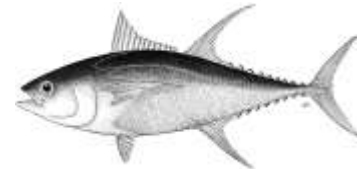


**DRAFT: EXECUTIVE SUMMARY: YELLOWFIN TUNA****Status of the Indian Ocean yellowfin tuna (YFT: *Thunnus albacares*) resource****TABLE 1. Yellowfin tuna:** Status of yellowfin tuna (*Thunnus albacares*) in the Indian Ocean

Area <sup>1</sup>	Indicators			2013 stock status determination
Indian Ocean	Catch 2012:	368,663 t		
	Average catch 2008–2012:	317,505 t		
MSY (1000 t):	Multifan	ASPM		
$F_{2010}/F_{MSY}$ :	344 t (290–453 t)	320 (283–358 t)		
$SB_{2010}/SB_{MSY}$ :	0.69 (0.59–0.90)	0.61 (0.31–0.91)		
$SB_{2010}/SB_0$ :	1.24 (0.91–1.40)	1.35 (0.96–1.74)		
	0.38 (0.28–0.38)	-		

<sup>1</sup>Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.

Colour key	Stock overfished ( $SB_{year}/SB_{MSY} < 1$ )	Stock not overfished ( $SB_{year}/SB_{MSY} \geq 1$ )
Stock subject to overfishing ( $F_{year}/F_{MSY} > 1$ )		
Stock not subject to overfishing ( $F_{year}/F_{MSY} \leq 1$ )		

**INDIAN OCEAN STOCK – MANAGEMENT ADVICE**

**Stock status.** No new stock assessment was carried out for yellowfin tuna in 2013. Previous stock assessment model results (2012) did not differ substantively from the previous (2011) assessment; 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). The stock assessment model used in 2012 suggests that the stock is currently **not overfished** ( $SB_{2010} > SB_{MSY}$ ) and **not subject to overfishing** ( $F_{2010} < F_{MSY}$ ) (Table 1 and Fig. 1). 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 368,663 t landed in 2012, a value over previous MSY estimates (344,000 t; Table 1), in comparison to 327,490 t in 2011 and 300,000 t in 2010. 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. If the provisional catch estimate for 2013 confirms the increasing trend, it may be necessary to carry out a new stock assessment in 2014.

The following key points should be noted:

- The Maximum Sustainable Yield 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 and 2012.
- 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.

However, although recent recruitment estimated by ASPM is similar to MFCL estimates, the ASPM recruitment trend is estimated to be at a lower level without any declining trend.

- Provisional reference points: Noting that the Commission in 2012 agreed to Recommendation 12/14 *on interim target and limit reference points*, 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).

**Outlook (Based on MultifanCL).** The potential yields from the fishery have also declined over the last five years as an increased proportion of the catch is comprised of smaller fish, primarily from the purse seine FAD fishery. The main mechanism that appears to be behind the very high catches in the 2003–2006 period is an increase in catchability by surface and longline fleets due to a high level of concentration across a reduced area and depth range. This was likely linked to the oceanographic conditions at the time generating high concentrations of suitable prey items that yellowfin tuna exploited. A possible increase in recruitment in previous years, and thus in abundance, cannot be completely ruled out, but no signal of it is apparent in either data or model results. This means that those catches probably resulted in considerable stock depletion.

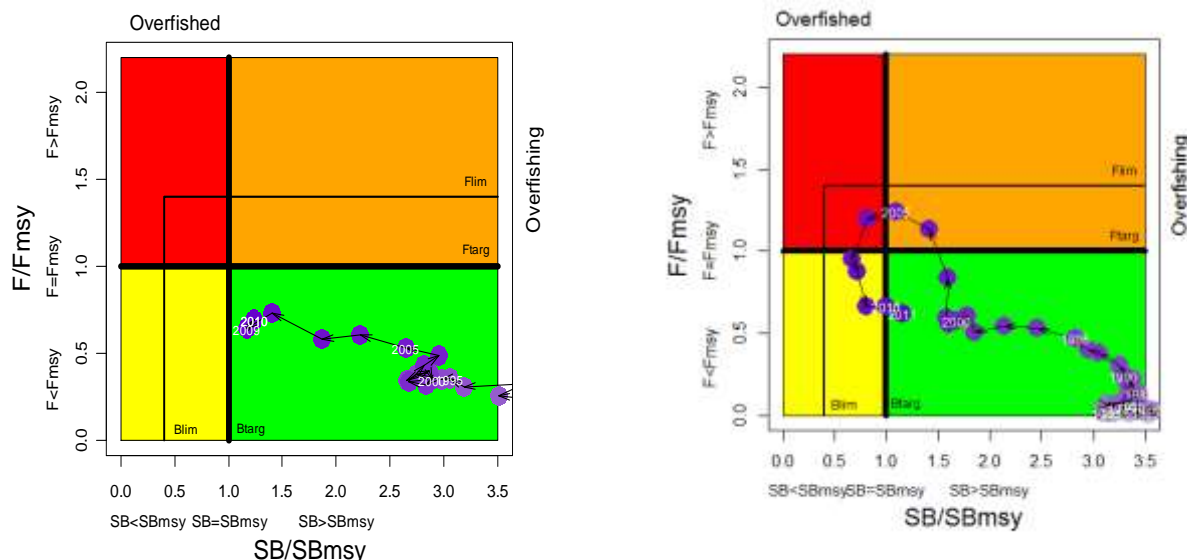
In an attempt to provide management advice independent of the MSY construct, the recent levels of absolute fishing mortality estimated from region 2 were compared to the natural mortality level. It is considered that the tagging data provides a reasonable estimate to fishing mortality for the main tag recovery period (2007–09). The estimates of fishing mortality for the main age classes harvested by the purse-seine fishery are considerably lower than the corresponding levels of natural mortality and on that basis, recent fishing mortality levels are not considered to be excessive.

The decrease in longline and purse seiner 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 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. Catches in 2010 (300,000 t) are within the lower range of MSY values. The current assessment indicates that catches of about the 2010 level are sustainable, at least in the short term. However, the stock is unlikely to support substantively higher yields based on the estimated levels of recruitment from over the last 15 years.

In 2011, the WPTT undertook projections of yellowfin tuna stock status under a range of management scenarios for the first time, following the recommendation of both the Kobe process and the Commission, to harmonise technical advice to managers across RFMOs by producing Kobe II management strategy matrices. The purpose of the table is to quantify the future outcomes from a range of management options (Table 2). The table describes the presently estimated probability of the population being outside biological reference points at some point in the future, where “outside” was assigned the default definitions of  $F > F_{MSY}$  or  $SB < SB_{MSY}$ . The timeframes represent 3 and 10 year projections (from the last data in the model), which corresponds to predictions for 2013 and 2020. The management options represent three different levels of constant catch projection: catches 20% less than 2010, equal to 2010 and 20% greater than 2010.

The projections were carried out using 12 different scenarios based on similar scenarios used in the assessment for the combination of those different MFCL runs: 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 (12 scenarios). 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 characterization is not complete; however, the WPTT feels that the projections may provide a relative ranking of different scenarios outcomes. The WPTT recognised at this time that the matrices do not represent the full range of uncertainty from the assessments. Therefore, the inclusion of the K2SM at this time is primarily intended to familiarise the Commission with the format and method of presenting management advice.



**Fig. 1.** Yellowfin tuna: MULTIFAN-CL Indian Ocean yellowfin tuna stock assessment Kobe plot. 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,  $\pm 20\%$  and  $\pm 40\%$ ) 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 2010) and probability (%) of violating reference point				
	60% (165,600 t)	80% (220,800 t)	100% (276,000 t)	120% (331,200 t)	140% (386,400 t)
$SB_{2013} < SB_{MSY}$	<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

## 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 13/03 on the recording of catch and effort by fishing vessels in the IOTC area of competence
- Resolution 13/07 concerning a record of licensed foreign vessels fishing for IOTC species in the IOTC area of competence and access agreement information
- 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 12/13 for the conservation and management of tropical tunas stocks in the IOTC area of competence.

- 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 by gear, area, country and year from 1950 to 2012 are shown in Tables 4, 5; Figs. 2, 3, 4, and 5. Contrary to the situation in other oceans, the artisanal fishery component in the Indian Ocean is substantial, taking 20–30% of the total catch. 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 longline vessels and, to a lesser extent, gillnet vessels. 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) and average annual catch for the period at around 480,000 t. Yellowfin tuna catches dropped markedly after 2006, with the lowest catches recorded in 2009. Catch levels in 2012 are estimated to be at around 370,000 t, although they represent preliminary figures.

**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 (2003–2012), in tonnes (Data as of September 2013). Catches by decade represent the average annual catch, noting that some gears were not used since the beginning of the fishery (refer to Fig. 2).

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
FS	-	-	18	31,561	64,974	89,377	136,881	168,392	123,998	85,044	53,526	74,985	36,049	32,135	36,453	64,593
LS	-	-	17	17,610	56,275	61,719	87,015	59,655	69,878	74,612	43,778	41,546	51,351	73,383	76,659	66,166
LL	21,990	41,250	29,493	34,090	71,557	70,227	70,225	99,768	130,993	88,365	65,490	39,354	36,552	37,073	33,957	40,756
LF	-	-	615	4,286	47,571	34,150	31,162	32,938	35,949	31,752	33,302	34,342	23,125	21,501	21,267	23,366
BB	2,111	2,318	5,810	8,295	12,805	16,061	17,277	15,876	16,734	18,017	16,268	18,326	16,819	14,105	14,016	15,386
GI	1,572	4,116	7,838	11,899	39,421	49,388	53,769	74,160	61,257	62,601	43,412	48,011	42,822	50,772	50,448	59,902
HD	728	1,779	4,772	11,488	26,073	42,737	43,768	52,447	47,288	40,898	40,961	41,163	37,160	43,398	66,347	70,797
TR	1,102	1,981	4,335	6,946	11,628	16,124	12,979	20,929	16,793	18,235	19,715	18,814	16,822	19,968	20,424	21,444
OT	80	193	453	1,844	3,318	5,055	4,012	4,631	4,220	5,294	5,897	7,060	7,071	7,665	7,919	6,253
<b>Total</b>	<b>27,583</b>	<b>51,637</b>	<b>53,351</b>	<b>128,019</b>	<b>333,622</b>	<b>384,838</b>	<b>457,089</b>	<b>528,797</b>	<b>507,111</b>	<b>424,819</b>	<b>322,349</b>	<b>323,602</b>	<b>267,771</b>	<b>300,000</b>	<b>327,490</b>	<b>368,663</b>

**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 (2003–2012), in tonnes (Data as of September 2013). Catches by decade represent the average annual catch. The areas are presented in Fig. 4a.

Area / Region	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
R1	2,146	4,715	6,951	16,783	74,549	86,730	82,305	125,641	129,465	108,572	80,564	74,481	59,642	65,334	77,905	89,020
R2	11,226	23,066	21,208	71,695	138,278	180,825	262,313	271,608	248,766	199,399	128,041	137,320	104,423	124,456	146,643	178,394
R3	844	7,516	5,892	9,592	23,974	24,750	22,968	27,389	25,591	24,770	24,617	21,297	20,063	19,565	20,159	19,365
R4	917	1,785	1,415	1,257	8,298	6,244	10,032	9,079	7,121	4,485	1,682	1,755	1,438	1,981	1,123	3,087
R5	11,253	13,226	16,074	22,606	67,947	61,369	54,882	69,154	65,387	67,863	62,446	57,492	66,764	62,458	57,007	57,978
R0 (North)	1,195	1,305	1,796	6,053	20,533	24,896	24,554	25,898	30,730	19,726	24,996	31,253	15,433	26,196	24,639	20,817
R0 (Other)	1	24	15	32	43	24	34	29	51	5	2	5	7	10	13	2
<b>Total</b>	<b>27,583</b>	<b>51,637</b>	<b>53,351</b>	<b>128,019</b>	<b>333,622</b>	<b>384,838</b>	<b>457,089</b>	<b>528,797</b>	<b>507,111</b>	<b>424,819</b>	<b>322,349</b>	<b>323,602</b>	<b>267,771</b>	<b>300,000</b>	<b>327,490</b>	<b>368,663</b>

**Areas:** Arabian Sea (R1); Off Somalia (R2); Mozambique Channel (R3); South Indian Ocean (R4); East Indian Ocean (R5); Bay of Bengal (R0(North)); Other Area (R0(Other))

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 made of adult fish, as opposed to bigeye tuna catches, of which the majority refers to juvenile fish. Purse seine vessels typically take fish ranging from 40 to 140 cm fork length (FL) and smaller fish are more common in the catches taken north of the equator. Catches of yellowfin tuna increased rapidly to around 130,000 t in 1993, and subsequently they fluctuated around that level, until 2003–05 when they were substantially higher (over or close to 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.

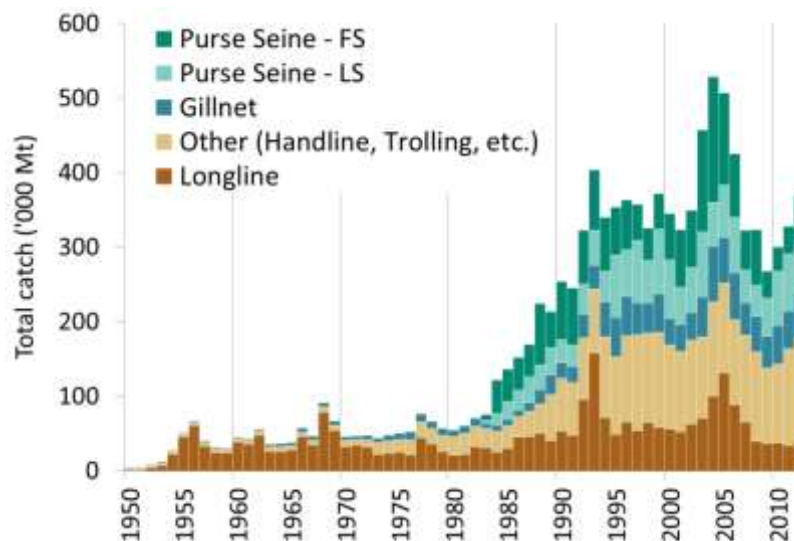
The purse seine fishery is characterised by the use of two different fishing modes (Table 4; Figs. 2, 3 and 5). The fishery on floating objects (FADs), catches large numbers of small yellowfin tuna in association with skipjack tuna and juvenile bigeye tuna, and a fishery on free swimming schools, catches 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%).

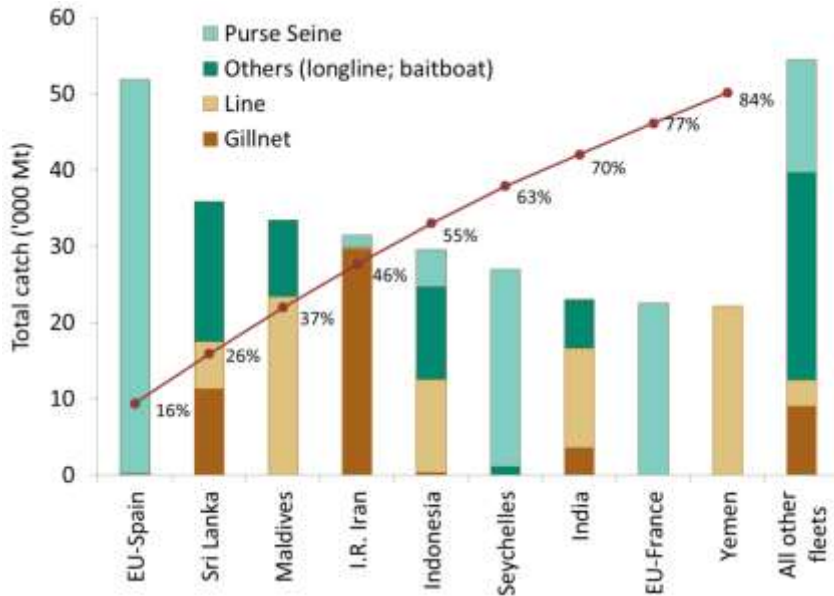
The longline fishery (Table 4; Fig. 2) started in the early 1950's and expanded rapidly over throughout the Indian Ocean. Longline vessels mainly catch large fish, from 80 to 160 cm FL, although smaller fish in the size range 60 cm – 100 cm (FL) have been taken by longliners from Taiwan,China since 1989 in the Arabian Sea. The longline fishery targets several tuna species in different parts of the Indian Ocean, 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, Korea and Taiwan,China) and a fresh-tuna longline component (small to medium scale fresh tuna longliners from Indonesia and Taiwan,China). The total longline catch of yellowfin tuna reached a maximum in 1993 ( $\approx 200,000$  t). Catches between 1994 and 2004 fluctuated between 85,000 t and 130,000 t. The second highest catches of yellowfin tuna by longline vessels were recorded in 2005 ( $\approx 165,000$  t). As was the case for the purse seine fleets, since 2005 longline catches have declined with current catches estimated to be at around 60,000 t, representing a two-fold decrease from the catches taken in 2005. The Scientific Committee believes that 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 (Fig. 5).

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). In recent years the total artisanal yellowfin tuna catch has been around 140,000–160,000 t, with the catch by gillnets (the dominant artisanal gear) at around 50,000 t. During the years 2004 and then in 2012 the catches by artisanal gears attained its maximum over the time series, peaking at 165,000 t and 170,000 t, respectively.

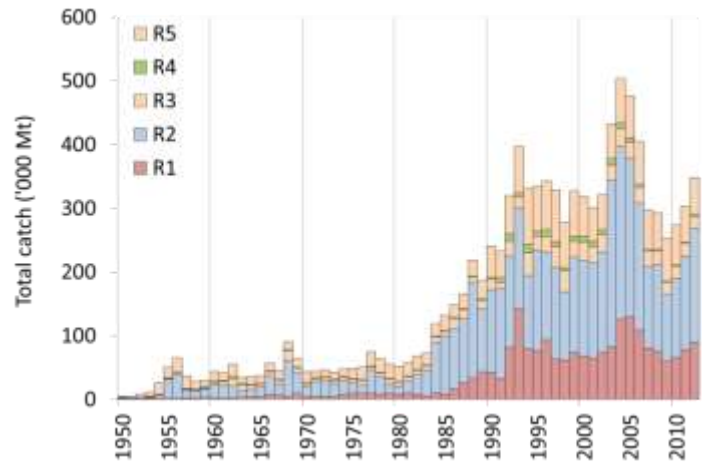
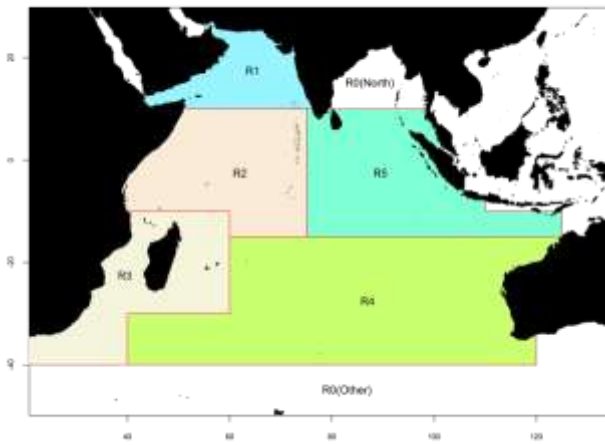
Yellowfin tuna catches in the Indian Ocean during 2003, 2004, 2005 and 2006 were much higher than in previous years (Fig. 2), while bigeye tuna catches remained at their average levels. Purse seine vessels currently take the bulk of the yellowfin tuna catch, mostly from the western Indian Ocean, around Seychelles (Tables 4, 5; Fig. 5; Off Somalia (R2) and Mozambique Channel (R3) (Figs. 4, 5). In 2003 and 2004, total catches by purse seine vessels in this area were around 225,000 t — about 50% more than the previous largest purse seine catch, which was recorded in 1995. Similarly, artisanal yellowfin tuna catches have been near their highest levels and longline vessels have reported higher than normal catches in the tropical western Indian Ocean during this period.



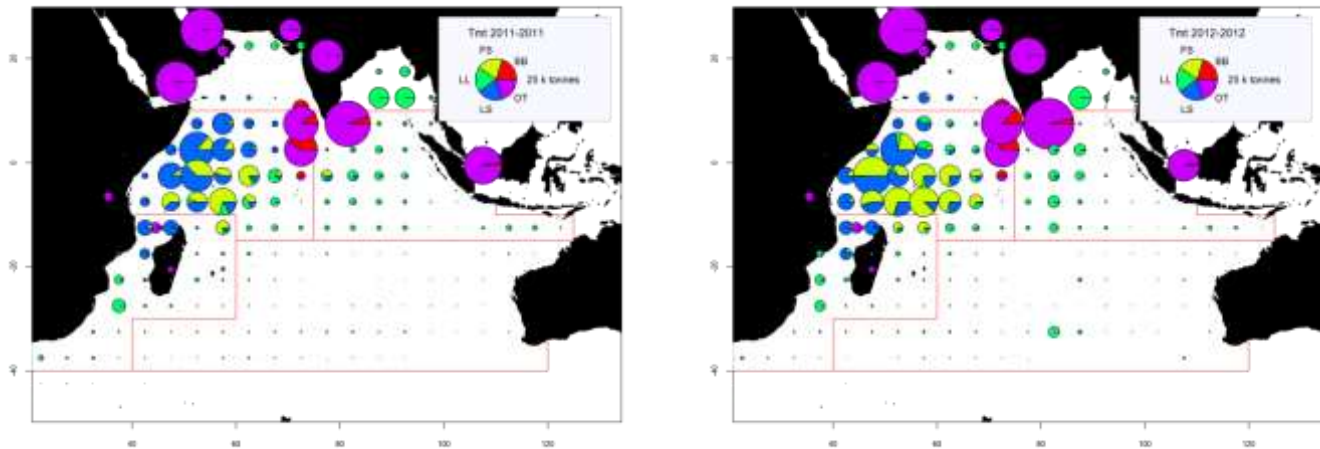
**Fig. 2. Yellowfin tuna:** Catches of yellowfin tuna by gear by year estimated for the WPTT (1950–2012) (Data as of September 2013). Purse seine free-school (FS); Purse seine associated school (LS).



**Fig. 3. Yellowfin tuna:** average catches in the Indian Ocean over the period 2009–12, by country (Data as of September 2013). 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.



**Fig. 4a–b. Yellowfin tuna:** Catches of yellowfin tuna by area by year estimated for the WPTT (1950–2012) (Data as of September 2013). Catches in areas R0 were assigned to the closest neighbouring area for the assessment. Areas: Arabian Sea (R1); Off Somalia (R2); Mozambique Channel (R3); South Indian Ocean (R4); East Indian Ocean (R5); Bay of Bengal (R0(North)); Other Area (R0(Other)).



**Fig. 5a–b. Yellowfin tuna:** Time-area catches (total combined in tonnes) of yellowfin tuna estimated for 2011 and 2012, by type of gear (Data as of September 2013). 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. 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 Iran and Pakistan, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Yemen, Oman, Comoros, Indonesia and India.

In recent years the catches of yellowfin tuna in the western Indian Ocean have dropped considerably, especially in areas off Somalia, Kenya and Tanzania and in particular between 2007 and 2011 (Figs. 4, 5). The drop in catches is the consequence of a drop in fishing effort due to the effect of piracy in the western Indian Ocean region. Even though the activities of purse seiners have been affected by piracy in the Indian Ocean, the effects have not been as marked as with longliners, for which current levels of effort are close to nil in the area impacted by piracy. 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 increased in 2012, as a consequence of increased security in the region.

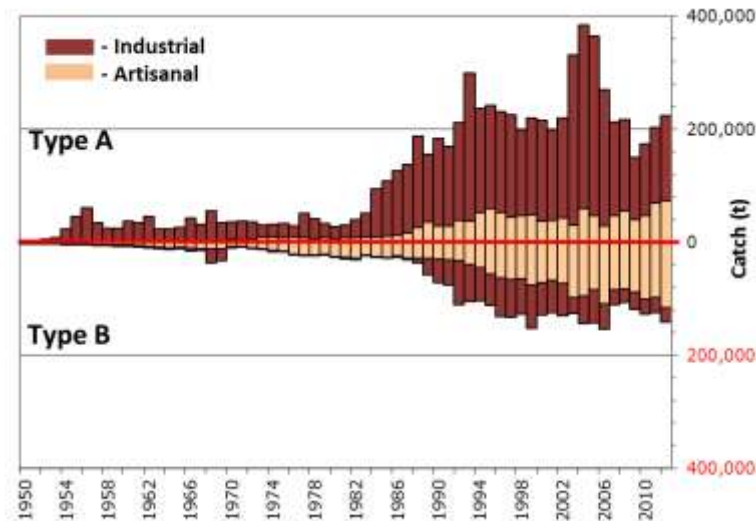
#### *Yellowfin tuna – uncertainty of catches*

**Retained catches** are generally well known (Fig. 6); 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.





**Fig. 6. Yellowfin tuna:** Uncertainty of annual catch estimates for yellowfin tuna (Data as of September 2013). Catches below the zero-line (**Type B**) refer to fleets that do not report catch data to the IOTC (estimated by the IOTC Secretariat), do not report catch data by gear and/or species (broken by gear and species by the IOTC Secretariat) or any of the other reasons provided in the document. Catches over the zero-line (**Type A**) refer to fleets for which no major inconsistencies have been found to exist. Light bars represent data for artisanal fleets and dark bars represent data for industrial fleets.

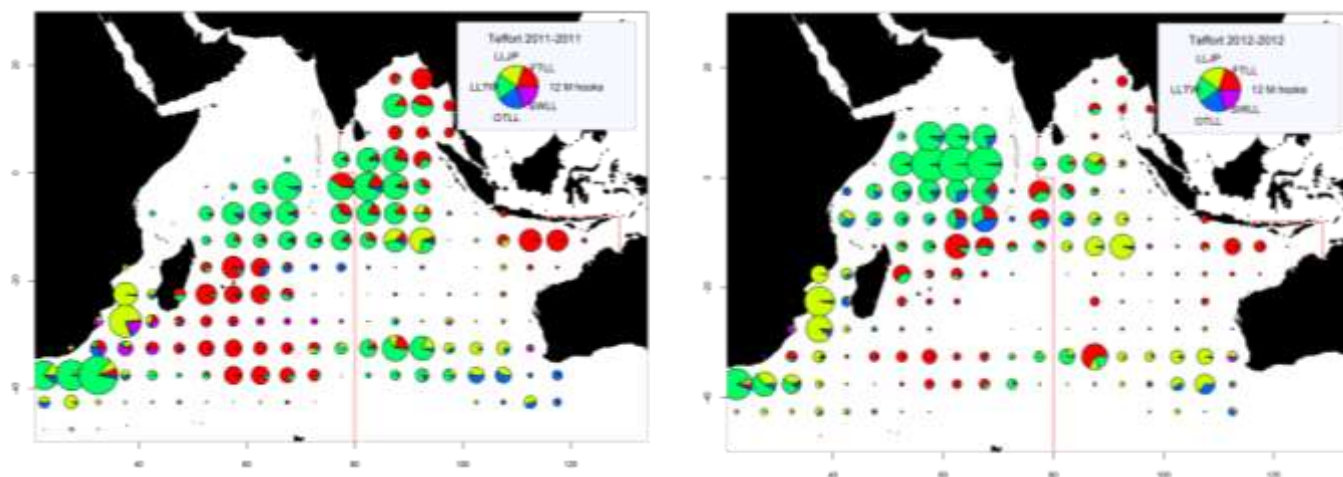
**Changes to the catch series:** There have not been significant changes to the total catches of yellowfin tuna since the WPTT in 2011. However, the IOTC Secretariat used new information compiled during 2012–13 to rebuild the catch series for the coastal fisheries operated in some countries, in particular Pakistan, Indonesia, Sri Lanka, and India. In general, the new catches of yellowfin tuna estimated by the IOTC Secretariat are slightly higher than those used in the past by the WPTT. More details about these reviews can be found in paper IOTC–2013–WPTT15–07 Rev\_1.

**CPUE Series:** Catch-and-effort data are available from the major industrial and artisanal fisheries. 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.

#### *Yellowfin tuna: Effort trends*

Total effort from longline vessels flagged to Japan, Taiwan, China and EU, Spain by five degree square grid in 2011 and 2012 are provided in Fig. 7, 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 2011 and 2012 are provided in Fig. 8. The total number of fishing trips by vessels flagged to the Maldives by 5 degree square grid, type of boat and gear, for the years 2011 and 2012 are provided in Fig. 9.



**Fig. 7.** Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2011 (left) and 2012 (right) (Data as of October 2013)

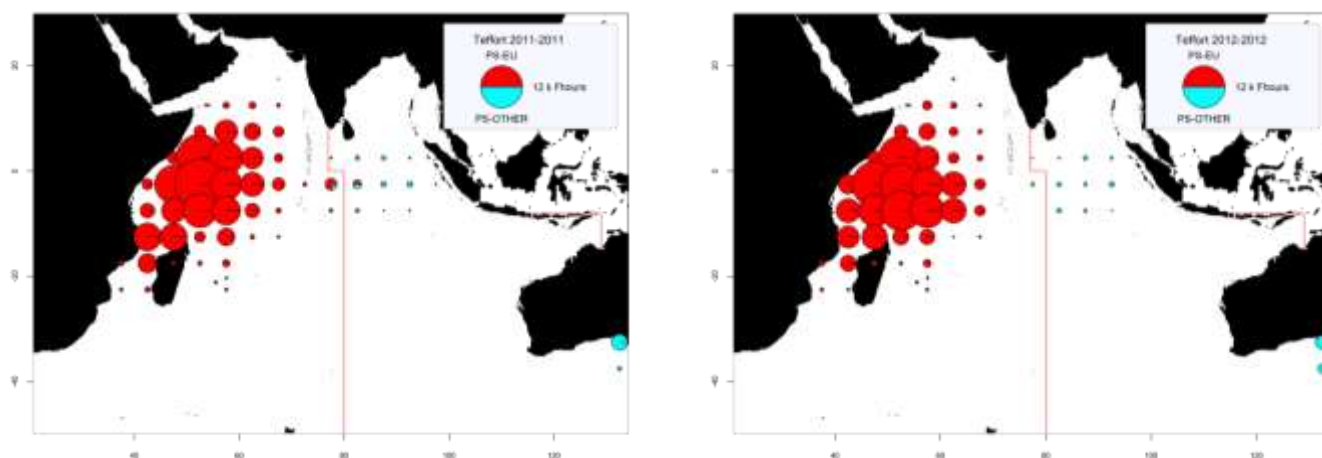
LLJP (light green): deep-freezing longliners from Japan

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)

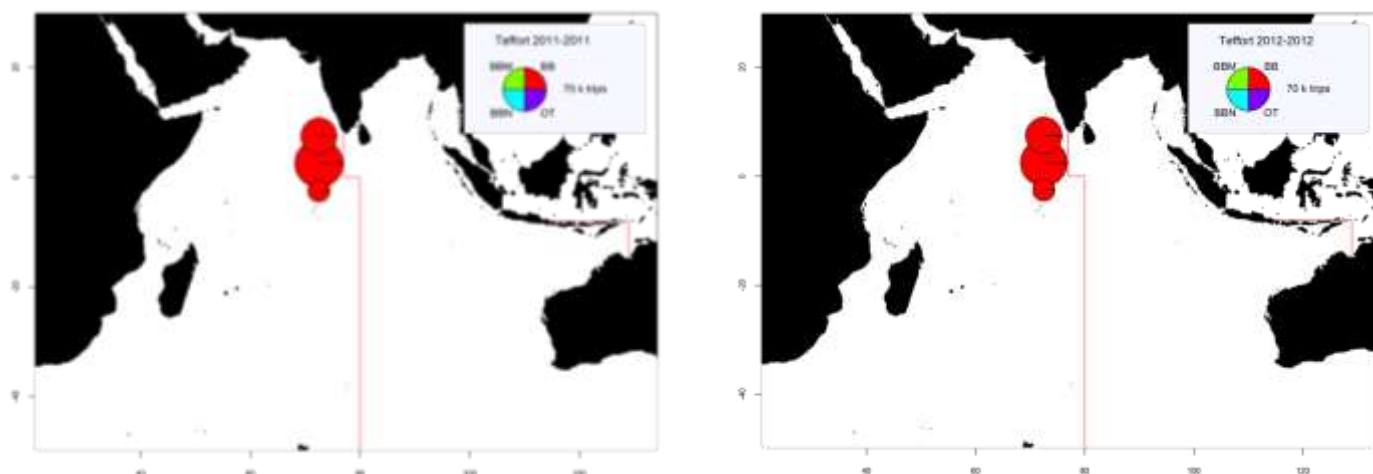
OTLL (blue): Longliners from other fleets (includes Belize, China, Philippines, Seychelles, South Africa, Rep. of Korea and various other fleets)



**Fig. 8.** Number of hours of fishing(Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2011 (left) and 2012 (right) (Data as of October 2013)

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)



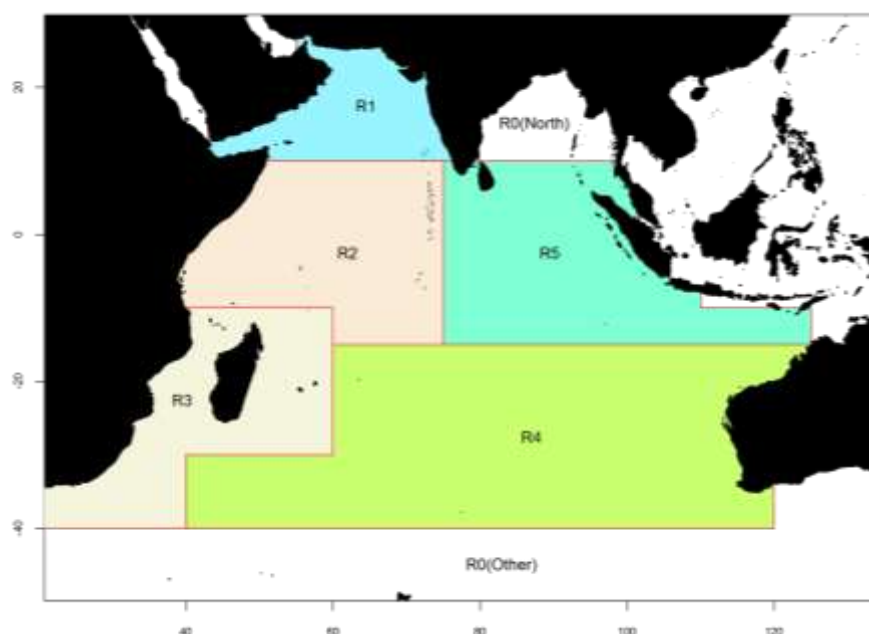
**Fig. 9.** Number of fishing trips by vessels flagged to the Maldives by 5 degree square grid, type of boat and gear, for the years 2011 (left) and 2012 (right) (Data as of October 2013)

BBN (blue): Baitboat non-mechanized; BBM (Green): Baitboat mechanized; BB (Red): Baitboat unspecified; UN (Purple): Unclassified gears

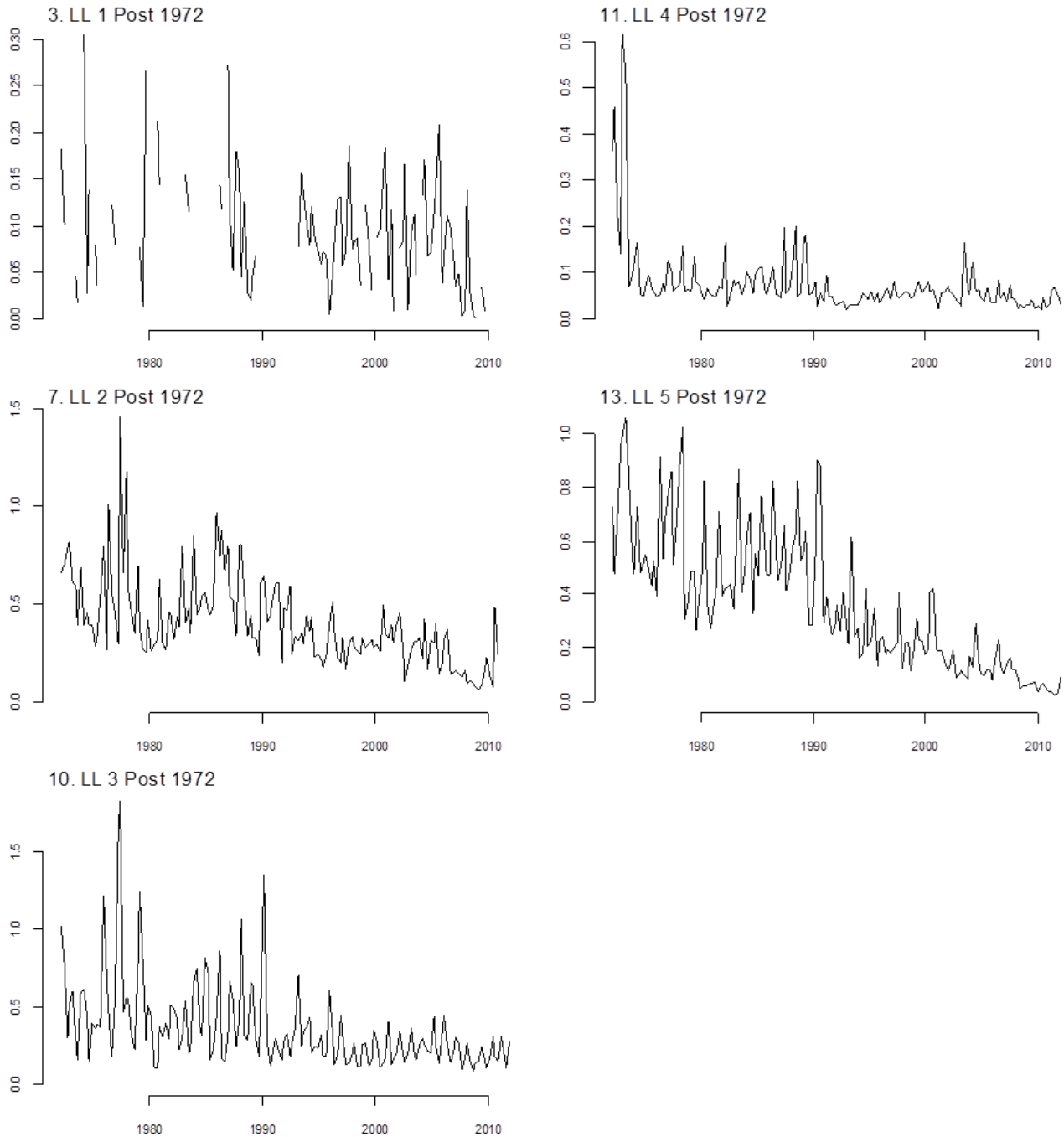
Note that the above maps were derived using the available catch-and-effort data in the IOTC database, which is limited to the number of baitboat calls (trips) by atoll by month for Maldivian baitboats for the period concerned. Note that some trips may be fully devoted to handlining, trolling, or other 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. 10), 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. 11). 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.



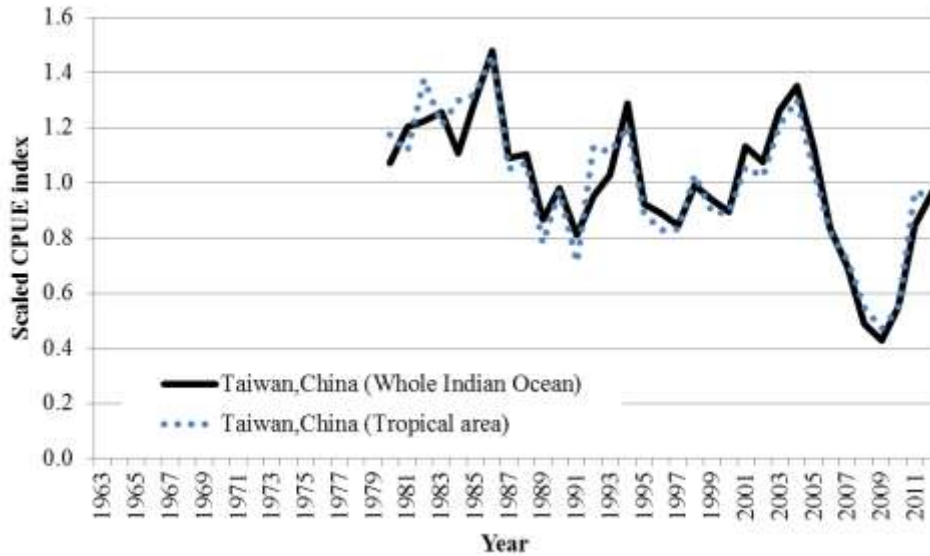
**Fig. 10.** Spatial stratification of the Indian Ocean for the MFCL assessment model carried out in 2012.



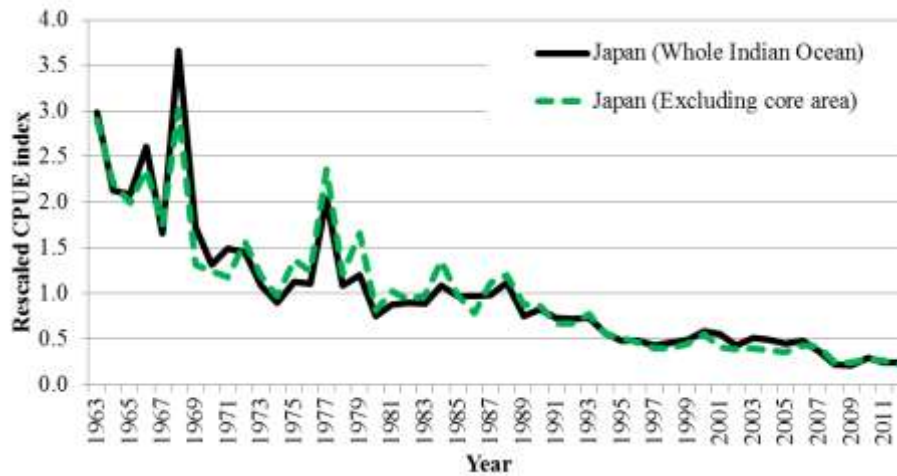
**Fig. 11. Yellowfin tuna:** Quarterly GLM standardised catch-per-unit-effort (CPUE) for the principal longline fisheries (LL 1 to 5) scaled by the respective region scalars.

For the longline fisheries (LL fisheries in regions 1–5; Fig. 10, CPUE indices analysed in 2013, were derived using generalised linear models (GLM) from the Japanese longline fleet (LL regions 2–5) and for the Taiwan,China longline fleet (LL region 1) to be used in the stock assessment in subsequent years for the stock assessment

The standardised CPUE trend estimated in 2013, for the Taiwan,China longline fleet (Fig. 12) is in contrast to the consistent negative trend displayed by the Japanese series (Fig. 13). The difference in the series between Taiwan,China and the Japan/Rep. of Korea standardised CPUE series, were questioned as it would seem intuitive that the trend should have decreased when catches increased significantly at the advent of the purse seine fishery. Scientists from these fleets need to resolve this by meeting inter-sessionally to assess why this may be occurring.



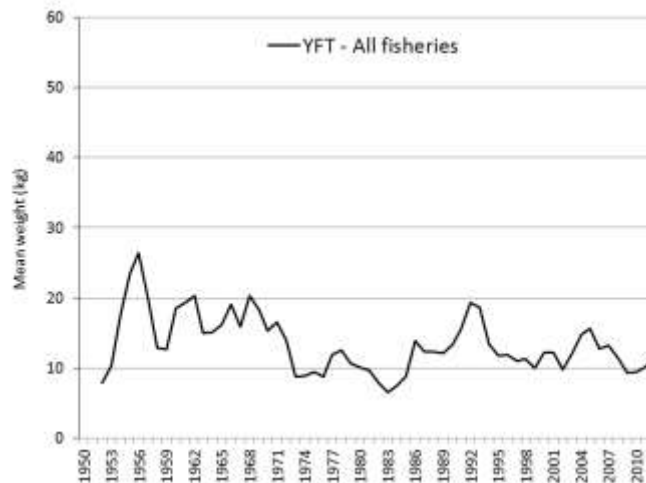
**Fig. 12. Yellowfin tuna:** Comparison of the two standardised longline CPUE series for Taiwan,China. Series have been rescaled relative to their respective means from 1963–2012.

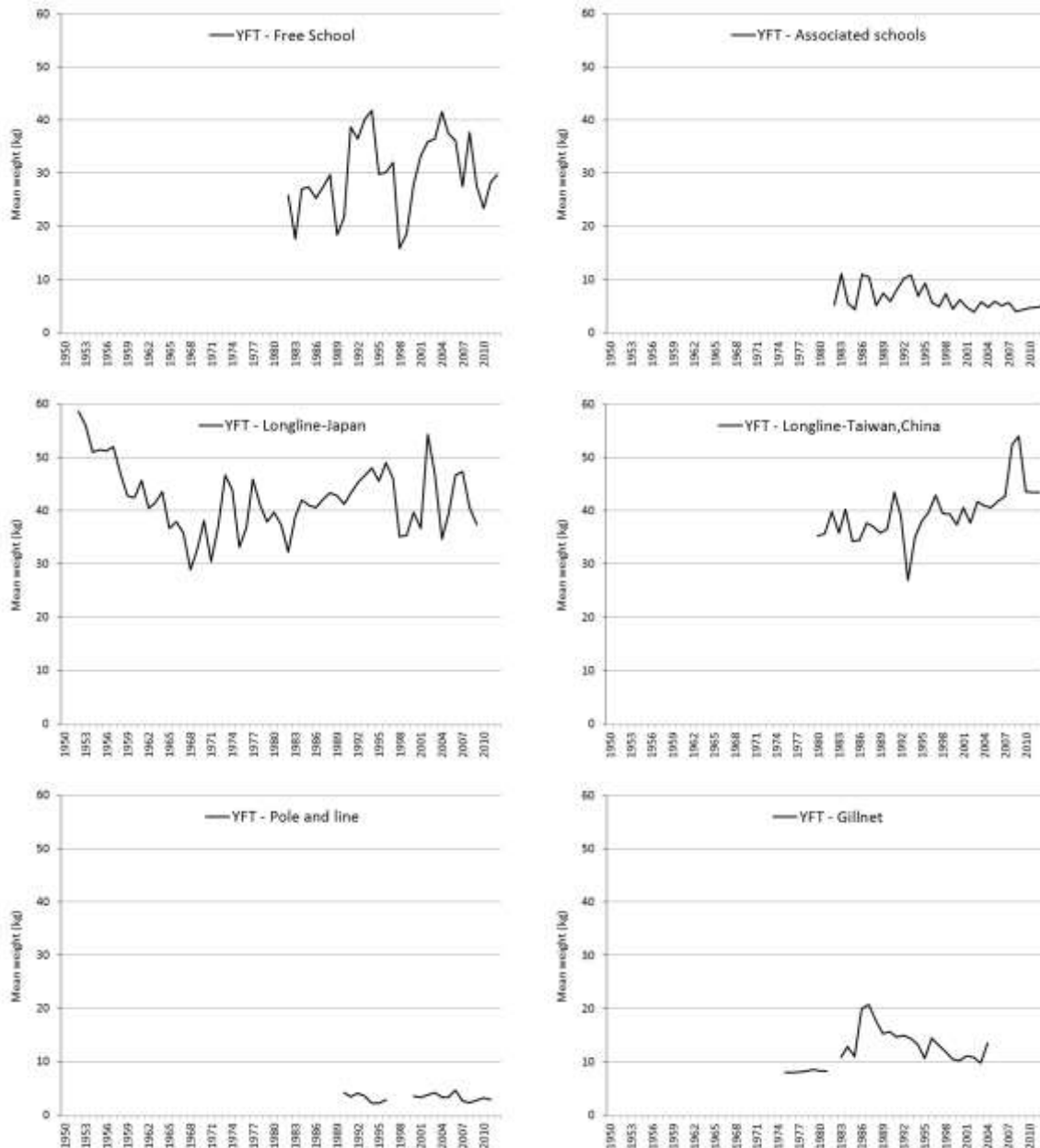


**Fig. 13. Yellowfin tuna:** Comparison of the two standardised longline CPUE series (with and without Region 2) for Japan. Series have been rescaled relative to their respective means from 1963–2012.

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

**Trends in average weight** can be assessed for several industrial fisheries (Fig. 14) 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.





**Fig. 14. Yellowfin tuna:** Changes in average weight (kg) of yellowfin tuna from 1950 to 2012 – all fisheries combined (top) and by main fleet (Data as of September 2013).

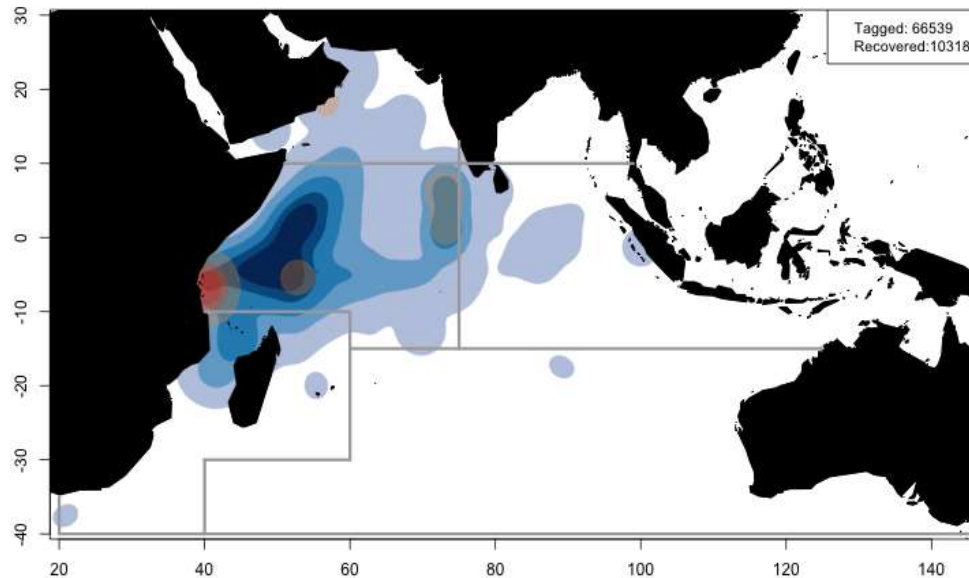
**Catch-at-Size table:** This is available although the estimates are more uncertain in some years and some fisheries due to:

- 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, Iran, India, Indonesia, Malaysia).

#### *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. 15). 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 were 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, of which 151 were recovered, mainly from the Maldives.



**Fig. 15. 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 2013, 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
2012 catch estimate	368,663 t
Mean catch from 2008–2012	317,505 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](http://www.fishbase.org)>