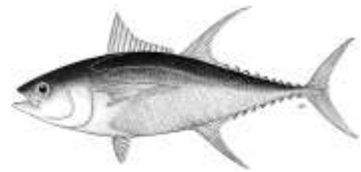
DRAFT: EXECUTIVE SUMMARY: YELLOWFIN TUNA

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			2014 stock status determination
Indian Ocean	Catch 2013:	402,084 t		(green)
	Average catch 2009–2013:	339,359 t		
		Multifan[2]	ASPM[3]	
	MSY (1000 t) (80% CI):	344 (290–453)	320 (283–358)	
	F_{MSY} (80% CI):	n.a (n.a.–n.a.)	n.a (n.a.–n.a.)	
	SB_{MSY} (1,000 t) (80% CI):	881 (784–986)	n.a (n.a.–n.a.)	
	F_{curr}/F_{MSY} (80% CI):	0.69 (0.59–0.90)	0.61 (0.31–0.91)	
	SB_{curr}/SB_{MSY} (80% CI):	1.24 (0.91–1.40)	1.35 (0.96–1.74)	
	SB_{curr}/SB_0 (80% CI):	0.38 (0.28–0.38)	–	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[2] most recent years data 2010. Range = range of the point estimates from the different runs.
[3] most recent years data 2011. Range: 80% CI.

Colour key	Stock overfished (SB_{year}/SB_{MSY}< 1)	Stock not overfished (SB_{year}/SB_{MSY}≥ 1)
Stock subject to overfishing(F_{year}/F_{MSY}> 1)	(red)	(orange)
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	(yellow)	(green)
Not assessed/Uncertain	(grey)	

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. No new stock assessment was carried out for yellowfin tuna in 2014, thus, stock status is determined on the basis of the 2012 assessment and other indicators presented in 2014. The stock assessment model results from 2012 did not differ substantively from the previous (2011) assessments; however, the final overall estimates of stock status differ somewhat due to the refinement in the selection of the range of model options due to increased understanding of key biological parameters (primarily natural mortality). Two trajectories are presented that compare the Kobe plots obtained from the MFCL and ASPM assessments. While the MFCL assessment indicates that fishing mortality is below the limit and target reference points during the whole time series, the ASPM model run indicates that the target reference points may have been exceeded during the period of high catches in the mid 2000's (2003–2006). However, estimates of total and spawning stock biomass show a marked decrease from 2004 to 2009 in both cases, corresponding to the very high catches of 2003–2006. Recent reductions in effort and, hence, catches resulted in a slight improvement in stock status in 2010. Spawning stock biomass in 2010 was estimated to be 38% (31–38%) (from Table 1) of the unfished levels. Total catch has continued to increase with 400,292 t and 402,084 t landed in 2012 and 2013, respectively, well in excess of previous MSY estimates (≈17% above the MSY level of 344,000 t; Table 1), in comparison to 327,453 t landed in 2011 and 299,713 t landed in 2010. Catches in 2010 (299,713) were within the lower range of MSY level and the last assessment indicated that catch of about the 2010 level were sustainable in the longer term. The previous assessment showed that the stock was unlikely to support substantially higher yields based on the estimated levels of recruitment from the last 15 years although higher yield would be expected if recruitment corresponds to the long term average. However, catch rates have improved in the purse seine fishery while remaining stable for the Japanese longline fleet. Therefore it is difficult to know whether the stock is moving towards a state of being subject to overfishing. Thus, on the weight-of-evidence available in 2014, the yellowfin tuna stock is determined to be **not overfished** and **not subject to overfishing** (Table 1 and Fig. 1).

Outlook. The decrease in longline and purse seine effort in recent years has substantially lowered the pressure on the Indian Ocean stock as a whole, indicating that current fishing mortality has not exceeded the MSY-related levels in recent years. If the security situation in the western Indian Ocean were to continue to improve, a rapid reversal in fleet activity in this region may lead to an increase in effort which the stock might not be able to sustain, as catches would then be likely to exceed MSY levels.

The Kobe strategy matrix based on the projections were carried out using 12 different scenarios of the assessment: LL selectivity flat top vs. dome shape; steepness values of 0.7, 0.8 and 0.9; and computing the recruitment as an average of the whole time series vs. 15 recent years and the probabilities in the matrices were computed as the percentage of the 12 scenarios being $SB>SB_{MSY}$ and $F<F_{MSY}$ in each year. In that sense, there are not producing the uncertainty related to any specific scenario but the uncertainty associated to different scenarios.

There was considerable discussion on the ability of the WPTT to carry out the projections with MFCL for yellowfin tuna. For example, it was not clear how the projection redistributed the recruitment among regions as recent distribution of recruitment differs from historic; which was assumed in the projections. The WPTT agreed that the true uncertainty is unknown and that the current characterisation is not complete; however, the WPTT feels that the projections may provide a relative ranking of different scenarios outcomes.

The following key points should be noted:

- **Maximum Sustainable Yield (MSY):** estimate for the whole Indian Ocean is 344,000 t with a range between 290,000–453,000 t for MFCL; 320,000 t with a range between 283,000 and 358,000 t for ASPM (Table 1). The management advice in 2012 indicated that annual catches of yellowfin tuna should not exceed the lower range of MSY (300,000 t) in order to ensure that stock biomass levels could sustain catches at the MSY level in the long term. Catches have exceeded this level in 2011, 2012 and 2013. Recent recruitment estimated by MFCL is estimated to be considerably lower than the whole time series average. If recruitment continues to be lower than average, catches below MSY would be needed to maintain stock levels. On the contrary, long term recruitment would give larger yield.
- **Provisional reference points**: Noting that the Commission in 2013 agreed to Resolution 13/10 *on interim target and limit reference points and a decision framework*, the following should be noted:
    - **Fishing mortality**: Current fishing mortality is considered to be below the provisional target reference point of F_{MSY}, and therefore below the provisional limit reference point of $1.4*F_{MSY}$ (Fig. 1).
    - **Biomass**: Current spawning biomass is considered to be above the target reference point of SB_{MSY}, and therefore above the limit reference point of $0.4*SB_{MSY}$ (Fig. 1).
- **Main fishing gear** (2009–13): Purse seine ≈33.8% (log ≈21.8% and free swimming school ≈12.0%); Longline ≈19.3% (frozen ≈11.7%, fresh ≈7.6%); Handline ≈17.3%; Gillnet ≈15.6%.
- **Main fleets**: European Union ≈26% (EU,Spain: ≈15%; EU,France: ≈11%); Sri Lanka ≈10%; Maldives ≈10%; Indonesia ≈10%; I.R. Iran ≈9%; Seychelles ≈8%.

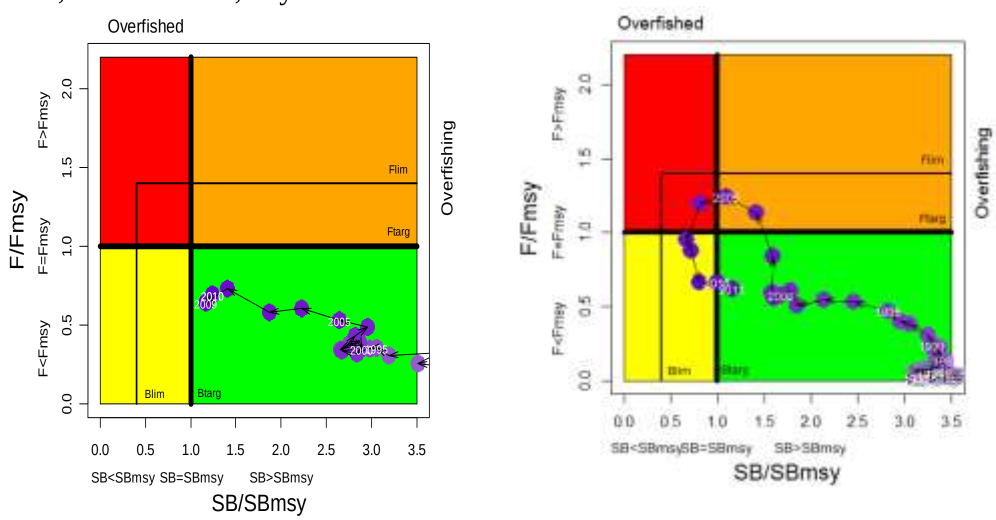


Fig. 1. Yellowfin tuna: MULTIFAN-CL and ASPM Indian Ocean yellowfin tuna stock assessment Kobe plots. Blue circles indicate the trajectory of the point estimates for the SB ratio and F ratio for each year 1972–2010 for a steepness value of 0.8. The left panel is output obtained from the base case run in MFCL. The right panel is obtained from the ASPM base case model run with steepness value of 0.9.

TABLE 2. Yellowfin tuna: 2011 MULTIFAN-CL Indian Ocean yellowfin tuna stock assessment Kobe II Strategy Matrix. Percentage probability of violating the MSY-based reference points for five constant catch projections (2010

catch level, ±10%, ± 20%, ± 30% and ± 40%) projected for 3 and 10 years. In the projection, however, 12 scenarios were investigated: the six scenarios investigated above as well as the same scenarios but with a lower mean recruitment assumed for the projected period. Note: from the 2011 stock assessment using catch estimates at that time.

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level for 2010) and probability (%) of violating MSY-based target reference points ($SB_{targ} = SB_{MSY}$; $F_{targ} = F_{MSY}$)**								
	60% (165,600t)	**70%** (193,200t)	**80%** (220,800t)	**90%** (248,400t)	**100%** (276,000t)	**110%** (303,600t)	**120%** (331,200t)	**130%** (358,800t)	**140%** (386,400t)
$SB_{2013} < SB_{MSY}$	<1		<1		<1		<1		<1
$F_{2013} > F_{MSY}$	<1		<1		58.3		83.3		100
$SB_{2020} < SB_{MSY}$	<1		<1		8.3		41.7		91.7
$F_{2020} > F_{MSY}$	<1		41.7		83.3		100		100

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level for 2010) and probability (%) of violating MSY-based limit reference points ($SB_{lim} = 0.4\ SB_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	60% (165,600t)	**70%** (193,200t)	**80%** (220,800t)	**90%** (248,400t)	**100%** (276,000t)	**110%** (303,600t)	**120%** (331,200t)	**130%** (358,800t)	**140%** (386,400t)
$SB_{2013} < SB_{Lim}$	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
$F_{2013} > F_{Lim}$	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
$SB_{2020} < SB_{Lim}$	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
$F_{2020} > F_{Lim}$	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

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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 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 13/03 *on the recording of catch and effort by fishing vessels in the IOTC area of competence*
- Resolution 13/10 *On interim target and limit reference points and a decision framework*
- Resolution 13/11 *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 12/11 *on the implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties*
- Resolution 10/02 *mandatory statistical requirements for IOTC Members and Cooperating non-Contracting Parties (CPC's)*
- 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 catch trends

Catches of yellowfin tuna (Table 4; Fig. 2) remained more or less stable between the mid-1950s and the early-1980s, ranging between 30,000 and 70,000 t, owing to the activities of longliners and, to a lesser extent, gillnetters. The catches increased rapidly with the arrival of the purse seiners in the early 1980s and increased activity of longliners and other fleets, reaching over 400,000 t in 1993. Catches of yellowfin tuna between 1994 and 2002 remained stable, between 330,000 and 350,000 t. Yellowfin tuna catches during 2003, 2004, 2005 and 2006 were much higher than in previous years, with the highest catches ever recorded in 2004 (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. After 2006 catches of yellowfin tuna dropped markedly, with the lowest catches recorded in 2009 at less than 270,000 t. Since 2009 catches of yellowfin tuna have once again been increasing, with catches over 400,000 t recorded in 2012 and 2013.

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 (2004–2013), in tonnes. Data as of September 2014. Catches by decade represent the average annual catch, noting that some gears were not used since the beginning of the fishery.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
FS	0	0	18	31,555	64,956	89,204	168,146	123,997	85,044	53,526	74,986	36,050	32,136	36,453	64,594	34,458
LS	0	0	17	17,616	56,293	61,892	59,901	69,877	74,612	43,778	41,546	51,352	73,383	76,659	66,166	101,905
LL	22,131	42,460	31,016	37,274	76,926	76,814	108,277	137,677	94,955	71,439	45,764	41,893	43,720	38,842	43,417	30,606
LF	0	0	615	4,286	47,572	34,149	32,938	35,949	31,751	33,303	34,343	23,125	21,501	20,510	27,182	36,326
BB	2,111	2,318	5,810	8,295	12,805	16,076	15,876	16,843	18,043	16,327	18,279	16,826	14,098	14,003	15,506	24,119
GI	1,572	4,115	7,838	11,899	39,420	49,243	74,001	61,210	62,488	43,452	47,978	41,945	50,780	51,053	63,626	56,843
HD	588	566	3,236	8,301	20,705	36,647	44,249	43,373	35,154	36,465	33,840	32,079	36,660	62,093	83,543	78,585
TR	1,102	1,981	4,335	6,912	11,568	16,010	20,609	17,186	18,180	19,783	18,221	16,586	19,717	19,940	28,049	31,007
OT	80	193	453	1,871	3,373	5,424	4,834	5,831	5,804	6,837	6,611	7,401	7,717	7,901	8,209	8,236

Total	27,584	51,633	53,339	128,008	333,619	385,459	528,832	511,945	426,033	324,911	321,567	267,255	299,713	327,453	400,292	402,084

Gears: Purse seine free-school (**FS**); Purse seine associated school (**LS**); Deep-freezing longline (**LL**); Fresh-tuna longline (**LF**); 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 (2004–2013), in tonnes. Data as of September 2014. Catches by decade represent the average annual catch. The areas are presented in Fig. 3a.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
R1	2,041	4,282	6,619	16,158	76,021	87,775	129,790	133,335	113,553	80,990	73,850	57,508	64,989	79,716	103,730	108,224
R2	11,870	23,055	21,135	71,743	134,778	174,247	261,240	239,622	188,414	120,829	131,981	99,716	117,940	140,865	173,989	175,352
R3	766	7,404	5,510	9,308	23,201	24,159	26,350	24,900	24,196	24,837	21,082	19,513	18,942	20,356	18,418	22,100
R4	997	1,919	1,633	1,325	3,633	3,337	5,674	4,372	3,090	1,293	1,225	1,145	1,364	1,431	1,408	1,707
R5	11,911	14,973	18,442	29,474	95,986	95,941	105,781	109,717	96,779	96,959	93,429	89,372	96,479	85,088	102,751	94,699
Total	**27,584**	**51,633**	**53,339**	**128,008**	**333,619**	**385,459**	**528,832**	**511,945**	**426,033**	**324,911**	**321,567**	**267,255**	**299,713**	**327,453**	**400,292**	**402,084**

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**).

Although some Japanese purse seine vessels have fished in the Indian Ocean since 1977, the purse seine (Fig. 2) 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. 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.

Catches of yellowfin tuna by purse seiners increased rapidly to around 130,000 t in 1993, and subsequently fluctuated around that level, until 2003–05 when catches increased substantially (i.e., around 200,000 t). The amount of effort exerted by the EU purse seine vessels (fishing for yellowfin tuna and other tunas) varies seasonally and from year to year.

The purse seine fishery is characterised by the use of two different fishing modes (Table 4 and Fig. 2). 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. Between 1995 and 2003, the FAD component of the purse seine fishery represented 48–66% of the sets undertaken (60–80% of the positive sets) and accounted for 36–63% of the yellowfin tuna catch by weight (59–76% of the total catch). The proportion of yellowfin tuna caught (in weight) on free-schools during 2003–06 (64%) was much higher than in previous or following years (at around 50%).

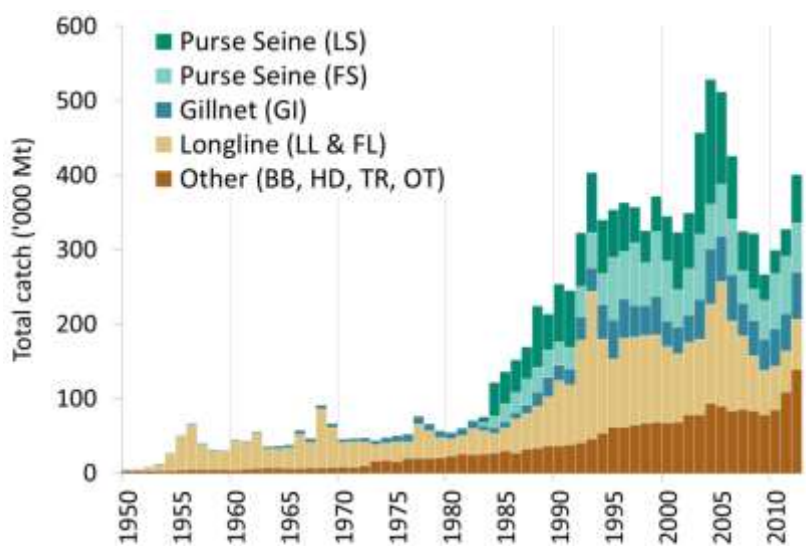


Fig. 2. Yellowfin tuna: Annual catches of yellowfin tuna by gear (1950–2012). Data as of September 2014.

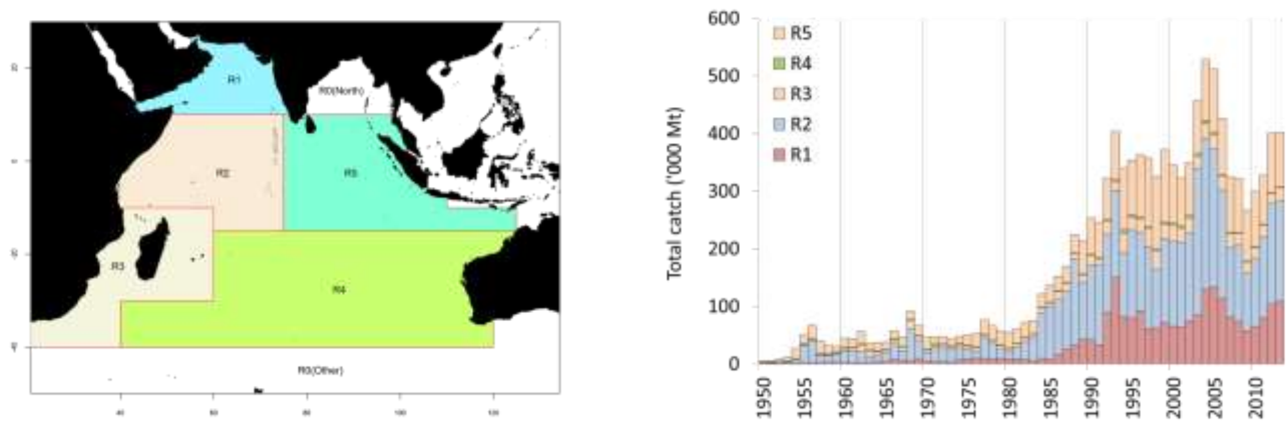


Fig. 3a, b. Yellowfin tuna: Catches of yellowfin tuna by area by year estimated for the WPTT (1950–2013). Data as of September 2014. Catches in areas R0 were assigned to the closest neighbouring area for the assessment. **Areas:** Arabian Sea (**R1**); Off Somalia (**R2**); Mozambique Channel, including southern (**R3**); South Indian Ocean including southern (**R4**); East Indian Ocean, including Bay of Bengal (**R5**).

The longline fishery (Table 4; Fig. 2) started in the early 1950's and expanded rapidly over throughout the Indian Ocean. 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. The longline fishery targets several tuna species in different parts of the Indian Ocean (Fig. 3), 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 (large scale deep-freezing longliners operating on the high seas from Japan, Rep. of Korea and Taiwan,China) and a fresh-tuna longline component (small to medium scale fresh tuna longliners from Indonesia and Taiwan,China) (Fig. 4).

The total longline catch of yellowfin tuna reached a maximum in 1993 (≈200,000 t). Catches between 1994 and 2004 fluctuated between 85,000 t and 130,000 t. The second highest catches of yellowfin tuna by longliners were recorded in 2005 (≈165,000 t). Similar to the trend for the purse seine fleets, since 2005 longline catches have declined with current catches estimated to be at around 60,000 t – more than a 60% decrease in catch levels compared to 2005. The recent drop in longline catches could be related, at least in part, with the expansion of piracy in the northwest Indian Ocean, which led to a marked drop in the levels of longline effort in one of the core fishing areas of the species (i.e., Area R2) (Fig. 3**)**.

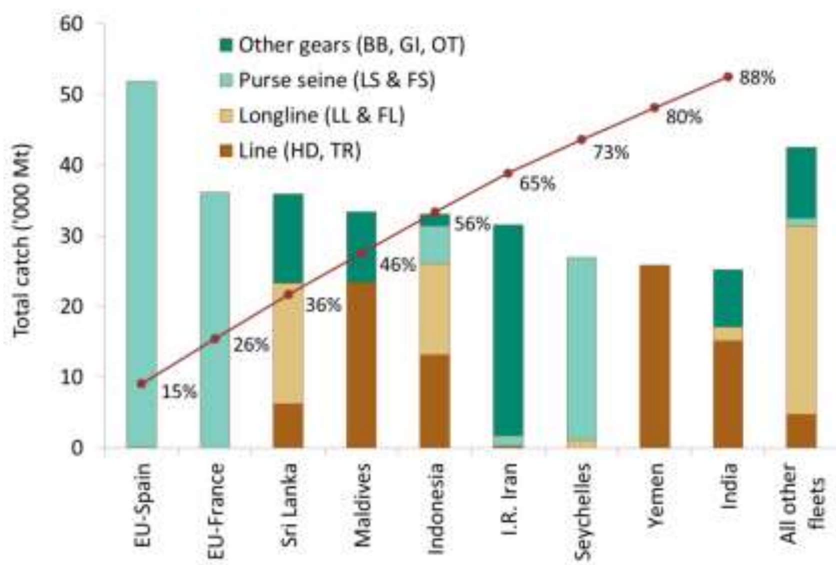


Fig. 4. Yellowfin tuna: average catches in the Indian Ocean over the period 2010–12, by fleet. Fleets are ordered from left to right, according to the importance of catches of yellowfin tuna reported. The red line indicates the (cumulative) proportion of catches of yellowfin tuna for the fleets concerned, over the total combined catches of this species reported from all fleets and fisheries. Data as of September 2014.

Catches by other gears, namely pole-and-line, gillnet, troll, hand line and other minor gears, have increased steadily since the 1980s (Table 4; Fig. 2). Contrary to the situation in other oceans, the artisanal fishery component of catches in the Indian Ocean are substantial, accounting for around 30% of the total catches of yellowfin tuna until the early 2000s. In recent years artisanal catches of yellowfin tuna have been around 135,000 t, increasing to over 200,000 t in 2012 and 2013 – more than half the total catches of yellowfin tuna in each of the last two years. Artisanal catches of yellowfin tuna are dominated by gillnets, with catches of around 50,000 t since 2011.

Purse seiners currently take the bulk of the yellowfin tuna catch, mostly from the western Indian Ocean, around Seychelles and off the coast of Somalia (area R2) and Mozambique Channel (area R3) (Tables 4, 5; Fig. 3). However in recent years the catches of yellowfin tuna in the western Indian Ocean have dropped considerably, especially in areas off Somalia, Kenya and Tanzania between 2007 and 2011 (Fig. 5). The drop in catches is, in part, the consequence of a drop in fishing effort due to the effect of piracy in the western Indian Ocean region – although the effects have not been as marked as with longliners. The main reason for this is the presence of security personnel onboard purse seine vessels of the EU and Seychelles, which has made it possible for purse seiners under these flags to continue operating in the northwest Indian Ocean. Longline effort levels in the western tropical area have also increased in 2012 and 2013, as a consequence of increased security in the region.

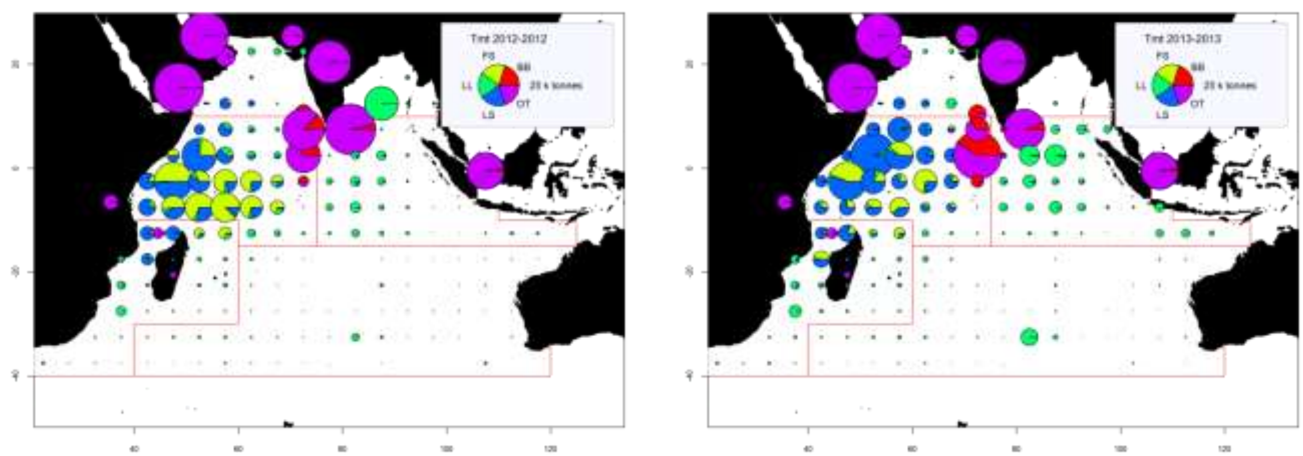


Fig. 5a, b. Yellowfin tuna: Time-area catches (total combined in tonnes) of yellowfin tuna estimated for the period 2004–08 by type of gear and for 2009–13, by year and type of gear. Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including drifting gillnets, and various coastal fisheries. Data as of September 2013. The 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: Status of Fisheries Statistics at the IOTC

Retained catches are generally well known (**Fig. 6a**); however, catches are less certain for:

- many coastal fisheries, notably those from Indonesia, Sri Lanka, Yemen, and Madagascar
- the gillnet fishery of Pakistan
- non-reporting industrial purse seiners and longliners (NEI), and longliners of India.

Discard levels are believed to be low although they are unknown for most industrial fisheries, excluding industrial purse seiners flagged in EU countries for the period 2003–2007.

CPUE Series: Catch-and-effort data are available from the major industrial and artisanal fisheries (**Fig. 6b**). However, these data are not available for some important fisheries or they 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 Iran and Pakistan

- the 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.

Trends in average weight (Figs. 6, 7, 8, 9, 10): Can be assessed for several industrial fisheries but they are very incomplete or of poor quality for some fisheries, namely hand lines (Yemen, Comoros, Madagascar), troll lines (Indonesia) and many gillnet fisheries.

Catch-at-Size table: This is available (**Fig. 6c**) 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, Iran, India, Indonesia, Malaysia).

Changes to the catch series: There have been no significant changes to the total catches of yellowfin tuna since the WPTT in 2013.

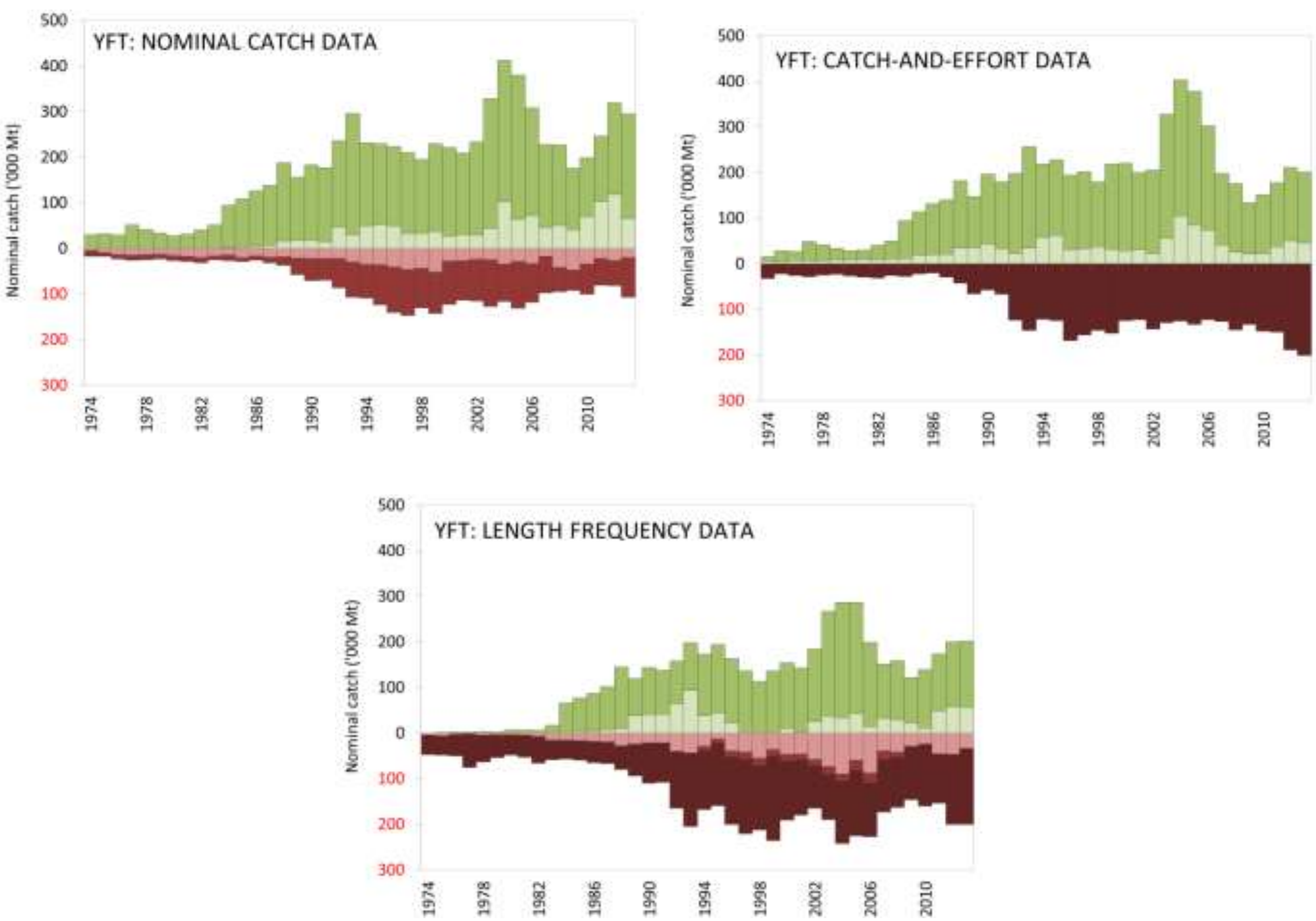


Fig. 6a-c. Yellowfin tuna: data reporting coverage (1974–2013). Each IOTC dataset (nominal catch, catch-and-effort, and length frequency) are assessed against IOTC reporting standards, where: a score of 0 indicates the amount of nominal catch associated with each dataset that is fully reported according 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 September 2014.

Key to IOTC Scoring system

Nominal Catch	By species	By gear
Fully available	0	0
Partially available (part of the catch not reported by species/gear)*	2	2
Fully estimated (by the IOTC Secretariat)	4	4

*Catch assigned by species/gear by the IOTC Secretariat; or 15% or more of the catches remain under aggregates of species

Catch-and-Effort	Time-period	Area
Available according to standards	0	0
Not available according to standards	2	2
Low coverage (less than 30% of total catch covered through logbooks)	2	
Not available at all	8	

Size frequency data	Time-period	Area
Available according to standards	0	0
Not available according to standards	2	2
Low coverage (less than 1 fish measured by metric ton of catch)	2	
Not available at all	8	

Key to colour coding

Total score is 0 (or average score is 0-1)
Total score is 2 (or average score is 1-3)
Total score is 4 (or average score is 3-5)
Total score is 6 (or average score is 5-7)
Total score is 8 (or average score is 7-8)

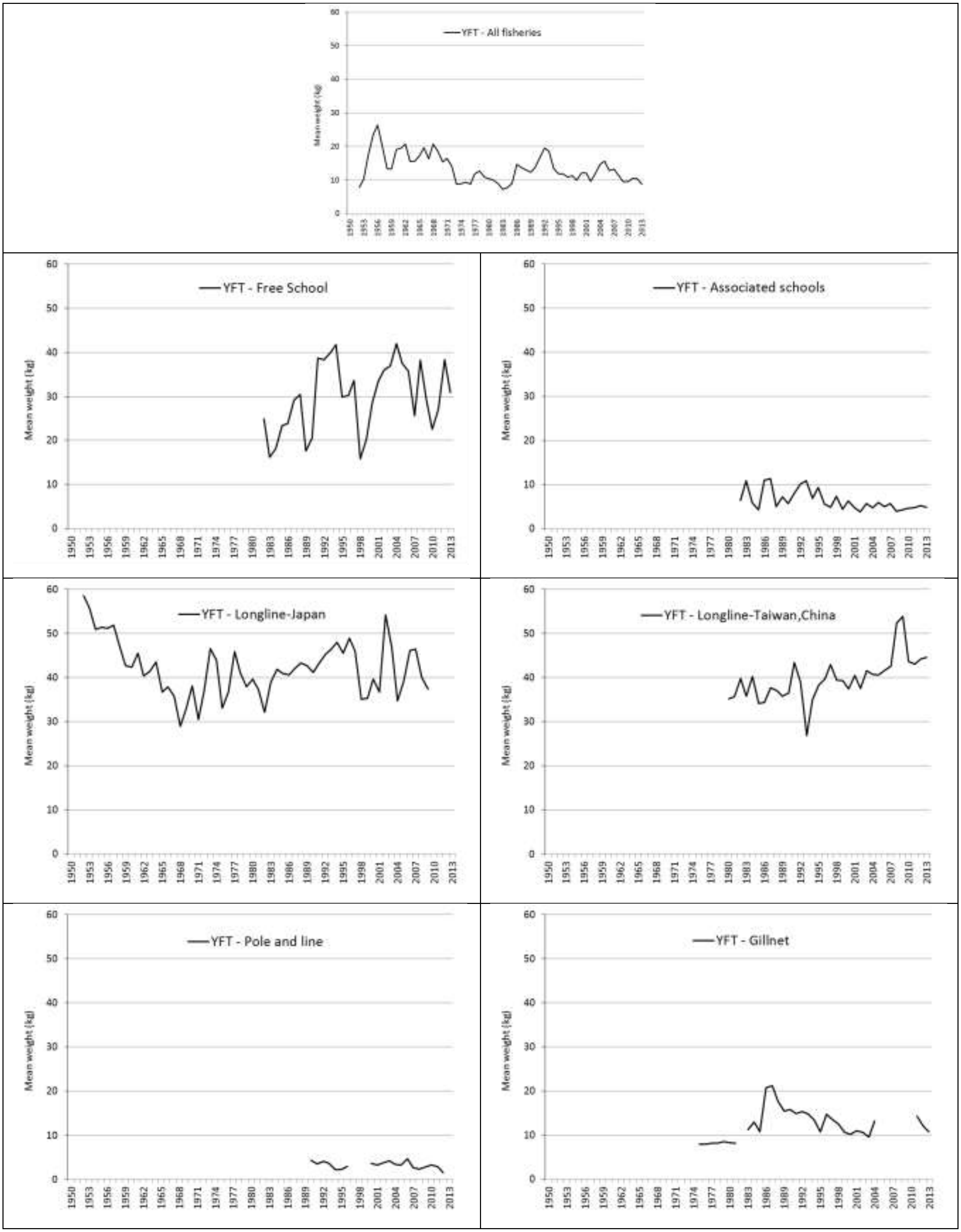
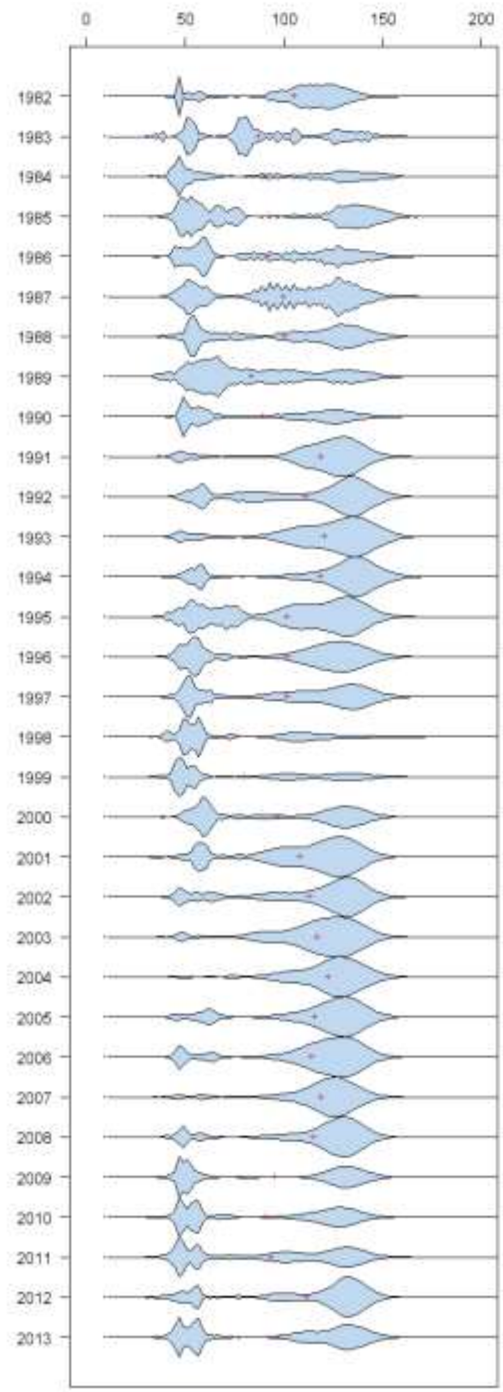


Fig. 7. Yellowfin tuna: Average weight of yellowfin tuna (YFT) taken by All fisheries combined (top), Purse seine on free (top left) and associated (top right) schools, Longlines from Japan (mid left) and Taiwan,China (mid right), Pole-and-line from Maldives and India (bottom left), Gillnets from Sri Lanka, Iran, and other countries (bottom right).

Yellowfin tuna (PS FS): size (in cm)



Yellowfin tuna (PS FS): no. of specimens ('000)
(raised to total catch)

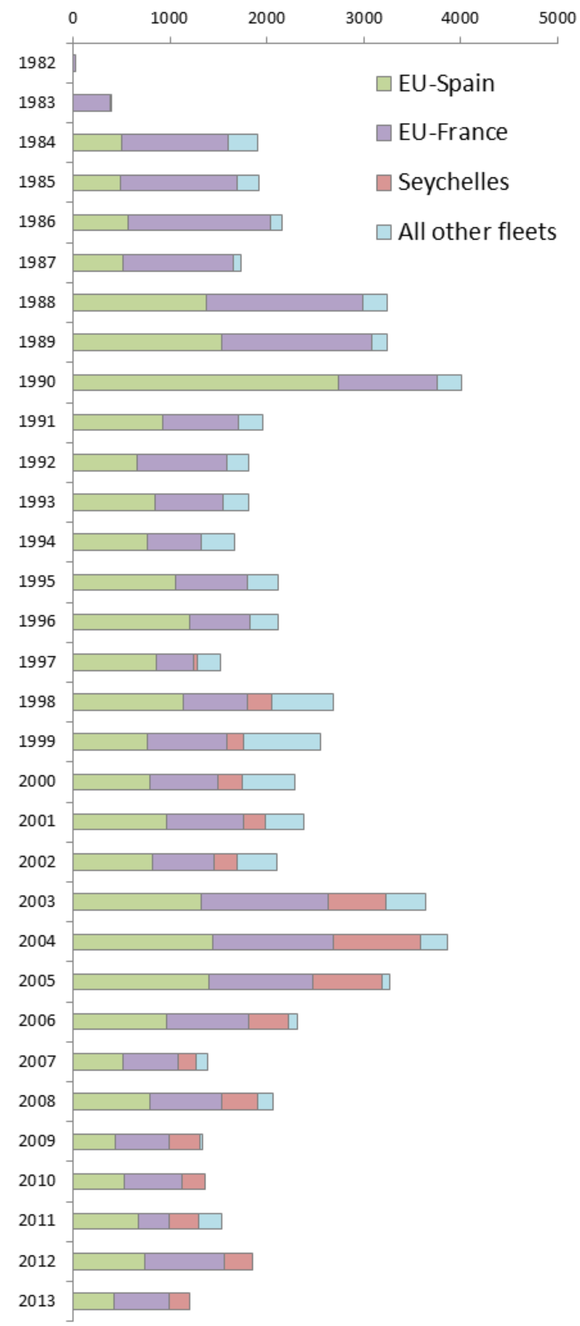
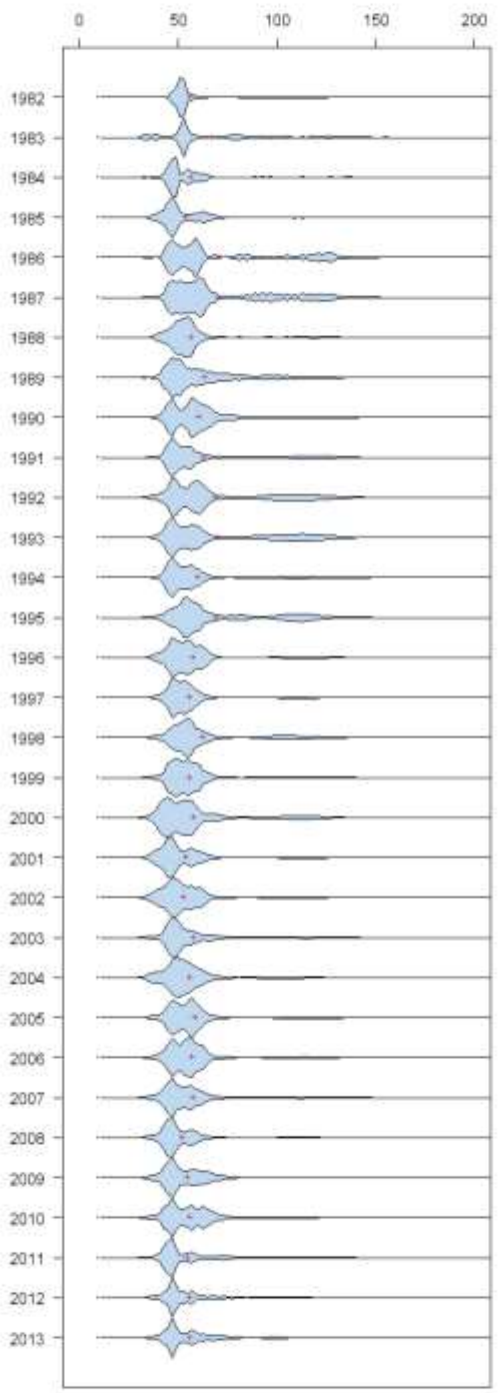


Fig. 8. Yellowfin tuna (PS Free school): **Left:** length frequency distributions for PS Free school fisheries (total amount of fish measured by 2 cm length class) derived from data available at the IOTC Secretariat. **Right**: Number of yellowfin tuna specimens sampled for lengths (raised to total catch),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

Yellowfin tuna (PS LS): size (in cm)



Yellowfin tuna (PS LS): no. of specimens ('000) (raised to total catch)

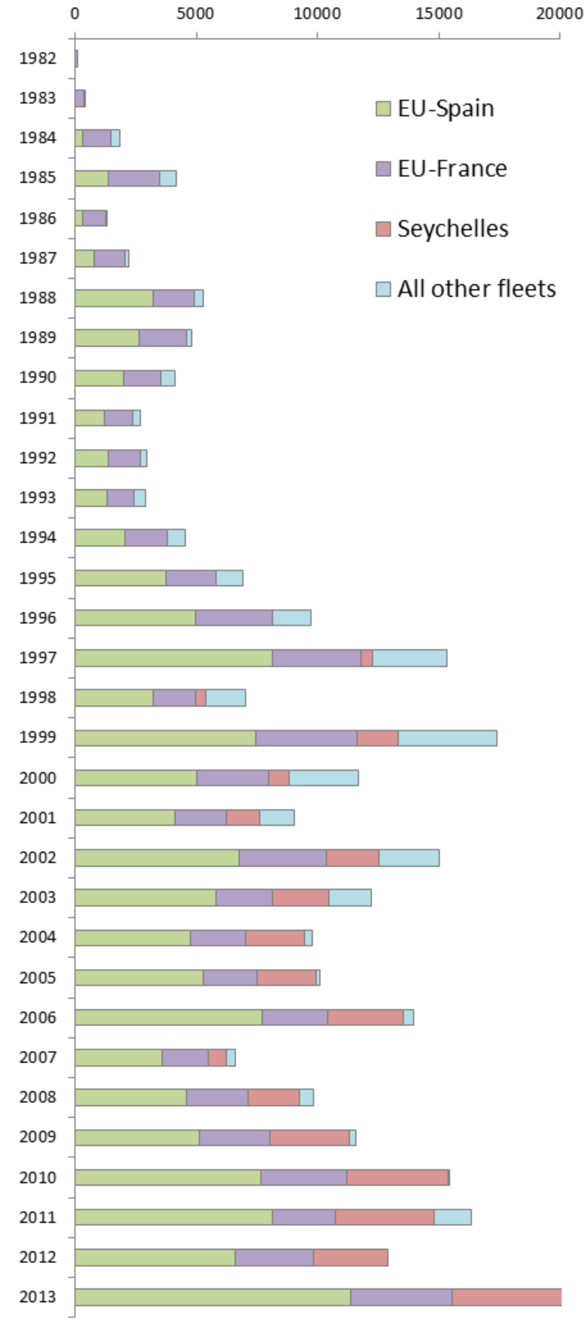


Fig. 9. Yellowfin tuna (PS Associated school): **Left:** length frequency distributions for PS Associated school fisheries (total amount of fish measured by 2 cm length class) derived from data available at the IOTC Secretariat. **Right**: Number of yellowfin tuna specimens sampled for lengths (raised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

Yellowfin tuna (LL samples): size (in cm) Yellowfin tuna (LL): no. of samples ('000)

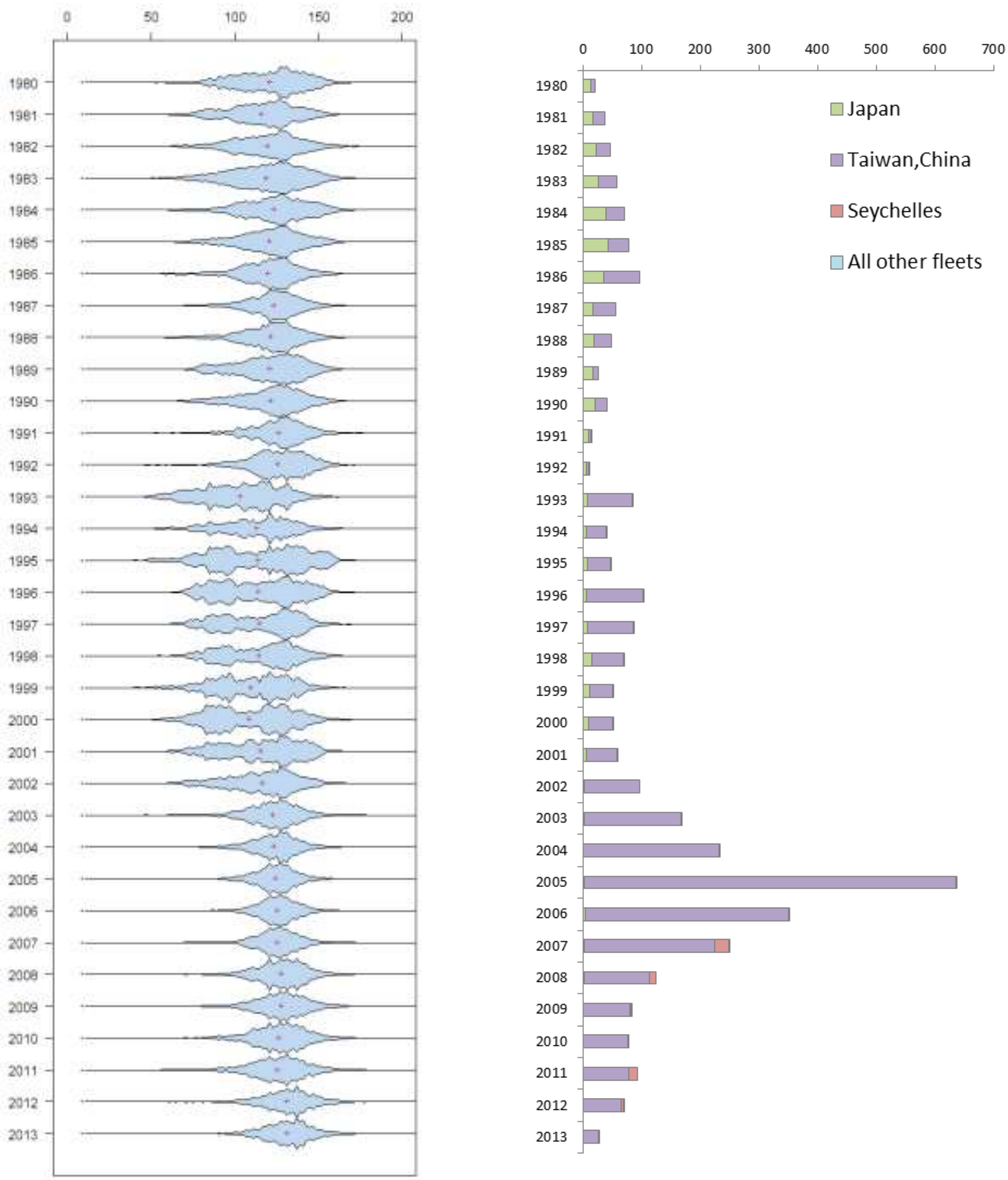


Fig. 10. Yellowfin tuna (longline: LL): **Left:** length frequency distributions for longline fisheries (total amount of fish measured by 2 cm length class) derived from data available at the IOTC Secretariat. **Right**: Number of yellowfin tuna specimens sampled for lengths, by fleet (longline only).

Yellowfin tuna: Effort trends

Total effort from longline vessels flagged to Japan, Taiwan,China and EU,Spain by five degree square grid in 2012 and 2013 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 2011 and 2012 are providedin Fig. 13. Effort data for 2013 has not yet been reported.

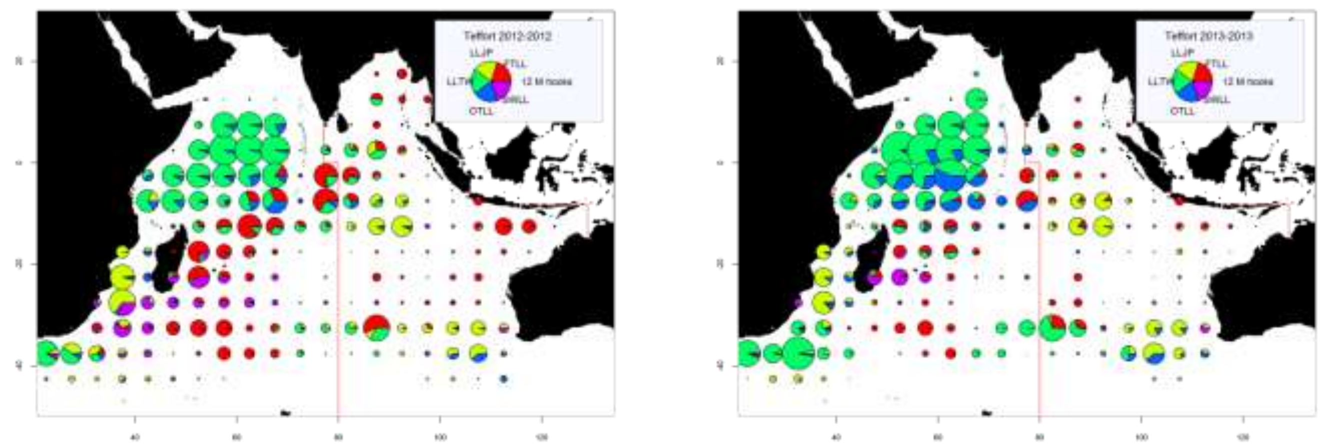


Fig. 11. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2012 (left) and 2013 (right) (Data as of September 2014).
LLJP (light green): deep-freezing longliners from Japan
LLTW (dark green): deep-freezing longliners from Taiwan,China
SWLL (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)

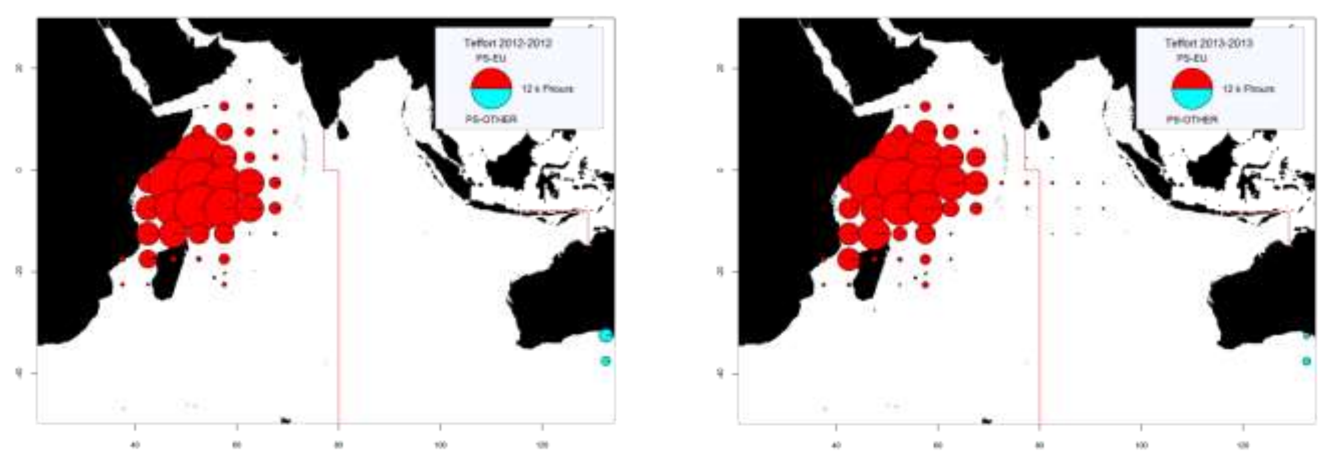


Fig. 12. Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2012 (left) and 2013 (right) (Data as of September 2014)
PS-EU (red): Industrial purse seiners monitored by the EU and Seychelles (operating under flags of EU countries, Seychelles 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)

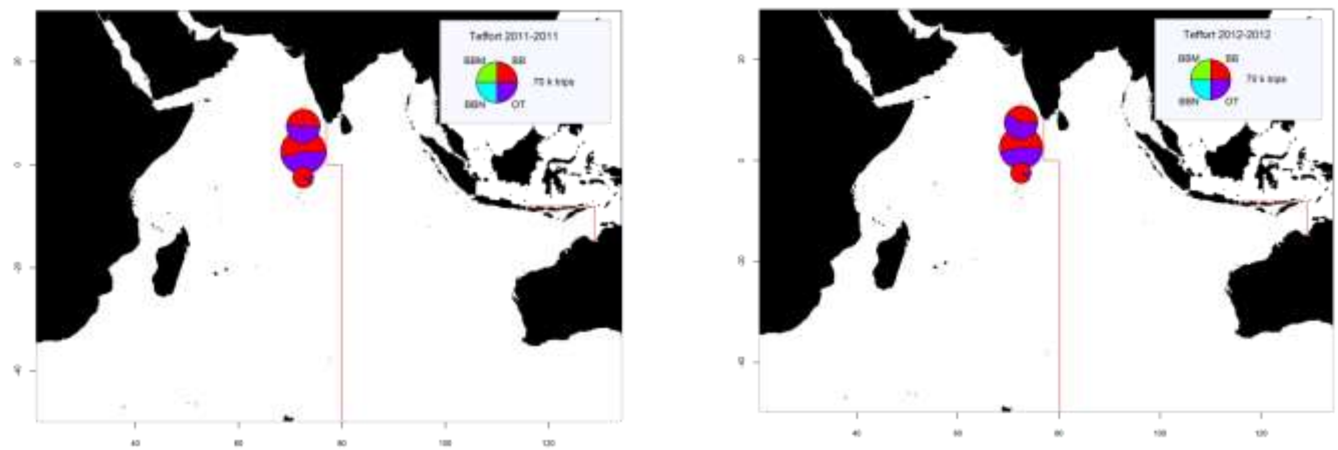


Fig. 13. Effort exerted by pole-and-line fleets in the Indian Ocean, in thousands (k) of trips (equivalent to fishing days), for the years 2011 (left) and 2012 (right) (Data as of September 2014). Note: Effort data for 2014 has not yet been reported. BBM (green): Pole-and-line (mechanized baitboats); 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

For the longline fisheries (LL fisheries in regions 1–5; Fig. 104, CPUE indices were derived using generalised linear models (GLM) from the Japan longline fleet (LL regions 2–5) and for the Taiwan,China longline fleet (LL region 1) to be used in the stock assessment. Standardised longline CPUE indices for the Taiwan,China fleet were available for 1979–2008. The GLM analysis used to standardise the Japan longline CPUE indices was refined for the 2011 and 2012 assessments to include a spatial (latitude*longitude) variable. The resulting CPUE indices were generally comparable to the indices derived from the previous model and were adopted as the principal CPUE indices for the 2012 assessment (Fig. 15). There is considerable uncertainty associated with the Japan CPUE indices for region 2 in the most recent year (2010) and no CPUE indices are available for region 1 for 2009–10.

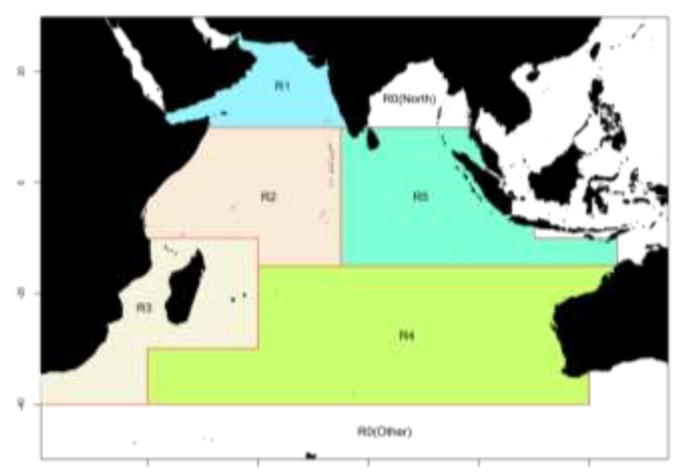


Fig. 14. Spatial stratification of the Indian Ocean for the MFCL assessment model carried out in 2012.

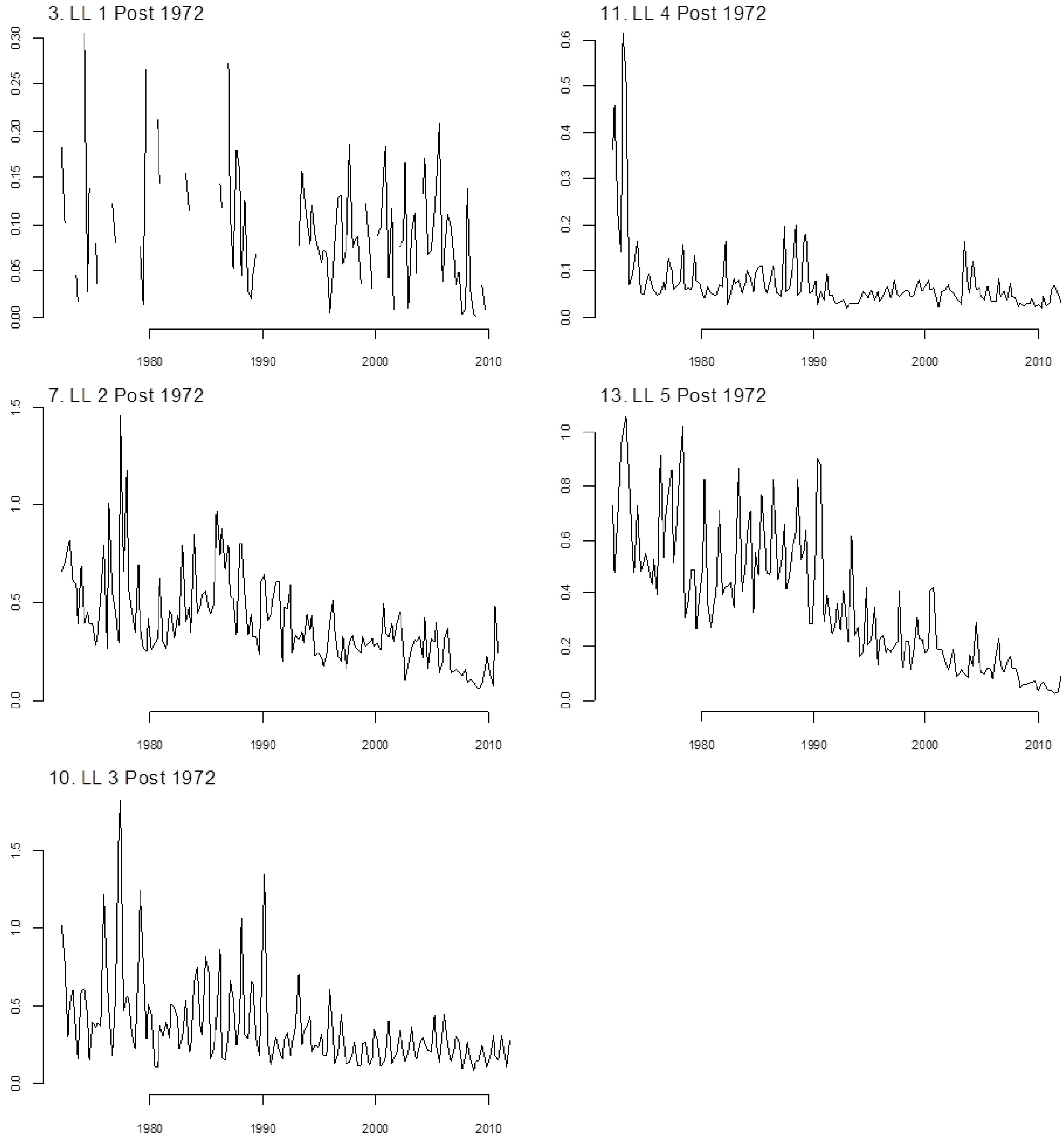


Fig. 15. Yellowfin tuna: Quarterly GLM standardised catch-per-unit-effort (CPUE) for the principal longline fisheries (LL 1 to 5) scaled by the respective region scalars.

In 2014, updated CPUE standardisations were presented for three of the main fleets as follows:

Japan – Catch-per-unit-of-effort (CPUE) from paper IOTC–2014–WPTT16–47 Rev_1 (Fig. 16) which provided the Japanese longline CPUE for yellowfin tuna in the Indian Ocean up to 2013 standardised by generalized linear model.

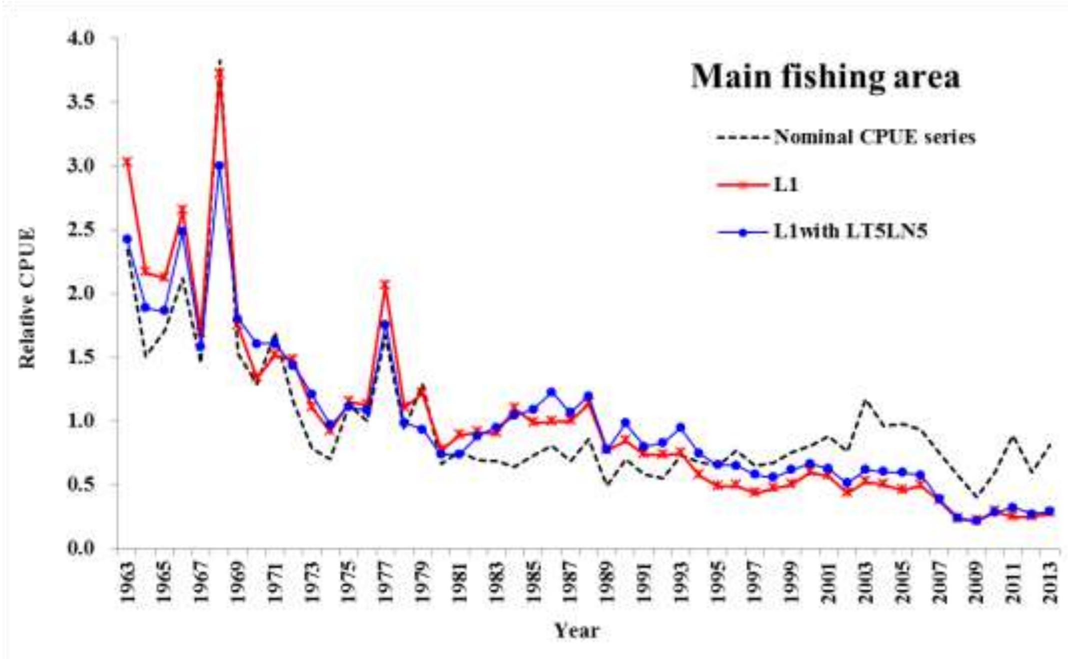


Fig. 16. Comparison of annual based area aggregated CPUE between the models with the effect of subarea and LT5LN5, standardized for whole fishing grounds expressed in relative scale overlaid with nominal CPUE. Series have been rescaled relative to their respective means from 1963–2013.

Rep. of Korea – Catch-per-unit-of-effort (CPUE) from paper IOTC–2014–WPTT16–49 (Fig. 17) which provided the CPUE standardisation of yellowfin tuna caught by Rep. of Korea tuna longline fishery in the Indian Ocean.

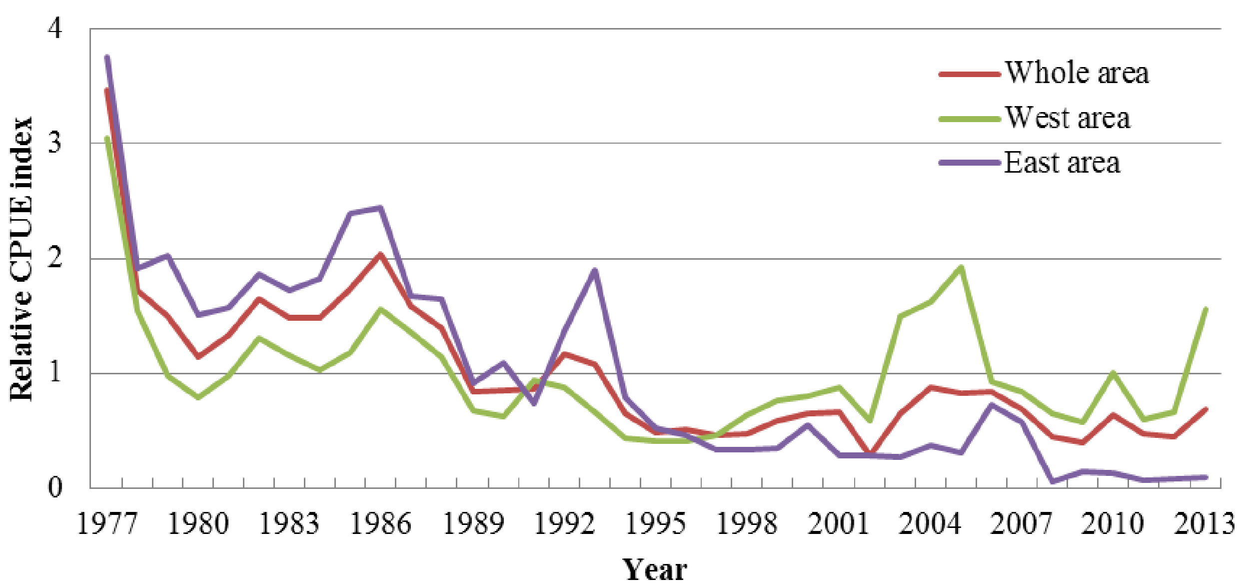


Fig. 17. Yellowfin tuna: Comparison of the standardised longline CPUE series for the Rep. of Korea. Series have been rescaled relative to their respective means from 1977–2013.

Taiwan,China longline CPUE comparison for bigeye tuna and yellowfin tuna from paper IOTC–2014–WPTT16–55 (Fig. 18) which detailed an analysis of Taiwna,China longline fisheries based on operational catch and effort data for bigeye tuna and yellowfin tuna in the Indian Ocean from 1979 to 2013.

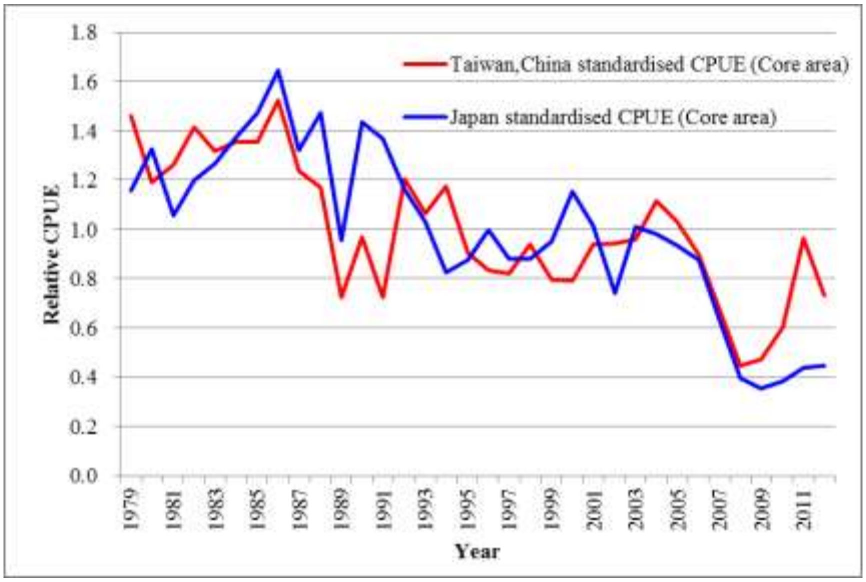


Fig. 18. Yellowfin tuna: Comparison of the standardised longline CPUE series (by area) for Taiwan,China. Series have been rescaled relative to their respective means from 1979–2013.

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. 19). 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, 10,834 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.

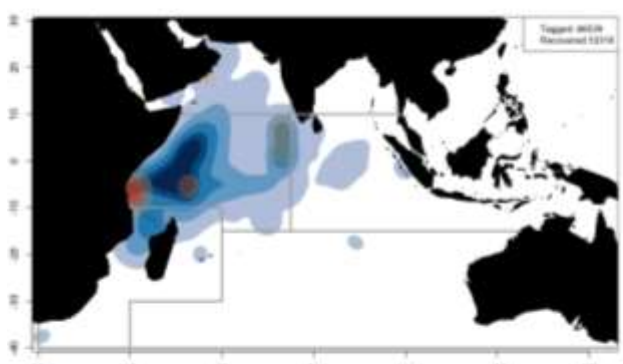


Fig. 19. Yellowfin tuna: Densities of releases (in red) and recoveries (in blue). The red line represents the stock assessment areas (Data as of September 2012).

STOCK ASSESSMENT

As no formal stock assessment was carried out in 2014, the management advice for yellowfin tuna was based on the 2012 MFCL stock assessment (based upon the base case analysis with short term recruitment with alternative steepness of the stock-recruitment relationship of 0.7, 0.8 and 0.9), the ASPM based case using steepness of 0.9, and current catch and effort trends presented at the current meeting. A major limitation of the ASPM model is that it is not spatially structured and thus does not allow the internal incorporation of tagging data, although it does externally by using the improved catch-at-age table and natural mortality estimates based on tagging data.

A range of quantitative modelling methods were applied to the yellowfin tuna assessment in 2012, ranging from the non-spatial, age-structured production model (ASPM) to the age and spatially-structured MULTIFAN-CL and SS3 analysis. The different assessments were presented to the WPTT in documents IOTC–2012–WPTT14–38, 39 and 40 Rev_2.

The following is worth noting with respect to the MFCL (MULTIFAN-CL) modelling and estimation approach used in 2012:

- The main features of the model in the 2012 assessment included a fixed growth curve (with variance) with an inflection, an age-specific natural mortality rate profile (M), the modelling of 25 fisheries including the separation of two purse seine fisheries into three time blocks, using logistic and cubic spline functions to estimate longline selectivities, separation of the analysis into five regions of the Indian Ocean as well as the three steepness parameters for the stock recruitment relationship (h=0.7, 0.8 and 0.9).
- In addition to another year of data, the 2012 assessment included several changes to the previous assessment: the longline CPUE indices were modified (Japanese updated with latest year which included information about latitude and longitude in the standardisation process for Regions 2–5 was supplied except for Region 2 in 2011; no update was available for the Taiwan,China index for Region 1; All of the analyses were conducted using a new version of MFCL provided by the Secretariat of the Pacific Community.

The problems identified in the catch data from some fisheries, and especially on the length frequencies in the catches of various fleets, a very important source of information for stock assessments. Length frequency data is almost unavailable for some fleets, while in other cases sample sizes are too low to reliably document changes in abundance and selectivity by age. Moreover, in general, catch data from some coastal fisheries is considered as poor.

The results of the MFCL model were studied in detail to improve the understanding of the estimated population dynamics and address specific properties of the model that were inconsistent with the general understanding of the yellowfin tuna stock and fisheries. The main issues identified are as follows:

- The model estimates a strong temporal decline in recruitment and in biomass within the eastern equatorial region (Region 5). This declining trend in recruitment is driven by the decline in the Japanese longline CPUE indices over the model period. There are limited data to reliably estimate recruitment in the region as the size data included in the model are considered uninformative. Consequently, the resulting recruitment and biomass trends may be unreliable. A participant noted that during this period the Taiwan,China longline fleet, a fleet more active than the Japanese longline fleet in this area, showed a stable nominal CPUE trend and high stable catches.
- The model estimates limited movement between the two equatorial regions. This is consistent with the low number of tag recoveries from the eastern equatorial region, an area from where recovery rates are difficult to estimate but probably low. Nonetheless, the low movement rate is consistent with the oceanographic conditions that prevailed during the main tag recovery period (see papers IOTC–2012–WPTT14–9 and 31). The model assumes a constant movement pattern throughout the model period and estimated movement pattern may not persist under different oceanographic conditions.
- Similarly, movement rates between the western equatorial region and the Arabian Sea (Region 1) were estimated to be very low. Although various recoveries crossing the border limit of 10°N line in both directions may suggest a higher mixing rate, the observation is consistent with the tag release/recovery observations (few tag releases from Region 2 were recovered in Region 1 and vice versa). However, reporting rates of most fisheries operating in Region 1 are estimated to be low and this may underestimate the low mixing rate observed by the model.
- The model estimated that fishing mortality rates within the western equatorial region did not increase during 2002–2006 period to the extent that would be anticipated given the large increase in catch from the purse seine fishery during that period (on average 470,000 t: well above all estimated MSY values). The large increase of catch, previously described due mainly to a catchability increased, will suggest an expected corresponding increase in fishing mortality well above the level of F_{MSY}. The explanation for this is that the longline standardised CPUE remained relatively constant during the period of high purse seine catch and in the subsequent years. To fit to the longline CPUE indices during this period the model increases the level of recruitment in the period that precedes the high purse seine catches which may be considered unreliable. This recruitment pattern was evident in all model options. However, further examination of the size frequency data is warranted to confirm that this recruitment trend is consistent with the other fisheries data. The status of the yellowfin tuna stock assessed by the model during the period of very high catches (2003–2006), estimated to be in the middle of the green area of the Kobe plot, was questioned by some participants.

The final base model option for the 2012 assessment incorporated the 5–region spatial structure, full selectivity of the older age classes by the longline fishery and estimated (average) natural mortality within the MFCL model, and a period of 4 quarter for tag mixing. For sensitivity analysis, a tag mixing period of 2 quarters was also analysed. In both cases three values of steepness (0.7, 0.8 and 0.9) were considered plausible. The estimated level of natural mortality was considerably higher than the level of natural mortality assumed in previous assessments. However, the estimated level of natural mortality was generally consistent with an external analysis of the tag release/recovery data (IOTC–2012–WPTT14–32), especially for younger ages, and with levels of natural mortality assumed for the assessment of yellowfin tuna by other RFMOs.

Biomass was estimated to have declined to about the B_{MSY} level, while fishing mortality rates had remained well below the F_{MSY} level. The base model estimated recent (1997–2011) recruitment levels that were considerably lower (approximately 25%) than the long term level of recruitment. This resulted in an apparent inconsistency between the annual trend in MSY based fishing mortality and biomass reference points and the observed catch trajectory. Biomass was estimated to have declined to about the B_{MSY} level, while fishing mortality rates had remained well below the F_{MSY} level. This pattern was evident for the range of steepness values considered for the stock-recruitment relationship. The recruitment trend may be an artefact of the model as there are limited data to reliably estimate the time series of recruitment and, hence, the model has considerable freedom to estimate recruitments to account for the observed decline in the longline CPUE abundance trend. The resulting estimates of MSY (380,000–450,000 t) are considerably higher than levels of catch sustained from the fishery and are considered to be overly optimistic. Similarly, the corresponding estimates of stock status are considered to be highly uncertain or unreliable.

It is considered more appropriate to formulate stock status advice based on the more recent period of recruitment on the basis that the level of recruitment from the early period is highly uncertain and that, at least in the short-term, recruitment would be more likely to be in line with recent levels. Estimating the stock status based on the recent (average 1997–2011) recruitment level resulted in lower MSY values, levels of fishing mortality that were comparable to the base model, and a more optimistic level of biomass relative to B_{MSY}.

The potential yield from the stock from different harvesting patterns was investigated by comparing alternative age specific patterns of fishing mortality that corresponded to the estimated selectivity of the main fisheries. A shift in the strategy to exclusively harvest the stock by longline or free-school purse seine would result in a substantial increase (50%) in the overall yield from the fishery relative to current yields. Conversely, a harvest pattern consistent with the purse seine FAD based fishery would result in a large (42%) reduction in overall yields. A shift to a gillnet based harvest pattern had a neutral effect relative to current yield. This analysis simply illustrates the relative yield per recruit of the individual fisheries, however, the results are theoretical and do not consider the complex nature of the operation of this multi-gear/multi-species fishery or the practicalities of substantially changing the harvest pattern.

Table 6. Key management quantities from the MFCL assessment, for the agreed scenarios of yellowfin tuna in the Indian Ocean. The range values represent the point estimates of different scenarios analysis (6 scenarios showing long term and short term recruitment with three values of steepness as well as the sensitivity analysis with 2 quarter for tag mixing, long- and short term recruitment and 0.8 value of steepness). The range is described by the range values between those scenarios.

Management Quantity	**Indian Ocean**
2013 catch estimate	402,084 t
Mean catch from 2009–2013	339,359 t
MSY	344,000 t (290,000–453,000 t)
Data period used in assessment	1972–2011
F_{2010}/F_{MSY}	0.69 (0.59–0.90)
B_{2010}/B_{MSY}	1.28 (0.97–0.1.38)
SB_{2010}/SB_{MSY}	1.24 (0.91–1.40)
B_{2010}/B_0	n.a.
SB_{2010}/SB_0	0.38 (0.28–0.38)
$B_{2010}/B_{0,\ F=0}$	n.a.
$SB_{2010}/SB_{0,\ F=0}$	n.a.

Literature Cited

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