

**EXECUTIVE SUMMARY: STATUS OF THE INDIAN OCEAN SKIPJACK TUNA (*KATSUWONUS PELAMIS*) RESOURCE**

**TABLE 1.** Status of skipjack tuna (*Katsuwonus pelamis*) in the Indian Ocean.

Area <sup>1</sup>	Indicators – 2011 assessment		2011 stock status determination
			2009 <sup>2</sup>
Indian Ocean	Catch 2010:	428,719 t	
	Average catch 2006–2010:	489,385 t	
	MSY (1 model):	594,000 t (395,000–843,000 t)	
	C <sub>2009</sub> /MSY (1 model) <sup>3</sup> :	0.81 (0.54–1.16)	
	SB <sub>2009</sub> /SB <sub>MSY</sub> (1 model):	2.56 (1.09–5.83)	
	SB <sub>2009</sub> /SB <sub>0</sub> (1 model):	0.53 (0.29–0.70)	

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

<sup>2</sup>The stock status refers to the most recent years' data used for the assessment.

<sup>3</sup>Due to numerical problems in the F<sub>MSY</sub> calculations for this population, the proxy reference point C/MSY is reported instead of F/F<sub>MSY</sub>, which should be interpreted with caution for the following reasons: it may incorrectly suggest F>F<sub>MSY</sub> when there is a large biomass (early development of the fishery or large recruitment event); it may incorrectly suggest that F<F<sub>MSY</sub> when the stock is highly depleted; due to a flat yield curve, C could be near MSY even if F << F<sub>MSY</sub>.

Colour key	Stock overfished (SB <sub>year</sub> /SB <sub>MSY</sub> < 1)	Stock not overfished (SB <sub>year</sub> /SB <sub>MSY</sub> ≥ 1)
Stock subject to overfishing (C <sub>year</sub> /MSY > 1)		
Stock not subject to overfishing (C <sub>year</sub> /MSY ≤ 1)		

**INDIAN OCEAN STOCK – MANAGEMENT ADVICE**

The WPTT **RECOMMENDED** the following management advice for skipjack tuna in the Indian Ocean, for the consideration of the Scientific Committee.

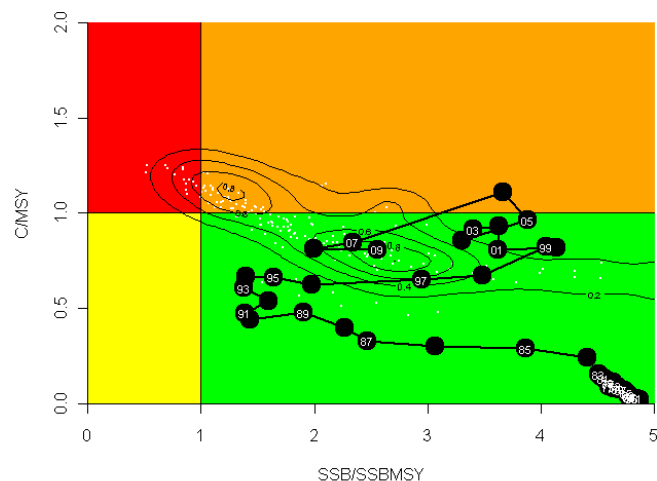
**Stock status.** The weighted results suggest that the stock is not overfished (B>B<sub>MSY</sub>) and that overfishing is not occurring (C<MSY, used as a proxy for F<F<sub>MSY</sub>) (Table 1 and Fig. 1). Spawning stock biomass was estimated to have declined by approximately 47 % in 2009 from unfished levels (Table 1).

**Outlook.** The recent declines in catches are thought to be caused by a recent decrease in purse seine effort as well as due to a decline in CPUE of large skipjack tuna in the surface fisheries. However, the WPTT does not fully understand the recent declines of pole and line catch and CPUE, which may be due to the combined effects of the fishery and environmental factors affecting recruitment or catchability. Catches in 2009 (455,999 t) and 2010 (428,719 t) as well as the average level of catches of 2006–2010 (489,385 t) were lower than median value of MSY.

The Kobe strategy matrix illustrates the levels of risk associated with varying catch levels over time and could be used to inform management actions. Based on the SS3 assessment, there is a low risk of exceeding MSY-based reference points by 2020 if catches are maintained at the current levels (< 20 % risk that B<sub>2019</sub> < B<sub>MSY</sub> and 30 % risk that C<sub>2019</sub>>MSY as proxy of F > F<sub>MSY</sub>) and even if catches are maintained below the 2006–2010 average (489,385 t).

The WPTT **RECOMMENDED** that the Scientific Committee consider the following:

- The median estimates of the Maximum Sustainable Yield for the skipjack tuna Indian Ocean stock is 564,000 t (Table 1) and considering the average catch level from 2005–2009 was 492,000 t [512,305 t], catches of skipjack tuna should not exceed the average of 2005–2009.
- If the recent declines in effort continue, and catch remains substantially below the estimated MSY, then urgent management measures are not required. However, recent trends in some fisheries, such as Maldivian pole-and-line, suggest that the situation of the stock should be closely monitored.
- The Kobe strategy matrix (Table 2) illustrates the levels of risk associated with varying catch levels over time and could be used to inform management actions.



**Fig. 1.** SS3 Aggregated Indian Ocean assessment Kobe plot. Black circles indicate the trajectory of the weighted median of point estimates for the SB ratio and C/MSY ratio for each year 1950–2009. Probability distribution contours are provided only as a rough visual guide of the uncertainty (e.g. the multiple modes are an artifact of the coarse grid of assumption options). Due to numerical problems in the  $F_{MSY}$  calculations for this population, the proxy reference point C/MSY is reported instead of  $F/F_{MSY}$ , which should be interpreted with caution for the reasons given under Table 1 above.

**TABLE 2.** SS3 Aggregated Indian Ocean assessment Kobe II Strategy Matrix. Weighted probability (percentage) of violating the MSY-based reference points for five constant catch projections (2009 catch level,  $\pm 20\%$  and  $\pm 40\%$ ) projected for 3 and 10 years.

Reference point and projection timeframe	Alternative catch projections (relative to 2009) and weighted probability (%) scenarios that violate reference point				
	60% (274,000 t)	80% (365,000 t)	100% (456,000 t)	120% (547,000 t)	140% (638,000 t)
$SB_{2013} < SB_{MSY}$	<1	5	5	10	18
$C_{2013} > MSY$ (proxy for $F_{2009}/F_{MSY}$ )	<1	<1	31	45	72
$SB_{2020} < SB_{MSY}$	<1	5	19	31	56
$C_{2020} > MSY$ (proxy for $F_{2009}/F_{MSY}$ )	<1	<1	31	45	72

## SUPPORTING INFORMATION

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

### CONSERVATION AND MANAGEMENT MEASURES

Skipjack tuna (*Katsuwonus pelamis*) in the Indian Ocean are currently subject to a number of conservation and management measures adopted by the Commission:

- Resolution 08/04 concerning the recording of catch by longline fishing vessels in the IOTC area.
- Resolution 09/02 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 10/03 concerning the recording of catch by fishing vessels in the IOTC area.
- Resolution 10/07 concerning a record of licensed foreign vessels fishing for tunas and swordfish in the IOTC area.
- Resolution 10/08 concerning a record of active vessels fishing for tunas and swordfish in the IOTC area.
- Recommendation 10/13 On the implementation of a ban on discards of skipjack tuna, yellowfin tuna, bigeye tuna, and non targeted species caught by purse seiners.
- Recommendation 11/06 Concerning the Recording of Catch by Fishing Vessels in the IOTC Area of Competence.

## FISHERIES INDICATORS

### General

Skipjack tuna (*Katsuwonus pelamis*) life history characteristics, including a low size and age at maturity, short life and high productivity/fecundity, make it resilient and not prone to overfishing. Table 3 outlines some of the key life history traits of skipjack tuna.

**TABLE 3.** Biology of Indian Ocean skipjack tuna (*Katsuwonus pelamis*)

Parameter	Description
Range and stock structure	Cosmopolitan species found in the tropical and subtropical waters of the Indian, Pacific and Atlantic Oceans. It generally forms large schools, often in association with other tunas of similar size such as juveniles of yellowfin tuna and bigeye tuna. The tag recoveries from the RTTP-IO provide evidence of rapid, large scale movements of skipjack tuna in the Indian Ocean, thus supporting the current assumption of a single stock for the Indian Ocean. Skipjack recoveries indicate that the species is highly mobile, and covers large distances. The average distance between skipjack tagging and recovery positions is estimated at 640 nautical miles. Skipjack tuna in the Indian Ocean are considered a single stock for assessment purposes.
Longevity	9–10 years
Maturity (50%)	Age: females and males <2 years. Size: females and males 41–43 cm. Unlike in <i>Thunnus</i> species, sex ratio does not appear to vary with size. Most of skipjack tuna taken by fisheries in the Indian Ocean have already reproduced.
Spawning season	High fecundity. Spawns opportunistically throughout the year in the whole inter-equatorial Indian Ocean (north of 20°S, with surface temperature greater than 24°C) when conditions are favourable.
Size (length and weight)	Maximum length: 110 cm FL; Maximum weight: 35.5 kg. The average weight of skipjack tuna caught in the Indian Ocean is around 3.0 kg for purse seine, 2.8 kg for the Maldivian baitboats and 4–5 kg for the gillnet. For all fisheries combined, it fluctuates between 3.0–3.5 kg; this is larger than in the Atlantic, but smaller than in the Pacific. It was noted that the mean weight for purse seine catch exhibited a strong decrease since 2006 (3.1 kg) until 2009 (2.4 kg), for both free (3.8 kg to 2.4 kg) and log schools (3.0 kg to 2.4 kg).

SOURCES: Collette & Nauen (1983); Froese & Pauly (2009); Grande et al. (2010).

### Catch trends

Catches of skipjack tuna increased slowly from the 1950s, reaching around 50,000 t during the mid-1970s, mainly due to the activities of pole-and-lines and gillnets (Fig. 2 and 3). The catches increased rapidly with the arrival of purse seiners in the early 1980s, and skipjack tuna became one of the most important tuna species in the Indian Ocean.

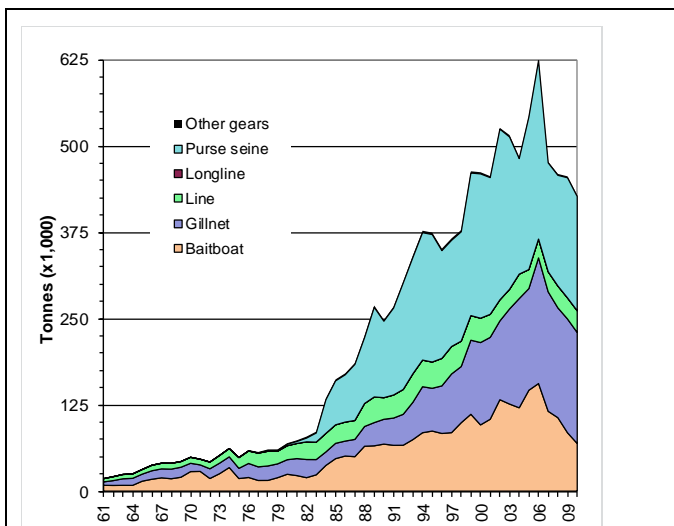
The increase in purse seine caught skipjack tuna post 1984 (Figs. 2 and 3) was due to the development of a fishery in association with Fish Aggregating Devices (FADs). Since the 1990's, 85% of the skipjack tuna caught by purse seine vessels was taken in association with FADs. Following the peak catches taken in 2002 (240,000 t) and 2006 (247,000 t), catches dropped markedly, probably as a consequence of exceptional purse seine catch rates on free schools of yellowfin tuna. In 2007 purse seine catches dropped by around 100,000 t (145,000 t), with similar catches recorded in 2008 and have remained low (150,000–160,000 t).

The constant increase in catches and catch rates of purse seiners until 2006 are believed to be associated with increases in fishing power and in the number of FADs used in the fishery. The sharp decline in purse seine catches shown since 2007 (resulting partially from an approximate 30% decline of effort) coincided with a similar decline in the catches of Maldivian pole-and-line vessels (Fig. 3). The Maldivian fishery effectively increased its fishing effort with the mechanisation of its pole-and-line fishery from 1974, including an increase in boat size and power and the use of anchored FADs since 1981. The decrease in catches of both fisheries may also be the result of a sharp decrease in the mean skipjack tuna weight during this period, from 3 kg in 2006 to 2.3 kg in 2010. It should be noted that during the period 2006–2010, the gillnet fishery was catching over 100,000 tons of large skipjack tuna (~4.3 kg).

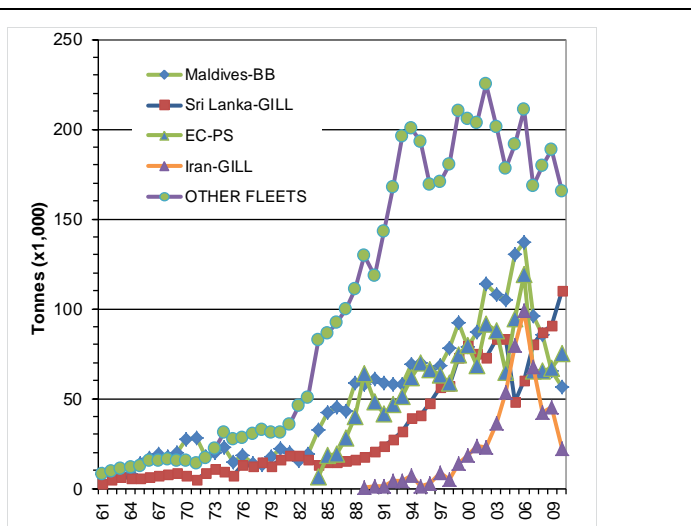
Several fisheries using gillnets have reported large catches of skipjack tuna in the Indian Ocean (Fig. 3), including the gillnet/longline fishery of Sri Lanka, driftnet fisheries of Iran and Pakistan, and gillnet fisheries of India and Indonesia. In recent years gillnet catches have represented as much as 20–30% of the total catches of skipjack tuna in the Indian Ocean. Although it is known that vessels from Iran and Sri Lanka have been using gillnets on the high seas in recent years, reaching as far as the Mozambique Channel, the activities of these fleets are poorly understood, as no time-area catch-and-effort series have been made available for those fleets to date.

The majority of the catches of skipjack tuna originate from the western Indian Ocean (Fig. 4). Since 2007 the catches of skipjack tuna in the western Indian Ocean have dropped considerably, especially in areas off Somalia, Kenya, Tanzania and around the Maldives. Although the drop in catches could be partially explained by a drop in catch rates and fishing effort by

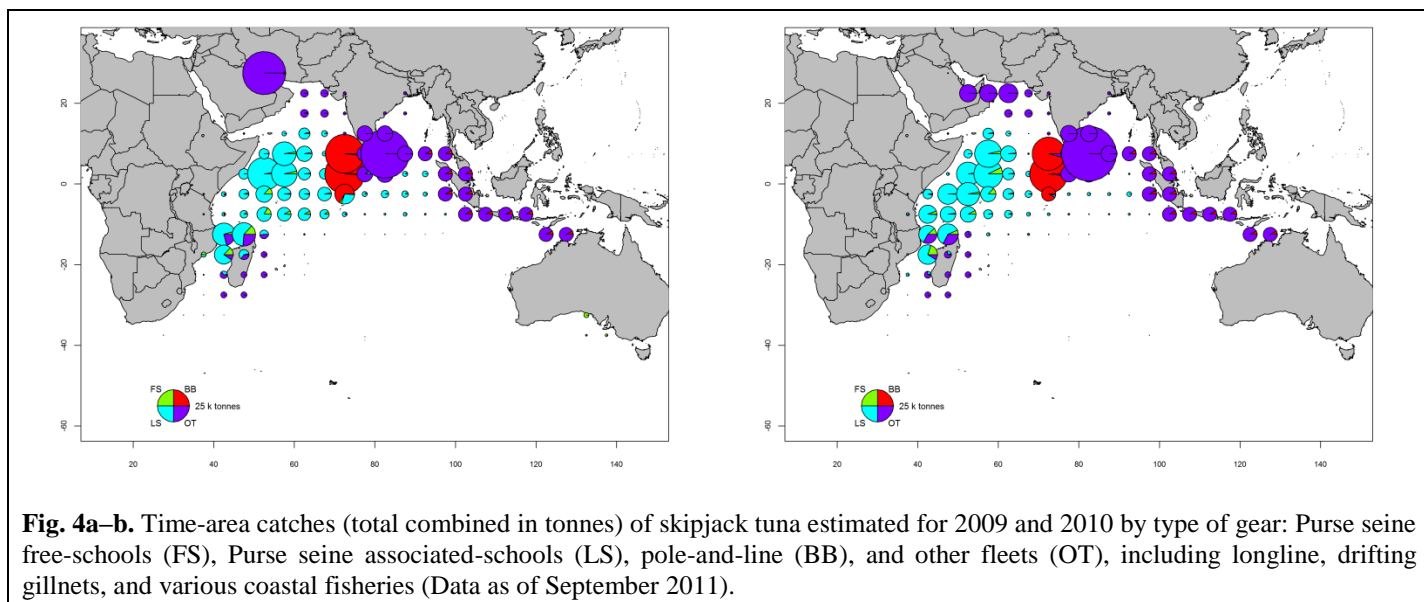
the purse seine fishery, due to the effects of piracy in the western Indian Ocean region, drops in the catches of other fisheries, in particular for the Maldives, are not fully understood.



**Fig. 2.** Annual catches of skipjack tuna by gear recorded in the IOTC Database (1961–2010) (Data as of September 2011).



**Fig. 3.** Annual catches of skipjack tuna by fleet recorded in the IOTC Database (1961–2010) (Data as of September 2011).



**Fig. 4a–b.** Time-area catches (total combined in tonnes) of skipjack tuna estimated for 2009 and 2010 by type of gear: Purse seine free-schools (FS), Purse seine associated-schools (LS), pole-and-line (BB), and other fleets (OT), including longline, drifting gillnets, and various coastal fisheries (Data as of September 2011).

**TABLE 4.** Best scientific estimates of the catches of skipjack tuna (*Katsuwonus pelamis*) by gear and main fleets [or type of fishery] by decade (1950–2000) and year (2001–2010), in tonnes. Data as of October 2011. Catches by decade represent the average annual catch, noting that some gears were not used for all years (refer to Fig. 2).

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
BB	9,292	13,176	22,305	40,579	82,592	118,783	104,130	132,426	126,131	120,718	146,133	155,841	115,599	106,388	84,532	69,032
FS			41	15,551	30,651	25,922	28,919	22,801	30,992	18,565	43,123	34,954	24,198	16,277	10,458	8,826
LS			125	33,570	124,096	164,300	159,646	215,781	180,556	137,882	168,012	211,940	120,925	128,596	148,717	141,797
OT	7,054	17,546	31,665	55,763	109,775	191,540	163,586	155,170	178,094	206,559	186,447	222,339	216,498	208,254	212,292	209,064
<b>Total</b>	<b>16,346</b>	<b>30,721</b>	<b>54,136</b>	<b>145,464</b>	<b>347,115</b>	<b>500,545</b>	<b>456,281</b>	<b>526,179</b>	<b>515,774</b>	<b>483,724</b>	<b>543,715</b>	<b>625,074</b>	<b>477,220</b>	<b>459,515</b>	<b>455,999</b>	<b>428,719</b>

**Fisheries:** Pole-and-Line (BB); Purse seine free-school (FS); Purse seine associated school (LS); Other gears nei (OT).

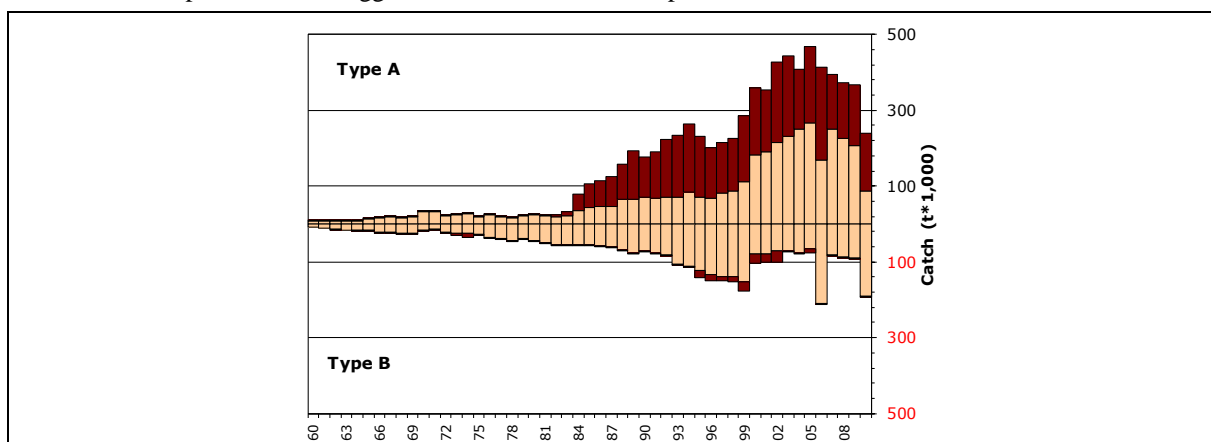
**TABLE 5.** Best scientific estimates of the catches of skipjack tuna (*Katsuwonus pelamis*) in the Western and Eastern Indian Ocean areas for the period 1950–2010 (in metric tons). Data as of October 2011.

Area	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
W	10,846	17,569	28,595	96,868	249,919	322,664	326,695	407,328	387,233	349,945	451,617	516,652	342,066	307,021	299,140	258,257
E	5,499	13,153	25,541	48,596	97,196	139,308	129,586	118,851	128,541	133,780	92,098	108,422	135,155	152,494	156,859	170,462

### Uncertainty of catches

Retained catches are generally well known for the industrial fisheries but are less certain for many artisanal fisheries (Fig. 5), notably because:

- Catches are not being reported by species.
- There is uncertainty about the catches from some important fleets including the Sri Lankan coastal fisheries, and the coastal fisheries of Comoros and Madagascar.
- Approximately 10–12 % of the reported catches from some coastal fisheries are uncertain.
- the catch series for skipjack tuna has not been substantially revised since the WPTT12 in 2010.
- levels of discards 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.



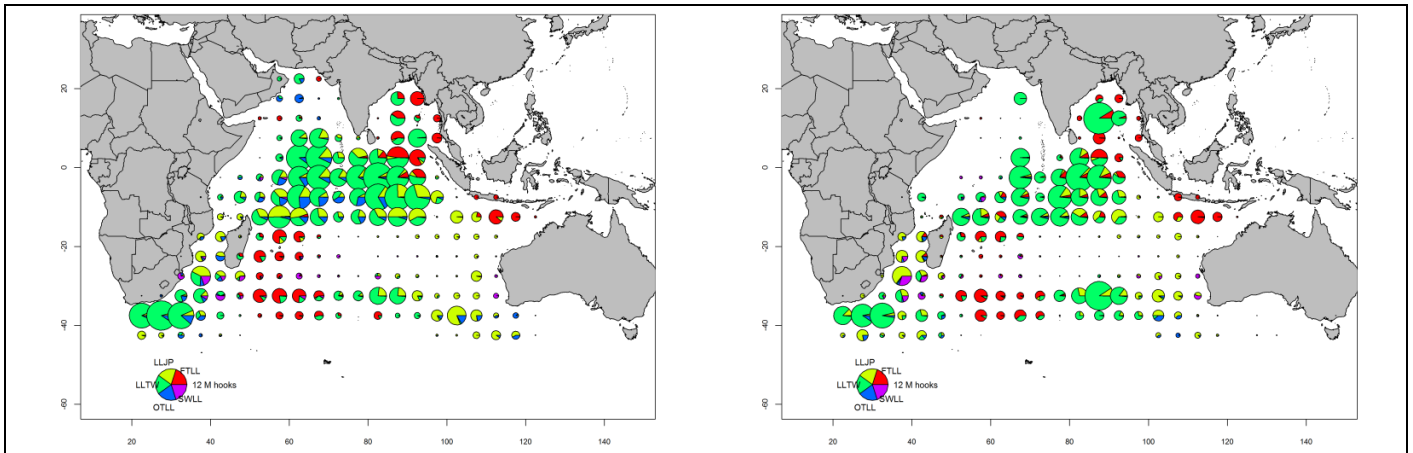
**Fig. 5.** Uncertainty of annual catch estimates for skipjack tuna (Data as of September 2011).

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.

- catch-and-effort series are available from various industrial and artisanal fisheries. However, these data are not available from some important fisheries or they are considered to be of poor quality, for the following reasons:
  - no data are available for the gillnet fishery of Pakistan.
  - although Iran has provided catch and effort data, it is not reported as per the IOTC standards.
  - 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 Indonesia, Madagascar and Comoros.

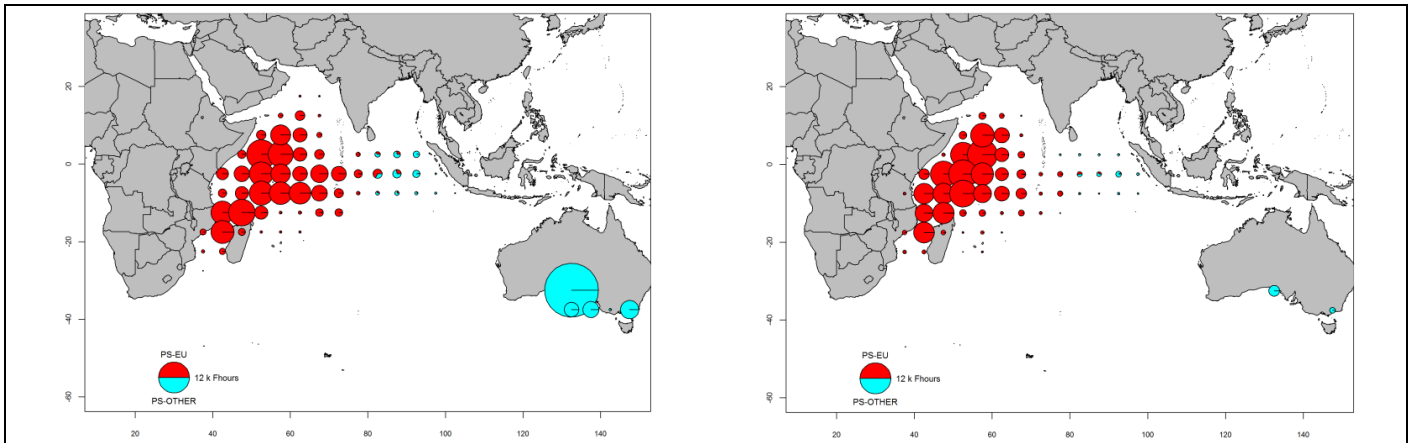
### Effort trends

Total effort from longline vessels flagged to Japan, Taiwan, China and EU, Spain by five degree square grid from 2007 to 2010 are provided in Fig. 6, 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 2007 to 2010 are provided in Fig. 7. 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 2009 and 2010 are provided in Fig. 8.



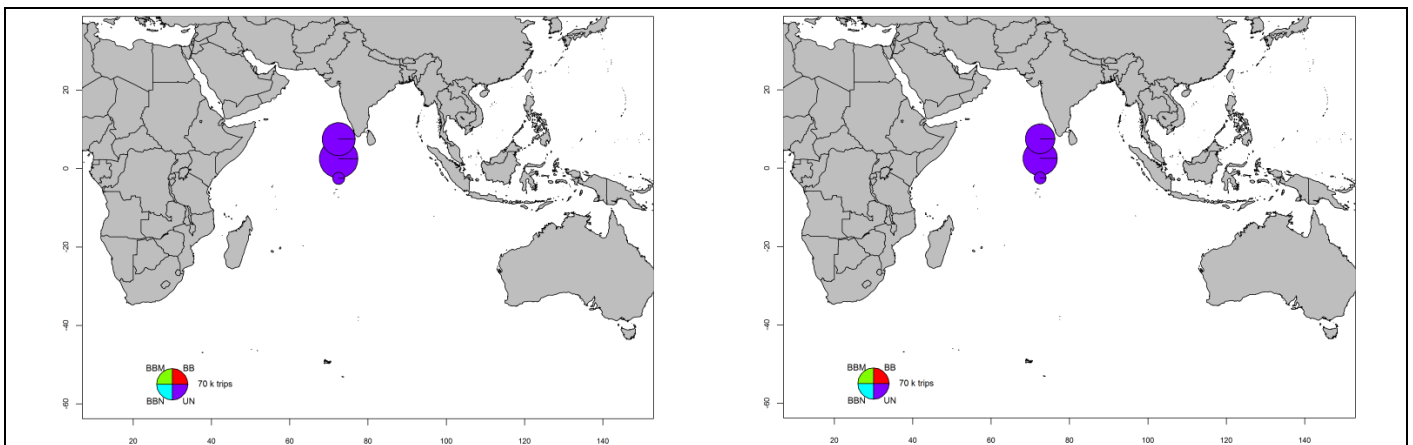
**Fig. 6.** Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).

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. 7.** Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).

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)



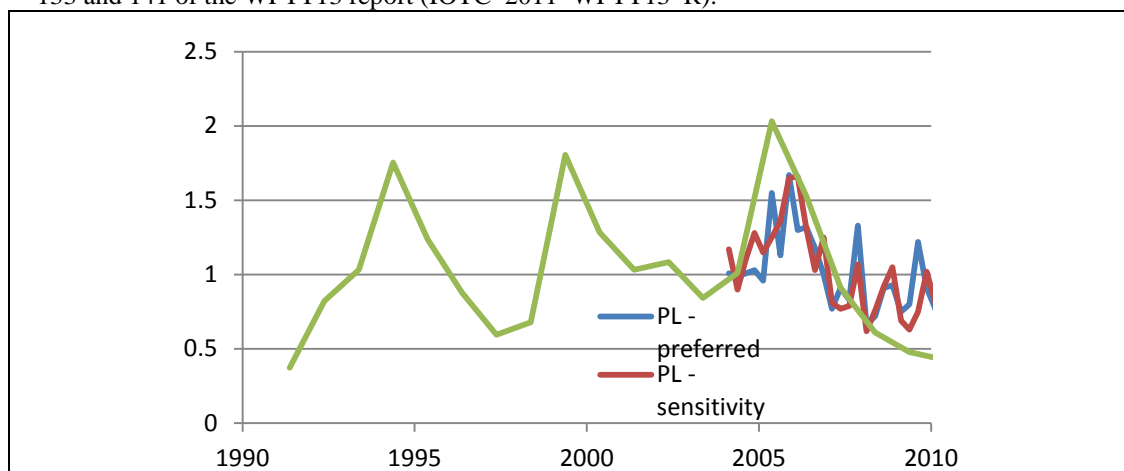
**Fig. 8.** Number of fishing trips by vessels flagged to the Maldives by 5 degree square grid, type of boat and gear, for the years 2009 (left) and 2010 (right) (Data as of August 2011).

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 handling, 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.

**Standardised catch-per-unit-effort (CPUE) trends**

The CPUE series available for assessment purposes are shown in Fig. 9, although only the ‘PL – preferred’ was used in the stock assessment model for 2011. The other two series were explored.

- Maldives data (2004–2010): Series1 (PL – preferred) from document IOTC–2011–WPTT13–29 and 31.
- Maldives data (2004–2010): Series 2 (PL – sensitivity) from document IOTC–2011–WPTT13–29 and 31. This series was not used in the assessment because initial results were very similar to the preferred series.
- EU,France purse seine free school data (1991–2010): Series from document IOTC–2011–WPTT13–20. This series was not used in the assessment because it was not standardized and likely subject to problems as noted in paragraphs 133 and 141 of the WPTT13 report (IOTC–2011–WPTT13–R).



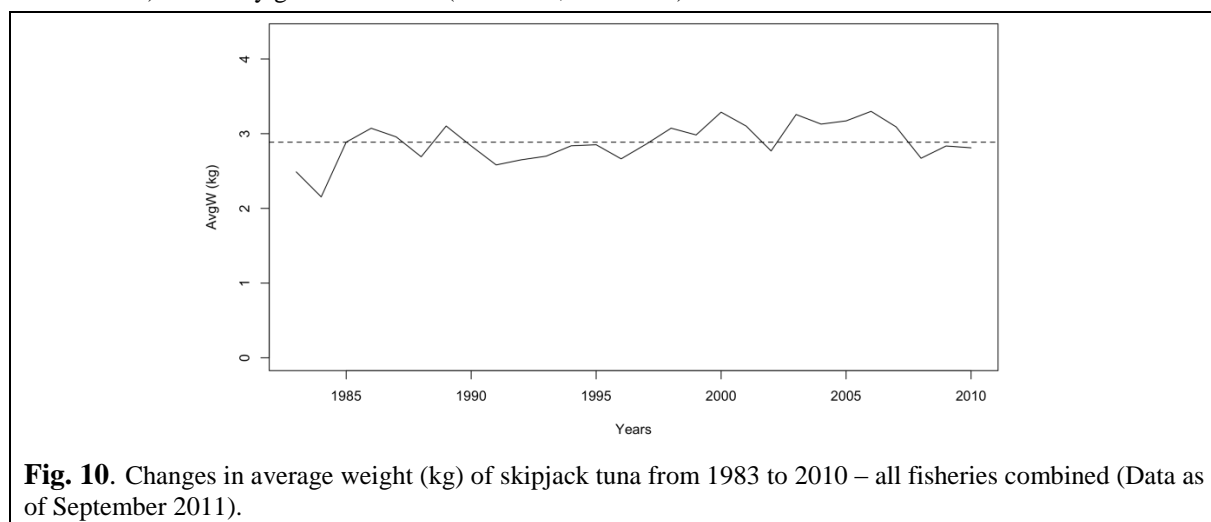
**Fig. 9.** Comparison of the two standardised Maldivian pole-and-line CPUE series for Indian Ocean skipjack tuna with the nominal EU,France purse seine free school CPUE series. Series have been rescaled relative to their respective means from 2004–2010.

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

Trends in average weight (Fig. 10) cannot be accurately assessed before the mid-1980s and are incomplete for most artisanal fisheries post-1980, namely hand lines, troll lines and many gillnet fisheries (Indonesia) (see paper IOTC–2011–WPTT13–08).

Catch-at-Size and Age tables are available but the estimates are uncertain for some years and fisheries due to:

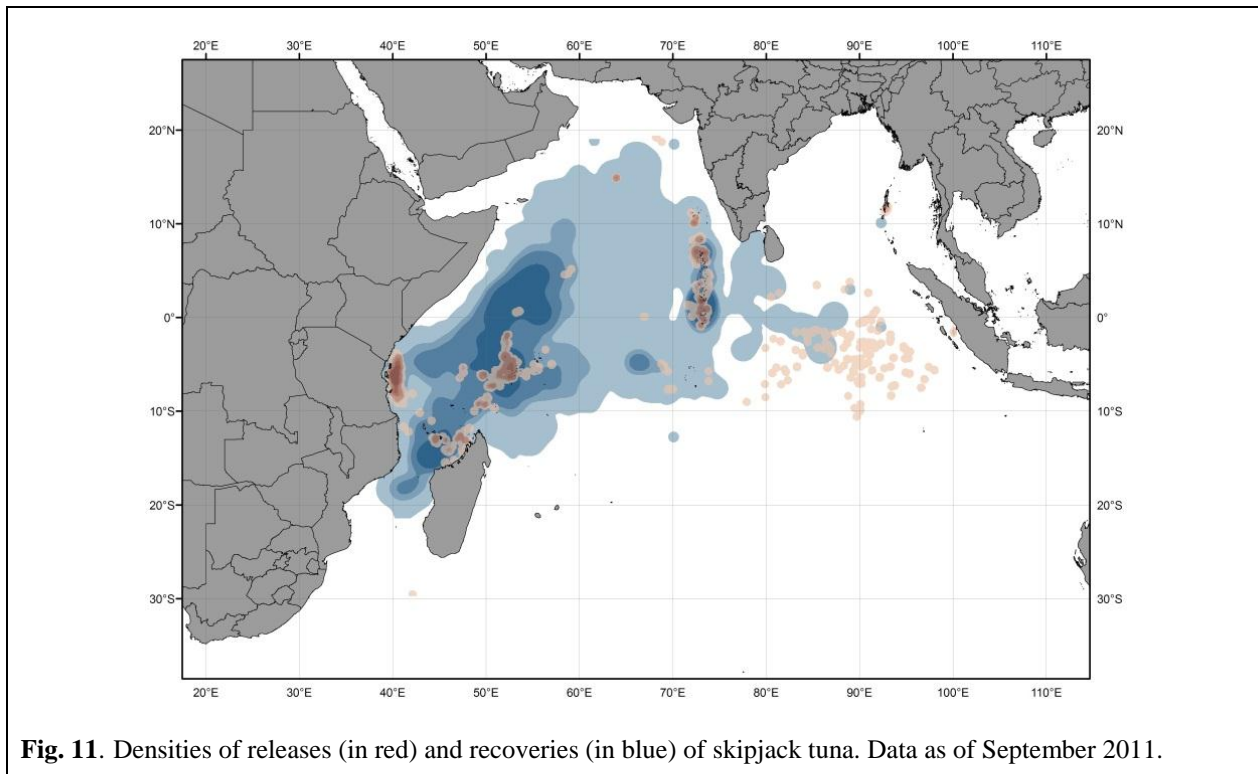
- the lack of size data before the mid-1980s.
- the paucity of size data available for some artisanal fisheries, notably most hand lines and troll lines (Madagascar, Comoros) and many gillnet fisheries (Indonesia, Sri Lanka).



**Fig. 10.** Changes in average weight (kg) of skipjack tuna from 1983 to 2010 – all fisheries combined (Data as of September 2011).

#### *Skipjack tuna – tagging data*

A total of 100,620 skipjack tuna were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP) which represented 49.8% of the total number of fish tagged. Most of the skipjack tuna tagged (77.8%) were tagged during the main Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) and were primarily released off the coasts of the Seychelles and Tanzania and in the Mozambique Channel (Fig. 11) between May 2005 and September 2007. The remaining were tagged during small-scale projects around the Maldives, India and the southwest and eastern Indian Ocean by institutions with the support of IOTC. To date 15,270 (15.2%) of the tagged fish have been recovered and reported to the IOTC Secretariat.



**Fig. 11.** Densities of releases (in red) and recoveries (in blue) of skipjack tuna. Data as of September 2011.

## STOCK ASSESSMENT

A single quantitative modelling method, a “Stock Synthesis III” (SS3), was applied to the skipjack tuna assessment in 2011, using data from 1950–2009. The model was age-structured, iterated on a quarterly time-step, spatially aggregated, with four fishing fleets and Beverton-Holt recruitment dynamics. Model parameters (virgin recruitment, selectivity by fleet, recruitment deviations, and  $M$  in some cases) were estimated by fitting predictions and observations of Maldivian pole-and-line CPUE (2004–2010), length frequency data for all fleets, and tag recoveries (for the purse seine fleets, and in some cases, the Maldivian pole-and-line fleet). The uncertainties and interactions among a range of assumptions was examined (including a range of fixed values for parameters that are known to be difficult to estimate). The stock status estimates represented a synthesis from 180 models (balanced factorial design of 5 assumptions, including i) 3  $M$  options (estimated internally, fixed at point estimates from the preliminary Brownie analysis (IOTC–2011–WPTT13–30), or fixed at ICCAT values), ii) 5 stock recruit steepness options ( $h = 0.55–0.95$ ), iii) 2 tagging program release/recovery options (RTTP or combined RTTP and small-scale), iv) 2 growth curve options and v) 3 tag recovery overdispersion options.

The following is worth noting with respect to the modelling approach used:

- The models estimate a steep biomass decline between 1980 and 1990 followed by a steep biomass increase. At this stage, there are no CPUE series during this period to inform the model. The catch increased in this period due to the onset of purse seine fishing and industrialization of the Maldivian pole and line fishery and thus, trends in recruitment are required to explain the biomass patterns. The biomass/recruitment trends were supported only by the length frequency data, and it is not likely that these data are sufficiently informative to estimate this trend. Furthermore, the trend is not evident in the nominal CPUE series from either the pole and line or purse seine fisheries.
- Due to numerical problems in the  $F_{MSY}$  calculations for this population, the proxy reference point  $C/MSY$  is reported instead of  $F/F_{MSY}$ , which should be interpreted with caution for the following reasons:
  - it may incorrectly suggest  $F > F_{MSY}$  when there is a large biomass (early development of the fishery or large recruitment event)
  - it may incorrectly suggest that  $F < F_{MSY}$  when the stock is highly depleted
  - due to a flat yield curve,  $C$  could be near  $MSY$  even if  $F \ll F_{MSY}$ .
- Although CPUE from the EU, France fleet targeting free school was only reliable for yellowfin tuna and bigeye tuna after 1991, due to species misidentification, for skipjack tuna this series could be extended back to 1983, as misidentification would not have occurred between this species and the others. It was noted, however, that this nominal series would not take into account changes in fishing/gear efficiency and so could still be unsuitable as an index of abundance for the earlier years. These restrictions also apply to the post–1991 series. However, it should be taken into account that the free school catch of purse seiners is relatively small in comparison to FAD-associated fishing (less than 10%) and the fishery is seasonal, located mainly in the Mozambique Channel during the first quarter of the year.
- Most of the natural mortality assumptions included in the assessment were lower than those assumed in other oceans. The values estimated within the model only using the WPTT tagging data were unrealistically low for ages 0–1. The values estimated within the model appeared plausible when the small-scale tagging data was included with the RTTP data. The values adopted from the independent Brownie analysis using only RTTP data showed a similar pattern of  $M(\text{age})$  to the SS3 RTTP+small-scale estimates, but were substantially lower. It was noted that there were some



differences in the way that the SS3 model and Brownie analysis estimated M, but it was not obvious why either of the approaches would be biased.

**TABLE 6.** Key management quantities from the SS3 assessment, for the aggregate Indian Ocean. Estimates represent 50<sup>th</sup> (5<sup>th</sup>–95<sup>th</sup>) percentiles from the weighted distribution of MPD results. Due to numerical problems in the  $F_{MSY}$  calculations for this population, the proxy reference point  $C/MSY$  is reported instead of  $F/F_{MSY}$ , which should be interpreted with caution for the reasons given in Table 1.

<b>Management Quantity</b>	<b>Aggregate Indian Ocean</b>
2009 catch estimate (1000 t)	456
Mean catch from 2005–2009 (1000 t)	492 [512]
MSY (1000 t) (90% CI)	564 (395–843)
Data period used in assessment	1950–2009
$C_{2009}/MSY$ (90% CI) (proxy for $F_{2009}/F_{MSY}$ )	0.81 (0.54–1.16)
$B_{2009}/B_{MSY}$	–
$SB_{2009}/SB_{MSY}$ (90% CI)	2.56 (1.09–5.83)
$B_{2009}/B_0$	–
$SB_{2009}/SB_0$ (90% CI)	0.53 (0.29–0.70)
$B_{2009}/B_{1950, F=0}$	–
$SB_{2009}/SB_{1950, F=0}$	0.53 (0.29–0.70)

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