OUTCOMES OF THE FOURTEENTH SESSION OF THE SCIENTIFIC COMMITTEE

PREPARED BY: IOTC SECRETARIAT, 02 OCTOBER, 2012

PURPOSE

To inform the Working Party on Tropical Tuna (WPTT) of the recommendations arising from the Fourteenth Session of the Scientific Committee held from 12–17 December 2011, specifically relating to the work of the WPTT.

BACKGROUND

At the 14th Session of the Scientific Committee (SC), the recommendations relevant to the work of the WPTT contained in Appendix A were adopted by the SC and provided to the Commission for its consideration.

In addition, the SC noted and endorsed the recommendations made by the WPTT in 2012, which included requests to address the deficiencies in data collection, monitoring and reporting by CPCs. The SC requested that the IOTC Secretariat communicate these recommendations to relevant parties so that they may address these matters in 2012 and provide progress updates to the WPTT at its next meeting.

The recommendations on the deficiencies in data collection, monitoring and reporting by CPCs in relation to tropical tunas will be discussed under agenda items 7, 8 and 9 and in paper IOTC–2012–WPTT14–06 and are therefore not presented in this paper.

DISCUSSION

In addition to the recommendations outlined in Appendix A, the SC made several other comments relevant to the WPTT, which participants are asked to consider:

Skipjack tuna

The SC **AGREED** that further investigation of the existing data irregularities, and expansion of the logbook programme to improve Maldivian CPUE analyses for skipjack tuna in the Indian Ocean be carried out in 2012. The SC also **AGREED** that further analyses of standardization of purse seine CPUE should be carried out in 2012. (para. 38)

Yellowfin tuna

The SC **NOTED** that Yield-per-recruit analyses are absent among the various methods used to assess the yellowfin tuna stock, whereas they are useful when there are several fleet components exploiting different age groups, and when gear regulations affecting age/size at first capture may be an important management tool. Therefore, the SC **AGREED** that the WPTT should be presented with such analytical approaches as part of the next assessment process. (para. 43)

Bigeye tuna

The SC **SUGGESTED** that at future WPTT meetings, the WPTT consider developing a figure that shows the likely status of the stock under different fishing scenarios, i.e. with and without particular fleets and gears, providing that sufficient data is available, noting that size sampling for some fleets is considered unreliable. The WPTT should also consider developing yield per recruit plots. (para. 50)

Implementation of the regional observer scheme

The SC **NOTED** the update on the implementation of the Regional Observer Scheme set out in Resolution 11/06 *on a Regional Observer Scheme* and **EXPRESSED** its concerns regarding the low level of implementation and reporting to the IOTC Secretariat of both the observer trip reports and the list of accredited observers since the start of the ROS in July 2010 (8 CPCs provided a list of accredited observers and 11 reports were submitted from 4 CPCs). (para. 138)

MPA effects on yellowfin tuna

The SC **AGREED** that the current network of closures is unlikely to be sufficient to protect yellowfin tuna stocks without additional management measures (e.g. a quota allocation system). (para. 183)

The Scientific Committee also adopted revised Executive Summaries for each of the tropical tuna species which are provided at Appendix B.

RECOMMENDATION

That the Working Party on Tropical Tuna **NOTE** the recommendations of the Fourteenth Session of the SC and consider how to progress these issues at the present meeting.

APPENDICES

Appendix A: Consolidated set of recommendations of the Fourteenth Session of the Scientific Committee (12–17 December, 2011) to the Commission, relevant to the Working Party on Tropical Tunas.

Appendix B: Status of the Indian Ocean Tropical Tuna species (bigeye tuna, skipjack tuna and yellowfin tuna).

APPENDIX A

CONSOLIDATED SET OF RECOMMENDATIONS OF THE FOURTEENTH SESSION OF THE SCIENTIFIC COMMITTEE (12–17 DECEMBER, 2011) TO THE COMMISSION RELEVANT TO THE WORKING PARTY ON TROPICAL TUNAS

Extract of the Report of the Fourteenth Session of the Scientific Committee

(IOTC–2011–SC14–R; Appendix XXXVIII, PAGES 248–259)

STATUS OF TUNA AND TUNA-LIKE RESOURCES IN THE INDIAN OCEAN

Tuna – Highly migratory species

SC14.01 (para. 129) The SC **RECOMMENDED** that the Commission note the management advice developed for each tropical tuna species as provided in the Executive Summary for each species.

- Bigeye tuna (*Thunnus obesus*) – Appendix XI
- Skipjack tuna (*Katsuwonus pelamis*) – Appendix XII
- Yellowfin tuna (*Thunnus albacares*) – Appendix XIII

GENERAL RECOMMENDATIONS TO THE COMMISSION

Dedicated workshop on CPUE standardisation

SC14.44 (para. 110) Noting the combined recommendations from the WPB, WPTmT and WPTT to hold a dedicated workshop on CPUE standardization in 2012, the SC **RECOMMENDED** that a dedicated, informal workshop on CPUE standardization, including issues of interest for other IOTC species, should be carried out before the next round of stock assessments in 2013, and that where possible it should include a range of invited experts, including those working on CPUE standardisation in other ocean/RFMOs, in conjunction with scientists from Japan, Republic of Korea and Taiwan,China, and supported by the IOTC Secretariat. The SC **NOTED** the CPUE workshop organised by ISSF and scheduled to be held late March 2012 in Hawai'i, USA, and urged national scientists working on purse seine CPUE standardisations to attend where possible.

Examination of the Effect of Piracy on Fleet Operations and Subsequent Catch and Effort Trends

SC14.46 (para. 127) In response to the request of the Commission (para. 40 of the S15 report), the SC **RECOMMENDED** that given the lack of quantitative analysis of the effects of piracy on fleet operations and subsequent catch and effort trends, and the potential impacts of piracy on fisheries in other areas of the Indian Ocean through the relocation of longliners to other fishing grounds, specific analysis should be carried out and presented at the next WPTT meeting by the CPCs most affected by these activities, including Japan, Republic of Korea and Taiwan,China.

Implementation of the Regional Observer Scheme

SC14.47 (para. 139) The SC **RECOMMENDED** that all IOTC CPCs urgently implement the requirements of Resolution 11/04 on a Regional Observer Scheme, which states that: "The observer shall, within 30 days of completion of each trip, provide a report to the CPCs of the vessel. The CPCs shall send within 150 days at the latest each report, as far as continuous flow of report from observer placed on the longline fleet is ensured, which is recommended to be provided with 1°x1° format to the Executive Secretary, who shall make the report available to the Scientific Committee upon request. In a case where the vessel is fishing in the EEZ of a coastal state, the report shall equally be submitted to that Coastal State." (para. 11), **NOTING** that the timely submission of observer trip reports to the Secretariat is necessary to ensure that the Scientific Committee is able to carry out the tasks assigned to it by the Commission, including the analysis of accurate and high resolution data, in particular for bycatch, which would allow the scientists to better assess the impacts of fisheries for tuna and tuna-like species on bycatch species.

SC14.48 (para. 143) The SC **AGREED** that such a low level of implementation and reporting is detrimental to its work, in particular regarding the estimation of incidental catches of non-targeted species, as requested by the Commission and **RECOMMENDED** the Commission to consider how to address the lack of implementation of observer programmes by CPCs for their fleets and reporting to the IOTC Secretariat as per the provision of Resolution 11/04 *on a Regional Observer Scheme*, noting the update provided in Appendix XXXIV.

Implementation of the Precautionary approach and Management strategy Evaluation

SC14.49 (para. 146) Noting that the development of an MSE process will require management objectives to be specified, the SC **RECOMMENDED** that the Commission provide clear guidance in this regard, noting that the adoption of the Precautionary Approach, as defined in the Fish Stocks Agreement, may be the first step.

SC14.50 (para. 149) The SC **RECOMMENDED** that interim target and limit reference points be adopted and a list of possible provisional values for the major species is listed in Table 5. These values should be replaced as soon as the MSE process is completed. Provisional target reference points would be based on the MSY level of the indicators, and on different multipliers for the limit reference points.

Table 5. Interim target and limit reference points.

Stock	Target Reference Point	Limit Reference Point
Albacore	B_{MSY}; F_{MSY}	$0.4*B_{MSY}$; $1.4*F_{MSY}$
Bigeye tuna	B_{MSY}; F_{MSY}	$0.5*B_{MSY}$; $1.3*F_{MSY}$
Skipjack tuna	B_{MSY}; F_{MSY}	$0.4*B_{MSY}$; $1.5*F_{MSY}$
Yellowfin tuna	B_{MSY}; F_{MSY}	$0.4*B_{MSY}$; $1.4*F_{MSY}$
Swordfish	B_{MSY}; F_{MSY}	$0.4*B_{MSY}$; $1.4*F_{MSY}$

SC14.51 (para. 157) The SC **ENDORSED** the roadmap presented for the implementation of MSE in the Indian Ocean in IOTC–2011–SC14–36 and **RECOMMENDED** the Commission agree to initiate a consultative process among managers, stakeholders and scientists to begin discussions about the implementation of MSE in IOTC.

Outlook on Time-Area Closures

SC14.55 (para. 173) Noting that the request contained in Resolution 10/01 does not specify the expected objective to be achieved with the current or alternative time area closures, and that the SC and WPTT were not clear about the intended objectives of the time-area closure taking into account recent reduction of effort as well as recent likely recovery of the yellowfin tuna population, the SC **RECOMMENDED** that the Commission specify clear objectives as to what are the management objectives to be achieved with this and/or alternative measures. This will, in turn, guide and facilitate the analysis of the SC, via the WPTT in 2012 and future years.

SC14.56 (para. 174) Noting the lack of research examining time-area closures in the Indian Ocean by the WPTT in 2011, as well as the slow progress made in addressing the Commission request, the SC **RECOMMENDED** that the SC Chair begins a consultative process with the Commission in order to obtain clear guidance from the Commission about the management objectives intended with the current or any alternative closure. This will allow the SC to address the Commission request more thoroughly.

Evaluation of the IOTC time-area closure

SC14.57 (para. 178) The SC **RECOMMENDED** that the Commission note that the current closure is likely to be ineffective, as fishing effort will be redirected to other fishing grounds in the Indian Ocean. The positive impacts of the moratorium within the closed area would likely be offset by effort reallocation. For example, the WPTmT noted that longline fishing effort has been redistributed to traditional albacore fishing grounds in recent years, thereby further increasing fishing pressure on this stock.

SC14.58 (para. 179) Noting that the objective of Resolution 10/01 is to decrease the overall pressure on the main targeted stocks in the Indian Ocean, in particular yellowfin tuna and bigeye tuna, and also to evaluate the impact of the current time/area closure and any alternative scenarios on tropical tuna population, the SC **RECOMMENDED** that the Commission specify the level of reduction or the long term management objectives to be achieved with the current or alternative time area closures, as these are not contained within the Resolution 10/01.

Alternative Management Measures; Impacts of the Purse-Seine Fishery; Juvenile Tuna Catches

SC14.60 (para. 190) The SC **NOTED** however, that the fishery statistics available for many fleets, in particular for coastal fisheries, are not accurate enough for a comprehensive analysis as has been repeatedly noted in previous WPTT and SC reports. In particular, the SC **RECOMMENDED** that all CPCs catching yellowfin tuna should undertake scientific sampling of their yellowfin tuna catches to better identify the proportion of bigeye tuna catches. Therefore, the SC **RECOMMENDED** the countries engaged in those fisheries to take immediate actions to reverse the situation of fishery statistics reporting to the IOTC Secretariat.

SC14.61 (para. 192) The SC **ADVISED** the Commission that the Western and Central Pacific Fisheries Commission has implemented since 2009 a FAD closure for the conservation of yellowfin tuna and bigeye tuna juveniles which has been very effective. The SC **RECOMMENDED** further investigation of the feasibility and impacts of such a measure, as well as other measures, in the context of Indian Ocean fisheries and stocks.

RESEARCH RECOMMENDATIONS AND PRIORITIES

Working Party on Tropical Tunas (WPTT)

CPUE standardisation

SC14.74 (para. 211) The SC **RECOMMENDED** that if possible, the IOTC Secretariat and Maldivian scientists continue the joint effort to standardize the Maldivian pole-and-line CPUE in preparation for assessment in 2012.

SC14.75 (para. 212) The SC **RECOMMENDED** that standardization of purse seine CPUE be made where possible using the operational data on the fishery, and that participants working on CPUE for the main fleets, attend the CPUE standardization workshop being organized by ISSF in Honolulu, Hawaii in 2012.

Stock assessment

SC14.76 (para. 213) Noting the difficulty of carrying out stock assessments for three tropical tuna species in a single year, the SC **RECOMMENDED** to a revised assessment schedule on a two- or three-year cycle for the three tropical tuna species as outlined in Table 9. Following the uncertainty remaining in the yellowfin tuna assessment the SC **AGREED** that priories for stock assessments in 2012 would be yellowfin tuna (Multifan-CL and SS3, Yield per recruit and possibly others) with an update of fishery indicators for the other two species.

Table 9. New schedule proposed for tropical tuna species stock assessment.

Species/Assessment year	2012	2013	2014	2015	2016	2017
Yellowfin tuna	Full	Update	Update	Full	Update	Update
Skipjack tuna	Update	Full	Update	Update	Full	Update
Bigeye tuna	Update	Update	Full	Update	Update	Full

Note: the schedule may be change depending on the situation of the stock from various sources such as fishery indicators, Commission requests, etc.

Additional topics for research

SC14.77 (para. 214) The SC **RECOMMENDED** the following core topic areas as priorities for research over the coming year in order of priority: update of the Brownie-Peterson method for the 3 tropical tuna species (possible issue for the 2012 IO Tuna Tagging Symposium).

- An updated yellowfin tuna growth curve (work in progress to be presented to 2012 Tuna Tagging Symposium).
- Multi-gear yield per recruit.

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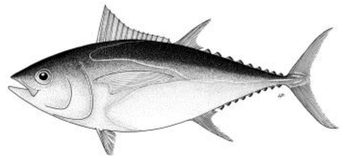

Status of the Indian Ocean bigeye tuna resource (*Thunnus obesus*)

TABLE 1. Status of bigeye tuna (*Thunnus obesus*) in the Indian Ocean.

Area[1]	Indicators – 2011 assessment			2011 stock status determination 2009[2]
		SS3[3]	ASPM[4]	
Indian Ocean	Catch:	102,000 t	71,500 t	
	Average catch last 5 years:	104,700 t	104,700 t	
	MSY:	114,000 (95,000–183,000 t)	102,900 t (86,600–119,300 t)	
	F_{curr}/F_{MSY}:	0.79 (0.50–1.22)	0.67 (0.48–0.86)	
	SB_{curr}/SB_{MSY} :	1.20 (0.88–1.68)	1.00 (0.77–1.24)	
	SB_{curr}/SB_0:	0.34 (0.26–0.40)	0.39	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[2]The stock status refers to the most recent years' data used for the assessment.
[3]Central point estimate is adopted from the 2010 SS3 model, percentiles are drawn from a cumulative frequency distribution of MPD values with models weighted as in Table 12 of 2010 WPTT report (IOTC–2010–WPTT12–R); the range represents the 5th and 95th percentiles.
[4]Median point estimate is adopted from the 2011 ASPM model using steepness value of 0.5 which is the most conservative scenario (values of 0.6, 0.7 and 0.8, which are more optimistic, are considered to be as plausible as these values but are not presented for simplification); the range represents the 90 percentile Confidence Interval.
Current period ($_{curr}$) = 2009 for SS3 and 2010 for ASPM.

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)		
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. Both assessments suggest that the stock is above a biomass level that would produce MSY in the long term and that current fishing mortality is below the MSY-based reference level (i.e. $SB_{current}/SB_{MSY}$ > 1 and $F_{current}/F_{MSY}$ < 1) (Table 1 and Fig. 1). Current spawning stock biomass was estimated to be 34–40 % (Table 1) of the unfished levels. The central tendencies of the stock status results from the WPTT 2011 when using different values of steepness were similar to the central tendencies presented in 2010.

Outlook. The recent declines in longline effort, particularly from the Japanese, Taiwan,China and Republic of Korea longline fleets, as well as purse seiner effort have lowered the pressure on the Indian Ocean bigeye tuna stock, indicating that current fishing mortality would not reduce the population to an overfished state.

Catches in 2010 (71,489 t) were lower than MSY values and catches in 2009 (102,664 t) were at the lower range of MSY estimates. The mean catch over the 2008–2010 period was 93,761 t which is lower than estimated MSY.

The Kobe strategy matrix (Combined SS3 and ASPM) illustrates the levels of risk associated with varying catch levels over time and could be used to inform management actions (Table 2). Based on the ASPM projections this year (2011) with steepness 0.5 value for illustration, there is relatively a low risk of exceeding MSY-based reference points by 2020 both when considering current catches of 71,489 t (maximum of 15% risk of $B<B_{MSY}$) or 2009 catches of 102,664 t (<40% risk that $B_{2020}<B_{MSY}$ and $F_{2020}>F_{MSY}$). Moreover, the SS3 projections from last year (2010) show that there is a low risk of exceeding MSY-based reference points by 2019 if catches are maintained at the lower range of MSY levels or at the catch level of 102,664 t from 2009 (< 30% risk that $B_{2019}<B_{MSY}$ and < 25% risk that F_{2019}>FMSY) (Table 1).

The SC **RECOMMENDED** the following:

- The Maximum Sustainable Yield estimate for the Indian Ocean ranges between 102,900 and 114,000 t (range expressed as the median value for 2010 SS3 and steepness value of 0.5 for 2011 ASPM for illustrative purposes (see Table 1 for further description)). Annual catches of bigeye tuna should not exceed the lower range of this estimate which corresponds to the 2009 catches and last year management advice.

- If the recent declines in effort continue, and catch remains substantially below the estimated MSY of 102,900–114,000 t, then immediate management measures are not required. However, continued monitoring and improvement in data collection, reporting and analysis is required to reduce the uncertainty in assessments.

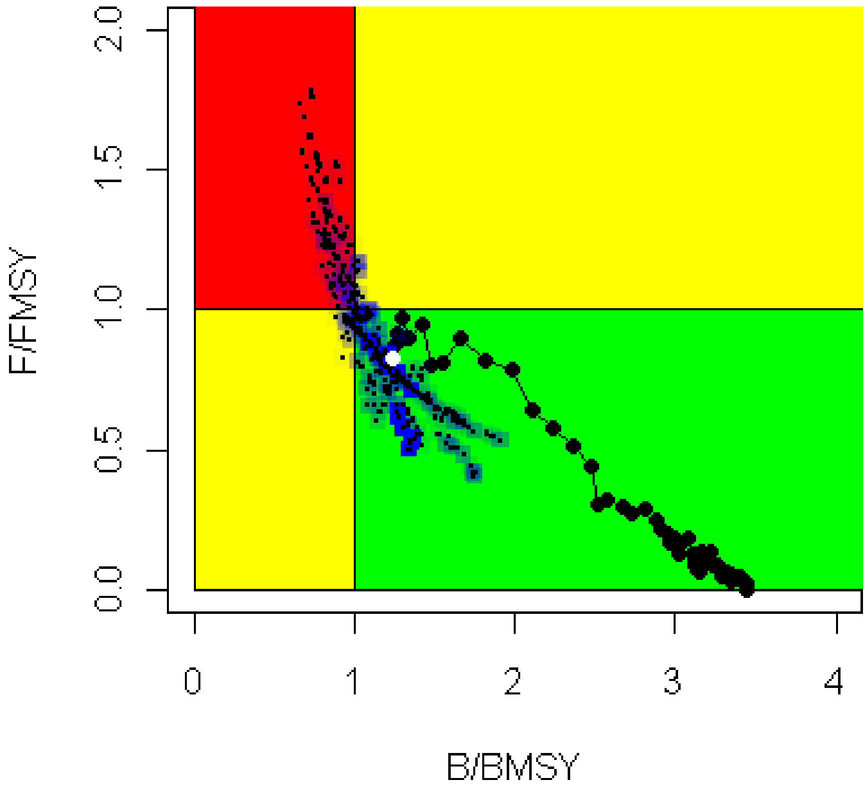

Fig. 1. SS3 Aggregated Indian Ocean assessment Kobe plot. Black circles represent the time series of annual median values from the weighted stock status grid (white circle is 2009). Blue squares indicate the MPD estimates for 2009 corresponding to each individual grid C model, with colour density proportional to the weighting (each model is also indicated by a small black point, as the squares from highly down weighted models are not otherwise visible).

TABLE 2. Bigeye tuna: Combined 2010 SS3 and 2011 ASPM Aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based reference points for five constant catch projections (2009 and 2010 catch levels, ± 20% and ± 40%) projected for 3 and 10 years. K2SM adopted from the 2011 ASPM model using steepness value of 0.5 (values of 0.6, 0.7 and 0.8 are considered to be as plausible as these values but are not presented for simplification).

Reference point and projection timeframe	**Alternative catch projections (relative to 2009) and probability (%) of violating reference point**				
	2010 SS3				
	60% (61,200 t)	**80%** (81,600 t)	**100%** (102,000 t)	**120%** (122,400 t)	**140%** (142,800 t)
$SB_{2012} < SB_{MSY}$	19	24	28	40	50
$F_{2012} > F_{MSY}$	<1	<6	22	50	68
$SB_{2019} < SB_{MSY}$	19	24	30	55	73
$F_{2019} > F_{MSY}$	<1	<6	24	58	73

Reference point and projection timeframe	**Alternative catch projections (relative to 2010) and probability (%) of violating reference point**				
			2011 ASPM[1]		
	60% (42,900t)	**80%** (57,200t)	**100%** (71,500t)	**120%** (85,800t)	**140%** (100,100t)
$SB_{2013} < SB_{MSY}$	4	8	15	24	35
$F_{2013} > F_{MSY}$	<1	<1	1	8	33
$SB_{2020} < SB_{MSY}$	<1	<1	1	11	41
$F_{2020} > F_{MSY}$	<1	<1	<1	5	38

SUPPORTING INFORMATION

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

CONSERVATION AND MANAGEMENT MEASURES

Bigeye tuna (*Thunnus obesus*) in the Indian Ocean is 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 10/01 *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 10/03 *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

Bigeye tuna *(Thunnus obesus)* inhabit the tropical and subtropical waters of the Pacific, Atlantic and Indian Oceans in waters down to around 300 m. Table 3 outlines some of the key life history traits of bigeye tuna relevant for management.

[1] Projections were undertaken with a steepness value at 0.5 which is the most conservative scenario. (values of 0.6, 0.7 and 0.8, which are more optimistic, are considered to be as plausible as these values but are not presented for simplification).

TABLE 3. Biology of Indian Ocean bigeye tuna (*Thunnus obesus*).

Parameter	Description
Range and stock structure	Inhabits the tropical and subtropical waters of the Pacific, Atlantic and Indian Oceans in waters down to around 300 m. Juveniles frequently school at the surface underneath floating objects with yellowfin and skipjack tunas. Association with floating objects appears less common as bigeye grow older. The tag recoveries from the RTTP-IO provide evidence of rapid and large scale movements of juvenile bigeye tuna in the Indian Ocean, thus supporting the current assumption of a single stock for the Indian Ocean. The average minimum distance between juvenile tag-release-recapture positions is estimated at 657 nautical miles. The range of the stock (as indicated by the distribution of catches) includes tropical areas, where reproduction occurs, and temperate waters which are believed to be feeding grounds.
Longevity	15 years
Maturity (50%)	Age: females and males 3 years. Size: females and males 100 cm.
Spawning season	Spawning season from December to January and also in June in the eastern Indian Ocean.
Size (length and weight)	Maximum length: 200 cm FL; Maximum weight: 210 kg. Newly recruited fish are primarily caught by the purse seine fishery on floating objects. 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 yellowfin tuna and are mainly limited to surface tropical waters, while larger fish are found in sub-surface waters.

SOURCES: Nootmorn (2004); Froese & Pauly (2009)

Catch trends

Bigeye tuna are mainly caught by industrial purse seine and longline fisheries and appears only occasionally in the catches of other fisheries (Fig. 2). However, in recent years the amounts of bigeye tuna caught by gillnet fisheries are likely to be considerably higher than what is reported, due to the major changes experienced in some of these fleets, notably changes in boat size, fishing techniques and fishing grounds.

Total annual bigeye tuna catches have increased steadily since the start of the fishery, reaching the 100,000 t level in 1993 and peaking at 150,000 t in 1999 (Fig. 2). Total annual catches averaged 130,849 t over the period 2001–2005 and 104,635 t over the period 2006–2010 (Table 4). In 2010, preliminary catches of bigeye tuna have been estimated to be at around 71,489 t, representing a large decrease in catches with respect to those estimated for 2009 and previous years (Figs. 2, 3).

The recent drop in catches of bigeye tuna could be related to the expansion of piracy in the western tropical Indian Ocean, which has led to a marked drop in the levels of longline effort in the core fishing area of the species (Figs. 4a, b).

Bigeye tuna has been caught by industrial longline fleets since the early 1950's, but before the mid-1970's they only represented an incidental component of the total catch. With the introduction of fishing practices that improved the access to the bigeye tuna resource and the emergence of a sashimi market in the mid-1970's, bigeye tuna became an important target species for the main industrial longline fleets (Figs. 2, 3). The catches estimated for 2010 are at around 46,000 t, representing less than half the longline catches of bigeye tuna recorded before the onset of piracy in the Indian Ocean.

The total catch of bigeye tuna by purse seiners in the Indian Ocean reached 40,700 t in 1999, but the average annual catch for the period 2006–2010 was 26,000 t (25,000 t for 2001–2005) (Fig. 2). Purse seiners mainly take small juvenile bigeye tuna (averaging around 5–6 kg) whereas longliners catch much larger and heavier fish; and therefore while purse seiners take much lower tonnages of bigeye tuna compared to longliners, they take larger numbers of individual fish.

Although the activities of purse seiners have been affected by piracy in the Indian Ocean, 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 since the mid-2009, which has made it possible for purse seiners to operate in the northwest Indian Ocean without a reduction in fishing effort (Fig. 4). However, in the IOTC area an approximate 30% reduction of the number of purse seiner has been observed since 2006.

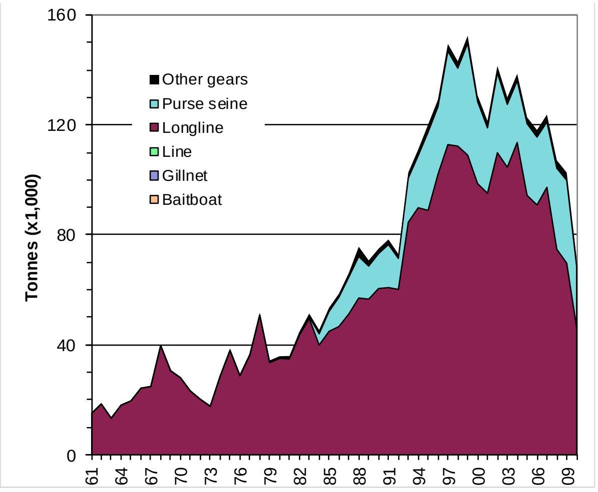

Fig. 2. Annual catches of bigeye tuna by gear recorded in the IOTC Database (1961–2010) (Data as of September 2011).

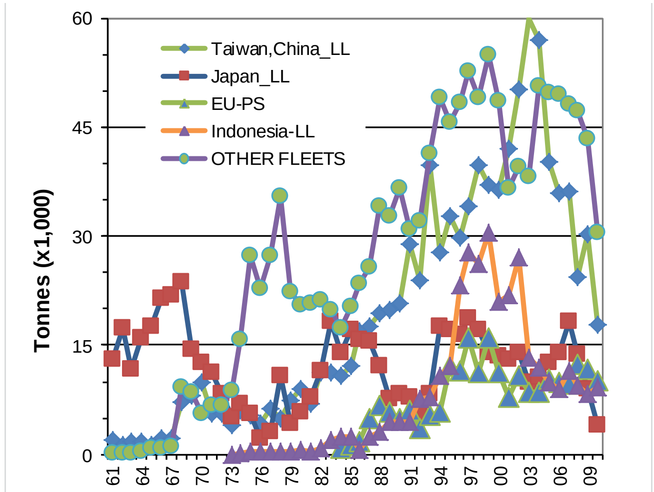

Fig. 3. Annual catches of bigeye tuna by fleet recorded in the IOTC Database (1961–2010) (Data as of September 2011).

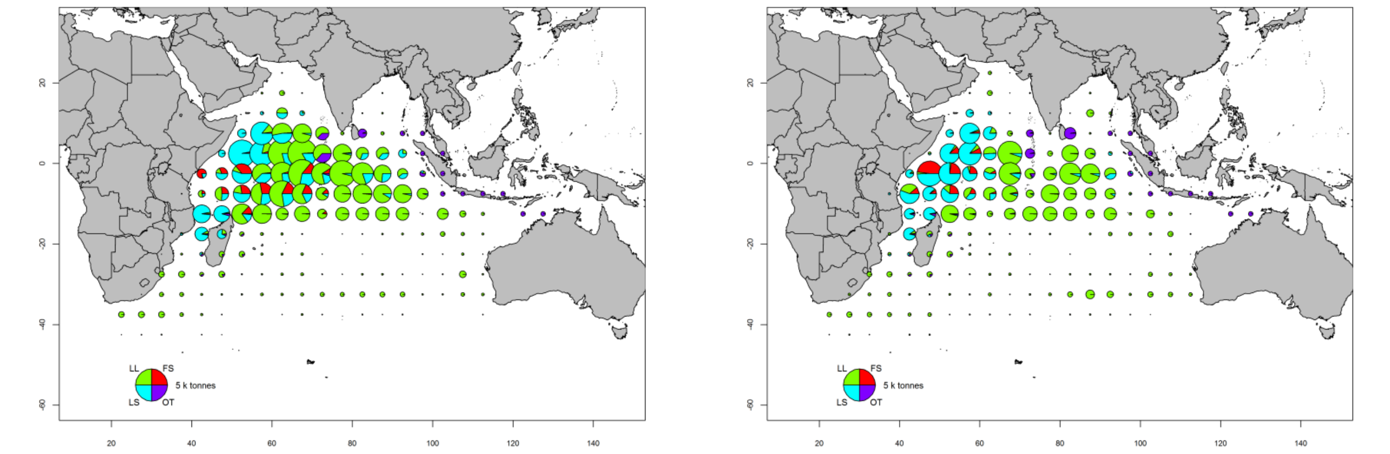

Fig. 4a–b. Time-area catches (total combined in tonnes) of bigeye tuna estimated for 2009 and 2010 by type of gear: Longline (LL), Purse seine free-schools (FS), Purse seine associated-schools (LS), and other fleets (OT), including pole-and-line, drifting gillnets, and various coastal fisheries (Data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

TABLE 4. Best scientific estimates of the catches of bigeye tuna (*Thunnus obesus*) 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
LL-TW	6,008	18,684	23,647	28,226	19,759	14,699	14,693	14,091	11,217	13,288	15,299	17,261	19,630	14,336	9,812	4,490
LL-JP	481	3,288	6,820	17,716	68,347	80,201	80,472	95,807	93,398	100,341	79,064	73,632	77,695	60,417	59,917	41,875
FS	0	0	0	2,067	4,808	6,042	4,260	4,099	7,172	3,658	8,501	6,406	5,670	9,648	5,317	3,827
LS	0	0	0	4,234	18,224	20,147	19,457	24,944	15,662	18,749	17,568	18,249	18,066	19,831	24,773	18,438
OT	154	279	575	1,544	2,298	2,577	2,564	2,504	2,573	2,549	2,315	2,616	2,667	2,897	2,846	2,859
Total	**6,642**	**22,252**	**31,043**	**53,787**	**113,437**	**123,666**	**121,447**	**141,445**	**130,023**	**138,584**	**122,748**	**118,164**	**123,728**	**107,129**	**102,664**	**71,489**

Fisheries: Longline Taiwan,China and assimilated fleets (LL-TW); Longline Japan and assimilated fleets (LL-JP); Purse seine free-school (**FS**); Purse seine associated school (**LS**); Other gears nei (**OT**).

Uncertainty of catches

Retained catches are thought to be well known for the major fleets (Fig. 5); but are uncertain for the fleets listed below, noting that catches for these fleets are considered to represent a small proportion of total catches:

- Non-reporting industrial purse seiners and longliners (NEI) and for other industrial fisheries (longliners of India and Philippines).
- Some artisanal fisheries including the pole-and-line fishery in the Maldives.

- The gillnet fisheries of Iran and Pakistan.
- The gillnet/longline fishery in Sri Lanka.
- The artisanal fisheries in Indonesia, Comoros and Madagascar.

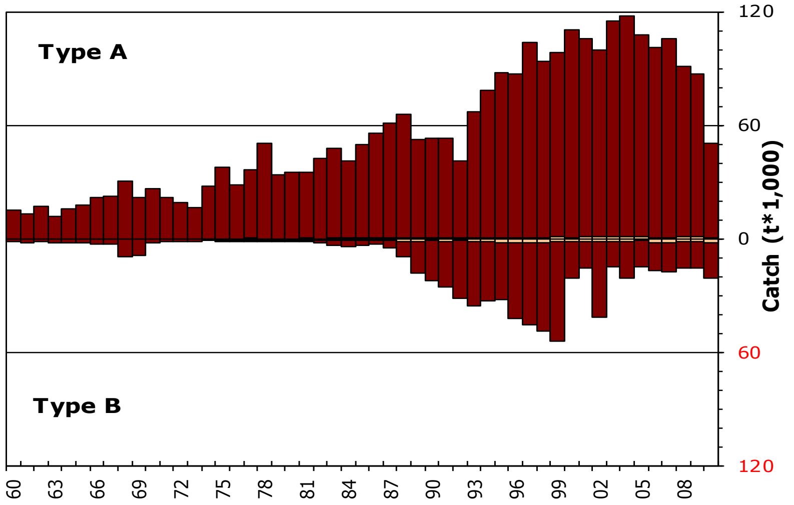

Fig. 5. Uncertainty of annual catch estimates for bigeye tuna (Data as of September 2011).

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.

- The catch series for bigeye tuna has not been significantly 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.
- Catch-and-effort series are generally available from the major industrial fisheries. However, these data are not available from some fisheries or they are considered to be of poor quality, especially throughout the 1990s and in recent years, for the following reasons:
    - non-reporting by industrial purse seiners and longliners (NEI).
    - no data are available for the fresh-tuna longline fishery of Indonesia, over the entire time series, and very little data available for the fresh-tuna longline fishery of Taiwan,China.
    - uncertain data from significant fleets of industrial purse seiners from Iran and longliners from India, Indonesia, Malaysia, Oman, Philippines, and Taiwan,China (fresh tuna up to 2006).
    - no data available for the highseas gillnet fisheries of Iran and Pakistan and the gillnet/longline fishery of Sri Lanka, especially in recent years.

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 vessles 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.

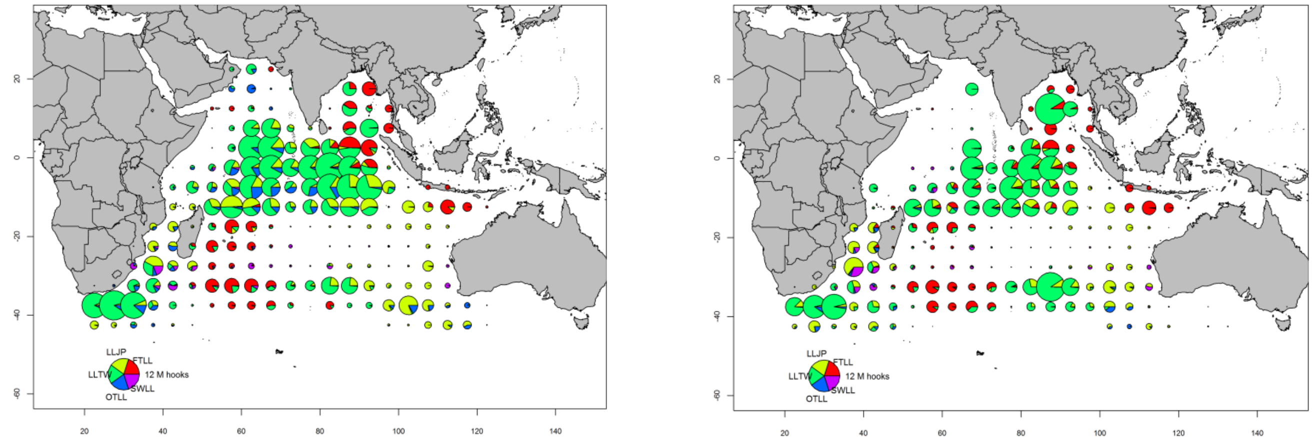

Fig. 6. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).
LLJP (light green): deep-freezing longliners from Japan
LLTW (dark green): deep-freezing longliners from Taiwan,China
SWLL (turquoise): 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)

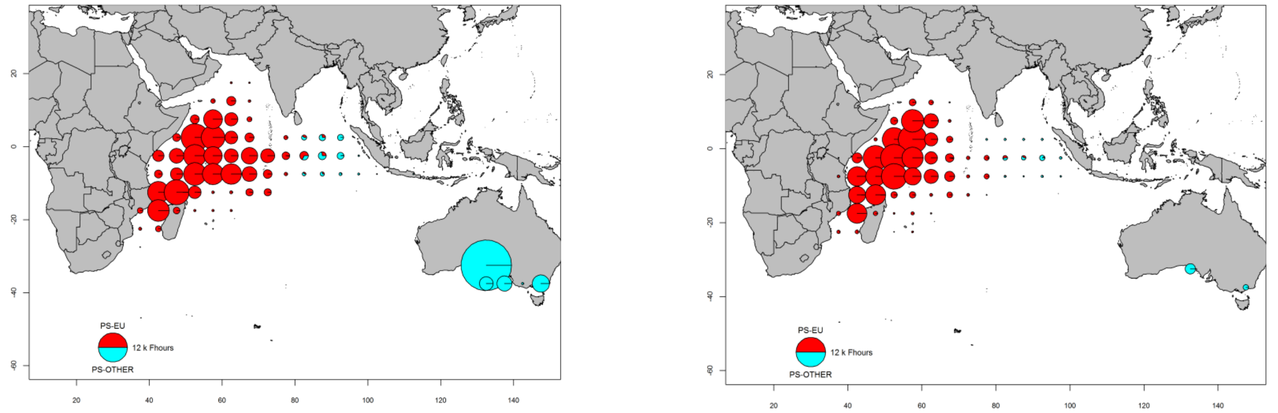

Fig. 7. Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).
PS-EU (red): Industrial purse seiners monitored by the EU and Seychelles (operating under flags of EU countries, Seychelles 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)

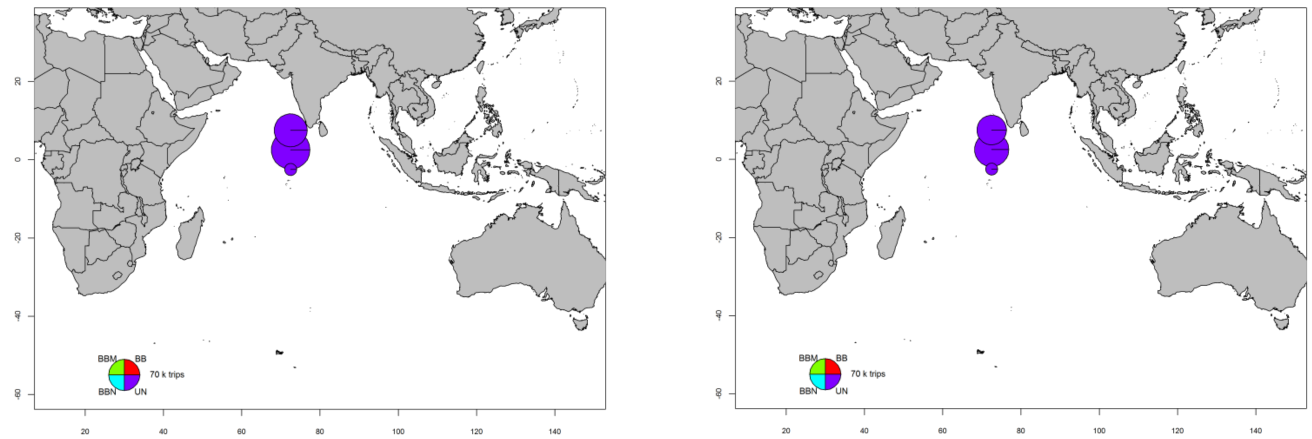

Fig. 8. Number of fishing trips by vessels flagged to the Maldives by 5 degree square grid, type of boat and gear, for the years 2009 (left) and 2010 (right) (Data as of August 2011).
BBN (blue): Baitboat non-mechanized; BBM (Green): Baitboat mechanized; BB (Red): Baitboat unspecified; UN (Purple): Unclassified 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 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.

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

Of the CPUE series available for assessment purposes, listed below, only the Japanese series from the tropical areas of the Indian Ocean was used in the stock assessment model for 2011 (shown in Fig. 10).

- Taiwan,China data (1980–2010): Series from document IOTC–2011–WPTT13–39 (Fig. 9).
- Japan data (1960–2010): Series 2 from document IOTC–2011–WPTT13–52. Whole Indian Ocean (Figs. 9 and 10).
- Rep. of Korean data (1977–2009): Series from document IOTC–2011–WPTT13–38 (Fig. 9).
- Japan data (1960–2010): Series1 from document IOTC–2011–WPTT13–52. Tropical area of Indian Ocean (Fig. 10).

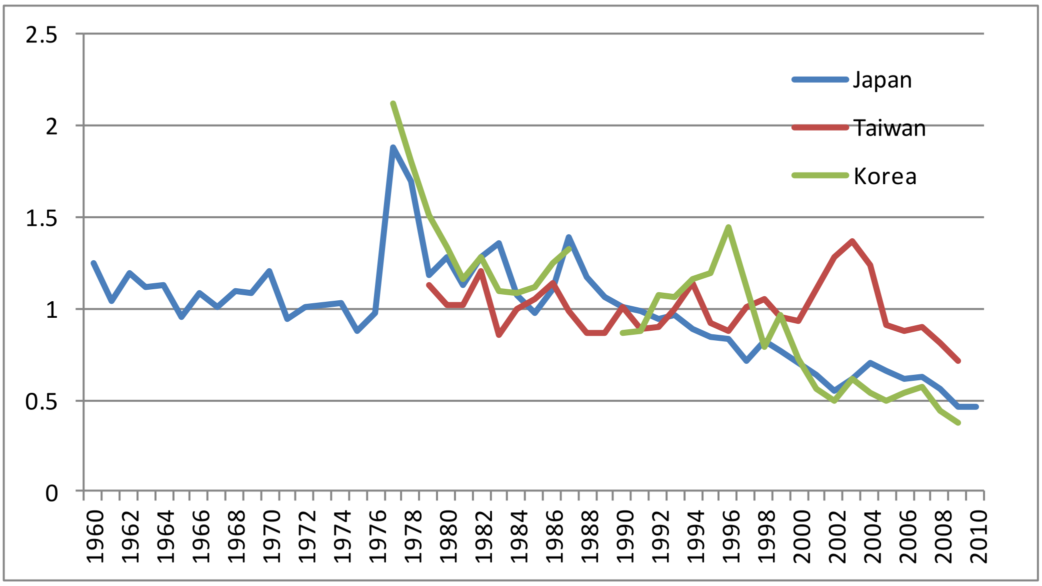

Fig. 9. Comparison of the three standardised CPUE series for Indian Ocean bigeye tuna. Series have been rescaled relative to their respective means from 1960–2010.

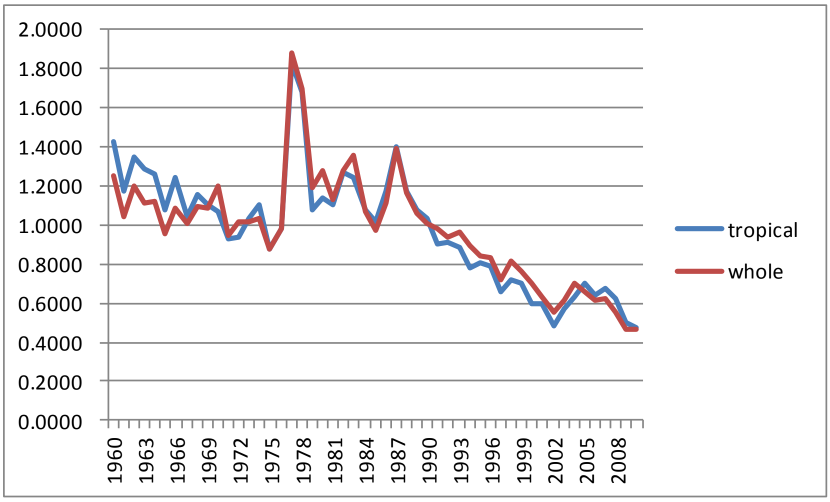

Fig. 10. Comparison of two Japanese standardised CPUE series for Indian Ocean bigeye tuna, one for the whole Indian Ocean and one for the tropical area only. Series have been rescaled relative to their respective means from 1960–2010.

The large increase in both the nominal and standardized bigeye tuna CPUEs for longline fleets in the Indian Ocean (as well as in the Atlantic) (Figs. 9 and 10). The increase in CPUEs may be due (1) to a large increase in the adult stock biomass, or (2) more probably to the introduction of deep longline in 1977. The fishery data does not allow to estimate a fully realistic trend of adult BET biomass during the seventies.

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

Trends in average weight (Fig. 11) can be assessed for several industrial fisheries although they are incomplete or of poor quality for most fisheries before the mid-1980s and for some fleets in recent years (e.g. Japan longline) (see paper IOTC–2011–WPTT13–08).

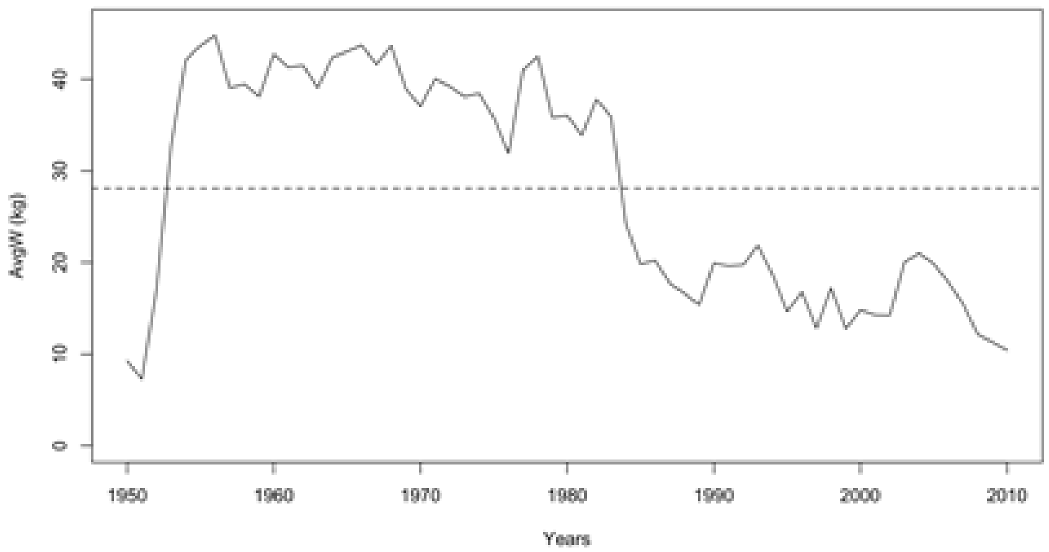

Fig. 11. Changes in average weight (kg) of bigeye tuna from 1950 to 2010 – all fisheries combined (Data as of September 2011).

- Catch-at-Size and Age tables are available but the estimates are highly uncertain for some periods and fisheries including:
    - the paucity of size data available from industrial longliners before the mid-60s, from the early-1970s up to the mid-1980s and in recent years (Japan).
    - the paucity of catch by area data available for some industrial fleets (NEI, India, Indonesia, Iran, Sri Lanka).

Tagging data

The WPTT **NOTED** that a total of 35,971 bigeye tuna were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP) which represented a 17.8% of the total number of fish tagged. Most of the bigeye tuna tagged (96.1%) were tagged during the main EU-funded Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) and were primarily released off the coast of Tanzania (Fig. 12) 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 5,563 (15.7%) of tagged fish have been recovered and reported to the IOTC Secretariat.

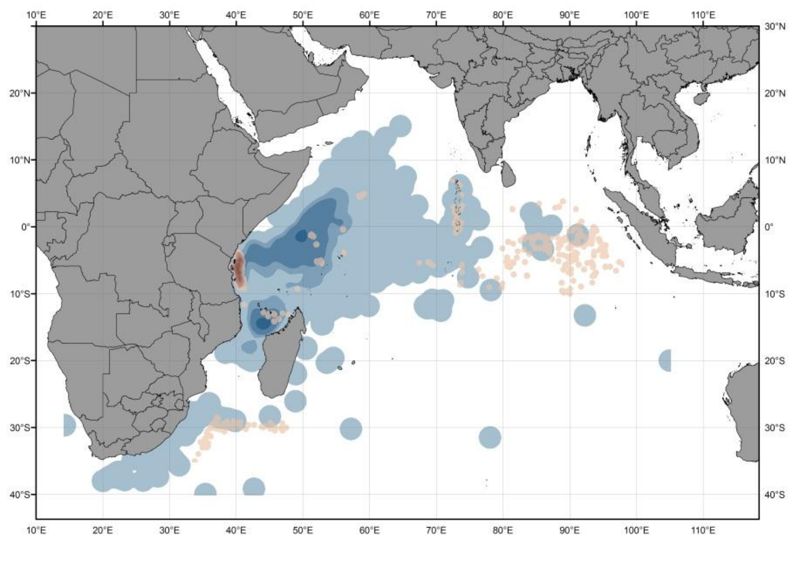

Fig. 12. Densities of releases (in red) and recoveries (in blue) of bigeye tuna. Data as of September 2011.

STOCK ASSESSMENT

A single quantitative modelling method (ASPM) was applied to the bigeye tuna assessment in 2011, using data from 1950–2010. The following is worth noting with respect to the modelling approach used:

- The steepness value (h=0.5) was selected on the basis of the likelihood and was near the lower boundary of what would be considered plausible for bigeye tuna. Selection of steepness on the basis of the likelihood was not considered reliable because i) steepness is difficult to estimate in general, and ii) substantial autocorrelation in the recruitment deviates was ignored in the likelihood term.
- Cohort-slicing to estimate ages from lengths introduces substantial errors, for long-living species such as bigeye tuna, except for the youngest ages.
- Uncertainty in natural mortality was not considered.

It is essential to include uncertainty in the steepness parameter as a minimum requirement for the provision of management advice. The general population trends and MSY parameters estimated by the ASPM model appeared to be plausibly consistent with the general perception of the fishery and the data. However, these results are considered to be uncertain because of i) uncertainty in the catch rate standardization, and ii) uncertainty in recent catches.

Management advice for bigeye tuna was based on the 2010 SS3 stock assessment and various steepness scenarios of the current 2011 ASPM stock assessment results (Tables 1, 5). For last year's SS3 assessment, the data did not seem to be sufficiently informative to justify the selection of any individual model and the results were combined on the basis of a model weighting scheme that was proposed to, and agreed by, the WPTT in 2010.

Key assessment results for the 2010 SS3 and 2011 ASPM stock assessments are shown in Tables 1, 2 and 5; Fig. 1.

Table 5. Key management quantities from the 2010 SS3 and 2011 ASPM assessments for bigeye tuna in the Indian Ocean.

Management Quantity	**2010 SS3**	**2011 ASPM**
2009 (SS3) and 2010 (ASPM) catch estimate	102,000 t	71,500 t
Mean catch from 2006–2010	104,700 t	104,700 t
MSY	114,000 t (95,000–183,000)	102,900 t (86,600–119,300) (2)
Data period used in assessment	1952–2009	1950–2010
F_{curr}/F_{MSY} (3)	0.79 (1) Range(1): 0.50 – 1.22	0.67 (0.48–0.86) (2)
B_{curr}/B_{MSY} (3)	–	–
SB_{curr}/SB_{MSY} (3)	1.20 (1) Range(1): 0.88 – 1.68	1.00 (0.77–1.24) (2)
B_{curr}/B_0 (3)	–	0.43 (n.a.)
SB_{curr}/SB_0 (3)	0.34(1) Range(1): 0.26 – 0.40	0.39(2)
$B_{curr}/B_{0,\ F=0}$ (3)	–	–
$SB_{curr}/SB_{0,\ F=0}$ (3)	–	–

[1] Central point estimate is adopted from the 2010 SS3 model, percentiles are drawn from a cumulative frequency distribution of MPD values with models weighted as in Table 12 of 2010 WPTT report (IOTC–2010–WPTT12–R); the range represents the 5^{th} and 95^{th} percentiles.
[2] Median point estimate is adopted from the 2011 ASPM model using steepness value of 0.5 (values of 0.6, 0.7 and 0.8 are considered to be as pausible as these values but are not presented for simplification); the range represents the 90 percentile Confidence Interval.
[3] Current period ($_{curr}$) = 2009 for SS3 and 2010 for ASPM.

LITERATURE CITED

Froese R, & Pauly DE, 2009. *FishBase*, version 02/2009, FishBase Consortium, <www.fishbase.org>.
Nootmorn, P., 2004. Reproductive biology of bigeye tuna in the eastern Indian Ocean. IOTC–2004–WPTT04–05.

EXECUTIVE SUMMARY: SKIPJACK TUNA

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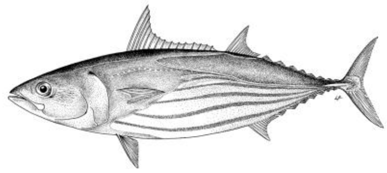

Status of the Indian Ocean skipjack tuna Resource (*Katsuwonus pelamis*)

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

Area[1]	Indicators – 2011 assessment		2011 stock status determination 2009[2]
Indian Ocean	Catch 2010:	428,719 t	(green)
	Average catch 2006–2010:	489,385 t	
	MSY (1 model):	564,000 t (395,000–843,000 t)	
	C_{2009}/MSY (1 model)[3]:	0.81 (0.54–1.16)	
	SB_{2009}/SB_{MSY} (1 model):	2.56 (1.09–5.83)	
	SB_{2009}/SB_0 (1 model):	0.53 (0.29–0.70)	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[2]The stock status refers to the most recent years' data used for the assessment.
[3]Due to numerical problems in the F_{MSY} calculations for this population, the proxy reference point C/MSY is reported instead of F/FMSY, 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 $F << F_{MSY}$.

Colour key	Stock overfished($SB_{year}/SB_{MSY}< 1$)	Stock not overfished ($SB_{year}/SB_{MSY}\geq 1$)
Stock subject to overfishing(C_{year}/MSY> 1)	(red)	(orange)
Stock not subject to overfishing (C_{year}/MSY$\leq$ 1)	(yellow)	(green)

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. The weighted results suggest that the stock is not overfished ($B>B_{MSY}$) and that overfishing is not occurring (C<MSY, used as a proxy for $F<F_{MSY}$) (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 fisheries 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 B2019 < BMSY and 30 % risk that C2019>MSY as proxy of F > FMSY) and even if catches are maintained below the 2006–2010 average (489,385 t).

The SC **RECOMMENDED** 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 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.

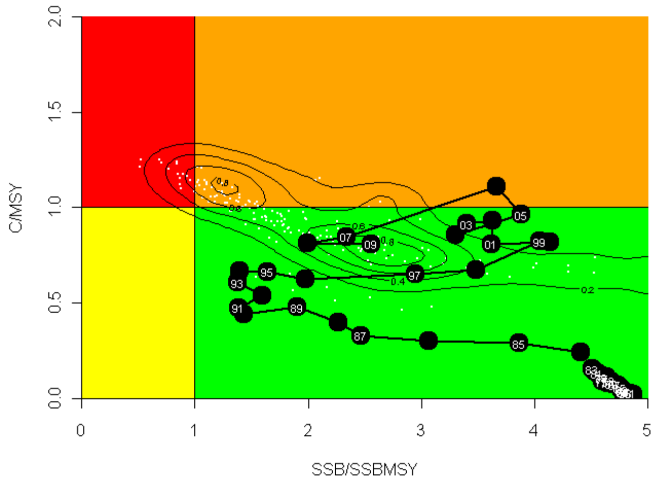

Fig. 1. SS3 Aggregated Indian Ocean assessment Kobe plot. Black circles indicate the trajectory of the weighted median of point estimates for the SB ratio and C/MSY ratio for each year 1950–2009. Probability distribution contours are provided only as a rough visual guide of the uncertainty (e.g. the 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, ± 20% and ± 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 easily 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	7 years
Maturity (50%)	Age: females and males <2 years. Size: females and males 41–43 cm. Unlike in *Thunnus* 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). NOAA (http://www.nmfs.noaa.gov/fishwatch/species/atl_skipjack.htm, 14/12/2011).

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 (AFADs) 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.

The absolute price of skipjack tuna in the world tuna market, as well as its relative value compared to yellowfin tuna prices, has been greatly increased during recent years: 80% increase of average landing values between the 2000–2006 (758 USD/t) and 2007–2011 (1355 USD/t) periods. It was considered that the high value had contributed to an increase in the fishing pressure and targeting on skipjack tuna during recent years.

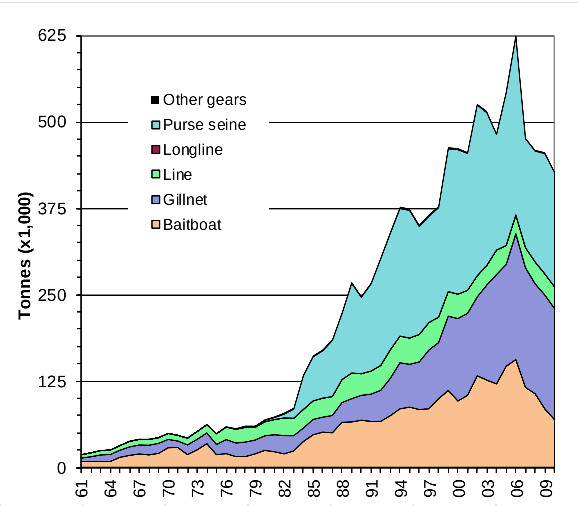

Fig. 2. Annual catches of skipjack tuna by gear recorded in the IOTC Database (1961–2010) (Data as of September 2011).

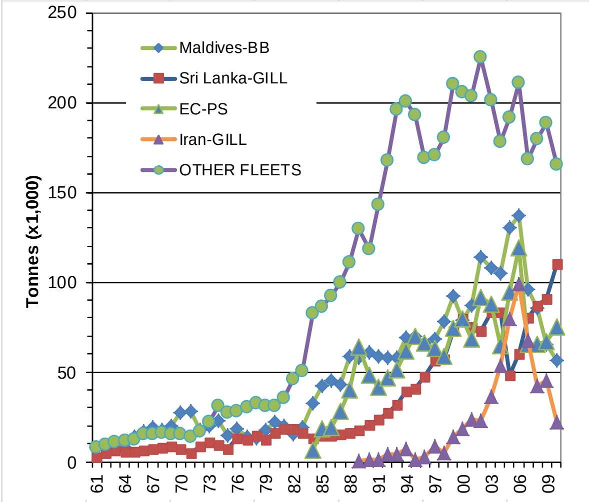

Fig. 3. Annual catches of skipjack tuna by fleet recorded in the IOTC Database (1961–2010) (Data as of September 2011).

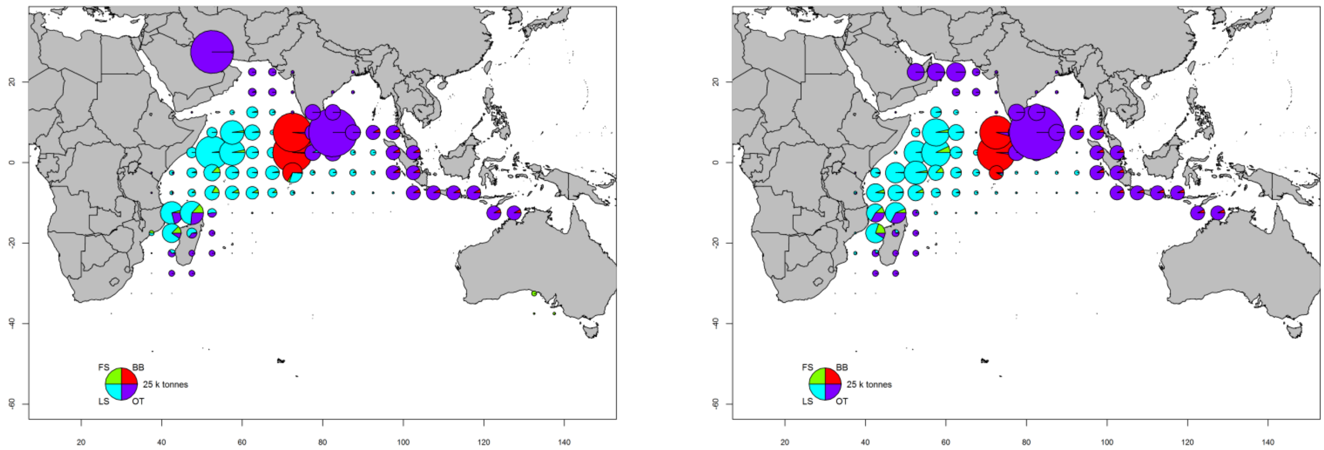

Fig. 4a–b. Time-area catches (total combined in tonnes) of skipjack tuna estimated for 2009 and 2010 by type of gear: Purse seine free-schools (FS), Purse seine associated-schools (LS), pole-and-line (BB), and other fleets (OT), including longline, drifting gillnets, and various coastal fisheries (Data 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
Total	**16,346**	**30,721**	**54,136**	**145,464**	**347,115**	**500,545**	**456,281**	**526,179**	**515,774**	**483,724**	**543,715**	**625,074**	**477,220**	**459,515**	**455,999**	**428,719**

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.

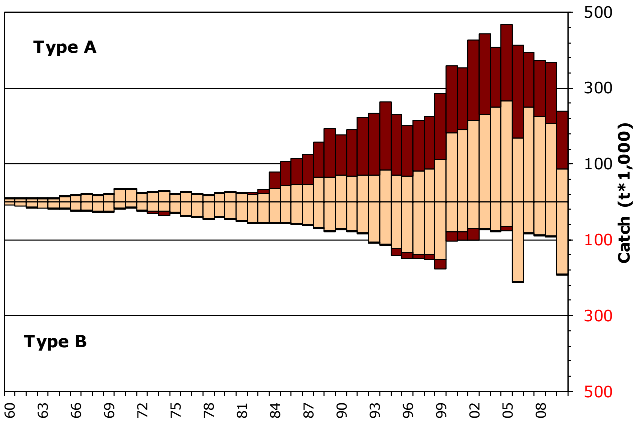

Fig. 5. Uncertainty of annual catch estimates for skipjack tuna (Data as of September 2011).

*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 purse seine vessles 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. 6. 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. 7.

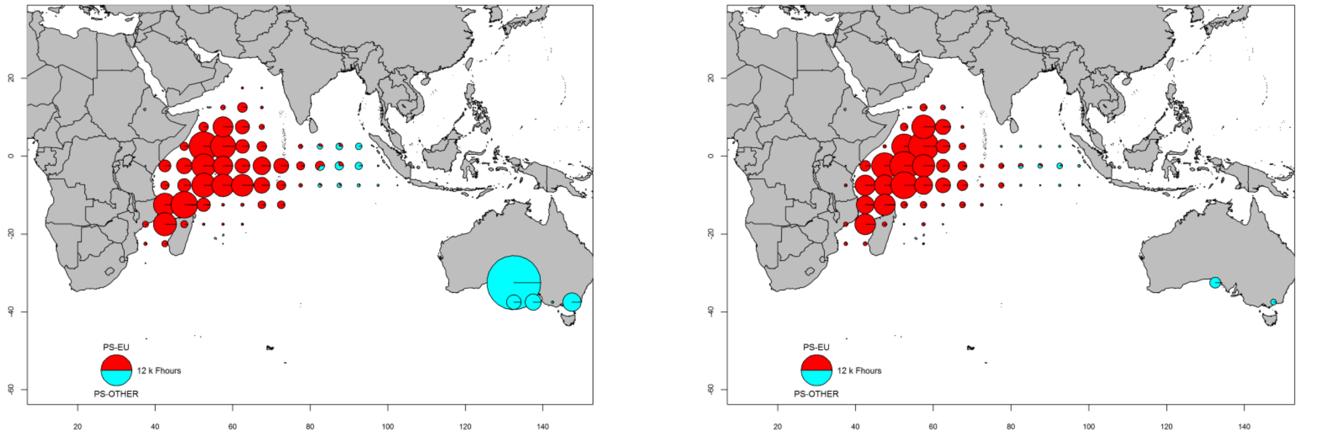

Fig. 6. Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).
PS-EU (red): Industrial purse seiners monitored by the EU and Seychelles (operating under flags of EU countries, Seychelles 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)

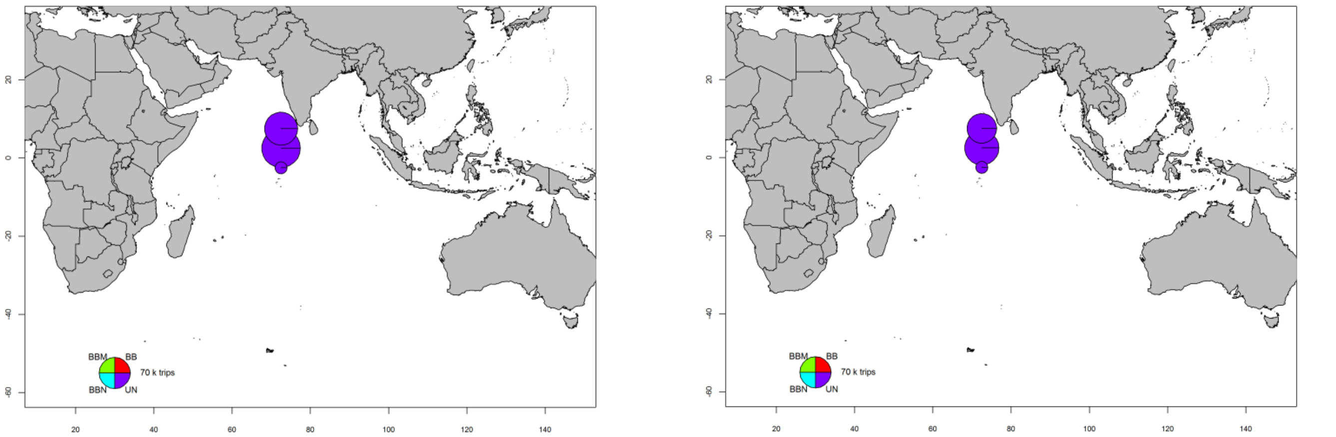

Fig. 7. Number of fishing trips by vessels flagged to the Maldives by 5 degree square grid, type of boat and gear, for the years 2009 (left) and 2010 (right) (Data as of August 2011).
BBN (blue): Baitboat non-mechanized; BBM (Green): Baitboat mechanized; BB (Red): Baitboat unspecified; UN (Purple): Unclassified 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 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.

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

The CPUE series available for assessment purposes are shown in Fig. 8 and 9, although only the 'Pole-and-line series (Fig.8)–was used in the stock assessment model for 2011.

- Maldives data (2004–2010): Series1 from document IOTC–2011–WPTT13–29 and 31.
- EU purse seine free and log school data (1991–2010) (Fig.9): Series from document IOTC–2011–WPTT13–27. These series were not used in the assessment because they were not standardized and likely subject to problems as noted in paragraphs 133 and 141 of the WPTT13 report (IOTC–2011–WPTT13–R).

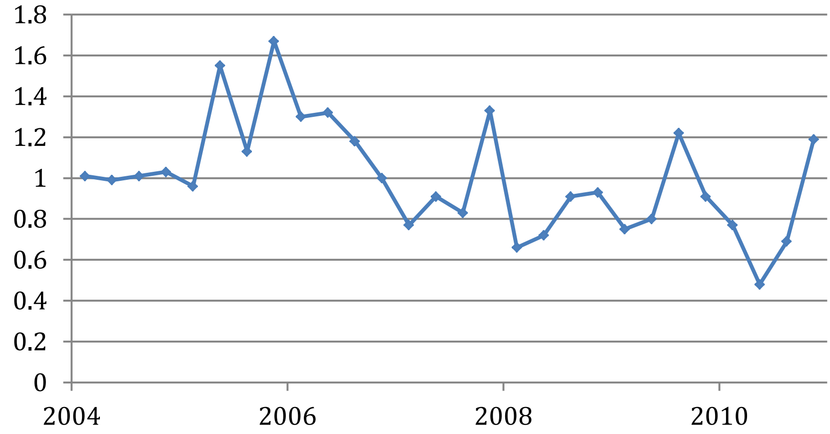

Fig. 8. Standardised Maldivian pole-and-line CPUE series for Indian Ocean skipjack tuna from 2004 to 2011. The series have been rescaled relative to their respective means from 2004–2010.

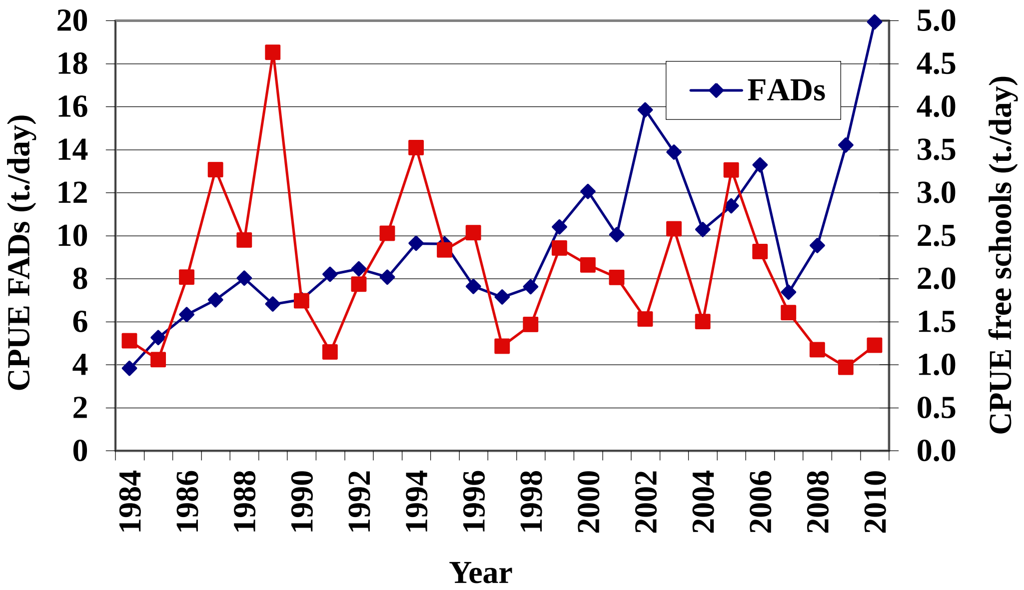

Fig. 9. Comparison of the European purse seine CPUE series for Indian Ocean skipjack caught on free and FAD associated school from 1984 to 2010.

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). While the average weight seems to be stable for all fisheries combined, baitboat and purse seiner are showing a decreasing trends during the last 5 years.

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).

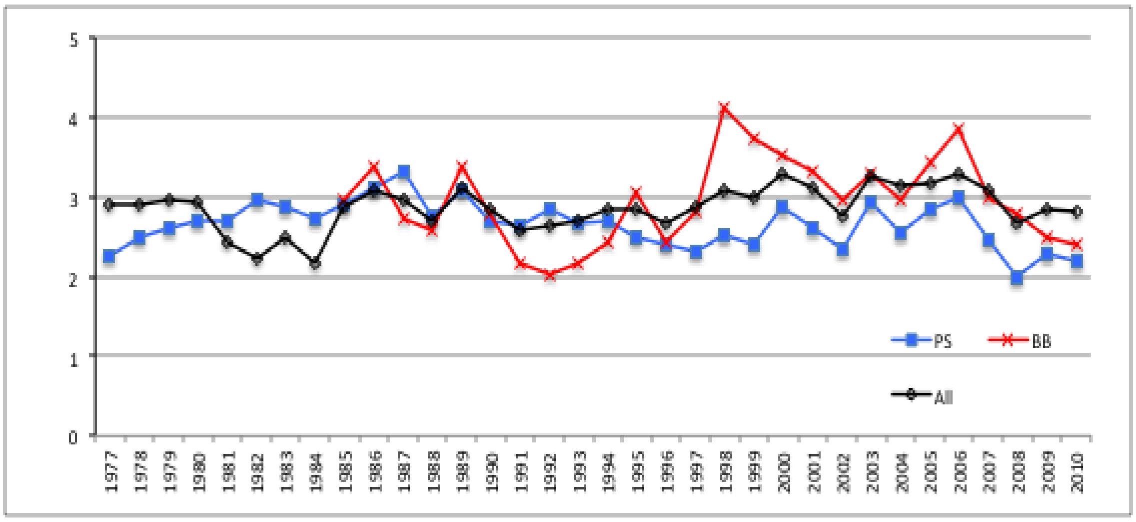

Fig. 10. Changes in average weight (kg) of skipjack tuna from 1977 to 2010 for Maldivian baitboat (BB) and purse seine (PS) as well as all fisheries combined (ALL). (Data as of September 2011).

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.

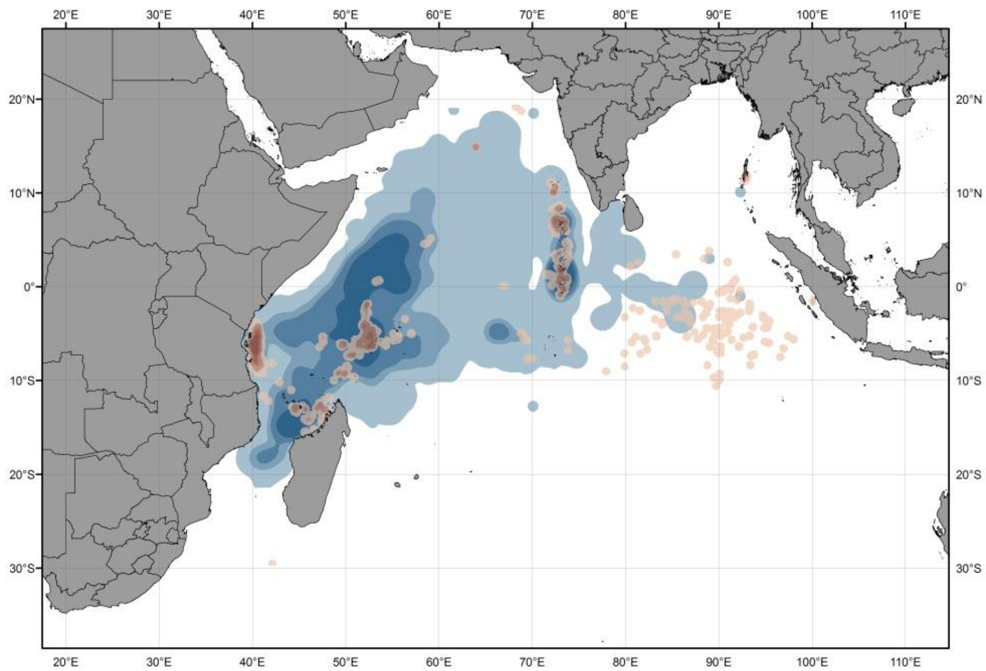

Fig. 11. Densities of releases (in red) and recoveries (in blue) of skipjack tuna. Data as of September 2011.

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 $F << F_{MSY}$.
- 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(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^{th} (5^{th}–95^{th}) 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.

Management Quantity	**Aggregate Indian Ocean**
2009 catch estimate	456,000 t
Mean catch from 2005–2009	512,000 t
MSY (90% CI)	564,000 t (395,000–843,000)
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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EXECUTIVE SUMMARY: YELLOWFIN TUNA

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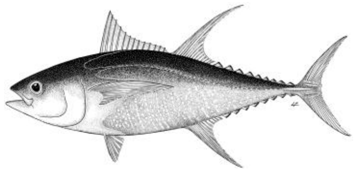

Status of the Indian Ocean yellowfin tuna resource (*Thunnus albacares*)

TABLE 1. Status of yellowfin tuna (*Thunnusalbacares*) in the Indian Ocean.

Area[1]	Indicators – 2011 assessment		2011 stock status determination 2009[2]
Indian Ocean	Catch 2010:	299,074 t	
	Average catch 2006–2010 (1000 t):	326,556 t	
	MSY:	357 (290–435)	
	F_{2009}/F_{MSY}:	0.84 (0.63–1.10)	
	SB_{2009}/SB_{MSY}:	1.61 (1.47–1.78)	
	SB_{2009}/SB_0 :	0.35 (0.31–0.38)	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[2]The stock status refers to the most recent years' data used for the assessment.

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. The stock assessment model used in 2011 suggests that the stock is currently not overfished ($B_{2009}>B_{MSY}$) and overfishing is not occurring ($F_{2009}<F_{MSY}$) (Table 1 and Fig. 1). Spawning stock biomass in 2009 was estimated to be 35% (31–38%) (from Table 1) of the unfished levels. However, estimates of total and spawning stock biomass show a marked decrease over the last decade, accelerated in recent years by the high catches of 2003–2006. It was noted that the current assessment does not explain the high catches of yellowfin tuna from 2003 to 2006, as it does not show peaks in fishing mortality or biomass for this period. Recent reductions in effort and, hence, catches has halted the decline.

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.

Outlook. 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 (299,074 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 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 $B<B_{MSY}$. 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 $B>B_{MSY}$ 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.

The SC **RECOMMENDED** the following:

- The Maximum Sustainable Yield estimate for the whole Indian Ocean is 357,000 t with a range between 290,000–435,000 t (Table 1), and 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.
- Recent recruitment 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.

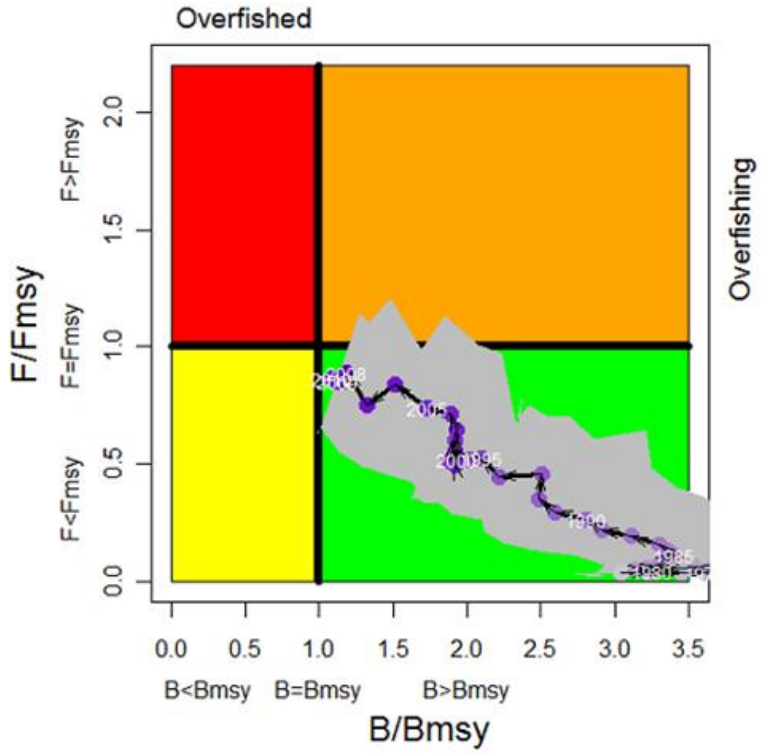

Fig. 1. MULTIFAN-CL Indian Ocean yellowfin tuna stock assessment Kobe plot. Blue circles indicate the trajectory of the point estimates for the B ratio and F ratio for each year 1972–2009. The equal weighted mean trajectory of the scenarios investigated in the assessment. The range is given by the different scenarios investigated..

TABLE 2. 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, ± 20% 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.

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)
$B_{2013}<B_{MSY}$	<1	<1	<1	<1	<1
$F_{2013}>F_{MSY}$	<1	<1	58.3	83.3	100
$B_{2020}<B_{MSY}$	<1	<1	8.3	41.7	91.7
$F_{2020}>F_{MSY}$	<1	41.7	83.3	100	100

There was considerable discussion on the ability of the WPTT to carry out projections with Multifan-FCL for yellowfin tuna. For example, it was not clear how the projection redistributed the recruitment among the different regions, as the recent recruitment distribution, assumed in the projections, was different from the historical one. The WPTT agreed that the true uncertainty remains 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 that, at this time, the Kobe 2 matrices do not represent the full range of uncertainty from the assessments. Therefore, the inclusion of these matrices at this time is primarily intended to familiarise the Commission with the format and method of presenting management advice.

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 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 10/01 *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 10/03 *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

Yellowfin tuna *(Thunnusalbacares)* 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. 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)

Catch trends

Contrary to the situation in other oceans, the artisanal fishery (*i.e.* vessels less than 24m fishing inside their EEZ) component of yellowfin tuna catches in the Indian Ocean is substantial, taking approximately 20–25% of the total catch landed. Catches of yellowfin tuna 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 (Fig. 2).

Catches of yellowfin tuna increased rapidly with the arrival of the purse seine fleets in the early 1980s (Figs. 2 and 3), along with increased activity by longline vessels, with more than 400,000 t landed in 1993. Purse seiners typically take fish ranging from 40–140 cm fork length and smaller fish are more common in the catches taken north of the equator.

The purse seine fishery is characterized by the use of two different fishing modes: a fishery on drifting objects (FADs), which catches large numbers of small yellowfin in association with skipjack tuna and juvenile bigeye tuna, and a 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 took 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 2003–2006 (64%) was much higher than in previous (49% for 1999–2002) or following years (55% for 2007–2009).

The longline fishery primarily catches large fish, from 80–160 cm fork length, although smaller fish in the size range 60–100 cm have been taken and reported 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, Rep. of Korea and Taiwan,China) and a fresh-tuna longline component (small to medium scale fresh tuna longliners from Indonesia and Taiwan,China). As was the case with purse seine fisheries, since 2005 longline catches have decreased substantially with current catches estimated to be at around 41,000 t, representing a more than three-fold decrease over the catches in 2005 (Fig. 2).

Total yellowfin tuna catches dropped markedly from the peak catches taken in 2006, with the lowest catches recorded since the early 1990's reported in 2009, at around 275,955 t. Preliminary catch levels in 2010 are estimated to be around 299,074 t (Tables 4, 5).

The recent drop in catches of yellowfin tuna could be related, at least in part, to the expansion of piracy in the western tropical Indian Ocean, which has led to a marked drop in the levels of longline effort in the core fishing area of the species (Figs. 4a, b) as well as to the decline in the number of purse seiners in the Indian Ocean (~30% reduction).

Catches by other gears, i.e. pole-and-line, gillnet, troll, hand line and other minor gears, have increased steadily since the 1980s (Fig. 2). In recent years the total artisanal yellowfin tuna catch has been between 140,000–160,000 t, with the catch by gillnets (the dominant artisanal gear) at around 80,000 t.

Most yellowfin tuna are caught in the Indian Ocean, north of 12°S, and in the north of the Mozambique Channel (Figs. 4a, b). 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 2008 and 2010. The drop in catches is the consequence of a generalised drop in fishing effort due to the effect of piracy in the western Indian Ocean region.

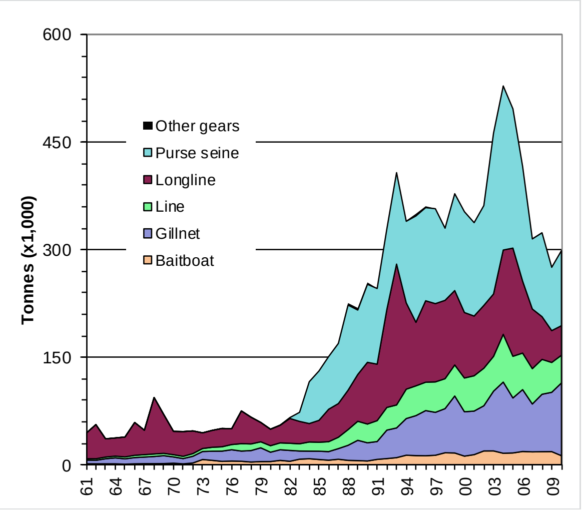

Fig. 2. Annual catches of yellowfin tuna by gear recorded in the IOTC Database (1961–2010) (Data as of September 2011).

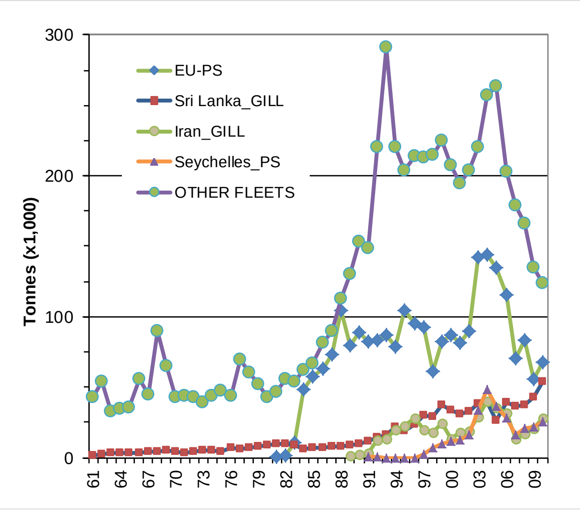

Fig. 3. Annual catches of yellowfin tuna by fleet recorded in the IOTC Database (1961–2010) (Data as of September 2011).

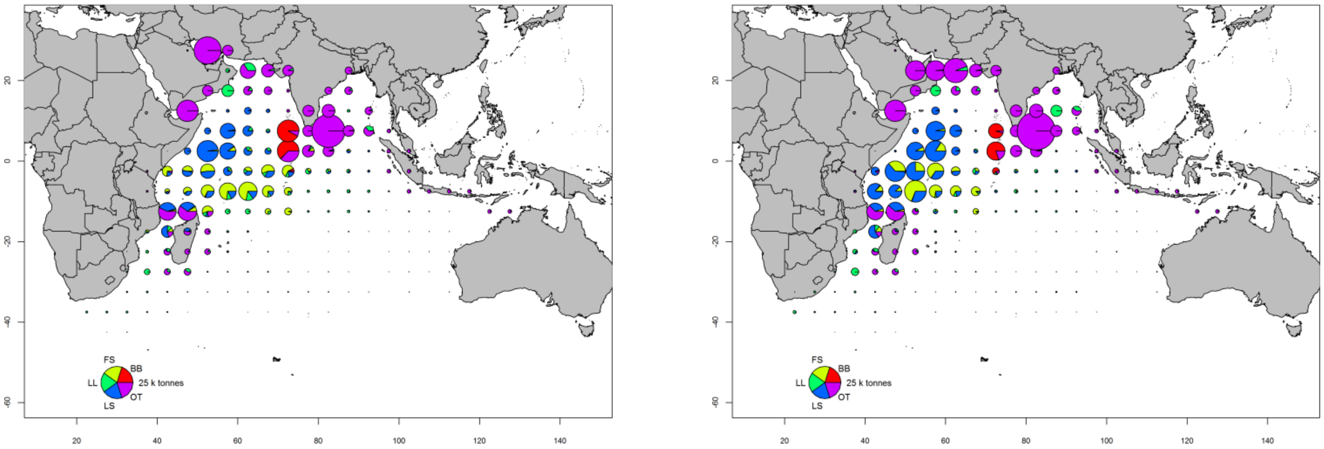

Fig. 4a–b. Time-area catches (total combined in tonnes) of yellowfin tuna estimated for 2009 and 2010 by type of gear: Longline (LL), Purse seine free-schools (FS), Purse seine associated-schools (LS), pole-and-line (BB), and other fleets (OT), including drifting gillnets, and various coastal fisheries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

TABLE 4. Best scientific estimates of the catches of yellowfin tuna (*Thunnus albacares*)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
FS	0	0	18	32,590	64,942	89,761	78,969	77,059	137,492	168,799	124,024	85,021	53,529	74,990	36,263	31,951
LS	0	0	17	18,090	56,304	61,909	50,997	61,933	86,585	59,597	69,873	74,454	43,843	41,453	51,565	72,199
LL	21,990	41,256	29,512	33,889	66,689	57,668	43,932	53,132	55,741	86,415	116,847	69,831	54,414	29,128	21,242	17,130
LF	0	0	615	4,286	47,570	32,827	39,323	34,429	31,292	31,125	33,991	30,475	28,752	30,424	23,157	24,089
BB	1,754	1,452	4,380	6,621	11,765	17,162	14,233	19,393	19,451	16,177	16,607	18,644	18,133	18,351	18,463	12,755
GI	2,604	7,569	12,861	15,261	50,192	76,053	60,748	62,982	83,283	99,254	76,660	86,286	66,693	80,086	82,695	101,418
HD	679	1,175	2,615	6,990	20,002	31,762	29,790	34,093	31,105	40,820	38,993	31,789	30,274	28,895	23,952	20,472
TR	832	1,514	3,502	7,193	16,825	19,479	19,453	18,288	17,270	25,798	19,136	19,160	19,061	19,770	17,682	18,177
OT	118	130	497	1,275	1,344	1,107	543	463	1,396	1,734	1,123	1,436	1,290	1,567	936	883
Total	**27,978**	**53,096**	**54,017**	**126,193**	**335,634**	**387,728**	**337,988**	**361,772**	**463,615**	**529,719**	**497,254**	**417,096**	**315,989**	**324,664**	**275,955**	**299,074**

Fisheries: 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. Best scientific estimates of the catches of yellowfin tuna (*Thunnus albacares*)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
R1	2,164	5,430	9,376	18,462	73,169	83,578	65,544	73,160	82,854	119,183	129,226	92,860	74,179	72,600	62,861	65,123
R2	11,899	23,101	20,921	72,400	143,122	183,679	156,045	164,369	265,456	278,103	248,113	204,035	126,450	135,499	100,973	111,041
R3	919	7,857	4,483	9,646	28,681	33,100	32,009	34,377	31,004	36,490	33,887	33,480	35,123	30,867	28,990	27,545
R4	918	1,799	1,370	1,075	3,314	2,122	3,376	3,328	2,387	3,802	2,904	1,363	540	507	427	498
R5	12,079	14,909	17,869	24,611	87,347	85,250	81,014	86,538	81,914	92,141	83,124	85,358	79,697	85,191	82,704	94,867
Total	**27,978**	**53,096**	**54,017**	**126,193**	**335,634**	**387,728**	**337,988**	**361,772**	**463,615**	**529,719**	**497,254**	**417,096**	**315,989**	**324,664**	**275,955**	**299,074**

*See Fig. 9 for a description of the areas

Uncertainty of catches

Retained catches are generally well known for the major fleets (Fig. 5); but are less certain for:

- Many coastal fisheries, notably those from Indonesia, Sri Lanka, Yemen, Madagascar and Comoros.
- The gillnet fishery of Pakistan.
- Non-reporting industrial purse seiners and longliners (NEI), and commercial longliners from India.

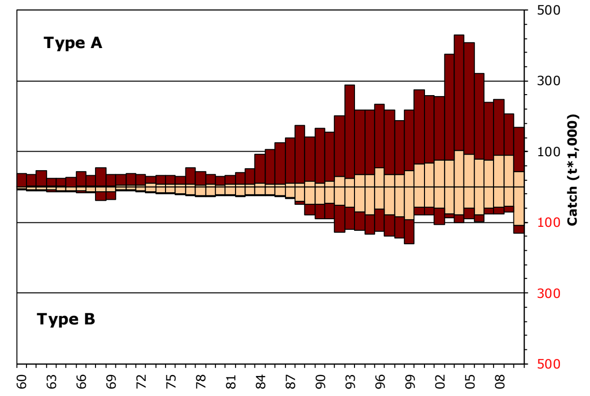

Fig. 5.Uncertainty of annual catch estimates for yellowfin tuna (Data as of September 2011).
Catches below the zero-line (Type B) refer to fleets that do not report catch data to the IOTC (estimated by the IOTC Secretariat), do not report catch data by gear and/or species (broken by gear and species 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.

- the catch series for yellowfin tuna has not been significantly revised since the WPTT12 in 2010, although there has been some revision to the time series of catch from the fisheries of India leading to changes in catches by gear.
- 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.
- catch-and-effort series are available from the major industrial and artisanal fisheries. However, these data are not available for some important artisanal 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 very little data available for the fresh-tuna longline fishery of Taiwan,China.
    - no data are available for the gillnet fisheries 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 Yemen, 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 vessles 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.

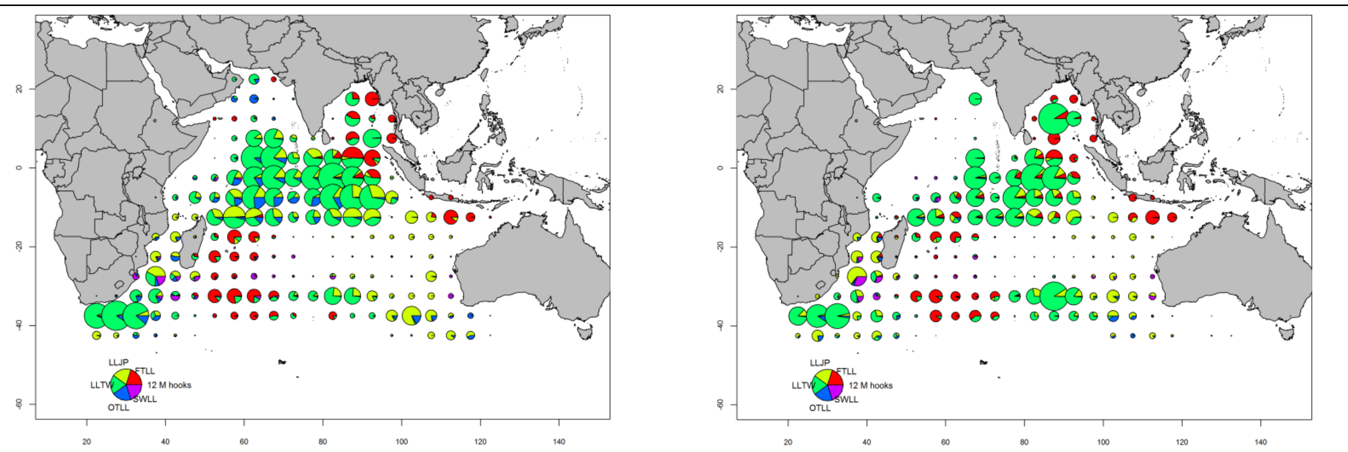

Fig. 6. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).
LLJP (light green): deep-freezing longliners from Japan
LLTW (dark green): deep-freezing longliners from Taiwan,China
SWLL (turquoise): 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)

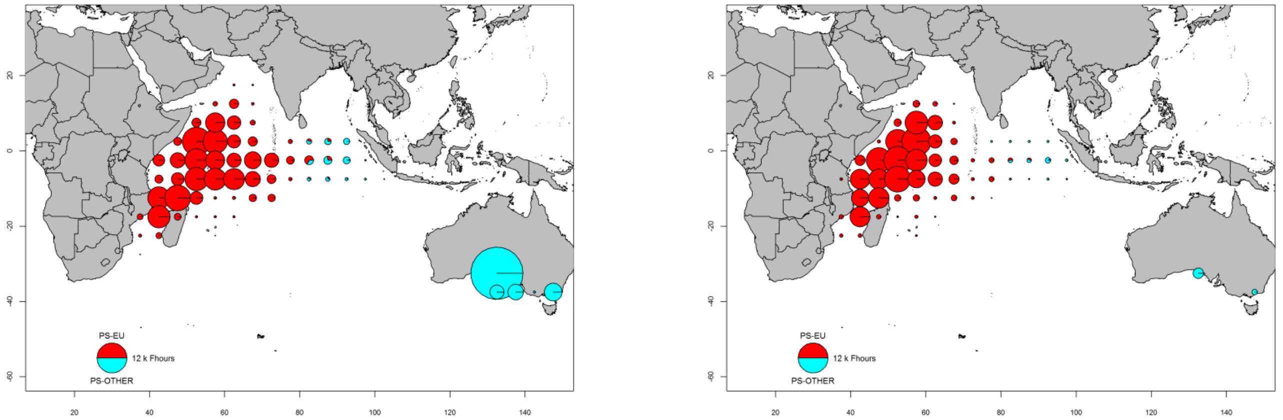

Fig. 7. Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).

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)

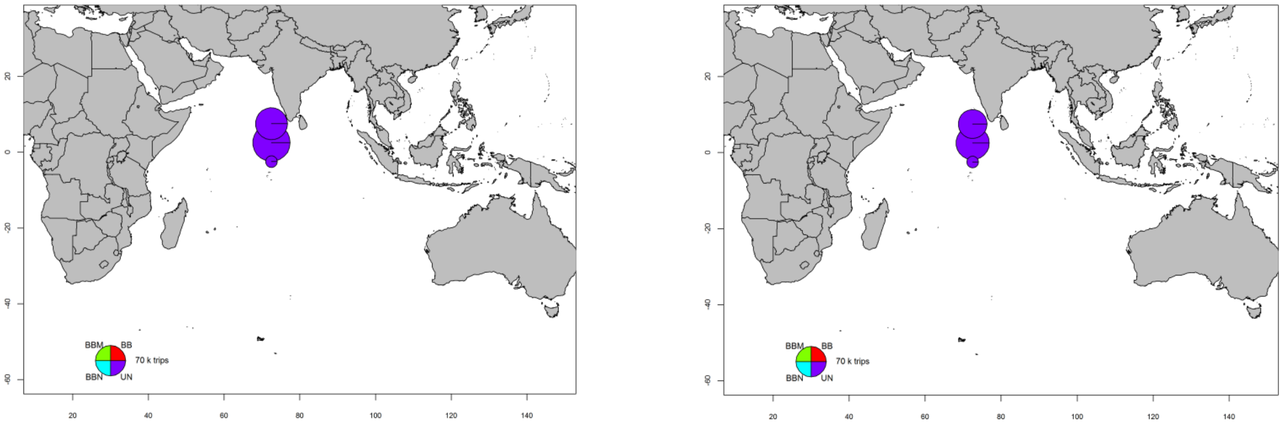

Fig. 8. Number of fishing tripsby vessels flagged to the Maldives by 5 degree square grid,type of boat and gear, for the years 2009 (left) and 2010 (right) (Data as of August 2011).

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 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.

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

For the longline fisheries (LL fisheries in regions 1–5; Fig. 9), CPUE indices were derived using generalized linear models (GLM) from the Japanese longline fleet (LL regions 2–5) and for the Taiwanese longline fleet (LL region 1) to be used in the stock assessment. Standardised longline CPUE indices for the Taiwanese fleet were available for 1979–2008. The GLM analysis used to standardise the Japanese longline CPUE indices was refined for the 2011 assessment 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 2011 assessment (Fig. 10). There is considerable uncertainty associated with the Japanese CPUE indices for region 2 in the most recent year (2010) and no CPUE indices are available for region 1 for 2009–10.

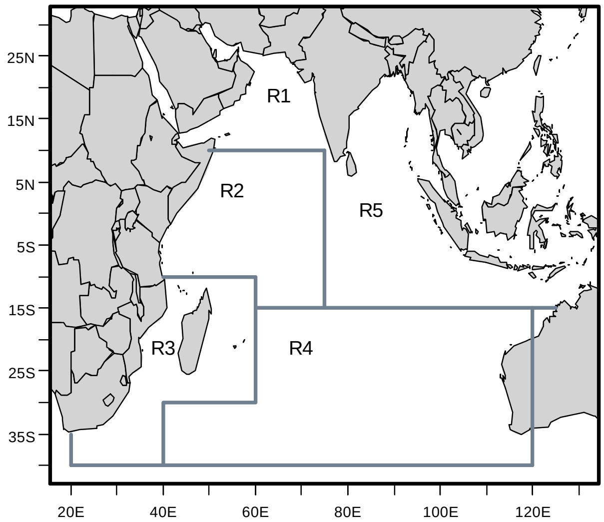

Fig. 9. Spatial stratification of the Indian Ocean for the MFCL assessment model.

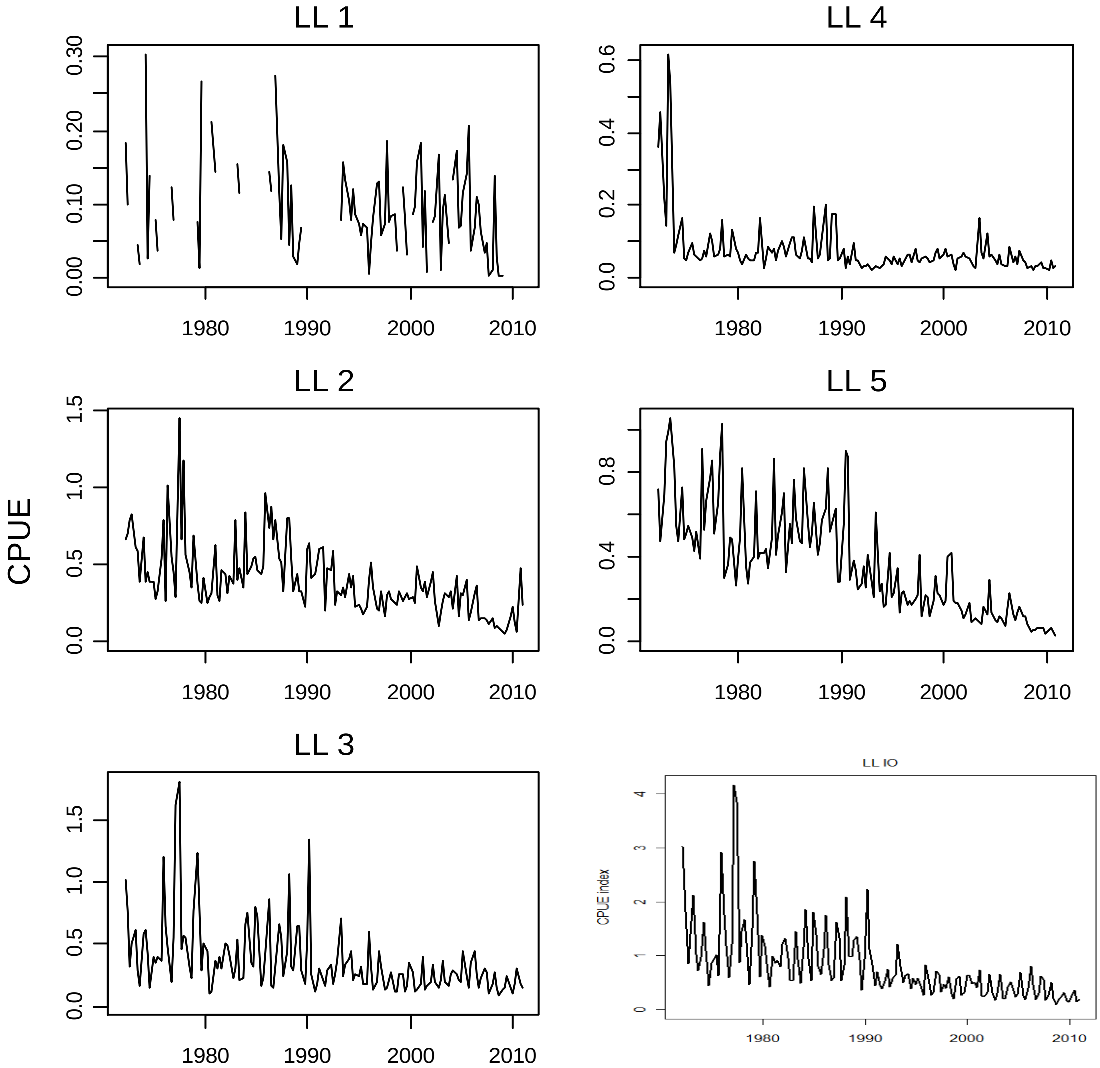

Fig. 10. Annualised GLM standardised catch-per-unit-effort (CPUE) for the principal longline fisheries (longline region 1: Taiwan,China and longline regions 2–5: Japan) and the whole Indian Ocean (IO), scaled by the respective region scalars.

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

- trends in average weight (Fig. 11) 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 (see paper IOTC–2011–WPTT13–08).

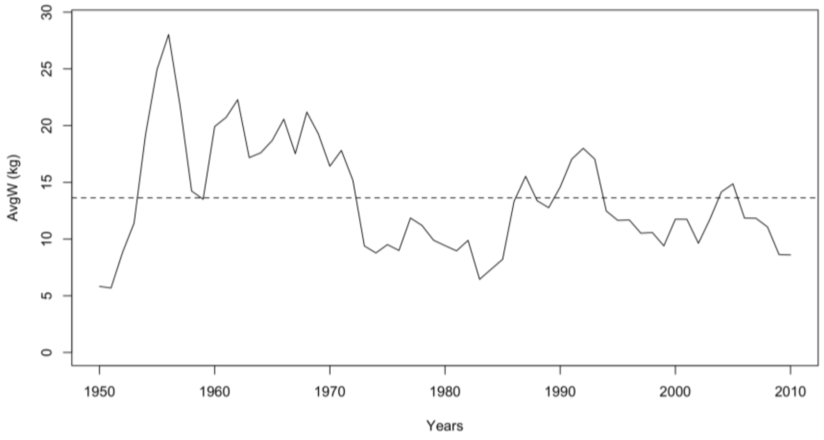

Fig. 11.Changes in average weight (kg) of yellowfin tuna from 1950 to 2010 – all fisheries combined (Data as of September 2011).

- catch-at-Size and Age tables are available although the estimates are more uncertain in some years and some fisheries due to:
  - size data not being available from important fisheries, notably Yemen, Pakistan, Sri Lanka and Indonesia (lines and gillnets) and Comoros and Madagascar (lines).
  - the paucity of size data available from industrial longliners from the late-1960s up to the mid-1980s.
  - the paucity of catch by area data available for some industrial fleets (NEI, Iran, India, Indonesia, Malaysia).

Tagging data

A total of 63,310 yellowfin tuna were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP) which represented 31.4% of the total number of fish tagged. Most of the yellowfin tuna tagged (86.4%) were tagged during the main Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) and were primarily released off the coasts of the Seychelles, in the Mozambique Channel, along the coast of Oman and off the coast of Tanzania (Fig. 12) 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 10,560 (16.7%) tagged fish have been recovered and reported to the IOTC Secretariat.

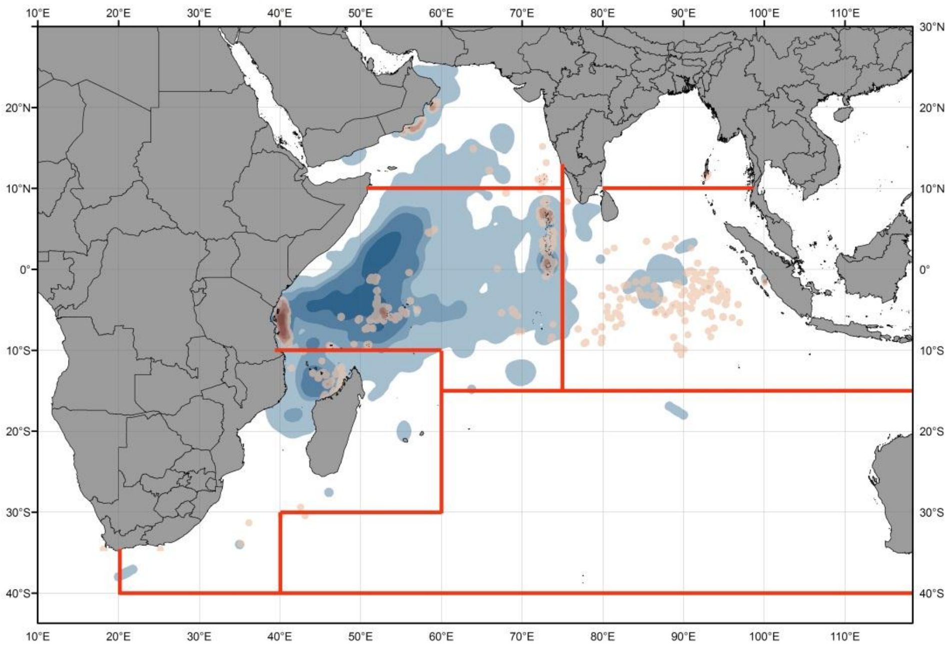

Fig. 12.Densities of releases (in red) and recoveries (in blue) of yellowfin tuna. Data as of September 2011.

STOCK ASSESSMENT

A single quantitative modelling method (MULTIFAN-CL) was applied to the yellowfin tuna assessment in 2011, using data from 1972–2010.The following is worth noting with respect to the modelling approach used:

- The main features of the model in the 2010 assessment included a fixed growth curve (with variance) with an inflection, an age-specific natural mortality rate profile (M), the modelling of 24 fisheries including the separation of two purse seine fisheries into three time blocks, using a cubic spline method to estimate longline selectivities in the place of a logistic curve, the down-weighting of length frequency data in the fitting, separation of the analysis into five regions of the Indian Ocean and the specification of four steepness parameters for the stock recruitment relationship (h=0.6, 0.7, 0.8 and 0.9).
- In addition to another year of data, the 2011 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 and the Taiwan,China index was revised for region 1); major historical catch revisions for fisheries in Region 5, splitting the longline fleet in Region 5 into distant water and fresh tuna logline fleets leaving 25 total fleets in the model; and the range of steepness evaluated was expanded to h=0.55-0.95.

While the biomass trends were very similar between the 2010 and 2011 assessments, the estimates of stock productivity and thus, the status, differed. There were several reasons for this: there was poor convergence in the 2010 assessment, thus the fits were suboptimal and alternative solutions were near optimal. Refitting the 2010 assessment is now more optimistic. Also, fitting the 2010 model to 2011 data was more optimistic. Thus, revisiting of key parameters and the inclusion of the latest year of data in the 2011 assessment appeared to be important. These issues are difficult to explore in the MFCL framework. The WPTT reviewed several alternative model structures and parameter formulations for the model that were presented in the assessment. These included: the new longline model structure for Region 5; alternative Japanese CPUE indices; a single region model where all 5 Regions were collapsed into one; a Region 2 model estimated separately from other Regions; the 5 values of steepness and alternative tag mixing periods (1–4 quarters). Additionally, an attempt was made to estimate age-specific M's. In regards to the latter, this parameter was not well estimated and the WPTT adopted the low M profile as the most appropriate way to proceed.

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 available tagging data has provided the WPTT with relevant information on various biological parameters, such as natural mortality and growth. Further use of these data should better support the analyses conducted by the WPTT.

In the previous assessment purse seine selectivity in the period 2003–2007 was separated into three blocks of time surrounding 2005 to accommodate the unusually large catches in the middle of that time period. This was continued in the current assessment. However, the WPTT questioned whether this was the most appropriate way to do this. An alternative was suggested in which the time blocks of PS fleet were removed and the same selectivity was applied throughout the period. This was explored in new model runs. Results were not demonstrably different.

Longline selectivity will be revisited in 2012 as it was suggested that this selectivity might still be best described by a logistic (flat-topped) model instead of a cubic spline approach, whereby the resulting selectivity was dome-shaped. This option reinvigorated a long standing debate that has yet to be resolved. A run whereby logistic selectivities were imposed was evaluated.

Generally, the runs with alternative parameter and model structures did not suggest large differences in the approach and resulted in qualitatively predictable outcomes. The WPTT felt that the alternative outcomes were an expression of uncertainties in the model, data and assessment. Therefore, the WPTT focused on following basic alternatives for characterizing the uncertainty: logistic versus cubic spline longline selectivity; using the low M profile; alternative steepness of the stock-recruitment relationship of 0.7, 0.8 and 0.9, and estimation of MSY based reference points using the average recruitment for the whole time series. It was determined that with current knowledge outcomes using these alternatives are equally likely and a combined evaluated was generated based upon this.

The final range of model options adopted by the WPTT included the 2 alternative parametrization of longline selectivity (cubic spline and logisitic) and three steepness options (0.7, 0.8 and 0.9). For the cubic spline model option, there is a strong temporal trend in recruitment and recent recruitments (average of the last 15 years) is estimated to be lower (80%) than the long term recruitment level. On that basis, it was agreed to also derived alternative MSY estimates based on the recent levels of recruitment for comparative purposes.Key assessment results for the MFCL stock assessment areshown in Tables 1, 2 and 6; Fig. 1.

It was noted that some of the results of the Multifan-CL model selected were not intuitive and have been discussed extensively by the WPTT and the SC. The SC **NOTED** the following points:

- the movements of yellowfin tuna, between the five regions used in the stock assessment, estimated by the model show insignificant mixing between some regions which may infer three nearly independent different stocks in the Arabian sea (area 1), the South-East Indian Ocean (area 5) and the rest of the Indian Ocean.

However, this result seems to be in contradiction with the biological knowledge of the stock and with the recent tagging results suggesting wide and fast movements between all areas.

- the levels and trends of biomass estimated by the model in each of the 5 areas seem unrealistic:
    - the very high initial biomass in the South-East area (area 5) and its major decline during recent years
    - the biomass in the South-West Indian Ocean (area 3) being larger than that of the Western equatorial Indian Ocean (area 2), which is recognized as the main yellowfin fishing area and consequently, where biomass should be at a much higher level.

Table 6. Key management quantities from the MFCL assessment, for the agreed scenarios of yellowfin tuna in the Indian Ocean.Values represent an equal weighting mean of the scenarios investigated. The range is described by the range values between those scenarios.

Management Quantity	**Indian Ocean**
2010 catch estimate	299,100 t
Mean catch from 2006–2010	326,600 t
MSY	357,000 t (290,000–435,000)
Data period used in assessment	1972–2010
F_{2009}/F_{MSY}	0.84 (0.63–1.10)
B_{2009}/B_{MSY}	1.46 (1.35–1.59)
SB_{2009}/SB_{MSY}	1.61 (1.47–1.78)
B_{2009}/B_0	0.49
SB_{2009}/SB_0	0.35 (0.31–0.38)
$B_{2009}/B_{0,\ F=0}$	0.58
$SB_{2009}/SB_{0,\ F=0}$	–

LITERATURE CITED

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