2008, and consequently indices are not available for some quarters. The area of operation of the Japan longline fleet is greatly reduced and the indices are therefore derived from a smaller proportion of the region. Standardisation methods can potentially account for changes in spatial distribution, although bias may be introduced. Nonetheless the CPUE indices based on combined fleet data showed similar trends to the Japan longline indices during and after the period of piracy.
- There was a substantial reduction of longline fishing effort by distant water fishing nations in the northern Arabian sea and consequently a lack of CPUE series from that region.

The multi-nation CPUE standardisation collaboration continue their efforts to improve the understanding of commercial CPUE as relative abundance indices, and expand future work to include other fleets, including the Indian survey.

The yellowfin tuna CPUE series available for assessment purposes, the Japan longline series would be used in the final stock assessment models investigated in 2015, for the reasons discussed above (**Fig. 14**).

- India data (1981–2012) from document IOTC–2015–WPTT17–24
- Taiwan,China data (1980–2014) from document IOTC–2015–WPTT17–25
- Japan data (1963–2014) from document IOTC–2015–WPTT17–26
- European Union data (purse seine on free-schools, including an annual 3% increase in fishing power; 1984–2014) and provided during the WPTT (no document provided)

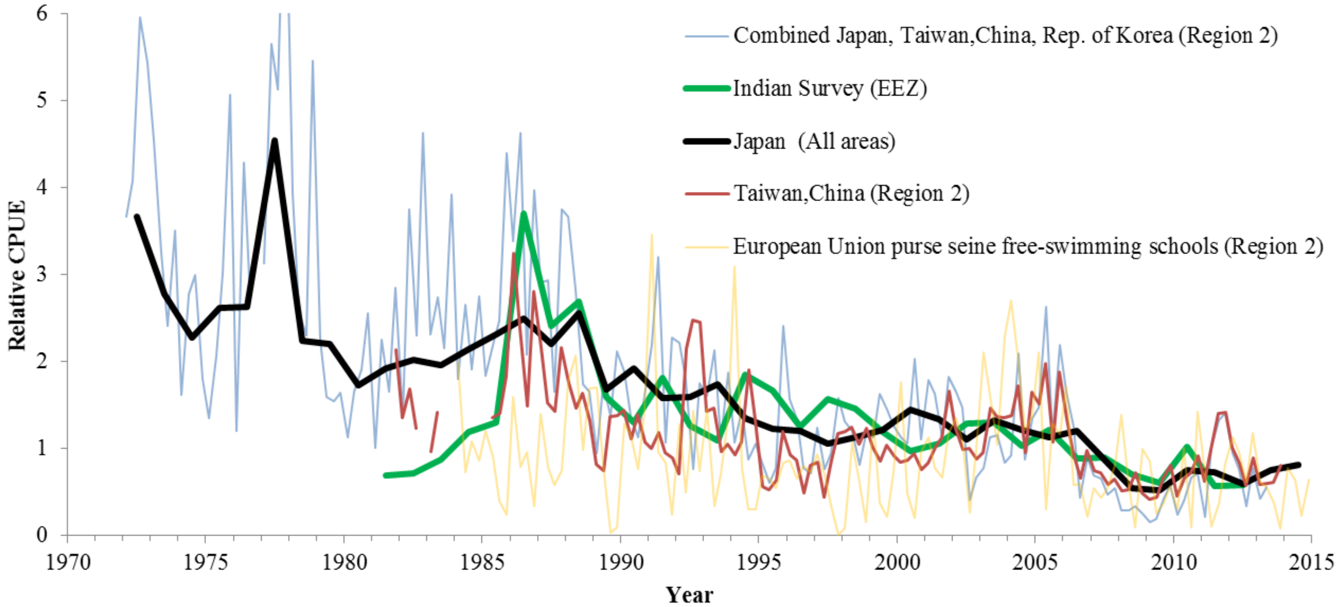


Fig. 14. Yellowfin tuna: Comparison of relative abundance indices derived from standardised commercial longline catch rates from Japan, Taiwan,China, and combined fleets series (Japan, Taiwan,China and Rep. of Korea), compared with the Indian survey (note that regions are not identical, all series are re-scaled relative to the 2001–10 mean, and observations before 1972 are omitted).

STOCK ASSESSMENT

The following should be noted with respect to the SS3 modelling approach used for determining stock status (**Table 6**) at the meeting:

- Biomass is high in region 2 given the size of the region in comparison to region 1. This is a consistent deficiency in the current assessment that has been present in previous assessments, and provides some justification for pooling these areas in future assessments. It's recognised that relative biomass by area is usually difficult to quantify and estimates usually depend on strong assumptions about shared selectivity, catchability and relative weighting of historically fished areas to extrapolate density to abundance. The model sensitivity that amalgamated the two regions yielded estimates of overall stock status that were very similar to the base model option, primarily due to the similar trends in the relative abundance indices from the two regions. On that basis, it was concluded that the results of the assessment were not sensitive to the regional structure in the western area of the assessment model.
- Around half of the recent yellowfin tuna catches is taken by artisanal fisheries, about which we have very little information on the total catches, their fishing areas and the sizes caught. This problem has an unquantified impact on the current yellowfin tuna assessment.
- The decline to low spawning biomass relative to MSY was not preceded by a period of high catch relative to MSY, and appears to have been largely caused by low recruitment. The declining spawning biomass estimates in the models are largely driven by declining CPUE in the longline fisheries, especially the low indices in region 1 (R1) during 2008 and 2009.
- The WPTT considered mechanisms which might have artificially caused the apparent recruitment decline in 2004-06, and explored alternative data sources for recruitment insight. These included:
    - Purse seine free school catch rates were low in 2006-07, for which a highly plausible cause would be a low catchability due to an anomalously deep thermocline in relation with a positive dipole event. The possibility these low catch rates would also be a consequence of low recruitment (as predicted by the model) cannot be discarded but cannot stand as the major cause of those low catch rates on free schools.
    - Purse seine log associated catches and catch rates were low in 2006–07. This is not inconsistent with the model estimates of lower recruitment in the preceding period, however, there may be other explanations for these lower catches.
    - That, by contrast to the low recruitment estimated by the model in 2004–06, the proportion of small size yellowfin tuna (less than 10kg) in the purse seine catch on FADs was stable from 2000 to 2008.

Purse seine species composition changes were not informative about yellowfin tuna recruitment, primarily because changes in skipjack tuna abundance need to be accounted for.
    - Removing longline CPUE observations from the model corresponding to the estimated recruitment decline did not substantively change the recruitment pattern.
- The low CPUE in recent years occurs at the same time as an increase in longline mean sizes, which is consistent with reduced recruitment, but which was not observed in purse seine free-school mean sizes and which may reflect changing selectivity from the longline fleets or insufficient size sampling from longline catches.
- Compared with the 2012 assessment the stock is now estimated to be considerably more depleted. In the 2012 assessment the south-western region was estimated to be less depleted than the equatorial region – while depletion in both areas is similar in the new assessment.
- Retrospective analyses terminating in 2011 were somewhat more pessimistic than the MFCL results from 2012. This is likely to be influenced by the way that MFCL introduces temporally varying recruitment in each region (the SS3 specification is thought to be more realistic in only introducing recruits to equatorial regions).
- A sensitivity analysis replacing the Japan longline CPUE in areas 1 and 4 with the Indian survey time series resulted in a slightly more optimistic outcome than the base case, though it was noted that the indices for 2013–14 were assumed to be equivalent to the 2012 survey index.
- A sensitivity analysis adding purse seine free school CPUE resulted in some conflict with the longline CPUE indices and slightly more optimistic outcomes than the base case. This was expected because the purse seine CPUE series did not decline to the same extent as the longline CPUE indices in region 1 (R1).
- It would be worth investigating whether the environmental movement co-variates could be replaced with consistent seasonal migration parameters (or whether the current series fit the data any better than a randomised time series).
- Natural mortality (M) is one of the most important parameter in all stock assessments, but it remains highly uncertain for yellowfin tuna. Our base assumption on M are much lower than the values used in the eastern Pacific Ocean by the IATTC. Based on the tag recoveries of the RTTP program after a long period at liberty, we are confident that out lower estimates of M are more appropriate for the Indian Ocean than the IATTC assumptions. However we are not confident that the functional form of M-at-age can be reliably estimated.
- Dome-shaped selectivity may be plausible for the longline fishery, and should be further explored in future assessments, recognising the interaction between selectivity and M.

Table 6. Yellowfin tuna: Key management quantities from the SS3 assessment, for the Indian Ocean. Values represent the Maximum Posterior Density from the base case and the confidence interval empirically derived from the covariance matrix.

Management Quantity	**Indian Ocean**
Most recent catch estimate (t) (2014)	427,440
Mean catch over last 5 years (t) (2010–2014)	368,853
h (steepness)	0.8
MSY (1,000 t) (80% CI)	421 (404–439)
Data period (catch)	1950–2014
CPUE series/period	1972–2014
F_{MSY} (80% CI)	0.165 (0.162–0.168)
SB_{MSY} or *B_{MSY} (1,000 t) (80% CI)	1,217 (1,165–1,268)
F_{2014}/F_{MSY} (80% CI)	1.34 (1.02–1.67)
B_{2014}/B_{MSY} (80% CI)	n.a.
SB_{2014}/SB_{MSY} (80% CI)	0.66 (0.58–0.74)
B_{2014}/B_{1950} (80% CI)	n.a.
SB_{2014}/SB_{1950} (80% CI)	0.23 (0.21–0.26)
$SB_{2014}/SB_{current,\ F=0}$ (80% CI)	0.30 (n.a.)

LITERATURE CITED

Froese R, Pauly DE (2009) *FishBase*, version 02/2009, FishBaseConsortium, <www.fishbase.org>