Report of the 18th Session of the IOTC Working Party on Tropical Tunas

Seychelles, 5–10 November 2016

DISTRIBUTION:
Participants in the Session
Members of the Commission
Other interested Nations and International Organizations
FAO Fisheries Department
FAO Regional Fishery Officers

BIBLIOGRAPHIC ENTRY
IOTC–WPTT18 2016. Report of the 18th Session of the IOTC Working Party on Tropical Tunas. Seychelles, 5–10 November 2016. *IOTC–2016–WPTT18–R[E]: 126 pp.*

Contact details:

Indian Ocean Tuna Commission
Le Chantier Mall
PO Box 1011
Victoria, Mahé, Seychelles
Ph: +248 4225 494
Fax: +248 4224 364
Email: secretariat@iotc.org
Website: http://www.iotc.org

ACRONYMS

aFAD	anchored Fish aggregating device
ASAP	Age-Structured Assessment Program
ASPIC	A Stock-Production Model Incorporating Covariates
ASPM	Age-Structured Production Model
B	Biomass (total)
BDM	Biomass Dynamic Model
BET	Bigeye tuna
B_{MSY}	Biomass which produces MSY
CE	Catch and effort
CI	Confidence Interval
CMM	Conservation and Management Measure (of the IOTC; Resolutions and Recommendations)
CPCs	Contracting parties and cooperating non-contracting parties
CPUE	Catch per unit of effort
current	Current period/time, i.e. $F_{current}$ means fishing mortality for the current assessment year.
EEZ	Exclusive Economic Zone
ENSO	El Niño–Southern Oscillation
EU	European Union
F	Fishing mortality; F_{2011} is the fishing mortality estimated in the year 2011
FAD	Fish aggregating device
F_{MSY}	Fishing mortality at MSY
GLM	Generalised linear model
HBF	Hooks between floats
IO	Indian Ocean
IOTC	Indian Ocean Tuna Commission
IWC	International Whaling Commission
K2SM	Kobe II Strategy Matrix
LL	Longline
M	Natural Mortality
MSC	Marine Stewardship Council
MSE	Management Strategy Evaluation
MSY	Maximum sustainable yield
n.a.	Not applicable
PS	Purse seine
q	Catchability
ROS	Regional Observer Scheme
SC	Scientific Committee, of the IOTC
SB	Spawning biomass (sometimes expressed as SSB)
SB_{MSY}	Spawning stock biomass which produces MSY (sometimes expressed as SSB_{MSY})
SCAA	Statistical-Catch-At-Age
SKJ	Skipjack tuna
SS3	Stock Synthesis III
Taiwan,China	Taiwan, Province of China
VB	Von Bertalanffy (growth)
WPTT	Working Party on Tropical Tunas of the IOTC
YFT	Yellowfin tuna

STANDARDISATION OF IOTC WORKING PARTY AND SCIENTIFIC COMMITTEE REPORT TERMINOLOGY

SC16.07 (para. 23) The SC **ADOPTED** the reporting terminology contained in Appendix IV and **RECOMMENDED** that the Commission considers adopting the standardised IOTC Report terminology, to further improve the clarity of information sharing from, and among its subsidiary bodies.

HOW TO INTERPRET TERMINOLOGY CONTAINED IN THIS REPORT

Level 1: From a subsidiary body of the Commission to the next level in the structure of the Commission:
RECOMMENDED, RECOMMENDATION: Any conclusion or request for an action to be undertaken, from a subsidiary body of the Commission (Committee or Working Party), which is to be formally provided to the next level in the structure of the Commission for its consideration/endorsement (e.g. from a Working Party to the Scientific Committee; from a Committee to the Commission). The intention is that the higher body will consider the recommended action for endorsement under its own mandate, if the subsidiary body does not already have the required mandate. Ideally this should be task specific and contain a timeframe for completion.

Level 2: From a subsidiary body of the Commission to a CPC, the IOTC Secretariat, or other body (not the Commission) to carry out a specified task:
REQUESTED: This term should only be used by a subsidiary body of the Commission if it does not wish to have the request formally adopted/endorsed by the next level in the structure of the Commission. For example, if a Committee wishes to seek additional input from a CPC on a particular topic, but does not wish to formalise the request beyond the mandate of the Committee, it may request that a set action be undertaken. Ideally this should be task specific and contain a timeframe for the completion.

Level 3: General terms to be used for consistency:
AGREED: Any point of discussion from a meeting which the IOTC body considers to be an agreed course of action covered by its mandate, which has not already been dealt with under Level 1 or level 2 above; a general point of agreement among delegations/participants of a meeting which does not need to be considered/adopted by the next level in the Commission's structure.
NOTED/NOTING: Any point of discussion from a meeting which the IOTC body considers to be important enough to record in a meeting report for future reference.

Any other term: Any other term may be used in addition to the Level 3 terms to highlight to the reader of and IOTC report, the importance of the relevant paragraph. However, other terms used are considered for explanatory/informational purposes only and shall have no higher rating within the reporting terminology hierarchy than Level 3, described above (e.g. **CONSIDERED**; **URGED**; **ACKNOWLEDGED**).

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 18th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT) was held in Seychelles, from 5–10 November 2016. The meeting was opened by the Chairperson, Dr M. Shiham Adam (Maldives) who welcomed participants and Vice-Chair, Dr Gorka Merino (EU,Spain). A total of 44 participants attended the Session (44 in 2015, 53 in 2014), including the IOTC Stock Assessment consultant (for bigeye tuna and yellowfin tuna), Mr Adam Langley, and ISSF-IOTC consultant, Dr Simon Hoyle.

The following are a subset of the complete recommendations from the WPTT18 to the Scientific Committee, which are provided at Appendix X.

Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets

WPTT18.02 (para. 85): **NOTING** paragraph 84, the WPTT **RECOMMENDED** continued work on joint analysis of operational catch and effort data from multiple fleets, to further develop methods and to provide indices of abundance for IOTC stock assessments, and **NOTED** that ISSF would be willing to contribute support for future activities, with the aim of normalizing the process of joint analysis of the operational catch and effort data within the IOTC.

Yellowfin tuna CPUE Summary discussion

WPTT18.04 (para. 165): The WPTT **RECOMMENDED** that efforts to develop abundance indicators using PS data should be continued. Given the difficulty of defining effort in PS fisheries, and the importance of obtaining an abundance index for skipjack, alternative methods such as those based on ratio methods and standardized species composition should also be considered.

Stock Synthesis III (SS3) assessment of yellowfin tuna

WPTT18.05 (para. 181): **NOTING** the discussions on the tagging mixing period during previous WPTT meetings, related to the assessment of yellowfin and other tropical tuna stocks, the WPTT **RECOMMENDED** that additional work to be conducted to elucidate the most appropriate approach to tag modelling in IOTC stock assessments[1].

Parameters for future analyses: Yellowfin tuna CPUE standardisation and stock assessments

WPTT18.06 (para. 191): The WPTT **RECOMMENDED** that development of the next stock assessment of yellowfin tuna should include a detailed review of the existing data sources (conducted by the stock assessment consultant, in collaboration with the IOTC Secretariat and main longline and purse seine fleets), including:

i. Size frequency data: Evaluation of the reliability of length composition from the longline fisheries (including recent and historical data), review of anomalies in the (EU) PS length composition data, and the need for a thorough review of the size frequency data held by IOTC, in collaboration with the fleets involved, to improve the utilization of these data in tropical tuna stock assessments.

ii. Collaborative longline CPUE: Further refinement of the procedures to standardize the composite longline logsheet data sets to develop the longline CPUE indices;

iii. Tagging data: Comprehensive analysis of the tag release/recovery data set;

iv. Alternative CPUE series: a review of the available data from the Indian tuna longline survey data.

Review of the draft, and adoption of the Report of the 18th Session of the WPTT

WPTT18.09 (para. 212): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT18, provided at Appendix X, as well as the management advice provided in the draft resource stock status summary for each of the three tropical tuna species under the IOTC mandate, and the combined Kobe plot for the three species assigned a stock status in 2016 (Fig. 15):

- Bigeye tuna (*Thunnus obesus*) – Appendix VI
- Skipjack tuna (*Katsuwonus pelamis*) – Appendix VII
- Yellowfin tuna (*Thunnus albacares*) – Appendix VIII

[1] See Appendix IV, Program of Work, Topic 6 for more details.

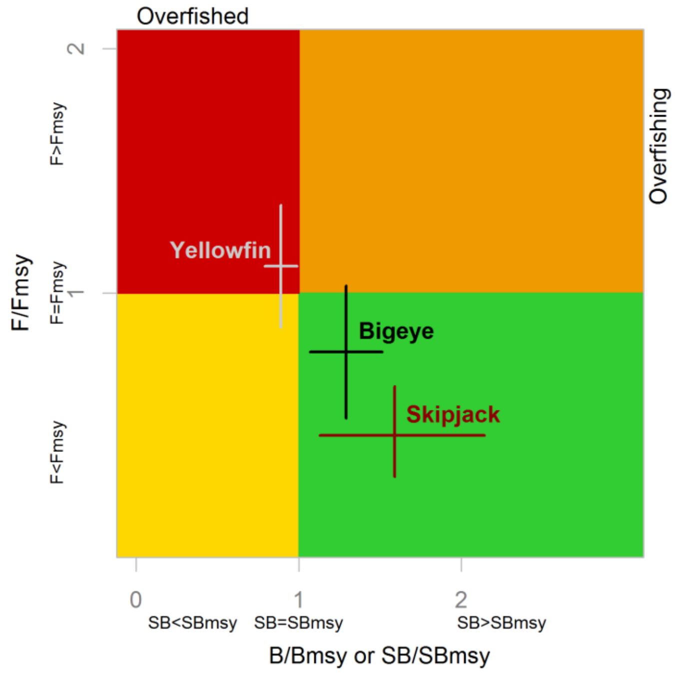


Fig.15. Combined Kobe plot for bigeye tuna (black: 2016), skipjack tuna (brown: 2014) and yellowfin tuna (grey: 2016) showing the estimates of current stock size (SB) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs with a 80% CI. Note that for skipjack tuna, the estimates are highly uncertain as F_{MSY} is poorly estimated, and as suggested for stock status advice it is better to use B_0 as a biomass reference point and C(t) relative to C_{MSY} as a fishing mortality reference point.

Stock status

A summary of the stock status for tropical tuna species under the IOTC mandate is provided in Table 1

Table 1. Status summary for species of tropical tuna under the IOTC mandate.

Stock	Indicators		2009	2010	2011	2012	2013	2014	2015	2016	Advice to the Commission
Bigeye tuna *Thunnus obesus*	Catch in 2015: Average catch 2011–2015: MSY (1000 t) (plausible range): F_{MSY} (plausible range): SB_{MSY} (1,000 t) (plausible range): F_{2015}/F_{MSY} (plausible range): SB_{2015}/SB_{MSY} (plausible range): SB_{2015}/SB_0 (plausible range):	92,736 t 101,515 t 104 (87-121) 0.17 (0.14-0.20) 525 (364-718) 0.76 (0.49-1.03) 1.29 (1.07-1.51) 0.38 (n.a. – n.a.)								84% **	In 2016, six models were applied to 2016 bigeye tuna stock assessment, the majority of which gave qualitatively similar results. Stock status is based on the Stock Synthesis III model formulation. On the weight-of-evidence available in 2016, the bigeye tuna stock is determined to be **not overfished** and is **not subject to overfishing**. If catch remains below the estimated MSY levels, 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. <Click here for full stock status summary>
Skipjack tuna *Katsuwonus pelamis*	Catch in 2015: Average catch 2011–2015: MSY (1000 t) (80% CI): $*F_{MSY}$ (80% CI): SB_{MSY} (1,000 t) (80% CI): $*F_{2013}/F_{MSY}$ (80% CI): SB_{2013}/SB_{MSY} (80% CI): SB_{2013}/SB_0 (80% CI):	393,954 t 394,320 t 684 (550–849) 0.65 (0.51–0.79) 875 (708–1,075) 0.62 (0.49–0.75) 1.59 (1.13–2.14) 0.58 (0.53–0.62)									No new stock assessment was carried out for skipjack tuna in 2015, thus, stock status is determined on the basis of the 2014 assessment and other indicators presented in 2016. On the weight-of-evidence available in 2016, the skipjack tuna stock is determined to be **not overfished** and is **not subject to overfishing**. If catch remains below the estimated MSY levels, 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. <Click here for full stock status summary>
Yellowfin tuna *Thunnus albacares*	Catch in 2015: Average catch 2011–2015: MSY (1000 t) (plausible range): F_{MSY} (plausible range): SB_{MSY} (1,000 t) (plausible range): F_{2015}/F_{MSY} (plausible range): SB_{2015}/SB_{MSY} (plausible range): SB_{2015}/SB_0 (plausible range):	407,575 t 390,185 t 422 (406-445) 0.15 (0.15-0.15) 947 (900-983) 1.11 (0.86-1.36) 0.89 (0.79-0.99) 0.29 (n.a.-n.a.)							94% **	68% **	In 2016, two models were applied to the update of the 2015 yellowfin tuna stock assessment, both of which give qualitatively similar results. Stock status is based on the Stock Synthesis III model formulation. On the weight-of-evidence available in 2016, the yellowfin tuna stock is determined to be **overfished** and **subject to overfishing.** The stock status determination changed in 2015 as a direct result of the large and unsustainable catches of yellowfin tuna taken over the last three (3) years, and the relatively low recruitment levels estimated by the model in recent years. Resolution 16/01 RESOLUTION 16/01 *On interim plan for*

										rebuilding the Indian Ocean yellowfin tuna stock in the IOTC area of competence implements reductions in catches (based on 2014 catch levels), in response to the increased fishing pressure on yellowfin tuna and change in stock status. <Click here for full stock status summary>

* Not estimable accurately in SS-III as ascending limb missing from equilibrium yield curve.

** Estimated probability that the stock is in the respective quadrant of the Kobe plot (shown below), derived from the confidence intervals associated with the current stock status.

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

1. Opening of the Meeting

1. The 18th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT) was held in Seychelles, from 5–10 November 2016. The meeting was opened by the Chairperson, Dr M. Shiham Adam (Maldives) who welcomed participants and Vice-Chair, Dr Gorka Merino (EU,Spain). A total of 44 participants attended the Session (44 in 2015, 53 in 2014), including the IOTC Stock Assessment consultant (for bigeye tuna and yellowfin tuna), Mr Adam Langley, and ISSF-IOTC consultant, Dr Simon Hoyle. The list of participants is provided at Appendix I. An invited expert was also due to participate in the meeting, but shortly before the meeting was unable to attend due to unforeseen circumstances.

2. Adoption of the Agenda and Arrangements for the Session

2. The WPTT **ADOPTED** the Agenda provided at Appendix II. The documents presented to the WPTT18 are listed in Appendix III.

3. The IOTC process: Outcomes, updates and progress

3.1 Outcomes of the 18th Session of the Scientific Committee

3. The WPTT **NOTED** paper IOTC–2016–WPTT18–03 which outlined the main outcomes of the 18th Session of the Scientific Committee (SC18), specifically related to the work of the WPTT, and **AGREED** to consider how best to progress these issues at the present meeting.

4. The WPTT **NOTED** that in 2015, the SC made a number of requests in relation to the WPTT17 report (noting that updates on Recommendations of the SC18 are dealt with under Agenda item 3.4 below). Those requests and the associated responses from the WPTT18 are provided below for reference.

- ***Yellowfin tuna***
  - (Para 87) *The SC **NOTED** that around half of the recent yellowfin tuna catch is harvested by artisanal fisheries, about which there is little information with regards to their catch, their fishing areas and the sizes of their captures. In addition, there is a lack of size frequency data for some industrial longline fleets fishing yellowfin tuna. **NOTING** that these problems contribute to increase the uncertainty in stock assessments, the SC **AGREED** that incorporating this type of uncertainty in future assessments is important to be included in the Program of Work for the WPTT. Moreover, CPCs should comply with IOTC data requirements in Resolutions 15/01 and 15/02.*
  - (Para 88) *The SC **NOTED** a series of issues identified with the SS3 stock assessment carried out in 2015 as detailed in the report of the WPTT17 (IOTC-2015-WPTT17-R). Briefly, these include, but are not limited to the following:*
    - *a. The decline to a low spawning biomass relative to MSY was not preceded by a period of high catch relative to MSY. The model interprets the trend in biomass as originating from low recruitment.*
    - *b. The sudden decrease in estimated recruitment in 2004 and 2005 is not observed in the nominal catch rates of purse seine fisheries using FADs, but it can be observed by other fishery indicators.*
    - *c. The problems related to the representativeness of the Japanese CPUE series, which is localised in a southern area of the distribution of yellowfin tuna and only accounts for 1% of the total catch in recent years.*
    - *d. The adult biomass as estimated by the longline CPUE indices has shown a sudden decline between 2007 and 2008 (piracy onset) whereas the adult yellowfin tuna nominal purse seine CPUE appears to be stable.*
  - (Para 89) *NOTING the difficulties with purse seine CPUE standardisation, the SC REQUESTED that the European Union place greater importance and effort into standardising their purse seine CPUE series on juveniles and adults, which would contribute to the next stock assessment for yellowfin tuna.*

3.2 Outcomes of the 20th Session of the Commission

5. The WPTT **NOTED** paper IOTC–2016–WPTT18–04 which outlined the main outcomes of the 20th Session of the Commission, specifically related to the work of the WPTT and **AGREED** to consider how best to provide the Scientific Committee with the information it needs, in order to satisfy the Commission's requests, throughout the course of the current WPTT meeting.

6. The WPTT **NOTED** the 12 Conservation and Management Measures (CMMs) adopted at the 20th Session of the Commission (consisting of 12 Resolutions and 0 Recommendations) as listed below:

IOTC Resolutions

- Resolution 16/01 On an interim plan for rebuilding the Indian Ocean yellowfin tuna stock
- Resolution 16/02 On harvest control rules for skipjack tuna in the IOTC area of competence
- Resolution 16/03 On the second performance review follow-up
- Resolution 16/04 On the implementation of a Pilot Project in view of Promoting the Regional Observer Scheme of IOTC
- Resolution 16/05 On vessels without nationality
- Resolution 16/06 On measures applicable in case of non-fulfilment of reporting obligations in the IOTC
- Resolution 16/07 On the use of artificial lights to attract fish
- Resolution 16/08 On the prohibition of the use of aircrafts and unmanned aerial vehicles as fishing aids
- Resolution 16/09 On establishing a Technical Committee on Management Procedures
- Resolution 16/10 To promote the implementation of IOTC Conservation and Management Measures
- Resolution 16/11 On port state measures to prevent, deter and eliminate illegal, unreported and unregulated fishing
- Resolution 16/12 Working Party on the Implementation of Conservation and Management Measures (WPICMM)

7. The WPTT **NOTED** that pursuant to Article IX.4 of the IOTC Agreement, the above mentioned Conservation and Management Measures became binding on Members, 120 days from the date of the notification communicated by the IOTC Secretariat in IOTC Circular 2016–054 (i.e., **27 September 2016**).

8. **NOTING** that the Commission also made a number of general comments and requests on the recommendations made by the Scientific Committee in 2015, which have relevance for the WPTT (details as follows: paragraph numbers refer to the *draft* report of the Commission (IOTC–2016–S20–R): the WPTT **AGREED** that any advice to the Commission would be provided in the relevant sections of this report, below.

- ***Report of the 18th Session of the Scientific Committee***
  - (Para 13*). The Commission **CONSIDERED** the list of recommendations made by the SC18 (Appendix VI) from its 2015 report (IOTC–2015–SC18–R) that related specifically to the Commission. The Commission **ENDORSED** the list of recommendations as its own, while taking into account the range of issues outlined in this Report (S20) and incorporated within Conservation and Management Measures adopted during the Session and as adopted for implementation as detailed in the approved annual budget and Program of Work.*
- ***Yellowfin tuna***
  - (Para. 18) *The Commission NOTED that, based on the assessment carried out in 2015, yellowfin stock biomass is below the level that will support the MSY and that fishing mortality is above the level that will produce the MSY. Thus, on the weight-of-evidence available in 2015, the yellowfin tuna stock is determined to be overfished and subject to overfishing.*
  - (Para 19) *The Commission NOTED that there is a very high risk of continuing to exceed the biomass MSY-based reference point if catches increase further or are maintained at current levels (2014) until 2017 (>99% risk that SB2017 < SBMSY), and similarly a very high risk that F2017 > FMSY (≈100%). The modelled probabilities of the stock achieving levels consistent with the Commission's*

current management objective (e.g. SB > SBMSY) are 50% for a future constant catch at 80% of current catch levels by 2024.

- (Para 20) *The Commission **NOTED** the following management advice provided by the SC "Projections show that current levels of catch would exacerbate the decline of this stock in the short term. The modelled probabilities of the stock achieving levels consistent with the interim target reference points (i.e. SB > SB_{MSY} and $F<F_{MSY}$) in 2024 are 50% for a future constant catch at 80% of the catch levels in 2014. If the Commission wishes to recover the stock to levels above the interim target reference points with 50% probability by 2024, the Scientific Committee recommends that catches be reduced by 20% of current levels".*
- (Para 21) *The Commission **NOTED** concerns about the status of yellowfin and **AGREED** that management measures should be taken urgently to reduce the fishing pressure on the stock. The Commission also **DISCUSSED** the possibility of an update to the yellowfin stock assessment in 2016 to follow the status of the stock closely.*
- (Para 22) *The Commission NOTED the advice of the Chair of the SC, that it would be premature to conduct another stock assessment on yellowfin in 2016.*

- **On an Interim Plan for Rebuilding the Indian Ocean Yellowfin Tuna Stock**
  - *(*Para 126*). The Commission **ADOPTED** Resolution 16/01 On an Interim Plan for Rebuilding the Indian Ocean Yellowfin Tuna Stock (Appendix XVI). This Resolution introduces a scheme for reduction of catches of yellowfin (from 2014 levels), by fishery, for all fishing vessels targeting tuna and tuna like species in the Indian Ocean of 24 meters overall length and over, and those under 24 meters if they fish outside the EEZ of their flag State, within the IOTC area of competence.*
  - (Para 127). *The Commission **AGREED** that the provisions of paragraph 7 of Resolution 15/08 are now superseded by paragraph 3b of this resolution, which limits the number of Fish Aggregating Devices (FADs) at no more than 425 active instrumented buoys and that 850 instrumented buoys may be acquired annually per vessel.*
- **On the implementation of a pilot project in view of promoting the Regional Observer Scheme of IOTC**
  - (Para. 130). *The Commission **ADOPTED** Resolution 16/04 On the implementation of a pilot project in view of promoting the Regional Observer Scheme of IOTC. This Resolution creates a pilot project aiming to enhance the implementation of the Resolution 11/04 on a Regional Observer Scheme and to raise the level of compliance to the implementation of Resolutions 15/01 and 15/02, respectively on the recording of catch and effort data by fishing vessels in the IOTC area of competence and on mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating non-Contracting parties (CPCs).*
- **On the use of artificial lights to attract fish**
  - (Para. 133). *The Commission **ADOPTED** Resolution 16/07 On the use of artificial lights to attract fish. This Resolution prohibits fishing vessels and other vessels including support, supply and auxiliary vessels flying the flag of an IOTC Contracting Party or Cooperating Non-Contracting Party (collectively CPCs) from using, installing or operating surface or submerged artificial lights for the purpose of aggregating tuna and tuna-like species beyond territorial waters.*
- **On the prohibition of the use of aircrafts and unmanned aerial vehicles as fishing aids**
  - (Para. 134). *The Commission **ADOPTED** Resolution 16/08 On the prohibition of the use of aircrafts and unmanned aerial vehicles as fishing aids. This Resolution prohibits the use of aircrafts and unmanned aerial vehicles as fishing aids on flagged fishing vessels, support and supply vessels by Contracting Parties and Cooperating Non-Contracting Party (collectively CPCs).*

3.3 Review of Conservation and Management Measures relating to tropical tunas

9. The WPTT **NOTED** paper IOTC–2016–WPTT18–05 which aimed to encourage participants at the WPTT18 to review some of the existing Conservation and Management Measures (CMM) relevant tropical tunas, noting the CMMs contained in document IOTC–2016–WPTT18–04; and as necessary to 1) provide recommendations to the Scientific Committee on whether modifications may be required; and 2) recommend whether other CMMs may be required.

10. The WPTT **AGREED** that it would consider proposing modifications for improvement to the existing CMMs following discussions held throughout the current WPTT meeting.

3.4 Progress on the Recommendations of WPTT17

11. The WPTT **NOTED** paper IOTC–2016–WPTT18–06 which provided an update on the progress made in implementing the recommendations from the previous WPTT meeting which were endorsed by the Scientific Committee, and **AGREED** to provide alternative recommendations for the consideration and potential endorsement by participants as appropriate given any progress.

12. The WPTT **RECALLED** that any recommendations developed during a Session, must be carefully constructed so that each contains the following elements:
    - a specific action to be undertaken (deliverable);
    - clear responsibility for the action to be undertaken (i.e. a specific CPC of the IOTC, the IOTC Secretariat, another subsidiary body of the Commission or the Commission itself);
    - a desired time from for delivery of the action (i.e. by the next working party meeting, or other date);
    - if appropriate, an approximate budget for the activity, so that the IOTC Secretariat may be able to use it as a starting point for developing a proposal for the Commission's consideration.

4. NEW INFORMATION ON FISHERIES AND ASSOCIATED ENVIRONMENTAL DATA RELATING TO TROPICAL TUNAS

4.1 Review of the statistical data available for tropical tunas

13. The WPTT **NOTED** paper IOTC–2016–WPTT18–07 which summarised the standing of a range of data and statistics received by the IOTC Secretariat for tropical tuna, in accordance with IOTC Resolution 15/02 *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPC's)*, for the period 1950–2015. The paper also provided a range of fishery indicators, including catch and effort trends, for fisheries catching tropical tunas in the IOTC area of competence. It covers data on nominal catches, catch-and-effort, size-frequency and other data, in particular release and recapture (tagging) data. A summary of the supporting information for the WPTT is provided in Appendix IV.

14. The WPTT **NOTED** the main tropical tuna data issues that are considered to negatively affect the quality of the statistics available at the IOTC Secretariat, by type of dataset and fishery, which are provided in Appendix V, and **REQUESTED** that the CPCs listed in the Appendix, make efforts to remedy the data issues identified and to report back to the WPTT at its next meeting.

15. The WPTT **AGREED** that all species specific discussion would be placed within the individual species sections below.

4.2 Review new information on fisheries and associated environmental data

Climate and oceanographic conditions

16. The WPTT **NOTED** paper IOTC–2016–WPTT18–09 which provided an update of the climate and oceanographic conditions in the Indian Ocean up to 2016, including the following abstract provided by the author:

    "Several descriptors of the ocean climate conditions are examined to depict the inter-annual trend and to track major changes that may affect the large pelagic ecosystem. The environmental series were updated to July 2016 and September 2016 depending on the variables. The main feature is the development of a strong positive Indian Ocean Dipole during the second semester of 2015. This dipole has coincided with the ENSO warm phase, with development of an El Niño event in the Pacific Ocean. The anomalies associated to the positive dipole were warmer sea surface temperature over most of the Indian Ocean, a deep thermocline ridge in the West Indian Ocean through November 2015 - May 2016 and a depleted primary productivity in the South Arabian Sea and in the Somali basin. The dipole turned into a negative phase in January 2016, reached its mature condition in May 2016 and is predicted to continue through the boreal fall. As expected during a positive dipole phase, the primary productivity has been reduced in the western region of the IO from July 2015 to February 2016 and has returned to a more productive phase since May 2016. The vertical current shear in the upper water column (4 to 145m) exhibits two distinct patterns along with the dipole situation, with weaker shear during positive dipoles and stronger shear during negative dipoles. Because of this pattern, it is suggested that further consideration be given

to use the vertical shear current as an additional environmental covariate in bigeye CPUE standardization."

17. The WPTT **NOTED** the introduction of additional environmental variables such as vertical current shear which is likely to the affect the depths reached by hooks for deep longline sets, and **REQUESTED** that the current shear be calculated over the entire depth range of the longline gear, potentially 0-400 m by 20 m.

18. The WPTT **NOTED** the difficulty in including environmental variables in CPUE standardisations, especially because of temporal and spatial autocorrelation and subsequent confounding effects and **SUGGESTED** that approaches should be explored (e.g., mixed effect models).

19. The WPTT **NOTED** the issues with the density and quality of observed environmental variables throughout the Indian Ocean, and that most oceanographic covariates used are model outputs, which may slightly differ from observations.

20. The WPTT **ENCOURAGED** that areas where the environmental data are known to be reliable (i.e., potentially areas in the Western Indian Ocean) should be selected to undertake analyses to identify processes that may affect catchability, and determine appropriate oceanographic covariates to be included in CPUE standardisations in those areas.

I.R. Iran tropical tuna fisheries

21. The WPTT **NOTED** paper IOTC–2016–WPTT18–10 which provided an overview of the tropical tuna catch in I.R. Iran, including the following abstract provided by the author:

    "This paper gives a description of the trends of tuna and tuna-like catches with emphasis Tropical tuna in Indian Ocean by Iranian fishing fleet. This report also discusses the actions taken by Iran in recent according to IOTC evaluation referring to member Countries compliance to IOTC rules, regulations and resolutions, the average level of member countries compliance in 2010 was 25%, for Iran it is reported about 11% and in 2015 the average indicator for member countries was 58%. During recent years Iran has carried out many efforts to enhance its compliance from 11% to 75%. Although there are still problems in some areas, but a lot of actions are in progress to remove those problems and build necessary infrastructures to fulfil all requirements."

22. The WPTT **RECALLED** the value of sampling in the I.R. Iran region as it captures a size range of yellowfin tuna (75–90 cm) that are not represented well elsewhere in the Indian Ocean.

23. The WPTT **NOTED** that recent declines in skipjack tuna catch by I.R. Iran vessels are most likely due to piracy, whereby vessels previously fishing in the south have moved back into the Persian Gulf and Oman Sea where there are relatively less skipjack tuna and more longtail tuna. The WPTT further **NOTED** that the recent decline in skipjack tuna is more evident than for other tropical tuna species targeted by the Iranian fishery.

Problems facing Somali Tunas

24. The WPTT **NOTED** paper IOTC-2016-WPTT18-11 which provided an overview of the problems facing Somali tuna fisheries (no abstract provided by the author).

25. The WPTT **NOTED** the difficulties faced by Somalia in the management of tuna resources in the Somali EEZ, including lack of technology, no industrial fishing fleet, potential for IUU fishing due to difficulties in securing and monitoring the Somali coastline, and lack of data collection and analysis.

Mauritius tropical tuna fishery

26. The WPTT **NOTED** paper IOTC–2016–WPTT18–12 which provided a review of the catch of tropical tunas from longline and purse seine vessels licensed in Mauritius, including the following abstract provided by the author:

    "*This paper provides an overview of the tropical tuna fisheries as recorded by Mauritius, for the national semi-industrial vessels that were licensed to fish in the Mauritius EEZ The semi-industrial longliners consist of vessels less than 24m that operate inside the EEZ (Exclusive Economic Zone) of Mauritius. These vessels target swordfish but tropical tunas are also obtained during the fishing operations. The range of areas that are covered by the fishing operation of the semi industrial longliners extended from latitudes 09°S-20°S and longitudes 55°E -62°E. A total of 5 longliners were in operation in 2015 with a total catch of 102.9 tonnes out of which 27.4 % consisted of yellowfin tuna and 12.91% was bigeye. The annual trend for the period of 2012-2015 shows that the levels of yellowfin tuna were higher compared to bigeye tuna except for the year 2013 where bigeye catches were higher with a percentage difference of 34.5%. The fork lengths of a total of 1558 yellowfin tuna were measured during unloading of the catch* *at port. The lengths of total number of yellowfin sampled during the 2012-2015 period ranged from 63 - 174 cm, with an average fork length of 119.1 cm. The percentage of mature fish varied between 91-97% in the catch of yellowfin sampled. A total of 1159 bigeye tuna were sampled during the four year period and the fork length distribution tuna was in the range 75-177cm with an average fork length of 118 cm".*

27. The WPTT **NOTED** that, despite the relatively low catches of tropical tunas reported by longline and purse seine vessels, catches appear to be relatively well sampled in terms of fish size – although currently no biological samples are being collected by Mauritius Albion Fisheries Research Centre.

Thailand tuna fisheries

28. The WPTT **NOTED** paper IOTC–2016–WPTT18–38 which provided an overview of tuna longline fishery in the east Indian Ocean, including the following abstract provided by the author:

"This report was based on the data extracted from fishing logsheets by six Thai tuna longliners which declared to Department of Fisheries, Thailand. Data from their logsheets displayed important information of their fishing operation and effort. During 2011-2015, fishing grounds were mainly in the Western coast of the Indian Ocean, fishing operations were recorded 2,070 fishing days. The highest total catch was in 2015 with 599.73 tonnes followed by 2014, 2012, 2011 and 2013 respectively (571.91, 470.41, 373.44 and 307.74 tonnes). The highest CPUE was found in 2014 with 13.28 fish/1,000 hooks followed by 2015 and 2012, respectively (12.38 and 10.83 fish/1,000 hooks). During 2011-2015, the bigeye tuna (Thunnus obesus) and yellowfin tuna (T. albacares) caught by number and weight were 29,008 fish (1,275.89 tonnes), 13,821 fish (449,28 tonnes) respectively. The average percentage composition by number of the bigeye tuna and yellowfin tuna were 44.44% and 21.18% and by weight 54.92% and 19.34%, respectively. In 2015,bigeye tuna and yellowfin tuna were caught 4,838 fishes (206.57 tons), 3,411 fishes (109.45 tonnes), respectively. The CPUEs of bigeye tuna and yellowfin tuna were 2.70 fish/1,000 hooks (115.48 kg/1,000 hooks) and 1.91 fish/1,000 hooks (61.19 kg/1,000 hooks), respectively."

29. The WPTT **NOTED** that there were no Thai longliners operating in the Indian Ocean in 2016. The WPTT was informed that the Regional Observer Scheme is ongoing, but observers cannot currently be deployed until current licensing issues with the Thai longline fleet have been resolved (possibly in 2017).

30. The WPTT **NOTED** discrepancies between the fishing effort maps and species composition produced in the paper and catch-and-effort data which were provided by Thailand to the Secretariat, and **REQUESTED** that the IOTC Secretariat liaise to resolve the discrepancies identified.

Characteristics of Indonesia's aFAD tuna fisheries

31. The WPTT **NOTED** paper IOTC–2016–WPTT18–29 which provided an overview of the characteristics of anchored FADs in Indonesian waters, including the following abstract provided by the author:

"With the primary aim of addressing information gaps on the scale and operations of Indonesia's FAD based tuna fisheries, to aid improved fisheries management, an Indonesia - Australia research collaboration conducted a study during Nov 2013 – Dec 2015 at four key fishing ports in eastern Indonesia and western Indonesia. The full outputs from this study, involving an enumeration program with skipper interviews, biological sampling and direct observations are to be published as final report and subsequent papers. Presented here are preliminary results from research at two locations in West Sumatera, Muara Padang and Bungus Fishing Port, and Pelabuhanratu Fishing Port in West Java." – see paper for full abstract.

32. The WPTT **NOTED** that Indonesian anchored FADs are designed with non-entangling material (e.g., palm fronds and nipa leaves) and that FADs were deployed by fishers without control from fisheries authorities which makes it difficult to estimate the overall number of anchored FADs.

33. The WPTT **NOTED** that size frequency data from FADs has been collected by the ACIAR-funded project, but has not yet been submitted to the Secretariat, and **REQUESTED** that size data from FADs be reported to the IOTC, especially since the fish captured are the smallest across all fisheries in the Indian Ocean and have significant value in assessments as an indicator of recruitment.

Using echo-sounder buoys to estimate biomass of species associated with FADs

34. The WPTT **NOTED** paper IOTC–2016–WPTT18–28 which provided an overview of echo-sounder data in relation to estimates of biomass of fish species associated with fish aggregating devices, including the following abstract provided by the author:

"Most of the drifting fish aggregating devices (DFADs) used by the industrial tropical tuna purse seine fishery are deployed with satellite linked echo- sounder buoys. These echo-sounders provide information on the accurate geo-location of the object and rough estimates of fish biomass aggregated along the trajectory of the FAD. However, current echo-sounder buoys do not provide biomass information by species or size composition under the DFADs. The aim of this study is to progress towards improved remote biomass estimates using echo-sounder buoys and a model based on existing knowledge of the vertical distribution and behavior of non-tuna and tuna species at DFADs and mixed species target strengths (TS) and weights for different depth layers. Results show that manufacturer's biomass estimates, although enhanced, can be further improved, indicating that the large variability in the Indian Ocean is not easily considered with a single model. Potential reasons driving echo-sounder buoy estimates variability, as well as the limitations encountered with these devices are discussed, including the lack of consistent TS values for skipjack, bigeye and yellowfin tunas."

35. The WPTT **ACKNOWLEDGED** that biomass estimation by FAD echo-sounder buoys is of great interest for developing alternative fisheries-independent relative abundance indices. However the partitioning between small and large tuna at a fixed depth may be an issue when estimating abundance by size and species, as there is likely to be overlap in the depth distribution of small and large fish and among species.

36. The WPTT **NOTED** that validation of target strength for yellowfin tuna is being tested in the Achotines laboratory in Panama. Similarly, both target strengths for bigeye tuna and skipjack tuna are already being analysed using information collected during scientific acoustic cruises in the Pacific Ocean.

Catch, Effort, and eCOsystem impacts of FAD fishing research project (CECOFAD)

37. The WPTT **NOTED** paper IOTC–2016–WPTT18–35 which summarised the main outcomes of the EU co-funded project CECOFAD, including the following abstract provided by the author:

    "The European Research project "Catch, Effort, and eCOsystem impacts of FAD-fishing" (CECOFAD) set out to improve our understanding of the use of drifting fish-aggregating devices (DFADs) in tropical purse seine tuna fisheries in open ocean ecosystems. Data from unofficial technology information related to FAD-fishing were retrieved and the changes over time in systems used for positioning buoys at-sea (radio, satellite transmitters, echo sounder buoys) were quantified. The total number of DFADs deployed at sea in the Atlantic and Indian oceans over the last ten years was estimated from 2 different approaches, based on information provided by the French tuna association and extrapolated to the other purse seiner fleets. From data collected within the FAD National Management Plan, the relationship between the number of active DFADs and the catch per Spanish purse seiner (with or without the assistance of a supply vessel), was explored."

38. The WPTT **NOTED** the wide range of activities covered by this project including FAD technology, CPUE standardisations, the impact of lost FADs on fragile ecosystems, evaluation of management measures, and new terminology related to FAD fishing activities.

39. The WPTT **NOTED** that the project assessed the impact of time area closures for FAD fishing on target and bycatch species, and **REQUESTED** the authors to further work to analyse the potential application to other areas for presenting in future WPTT meetings.

40. The WPTT **REQUESTED** the authors to present the FAD terminology developed in this project to the upcoming WPDCS meeting, in order to harmonize the terminology used by other tRFMOs.

Integrating scientific and French tropical tuna purse seine skippers knowledge for better management of dFAD fisheries

41. The WPTT **NOTED** paper IOTC–2016–WPTT18–36 which presented the perception of French fishers through interviews on the functioning and management of FAD fishing, and other quantitative sources of information, including the following abstract provided by the author:

    "Since the mid-1990s, the use of drifting Fish Aggregating Devices (dFADs) by purse seiners, artificial objects specifically designed to aggregate fish, has become an important mean of catching tropical tunas. In recent years, the massive deployments of dFADs, as well as the massive use of tracking devices on dFADs and natural floating objects, such as GPS buoys, have raised serious concerns for tropical tuna stocks, bycatch species and pelagic ecosystem functioning. Despite these concerns, relatively little is known about the modalities of dFAD use, making it difficult to assess and manage the impacts of this fishing practice. The present paper provides an overview of a 4-year research project on the use of dFADs by tropical tuna purse seiners in the Western Indian Ocean. Though our primary objective was to derive information on dFAD fisheries from a large variety of quantitative sources of information (GPS

buoy positions, onboard observers, logbooks and VMS), a multi-disciplinary approach was adopted throughout our research. Quantitative results (estimates of dFAD use, fishing efficiency and impacts of dFAD use) were discussed with French purse seine skippers during semi-structured interviews to understand their perception of the impacts of dFAD use and to propose adapted management options for tropical tuna purse seine dFAD fisheries. Interviews with French purse seine skippers revealed the existence of a competition between EU purse seine fleets, encouraging the recent increase in the use of dFADs. They underlined the need for a more efficient management of the fishery, including the implementation of catch quotas, a limitation of the capacity of purse seine fleets and a regulation of the use of support vessels."

42. The WPTT **ACKNOWLEDGED** the value of information from interviews to complement the scientific observations made on FADs.

43. The WPTT **NOTED** that FADs and support vessels are components of fishing capacity related to purse seine fisheries. However, efforts to control fishing capacity should consider all fishing gears, as purse seine only represent 35% of total catches of tropical tunas.

44. The WPTT **NOTED** the statement made by the participant from the Republic of Mauritius, which reiterates the position conveyed in the statements made by the Republic of Mauritius at the 13th Session of the Compliance Committee and contained in Report IOTC-2016-CoC13-R at Appendix IVA[2] (Paper 36).

Validation of VMS data and identification of fishing activities of Spanish tuna purse seiners

45. The WPTT **NOTED** paper IOTC–2016–WPTT18–39 which compared four different sources of high-resolution georeferenced data (VMS, portable GPS, observer data, and fishing log books) to inform on the type of purse seine activity, including the following abstract provided by the author:

"Understanding fishing effort and fleet behavior is of primary importance for a proper management of tuna resources, particularly when uncertainties exist in the catch per unit of effort (CPUE) index. Tropical tuna purse seine fisheries are of extremely importance, accounting for about half of the world market tropical tunas. Using Vessel Monitoring System data with a frequency of 1 ping/hour, this study develops a methodological framework that validates and investigates the activity of Spanish tropical tuna purse seine fleet in the tropical Atlantic Ocean by comparing them with observer, fishing logbook and fine-scale vessel tracking data. We present statistics and summary parameters of fishing related activities of Spanish purse seiners, including FAD-oriented activities, as well as examples for potential identification of fishing effort distribution. Results showed that vessels' activity and associated effort are reasonably well identified by the proposed method and highlighted the importance of accessing accurate fisheries-related data for correct validation of activities. This work contributes towards the use of VMS data to increase our knowledge on fleets behaviour and strategy and presents a methodology able to provide insight into the potential relationship between significant changes and fleet behavior, which appears to be crucial for a proper definition of the effort to be used in CPUE of this fishery. Results obtained through the methodology developed in this study should be compared to outputs from other validated fleets like, for example, French fleet, which are supposed to less rely on FADs in their fishing strategy."

46. The WPTT **NOTED** that VMS can provide improvements in estimates of the searching effort based on the area covered, compared to searching time estimated from logbooks or observer data.

47. The WPTT **NOTED** that VMS data are sufficient to describe adequately the setting and searching activities and that the use of higher resolution data was not necessary. Nevertheless, higher resolution data can be useful for more specific research questions.

Note on the size frequencies of the YFT & BET catches by PS used in the SS3 model

48. The WPTT **NOTED** paper IOTC–2016–WPTT18–INFO1 which provided a discussion of the size frequency data reported to the IOTC Secretariat by the European purse seine fleet, and input files prepared by the IOTC Secretariat for the SS3 model.

49. The WPTT **ACKNOWLEDGED** that while the anomalies in the purse seine size data do not likely affect the outcomes of the assessment model, the WPTT **REQUESTED** that all three types of size data (i.e., raw samples,

[2] http://www.iotc.org/documents/report-13th-session-compliance-committee

weighted and extrapolated size data) be submitted to the IOTC Secretariat by the EU to resolve the current anomalies in the size data to be included in future assessments.

50. The WPTT **ACKNOWLEGED** that the large amount of size data available for the EU purse seine fleet is considered to be the most reliable source of size frequency data available in the IOTC database and **REQUESTED** that these data are analysed in more detail to investigate the source of variation (e.g., by area and time) and updated accordingly when providing inputs for future tropical tuna stock assessments – particularly in the case of yellowfin tuna and bigeye tuna.

51. The WPTT also **NOTED** that there was concern regarding the high degree of variation in the length composition data available from the longline fisheries. The differences in length composition amongst fleets and over time periods (historical and recent) may indicate biases in the collection of these data from some fleets, changes in fishing operation, and/or high levels of sampling error (related to low sample sizes) and **REQUESTED** a thorough review of the longline length frequency data held by IOTC is required to improve the utilization of these data in the tropical tuna stock assessments.

Proposals for improved figures in the tropical tunas statistical summaries

52. The WPTT **NOTED** paper IOTC–2016–WPTT18–33 which detailed proposals for alternative figures in the tropical tunas statistical summaries.

53. The WPTT **NOTED** that expanding the current set of information presented in the figures of the tropical tuna statistical appendices would be useful, and **REQUESTED** that proposed changes to the figures be discussed at the next session of the WPDCS and to be considered by the SC prior to inclusion into the supplementary information appended to the executive summaries.

54. The WPTT **REQUESTED** the IOTC Secretariat to explore possible options for the development of an online interface to allow users to generate figures using the publically disseminated dataset of the IOTC.

Pakistan gillnet fisheries targeting tropical tunas

55. The WPTT **NOTED** paper IOTC–2016–WPTT18–INF03 which provides an overview of the status of gillnet fisheries in Pakistan targeting tropical tunas.

56. The WPTT **NOTED** the large differences in catches estimated by the Pakistan Ministry of Ports and Shipping and the (substantially higher) catches estimates by the WWF funded Observer Program, and **REQUESTED** that Pakistan, WWF and the IOTC Secretariat collaborate in order to understand the reason for the discrepancies, and in addition explore ways to improve data collection and reporting of data to the IOTC over the longer term.

57. The WPTT also **REQUESTED** that Observer data collected by WWF funded Observers, is made available to the IOTC Secretariat by formal submission of the by the Pakistan Ministry of Ports and Shipping.

5. BIGEYE TUNA – REVIEW OF NEW INFORMATION ON STOCK STATUS

5.1 Review of the statistical data available for bigeye tuna

58. The WPTT **NOTED** paper IOTC–2016–WPTT18–07 which summarised the standing of a range of data and statistics received by the IOTC Secretariat for bigeye tuna, in accordance with IOTC Resolution 15/02 *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPC's)*, for the period 1950–2015. The paper also provided a range of fishery indicators, including catch and effort trends, for fisheries catching bigeye tuna in the IOTC area of competence. It covers data on nominal catches, catch-and-effort, size-frequency and other data, in particular release and recapture (tagging) data. A summary of the supporting information for the WPTT is provided in Appendix IVb.

59. The WPTT **REQUESTED** that Pakistan, WWF, and the IOTC Secretariat collaborate to understand and reconcile differences between recent catches reported by the Pakistan Ministry of Ports and Shipping, sampling conducted by WWF, and historical data reported by Pakistan, and for the IOTC Secretariat to provide an update to the next WPTT meeting – particularly in relation to revision of catches of bigeye tuna and yellowfin tuna for the driftnet fishery.

60. The WPTT **RECALLED** that, compared to other IOTC species (including other tropical tuna species) the overall quality of the data available for bigeye tuna is considered to be relatively good, given the majority of catches are accounted for by industrial fisheries which have good reporting systems. However, catches of bigeye tuna from coastal fisheries have increased in recent years and may be underestimated, in particular for the

coastal fisheries of Indonesia (juvenile tunas) and driftnet gillnet fisheries, due to the lack of data or poor reporting of bigeye tuna catches for some coastal fisheries (e.g. Pakistan gillnets).

61. The WPTT **NOTED** that the uncertainty in total catches, particularly for most coastal fisheries, should be accounted in the stock assessments and that some modelling runs should be conducted based on alternative catch series that reflect the uncertainty in catches. This uncertainty is exacerbated by underestimation of the real bigeye tuna catches as small bigeye tuna are often misidentified as yellowfin tuna. The approach currently used to score the quality of data by the IOTC Secretariat is mainly focused on data reporting and timeliness. Collaborative work with CPCs needs to be undertaken to propose a set of indicators aimed at better reflecting the level of uncertainty in the data available at the IOTC Secretariat.

62. **NOTING** the on-going issue regarding the accuracy of total catch estimates related to the capture and identification of juvenile bigeye tuna (due to difficulties of species identification), the WPTT **REQUESTED** that CPCs catching large numbers of juvenile tuna improve the enumeration and classification of this species.

63. The WPTT **NOTED** that in the case of the Maldives and other coastal fisheries, juveniles of bigeye tuna often account for an appreciable amount of the total catch but are either not reported or assigned to an 'Other' species category and **RECOMMENDED** the IOTC Secretariat and Maldives collaborate to improve reliability of catches of bigeye tuna – particularly for historical catch series prior to the introduction of logbooks in 2010.

5.2 Review new information on the biology, ecology, stock structure, their fisheries and associated environmental data for bigeye tuna

Sex-ratio, size at maturity, spawning period and fecundity of bigeye tuna (Thunnus obesus) in the western Indian Ocean.

64. The WPTT **NOTED** paper IOTC–2016–WPTT18–37 which provides a summary of the biological indicators of bigeye tuna in the western India Ocean, including the following abstract provided by the author:

    "Opportunistic sampling of bigeye tuna (Thunnus obesus; BET) was conducted in the western Indian Ocean from 2010 to 2015 to study important reproductive traits (i.e., sex-ratio, size at maturity, spawning season and fecundity) with the aim to provide reliable information to improve the stock assessment. Overall 507 BET were sampled (including 204 females, 216 males and 87 indeterminate fishes) from which 158 ovaries were analyzed histologically. Significant bias towards females was found in the sex ratio of small individuals while males appeared dominant at large sizes. High reproductive activity was observed from January to March. The size at which 50% of females reach maturity (L50) was estimated at 102±4.5 cm fork length (LF), setting maturity threshold at primary vitellogenic oocyte stage. Mean batch fecundity (FB) was estimated at 0.75±0.52 million oocytes and mean relative batch fecundity (FBrel) at 11.54±7.11 oocytes per gram of fish weight. No significant relationship between fecundity (FB and FBrel) and size (LF) was found."

65. The WPTT **NOTED** that while the catchability of spawning females in purse seiners maybe larger than the catchability of non-spawning females, which may bias the maturity estimation, similar estimates of size at maturity are found in studies using longline samples.

66. The WPTT **ACKNOWLEDGED** the scientific value to expand similar biological sampling and analysis in the Eastern Indian Ocean through the observer program and **NOTED** that these biological data have been submitted to the IOTC Secretariat and this data could be made available for further analysis through an official request made to the data owners (i.e., IOTC CPCs).

5.3 Review of new information on the status of bigeye tuna

5.3.1 Nominal and standardised CPUE indices

Japan longline CPUE for bigeye tuna

67. The WPTT **NOTED** paper IOTC–2016–WPTT18–18 which provided the Japanese longline CPUE for bigeye tuna in the Indian Ocean standardised by GLM, including the following abstract provided by the author:

    "*Standardization of Japanese longline CPUE for bigeye tuna was conducted for 1960-2015 by using GLM (generalized linear model, log normal error structured). Methods of standardization are the same as or similar to those provided at IOTC WPTT in 2015 or before. The effects of season (month or quarter), subarea, LT1LN1 (one degree latitude-longitude block), or LT5LN5 (five degree latitude-longitude block), SST (sea surface temperature), NHF (number of hooks between floats) and material of main line, and several interactions between them were used for standardization. The trend of CPUE* *slightly differed by area, but high jump in 1977 and 1978, slight decrease after that, and increasing trend in the recent few years, but decrease in the latest year are seen as for each area. No clear difference of the trend of CPUE was observed based on the model with subarea, LT1LN1 or LT5LN5.*"

68. The WPTT **WELCOMED** the updated catch rate standardisation for the Japan fleet in the Indian Ocean for bigeye tuna (Fig. 1).

69. The WPTT **NOTED** that the Japanese fleet had not returned to the western equatorial region (R1) following the decline of piracy, and the analysis estimated large residuals for that region in recent years. The WPTT **AGREED** that the recent Japanese CPUE from that region might therefore not be fully representative of the relative abundance in the region.

70. The WPTT **NOTED** that the analyses with 1x1 and 5x5 fixed spatial effects were similar and queried whether these effects could replace environmental factors, since adding the spatial effects substantially reduces the amount of variance explained by the environmental factors.

71. The WPTT **NOTED** the patterns in the residuals associated with the eastern area, and suggested that the cause of the pattern should be investigated, since the lack of fit may introduce bias if it is associated with one part of the time series.

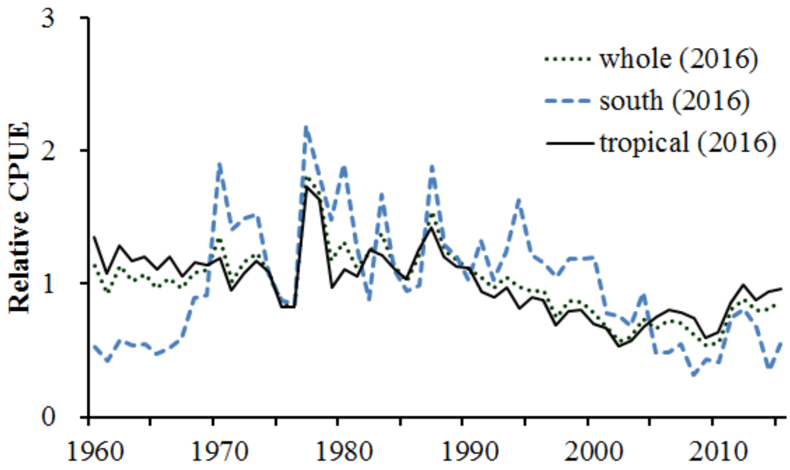


Fig.1. Bigeye tuna: Comparison of the standardised longline CPUE series for Japan. Series have been rescaled relative to their respective means from 1960–2015.

Taiwan,China longline standardised CPUE

72. The WPTT **NOTED** paper IOTC–2016–WPTT18–34 which provided an update to the CPUE standardisations for bigeye tuna and yellowfin tuna caught by Taiwan,China longline fishery in the Indian Ocean using generalized linear model, including the following abstract provided by the author:

"Updated Taiwanese longline fishery data to 2015 was used in this analysis. Cluster analysis was used to classify longline sets in relation to species composition of the catches to understand whether cluster analysis could identify distinct fishing strategies. Bigeye and Yellowfin tuna CPUE standardization were presented. All analyses were based on the approaches used by the collaborative workshop of longline data and CPUE standardization for bigeye and yellowfin tuna held in April 2016 in Taipei and in July 2016 in Shanghai."

73. The WPTT **NOTED** that clustering occurred after aggregating all sets by an individual vessel within a month, which was considered to be a reasonable compromise that admits that while consecutive sets tend to have similar targeting, targeting can also change within an actual multi-month trip.

74. The WPTT **NOTED** the updated CPUE analysis (Fig.2) and encouraged the authors to continue their analyses as part of the multi-nation collaborative effort to improve CPUE standardisations**.**

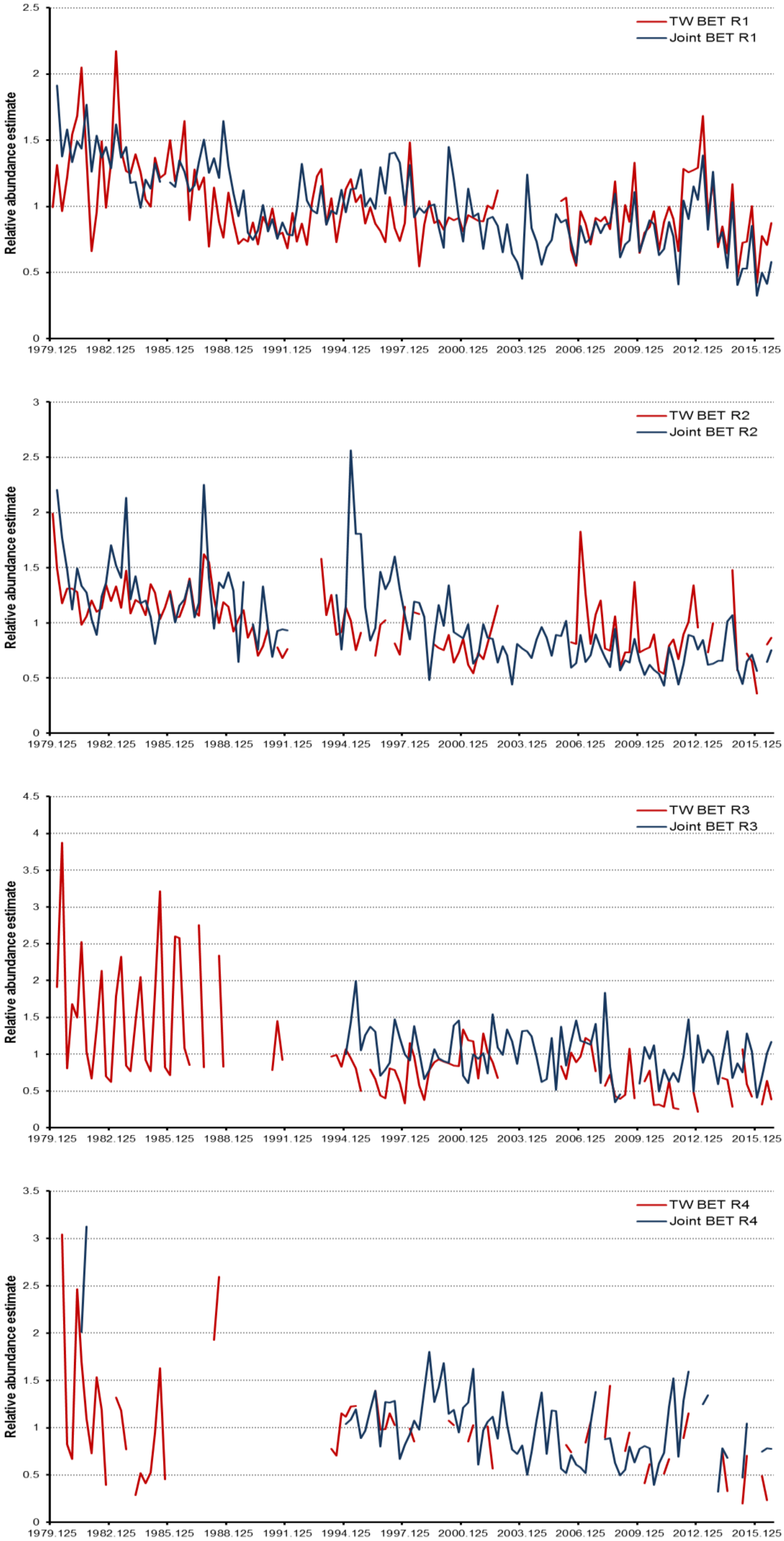


Fig.2. Comparisons of Taiwan,China bigeye tuna CPUE time series (red) with those estimated during the 2016 collaborative project (blue) by region.

Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets

75. The WPTT **NOTED** paper IOTC–2016–WPTT18–14 which provided an update of the collaborative study of longline data and CPUE standardization for bigeye, yellowfin, and albacore tuna, including the following abstract provided by the author:

> "*The paper presents the results of a collaborative study between national scientists with expertise in Japanese, Taiwanese, and Rep. of Korean longline fleets, and an independent scientist to address several important issues related to albacore, bigeye and yellowfin tuna CPUE indices in the Indian Ocean, to validate and improve methods for developing indices of abundance for tropical tunas. Data were aggregated by vessel-month and clustered on species composition in the catch, by fleet and region. The clustered data for all fleets were combined into a joint dataset. Data for each region were standardized using delta lognormal generalised linear models. Models for tropical regions included a cubic spline fitted to hooks between floats, while models for temperate areas included a categorical variable for cluster. The indices were broadly similar to those generated from Japanese data for the most recent bigeye and yellowfin assessments, but with important differences likely to influence assessment outcomes, due to different standardization methods and better data coverage. As in previous indices, there was a discontinuity around 1978 for bigeye in tropical areas, during a period with little effort in northern areas and an almost complete change in hooks between floats. This suggests a change in fishing behavior, and possibly a complete change in the fleet. There are also concerns about possible target change between bigeye and yellowfin tuna in tropical areas, where cluster analysis was not successfully applied.*"

76. The WPTT **NOTED** a number of suggestions for further work to improve the indices, including:
    i. Develop a simulator to test methods for standardizing CPUE, and to allow the development and testing of new code during periods when the joint data are unavailable.
    ii. Investigate the 1976-80 discontinuity in the tropical CPUE of bigeye and (to a lesser extent) yellowfin.
    iii. Explore options for extending the Japanese time series of vessel effects into the pre-1979 period.
    iv. Increase understanding of the fisheries that provide the CPUE by a) exploring the size data associated with each fleet, if possible with size data at the vessel set level; and b) exploring vessel movement patterns through time.
    v. Develop standard methods for estimating relative regional weights so as to apportion relative abundance among regions.
    vi. Explore alternative modelling and data transformation methods in order to normalise residuals and to accommodate strata with no zero catches.
    vii. Develop separate indices for each fleet.
    viii. Add subarea-time interactions to the standardization models, to address differences in trends among areas. Explore residual patterns spatially and among clusters, fleets and vessels through time, and change models where necessary to address any problems identified. Develop additional residual and exploratory plots to explore possible confounding effects, such as maps of residuals by season to explore seasonal catchability changes.
    ix. Test alternative methods for identifying and accounting for targeting.

77. The WPTT **NOTED** the excellent progress of previous CPUE workshops towards attaining reliable abundance indices for the stock assessment and Management Strategy Evaluation processes (Fig.3).

78. The WPTT **NOTED** that logbook ID codes were provided for the first time by Japan, which permitted cluster analysis to be carried out for the entire time series.

79. The WPTT **NOTED** that operational data should be collected and analysed wherever possible, and the scope of the studies should be expanded to include other fleets (e.g., Seychelles industrial longline and Indian survey data), and applied to other species of relevance to IOTC Working Parties (e.g., albacore and billfish).

80. The WPTT **ACKNOWLEDGED** that the joint analysis has made good progress toward identifying a unified CPUE series that reduces the number of temporal and spatial gaps in the time series. **NOTING** that it is not very satisfactory to blend multiple conflicting CPUE series within an assessment, the WPTT **DISCUSSED** whether combining data from multiple fleets in the same CPUE analysis resolves this issue or hides the blending in the analysis and **AGREED** that fleet-specific residual patterns require further analysis.

81. The WPTT **NOTED** that the CPUE analysis code can be made publicly available, in the interests of transparency, but that most of the operational data used by the joint-CPUE will remain confidential.

82. The WPTT **NOTED** that high performance cloud computing or related techniques could be used to reduce analytical time constraints in the future, as long as data security concerns could be addressed.

83. The WPTT **NOTED** that these CPUE analyses cannot account for all of the factors that cause catchability changes, as demonstrated by the 1979 Japanese anomaly that does not appear to be explainable by an abundance change. Additionally there were several hundred different analyses, and it may not be appropriate to assume that there is a uniquely preferable series. Accordingly, the WPTT **REQUESTED** advice from the authors about using multiple CPUE series to capture the plausible relative abundance uncertainties for the stock assessment, and particularly for the MSE process.

84. The WPTT **AGREED** that:
    i. More credence should be given to CPUE indices based on operational data, since analyses of these data can take more factors into account, and analysts are better able to check the data for inconsistencies and errors.
    ii. Taiwan,China fleets provide all available logbook data to data analysts, representing the best and most complete information possible. This stems from the fact that the dataset currently used by scientists from Taiwan,China is incomplete and not updated with logbooks that arrive after finalisation.
    iii. That vessel identity information for the Japanese fleets for the period prior to 1979 should be obtained either from the original logbooks or from some other source, to the greatest extent possible to allow estimation of catchability change during this period. During this period there was significant technological change (e.g. deep freezers), targeting changes (e.g. yellowfin tuna to bigeye tuna), and rapid changes in average catch rate.
    iv. Examining operation level data across all longline fleets (Rep. of Korea, Japan and Taiwan,China) will give us a better idea of what is going on with the fishery and stock especially if some datasets have low sample sizes or effort in some years, and others have higher sample sizes and effort, so we have a representative sample covering the broadest areas in the Indian Ocean. This will also avoid having no information in certain strata if a fleet were not operating there, and avoid combining two indices in that case.
    v. That it would useful to explore spatial interaction terms. The author noted that spatial interactions were accounted at the regional level by conducting independent analyses, but that exploring spatial interactions within regions would be desirable in the next iteration.
    vi. That efforts should be made to increase the efficiency, reliability, and transparency of the analysis process.
    vii. That size composition data should be examined in relation to the divergent patterns among Japanese, Taiwanese and Rep. of Korean CPUE, and sharp changes in Japanese CPUE in 1976-79. This may help explain whether there are selectivity changes, catchability changes, and/or changes in age-structure.
    viii. That members should explore options to normalise the joint standardization of catch and effort data from multiple fleets to produce abundance indices for IOTC stock assessments.

85. **NOTING** paragraph 84, the WPTT **RECOMMENDED** continued work on joint analysis of operational catch and effort data from multiple fleets, to further develop methods and to provide indices of abundance for IOTC stock assessments, and **NOTED** that ISSF would be willing to contribute support for future activities, with the aim of normalizing the process of joint analysis of the operational catch and effort data within the IOTC.

86. The WPTT **THANKED** ISSF for their continued support in the development of the joint-CPUE and **ENCOURAGED** the CPCs involved to continue their collaborative efforts in improving the standardized longline CPUE.

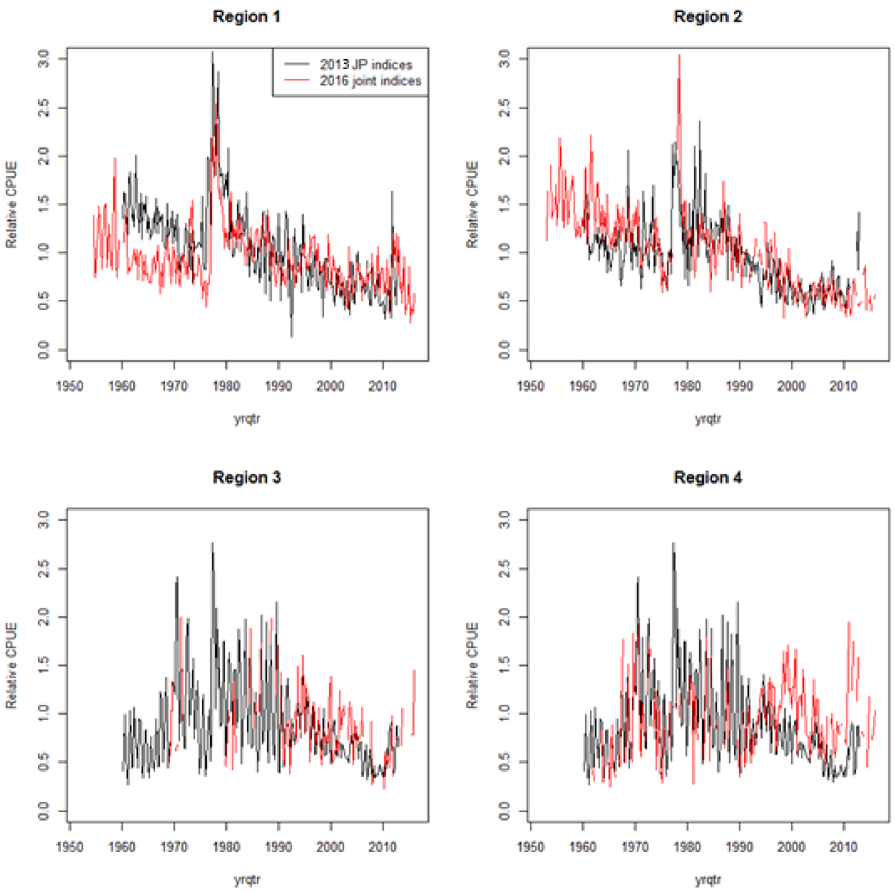


Fig.3. Comparison of the 2016 joint indices described in this paper (red), with the Japanese indices developed in 2013 and used in the 2013 bigeye stock assessment (black).

Bigeye tuna CPUE summary discussion

87. The WPTT **NOTED** the following points in relation to the longline CPUE discussions:
    - The latest bigeye tuna CPUE series were relatively consistent with each other.
    - The collaborative longline CPUE series were given the primary emphasis in the stock assessments.
    - There was concern about a possible substantial change in catchability in the Japanese longline fleet in 1976-79, given the rapid change in bigeye CPUE, large change in HBF, and low Japanese effort in northern tropical areas. Similar changes are seen in other oceans at around the same time.

88. The WPTT **RECOMMENDED** that the multi-nation CPUE standardisation collaboration continue their efforts to improve the understanding of commercial CPUE as relative abundance indices, and expand future work to include other fleets, including the Seychelles longline fleet.

89. The WPTT **NOTED** that of the bigeye tuna CPUE series available for assessment purposes, the collaborative longline CPUE series would be used in the final stock assessment models investigated in 2016, for the reasons discussed above (Tables 2, 3; Fig. 4).

5.3.2 Stock assessments

90. The WPTT **NOTED** that six (6) modelling methods (ASAP, BDM, ASPIC, SCAA, BSPM, and SS3) were applied to the assessment of bigeye tuna in 2016. The different assessments were presented to the WPTT in documents IOTC–2016–WPTT18–15, 16, 17, 18_Rev1, 19, 20. Each model is summarised in the sections below.

91. The WPTT **NOTED** that results from several assessment models were presented, and it was not clear how to synthesize the results of the range of models. Some of the models' analyses were much more detailed than others and used more of the available data. As some of the models were very similar and did not seem to provide significantly new insight from each other, the WPTT **REQUESTED** the WPM to provide guidance on the most appropriate models to use in the future, and how to provide advice when multiple models are presented.

Bigeye tuna: Summary of stock assessment models in 2016

92. The WPTT **NOTED** Table 2, which provides an overview of the key features of each of the stock assessments presented in 2016 for the Indian Ocean-wide assessment of bigeye tuna (**6** model types). Similarly, Table 3 provides a summary of the stock assessment results.

Table 2. Bigeye tuna: Indian Ocean-wide assessments. Summary of final stock assessment model features as applied to the Indian Ocean bigeye tuna resource in 2016.

Model feature	**ASAP (Doc#15)**	**BDM (Doc#16)**	**ASPIC (Doc# 17)**
Software availability	NMFS toolbox	mpb (R-package)	NMFS toolbox
Population spatial structure / areas	1	1	1
Number CPUE Series	4	1	1
Uses Catch-at-length/age	Yes (CAA)	No	No
Uses tagging data	No	No	No
Age-structured	Yes	No	No
Sex-structured	No	No	No
Number of Fleets	7	1	1
Stochastic Recruitment	Yes	No	No

Model feature	**SCAA (Doc#18 Rev1)**	**BSPM (Doc#19)**	**SS3 (Doc# 20)**
Software availability	http://oceaninfo.ddo.jp /kobeaspm/aspm/%20ASPM.zip	Own codes based on R an WinBUGS	NMFS toolbox
Population spatial structure / areas	1	1	4
Number CPUE Series	1	1	4
Uses Catch-at-length/age	Yes	No	No
Uses tagging data	No	No	Yes
Age-structured	Yes	Aggregated	Yes
Sex-structured	No	Aggregated	No
Number of Fleets	7	Aggregated	15
Stochastic Recruitment	Yes	Process error for aggregated biomass (estimated)	Yes

Table 3. Bigeye tuna: Summary of key management quantities from the assessments undertaken in 2016 (See specific working papers for descriptions of the management quantity calculations).

Management quantity	ASAP (Doc#15)	BDM (Doc#16)	ASPIC (Doc# 17)
Most recent catch estimate (t) (2015)*	92,736	92,736	92,736
Mean catch over last 5 years (t) (2011–2015)	101,515	101,515	101,515
h (steepness)	Base=0.8 (0,7,0.9)	n.a.	n.a.
MSY (1,000 t) (80% CI)	82.3 (80.4-84.1)	107.45 (62.87–126.24)	96.7 (55.2–125.7)
Data period (catch)	1979–2015	1979–2015	1950-2015
CPUE series/period	Joint LL CPUE tropical and temperate (R1+R2+R3+R4), annual (1979-2015)	Joint LL CPUE tropical R2, annual (1979-2015)	Region specific joint LL CPUE (R1, R2, R3), annual (1979-2015)
F_{MSY} (80% CI)	0.139 (0.132-0.146)	0.156 (0.049-0.332)	0.077 (0.029-0.161)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	453.4 (432.7-474.1)	708.61 (371.87-1300.45)	1257 (774-1999)
F_{2015}/F_{MSY} (80% CI)	1.118 (1.058-1.177)	0.843 (0.55-1.80)	0.741 (0.488-1.485)
B_{2015}/B_{MSY} (80% CI)	n.a.	1.054 (0.761-1.36)	1.295 (1.111-1.520)
SB_{2015}/SB_{MSY} (80% CI)	1.317 (1.256-1.377)	n.a.	n.a.
B_{2015}/B_{1950} (80% CI)	n.a.	0.397 (0.27-0.52)	0.71 (n.a.)
SB_{2015}/SB_{1950} (80% CI)	n.a.	n.a.	n.a.
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	0.381 (0.377-0.385)	n.a.	n.a.

Management quantity	SCAA (Doc#18 Rev1)	BSPM (Doc#19)	SS3 (Doc# 20)
Most recent catch estimate (t) (2015)*	92,736	92,736	93,040
Mean catch over last 5 years (t) (2011–2015)	101,515	101,515	101,483
h (steepness)	0.7	n.a.	0.7, 0.8, 0.9
MSY (1,000 t) (80% CI)	124 (101–147)	105 (57–148)	104 (87-121)
Data period (catch)	1979-2015	1960-2015	1975-2015
CPUE series/period	Joint CPUE tropical (R1+R2), annual (1979-2015)	Joint CPUE tropical (R1+R2), annual (1960-2015)	1979-2015
F_{MSY} (80% CI)	0.29 (n.a.)	0.091 (0.027-0.199)	0.169 (0.137-0.200)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	692 (n.a.)	113 (58-286)	525 (364-718)
F_{2015}/F_{MSY} (80% CI)	0.79 (0.53-1.13)	1.174 (0.748-2.31)	0.76 (0.489-1.031)
B_{2015}/B_{MSY} (80% CI)	n.a.	0.76 (0.628-0.928)	n.a
SB_{2015}/SB_{MSY} (80% CI)	0.96 (0.84-1.21)	n.a.	1.29 (1.066-1.514)
B_{2015}/B_{1950} (80% CI)	n.a.	0.38 (0.31-0.46)	n.a
SB_{2015}/SB_{1950} (80% CI)	0.43(n.a.–n.a.)**	n.a.	n.a.
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	n.a.	n.a.	0.38 (n.a.-n.a.)

** Note:any minor differences in the most recent catch estimates due to updates in the nominal catches prior to the WPTT meeting.*

n.a. = not available

**** =** SB_{2015}/SB_{1979}

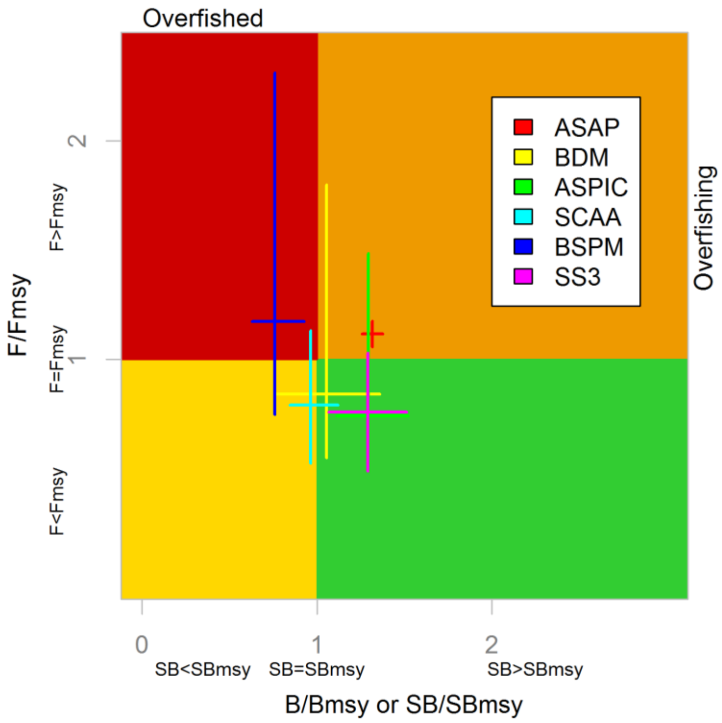


Fig.4. Kobe plot comparing estimates of 2015 stock status for bigeye tuna from the various model options used for the stock assessment of bigeye tuna in 2016. The (80%) confidence intervals associated with the stock status from each model option were determined from the error structure of the model (or set of model runs) from each option.

Age Structured Assessment Program (ASAP) of bigeye tuna

93. The WPTT **NOTED** paper IOTC–2016–WPTT18–15 which provided a stock assessment of bigeye tuna in the Indian Ocean using an Age Structured Assessment Program model (ASAP), including the following abstract provided by the authors:

    "This paper conducted a stock assessment for Indian Ocean bigeye tuna (Thunnus obesus) using Age Structured Assessment Program (ASAP), based on fishery-specific catch and catch-at-age data. The assessment considered that the bigeye tuna stock were subject to 7 fisheries, i.e., Deep longline fishery (LL), Purse seine fishery of free-school (PSFS), Purse seine fishery of associated-school (PSLS), Pole-and-line and small seine fisheries (BB), Fresh longline fishery (FL), Line fishery (LINE), and Other fishery (OTHER). The stock was modelled on yearly basis from 1979 to 2015. The catch-per-unit-effort (CPUE) standardized using joint fishery data from the main longline fleets were used as abundance indices for tuning the model. Key sources of uncertainty were considered to be from steepness (h = 0.7, 0.8, and 0.9 assumed) of Beverton-Holt stock-recruitment relationship, natural mortality (M, high and low levels), and weighting schemes for area-specific abundance indices. Models were run considering combinations of these uncertainties. The assessment results, including MSY and related biological reference points, were sensitive to the assumed values of h and M. In particular, models with low M assumptions resulted in unrealistic estimates of model parameters and were not used for justifying stock status. Overall, the current stock of BET in the Indian Ocean is not overfished, and slight overfishing is occurring at the beginning of 2015. The stock status was more optimistic under the assumptions of higher steepness parameter. The impact of CPUE weighing factors on stock status was neglectable, which is mostly because of the consistent trends of the indices series."

94. The WPTT **NOTED** the key assessment results for the ASAP model as shown below (Tables 4, 5; Fig.5), with refer to the revised version of the model with revised catch-at-age data published by the IOTC Secretariat.

95. The WPTT **NOTED** the following with respect to the ASAP modelling approach presented at the meeting:
    i. The model is heavily driven by age data for each fishery, which are seldom available for the early periods of the fishery. That is why it was preferred to start the model from the late 1970s.
    ii. The data used for this analysis is Catch and Age data made available by the IOTC Secretariat, which presented some unexpected behaviour for some fisheries. The data were subsequently revised when the

results of this assessment had already been provided. However, the data is already available for the scientists in the WPTT.

iii. That the initial depletion at the start of the model was not set, it was estimated by the model.

iv. The scenarios with lower natural mortality lead to unrealistic results. This is contrary to the SS3 results.

v. The constraint selectivity at age 1 may be causing inconsistent selectivity patterns.

Table 4. Key management quantities from the ASAP assessment, for the aggregate Indian Ocean.

Management Quantity	Aggregate Indian Ocean
Most recent catch estimate (t) (2015)	92,736
Mean catch over last 5 years (t) (2011–2015)	101,515
h (steepness)	Base=0.8 (0,7,0.9)
MSY (1,000 t) (80% CI)	82.3 (80.4-84.1)
Data period (catch)	1979–2015
CPUE series/period	1979–2015
F_{MSY} (80% CI)	0.139 (0.132-0.146)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	453.4 (432.7-474.1)
F_{2015}/F_{MSY} (80% CI)	1.118 (1.058-1.177)
B_{2015}/B_{MSY} (80% CI)	n.a.
SB_{2015}/SB_{MSY} (80% CI)	1.317 (1.256-1.377)
B_{2015}/B_{1950} (80% CI)	n.a.
SB_{2015}/SB_{0} (80% CI)	n.a.
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	0.381 (0.377-0.385)

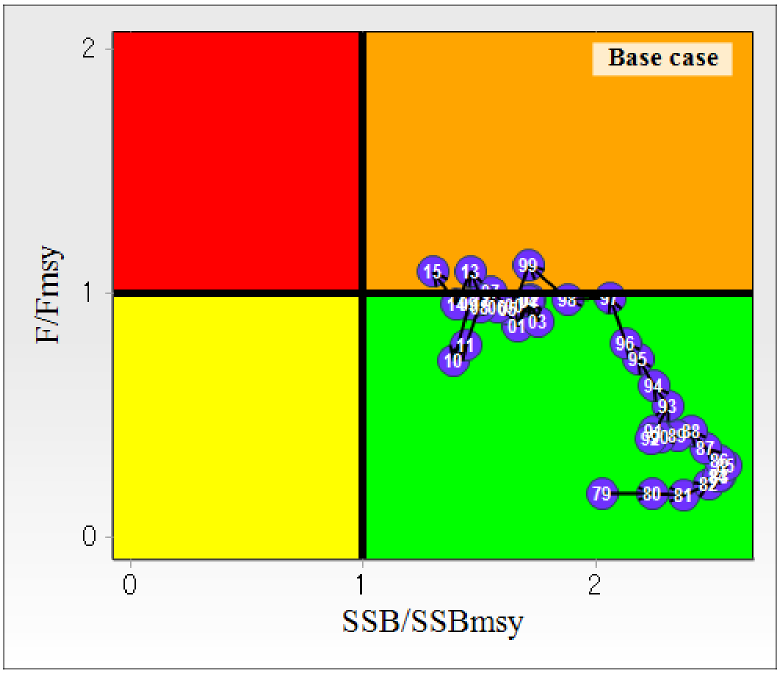


Fig.5. Bigeye tuna: ASAP Indian Ocean assessment Kobe plot (Base case evaluation). Circles indicate the trajectory of the point estimates for the SB/SB_{MSY} ratio and F/F_{MSY} ratio for each year 1979–2015.

Table 5. Bigeye tuna: ASAP aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for nine constant catch projections (average catch level from 2015 (92,736 t), ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**								
	60% (55,642t)	**70% (64,915t)**	**80% (74,189t)**	**90% (83,462t)**	**100% (92,736t)**	**110% (102,010t)**	**120% (111,283t)**	**130% (120,557t)**	**140% (129,830t)**

$SB_{2018} < SB_{MSY}$	0	0	0	0	0	0	0	0	0
$F_{2018} > F_{MSY}$	0	0	11	45	76	93	97	99	100
$SB_{2025} < SB_{MSY}$	0	0	0	1	3	5	8	11	16
$F_{2025} > F_{MSY}$	3	9	20	34	49	63	74	83	89
Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.5\ B_{MSY}$; $F_{Lim} = 1.3\ F_{MSY}$)**								
	60% (55,642t)	**70% (64,915t)**	**80% (74,189t)**	**90% (83,462t)**	**100% (92,736t)**	**110% (102,010t)**	**120% (111,283t)**	**130% (120,557t)**	**140% (129,830t)**
$SB_{2018} < SB_{lim}$	0	0	0	0	0	0	0	0	0
$F_{2018} > F_{lim}$	0	0	0	0	3	19	47	71	87
$SB_{2025} < SB_{lim}$	0	0	0	0	0	0	0	0	1
$F_{2025} > F_{lim}$	0	1	4	9	18	29	42	33	66

Biomass Dynamic Model (BDM) of bigeye tuna

96. The WPTT **NOTED** paper IOTC–2016–WPTT18–16 which provided a stock assessment of bigeye tuna in the Indian Ocean using an Biomass Dynamic Model (BDM), including the following abstract provided by the authors:

"In the 17th session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT), the stock status of bigeye was based on the 2013 stock assessment, which estimated that the stock was in the green area of the Kobe diagram (i.e. not overfished and overfishing was not occurring). On its 20th session (S20), the IOTC Commission requested a stock assessment of this stock. In 2013, the stock status was provided using Stock Synthesis (SS3), an integrated age structured statistical model, and in 2016 it is expected to be assessed again by SS3. In this paper we present a stock assessment for Indian Ocean bigeye using a biomass dynamic model and two modelling scenarios that aim at supporting the work of the WPTT. Overall, using the new information made available by the Secretariat with the two scenarios, we estimate that the stock is not overfished and not undergoing overexploitation with a 61% of probability. However, some differences are found between logistic and skewed production functions. We present a full set of diagnostics for each run, including residuals, retrospective analyses, bootstrapped and jackknife estimates and likelihood profiles, in order to facilitate the selection of modelling choices. Such diagnostics can be applied to a wide variety of models. We also present the results of catch projections and their impact through Kobe 2 Strategy Matrices (K2SM). According to these, catches as high as 130 thousand tons (40% more than in 2015) would allow the stock being above its BMSY with more than 50% probability in 2020 but not further in time. However, with catches of 120 thousand tons, the stock would be at B>BMSY with more than 50% of probability in 2030. If current catches of 92,736 tons are maintained, the probability of the stock being above BMSY would be as high as 70% in 2030. Finally, we show the results of projections with alternative Harvest Control Rules through K2SM and catch matrices."

97. The WPTT **NOTED** the key assessment results for the BDM model as shown below (Table 6; Fig.6).

98. The WPTT **NOTED** the following with respect to the BDM modelling approach presented at the meeting:
    i. Additional models to the Fox model were explored but using a shaped production function (Fox) like the one used for this analysis is often mentioned as more suitable.
    ii. The assumption of using virgin biomass at the start of the time series used (i.e., 1979) may need to be explained and discussed by the group.

Table 6. Bigeye tuna: Key management quantities from the BDM stock assessment, for the Indian Ocean.

Management Quantity	Indian Ocean
Most recent catch estimate (t) (2015)	92,736
Mean catch over last 5 years (t) (2011–2015)	101,515
h (steepness)	n.a.
MSY (1,000 t) (80% CI)	107.45 (62.87–126.24)
Data period (catch)	1979–2015
CPUE series/period	1979–2015
F_{MSY} (80% CI)	0.156 (0.049-0.332)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	708.61 (371.87-1300.45)
F_{2015}/F_{MSY} (80% CI)	0.843 (0.56-1.80)
B_{2015}/B_{MSY} (80% CI)	1.054 (0.76-1.36)
SB_{2015}/SB_{MSY} (80% CI)	n.a.
B_{2015}/B_{1950} (80% CI)	0.397 (0.27-0.52)
SB_{2015}/SB_{1950} (80% CI)	n.a.
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	n.a.

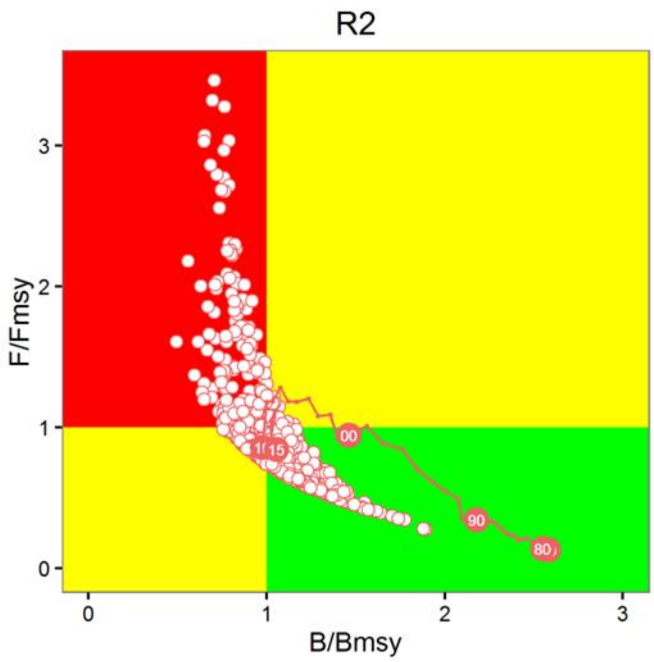


Fig.6. Bigeye tuna: BDM Indian Ocean assessment Kobe plot. Numbered pink dots indicate the trajectory of the point estimates for the B/B_{MSY} and F/F_{MSY} ratios for each year (1979–2015) and white dots indicate the 500 bootstrapped stock status estimates for 2015.

A Stock-Production Model Incorporating Covariates (ASPIC) of bigeye tuna

99. The WPTT **NOTED** paper IOTC–2016–WPTT18–17 which provided a stock assessment of bigeye tuna in the Indian Ocean using A Stock-Production Model Incorporating Covariates (ASPIC), including the following abstract provided by the authors:

"An assessment for the Indian Ocean stock of bigeye tuna was conducted based on ASPIC. A time series of catch (1950-2015) and that of standardized CPUE (Japanese longline or longline 'joint') were used for the analysis with logistic and Fox models. Convergence and reasonable results were obtained for all the scenarios. The scenario with joint CPUE and Fox model was selected as a reference case based on representativeness of CPUE and value of objective function. According to the reference case, the stock status was estimated to be in the green zone of Kobe plot. Kobe II (risk assessments) indicated that the

risk of B and F exceeding MSY level is lower than 50% if future catch is up to 40% and 20% higher than current level, respectively."

100. The WPTT **NOTED** the key assessment results for the ASPIC model as shown below (Tables 7, 8; Fig.7).

101. The WPTT **NOTED** with respect to the ASPIC modelling approach presented at the meeting, that using the complete data series, including the multiplication of a factor of 2 in 1979 in the indices, would lead to an unreal index of biomass dynamics for those years, i.e., that such a short term increase of an adult biomass of BET estimated by the GLM CPUEs is unrealistic, given the adult biomass is the cumulative weight of a large number of cohorts (probably >10 year classes), and then such adult biomass necessarily must show a major short term inertia.

Table 7. Bigeye tuna: Key management quantities from the ASPIC stock assessment, for the Indian Ocean.

Management Quantity	Indian Ocean
Most recent catch estimate (t) (2015)	92,736
Mean catch over last 5 years (t) (2011–2015)	101,515
h (steepness)	n.a.
MSY (1,000 t) (80% CI)	96.7 (55.2–125.7)
Data period (catch)	1950-2015
CPUE series/period	Joint CPUE tropical (R1+R2), annual (1954-2015)
F_{MSY} (80% CI)	0.077 (0.029-0.161)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	1257 (774-1999)
F_{2015}/F_{MSY} (80% CI)	0.741 (0.488-1.485)
B_{2015}/B_{MSY} (80% CI)	1.295 (1.111-1.520)
SB_{2015}/SB_{MSY} (80% CI)	n.a.
B_{2015}/B_{1950} (80% CI)	0.71 (n.a.)
SB_{2015}/SB_{1950} (80% CI)	n.a.
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	n.a.

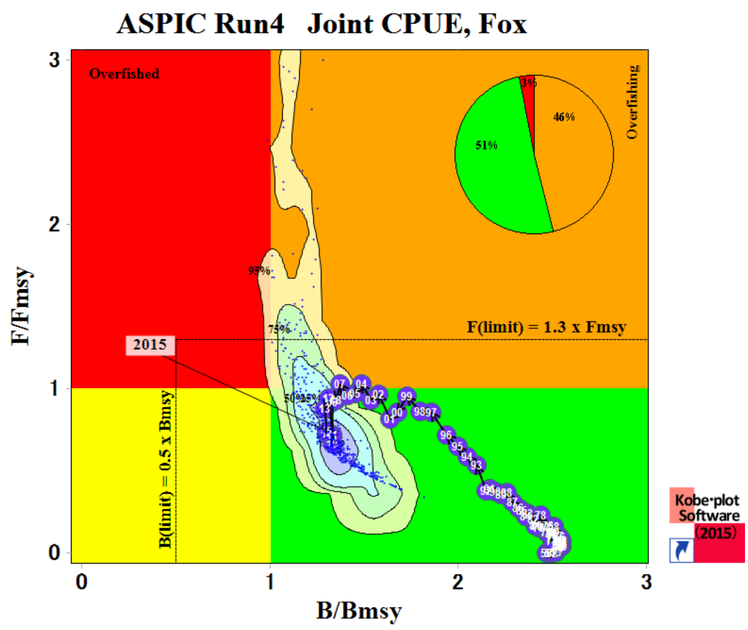


Fig.7. Bigeye tuna: ASPIC Aggregated Indian Ocean assessment Kobe plot. Blue dots indicate the trajectory of the point estimates for the B/B_{MSY} ratio and F/F_{MSY} ratio for each year 1950–2015. The shaded areas represent the 25%, 50%, 75% and 95% confidence intervals associated with the 2015 stock status. The black lines are the IOTC interim reference points.

Table 8. Bigeye tuna: ASPIC aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for nine constant catch projections (average catch level from 2015 (92,736 t), ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**								
	60% (55,642t)	**70% (64,915t)**	**80% (74,189t)**	**90% (83,462t)**	**100% (92,736t)**	**110% (102,010t)**	**120% (111,283t)**	**130% (120,557t)**	**140% (129,830t)**
$B_{2018} < B_{MSY}$	18	18	19	20	20	20	21	21	22
$F_{2018} > F_{MSY}$	0	0	2	7	17	25	39	51	66
$B_{2025} < B_{MSY}$	3	5	6	10	16	21	27	36	47
$F_{2025} > F_{MSY}$	0	0	0	2	11	28	53	73	86
Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.5\ B_{MSY}$; $F_{Lim} = 1.3\ F_{MSY}$)**								
	60% (55,642t)	**70% (64,915t)**	**80% (74,189t)**	**90% (83,462t)**	**100% (92,736t)**	**110% (102,010t)**	**120% (111,283t)**	**130% (120,557t)**	**140% (129,830t)**
$B_{2018} < B_{Lim}$	0	0	0	0	0	0	0	0	0
$F_{2018} > F_{Lim}$	0	0	0	0	2	5	11	19	26
$B_{2025} < B_{Lim}$	0	0	0	0	0	0	0	0	0
$F_{2025} > F_{Lim}$	0	0	0	0	0	3	14	31	52

Statistical-Catch-At-Age (SCAA) of bigeye tuna

102. The WPTT **NOTED** paper IOTC–2016–WPTT18–18 which provided a stock assessment of bigeye tuna in the Indian Ocean using Statistical Catch At Age (SCAA), including the following abstract provided by the authors:

> *"We attempted stock assessments for the Indian Ocean bigeye tuna by SCAA (Statistical–Catch-At-Age) considering the possible regime shift before and after 1978/79. The reason why we considered the regime shift is that trends of standardized CPUE before and after 1978/79 are highly heterogeneous. In this connection, we examined three periods in SCAA runs, i.e., (a) All period (1954-2015), (b) New regime (I) (1978-2015) and (c) (II) (1979-2015). We made different runs (27, 81 and 81 scenarios respectively) by varying plausible values of h (steepness), B0/K and Sigma R (SR relations). It was suggested that SCAA by all period (a), did not provide the realistic results, while SCAA by two new regimes (b) and (c), plausible although they provided different stock statuses. Then using all converged runs in (b) and (c) (total 54 scenarios) and considering relevant uncertainties, we selected the median point as the representative (selected) result of the SCAA stock assessment, i.e., the 55th run in (c) new regime hypothesis starting 1979. The representative run suggests that the 2015 status stock is in the yellow zone of the Kobe plot (not overfishing but overfished), i.e., F2015/Fmsy=0.82 and SSB2015/SSBmsy=0.95. In this study we also explored to evaluate slicing and probability based CAA (Catch-At-Age)."*

103. The WPTT **NOTED** the key assessment results for the SCAA model as shown below (Table 9; Fig.8).

104. The WPTT **NOTED** with respect to the SCAA modelling approach presented at the meeting that changes to the number of hooks from around the late-1970s may explain a sudden increase in the CPUE in 1978, but there seems to be also a notable change in the number of hooks in the mid-1990s, but sudden CPUE changes are not observed.

105. The WPTT further **NOTED** that the changes observed for BET have also been observed out of the Indian Ocean for other species, in various periods

Table 9. Bigeye tuna: Key management quantities from the SCAA stock assessment, for the Indian Ocean.

Management Quantity	**Indian Ocean**
Most recent catch estimate (t) (2015)	92,736
Mean catch over last 5 years (t) (2011–2015)	101,515
h (steepness)	0.7

MSY (1,000 t) (80% CI)	124 (101–147)
Data period (catch)	1979-2015
CPUE series/period	Joint CPUE tropical (R1+R2), annual (1979-2015)
F_{MSY} (80% CI)	0.29 (n.a.)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	692 (n.a.)
F_{2015}/F_{MSY} (80% CI)	0.79 (0.53-1.13)
B_{2015}/B_{MSY} (80% CI)	n.a.
SB_{2015}/SB_{MSY} (80% CI)	0.96 (0.84-1.21)
B_{2015}/B_{1950} (80% CI)	n.a.
SB_{2015}/SB_{1979} (80% CI)	0.43 (n.a.–n.a.)
$SB_{2015}/SB_{current, F=0}$ (80% CI)	n.a.

n.a.=not available

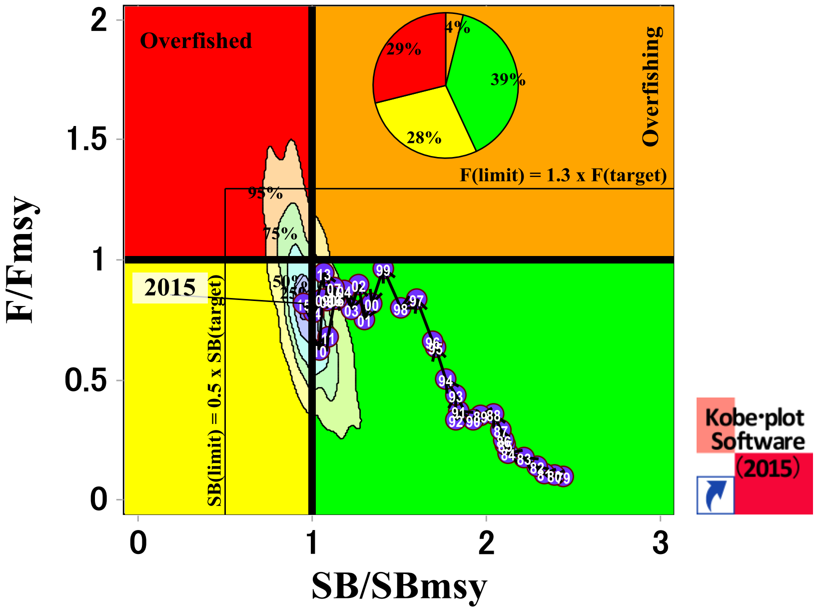


Fig.8. Bigeye tuna: SCAA Aggregated Indian Ocean assessment Kobe plot. Blue dots indicate the trajectory of the point estimates for the SB/SB_{MSY} ratio and F/F_{MSY} ratio for each year 1950–2015. Confidence intervals (25%, 50%, 75%, and 95%) are also shown in relation to the 2015 stock status. The black lines are the IOTC interim reference points.

Bayesian State-Space Production model (BSPM) of bigeye tuna

106. The WPTT **NOTED** paper IOTC–2016–WPTT18–19 which provided results of the Bayesian state-space production models (BSPM) for the Indian Ocean bigeye tuna and their predictive evaluation, including the following abstract provided by the authors, including the following abstract provided by the authors:

"In stock assessment, it is not straightforward to choose a plausible range of models objectively from several models if different data set are used because it is not possible to use model selection criteria like AIC in these situations. However, as shown in Kell et al. (2016), where a hindcasting approach was proposed, predictive evaluation via cross-validation would be a possible procedure under those circumstances. Here, as an attempt using data for bigeye tuna, we applied a model selection method with predictive evaluation of biomass index to Bayesian state-space production models although the data used is common to the model in this case. Using a selected model, we also assessed the population status of the stock. Non-informative priors were used and posterior samples were generated using a Markov chains Monte Carlo (MCMC) method. The results suggested that F-ratio (2015) is higher than the MSY level (1.17) and B-ratio is lower than 1 (0.76). Given that this analysis has a preliminary nature as stock assessment, the paper may not be so useful for management advice, but this approach could give an opportunity to help in choosing models in future assessment."

107. The WPTT **NOTED** that the model selected as base case included a dynamic catchability coefficient with two periods of q (i.e., q1 (1960-1978) and q2 (1979-2015)).

108. The WPTT **NOTED** that process error estimated in this analysis could explain part of the jump of CPUE observed in 1978-1979. However, additional analysis is required in order to confirm this.

109. The WPTT **NOTED** that the results of the BSPM are aimed at producing feedback from the WPTT, rather than management advice, and that the BSPM is intended to bridge the gap between the two surplus production models (ASPIC and SCAA, that do not consider changes in catchability) and the SS3 age structured models (IOTC-2016-WPTT18-17, 18, and 20) in order to explore the reasons for the change in the CPUE indices around 1979. For this reason no management quantities, Kobe plot and Kobe strategy plot have been included in the report.

Stock Synthesis III (SS3) of bigeye tuna

110. The WPTT **NOTED** paper IOTC–2016–WPTT18–20 which provided a stock assessment of bigeye tuna in the Indian Ocean for 2012 using SS3, including the following abstract provided by the authors:

> *"A stock assessment of Indian Ocean bigeye tuna was conducted using a statistical age structured population model implemented in Stock Synthesis. The assessment was based on previous assessments of bigeye tuna conducted in 2010 and 2013. The model was configured with a four region spatial structure, 15 region specific fisheries and a quarterly time step for the 1975-2015 model period. The model assumed equilibrium conditions in 1975 and estimated initial fishery exploitation rates. The model data sets included fishery catches, region specific longline CPUE indices from the composite logsheet data, fishery length composition data, and tag release/recovery data. A wide range of model runs were conducted to investigate the structural assumptions of the model and the influence of the various input data sets. The modelling identified considerable conflict among the main input data sets, especially between the longline CPUE indices from the two equatorial regions, between the tag recoveries and the longline CPUE indices, and between the tag recoveries and the length composition data from the purse seine FAD fishery (the main tag recovery fishery). The magnitude of overall stock abundance was particularly sensitive to the treatment of the tagging data set; a greater emphasis of these data resulted in lower estimates of overall stock size. The final model options selected for management advice included two options for the weighting of the tagging data (tag lambda 1.0 and 0.1) with three alternative levels of steepness for the spawner-recruit relationship (0.7, 0.8, 0.9) representing a total of six model options."*

111. The WPTT **NOTED** the key assessment results for the Stock Synthesis III model (SS3) as shown below (Tables 10, 11; Fig.9).

Table 10. Bigeye tuna: Key management quantities from the SS3 assessment, for the Indian Ocean. Values represent the average Maximum Posterior Density from the six model options and the confidence interval was derived from the covariance matrices from the six model options.

Management Quantity	**Aggregate Indian Ocean**
Most recent catch estimate (t) (2015)	93,040
Mean catch over last 5 years (t) (2011–2015)	101,483
h (steepness)	0.7, 0.8, 0.9
MSY (1,000 t) (80% CI)	104 (87-121)
Data period (catch)	1975-2015
CPUE series/period	1979-2015
F_{MSY} (80% CI)	0.169 (0.137-0.200)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	525 (364-718)
F_{2015}/F_{MSY} (80% CI)	0.76 (0.489-1.031)
B_{2015}/B_{MSY} (80% CI)	n.a.
SB_{2015}/SB_{MSY} (80% CI)	1.29 (1.066-1.514)
B_{2015}/B_{1950} (80% CI)	n.a.
SB_{2015}/SB_{1950} (80% CI)	0.38 (n.a.-n.a.)
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	n.a.

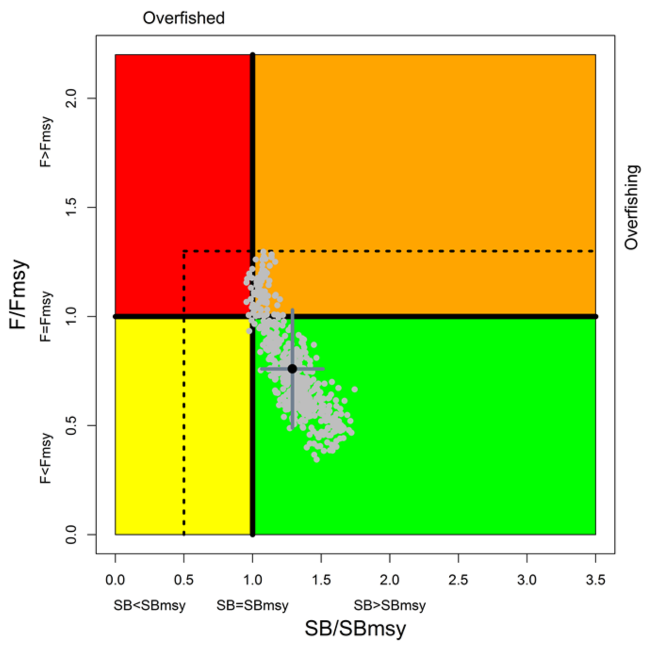


Fig.9. Bigeye tuna: SS3 Aggregated Indian Ocean assessment Kobe plot. Dotted black lines are the interim limit reference points adopted by the Commission via Resolution 15/10. The grey points represent 500 estimates of 2015 stock status from the six model options. The black point represents the average of the six model options with associated 80% confidence interval.

Table 11. Bigeye tuna: Stock Synthesis base case Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (average catch level from 2015 (93,040t), ± 20%, + 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and weighted probability (%) scenarios that violate reference point**			
	80% (74,432t)	**100%** (93,040t)	**120%** (111,648t)	**140%** (130,256t)
$B_{2018} < B_{MSY}$	11	20	30	40
$F_{2018} > F_{MSY}$	2	19	40	61
$B_{2025} < B_{MSY}$	6	25	49	60
$F_{2025} > F_{MSY}$	1	19	42	53
Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.5\ B_{MSY}$; $F_{Lim} = 1.3\ F_{MSY}$)**			
	80% (74,432t)	**100%** (93,040t)	**120%** (111,648t)	**140%** (130,256t)
$B_{2018} < B_{LIM}$	0	0	0	0
$F_{2018} > F_{LIM}$	0	4	18	37
$B_{2025} < B_{LIM}$	0	1	12	33
$F_{2025} > F_{LIM}$	0	9	30	48

112. The WPTT **CONGRATULATED** the consultant for their comprehensive work, **NOTING** that a large number of sensitivities were conducted to investigate key structural assumptions. A number of these model sensitivities to characterise the main sources of uncertainty were conducted relative to the base model, including:
   i. SRR steepness at 0.7 and 0.9 (base case is 0.8)
   ii. Sensitivity to weighting of tagging data.
   iii. Natural mortality (higher value)
   iv. New maturity ogive

113. The WPTT **NOTED** the following with respect to the input information for the SS3 modelling approach presented at the meeting:
   i. Tag recoveries were assigned to individual fisheries. For a proportion of the purse seine tag recoveries there were insufficient data to distinguish between recoveries from FAD and free school sets and some assumptions were required to assign tags to the respective fisheries.
   ii. Some of the Indian Ocean bigeye catch was taken outside the spatial domain of the model regions. This component of the catch was reassigned to adjacent model regions.
   iii. The need to provide documentation to describe the various IOTC datasets and the processes used to prepare the data in order to improve the results and outcomes of the stock assessment.
   iv. Size data from most fisheries were down weighted in the assessment model. The longline length frequency informs the model regarding the selectivity of the longline fisheries, although these data are assigned a very low weight in the log-likelihood. Length frequency data from the Taiwanese longline fishery from 1997-2015 in particular are considered unreliable and were not included in the model data sets. Length frequency data from all other fisheries were given a very low weight in the model likelihood, with the exception of the purse seine FAD length composition data.
   v. The reason for the smoothed size distribution shown for FL2 is because it was estimated from raw data using a length key.
   vi. To model the tagging data effectively requires a fine-scale spatial model, which is not possible within a stock assessment model like SS3. It was suggested that it would be better to model the tagging data outside the stock assessment, and to introduce the parameter estimates into the assessment as prior distributions or penalties. This may allow greater utilisation of the tagging data set, including the shorter-term tag recoveries.
   vii. The model structure commences in 1975 and incorporates CPUE from 1979-2015. The CPUE indices from the preceding period were not included in the final model options, as there was an apparent shift in the CPUE indices in the late 1970s that appears to correspond to a change in the degree of targeting of bigeye tuna. Prior to 1978 shows very low numbers of hooks between floats (HBF) targeting other species; while from the late-1970s onwards increased targeting of bigeye tuna coincided with the shift in CPUE.
   viii. The assignment of age to the tag releases (based on fish length) and the subsequent age at recapture (PS-FS/PS-LS) fits very well with the established growth curve used for the stock assessment. There are considerably more long term tag recoveries now available and the WPTT **AGREED** to update the estimation of the growth curve incorporating the new recoveries.
   ix. That size data from the fresh LL fisheries could be included with other LL fleets if they are similar, so that the complexity of the model would be reduced.
   x. The main indices of stock abundance are the region specific composite longline CPUE indices. The tagging data provides abundance information for the limited tag recovery period and these data also influence the estimates of the overall magnitude stock (SB_0). The relative weighting of the tagging data in the total likelihood was influential in the estimation of stock size; higher weighting of the tagging data resulted in lower estimates of stock size. The estimates of stock size are likely to be biased due to violation of the tag mixing assumptions.

114. The WPTT **NOTED** the following with respect to the biological parameters and structure of the SS3 modelling approach presented at the meeting:
   i. The model options table available can help elucidating the implications for management of the different modelling alternatives explored with SS3.
   ii. Exploring the impact of higher variability of catchability can strengthen the results presented.
   iii. The issues of such a complex model as SS3 cannot be solved only by weighting, and that the model will not be completely consistent with the current use of tag information.
   iv. That the overall tendencies of all the models presented will have to be used to give management advice. However, some issues will have to be solved in the future.
   v. Tagging data informs the model on growth and natural mortality, externally of the model estimation process.
   vi. The estimates of the proportion of recruitment in each region was sensitive to the treatment (weighting) of the tagging data.
   vii. The base model options estimated age-specific selectivity parameters primarily to be aligned with the age structure of tag release/recovery data set and the fishery length composition data. Model options that investigated length based selectivity did not yield substantively different results from the base model.

115. The WPTT **NOTED** the following with respect to the results produced with the SS3 modelling approach presented at the meeting, following discussion of the preliminary results and subsequent sensitivity trials conducted at the meeting:
   i. The model results contained the reference case (lambda=1.0) and a series of sensitivities to cover uncertainties on selectivity, maturity, natural mortality and weighting of tagging information.
   ii. The estimated MSY is correlated to the level of steepness used in the model.
   iii. Model scenarios assuming a higher level of natural mortality yielded more optimistic estimates of stock status.
   iv. Reducing the relative weighting of the tagging data resulted in a more optimistic stock status. In both cases of tag weighting the stock is on average in the green zone of the Kobe plot.
   v. The potential benefit of a juvenile fish abundance index, e.g. the potential to derive CPUE indices from the PS-LS fishery catch and effort data.
   vi. None of the scenarios presented satisfy all the data series requirements to accept a reference case for management advice. However, none of the models yield significantly conflicting results.
   vii. That it would be good to have the results of stock status in relation to BRPs to help the decision making.
   viii. The current structure of the SS3 model used to assess bigeye tuna presents a multidimensional problem as tagging data spatial structure (mixing) seems to be incompatible with the spatial structure of the stock assessment. The WPTT **NOTED** that in the future, it may be needed to change the spatial structure of the stock assessment and adopt a more detailed spatial structure.
   ix. That the CPUE decreases more than 10% of the B0/Binitial between 1950 and 1978, and this may challenge the assumption of B at the initial period of the simulation at 0.92 of pristine levels.
   x. There may be an overall scaling problem in the assessment. Generally, this information is obtained from tag data or size data.

116. The WPTT **NOTED** the results of a new set of runs requested with SS3, which included:
   i. A range of model options with different weightings associated with the tagging data.
   ii. A model option that commenced in 1950 and partitioned the longline CPUE indices into two time periods (1953-1975 and 1979-2015) with different catchability coefficients estimated for each time period. The model estimated a recruitment deviates for the entire time period. Recruitment was estimated to be lower during the earlier period compared to the latter period. The WPTT was concerned that the change in the level of recruitment between the two periods may be due to model miss-specification rather than a regime shift. On that basis, the model scenario that commenced in 1950 was not used for the provision of management advice.

117. The WPTT **AGREED** on the runs including information starting in 1975. With regards to projections, the WPTT **NOTED** the benefit of showing the probabilistic results of the projections relative to BMSY and to the depletion level.

118. The WPTT **AGREED** to produce stock status estimations and the projections for the management advice with a grid of six scenarios, which include three levels of steepness (0.7, 0.8 and 0.9) and two weightings of tag information. The projections were conducted using deterministic recruitment and constant catch.

Parameters for future analyses: Bigeye tuna CPUE standardisation and stock assessments

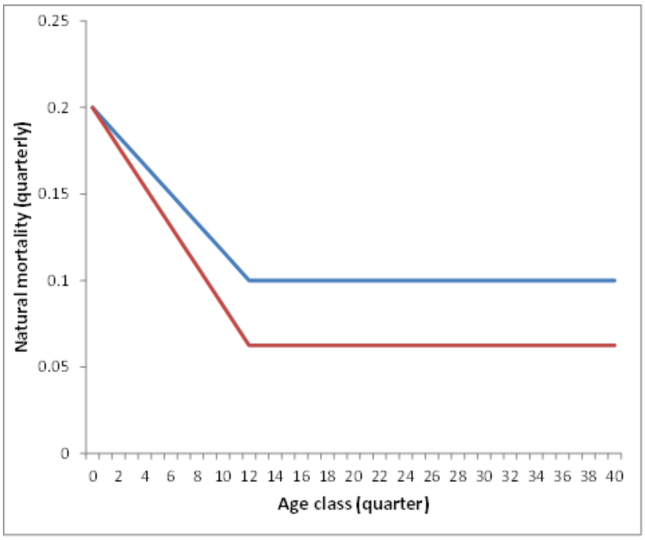
119. The WPTT **RECALLED** that in order to obtain comparable CPUE standardisations, the analyses should be conducted with similar parameters and resolutions when the stock is next assessed. The improved methods recommended by the CPUE workshop should also be applied. Table 12 provides a set of parameters that shall give guidelines for the standardisation of CPUE.

Table 12. Bigeye tuna: Parameters for the future standardisation of CPUE series.

CPUE standardisation parameters	2016 CPUE standardisations for consistency
Area	By region, 4 regions
CE Resolution	Operational data
Data preparation	Cluster analysis or related approaches to select data or add cluster parameters
GLM Factors	Year-Quarter, 5 degree cells, HBF or cluster, vessel
Model	Delta lognormal, lognormal + constant
	Proposed updates to standardisation methods
Area	By region, 5 regions
CE Resolution	As above
Data preparation	As above
Factors	As above, plus sub-area * time interaction
Model	As above
Other possible changes	Transform response variable

120. The WPTT **RECALLED** that the model parameters contained in Table 13 could be considered appropriate for future bigeye tuna stock assessments preliminary base case analysis, with appropriate sensitivity runs.

Table 13. Bigeye tuna: Model parameters for use in future base case and sensitivity stock assessment runs.

Biological parameters	Value for assessments
Sex ratio	1:1
Age (longevity)	10 years
Natural mortality	Age specific, quarterly M. 2 alternative M options (base low, sensitivity high). 
Growth formula	VB log K 2-stanza growth (Eveson et al. 2012 IOTC–2012–WPTT14–23) or appropriate re-analysis based on more recent data
Weight-length allometry	$W=aL^b$ with $a= 3.661^{-05}$ and $b=2.901$ common to sex
Maturity	Length-specific (50% mature at length 110 cm) – or age-based equivalent[3].

[3] Updated ogive taken from Zudaire, et al., 'Sex-ratio, size at maturity, spawning period and fecundity of bigeye tuna (Thunnus obesus) in the western Indian Ocean', IOTC–2016–WPTT18–37.

Fecundity	Proportional to the spawning biomass
Stock-recruitment	B&H, h=0.8 (plus sensitivity e.g. 0.7 and 0.9), sigma_R=0.6
Other parameters	
Spatial structure	As in previous assessment, or harmonize with yellowfin tuna spatial structure if possible (4 model regions, similar to YFT tuna)
Fisheries	15 (Longline (6); Baitboat (pole-and-line); Purse seine free school (3); Purse seine log school (3); Other (2))
Abundance indices	Composite longline indices, region-specific.
Selectivity	Age based, fishery specific

5.3.3 Selection of Stock Status indicators for bigeye tuna

121. The WPTT **AGREED** that the average of six model scenarios from the SS3 stock assessment would be used for development of management advice for the Scientific Committee's consideration. The other models (ASAP, ASPIC, BDM, BSPM, and SCAA) were discussed as supporting evidence.

5.4 Development of management advice on the status of bigeye tuna & update of the bigeye tuna Executive Summary for the consideration of the Scientific Committee

122. The WPTT **ADOPTED** the management advice developed for bigeye tuna (*Thunnus obesus*), as provided in the draft resource stock status summary and **REQUESTED** that the IOTC Secretariat update the draft stock status summary for bigeye tuna with the latest 2015 catch data (if necessary), and for the summary to be provided to the SC as part of the draft Executive Summary, for its consideration:
    i. Bigeye tuna (*Thunnus obesus*) – Appendix VI

5.5 Bigeye tuna Management Strategy Evaluation process update

123. The WPTT **NOTED** paper IOTC–2016–WPTT18–32, which provided an update on the tropical tunas management strategy evaluation development framework. A summary of this document and discussion is presented in Agenda item 8 below.

6. Skipjack Tuna – Review of New Information on Stock Status

6.1 Review of the statistical data available for skipjack tuna

124. The WPTT **NOTED** paper IOTC–2016–WPTT18–07 which summarised the standing of a range of data and statistics received by the IOTC Secretariat for skipjack tuna, in accordance with IOTC Resolution 15/02 *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPC's)*, for the period 1950–2015. The paper also provided a range of fishery indicators, including catch and effort trends, for fisheries catching skipjack tuna in the IOTC area of competence. It covers data on nominal catches, catch-and-effort, size-frequency and other data, in particular release and recapture (tagging) data. A summary of the supporting information for the WPTT is provided in Appendix IVc.

125. The WPTT **NOTED** that the EU is in the process of recalculating the estimated weight of catches of skipjack tuna, from around the early 2000s onwards, based on revisions to the length-weight conversion factors (used to estimate the total weight of catches by species), which will impact estimates of the species composition reported from EU-PS samples – with a possible increase in overall skipjack tuna catches and associated reduction in bigeye and yellowfin tuna as a consequence.

126. **NOTING** the decline in skipjack tuna catches reported by the Maldives pole-and-line fleet since the mid-2000s, the WPTT **RECALLED** that it had requested the Maldives, in collaboration with the IOTC Secretariat, assess the extent to which the changes in catches of skipjack tuna are related to the improvements in the data collection and introduction of logbooks, as compared to changes in the fishery (e.g. a shift from pole-and-line targeting skipjack tuna to handlines targeting yellowfin tuna).

6.2 Review new information on the biology, ecology, stock structure, their fisheries and associated environmental data for skipjack tuna

Temporal and operational effects on the catch rates of Skipjack Tuna in gillnet fishery of Sri Lanka

127. The WPTT **NOTED** IOTC–2016–WPTT18–30 was presented, describing a preliminary attempt to standardize Sri Lankan gillnet CPUE for use as a relative abundance index. The following summary was provided by the author, and included the following abstract by the authors:

"The aim of the present study is to examine the relative influence of temporal and operational factors to change the catch rates of skipjack tuna (Katsuwonus pelamis) in the gillnet fishery of Sri Lanka. Skipjack tuna is the key target species in the gillnet fishery. Gillnets are sometimes operated as a gear combination and the most popular gear combination is gillnet–longline combination. Apart from that, gillnet-handline and gillnet-ringnet are other frequently used gear combinations in Sri Lankan tuna fishery. Skipjack tuna landed by Sri Lankan fishing vessels were monitored during the period January 2005 – December 2012 at the major tuna landing sites and fishery harbours in Sri Lanka. Five types of vessels which are operated targeting tuna and tuna-like fish, catch skipjack tuna. At the field, the unloaded skipjack tuna catch of the vessels was recorded. In addition, the parameters related to fishing operations were recorded: boat type, used gear/ gear combination, number of days taken for completion of the fishing trip and number of net panels used per fishing operation. Two temporal variables used for this study are "year" and "month". A monthly series of skipjack tuna CPUE (Catch Per Boat Per Trip) was derived from the catch data. A Gamma based Generalized Linear Model (GLM) was fitted to determine the relationship between the explanatory variables and monthly average CPUE. All zero-catch rates of skipjack tuna were excluded for the analysis. All main effects and their first order interactions were taken into the account. The fitted GLM model explains 85.8% of the deviance and the vessel type was found to be the most significant factor for determining the catch rates of skipjack tuna. Among the first order interactions, year : month was found to be the key explanatory variable."

128. The WPTT **ACKNOWLEDGED** the value of this paper as it represents the first CPUE standardisation from Sri Lanka, and also for gillnet fisheries, and **ENCOURAGED** Sri Lanka to continue to refine and improve the CPUE standardisation with a view to incorporating the CPUE series in future IOTC stock assessments, ideally using detailed logbook data available since 2014.

129. The WPTT **NOTED** that the Sri Lankan gillnet fishery vessels tend to operate multiple gear types (e.g. gillnet-longline vessels), and that the aggregated catch data reported prior to 2014 cannot be attributed accurately to gear-type.

130. The WPTT **NOTED** the relatively low percentage of bigeye tuna in the Sri Lankan gillnet fishery compared with catches from purse seine fleets operating in a similar area, although it remains unclear whether this is due to species misidentification of bigeye tuna, or is an accurate representation of the catch.

Preferred feeding habitats of skipjack tuna common to the eastern central Atlantic and western Indian Oceans

131. The WPTT **NOTED** paper IOTC–2016–WPTT18–31 that provided an overview of the preferred feeding habitat of skipjack tuna and relations with carrying capacity and vulnerability to purse seine fishing, and included the following abstract by the authors:

"A single Ecological Niche model was developed for skipjack tuna (Katsuwonus pelamis) in the eastern central Atlantic Ocean (AO) and western Indian Ocean (IO) using an extensive set of precise spatial occurrence data from the European purse seine fleet during 1998-2014. Productive fronts of chlorophyll-a were used as proxy for food availability while mixed layer depth, sea surface temperature, oxygen concentration, salinity, current velocity and sea surface height anomaly were selected to define skipjack physical oceanographic preferences. The common environmental feeding niche identified for skipjack emphasized highly contrasted oceanographic regimes between oceans with seasonal occurrence of gyre-type productive features at mesoscale in the IO and large scale upwelling systems that seasonally shrink and swell in the AO." – see paper for full abstract.

132. The WPTT **NOTED** the advancement made on this topic, which was introduced at WPTT17 and **ENCOURAGED** the continuation of the work. A number of elements were **NOTED** including the use of Atlantic and Indian Ocean information to define the habitat preference for skipjack available to purse seiners, which likely improve the robustness of the analysis, and that it would be of interest to compare outcomes from other ecosystem models, such as APECOSM, to further evaluate robustness of the outcomes since this model has been applied to the Indian Ocean skipjack.

133. The WPTT also **NOTED** that chlorophyll-a is used as an index of skipjack feeding habitat, which may better account for time and spatial lags in the analysis.

Review of new information on the status of skipjack tuna

6.2.1 Nominal and standardised CPUE indices

Fishery indicators suggest symptoms of overfishing for the Indian Ocean skipjack stock

134. The WPTT **NOTED** paper IOTC–2016–WPTT18–INF02 that provided an overview of parameters of skipjack tuna fisheries, mostly in relation to purse seiners.

135. The WPTT **CONSIDERED** the concerns raised by the paper about the status of skipjack stocks based upon the indicators presented by the author, and that excess capacity compounded by accelerated FAD usage could exacerbate the status of the skipjack stock, features that will undoubtedly be considered in the next stock assessment.

136. The WPTT **NOTED** that some of the indicators highlighted could be indicative of stock decline or, on the other hand, might indicate lower average school size and/or spatial redistribution of biomass (e.g., due to school fragmentation due to increased use of FADs in the Indian Ocean indicating the trade-off between the optimal number of FADs and catch rate of FADs). This feature could be examined using observer data examining the frequency of FAD visits for which no fishing was conducted due to low skipjack abundance at the FAD.

137. The WPTT **NOTED** that indicators such as average size be standardized to account for within year factors that are independent of abundance and that future stock assessments could significantly benefit if alternative abundance indexing methods, such as through FAD echo-sounder data, could be further developed.

138. The WPTT **NOTED** that as skipjack tuna was not the priority species at WPTT18, no other papers were submitted for this agenda item in 2016.

Parameters for future analyses: Skipjack tuna CPUE standardisation and stock assessments

139. The WPTT **RECALLED** its previous agreement that in order to obtain comparable CPUE standardisations, the analyses shall be conducted with similar parameters and resolutions. Table 14 provides a set of parameters, discussed during the WPTT18 that shall give guidelines, if available, for the standardisation of CPUE, to be used as indices of abundance for the next scheduled stock assessment of skipjack tuna.

Table 14. Skipjack tuna: A set of parameters for the standardisation of CPUE series in preparation for the next WPTT meeting.

CPUE standardisation parameters	Value for next CPUE standardisation
Area	*To be defined (possible eastern and western Indian Ocean.* Explore core area(s)
CE Resolution	Operational data
Factors	Year, Quarter, Area, vessel characteristics, environmental + interactions, number of FADs and species composition
Model	Negative binomial, zero-inflated or delta-lognormal models

140. The WPTT **RECALLED** that the model parameters contained in Table 15 could be considered appropriate for future skipjack tuna stock assessments preliminary base case analysis, with appropriate sensitivity runs.

Table 15. Skipjack tuna: Model parameters agreed to by the WPTT for use in future base case stock assessment runs.

Biological parameters	Value for assessments
Stock structure	1 and 2 areas
Sex ratio	1:1
Age (longevity)	7+ years
Natural mortality	M=0.8 (/year) constant over ages (or estimated within the model to be 1.48 age 0-1,1.13 age 1-2, 1.13 age 2-3, 0.83 for 3-4 and older)
Growth formula	VB log K 2-stanza growth (Eveson et al. 2015) *
Weight-length allometry	$W=aL^b$ with $a= 5.32*10^{-6}$ and $b=3.34958$ common to sex **
Maturity	Length-specific (50% mature at length 38 cm, fully mature at 44 cm)
Fecundity	Proportional to the spawning biomass
Stock-recruitment	B&H, h=0.8 (plus sensitivity e.g. 0.7 and 0.9), sigma_R=0.6
Other parameters	
Fisheries	4 (Maldives PL, Purse Seine FS, Purse Seine LS, Other)
Abundance indices	PSFS/PSLS combined, Maldives PL
Selectivity	Fishery specific. Cubic splines

* Eveson J P, Million J, Sardenne F & Le Croizier G (2015) Estimating growth of tropical tunas in the Indian Ocean using tag-recapture data and otolith-based age estimates. Fisheries Research: Indian Ocean Tuna Tagging Programme special issue.

** Updates to the weight-length allometry proposed in IOTC-2014-WPDCS10-INF02[4], to be formally presented for adoption at the IOTC WPDCS12 (2016).

6.2.2 Stock assessments

141. The WPTT **NOTED** that as skipjack tuna was not the priority species at WPTT18, no papers were submitted for this agenda item in 2016.

6.2.3 Selection of Stock Status indicators for skipjack tuna

142. The WPTT **AGREED** that the advice on the status of skipjack tuna in 2016 is derived from the most recent assessment, conducted in 2014, using an integrated statistical assessment method. In 2014, 81 model formulations were investigated to ensure that various plausible sources of uncertainty were incorporated and represented in the final result. In general, the data did not seem to be sufficiently informative to justify the selection of any individual model, and the results are shown as a grid and the median value of the grid. The grid based approach covered the uncertainty in the assessment which is large.

6.3 Development of management advice for skipjack tuna

143. The WPTT **ADOPTED** the management advice developed for skipjack tuna as provided in the draft resource stock status summary.

6.4 Executive Summary for the consideration of the Scientific Committee

144. The WPTT **REQUESTED** that the IOTC Secretariat update the draft stock status summary for skipjack tuna with the latest 2015 catch data (if necessary), and for the summary to be provided to the SC as part of the draft Executive Summary, for its consideration:
    i. Skipjack tuna (*Katsuwonus pelamis*) – Appendix VII.

6.5 Update of the skipjack tuna Skipjack tuna Management Strategy Evaluation process update

145. The WPTT **NOTED** as indicated in IOTC-2016-WPTT18-05, that the Commission adopted Resolution 16/02 *On harvest control rules for skipjack tuna in the IOTC Area of Competence*, which was informed by the MSE process undertaken and endorsed by SC18.

[4] Available at: http://www.iotc.org/documents/long-term-monitoring-biology-tropical-tunas-through-routine-sampling-cannery-victoria

7. YELLOWFIN TUNA – REVIEW OF NEW INFORMATION ON STOCK STATUS

7.1 Review of the statistical data available for yellowfin tuna

146. The WPTT **NOTED** paper IOTC–2016–WPTT18–07 which summarised the standing of a range of data and statistics received by the IOTC Secretariat for yellowfin tuna, in accordance with IOTC Resolution 15/02 *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPC's)*, for the period 1950–2015. The paper also provided a range of fishery indicators, including catch and effort trends, for fisheries catching yellowfin tuna in the IOTC area of competence. It covers data on nominal catches, catch-and-effort, size-frequency and other data, in particular release and recapture (tagging) data. A summary of the supporting information for the WPTT is provided in Appendix IVd.

147. The WPTT **NOTED** that catches for Yemen were updated by the IOTC Secretariat in 2016, using FAO estimates, and **REQUESTED** that the IOTC Secretariat provide the WPTT further clarification of the FAO estimates, particularly in relation to catches of yellowfin tuna (of which Yemen currently accounts for around 7% of total catches).

148. The WPTT **NOTED** that total catches of yellowfin tuna published by the IOTC Secretariat were revised downwards for 2014 by around 22,000 t (around 5% of total catches of yellowfin tuna in 2014), mostly due to the double counting of catches of Mayotte in the IOTC database, however it was **ACKOWLEDGED** that the subsequent revision to 2014 catches had minimal impact on the results of the updated yellowfin tuna assessment presented in 7.3.2 below.

149. The WPTT **RECALLED** that according to the information within the IOTC database, some longline fleets, in particular the Taiwan,China longline fleet, have resumed fishing in the western central tropical area since January 2012, although longline fishing effort in the area remains significantly below the levels before the onset of piracy (i.e. compared to the early-mid 2000s). However, longline vessels flagged to Japan continue to be largely absent from the area since July 2009 due to on-going concerns with security in the sub-region.

150. The WPTT further **RECALLED** that catch-and-effort and size data for yellowfin tuna (and for other tropical tuna species) is either unavailable or is not reported to IOTC standards for many coastal fisheries which account for over half of total tropical tuna catches in recent years, including gillnet and fresh-tuna longline fleets operating on the high seas, and **STRONGLY ENCOURAGED** coastal fleets to improve their data collection and reporting systems required to meet the mandatory reporting obligations of IOTC Resolution 15/02.

7.2 Review new information on the biology, ecology, stock structure, their fisheries and associated environmental data for yellowfin tuna

Length Distribution of Yellowfin Tuna from the Maldives Pole-and-line and Handline Tuna Fisheries

151. The WPTT **NOTED** paper IOTC–2016–WPTT18–21 which provided a summary of the length distribution of yellowfin tuna fisheries in the Maldives pole-and-line and handline fisheries, including the following abstract provided by the author:

> *"Maldives tuna fishery used to be predominantly comprised of pole-and-line and troll gear to exploit skipjack tuna (Katsuwonus pelamis) and similarly sized yellowfin tuna (Thunnus albacares) and neritic species of frigate (Auxis thazard) and kawakawa (Euthynnus affinis). With increased private sector access to overseas markets in the Far East and Europe, Maldives tuna fishermen began targeting adult sized yellowfin tuna using handline gear beginning the late 1990s. Prior to this, only small seasonal handline fisheries and a foreign licensed longline fleet operating within the EEZ exploited sub-adult and adult sized fish respectively. Recent years' catch data showed a 47% and 44% increase in YFT catch from all gears and handline respectively. Length data collected by Marine Research Centre demonstrate that approximately 80% of the pol-and-line caught yellowfin tuna are between 38 and 62 cm FL. On the other hand, as much as 80% of the handline caught yellowfin tuna fall between 102 and 162 cm FL. Market preference for fish above 18 kg (about 105 cm FL) encourages handline yellowfin tuna fishermen to target larger individuals. The separate size classes from both the PL and HL fishery allows traceability of catch from both fisheries."* – see paper for full abstract.

152. The WPTT **NOTED** that the Maldives handline fishers exploit surface swimming free schools or dolphin associated schools using live bait to attract the fish and are not usually allowed to fish on anchored FADs.

Assessment of yellowfin tuna caught by artisanal fishers in Kenya between 2013 and 2016

153. The WPTT **NOTED** paper IOTC–2016–WPTT18–22 which provided a summary of catches of yellowfin tuna from Kenya's Catch Assessment Survey, including the following abstract provided by the author:

"*Yellowfin tuna (Thunnus albacares), is one of the target pelagic species by artisanal fishers in Kenya. The main tuna fishing season in Kenya is between October and February. From the 2013 to 2016 season, the routine catches of yellowfin tuna were recorded at various landing sites along the Kenyan coastline. This paper looks at the lengths frequency and CPUE of yellowfin tuna caught by artisanal fishers between January 2014 and December 2015. The main fishing area recorded for the yellowfin tuna catches was in the Watamu banks where the catches of yellowfin tuna were highest. A total of 59 fishing trips were monitored for length frequency where catches ranging between 40 and 477 kgs per boat per day. The weight was recorded to the nearest 0.5 kgs while lengths were recorded at nearest 0.5cm.The average CPUE per boat was 138.8 Kgs. On average, there were five fishers per boat. The average size in length was 78.5 cm and weighed 7.5 kgs. The main fishing season in 2014 was between September and December while the peak season in 2015 was between July and October. The main gears used by fishers while targeting Yellowfin tuna were trolling lines and handlines.*"

154. The WPTT **NOTED** that Kenya is in the process of implementing a new data collection system based on a Catch Assessment Survey, which is producing some differences in the total catch between the two systems and **REQUESTED** the IOTC Secretariat provide assistance in reconciling the discrepancies between the two data collection systems.

155. The WPTT **NOTED** the differences in the size of yellowfin tunas caught between the artisanal and recreation fisheries, and that sizes of the yellowfin tunas from recreational fisheries are generally larger due to catches originating from deep waters, as compared to artisanal fisheries which are from the coastline.

The relationships between muscle fat content and biological parameters in Thunnus albacares in the high seas of the Indian Ocean

156. The WPTT **NOTED** paper IOTC–2016–WPTT18–23 which offers a description of the relationships between muscle fat content and biological parameters from the West-Central Indian Ocean, including the following abstract provided by the author:

"*The relationships between muscle fat content fluctuation and biological parameters of the yellowfin tuna (Thunnus albacares) were studied to better understand its characteristics of growth, reproduction and the fishing ground. The biological data and muscle fat content of 91 yellowfin tuna were collected from the longline fishery in waters of 6°33'N～10°33'S, 44°54'E ～88°0' E, Western Central Indian Ocean from October, 2013 to April, 2014. Histogram count figures were made to show the spatial or temporal distribution of fat content and fat content by gender, dressed weight, and gonad maturity. A generalized additive model (GAM) was used to analyze the relationships between fat content and condition factor (K), somatic index (SI), gonadosomatic index (GSI) and fork length (FL). Results showed that: (1) the fat content of yellowfin tuna was in the range of 0.1~26.7 %, and the average was 6.94 %; (2) the fat content of yellowfin tuna was low from October to December, 2013, increasing after December, 2013. The fat content of the area in 2°N～3°N，59°E～60°E was the highest (15.3%) and that of the area in 7°S～8°S，44°E～45°E was the lowest (1.2%), there was significant differences among them; (3) there were no significant differences among the fat content by gender, gonad weight, gonad maturity stages or fork length; (4) By GAM, the results showed that there were no significant correlations between fat content and K, SI, GSI or FL. Results of this study suggest that: (1) the yellowfin tuna begin to reproduce in March and April; (2) the area of 2°N～3°N，59°E～60°E might be an important spawning ground; (3) there was no significant correlation between female reproductive capability and muscle fat content.*"

7.3 Review of new information on the stats of yellowfin tuna

7.3.1 Nominal and standardised CPUE indices

Standardization of topical tuna purse seine CPUE for yellowfin tuna

157. The WPTT **NOTED** paper IOTC–2016–WPTT18–24 which provided an update on efforts to standardize purse seine CPUE for yellowfin tuna caught by the EU (French and Spanish) purse seine fleet, including the following abstract provided by the author:

"*We revised the existing framework for tuna CPUE standardisation in light of the increasing literature that advocates the use of mixed effects models to account for the characteristics of logbook data. We* *apply the framework on yellowfin tuna (YFT) from the Indian Ocean, caught by the purse seine EU fleet (Spain and France) from 1984 to 2015. We used a comprehensive list of candidate covariates, including nonconventional covariates, and run exploratory models to assess the contribution of each covariate. Due to the large number of covariates, the lasso – least absolute shrinkage and selection operator- method was applied for data mining and model selection purposes. The results are two standardised YFT CPUE time series for the period 1984-2015, one for large fish caught in free-school related sets, and one for mainly juveniles caught in floating object related sets. Issues on the usefulness of highly aggregated data (low resolution: annual and fleet wide) is discussed along with the need for more detailed information on the use of dFADs, preferably at the level of a fishing trip.*"

158. The WPTT **NOTED** that the authors could also employ the analysis used by ICCAT to quantify the relative change in efficiency between log-school and free-school sets by taking the ratio of CPUE from the two series.

159. The WPTT **NOTED** that GAMs could be used in an exploratory analysis to identify potential variables and mechanisms that might affect catchability, and that the exploratory process should be documented.

160. The WPTT **NOTED** that use of the binomial component of the delta-lognormal model for PS fisheries is questionable, as a fishing set will only be made if fish have been detected. A zero catch will indicate a setting problem rather than an absence of fish.

Japan longline – Catch-per-unit-of-effort (CPUE)

161. The WPTT **NOTED** paper IOTC–2016–WPTT18–25 which presented an updated Japanese longline CPUE for yellowfin tuna in the Indian Ocean standardised by GLM, including the following abstract provided by the author:

"*Japanese longline CPUE for yellowfin tuna in the Indian Ocean (area aggregated and area-specific) was standardized up to 2015 by GLM. Basically, standardized CPUEs showed similar trends among areas. CPUE continuously decreased from early 1960s to 1974, and kept in the same level until 1990. Thereafter, it declined to historical low level in recent years. The stable trend in recent years at all models indicates decreased effort caused by piracy activity in area 2 (northwest) has little effect on overall CPUE trends. Applying 5 degree latitude/longitude effect showed large effect on the CPUE trend for Area 3 (southwest) and 4 (south). There was some difference of area aggregated CPUE between the model with subarea and with 1 or 5 degree latitude/longitude, and the effect of number of hooks between floats was more realistic for the model with 1 or 5 degrees latitude/longitude.*"

162. The WPTT **WELCOMED** the updated catch rate standardisation for the Japan fleet in the Indian Ocean for yellowfin tuna (Fig. 10) and **ENCOURAGED** the authors to continue their analyses as part of the multi-nation collaborative effort to improve CPUE standardisations.

163. The WPTT **NOTED** that the changing spatial distribution of Japanese LL effort has the potential to bias CPUE indices. The inclusion of fixed spatial effects (1x1 or 5x5 latitude-longitude grids) attempts to account for this problem by assuming that the relative tuna density among blocks remains constant over time, such that an observation from any grid is informative about abundance for the whole region. Limitations of this approach include the variable density of tuna within model grids, limited observations with which to estimate some strata, and time-area interactions (including seasonality) which were not estimated and cannot be estimated from missing strata.

164. The WPTT **DISCUSSED** whether the decline in Japanese effort might bias the CPUE standardization through the attrition of less efficient vessels. It was expected that the inclusion of fixed vessel effects would account for much of this effect.

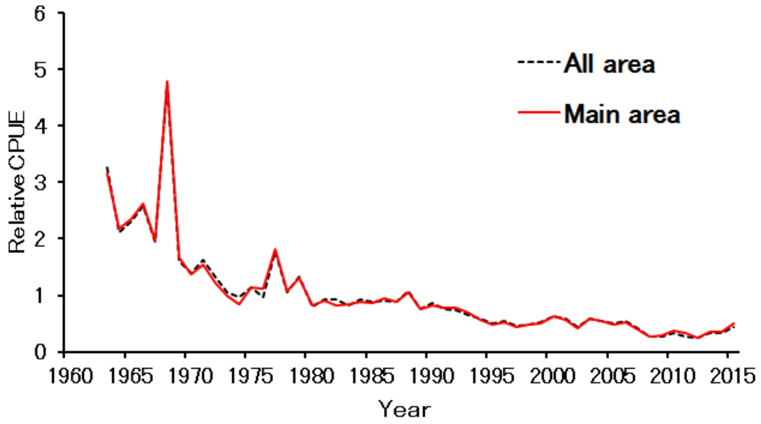


Fig.10. Yellowfin tuna: Comparison of the standardised longline CPUE series for Japan. Series have been rescaled relative to their respective means from 1963-2015.

Yellowfin tuna CPUE Summary discussion

165. The WPTT **RECOMMENDED** that efforts to develop abundance indicators using PS data should be continued. Given the difficulty of defining effort in PS fisheries, and the importance of obtaining an abundance index for skipjack, alternative methods such as those based on ratio methods and standardized species composition should also be considered.

166. The WPTT **REITERATED** that the multi-nation CPUE standardisation collaboration continue their efforts to improve the understanding of commercial CPUE as relative abundance indices, and expand future work to include other fleets.

167. The WPTT **NOTED** that of the yellowfin tuna CPUE series available for assessment purposes, the collaborative longline CPUE series would be used in the final stock assessment models investigated in 2016, for the reasons discussed above (Figs. 11 & 12).

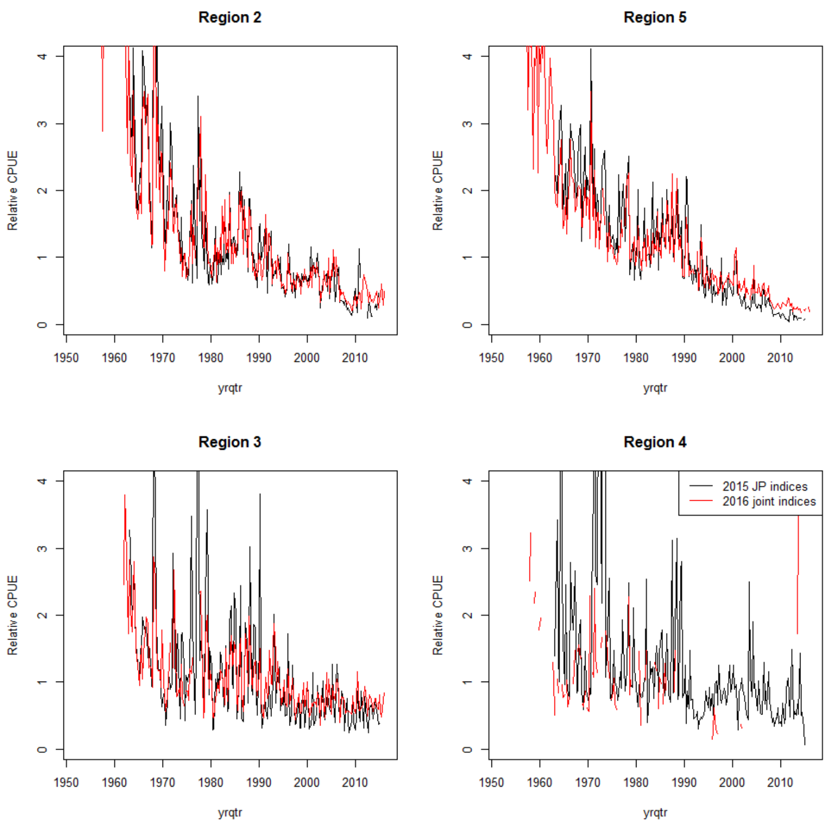


Fig.11: Comparison of the 2016 joint indices described in this paper (red) with the Japanese indices developed in 2015 and used in the 2015 yellowfin stock assessment (black).

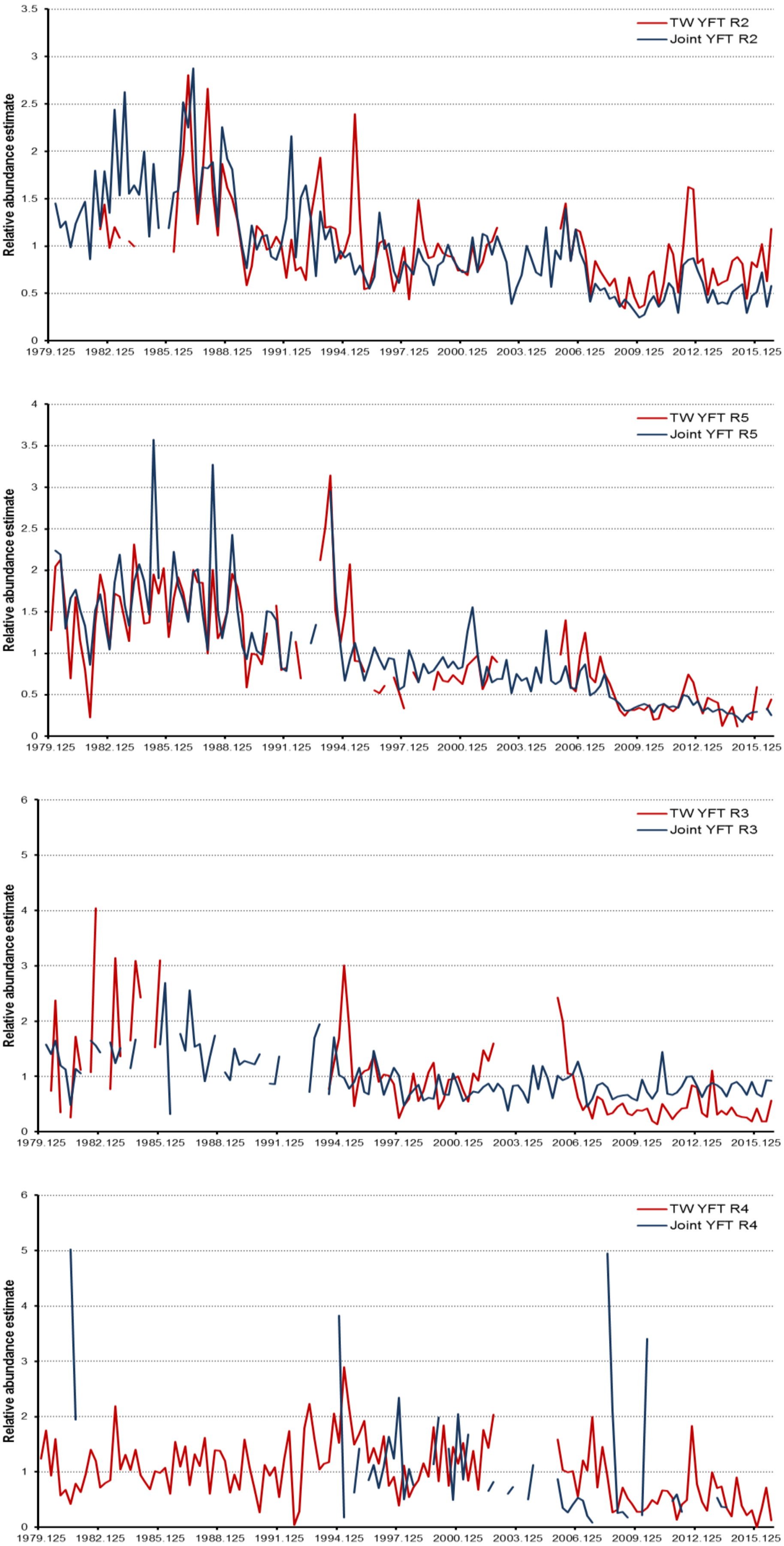


Fig.12. Comparisons of Taiwan,China yellowfin tuna CPUE time series (red) with those estimated during the 2016 collaborative project (blue) by region.

7.3.2 Stock assessments

168. The WPTT **NOTED** that two (2) modelling methods (BDM and SS3) were applied to the assessment of yellowfin tuna in 2016. The different assessments were presented to the WPTT in documents IOTC–2016–WPTT18–26 and 27. Each model is summarised in the sections below.

Yellowfin tuna: Summary of stock assessment models in 2016

169. The WPTT **NOTED** Table 16, which provide an overview of the key features of each of the stock assessments presented in 2016 for the Indian Ocean-wide assessments (2 model types). Similarly, Table 17 provide a summary of the assessment results.

Table 16. Yellowfin tuna: Indian Ocean-wide assessments. Summary of final stock assessment model features as applied to the Indian Ocean yellowfin tuna resource in 2016.

Model feature	**BDM (Doc#26)**	**SS3 (Doc# 27)**
Software availability	mpb (R-package)	NMFS toolbox
Population spatial structure / areas	1	4
Number CPUE Series	1	4
Uses Catch-at-length/age	No	Integrates LF data
Uses tagging data	No	Yes
Age-structured	No	Yes
Sex-structured	No	No
Number of Fleets	1	21
Stochastic Recruitment	No	Yes

Table 17. Yellowfin tuna: Summary of key management quantities from the assessments undertaken in 2016 (See specific working papers for descriptions of the management quantity calculations).

Management quantity	**BDM (Doc#26)**	**SS3 (Doc#27)**
Most recent catch estimate (t) (2015)	407,575	407,575
Mean catch over last 5 years (t) (2011–2015)	390,185	390,185
h (steepness)	n.a.	0.8
MSY (1,000 t) (80% CI)	338 (188–480)	422 (406-444)
Data period (catch)	1972–2015	1950–2015
CPUE series/period	Joint LL CPUE 1972–2015 (R5)	Region specific, Joint LL CPUE, quarterly, 1972–2015
F_{MSY} (80% CI)	0.26 (0.055-0.422)	0.151 (0.148-0.154)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	1,401 (877-3,310)	947 (900-983)
F_{2015}/F_{MSY} (80% CI)	1.416 (0.495-3.289)	1.11 (0.859-1.361)
B_{2015}/B_{MSY} (80% CI)	0.914 (0.539-1.721)	n.a.
SB_{2015}/SB_{MSY} (80% CI)	n.a.	0.89 (0.790-0.990)
B_{2015}/B_{1950} (80% CI)	0.316 (0.166-0.624)	n.a.
SB_{2015}/SB_{1950} (80% CI)	n.a.	0.289 (n.a.-n.a.)
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	n.a.	n.a.

n.a. = not available

Biomass Dynamic Model (BDM) assessment of yellowfin tuna

170. The WPTT **NOTED** paper IOTC–2015–WPTT17–26 which provided a stock assessment of yellowfin tuna in the Indian Ocean by using Bayesian Dynamic Model (BDM), including the following abstract provided by the authors:

"In the 17th session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT), the stock status of yellowfin was estimated to be in the red area of the Kobe diagram with 94% probability. As a consequence, on its 20th session (S20), the IOTC Commission adopted an interim plan for rebuilding this stock (Res 16/01) introducing a scheme for a reduction of catches and requested its Scientific Committee (SC) via the WPTT to conduct a new assessment of the status of yellowfin in 2016, using all available information. In 2015, the stock status was provided using Stock Synthesis (SS3), an integrated age structured statistical model, and in 2016 it is expected to be assessed again by SS3. In this paper we present a stock assessment for Indian Ocean yellowfin using a biomass dynamic model and four modelling scenarios that aim at supporting the work of the WPTT. Overall, using the new information made available by the Secretariat with the four scenarios, we estimate that the stock is overfished and undergoing overexploitation with a 50% of probability, notably in a better condition than in the estimation from 2015 WPTT. However, significant differences are found between logistic and skewed production functions and with the inclusion/exclusion of data prior to 1970. We present a full set of diagnostics for each run, including residuals, retrospective analyses, bootstrapped and jackknife estimates and likelihood profiles, in order to facilitate the selection of modelling choices. Such diagnostics can be applied to a wide variety of models. We also present the results of catch projections and their impact through Kobe 2 Strategy Matrices (K2SM). According to these, catches would need to be below 330,000 tons (19% less than in 2015) so that the stock is at levels equal or above BMSY with 50% of probability in 2020. Finally, we show the results of projections with alternative Harvest Control Rules through K2SM and catch matrices."

171. The WPTT **NOTED** the key assessment results for the BDM model as shown below (Table 18, ; Fig.13).

Table 18. Yellowfin tuna: Key management quantities from the BDM stock assessment, for the Indian Ocean.

Management Quantity	**Indian Ocean**
Most recent catch estimate (t) (2015)	407,575
Mean catch over last 5 years (t) (2011–2015)	390,185
h (steepness)	n.a.
MSY (1,000 t) (80% CI)	338 (188–480)
Data period (catch)	1972–2015
CPUE series/period	Joint LL CPUE 1972–2015 (R5)
F_{MSY} (80% CI)	0.26 (0.055-0.422)
SB_{MSY} or *B_{MSY} (1,000 t) (80% CI)	1,401 (877-3,310)
F_{2015}/F_{MSY} (80% CI)	1.416 (0.495-3.289)
B_{2015}/B_{MSY} (80% CI)	0.914 (0.539-1.721)
SB_{2015}/SB_{MSY} (80% CI)	n.a.
B_{2015}/B_{1972} (80% CI)	0.316 (0.166-0.624)
SB_{2015}/SB_{1972} (80% CI)	n.a.
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	n.a

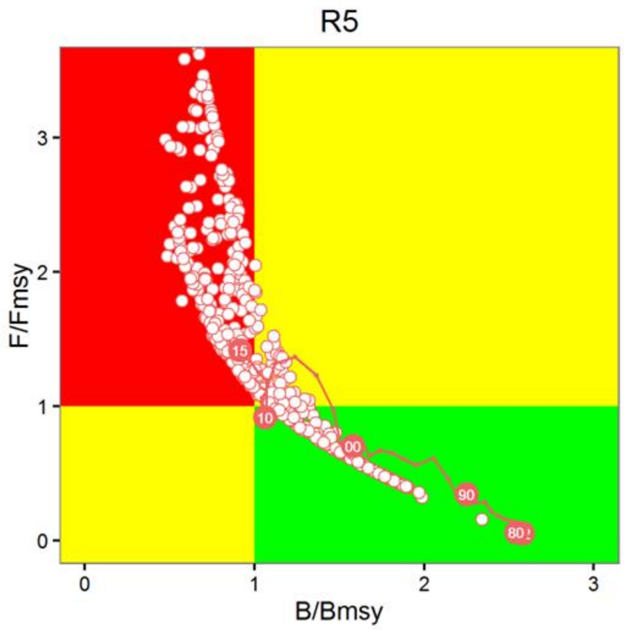


Fig.13. Yellowfin tuna: BDM Aggregated Indian Ocean assessment Kobe plot. Red dots indicate the trajectory of the point estimates for the B/B_{MSY} ratio and F/F_{MSY} ratio for each year 1972–2015. White dots indicate 500 bootstraped estimates of stock status in 2015.

172. The WPTT **NOTED** with respect to the BDM modelling approach: that the scenarios tested included regional indices fitted separately and in combination, and that indices from one region should not be used to characterize a complete stock. Therefore, the WPTT **NOTED** that using the combined index made available by the Secretariat would have been more appropriate instead of the three scenarios of single abundance indices run in isolation or combined.

173. The WPTT **NOTED** that the model results presented would only be useful for data exploration.

Stock Synthesis III (SS3) assessment of yellowfin tuna

174. The WPTT **NOTED** paper IOTC–2016–WPTT18–27 which provided an update to the stock assessment of yellowfin tuna in the Indian Ocean using Stock Synthesis III, including the following abstract provided by the author:

“*A stock assessment of Indian Ocean yellowfin tuna was conducted in 2015 using Stock Synthesis. Following the direction of the Commission (SC20 Resolution 16/01), the stock assessment was updated for 2016. The 2016 assessment used the base case model from WPTT17 and incorporated the revised and updated yellowfin catches, extending the model period to include 2015. The primary indices of stock abundance in the model are the region specific longline CPUE indices. For 2016, the model utilized the new composite longline CPUE indices derived from the logsheet data from the three main distant water longline fleets, replacing the Japanese longline CPUE indices used in the previous assessment. The inclusion of the composite CPUE indices resulted in a somewhat more optimistic estimate of current stock status, primarily due to the lower decline in the CPUE indices from the eastern equatorial region. A number of additional model runs were conducted to investigate the sensitivity of the model results to the treatment of the tag release/recovery data. These results highlighted a need for a more thorough analysis of the tag release/recovery data to determine the most appropriate treatment of these data in the next yellowfin tuna stock assessment.*”

175. The WPTT **NOTED** the key assessment results for the Stock Synthesis III model (SS3) as shown below (Tables 19, 20; Fig.14).

Table 19. Yellowfin tuna: Key management quantities from the SS3 assessment, for the Indian Ocean. Values represent the Maximum Posterior Density from the base case and the confidence interval empirically derived from the covariance matrix.

Management Quantity	Indian Ocean
Most recent catch estimate (t) (2015)	407,574
Mean catch over last 5 years (t) (2011–2015)	390,188
h (steepness)	0.8
MSY (1,000 t) (80% CI)	422 (406-444)
Data period (catch)	1950–2015
CPUE series/period	1972–2015
F_{MSY} (80% CI)	0.151 (0.148-0.154)
SB_{MSY} or $*B_{MSY}$ (1,000 t) (80% CI)	947 (900-983)
F_{2015}/F_{MSY} (80% CI)	1.11 (0.859-1.361)
B_{2015}/B_{MSY} (80% CI)	n.a.
SB_{2015}/SB_{MSY} (80% CI)	0.89 (0.790-0.990)
B_{2015}/B_{1950} (80% CI)	n.a.
SB_{2015}/SB_{1950} (80% CI)	0.289 (n.a.-n.a.)
$SB_{2015}/SB_{current,\ F=0}$ (80% CI)	n.a.

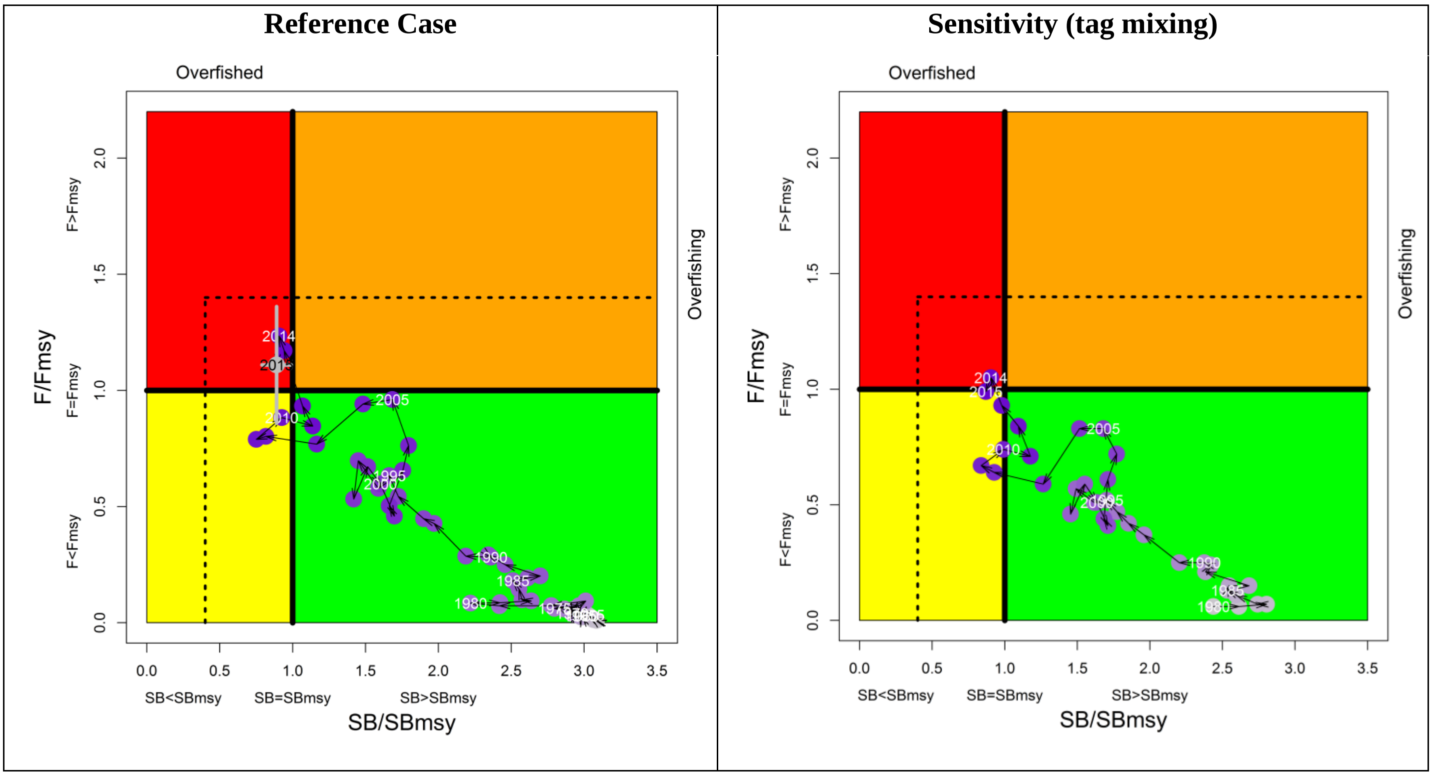


Fig.14. Yellowfin tuna: **Left**) SS3 Indian Ocean assessment Kobe plot reference case. **Right)** SS3 Indian Ocean assessment Kobe plot sensitivity case (tag mixing, 3 quarters in the base case vs. 8 in the sensitivity)). Blue dots indicate the trajectory of the mode of the posterior distribution estimates for the SB/SB_0 ratio and F proxy ratio for each year 1950–2015 for the base model (left panel). Dotted black lines refer to the interim limit reference points adopted by the Commission via Resolution 15/10. The grey line represents the 80% confidence interval associated with the 2015 stock status.

Table 20. Yellowfin tuna: Stock synthesis assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (relative to the catch level from 2015 (407,574t) -30%, - 25%, ± 20%, -15%,± 10%, -5%), projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**								
	70% (285,302t)	75% (305,680t)	80% (326,059t)	85% (346,438t)	90% (366,816t)	95% (387,195t)	100% (407,574t)	110% (448,331t)	120% (489,089t)
$B_{2018} < B_{MSY}$	53	61	67	77	80	88	88	97	99
$F_{2018} > F_{MSY}$	2	7	23	47	65	73	100	100	100
$B_{2025} < B_{MSY}$	6	n.a.	20	37	60	100	100	100	100
$F_{2025} > F_{MSY}$	0	n.a.	10	40	57	100	100	100	100
Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.4\ B_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	70% (285,302t)	75% (305,680t)	80% (326,059t)	85% (346,438t)	90% (366,816t)	95% (387,195t)	100% (407,574t)	110% (448,331t)	120% (489,089t)
$B_{2018} < B_{Lim}$	2	1	2	4	6	6	12	21	38
$F_{2018} > F_{Lim}$	0	0	1	10	32	52	100	100	100
$B_{2025} < B_{Lim}$	0	n.a.	1	7	30	>30*	>30*	>30*	>30*
$F_{2025} > F_{Lim}$	0	n.a.	0	11	53	>30*	>30*	>30*	>30*

** At least one fishery not able to take the catch due to absence of vulnerable fish during the project period. The probability levels are not well determined, but likely progressively exceed 30% as the catch level increases beyond 90%.*

176. The WPTT **NOTED** an updated SS3 modelling approach from 2015 stock assessment specifications with additional data sets which include:
    i. Fishery catches from 2015.
    ii. Revised purse seine catches from 2014.
    iii. Composite LL CPUE indices for Regions 1-4[5] (Hoyle, et al 2016).
    iv. CPUE indices for free school (1984-2015) and FAD (2004-2014) from Katara et al (2016).
177. The WPTT **NOTED** that CPUE indices for the PS fishery were available and were included in a number of model trials. However, the WPTT did not consider these indices to represent stock abundance alone and consequently did not include these indices in the final model options.
178. The WPTT **NOTED** the impact of each one of the changes made to the 2015 stock assessment model specification and that the most influential factor is the use of the joint LL CPUE indices, which would lead a stock status estimation of overexploited stock and stock undergoing overexploitation – but at relatively lower levels in *F* than estimated for 2014 (-17%), and with higher biomass levels of +35%.
179. The WPTT **NOTED** a series of sensitivity runs made to the updated base case:
    i. CPUE indices for free school (1984-2015) and FAD (2004-2014), from Katara et al (2016).
    ii. Down weighting of tagging information
    iii. Increasing the tagging mixing period to 8 quarters.
180. The WPTT **NOTED** that more time is needed to work on the yellowfin assessment, in particular to explore the influence of tagging information, and that in the base case model, there is conflict between the tag/release recovery data and CPUE data. However, the sensitivity analysis that down weights the tag data led to questionable results that should be further investigated.

[5] Hoyle, et al (2016), Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets in 2016, IOTC-2016-WPTT18-14, available at: http://www.iotc.org/documents/collaborative-study-tropical-tuna-cpue-multiple-indian-ocean-longline-fleets-2016.

181. **NOTING** the discussions on the tagging mixing period during previous WPTT meetings, related to the assessment of yellowfin and other tropical tuna stocks, the WPTT **RECOMMENDED** that additional work be conducted to elucidate the most appropriate approach to tag modelling in IOTC stock assessments[6].

182. The WPTT **NOTED** that using the new joint LL CPUE results in a more realistic fishing mortality in the NE area of the Indian Ocean, which contributes to lowering the uncertainty in the current assessment compared to last year.

183. The WPTT **NOTED** that, for consistency purposes, the Update scenario would have to be included, and that the diagnostics of the scenario with the extended tagging period are the best.

184. The WPTT **NOTED** the need to explain the changes to the model assumptions and also any changes in the management advice between the 2015 and 2016 stock assessment.

185. The WPTT **NOTED** the limitations of the work with the limited resources dedicated by the Commission but also **NOTED** some exploratory work suggested that additional analyses would be beneficial to improve the quality of future assessments.

186. The WPTT **AGREED** on using the Update model as the Reference Case to provide stock status estimation and management advice for yellowfin tuna. The WPTT also **NOTED** the benefit of extending the mixing period of the tag information and **AGREED** that tag dynamics should be further investigated in the next stock assessment of yellowfin tuna.

187. The WPTT **NOTED** that the scenario with an extended mixing period for the tagging information results in the stock at very similar levels relative to B_{MSY} of the base case scenario, but a fishing mortality for 2015 below the estimated F_{MSY}.

188. The WPTT **NOTED** that the projections reflect low recruitment estimated for the recent past, which results in a decline in spawning biomass in the short term, regardless of the catch level projected, until the projected deterministic recruitments enter the spawning population.

Parameters for future analyses: Yellowfin tuna CPUE standardisation and stock assessments

189. The WPTT **RECALLED** that in order to obtain comparable assessments, the CPUE standardisations should be conducted with similar parameters and resolutions. However the improved methods recommended by the CPUE workshop should also be applied so that standardisation procedures can make progress. Table 21 provides a set of parameters, discussed during WPTT meetings that shall give guidelines, if available, for the standardisation of CPUE in the unimproved state.

Table 21. Yellowfin tuna: Parameters for the future standardisation of CPUE series.

CPUE standardisation parameters	2016 CPUE standardisations for consistency
Area	By region
CE Resolution	Operational data
Data preparation	Cluster analysis or related approaches to select data or add cluster parameters
Factors	Year, Quarter, 5 degree squares, HBF or cluster, vessel
Model	Delta lognormal, lognormal + constant
	Proposed updates to standardisation methods
Area	As above
CE Resolution	As above
Data preparation	As above
Factors	As above, plus sub-area * time interaction
Model	As above
Other possible changes	Transform response variable

[6] See Appendix IV, Program of Work, Topic 6 for more details.

Table 22. Yellowfin tuna: Model parameters agree to by the WPTT for use in future base case stock assessment runs.

Biological parameters	**Value for assessments**
Spatial structure	4 regions
Sex ratio	Sex aggregated
Age (longevity)	60 quarterly age classes with the last representing a plus group.
Natural mortality	Age-specific. Relative variation amongst ages based on WCPO yellowfin assessment and overall scale of natural mortality estimated in 2012 Indian Ocean yellowfin tuna assessment (see Figure 16 in SS3 assessment). Constant over time and among regions.
Growth formula	Estimates in Fonteneau 2008 (Replace with Eveson et al. 2015 and/or Dortel et al. 2015, but not for 2016 update). SD of length-at-age based on a constant coefficient of variation of average length-at-age.
Weight-length allometry	a = 1.7665e-05, b = 3.03542
Maturity	age-class 0-4: 0; 5: 0.1; 6: 0.15; 7: 0.2; 8: 0.5; 9: 0.5; 10: 0.7; 11: 0.9; 12-28: 1.0 (based on Zudaire et al. 2013)
Fecundity	Assume constant, since results are based on spawning biomass rather than egg production. (Potential to change this post-2016.)
Stock-recruitment	Beverton-Holt steepness of 0.8 with sensitivities at 0.7 and 0.9.
Other parameters	
Fisheries	25 fisheries defined by region and gear type, with temporal splits to reflect selectivity change in the region 1b PS fisheries.
Abundance indices	Regional standardised longline CPUE indices estimated jointly across flags
Selectivity	Age specific, constant over time. Principal longline fisheries share logistic selectivity parameters. Common selectivity for all PSLS fisheries. Common selectivity for all PSLS fisheries. LF4 fishery logistic selectivity. All other fisheries: double normal selectivity. OT 1a & 4 and TR 1b & 4 share selectivity parameters.

190. The WPTT **RECALLED** that the model parameters contained in Table 21 could be considered appropriate for future yellowfin tuna stock assessments preliminary base case analysis, with appropriate sensitivity runs.

191. The WPTT **RECOMMENDED** that development of the next stock assessment of yellowfin tuna should include, or be associated with, a detailed review of the existing data sources, including:
   i. Size frequency data: Evaluation of the reliability of length composition from the longline fisheries (including recent and historical data), review of anomalies in the (EU) PS length composition data, and the need for a thorough review of the size frequency data held by IOTC, in collaboration with the fleets involved, to improve the utilization of these data in tropical tuna stock assessments.
   ii. Tagging data: Further analysis of the tag release/recovery data set.
   iii. Alternative CPUE series: a review of the available data from the Indian tuna longline survey data.

7.3.3 Selection of Stock Status indicators for yellowfin tuna

192. The WPTT **AGREED** that the base case model run from the SS3 stock assessment would be used for development of management advice for the Scientific Committee’s consideration.

7.4 Development of management advice for yellowfin tuna & update of yellowfin tuna Executive Summary for the consideration of the Scientific Committee

193. The WPTT **ADOPTED** the management advice developed for yellowfin tuna as provided in the draft resource stock status summary and **REQUESTED** that the IOTC Secretariat update the draft stock status summary for the yellowfin tuna with the latest 2015 catch data (if necessary), and for the summary to be provided to the SC as part of the draft Executive Summary, for its consideration:

    i. Yellowfin tuna (*Thunnus albacares*) – Appendix VIII.

7.5 Yellowfin tuna Management Strategy Evaluation process update

194. The WPTT **NOTED** paper IOTC–2016–WPTT18–32, which provided an update on the tropical tunas management strategy evaluation development framework. A summary of this document and discussion are presented below in Agenda item 8 below.

8. DEVELOPMENT OF OPTIONS FOR ALTERNATIVE MANAGEMENT MEASURES FOR TROPICAL TUNAS IN THE IOTC AREA OF COMPETENCE

195. The WPTT **NOTED** IOTC–2016–WPTT18–32 was presented, which describes progress on the development of Management Strategy Evaluation (MSE) for Indian Ocean yellowfin and bigeye tunas, and solicits feedback from the WPTT for the next iteration. The following summary was provided by the author:

    "The IOTC has opted to use MSE to help meet its management objectives for the main commercial species, with the target of having MSE results presented to the Commission by 2018 for bigeye and yellowfin tunas. Working Paper IOTC–2016–WPTT18–32 is the final report and user manual from the completed first phase project, conducted with funds provided by the EU through FAO, and CSIRO, Australia. In addition to a general introduction to MSE, the document describes i) the simulation software, ii) demonstration case Operating Models (OMs) conditioned using SS3 assessment software, iii) candidate Management Procedures (MPs), iv) MSE results for the demonstration case OMs and range of MPs, and v) a critique of issues that were identified during the first phase that need to be reviewed and endorsed by the appropriate IOTC technical working parties to facilitate the next phase of the work. The presentation to the WPTT emphasized the OM development process, and sought expert feedback from the WPTT participants and endorsement for the next phase. The approach used in the IWC, CCSBT and for IOTC albacore was adopted, in which the OM for each species represents an ensemble of stock assessment models. Each individual model within the ensemble is fit to the assessment data, and they vary in terms of structural assumptions, input data and/or fixed values for parameters that are known to be difficult to estimate. The ensemble represents a balanced cross of interacting assumptions (the demonstration case consisted of 54 models for YFT and 18 for BET). This approach ensures that each scenario in the OM is reasonably consistent with the data and the insights from the stock assessment process, while the use of an ensemble helps to ensures that the MPs are tested against a range of models that encompass assessment uncertainties."

196. The WPTT **CONGRATULATED** the authors on the progress made to date. In response to the authors request, a number of suggestions were made to further progress development of the Operating Model (OM):

    i. The WPTT **AGREED** that it was critical to represent CPUE uncertainty in the OM ensemble, but found it difficult to propose specific scenarios. It was thought that the long term catchability trends of 0 and 1% per annum would bracket the uncertainty in vessel-specific efficiency that remains after the CPUE standardization. The use of standardized CPUE series with and without cluster (targeting) analyses would provide alternative interpretations of targeting changes in the tropical regions.

    ii. The WPTT **NOTED** that it would be desirable to include sex-disaggregated scenarios to represent potential sex-specific differences in growth, mortality and movement. However, it was recognized that sex-specific parameters are poorly known, the OM would require structural changes and the project timeline could be delayed by a year if the conditioning raised new challenges.

    iii. The WPTT **NOTED** that it is important to maintain a firm MSE development timeline and not re-iterate the OM conditioning more often than necessary. However, the WPTT **AGREED** that both the BET and YFT OMs should be updated in relation to the new assessments at this time, because there were substantial changes to the assessments in 2016, and this was the first opportunity for the WPTT to provide feedback on the OM assumptions.

iv. The WPTT **DISCUSSED** which uncertainties to include in the OM ensembles, and **AGREED** the grids described in Table 23. Any dimensions that do not appear to add useful uncertainty to the grid may be excluded.

v. The WPTT **NOTED** that it may be worth adding a trend in selectivity toward younger ages for the longline fleet in the projections, as estimated in Atlantic tuna fisheries. This may be explored in the context of a robustness scenario if a specific proposal can be provided to the developers.

Table 23. Grid of interacting assumptions proposed for YFT and BET Operating Models ensembles.

YFT OM ensemble 3 x 3 x 3 x 2 x 2 x 2 options = 216 configurations		
Grid Dimension	Levels	Notes
M	0.6 0.8 1.0	Multiplier relative to 2015 reference case assessment
Steepness	0.7 0.8 0.9	Beverton-Holt relationship
Tag lambdas	0.0 0.1 1.0	weighting factor for one or both components of tag likelihood
Tag Mixing period	3 8	Quarters
Relative abundance (CPUE) bias	0.0 1.0	Historical and future catchability trend (percent per annum compounded)
CPUE analysis for tropical tuna targeting	CLU HBF	CLU = cluster analysis (no HBF) HBF = hooks between floats
BET OM ensemble 3 x 3 x 3 x 1 x 2 x 2 options = 108 configurations		
Grid Dimension	Levels	Notes
M	0.6 0.8 1.0	Multiplier for M(a=4) relative to 2013 reference case assessment
Steepness	0.7 0.8 0.9	Beverton-Holt relationship
Tag lambdas	0.0 0.1 1.0	weighting factor for one or both components of tag likelihood
Tag Mixing period	4	Quarters
Relative abundance (CPUE) bias	0.0 1.0	Historical and future catchability trend (percent per annum compounded)
CPUE analysis for tropical tuna targeting	CLU HBF	CLU = cluster analysis (no HBF) HBF = hooks between floats

9. WPTT PROGRAM OF WORK

9.1 Revision of the WPTT Program of Work (2017–2021)

197. The WPTT **NOTED** paper IOTC–2016–WPTT18–08 which provided the WPTT18 with an opportunity to consider and revise the WPTT Program of Work (2017–2021), by taking into account the specific requests of the Commission, Scientific Committee, and the resources available to the IOTC Secretariat and CPCs.

198. The WPTT **RECALLED** that the SC, at its 18th Session, made the following request to its working parties:

> "*The SC **REQUESTED** that during the 2016 Working Party meetings, each group not only develop a Draft Program of Work for the next five years containing low, medium and high priority projects, but that all High Priority projects are ranked. The intention is that the SC would then be able to review the rankings and develop a consolidated list of the highest priority projects to meet the needs of the Commission. Where possible, budget estimates should be determined, as well as the identification of potential funding sources*." (SC18. Para 154)

199. The WPTT **REQUESTED** that the Chairperson and Vice-Chairperson of the WPTT, in consultation with the IOTC Secretariat, develop Terms of Reference (TOR) to for each of the high priority projects that are yet to be funded, for circulation to potential funding sources.

200. **NOTING** that the current IOTC *Guidelines for the presentation of CPUE standardisations and stock assessment models* (IOTC–2015–WPTT17–INF01) may need revising, as it was felt that the current Stock Status summary

table, which is the principal communication tool regarding stock status used on the IOTC website, understates uncertainty in stock status evaluations, the WPTT **REITERATED** that the following be reviewed:

- the annual status coding scheme;
- the historic coding scheme;
- consideration of the status coding scheme for years when no quantitative stock assessment is available.

201. The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2017–2021), as provided at Appendix IX.

Data exchange timings

202. **NOTING** that the current time frames for data exchange do not allow enough time to conduct thorough stock assessment analyses, which has a detrimental effect on the quality of advice provided, the WPTT **ENCOURAGED** that exchanges of data (CPUE indices and coefficient of variation) should be made as early as possible, but **no later than** 60 days prior to a working party meeting, so that stock assessment analysis can be provided to the IOTC Secretariat no later than 30 days before a working party meeting.

Consultants

203. **NOTING** the excellent work by IOTC consultants in the past and for the WPTT18, the WPTT **RECALLED** that the Commission has pre-approved a consultant to undertake a skipjack tuna stock assessment in 2017, by the inclusion of funds in the 2017 budget. The WPTT **CONSIDERED** whether a multi-species assessment would be required for subsequent WPTT meetings, given the likelihood of more regular updates of stock status required to support Resolution 16/01 *On interim plan for rebuilding the Indian Ocean yellowfin tuna stock in the IOTC Area of Competence*, and Resolution 16/02 *On harvest control rules for skipjack tuna in the IOTC Area of Competence*.

204. The WPTT **AGREED** that a number of priority issues (in order of importance) should be examined to support further development of the stock assessments for tropical tunas. The Chairperson and IOTC Secretariat shall develop Terms of Reference and seek funding. Specifically:

- Yellowfin tuna
  - Further development of the collaborative longline CPUE, and European purse seine CPUE.
  - Review of the purse seine and longline size data for tropical tunas in the IOTC database.
  - Review of the assumptions associated with the mixing of tagged fish following release.
  - Determination of the structural uncertainty of the assessment model, incorporating the interactions among key model parameters (e.g., a grid approach).
  - Exploration of alternate assessment areas.
  - Development of a two sex model to account for sex specific differences in the biological parameters (especially growth and natural mortality).
- Skipjack tuna
  - Evaluation of Maldives logbook, CPUE series.
  - European purse seiner CPUE.
  - External fisheries indicators (e.g., no. of FADs).
  - Derive a time series of abundance from assessment outputs of YFT or BET and data on the species composition of PS.

9.2 Development of priorities for an Invited Expert at the next WPTT meeting

205. Unfortunately the invited expert for the meeting withdrew their application at short notice, due to unforeseen circumstances. However the WPTT **NOTED** with thanks, the outstanding contributions of the IOTC consultants, Mr. Adam Langley, New Zealand, and Dr Simon Hoyle, New Zealand, both prior to and during the WPTT meeting which contributed greatly to the group's understanding of tropical tuna data, CPUE standardisation and stock assessment methods.

206. The WPTT **AGREED** to the following core areas of expertise and priority areas for contribution that need to be enhanced for the next meeting of the WPTT in 2017, by an Invited Expert:

i. **Expertise**: Stock assessment; including from regions other than the Indian Ocean; size data analysis; and CPUE standardisation.

ii. **Priority areas for contribution**: Providing expert advice on stock assessments; refining the information base, historical data series and indicators for tropical tuna species for stock assessment purposes (species focus: skipjack tuna and yellowfin tuna).

10. Other Business

10.1 Election of a Chair and Vice-Chairperson of the WPTT for the next biennium

207. The WPTT **NOTED** that the first term of the current Chairperson, Dr. M. Shiham Adam (Maldives) and Vice-chairperson, Dr. Gorka Merino (Spain) is due to expire at the closing of the current WPTT meeting and as such, participants either need to re-elect Dr. Adam and Dr. Merino for a second and final term, or a new Chair and Vice Chairperson needs to be elected.

208. The WPTT **CALLED** for nominations for the newly vacated positions of Chair and Vice-Chairperson for the next biennium. Dr. M. Shiham Adam (Maldives) and Dr. Gorka Merino (Spain) were nominated for a second term and unanimously re-elected as Chairperson and Vice-Chairperson, respectively, of the WPTT for the next *biennium*.

209. The WPTT **RECOMMENDED** that the SC note that Dr. M. Shiham Adam (Maldives) and Mr. Gorka Merino (Spain) were re-elected as Chairperson and Vice-Chairperson, respectively, of the WPTT for the next *biennium*.

10.2 Date and place of the 19th and 20th Sessions of the WPTT

210. The WPTT **THANKED** the IOTC Secretariat for hosting the 18th Session of the WPTT and commended Seychelles on the warm welcome, the excellent facilities and assistance provided to the IOTC Secretariat in the organisation and running of the Session.

211. **NOTING** the discussion on who would host the 19th and 20th Sessions of the WPTT in 2017 and 2018 respectively, the WPTT **REQUESTED** that the IOTC Secretariat liaise with CPCs to determine if they would be able to host the 19th and 20th sessions of the WPTT respectively (Table 24).

Table 24. Draft meeting schedule for the WPTT (2017 and 2018).

Meeting	2017		2018	
	Date	**Location**	**Date**	**Location**
Working Party on **Tropical Tunas**	Third week in October (6 days)	TBD	Third week in October (6 days)	TBD

10.3 Review of the draft, and adoption of the Report of the 18th Session of the WPTT

212. The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT18, provided at Appendix X, as well as the management advice provided in the draft resource stock status summary for each of the three tropical tuna species under the IOTC mandate, and the combined Kobe plot for the three species assigned a stock status in 2016 (Fig. 15):
    - Bigeye tuna (*Thunnus obesus*) – Appendix VI
    - Skipjack tuna (*Katsuwonus pelamis*) – Appendix VII
    - Yellowfin tuna (*Thunnus albacares*) – Appendix VIII

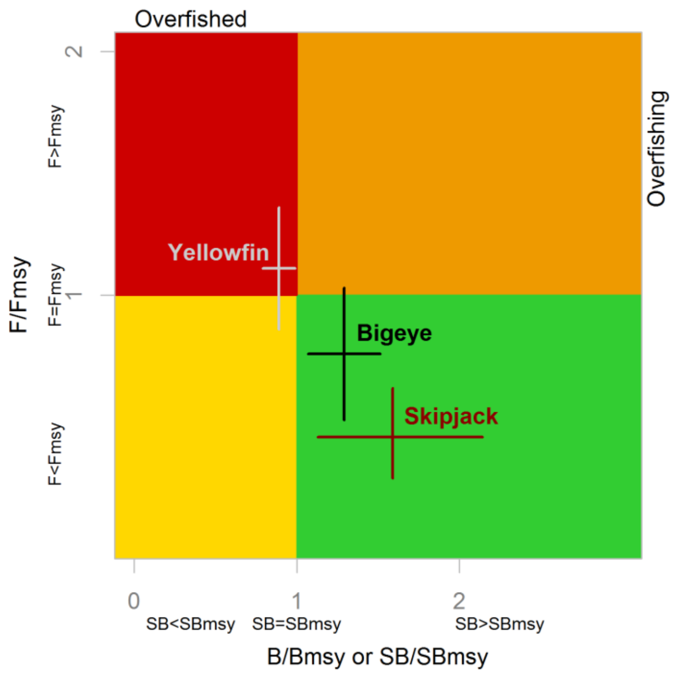


Fig.15. Combined Kobe plot for bigeye tuna (black: 2016), skipjack tuna (brown: 2014) and yellowfin tuna (grey: 2016) showing the estimates of current stock size (SB) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs with a 80% CI. Note that for skipjack tuna, the estimates are highly uncertain as F_{MSY} is poorly estimated, and as suggested for stock status advice it is better to use B_0 as a biomass reference point and C(t) relative to C_{MSY} as a fishing mortality reference point.

213. The report of the 18th Session of the Working Party on Tropical Tunas (IOTC–2016–WPTT18–R) was **ADOPTED** on the 10 November 2016.

APPENDIX I
LIST OF PARTICIPANTS

Chairperson
Dr M. Shiham **Adam**
Marine Research Centre,
Maldives
Email: msadam@mrc.gov.mv

Vice-Chairperson
Dr Gorka **Merino**
AZTI Tecnalia, Spain,
European Union
Email: gmerino@azti.es

Dr Simon **Hoyle**
IOTC Consultant,
New Zealand
Email:
simon.hoyle@gmail.com

Mr Adam **Langley**
IOTC Consultant,
New Zealand
Email:
adam_langley@xtra.co.nz

Other Participants:
Mr Mohamed **Ahusan**
Marine Research Centre
Maldives
Email: mahusan@mrc.gov.mv

Mr Mokhtar **Akhondi**
Iran Fisheries Organization
Iran (Islamic Republic of)
Email:
akhondi2200@yahoo.com

Ms Cindy **Assan**
Seychelles Fishing Authority
Email: cassan@sfa.sc

Mr John **Burton**
IPNLF
Email: john.burton@ipnlf.org

Dr Massimiliano **Cardinale**
SLU
Email:
massimiliano.cardinale@slu.se

Dr Emmanuel **Chassot**
IRD
France
Email:
emmanuel.chassot@ird.fr

Dr Wetjens **Dimmlich**
WWF
Email:
wdimmlich@wwf.panda.org

Mr Laurent **Floch**
IRD
France
Email: laurent.floch@ird.fr

Dr Alain **Fontenau**
IRD, France
Email: Alain.fonteneau@ird.fr

Ms Veronique **Garrioch**
IBL Seafood and Marine
Email:
vgarrioch@iblgroup.com

Mr James **Geehan**
IOTC Fisheries Statistician
Email: james.geehan@iotc.org

Dr. Sisira **Haputhantri**
National aquatic Resources
Research and Development
Agency (NARA)
Sri Lanka
Email:
sisirahaputhantri@yahoo.com

Mr Miguel **Herrera**
OPAGAC
Spain
Email:
Miguel.Herrera@opagac.org

Mr. Muhammad Farhan **Khan**
Ministry of Ports and Shipping
Islamic Republic of Pakistan
Email:
farhankhan704@gmail.com

Dr Dale **Kolody**
CSIRO
Australia
Email: dale.kolody@csiro.au

Dr Toshihide **Kitakado**
Tokyo University of Marine
Science and Technology,
Japan
Email:
kitakado@kaiyodai.ac.jp

Dr Julien **Lebranchu**
IRD
France
Email: julien.lebranchu@ird.fr

Dr. Sung Il **Lee**
National Institute of Fisheries
Science
Rep. of Korea
k.sungillee@gmail.com

Dr. Mikyung **Lee**
National Institute of Fisheries
Science
Rep. of Korea
cc.mklee@gmail.com

Dr. Jon **Lopez**
AZTI Tecnalia, Spain,
European Union
Email: jlopez@azti.es

Mr. Vincent **Lucas**
Senior Fisheries Officer
Seychelles Fishing Authority
Seychelles
Email: vlucas@sfa.sc
Mrs Juliette **Lucas**
Seychelles Fishing Authority
Seychelles
Email: jlucas@sfa.sc

Ms Hannah **Macintyre**
IPNLF

Email: Hannah.Macintyre@marks-and-spencer.com

Dr Francis **Marsac**
IRD, France, European Union
Email: francis.marsac@ird.fr

Dr Takayuki **Matsumoto**
National Research Institute of Far Seas Fisheries
Japan
Email: matumot@affrc.go.jp

Mr Hilario **Murua**
AZTI
Spain
Email: hmurua@azti.es

Mr Stephen Ndegwa
State Department of Fisheries and Blue Economy
Kenya
Email: ndegwafish@yahoo.com

Dr Tom **Nishida**
National Research Institute of Far Seas Fisheries of Japan,
Japan
Email: tnishida@affrc.go.jp

Mr Kento **Otsuyama**
Tokyo University of Marine Science and Technology
Japan
Email: k_otsuyama0303@yahoo.co.jp

Dr Jan Robinson
Fisheries consultant
Email: janrobinson71@gmail.com

Dr Gerald **Scott**
International Seafood Sustainability Foundation,
Email: gpscott_fish@hotmail.com

Mr Anwar **Sheik Mamode**
Albion Fisheries Research Centre
Mauritius
Email: asheik-mamode@govmu.org

Prof. Liming **Song**
Shanghai Ocean University
China
Email: lmsong@shou.edu.cn

Dr Yuji **Uozumi**
National Research Institute of Far Seas Fisheries
Japan
Email: uozumi@japantuna.or.jp

Mr Anung **Widodo**
Centre Fisheries Research and Development
Indonesia
Email: anungwd@yahoo.co.id

Mr Ashley **Williams**
Department of Agriculture
Australia
Email: ashley.williams@jcu.edu.au

Mr Aekkarat **Wongkeaw**
Department of Fisheries
Thailand
Email: aekfish@hotmail.com

Mr Arief **Wujdi**
Research Institute for Tuna Fisheries, Indonesia
Email: arief_wujdi@yahoo.com

Dr. Abdi Ali **Yare**
The Ministry of Fisheries and Marine Resources,
Somalia
Email:

Dr Yu-min **Yeh**
Nanhua University
Email: ymyeh@mail.nhu.edu.tw

Mr Jiangfeng **Zhu**
Shanghai Ocean University
China
Email: jfzhu@shou.edu.cn

APPENDIX II
AGENDA FOR THE 18TH WORKING PARTY ON TROPICAL TUNAS

Date: 5–10 November 2016
Location: Seychelles
Venue: International Conference Centre Seychelles (ICCS)
Time: 09:00 – 17:00 daily
Chair: Dr Shiham Adam (Maldives) **Vice-Chair**: Dr Gorka Merino (EU,Spain)

1. **OPENING OF THE MEETING** (Chair)

2. **ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION** (Chair)
   - IOTC–2016–WPTT18–01a Draft: Agenda of the 18th Working Party on Tropical Tunas
   - IOTC–2016–WPTT18–01b Draft: Annotated agenda of the 18th Working Party on Tropical Tunas
   - IOTC–2016–WPTT18–02 Draft: List of documents for the 18th Working Party on Tropical Tunas

3. **THE IOTC PROCESS: OUTCOMES, UPDATES AND PROGRESS**
   - 3.1 **Outcomes of the 18th Session of the Scientific Committee (IOTC Secretariat)**
     - IOTC–2016–WPTT18–03 Outcomes of the 17th Session of the Scientific Committee (IOTC Secretariat)
   - 3.2 **Outcomes of the 20th Session of the Commission (IOTC Secretariat)**
     - IOTC–2016–WPTT18–04 Outcomes of the 19th Session of the Commission (IOTC Secretariat)
   - 3.3 **Review of Conservation and Management Measures relevant to tropical tunas (IOTC Secretariat)**
     - IOTC–2016–WPTT18–05 Review of Conservation and Management Measures relevant to tropical tunas (IOTC Secretariat)
   - 3.4 **Progress on the recommendations of WPTT17 (IOTC Secretariat)**
     - IOTC–2016–WPTT18–06 Progress made on the recommendations of WPTT17 (IOTC Secretariat)

4. **NEW INFORMATION ON FISHERIES AND ASSOCIATED ENVIRONMENTAL DATA RELATING TO TROPICAL TUNAS**
   - **4.1 Review of the statistical data available for tropical tunas (IOTC Secretariat)**
     - IOTC–2016–WPTT18–07 Review of the statistical data and fishery trends for tropical tunas (IOTC Secretariat)
   - **4.2 Review new information on fisheries and associated environmental data (general CPC papers)**
     - IOTC–2016–WPTT18–09 Outline of climate and oceanographic conditions in the Indian Ocean: an update to August 2016 (Marsac F)
     - IOTC–2016–WPTT18–10 Review of Iran fisheries and tropical tuna catch in the Indian Ocean (Akhondi M)
     - IOTC–2016–WPTT18–11 Problems facing Somali Tunas (Yare A)
     - IOTC–2016–WPTT18–12 An overview of the tropical tuna catches by Mauritian Semi-Industrial Longliners (Mamode S, Sooklall T, and Curpen-Mahadoo M)
     - IOTC–2016–WPTT18–38 Tuna longline fishery by Thail longliners in the Indian Ocean during 2011-2015 (Wongkeaw A, et al)
     - IOTC–2016–WPTT18–29 Characteristics of tuna fisheries associated with anchored FADs in the Indonesian Indian Ocean (Fisheries Management Areas 572 and 573) (Widodo A, et al)
     - IOTC–2016–WPTT18–28 Using fishers' echo-sounder buoys to estimate biomass of fish species associated with fish aggregating devices in the Indian Ocean (Orúe B, Lopez J, Moreno G, Santiago J, Soto M, Murua H)
     - IOTC–2016–WPTT18–35 Results achieved within the framework of the EU research project: Catch, Effort, and eCOsystem impacts of FAD-fishing (CECOFAD) (Gaertner D et al)
     - IOTC–2016–WPTT18–36 Integrating scientific and French tropical tuna purse seine skippers knowledge for a better management of dFAD fisheries in the Indian Ocean (Maufroy A, et al)

- IOTC–2016–WPTT18–39 Validation of VMS data and identification of fishing activities of the Spanish tuna purse seine fleet (Punzon A, et al)
- IOTC–2016–WPTT18–33 Proposals for improved figures in the tropical tunas executive summaries (Fonteneau F, Marsac F)

5. BIGEYE TUNA – REVIEW OF NEW INFORMATION ON STOCK STATUS

5.1 Review of the statistical data available for bigeye tuna (IOTC Secretariat)

5.2 Review new information on bigeye tuna biology, ecology, stock structure, their fisheries and associated environmental data (CPC papers)

- IOTC–2016–WPTT18–37 Sex-ratio, size at maturity, spawning period and fecundity of bigeye tuna (Thunnus obesus) in the western Indian Ocean (I. Zudaire et al.)

5.3 Review of new information on the status of bigeye tuna (all)

- Nominal and standardised CPUE indices

- IOTC–2016–WPTT18–13 Japanese longline CPUE for bigeye tuna in the Indian Ocean standardized by GLM (Matsumoto T, et al.)
- IOTC–2016–WPTT18–34 Updated CPUE standardizations for bigeye and yellowfin tuna caught by Taiwanese longline fishery in the Indian Ocean using generalized linear model (Yeh Y and Chang S)
- IOTC–2016–WPTT18–14 Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets in 2016 (Hoyle S, et al).

- Stock assessments

- IOTC–2016–WPTT18–15 Stock assessment of Indian Ocean bigeye tuna (Thunnus obesus) using Age-Structured Assessment Program (ASAP) (Zhu J)
- IOTC–2016–WPTT18–16 Assessment of Indian Ocean bigeye (Thunnus obesus) using a biomass dynamic model (Merino G, Kell L, Murua H)
- IOTC–2016–WPTT18–17 Stock and risk assessments of bigeye tuna in the Indian Ocean based on ASPIC (Matsumoto, T et al.)
- IOTC–2016–WPTT18–18 Stock assessment of bigeye tuna in the Indian Ocean using
- Statistical-Catch-At-Age (SCAA) (Nishida T, Kitakado T, and Matsumoto T)
- IOTC–2016–WPTT18–19 Bayesian state-space production models for the Indian Ocean bigeye tuna and their predictive evaluation (Otsuyama K and Kitakado T)
- IOTC–2016–WPTT18–20 Stock assessment of bigeye tuna in the Indian Ocean for 2016 (Langley A)

- Selection of Stock Status indicators for bigeye tuna

5.4 Development of management advice for bigeye tuna (all)

5.5 Update of bigeye tuna Executive Summary for the consideration of the Scientific Committee (all)

6. SKIPJACK TUNA – REVIEW OF NEW INFORMATION ON STOCK STATUS

6.1 Review of the statistical data available for skipjack tuna (IOTC Secretariat)

6.2 Review new information on skipjack tuna biology, ecology, stock structure, their fisheries and associated environmental data (CPC papers)

- IOTC–2016–WPTT18–30 Temporal and operational effects on the catch rates of Skipjack Tuna (Katsuwonus pelamis) in gillnet fishery of Sri Lanka (Haputhantri S.)
- IOTC–2016–WPTT18–31 Environmental niche of skipjack tuna common to the eastern central Atlantic and western Indian Oceans and links with catches (Druon J, Chassot E, Murua H, Soto M)

6.3 Review of new information on the status of skipjack tuna (all)

- Nominal and standardised CPUE indices
- Stock assessments
- Selection of Stock Status indicators for skipjack tuna

6.4 Development of management advice for skipjack tuna (all)

6.5 Update of skipjack tuna Executive Summary for the consideration of the Scientific Committee (all)

7. YELLOWFIN TUNA – REVIEW OF NEW INFORMATION ON STOCK STATUS

7.1 Review of the statistical data available for yellowfin tuna (IOTC Secretariat)

7.2 Review new information on yellowfin tuna biology, ecology, stock structure, their fisheries and associated environmental data (CPC papers)

- IOTC–2016–WPTT18–21 Size Distribution of Yellowfin tuna in the Maldives Pole-and-line and Handline Tuna Fisheries (Ahusan M et al)
- IOTC–2016–WPTT18–22 Assessment of yellowfin tuna (Thunnusalbacares) caught by artisanal fishers in Kenya between 2013 and 2016 (Ndegwa S)
- IOTC–2016–WPTT18–23 The relationships between muscle fat content and biological parameters in yellowfin tuna (Thunnus albacares) in the high seas of the Indian Ocean (Liming S and Zhibin S)

7.3 Review of new information on the status of yellowfin tuna (all)

- Nominal and standardised CPUE indices
- IOTC-2016-WPTT18-24 A framework for the standardisation of tropical tuna purse seine CPUE: application to the yellowfin tuna in the Indian Ocean (Isidora K, Gaertner D, et al)
- IOTC-2016-WPTT18-25 Japanese longline CPUE for yellowfin tuna in the Indian Ocean standardized by generalized linear model (Matsumoto T, et al)
- Stock assessments
- IOTC-2016-WPTT18-26 Assessment of Indian Ocean yellowfin (Thunnus albacares) using a biomass dynamic model (Merino G, Kell L, Murua H)
- IOTC-2016-WPTT18-27 An update of the 2015 Indian Ocean Yellowfin Tuna stock assessment for 2016 (Langley A)
- Selection of Stock Status indicators for yellowfin tuna

7.4 Development of management advice for yellowfin tuna (all)

7.5 Update of yellowfin tuna Executive Summary for the consideration of the Scientific Committee (all)

8. DEVELOPMENT OF OPTIONS FOR ALTERNATIVE MANAGEMENT MEASURES FOR TROPICAL TUNAS IN THE IOTC AREA OF COMPETENCE

9. WPTT PROGRAM OF WORK

9.1 Revision of the WPTT Program of Work (2017–2021)

- IOTC–2016–WPTT18–08 Revision of the WPTT Program of Work (2016–2020) (IOTC Secretariat)
- IOTC–2016–WPTT18–32 IOTC Yellowfin and Bigeye Tuna Management Strategy Evaluation: Phase 1 Technical Support Project Final Report (Kolody D and Jumppanen P)

9.2 Development of priorities for an Invited Expert at the next WPTT meeting

10. OTHER BUSINESS

10.1 Date and place of the 19th and 20th Sessions of the WPTT (Chair and IOTC Secretariat)

10.2 Review of the draft, and adoption of the Report of the 18th Session of the WPTT (Chair)

APPENDIX III
LIST OF DOCUMENTS

Document	Title	Availability
IOTC–2016–WPTT18–01a	Draft: Agenda of the 18th Working Party on Tropical Tunas	✓(16 August 2016)
IOTC–2016–WPTT18–01b	Draft: Annotated agenda of the 18th Working Party on Tropical Tunas	✓(28 August 2016)
IOTC–2016–WPTT18–02	Draft: List of documents for the 18th Working Party on Tropical Tunas	✓(24 August 2016)
IOTC–2016–WPTT18–03	Outcomes of the 18th Session of the Scientific Committee (IOTC Secretariat)	✓(6 October 2016)
IOTC–2016–WPTT18–04	Outcomes of the 20th Session of the Commission (IOTC Secretariat)	✓(23 September 2016)
IOTC–2016–WPTT18–05	Review of Conservation and Management Measures relevant to tropical tunas (IOTC Secretariat)	✓(4 October 2016)
IOTC–2016–WPTT18–06	Progress made on the recommendations of WPTT17 (IOTC Secretariat)	✓(6 October 2016)
IOTC–2016–WPTT18–07	Review of the statistical data and fishery trends for tropical tunas (IOTC Secretariat)	✓(28 October 2016)
IOTC–2016–WPTT18–08	Revision of the WPTT Program of Work (2017–2021) (IOTC Secretariat)	✓(4 October 2016)
Environmental conditions		
IOTC–2016–WPTT18–09	Outline of climate and oceanographic conditions in the Indian Ocean: an update to August 2016 (Marsac F)	✓(28 October 2016)
Fisheries information		
IOTC–2016–WPTT18–10	Review of Iran fisheries and tropical tuna catch in the Indian Ocean (Akhondi M)	✓(21 October 2016)
IOTC–2016–WPTT18–11	Problems facing Somali Tunas (Yare A)	✓(2 November 2016)
IOTC–2016–WPTT18–12	An Overview of the tropical tuna catches by Mauritian Semi-Industrial Longliners (Mamode S, Sooklall T, and Curpen-Mahadoo M)	✓(20 October 2016)
IOTC–2016–WPTT18–38	Tuna longline fishery by Thail longliners in the Indian Ocean during 2011-2015 (Wongkeaw A, et al)	✓(21 October 2016)
Bigeye tuna		
IOTC–2016–WPTT18–37	Sex-ratio, size at maturity, spawning period and fecundity of bigeye tuna (Thunnus obesus) in the western Indian Ocean (I. Zudaire et al).	✓(21 October 2016)
IOTC–2016–WPTT18–13	Japanese longline CPUE for bigeye tuna in the Indian Ocean standardized by GLM (Matsumoto T, et al.)	✓(21 October 2016)
IOTC–2016–WPTT18–34	Updated CPUE standardizations for bigeye and yellowfin tuna caught by Taiwanese longline fishery in the Indian Ocean using generalized linear model (Yeh Y and Chang S)	✓(20 October 2016)
IOTC–2016–WPTT18–14	Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets in 2016 (Hoyle S, et al).	✓(23 October 2016)
IOTC–2016–WPTT18–15_Rev1	Stock assessment of Indian Ocean bigeye tuna (Thunnus obesus) using Age-Structured Assessment Program (ASAP) (Zhu J)	✓(21 October 2016) & (13 November 2016)
IOTC–2016–WPTT18–16	Assessment of Indian Ocean bigeye (Thunnus obesus) using a biomass dynamic model (Merino G, Kell L, Murua H)	✓(20 October 2016)
IOTC–2016–WPTT18–17	Stock and risk assessments of bigeye tuna in the Indian Ocean based on ASPIC (Matsumoto, T et al.)	✓(21 October 2016)
IOTC–2016–WPTT18–18	Stock assessment of bigeye tuna in the Indian Ocean using Statistical-Catch-At-Age (SCAA) (Nishida T, Kitakado T, and Matsumoto T)	✓(1 November 2016)
IOTC–2016–WPTT18–19	Bayesian state-space production models for the Indian Ocean bigeye tuna and their predictive evaluation (Otsuyama K and Kitakado T)	✓(1 November 2016)

Document	Title	Availability
IOTC–2016–WPTT18–20	Stock assessment of bigeye tuna in the Indian Ocean for 2016 (Langley A)	✓(10 October 2016)
Yellowfin tuna		
IOTC–2016–WPTT18–21	Size Distribution of Yellowfin tuna in the Maldives Pole-and-line and Handline Tuna Fisheries (Ahusan M et al)	✓(21 October 2016)
IOTC–2016–WPTT18–22	Assessment of yellowfin tuna (Thunnusalbacares) caught by artisanal fishers in Kenya between 2013 and 2016 (Ndegwa S)	✓(26 October 2016)
IOTC–2016–WPTT18–23	The relationships between muscle fat content and biological parameters in yellowfin tuna (Thunnus albacares) in the high seas of the Indian Ocean (Liming S and Zhibin S)	✓(18 October 2016)
IOTC–2016–WPTT18–24	A framework for the standardisation of tropical tuna purse seine CPUE: application to the yellowfin tuna in the Indian Ocean (Isidora K, Gaertner D, et al)	✓(28 October 2016)
IOTC–2016–WPTT18–25	Japanese longline CPUE for yellowfin tuna in the Indian Ocean standardized by generalized linear model (Matsumoto T, et al)	✓(21 October 2016)
IOTC–2016–WPTT18–26	Assessment of Indian Ocean yellowfin (Thunnus albacares) using a biomass dynamic model (Merino G, Kell L, Murua H)	✓(20 October 2016)
IOTC–2016–WPTT18–27	An update of the 2015 Indian Ocean Yellowfin Tuna stock assessment for 2016 (Langley A)	✓(14 October 2016)
Fish Aggregating Devices		
IOTC–2016–WPTT18–28	Using fishers' echo-sounder buoys to estimate biomass of fish species associated with fish aggregating devices in the Indian Ocean (Orúe B, Lopez J, Moreno G, Santiago J, Soto M, Murua H)	✓(28 October 2016)
IOTC–2016–WPTT18–29	Characteristics of tuna fisheries associated with anchored FADs in the Indonesian Indian Ocean (Fisheries Management Areas 572 and 573) (Widodo A, et al)	✓(20 October 2016)
IOTC–2016–WPTT18–35	Results achieved within the framework of the EU research project: Catch, Effort, and eCOsystem impacts of FAD-fishing (CECOFAD) (Gaertner D et al)	✓(17 October 2016)
IOTC–2016–WPTT18–36	Integrating scientific and French tropical tuna purse seine skippers knowledge for a better management of dFAD fisheries in the Indian Ocean (Maufroy A, et al)	✓(17 October 2016)
Skipjack tuna		
IOTC–2016–WPTT18–30	Temporal and operational effects on the catch rates of Skipjack Tuna (Katsuwonus pelamis) in gillnet fishery of Sri Lanka (Haputhantri S.)	✓(21 October 2016)
IOTC–2016–WPTT18–31	Preferred feeding habitat of skipjack tuna in the eastern central Atlantic and western Indian Oceans: relations with carrying capacity and vulnerability to purse seine fishing (Druon J, Chassot E, Murua H, Soto M)	✓(24 October 2016)
MSE updates		
IOTC–2016–WPTT18–32	IOTC Yellowfin and Bigeye Tuna Management Strategy Evaluation: Phase 1 Technical Support Project Final Report (Kolody D and Jumppanen P)	✓(5 October 2016)
Other papers		
IOTC–2016–WPTT18–39 Rev_1	Validation of VMS data and identification of fishing activities of the Spanish tuna purse seine fleet (Punzon A, et al)	✓(28 October 2016) & (5 November 2016)
IOTC–2016–WPTT18–33	Proposals for improved figures in the tropical tunas executive summaries (Fonteneau F and Marsac F)	✓(18 October 2016)
Information papers		
IOTC–2016–WPTT18–INFO1	Note on the size frequencies of the YFT & BET catches by PS used in the SS3 model (Fonteneau F)	✓(3 November 2016)
IOTC–2016–WPTT18–INFO2	Fishery indicators suggest symptoms of overfishing for the Indian Ocean skipjack stock (Fonteneau F and Marsac F)	✓(3 November 2016)
IOTC–2016–WPTT18–INFO3	Status of Tropical Tuna Gillnet fisheries in Pakistan	✓(4 November 2016)

APPENDIX IVA
STATISTICS FOR TROPICAL TUNAS

(Extracts from IOTC–2016–WPTT18–07)

Fisheries and catch trends for tropical tuna species

- Main species: Yellowfin tuna accounts for 45% of total catches of tropical tunas, followed closely by skipjack tuna (≈44%), while catches of bigeye tuna account for the remaining 11% of catches (**Fig. 1d**).

- Main fishing gear (2012-15): purse seiners account for 36% of total catches of tropical tunas, with important catches also reported by gillents (19%), handlines and trolling (18%), longlines (14%), and pole-and-line (11%), in both coastal waters and the high seas.

  Tropical tunas are the target species of many industrial and artisanal fisheries throughout the Indian Ocean, although they are also a bycatch of fisheries targeting other tunas, small pelagic species, or other non-tuna species.

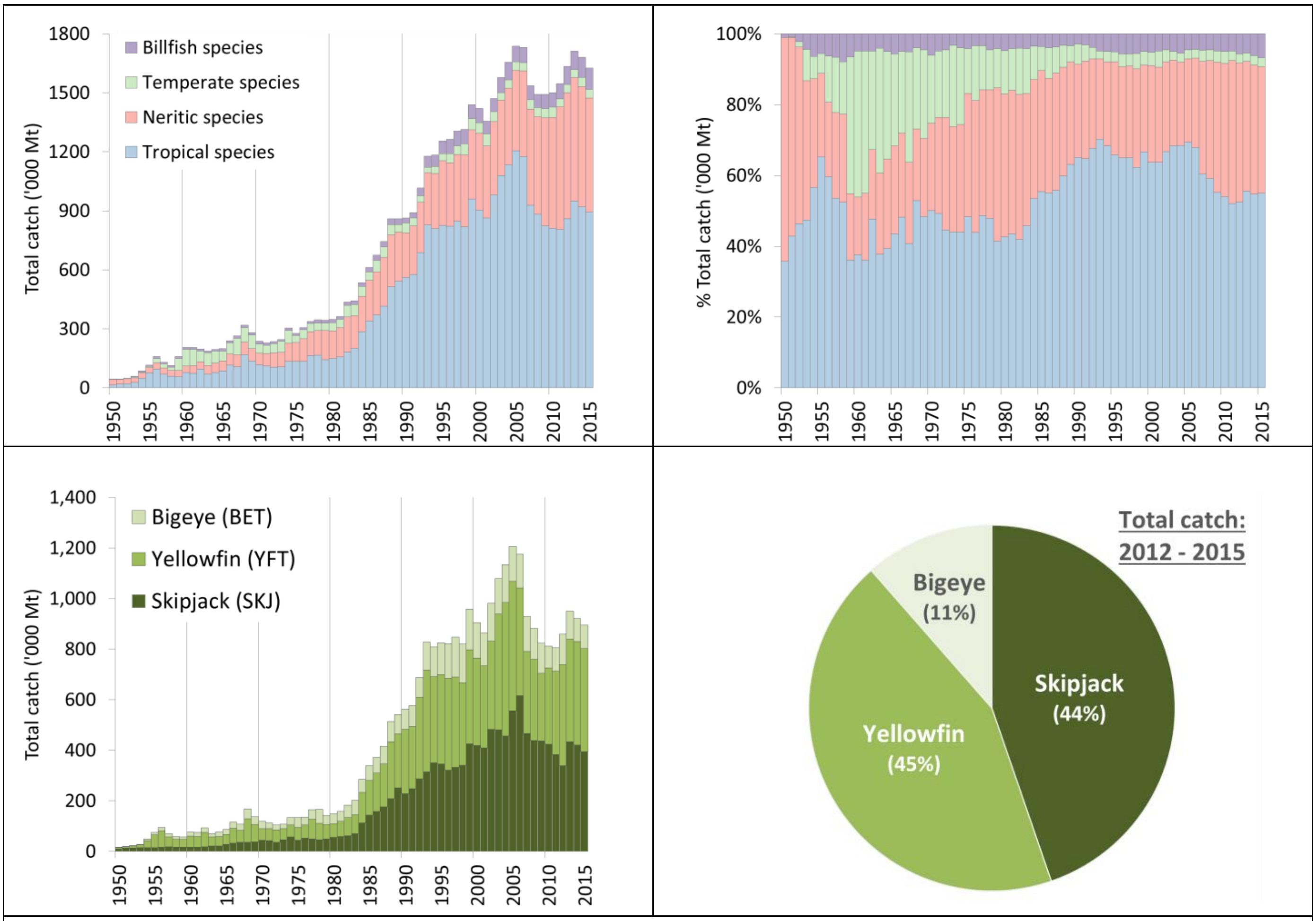
- Main fleets (i.e., highest catches in recent years): Tropical tunas are caught by both coastal countries in the Indian Ocean and distant water fishing nations (**Fig. 2**).

  In recent years the coastal fisheries of five countries (Indonesia, Maldives, Sri Lanka, I.R. Iran, and India) have accounted for ≈55% of the total catches of tropical tuna species in the Indian Ocean, while the industrial purse seiners and longliners flagged as EU-Spain, Seychelles and EU-France reported a further 27% of total catches of these species.

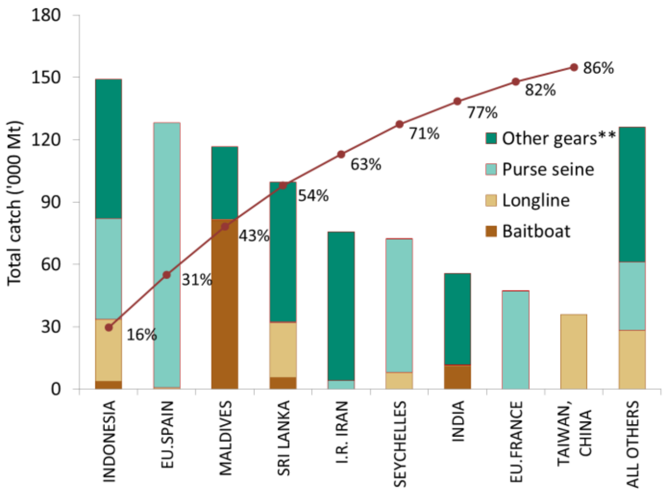
- Retained catch trends: The importance of tropical tunas to the total catches of IOTC species in the Indian Ocean has changed over the years (**Figs. 1a-b.**), in particular following the arrival of industrial purse seine fleets to the Indian Ocean in the early-1980s targeting tropical tunas. With the onset of piracy in the late-2000s, the activities of fleets operating in the north-west Indian Ocean have been displaced or reduced – particularly the Asian distant-water longline fleet – leading to a relative decline in the proportion of catches from tropical tunas (i.e., currently around 55% of total catches of all IOTC species, compared to ≈60% over the (pre-piracy) period 1950-2008).

  Since 2012 catches of tropical tunas appear to show signs of recovery – in particular catches from the distant water longline fleets (e.g., Taiwan,China) – as a result of the reduction of the threat of piracy and return of fleets and to the north-west Indian Ocean. Total catches of tropical tunas have increased from < 820,000 t during the years of piracy in the late 2000s, to over 950,000 t in 2013.

- Economic markets: The majority of catches of tropical tuna species are sold to international markets, including the *sashimi* market in Japan (large specimens of yellowfin tuna and bigeye tuna in fresh or deep-frozen condition), and processing plants in the Indian Ocean region or abroad (small specimens of skipjack tuna and, to a lesser extent, yellowfin tuna and bigeye tuna). A component of the catches of tropical tunas, in particular skipjack tuna caught by some coastal countries in the region, is sold in local markets or retain by the fishermen for direct consumption.



Figs. 1a-d. Top: Contribution of the three tropical tuna species under the IOTC mandate to the total catches of IOTC species in the Indian Ocean, over the period 1950-2015 (a. Top left: total catch; b. Top right percentage, same colour key as Fig. 1a).; **Bottom:** Contribution of each tropical tuna species to the total combined catches of tropical tunas (c. Bottom left: nominal catch of each species, 1950-2015; d. Bottom right: share of tropical tuna catch by species, 2012-15)



*** Other gears includes handline, gillnet, gillnet-longline, trawling*

Fig. 2. All tropical tunas: average catches in the Indian Ocean over the period 2012–15, by country. Countries are ordered from left to right, according to the importance of catches of tropical tunas reported. The red line indicates the (cumulative) proportion of catches of tropical tunas for the countries concerned, over the total combined catches of species reported from all countries and fisheries.

APPENDIX IVB
MAIN STATISTICS OF BIGEYE TUNA

(Extracts from IOTC–2016–WPTT18–07)

Fisheries and main catch trends

- Main fishing gear (2012–15): industrial fisheries account for the majority of catches of bigeye tuna, i.e., deep-freezing and fresh longline (≈57%) and purse seine (≈27%) (**Table 2; Fig. 3**).

  In recent years catches by gillnet fisheries have also been increasing, due to major changes some fleets (e.g., Sri Lanka and I.R. Iran); notably changes in boat size, fishing techniques and fishing grounds, with vessels using deeper gillnets on the high seas in areas important for bigeye tuna targeted by other fisheries.

- Main fleets (and primary gear associated with catches): percentage of total catches (2012–15):
  Indonesia (fresh longline, coastal longline, and coastal purse seine): 26%; Taiwan,China (longline): 22%; Seychelles (longline and purse seine): 11%; EU-Spain (purse seine): 10% (**Fig. 5**).

- Main fishing areas: Primary: Western Indian Ocean, in waters off Somalia (West A1), although in recent years fishing effort has moved eastwards due to piracy. Secondary: Eastern Indian Ocean (East A2) (**Table 3; Fig.4**).

  In contrast to yellowfin tuna and skipjack tuna – where the majority catches are taken in the western Indian Ocean – bigeye tuna is also exploited in the eastern Indian Ocean, particularly since the late 1990's due to increased activity of small longliners fishing tuna to be marketed fresh (e.g., Indonesia). However, in recent years catches of bigeye tuna in the eastern Indian Ocean have shown a decreasing trend, as some vessels have moved south to target albacore.

- Retained catch trends:

  Total catches of bigeye tuna in the Indian Ocean increased steadily from the 1970's, from around 20,000 t in the 1970s, to over 150,000 t by the late 1990s with the development of the industrial longline fisheries and arrival of European purse seiners during the 1980s. Since 2007 catches of bigeye tuna by longliners have been relatively low - less than half the catch levels recorded - before the onset of piracy in the Indian Ocean (e.g., ≈50,000 t).

  Longline fisheries:

  Bigeye tuna have been caught by industrial longline fleets since the early 1950's, but before 1970 only represented incidental catches. After 1970, the introduction of fishing practices that improved catch rates of bigeye tuna, and emergence of a sashimi market, resulted in bigeye tuna becoming a primary target species for the industrial longline fleets. Large bigeye tuna (averaging just above 40 kg) are primarily caught by longliners, in particular deep-freezing longliners.

  Since the late 1980's Taiwan,China has been the major longline fleet targeting bigeye tuna in the Indian Ocean, accounting for as much as 40-50% of the total longline catch in the Indian Ocean (**Fig. 5**).

  Between 2007 and 2011 catches have fallen sharply, largely due to the decline in the number of Taiwanese longline vessels active in the north-west Indian Ocean in response to the threat of piracy. Since 2012 catches appear to show some signs of recovery as a consequence of improvements in security in the area off Somalia and return of fleets (mostly Taiwan,China longline vessels) resuming activities in their main fishing grounds (West (A1)). However current catches still remain far below levels recorded in 2003 and 2004.

  Purse seine fisheries:

  Since the late 1970's, bigeye tuna has been caught by purse seine vessels fishing on tunas aggregated on floating objects and, to a lesser extent, associated to free swimming schools (**Fig. 3**) of yellowfin tuna or skipjack tuna. Purse seiners under flags of EU countries and Seychelles account for the majority of purse seine catches of bigeye tuna in the Indian Ocean (**Fig. 5**) – mainly small juvenile bigeye (averaging around 5 kg) compared to longliners which catch much larger sized fish. While purse seiners take lower tonnages of bigeye tuna compared to longliners, they take larger numbers of individual fish.

  While the activities of purse seiners have also been affected by piracy in the Indian Ocean, the decline in catches of tropical tunas have not been as marked as for longline fleets. The main reason is the presence of security personnel onboard purse seine vessels of the EU and Seychelles, which has made it possible for vessels under these flags to continue operating in the northwest Indian Ocean (**Fig. 6**).

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

***Changes to the catch series*:** Minor revisions to 2014 catches of bigeye tuna (around -7%, or 7,500 t), as a result of final data received in December 2014 for longline fleets, plus revisions to catches for several other fleets (e.g., Indonesia, NEI fleet, Madagascar, EU-France). Otherwise no major changes to the catch series since the WPTT meeting in 2015.

Table 2. Bigeye tuna: Best scientific estimates of the catches of bigeye tuna (*Thunnus obesus*) by gear and main fleets [or type of fishery] by decade (1950–2009) and year (2006–2015), in tonnes. Catches by decade represent the average annual catch, noting that some gears were not in operation since the beginning of the fishery. Data as of September 2016.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BB	21	50	266	1,536	2,968	5,069	5,176	6,047	6,109	6,874	6,789	6,880	6,878	7,266	6,188	5,717
FS	-	-	0	2,340	4,824	6,196	6,407	5,672	9,646	5,301	3,792	6,222	7,180	4,654	4,845	8,966
LS	-	-	0	4,852	18,315	20,273	18,526	18,104	19,874	24,708	18,486	16,386	10,434	22,814	15,032	15,860
LL	6,488	21,861	30,413	43,079	62,350	71,465	73,350	74,531	51,883	52,077	32,420	36,158	67,451	45,646	35,625	31,367
FL	-	-	218	3,066	26,282	23,490	18,788	22,450	23,323	15,810	9,782	12,031	12,495	14,710	13,383	16,153
LI	43	295	658	2,384	4,272	5,935	5,891	6,827	6,939	8,001	8,541	8,046	7,617	8,963	9,001	8,132
OT	38	63	164	860	1,408	3,765	4,673	4,622	4,742	6,029	5,558	6,989	8,363	6,790	6,781	6,542
Total	**6,589**	**22,269**	**31,720**	**58,118**	**120,419**	**136,194**	**132,813**	**138,255**	**122,516**	**118,801**	**85,368**	**92,712**	**120,418**	**110,844**	**90,856**	**92,736**

Gears: Pole-and-Line (**BB**); Purse seine free-school (**FS**); Purse seine associated school (**LS**); Deep-freezing longline (**LL**); Fresh-tuna longline (**FL**); Line (handline, small longlines, gillnet & longline combine) (**LI**); Other gears nei (gillnet, trolling & other minor artisanal gears)(**OT**).

Table 3. Bigeye tuna: Best scientific estimates of the catches of bigeye tuna (*Thunnus obesus*) by area [as used for the assessment] by decade (1950–2009) and year (2006–2015), in tonnes. Catches by decade represent the average annual catch. Data as of September 2016.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
A1	2,478	11,965	17,642	35,960	60,915	80,740	85,414	84,927	72,300	63,459	44,882	46,666	80,236	67,856	51,598	54,612
A2	3,909	7,280	10,271	18,018	45,972	45,533	41,069	48,449	45,688	51,843	36,262	41,669	35,268	37,437	34,424	33,238
A3	202	3,024	3,806	4,139	13,531	9,921	6,330	4,879	4,528	3,499	4,224	4,378	4,915	5,550	4,833	4,886
Total	**6,589**	**22,269**	**31,720**	**58,118**	**120,419**	**136,194**	**132,813**	**138,255**	**122,516**	**118,801**	**85,368**	**92,712**	**120,418**	**110,844**	**90,856**	**92,736**

Areas: West Indian Ocean, including Arabian sea (A1); East Indian Ocean, including Bay of Bengal (A2); Southwest and Southeast Indian Ocean, including southern (A3). Catches in Areas (**0**) were assigned to the closest neighbouring area for the assessment.

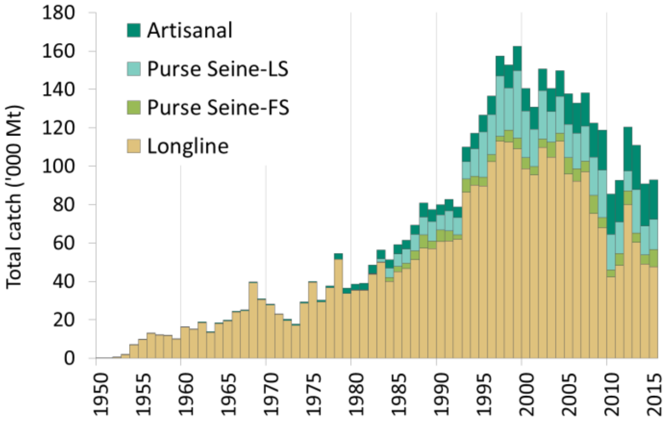
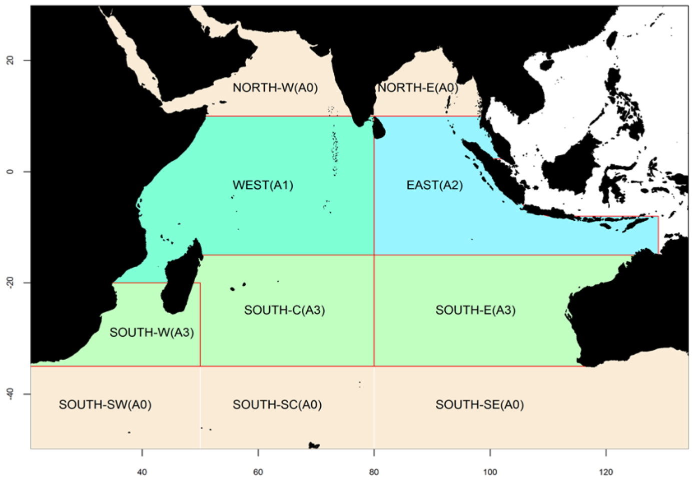


Fig. 3. Annual catches of bigeye tuna by gear (1950–2015). Data as of September 2016.

Gears (as agreed by WPTT): Longline Taiwan,China and associated fleets **(Longline-Taiwan);** Longline Japan and associated fleets **(Longline-Japan)**; Purse seine free-school (**FS**); Purse seine associated school (**LS**); Other gears nei (pole-and-Line, handline, small longlines, gillnet, trolling & other minor artisanal gears) (**Artisanal**).



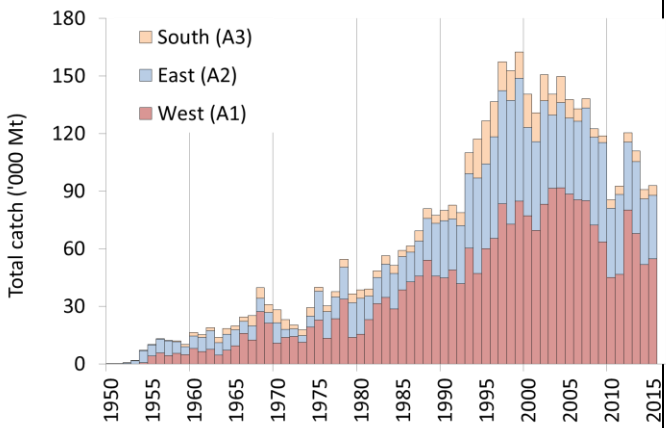


Fig. 4(a-b). Bigeye tuna: Catches of bigeye tuna by (SS3) stock assessment area by year (1950–2015). Catches outside the areas presented in the map were assigned to the closest neighbouring area for the assessment. Data as of September 2016.

Areas: West Indian Ocean (**A1**); East Indian Ocean (**A2**); Southwest and Southeast Indian Ocean (**A3**). Catches in Areas (**0**) were assigned to the closest neighbouring area for the assessment.

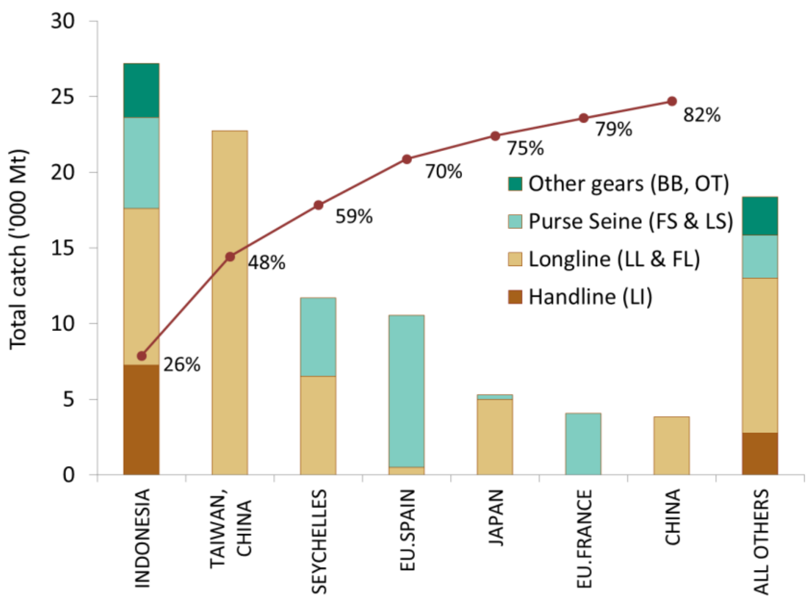


Fig. 5. Bigeye tuna: average catches in the Indian Ocean over the period 2012–15, by country. Countries are ordered from left to right, according to the importance of catches of bigeye reported. The red line indicates the (cumulative) proportion of catches of bigeye for the countries concerned, over the total combined catches of this species reported from all countries and fisheries. Data as of September 2016.

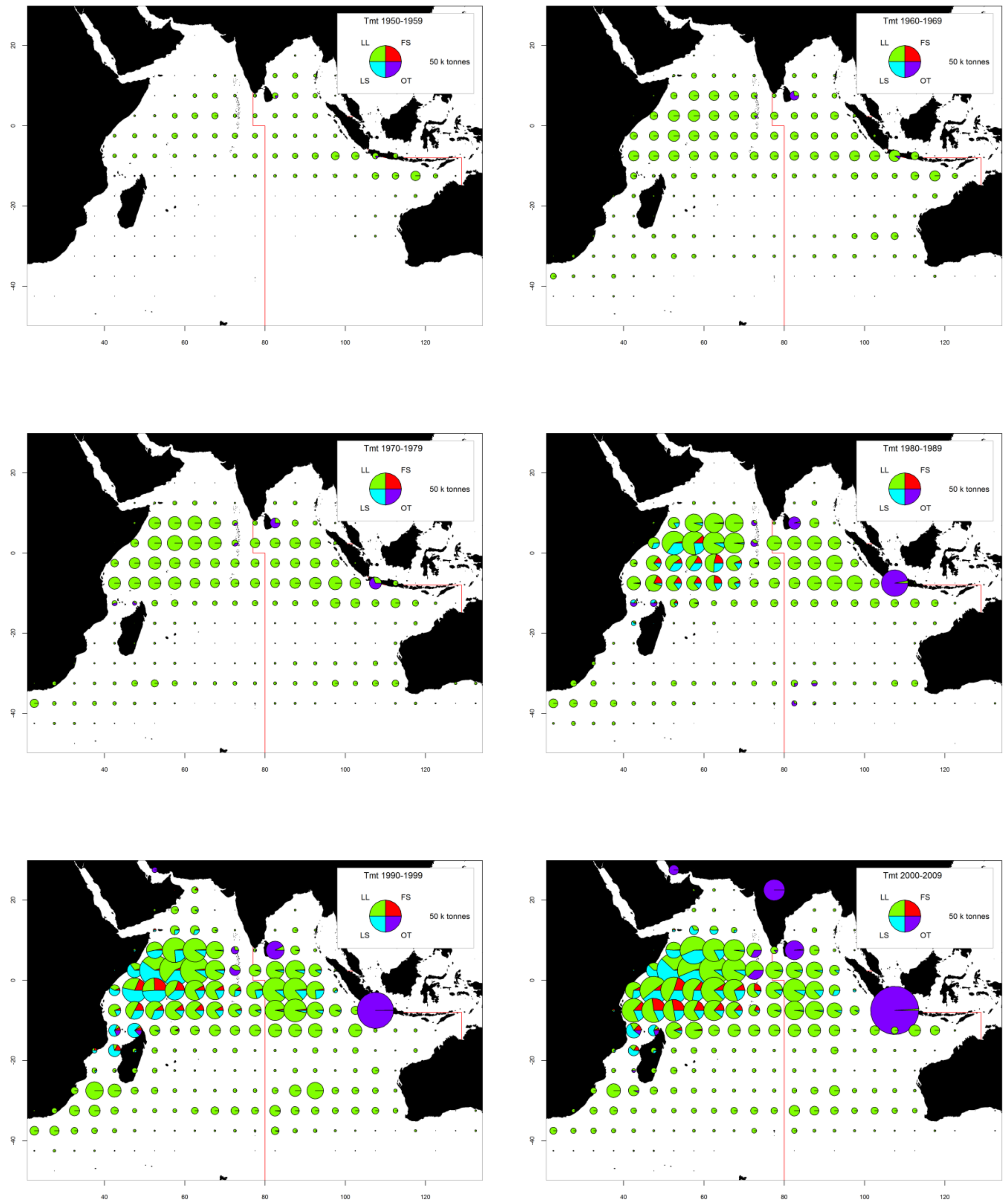


Fig. 6(a-f). Bigeye tuna: Time-area catches (total combined in tonnes) of bigeye tuna estimated for the period 1950–2009, by decade and type of gear.Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), and other fleets (**OT**), including pole-and-line, drifting gillnets, and various coastal fisheries.

The catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded within the area of the countries concerned, in particular driftnets from I.R. Iran, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Indonesia.

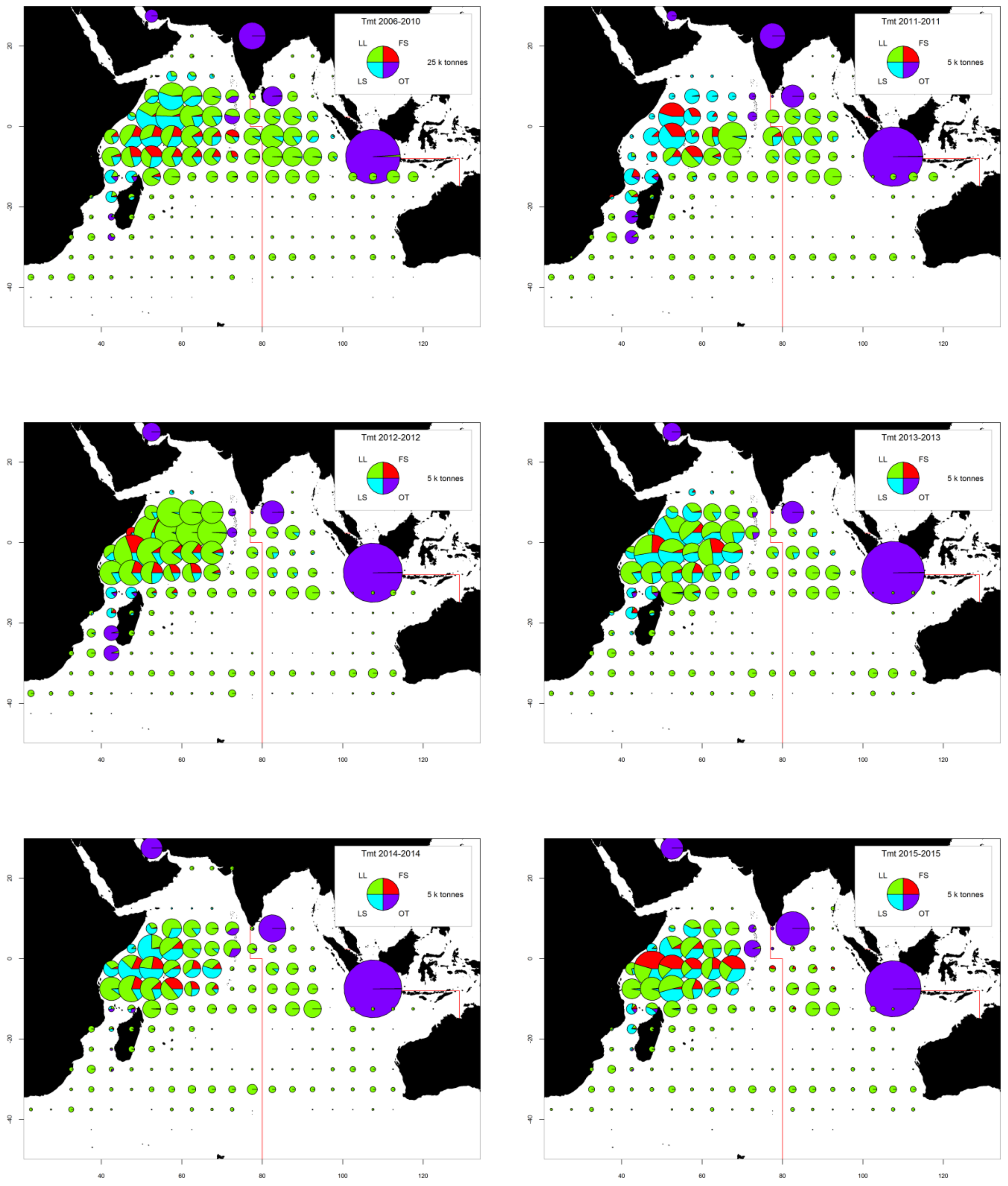


Fig. 7(a-f). Time-area catches (total combined in tonnes) of bigeye tuna estimated for the period 2006–2010 by type of gear and for 2011–15, by year and type of gear. Longline (LL), Purse seine free-schools (FS), Purse seine associated-schools (LS), and other fleets (OT), including pole-and-line, drifting gillnets, and various coastal fisheries.
The catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded within the area of the countries concerned, in particular driftnets from I.R. Iran, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Indonesia.

Bigeye tuna: data availability and related data quality issues

Retained catches

- Data are considered to be relatively reliable for the main industrial fleets targeting bigeye tuna, with the proportion of catches estimated or adjusted by the IOTC Secretariat relatively low (**Fig. 8a**).
- Catches are less certain for the following fisheries/fleets:
  - Non-reporting industrial purse seiners and longliners (NEI) and other industrial fisheries (e.g. longliners of India).
  - Some artisanal fisheries, including: pole-and-line fishery in Maldives, drifting gillnet fisheries of I.R. Iran (before 2012) and Pakistan, Sri Lanka (gillnet-longline fishery) and the artisanal fisheries in Indonesia, Comoros (before 2011) and Madagascar.

Catch-per-unit-effort (CPUE) trends

- Availability: Standardized CPUE series are available for the major industrial longline fisheries (i.e., Japan, Rep. of Korea, Taiwan,China).

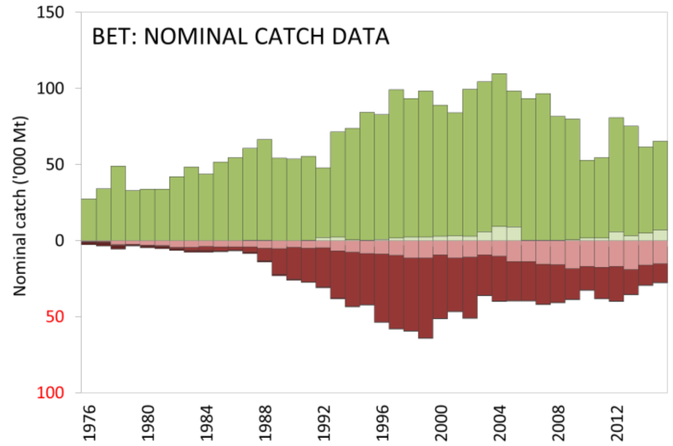
  For most other fisheries, catch-and-effort are either not available (**Fig. 8b**), or are considered to be of poor quality – especially since the early-1990s and for the following fisheries/fleets:
  - NEI purse seine and longliners: no data available.
  - Fresh-tuna longline fisheries: no data are available for the fresh-tuna longline fishery of Indonesia, while data for the fresh-tuna longline fishery of Taiwan,China are only available since 2006;
  - Other industrial fisheries: uncertain data from significant fleets of industrial purse seiners from I.R. Iran, and longliners from India, Indonesia, Malaysia, Oman, and Philippines;
  - Artisanal/coastal fisheries: incomplete or missing data for the driftnet fisheries of I.R. Iran and Pakistan, and the gillnet-longline fishery of Sri Lanka, especially in recent years.

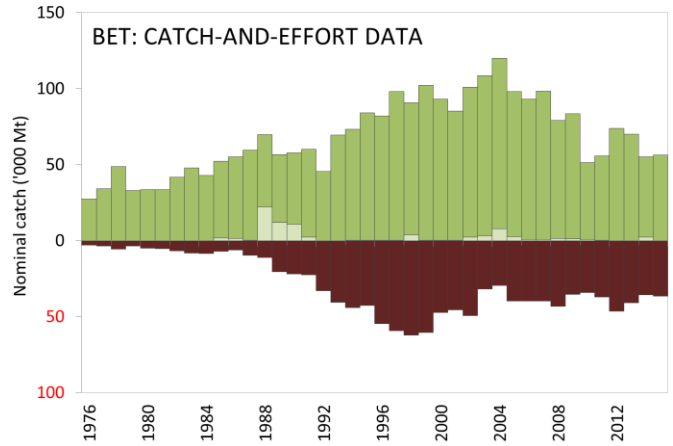
Fish size or age trends (e.g., by length, weight, sex and/or maturity)

- Average fish weight: can be assessed for several industrial fisheries although they are incomplete (**Fig. 8c**) or of poor quality for most fisheries before the mid-1980s and for some fleets in recent years (e.g. Japan and Taiwan,China longline) .
- Catch-at-Size (Age) table: data are available, but the estimates are more uncertain for some years and some fisheries due to:

  i. lack 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 and Taiwan,China).

  ii. lack of size data available for some industrial fleets (NEI, India, Indonesia, I.R. Iran, Sri Lanka).





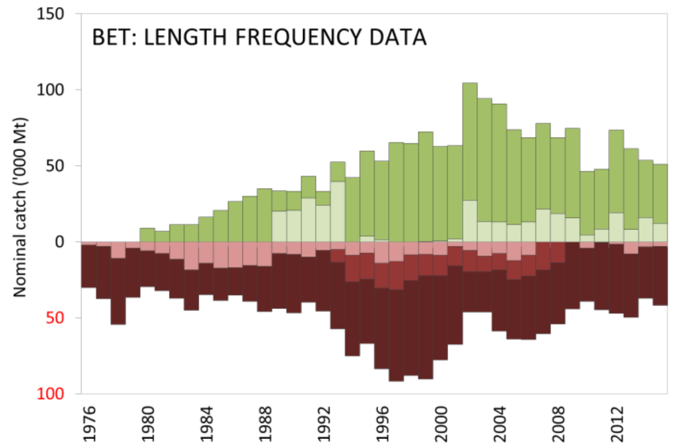


Fig. 8a-c. Bigeye tuna: data reporting coverage (1976–2015).

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

Data as of September 2016.

IOTC Data reporting score:

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

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

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

* E.g., Catch-and-effort not fully disaggreaged by species, gear, area, or month.

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

* E.g., Size data not fully available by species, gear, gear, month, or recommended size interval.

Key to colour coding

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

Bigeye tuna: Tagging data

- A total of 35,997 bigeye tuna (17.9%) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP). Most of them (96.0%) were tagged during the main Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) and released off the coast of Tanzania in the western Indian Ocean, between May 2005 and September 2007 (**Fig. 9**). The remaining were tagged during small-scale projects, and by other institutions with the support of the IOTC Secretariat, in the Maldives, Indian, and in the south west and the eastern Indian Ocean.
- To date, 5,824 specimens (16.2% of releases for this species) have been recovered and reported to the IOTC Secretariat[7]. These tags were mainly reported from the purse seine fleets operating in the Indian Ocean (90.7%), while 5.4% were recovered from longline vessels.

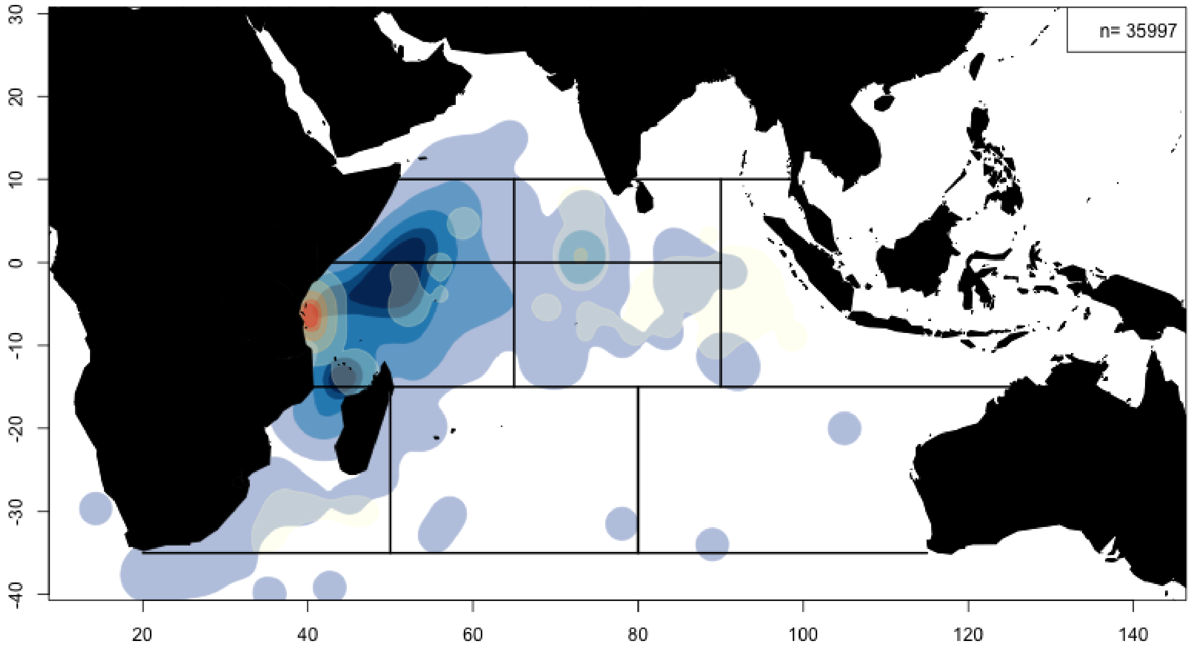


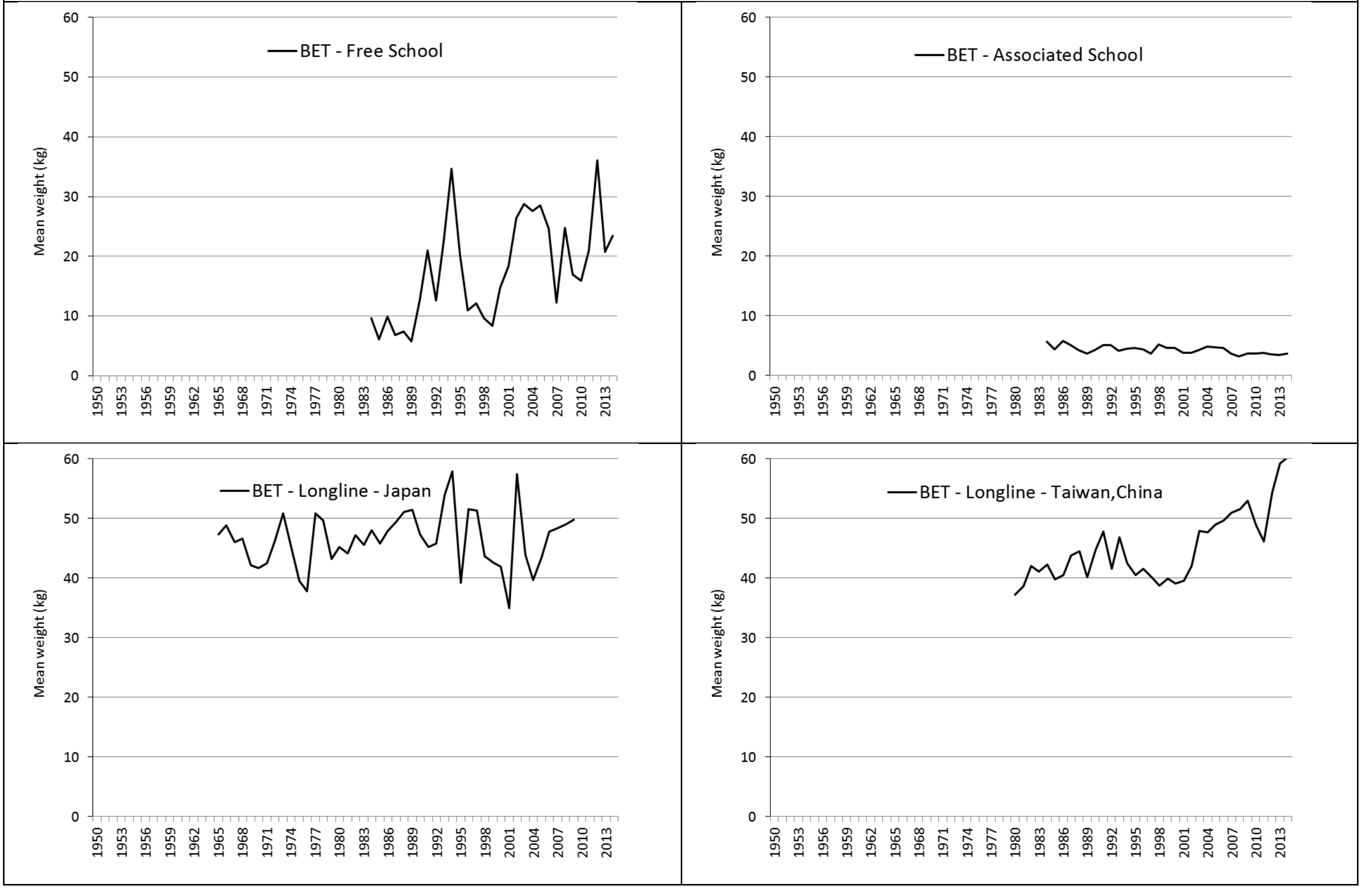
Fig. 9. Bigeye tuna: densities of releases (in red) and recoveries (in blue). The black line represents the stock assessment areas. Includes specimens tagged during the IOTTP and also Indian Ocean (Maldivian) tagging programmes during the 1990s.

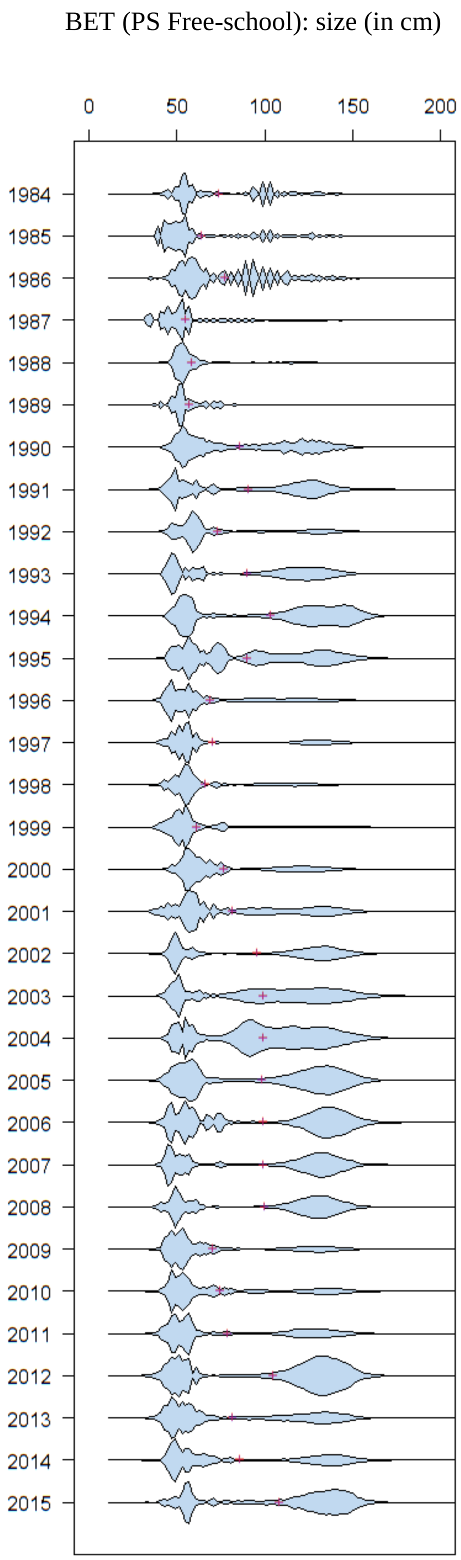
[7] Recoveries by species based on species ID recorded during tagging, prior to release.

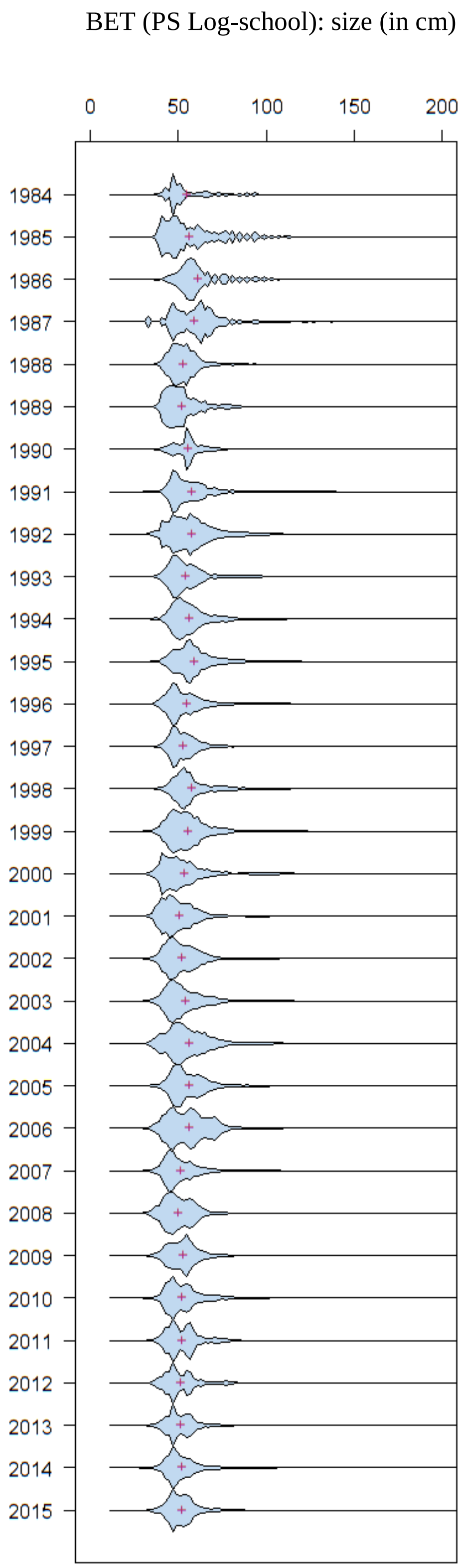
Bigeye tuna (BET)

Average weight of bigeye tuna (BET) taken by:

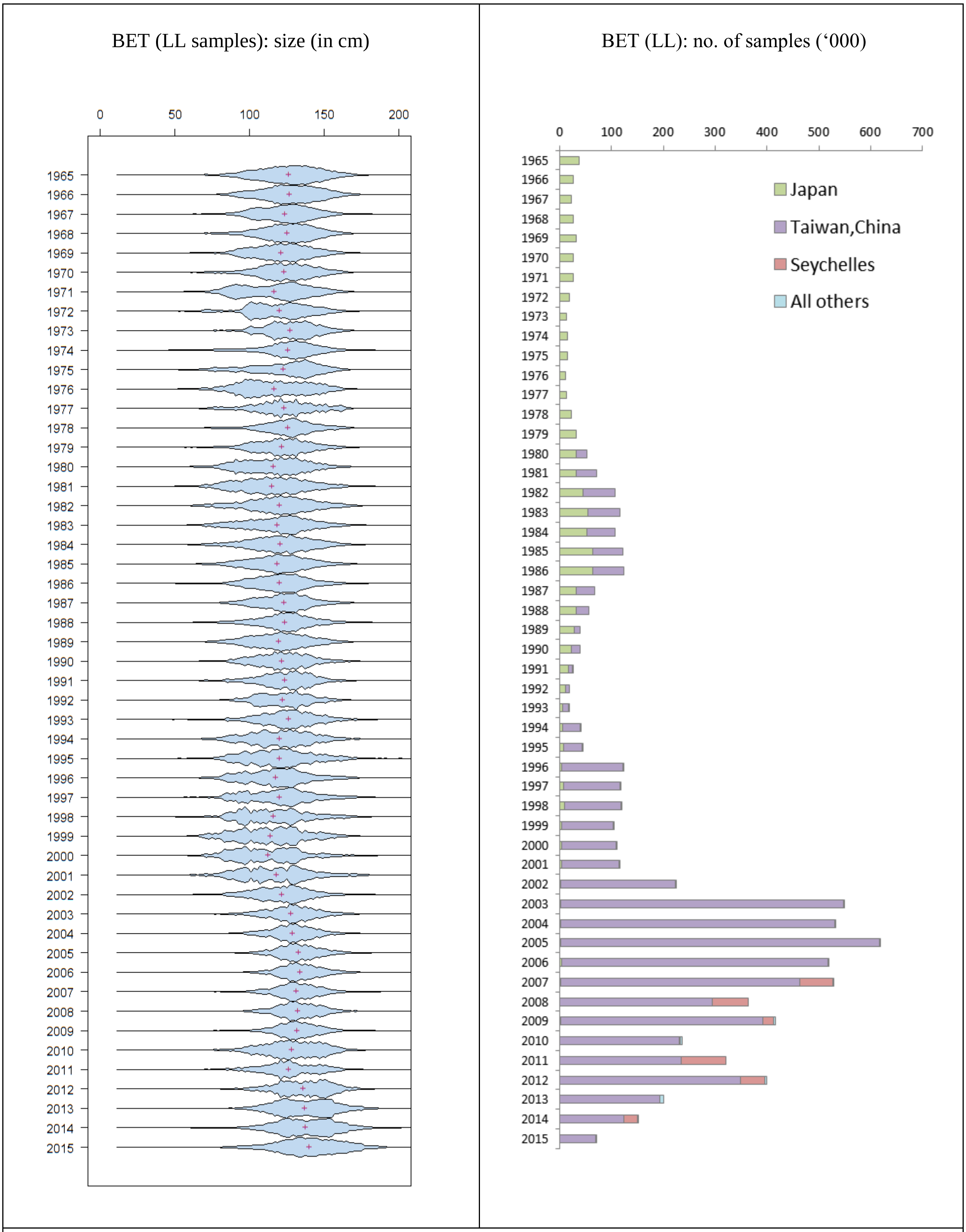
- Purse seine on free (top left) and associated (top right) schools,
- Longlines from Japan (second row left) and Taiwan,China (second row right)
- All fisheries (bottom row left), and all fisheries and main gears (bottom row left)







Bigeye tuna (purse seine): Left: **length frequency distributions for BET PS Free school fisheries (by 2 cm length class).** Right**: Length frequency distributions for BET PS Associated (log) school fisheries (by 2 cm length class). Source: IOTC database.**



Bigeye tuna (longline): Left: **length frequency distributions for longline fisheries (by 2 cm length class) derived from data available at the IOTC Secretariat.** Right**: Number of bigeye tuna specimens sampled for lengths, by fleet (longline only).**

APPENDIX IVC
MAIN STATISTICS OF SKIPJACK TUNA

(Extracts from IOTC–2016–WPTT18–07)

Skipjack tuna (*Katsuwonus pelamis*)

Fisheries and main catch trends

- Main fishing gear (2012–15): skipjack tuna are mostly caught by industrial purse seiners (≈39%), gillnet (≈26%) and pole-and-line (≈21%) (**Table 4; Fig. 10**).

- Main fleets (and primary gear associated with catches): percentage of total catches (2012–15):

  Almost 70% of catches are accounted for by four fleets (**Fig. 12**):

  - Indonesia (coastal purse seine, troll line, gillnet): 21%; Maldives (pole-and-line): 17%; Sri Lanka (gillnet-longline): 15%; EU-Spain (purse seine): 15%.

- Main fishing areas:

  Primary: Western Indian Ocean (West R2), in waters off Somalia (**Table 5; Fig.11**)

  - In recent years catches of skipjack in this area have dropped considerably as fishing effort has been displaced or reduced due to piracy – particularly catches from industrial purse seiners and fleets using driftnets flagged under I.R. Iran and Pakistan.

  Secondary: Maldives (Area R2b)

  - Since the mid-2000s decreases in skipjack catches have also been reported by the Maldivian pole-and-line fishery – although the reasons remain unclear, but may possibly be related to a change in targeting to yellowfin tuna.

- Retained catch trends:

  Purse seine fisheries:

  The increase in catches of skipjack tuna in the last 30 years have largely been driven by the arrival of purse seiners in the early 1980s, and the development of the fishery in association with Fish Aggregating Devices (FADs) since the 1980s. In recent years, well over 90% of the skipjack tuna caught by purse seine vessels are taken from around FADs.

  Annual catches peaked at over 600,000 t in 2006. The constant increase in catches and catch rates of purse seiners until 2006 are believed to be associated with increases in fishing power and also an increase in the number of FADs (and technology associated with them) used in the fishery.

  Since 2006 catches have declined to around 340,000 t in 2012 – the lowest catches recorded since 1998 – although catches since 2013 have ranged between 390,000 t to 425,000 t.

  Pole-and-line fisheries:

  The Maldivian pole-and-line fishery effectively increased its fishing effort with the mechanisation of its fleet since 1974, including an increase in boat size and power, as well as the use of anchored FADs since 1981. Skipjack tuna represents around 80% of the total catch of Maldives, where catches of skipjack tuna increased regularly between 1980 and 2006 – from around 20,000 t to over 130,000 t.

  Catches of skipjack tuna reported by Maldives pole-and-line have since declined in recent years to as low as 55,000t - less than half the catches taken in 2006 - although the reasons for the decline remain unclear. One explanation may be improvements in the data collection with the introduction of logbooks and more accurate, albeit lower, estimates of skipjack landed; while the introduction of handlines and a shift in targeting from skipjack tuna to yellowfin tuna may also be a contributing factor.

  Gillnet fisheries:

Several fisheries using gillnets have reported large catches of skipjack tuna in the Indian Ocean, including the gillnet/longline fishery of Sri Lanka, driftnet fisheries of I.R. Iran and Pakistan, and gillnet fisheries of Indonesia. In recent years gillnet catches have represented as much as 20% to 30% of the total catches of skipjack tuna in the Indian Ocean. Although it is known that vessels from I.R. 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.

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

Changes to the catch series**:** no major changes to the catch series since the WPTT meeting in 2015.

Table 4. Skipjack tuna: Best scientific estimates of the catches of skipjack tuna (*Katsuwonus pelamis*) by gear and main fleets [or type of fishery] by decade (1950–2009) and year (2006–2015), in tonnes. Catches by decade represent the average annual catch, noting that some gears were not used since the beginning of the fishery. Data as of September 2016.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BB	9,000	12,800	19,275	35,459	67,760	100,496	136,695	95,807	85,584	65,018	71,585	52,489	51,134	72,583	67,301	68,965
FS	0	0	0	13,658	25,197	24,342	32,684	23,567	14,863	9,498	8,708	8,930	2,924	5,625	6,467	7,546
LS	0	0	0	30,673	107,845	153,298	190,553	108,252	117,835	135,797	139,770	120,115	77,992	117,046	118,869	118,915
OT	6,015	14,067	27,597	49,997	118,867	198,114	256,228	237,993	220,143	227,486	203,928	201,671	206,667	239,038	228,793	198,529
Total	**15,015**	**26,867**	**46,872**	**129,788**	**319,670**	**476,251**	**616,161**	**465,620**	**438,425**	**437,799**	**423,991**	**383,205**	**338,718**	**434,292**	**421,430**	**393,955**

Gears: Pole-and-Line (**BB**); Purse seine free-school (**FS**); Purse seine associated school (**LS**); Other gears nei (**OT**) (e.g., troll line, handline, beach seine, Danish seine, liftnet).

Table 5. Skipjack tuna: Best scientific estimates of the catches of skipjack tuna (*Katsuwonus pelamis*) by area [as used for the assessment] by decade (1950–2009) and year (2006–2015), in tonnes. Catches by decade represent the average annual catch. Data as of September 2016.

	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
R1	4,524	9,951	19,284	34,584	80,744	118,318	109,014	137,692	139,937	151,486	154,434	153,882	149,769	167,639	145,972	130,356
R2	1,492	4,116	8,313	59,744	171,166	257,437	370,451	232,121	212,903	221,295	197,972	176,835	137,814	194,070	208,157	194,633
R2b	9,000	12,800	19,275	35,459	67,760	100,496	136,695	95,807	85,584	65,018	71,585	52,489	51,134	72,583	67,301	68,965
Total	**15,015**	**26,867**	**46,872**	**129,788**	**319,670**	**476,251**	**616,161**	**465,620**	**438,425**	**437,799**	**423,991**	**383,205**	**338,718**	**434,292**	**421,430**	**393,954**

Areas: East Indian Ocean (**R1**); West Indian Ocean, (**R2**); Maldives baitboat (R2b).

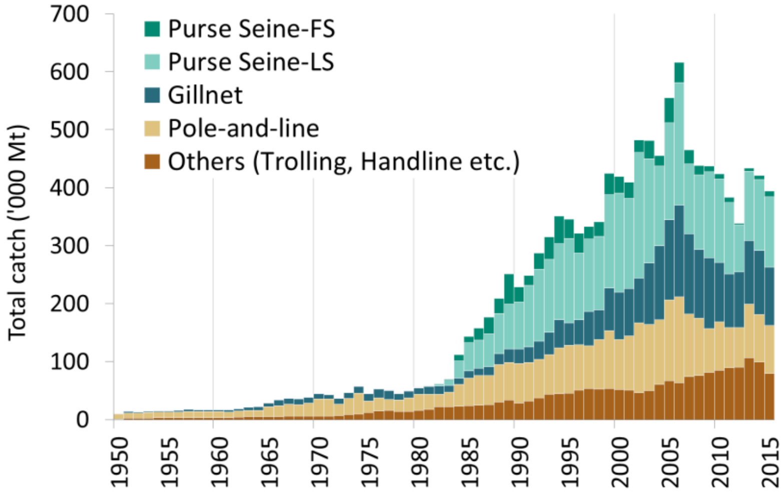


Fig. 10. Annual catches of skipjack tuna by gear (1950–2015). Data as of October 2016.

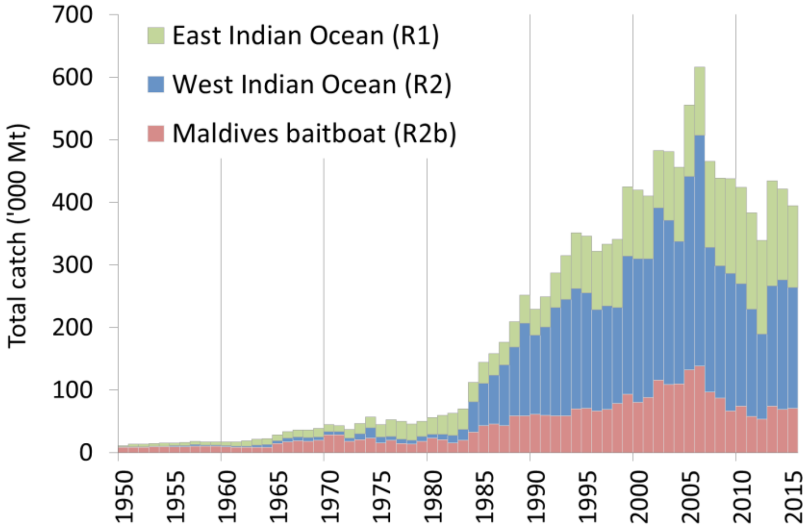


Fig. 11. Skipjack tuna: Catches of skipjack tuna by area by year estimated for the WPTT (1950–2015). **Areas**: East Indian Ocean (**R1**); West Indian Ocean (**R2**); Maldives baitboat (**R2b**). Data as of September 2016.

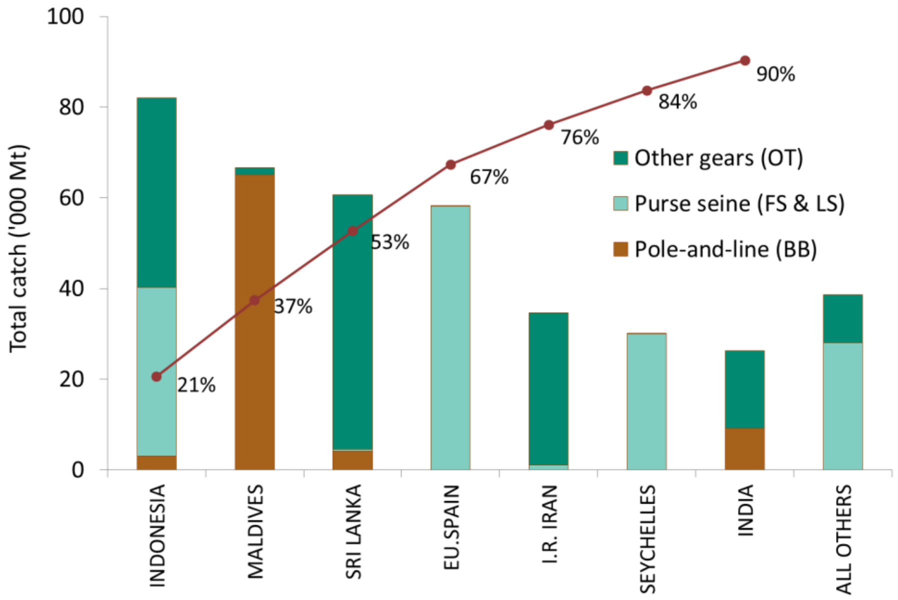


Fig. 12. Skipjack tuna: average catches in the Indian Ocean over the period 2012–15, by country. Countries are ordered from left to right, according to the importance of catches of skipjack reported. The red line indicates the (cumulative) proportion of catches of skipjack for the countries concerned, over the total combined catches of this species reported from all countries and fisheries. Data as of October 2016.

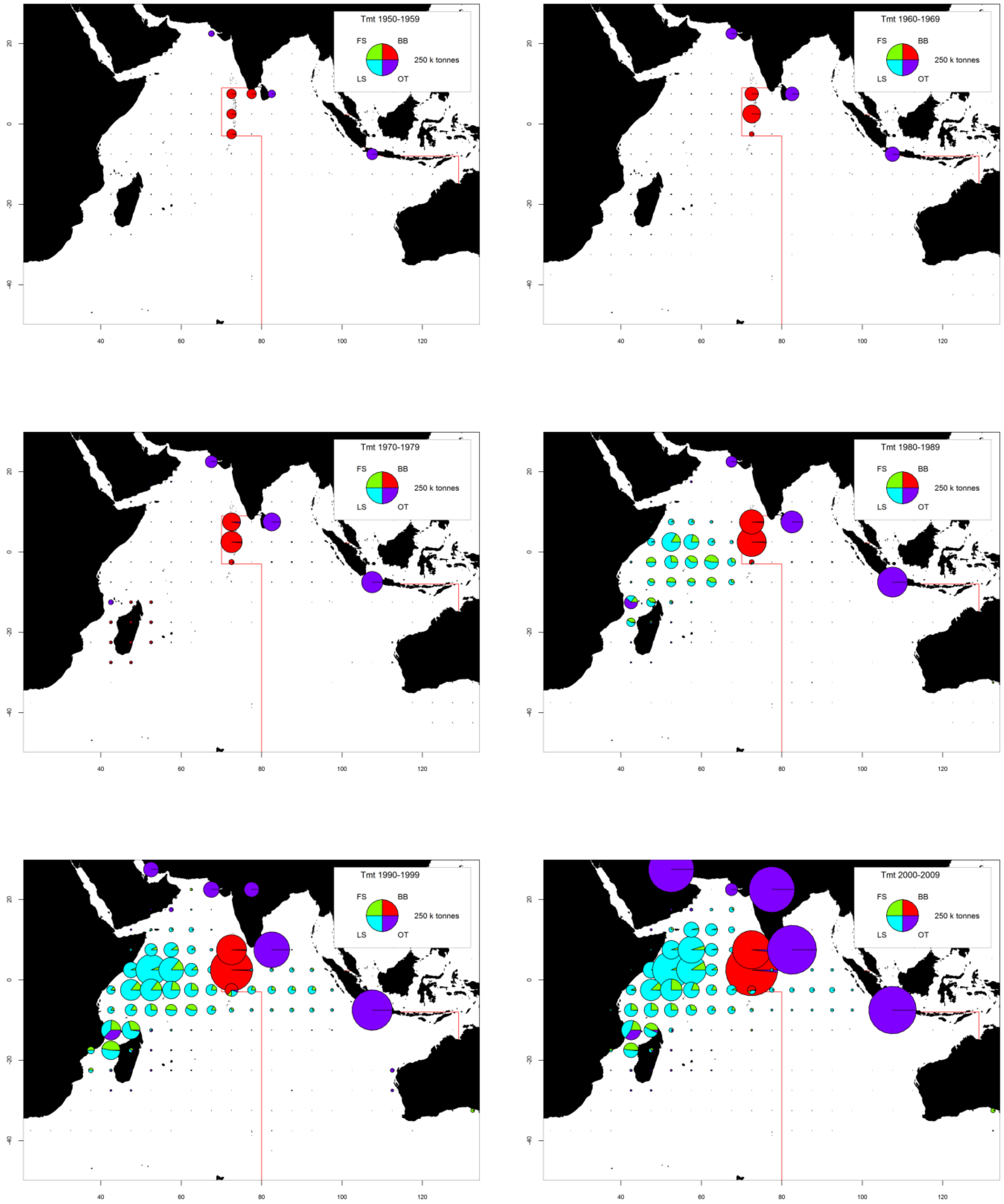


Fig. 13(a-f). Skipjack tuna: Time-area catches (total combined in tonnes) of skipjack tuna estimated for the period 1950–2009, by decade and type of gear. Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including longline, drifting gillnets, and various coastal fisheries.

The catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded within the area of the countries concerned, in particular driftnets from I.R. Iran and Pakistan, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Comoros, Indonesia and India.

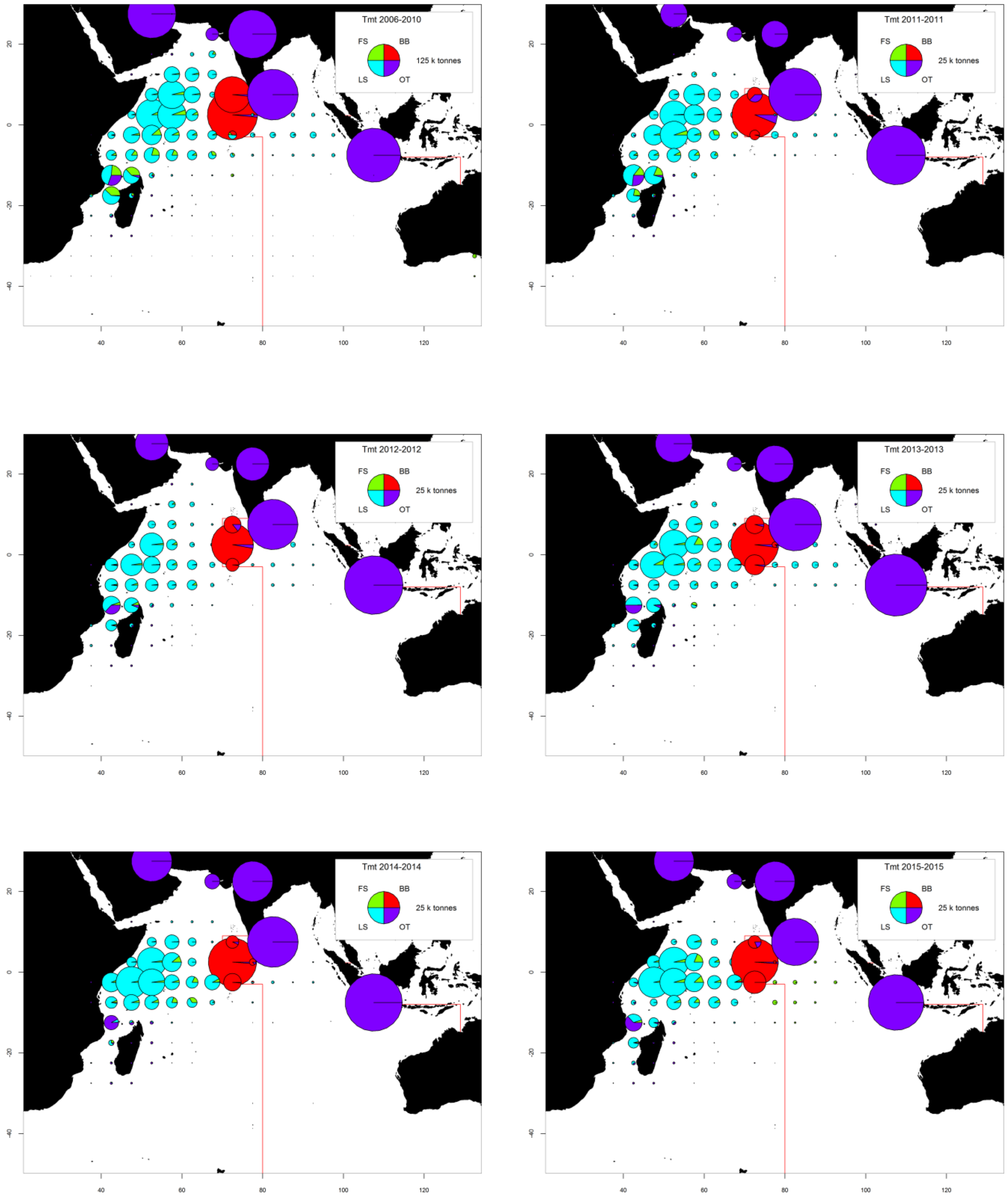


Fig. 14(a-f). Skipjack tuna: Time-area catches (total combined in tonnes) of skipjack tuna estimated for the period 2006–10 by type of gear and for 2011–15, by year and type of gear. Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (BB), and other fleets (**OT**), including longline, drifting gillnets, and various coastal fisheries.

Catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded within the area of the countries concerned, in particular driftnets from I.R. Iran and Pakistan, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Comoros, Indonesia and India.

Skipjack tuna: data availability and related data quality issues

Retained catches

- Retained catches are considered to be generally well known for the major industrial fleets, with the proportion of catches estimated, or adjusted, by the IOTC Secretariat relatively low (**Fig. 15a**). Catches are less certain for many artisanal fisheries for a number of reasons, including:
  - catches not fully reported by species;
  - uncertainty in the catches from some significant fleets including the Sri Lankan coastal fisheries, and coastal fisheries of Comoros and Madagascar.

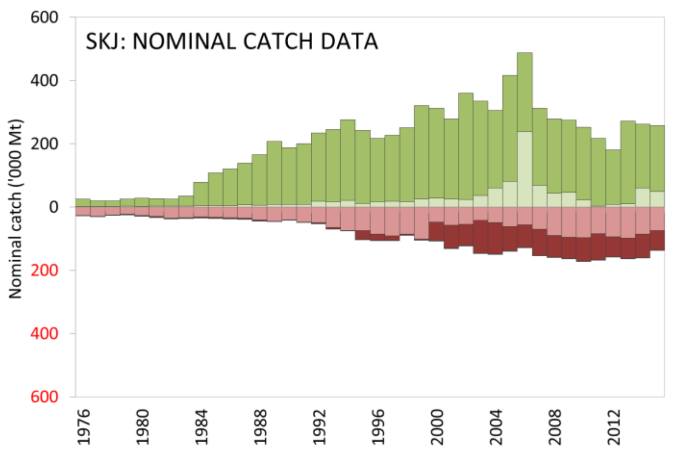
Catch-per-unit-effort (CPUE) trends

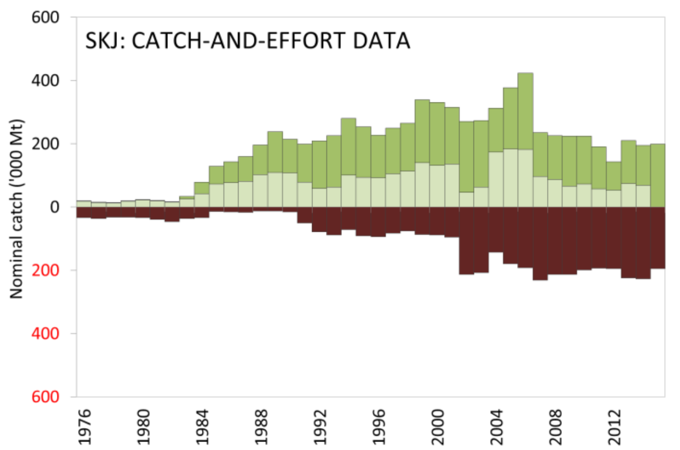
- Catch-and-effort series are available for the various industrial and artisanal fisheries (e.g., Maldives pole-and-line fishery, EU-France purse seine).

  However for a number of other important fisheries catch-and-effort are either not available (**Fig. 15b**), or are considered to be of poor quality, notably:
  - ➢ insufficient data available for the gillnet fisheries of I.R. Iran and Pakistan;
  - ➢ poor quality effort data for the gillnet-longline fishery of Sri Lanka. In previous years catch-and-effort has not been reported fully by area, or disaggregated by gear (i.e., gillnet-longline) according to the IOTC reporting standards – however in 2014 detailed information by EEZ area (for coastal fisheries) and grid area (for offshore fisheries) and gear was submitted to the IOTC Secretariat for the first time;
  - ➢ no catch-and-effort data are available for important coastal fisheries using hand and/or troll lines, in particular Indonesia, India and Madagascar.

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

- Average fish weight: trends in average weights cannot be assessed before the mid-1980s and are also incomplete for most artisanal fisheries, namely hand lines, troll lines and many gillnet fisheries (e.g., Indonesia) (**Fig. 15c**).
- Catch-at-Size (Age) table: are available but the estimates are uncertain for some years and fisheries due to:
  - ➢ a general lack of size data before the mid-1980s, for all fleets/fisheries;
  - ➢ lack of size data available for some artisanal fisheries, notably most hand lines and troll line fisheries (e.g., Madagascar, Comoros) and many gillnet fisheries (e.g., Indonesia, Sri Lanka) – although in 2014 Sri Lanka reported size information for gillnets for the first time since the early-1990s.





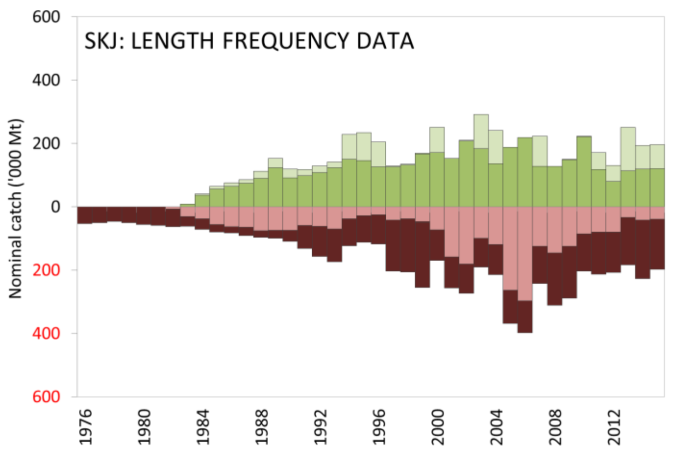


Fig. 15a-c. Skipjack tuna: data reporting coverage (1976–2015).

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

Data as of September 2016.

IOTC Data reporting score:

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

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

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

* E.g., Catch-and-effort not fully disaggreaged by species, gear, area, or month.

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

* E.g., Size data not fully available by species, gear, gear, month, or recommended size interval.

Key to colour coding

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

Skipjack tuna: Tagging data

- A total of 101,212 skipjack (representing 50.2% of the total number of fish tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP). Most of them, 77.4%, were released during the main Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) and were released around Seychelles, in the Mozambique Channel and off the coast of Tanzania, between May 2005 and September 2007 (**Fig. 16**). The remaining were tagged during small-scale tagging projects, and by other institutions with the support of IOTC, around the Maldives, India, and in the south west and the eastern Indian Ocean.
- To date, 17,667 specimens (17.5% of releases for this species), have been recovered and reported to the IOTC Secretariat. Around 69.6% of the recoveries were from the purse seine fleets operating from the Seychelles, and around 28.8% by the pole-and-line vessels mainly operating from the Maldives. The addition of the data from the past projects in the Maldives (in 1990s) added 14,506 tagged skipjack tuna to the databases, or which 1,960 were recovered mainly in the Maldives.

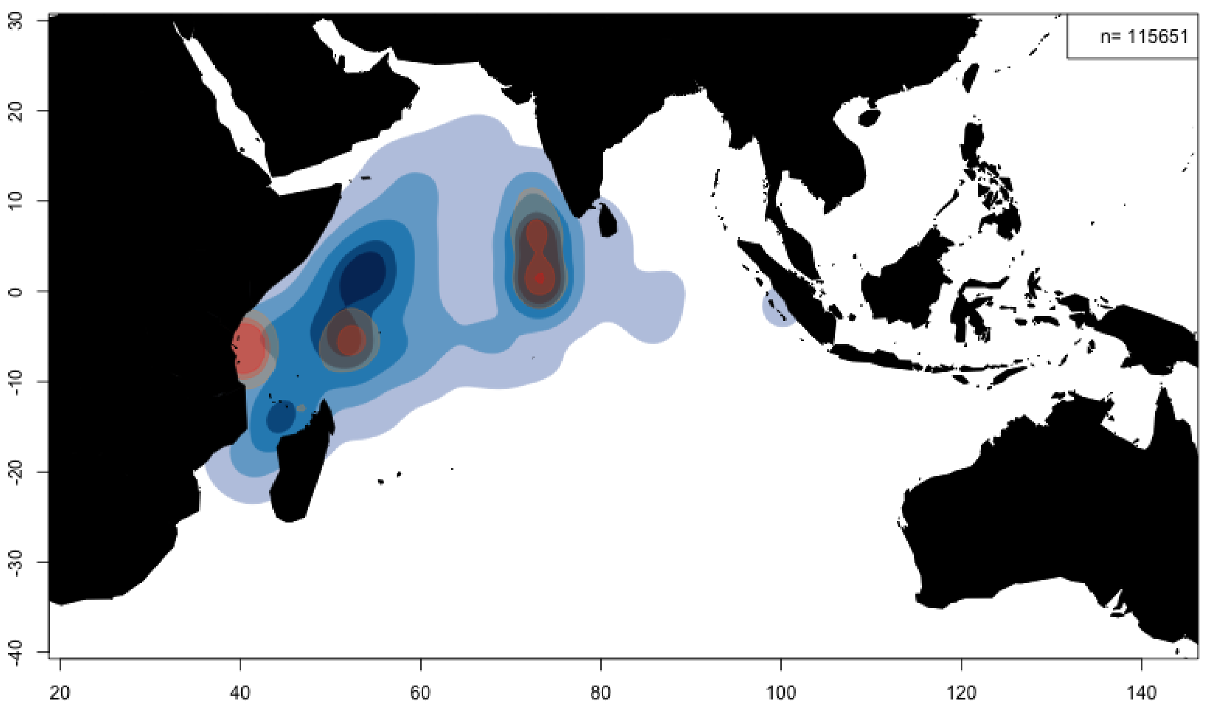
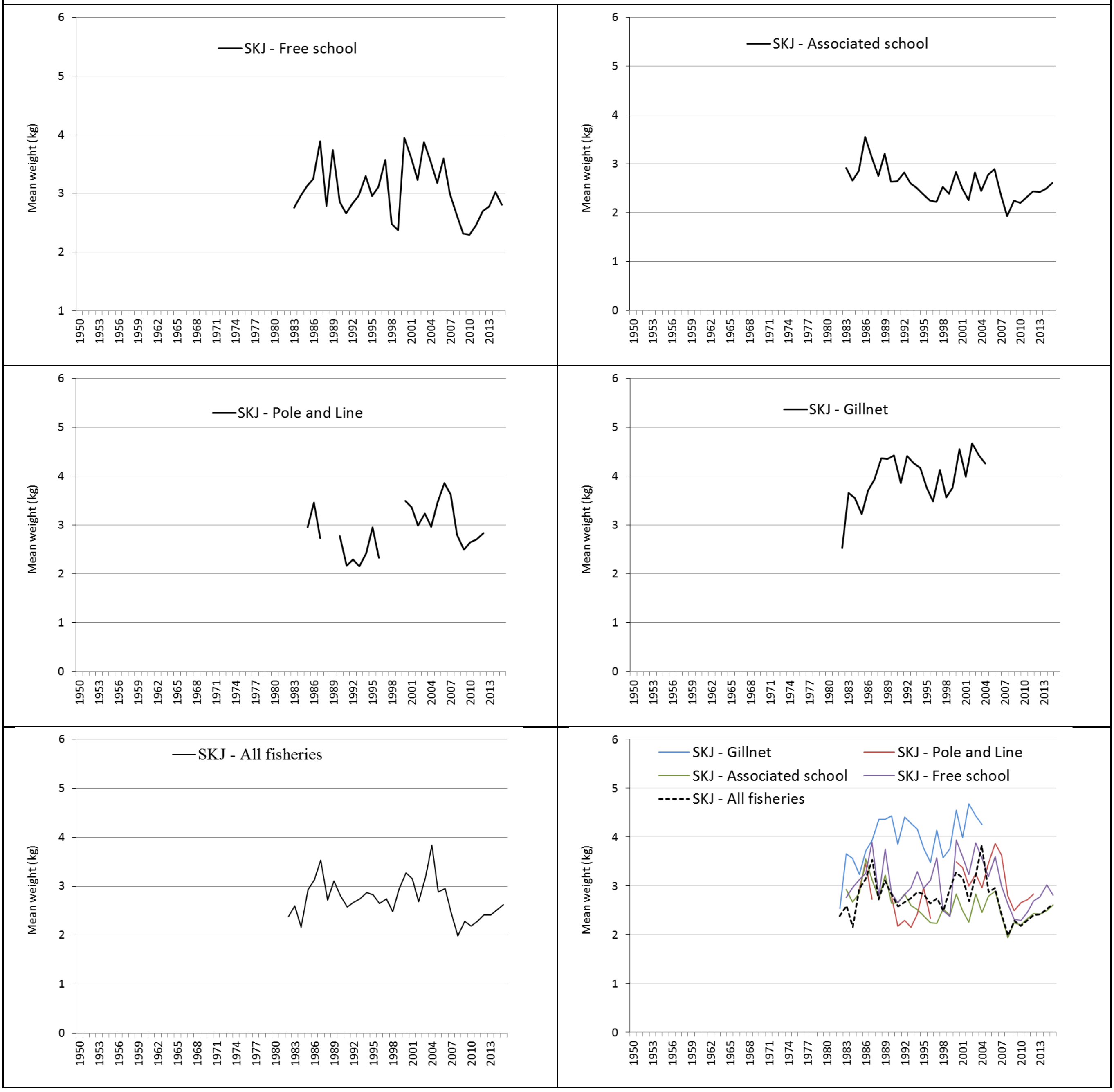


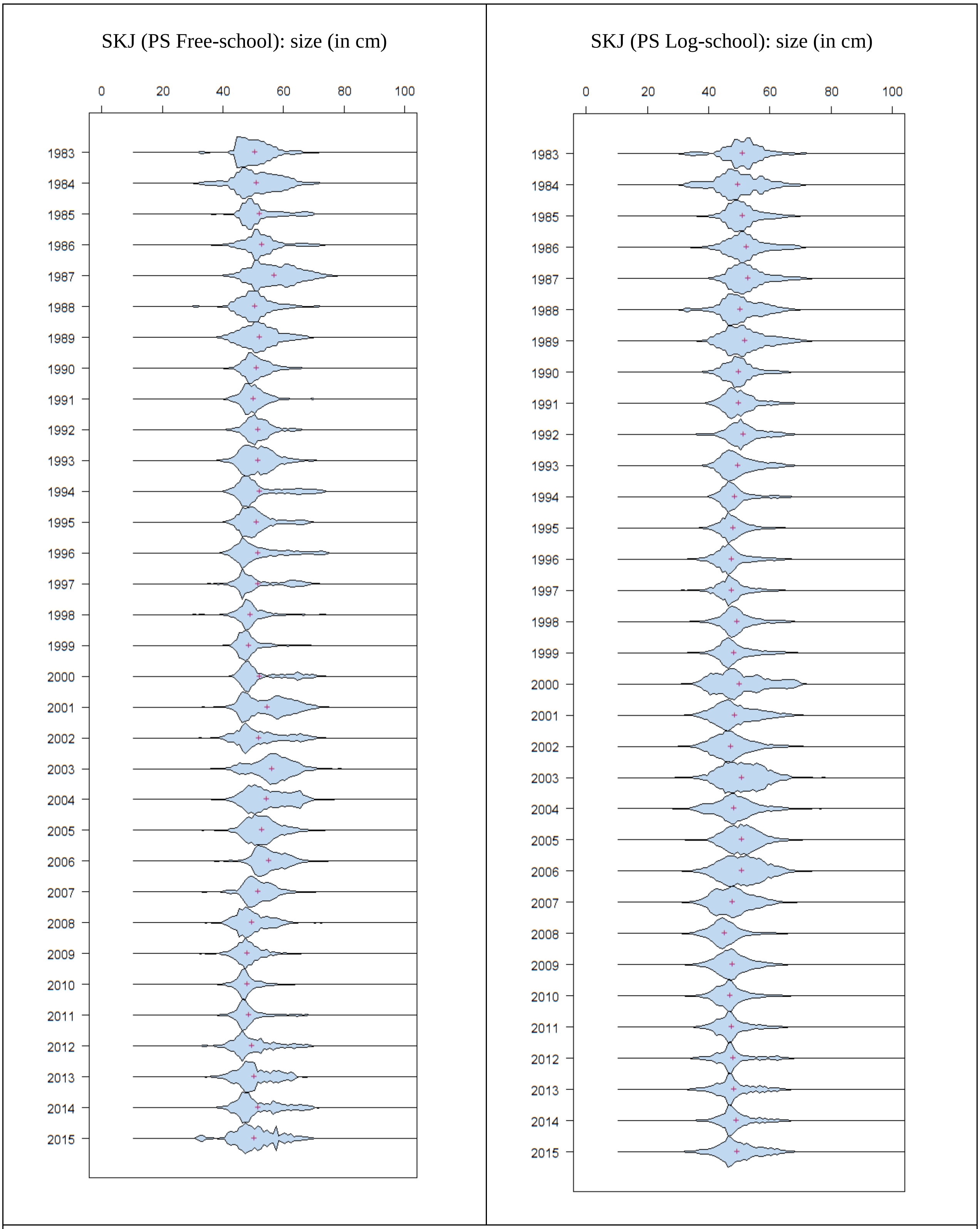
Fig. 16. Skipjack tuna: Densities of releases (in red) and recoveries (in blue). Includes specimens tagged during the IOTTP and also Indian Ocean (Maldivian) tagging programmes during the 1990s.

Skipjack tuna (SKJ)

Average weight of skipjack tuna (SKJ) taken by:

- Purse seine on free (top left) and associated (top right) schools,
- Pole-and-line from Maldives and India (second row left), and gillnets from Sri Lanka, Iran, and other countries (second row right)
- All fisheries (bottom row left), and all fisheries and main gears (bottom row left)





Skipjack tuna (purse seine): **Left:** length frequency distributions for SKJ PS Free school fisheries (by 2 cm length class). **Right**: Length frequency distributions for SKJ PS Associated (log) school fisheries (by 2 cm length class). Source: IOTC database.

APPENDIX IVD
MAIN STATISTICS OF YELLOWFIN TUNA

(Extracts from IOTC–2016–WPTT18–07)

Fisheries and main catch trends

- Main fishing gear (2012–15): In recent years catches have been evenly split between industrial and artisanal fisheries. Purse seiners (free and associated schools) and longline fisheries still account for around 50% of total catches, while catches from artisanal gears – namely handline, gillnet, and pole-and-line – have steadily increased since the 1980s (**Table 6**; **Fig. 17**).

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

- Main fleets (and primary gear associated with catches): percentage of total catches (2012–15):

  EU-Spain (purse seine): 15%; Maldives (handline, pole-andline): 12%; Indonesia (fresh longline, handline): 10%; I.R. Iran (gillnet): 9% (**Fig. 19**).

- Main fishing areas: Primary: Western Indian Ocean, around Seychelles and waters off Somalia (Area R2), and Mozambique Channel (Area R3) (**Fig.18**).

- Retained catch trends:

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

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

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

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

  Purse seine fishery:

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

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

  Longline fishery:

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

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

  Changes to the catch series**:** In 2014 catches of yellowfin tuna were revised downwards by approximately 20,000 t (≈5% of total yellowfin catches) due to misreporting of catches by Mayotte, and also revisions to catches catches for other fleets (e.g., Yemen). Otherwise there were no major changes to the catch series since the WPTT meeting in 2014.

Table 6. Yellowfin tuna: Best scientific estimates of the catches of yellowfin tuna (*Thunnus albacares*) by gear and main fleets [or type of fishery] by decade (1950–2009) and year (2006–2015), in tonnes. Catches by decade represent the average annual catch, noting that some gears were not used since the beginning of the fishery. Data as of September 2016.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
FS	-	-	18	31,552	64,938	89,204	85,039	53,527	74,986	36,048	32,136	36,453	64,594	34,457	45,799	67,254
LS	-	-	17	17,597	56,279	61,890	74,601	43,777	41,539	51,352	73,382	76,658	66,165	101,906	88,373	75,879
LL	21,990	41,352	29,589	33,968	66,318	56,879	70,714	51,426	26,038	19,999	18,744	20,667	19,671	16,012	15,654	16,598
LF	141	1,214	2,281	7,721	58,526	55,539	57,138	55,620	58,102	49,884	50,484	43,455	54,642	60,679	61,982	58,534
BB	2,111	2,318	5,810	8,295	12,803	16,072	18,022	16,326	18,280	16,828	14,105	14,010	15,511	24,047	20,501	17,790
GI	1,565	4,108	7,928	11,993	39,540	49,393	62,579	43,510	47,872	41,907	51,121	50,967	63,458	56,159	66,539	67,797
HD	561	555	2,956	7,635	19,480	34,769	34,678	34,636	31,371	28,945	35,003	60,492	79,695	70,227	71,033	80,531
TR	1,092	1,958	4,292	7,327	12,264	16,144	17,371	19,052	16,514	14,611	19,058	18,731	28,551	32,702	30,634	15,950
OT	80	193	454	1,871	3,379	5,402	5,800	6,703	6,556	7,361	7,705	7,872	8,214	8,861	7,996	7,240
Total	**27,539**	**51,698**	**53,345**	**127,960**	**333,524**	**385,292**	**425,942**	**324,577**	**321,258**	**266,935**	**301,738**	**329,305**	**400,501**	**405,050**	**408,511**	**407,573**

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

Table 7. Yellowfin tuna: Best scientific estimates of the catches of yellowfin tuna (*Thunnus albacares*) by area by decade (1950–2009) and year (2006–2015), in tonnes. Catches by decade represent the average annual catch. The areas are presented in Fig. 20(a). Data as of September 2016.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
R1	1,933	4,398	8,671	20,043	75,074	85,385	101,268	78,629	72,123	60,238	71,820	103,549	131,953	118,818	129,634	141,075
R2	12,260	24,036	22,128	73,396	142,289	180,712	202,148	123,070	134,824	99,681	115,068	121,507	145,543	155,463	161,886	165,132
R3	724	7,449	4,283	7,400	21,812	23,591	23,683	23,613	19,907	18,536	18,195	18,909	17,064	20,841	9,601	13,733
R4	918	1,799	1,356	1,085	3,411	2,503	1,864	1,031	577	890	1,413	522	593	833	511	1,269
R5	11,705	14,015	16,909	26,037	90,939	93,100	96,979	98,234	93,827	87,590	95,242	84,818	105,348	109,095	106,879	86,364
Total	**27,539**	**51,698**	**53,345**	**127,960**	**333,524**	**385,292**	**425,942**	**324,577**	**321,258**	**266,935**	**301,738**	**329,305**	**400,501**	**405,050**	**408,511**	**407,573**

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

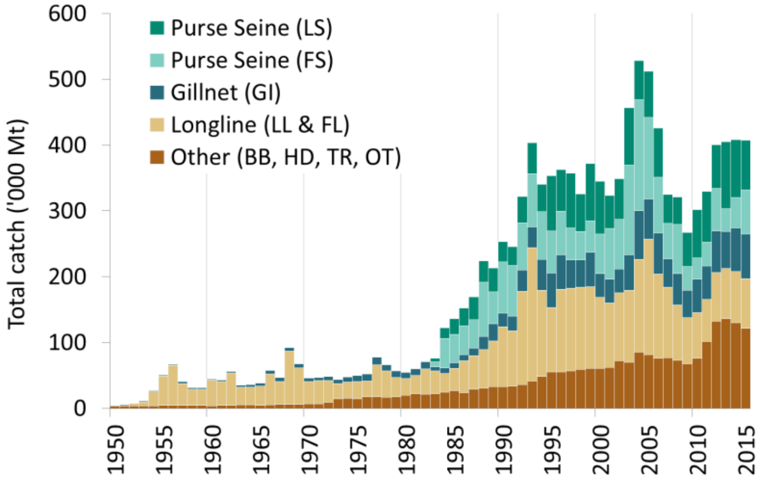


Fig. 17. Annual catches of yellowfin tuna by gear (1950–2015). Data as of September 2016.

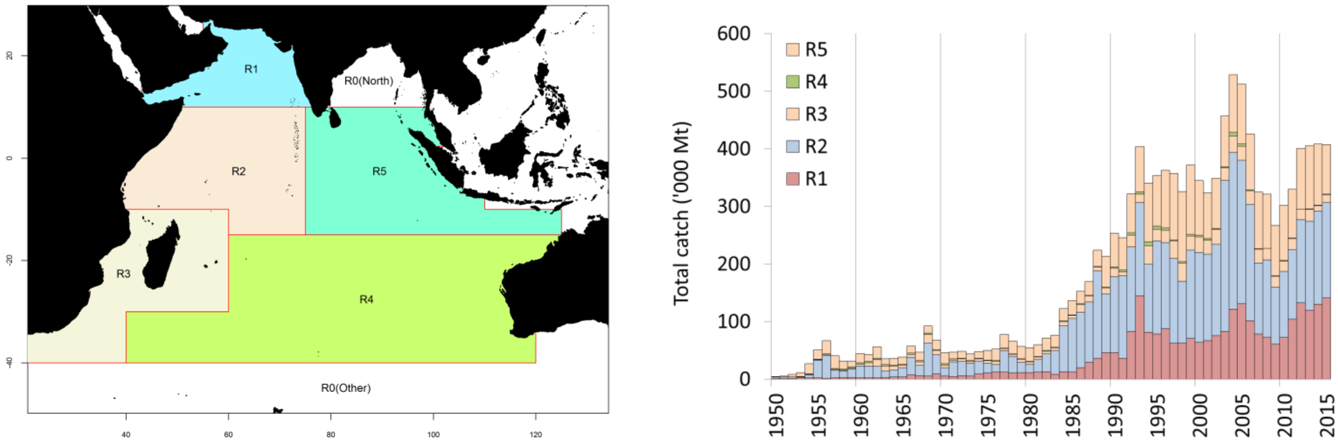


Fig. 18(a-b). Yellowfin tuna: Catches of yellowfin tuna by area by year estimated for the WPTT (1950–2015). Catches in areas R0 were assigned to the closest neighbouring area for the assessment. Data as of September 2016.

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

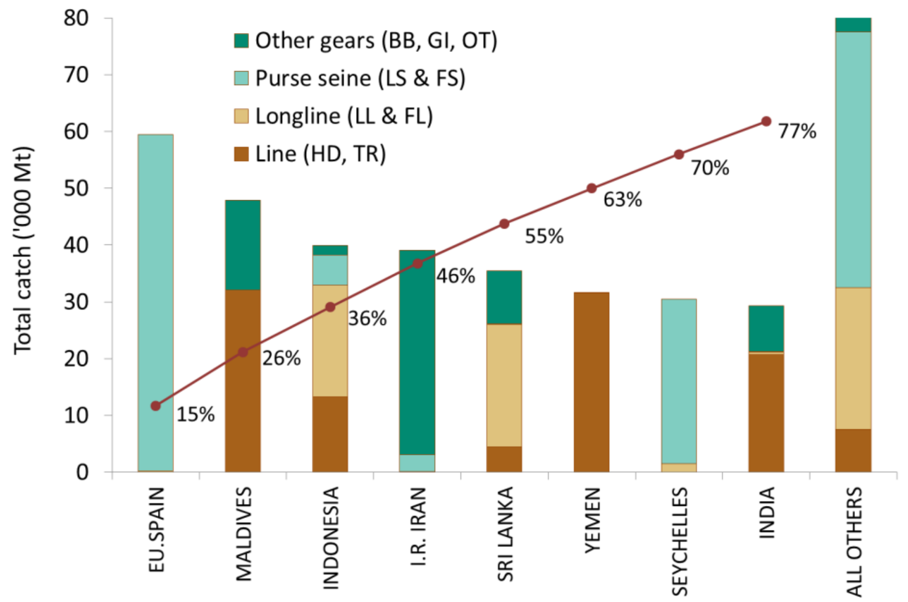


Fig. 19. Yellowfin tuna: average catches in the Indian Ocean over the period 2012–15, by country. Countries are ordered from left to right, according to the importance of catches of yellowfin reported. The red line indicates the (cumulative) proportion of catches of yellowfin for the countries concerned, over the total combined catches of this species reported from all countries and fisheries. Data as of September 2016.

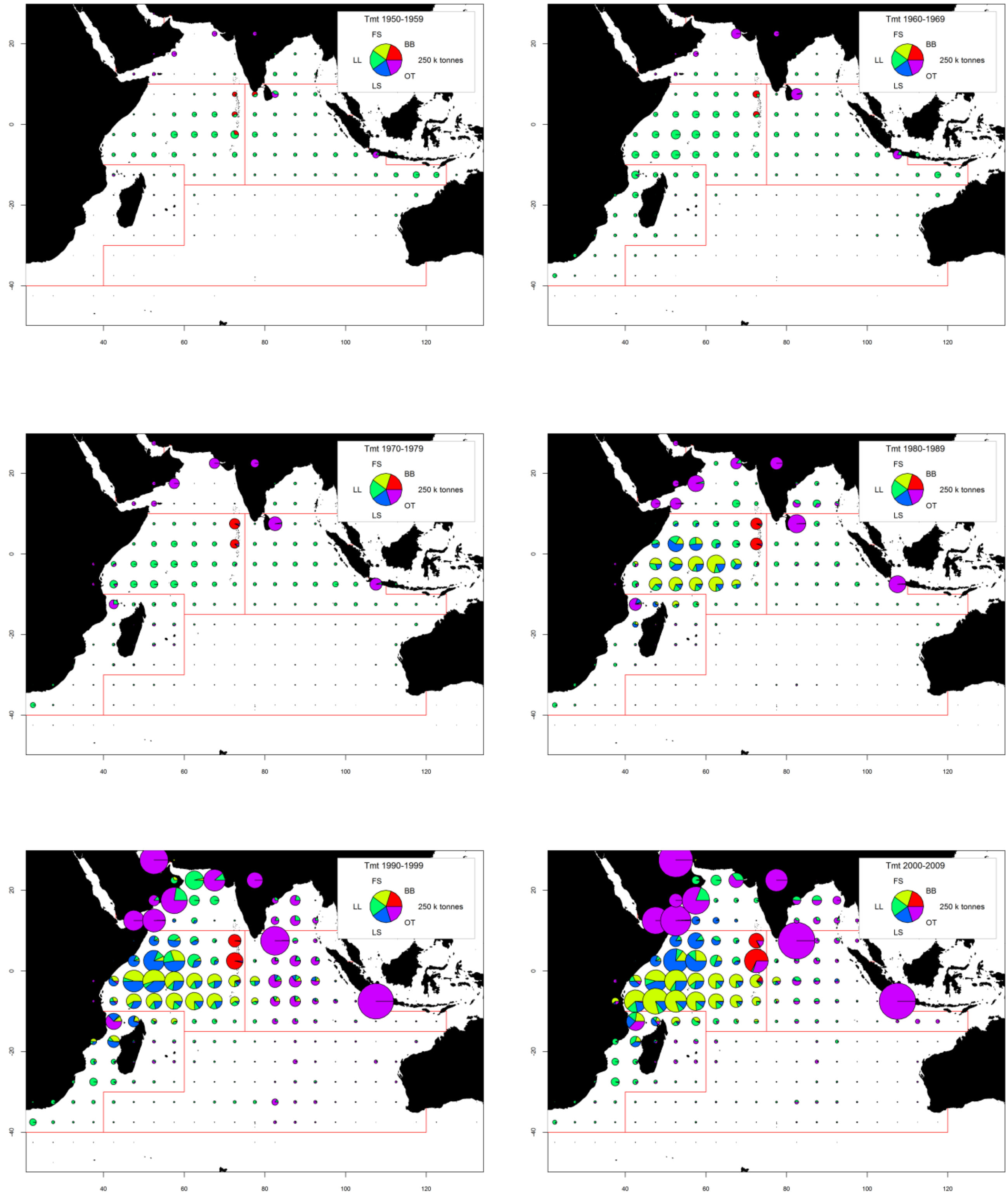


Fig. 20(a-f). Yellowfin tuna: Time-area catches (total combined in tonnes) of yellowfin tuna estimated for the period 1950–2009, by decade and type of gear. Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including drifting gillnets, and various coastal fisheries.

Catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded within the area of the countries concerned, in particular driftnets from I.R. Iran and Pakistan, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Yemen, Oman, Comoros, Indonesia and India.

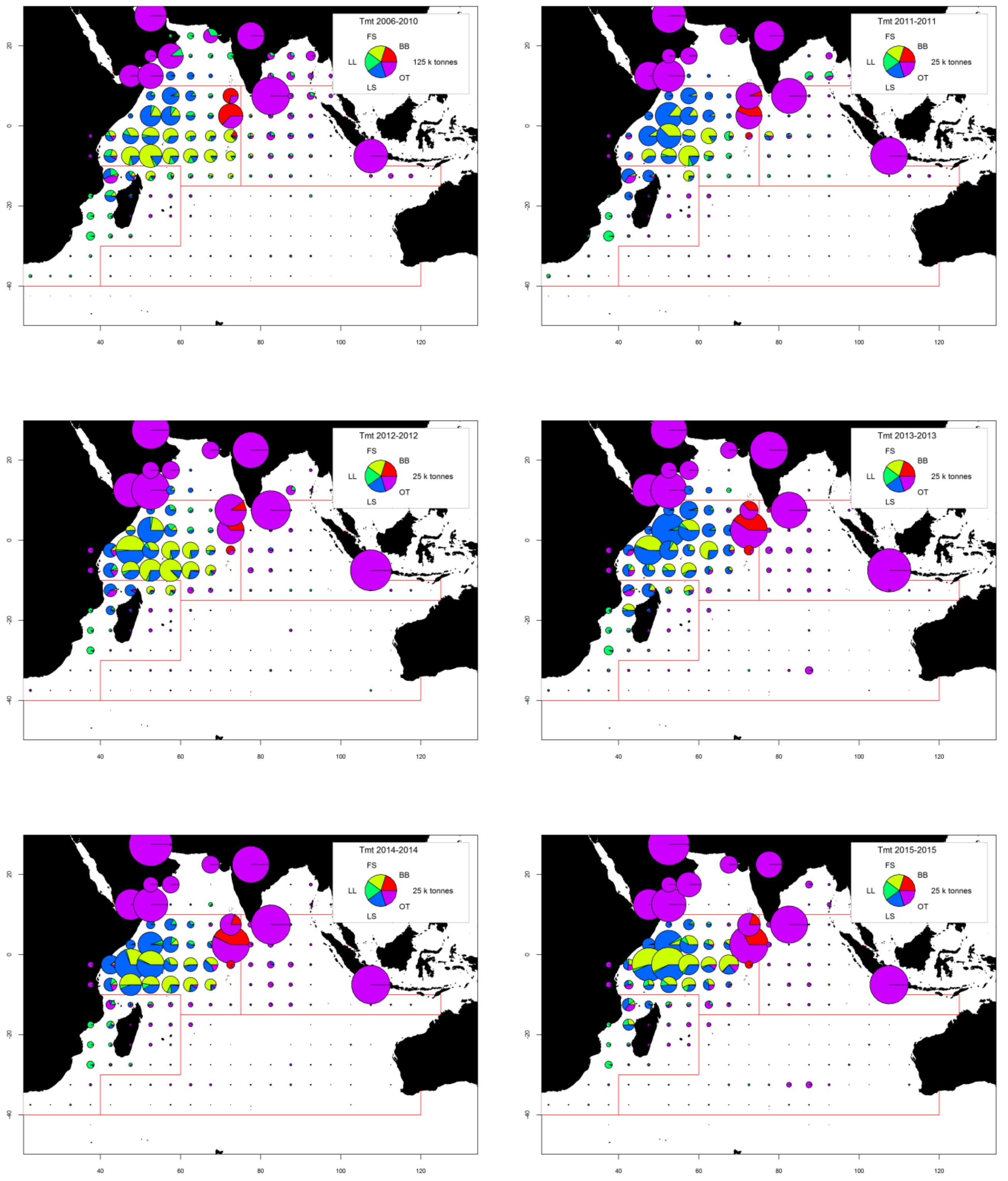


Fig. 21(a-f). Time-area catches (total combined in tonnes) of yellowfin tuna estimated for the period 2006–2010 by type of gear and for 2011–2015, by year and type of gear. Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including drifting gillnets, and various coastal fisheries.

Catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded within the area of the countries concerned, in particular driftnets from I.R. Iran and Pakistan, gillnet and longline fishery of Sri Lanka, and coastal fisheries of Yemen, Oman, Comoros, Indonesia and India.

Yellowfin tuna: data availability and related data quality issues

Retained catches

- Data are considered to be generally well known for the major industrial fisheries, with the proportion of catches estimated, or adjusted, by the IOTC Secretariat relatively low (**Fig. 22a**). Catches are less certain for the following fisheries/fleets:
  - many coastal fisheries, notably those from Indonesia, Sri Lanka, Yemen, and Madagascar;
  - gillnet fishery of Pakistan;
  - Non-reporting industrial purse seiners and longliners (NEI), and longliners of India.

Catch-per-unit-effort (CPUE) trends

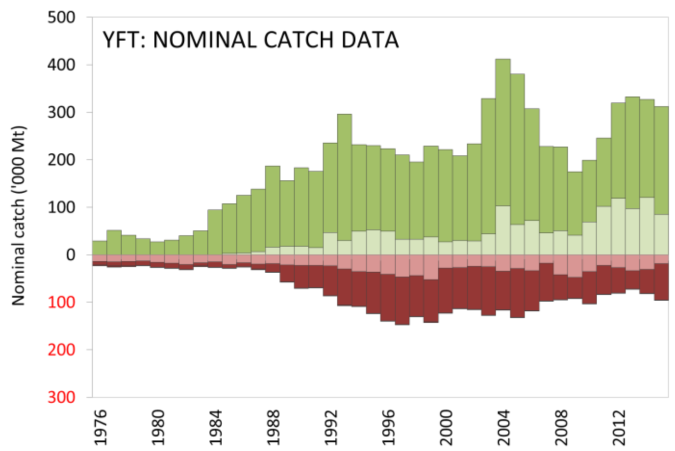
- Availability: Catch-and-effort series are available for the major industrial and artisanal fisheries (e.g., Japan longline, Taiwan,China) (**Fig. 22b**).

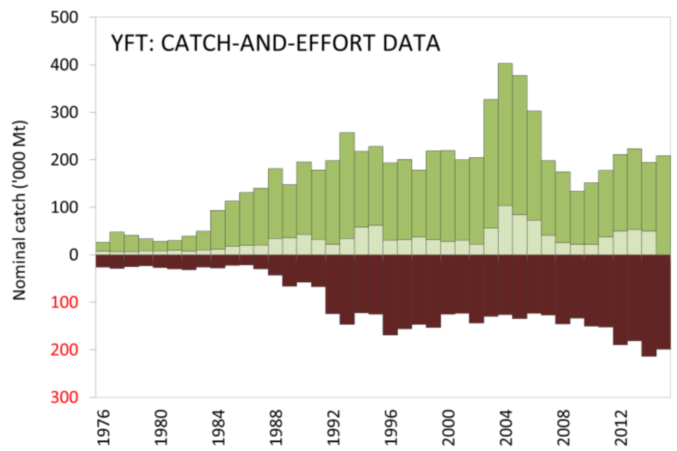
  However, for other important fisheries catch-and-effort are either not available, or are considered to be of poor quality for the following reasons:
  - no data are available for the fresh-tuna longline fishery of Indonesia, over the entire time series, and data for the fresh-tuna longline fishery of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

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

- Average fish weight: trends in average weight 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 (**Fig. 22c**).
  - ➢ Purse seine vessels typically take fish ranging from 40 to 140 cm fork length (FL), while smaller fish are more common in catches taken north of the equator.
  - ➢ Longline gear mainly catches large fish, from 80 to 160 cm FL, although smaller fish in the size range 60 cm – 100 cm (FL) have been taken by longliners from Taiwan,China since 1989 in the Arabian Sea.

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





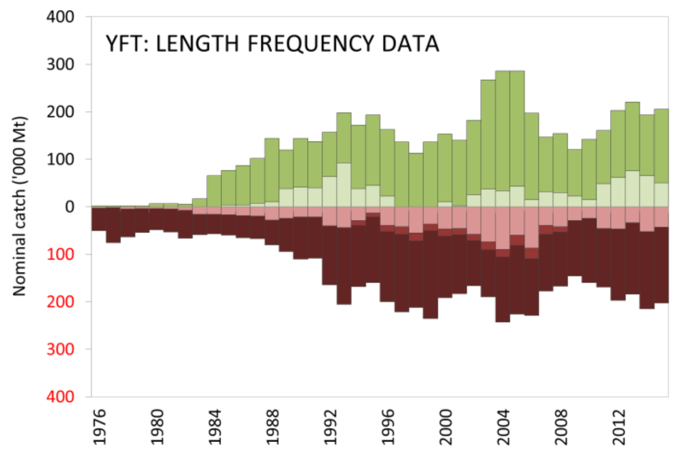


Fig. 22a-c. Yellowfin tuna: data reporting coverage (1976–2015).

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

Data as of September 2016.

<u>IOTC Data reporting score:</u>

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

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

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

* E.g., Catch-and-effort not fully disaggreaged by species, gear, area, or month.

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

* E.g., Size data not fully available by species, gear, gear, month, or recommended size interval.

Key to colour coding

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

Yellowfin tuna: tagging data

- A total of 63,328 yellowfin tuna (representing 31.4% of the total number of specimens tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP). Most of the tagged specimens (86.4%) were released during the main Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) and were released around Seychelles, in the Mozambique Channel, along the coast of Oman and off the coast of Tanzania, between May 2005 and September 2007 (**Fig. 23**). The remaining specimen were tagged during small-scale tagging projects, and by other institutions with the support of IOTC Secretariat, in Maldives, India, and in the south west and the eastern Indian Ocean.
- To date, around 10,840 specimens (17.1%), have been recovered and reported to the IOTC Secretariat. More than 85.9% of these recoveries we made by the purse seine fleets operating in the Indian Ocean, while around 9.1% were made by pole-and-line and less than 1% by longline vessels. The addition of the data from the past projects in the Maldives (in 1990s) added 3,211 tagged yellowfin tuna to the databases, or which 151 were recovered, mainly from the Maldives.

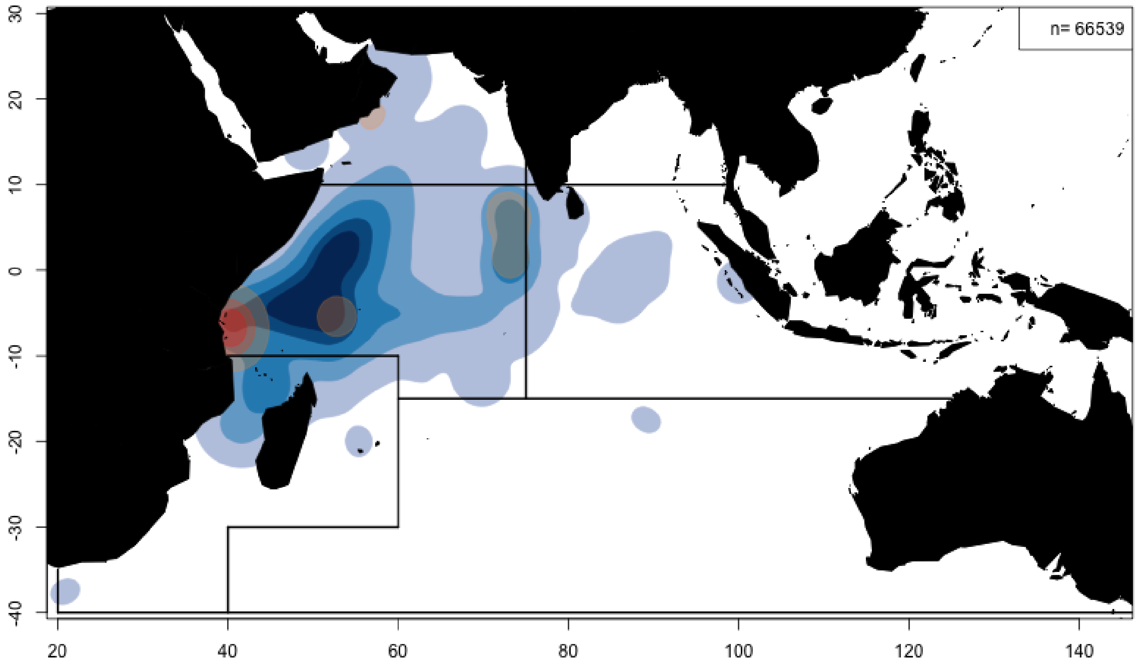
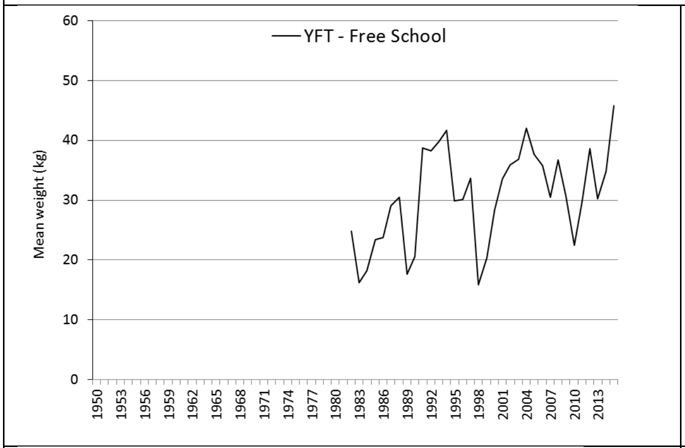


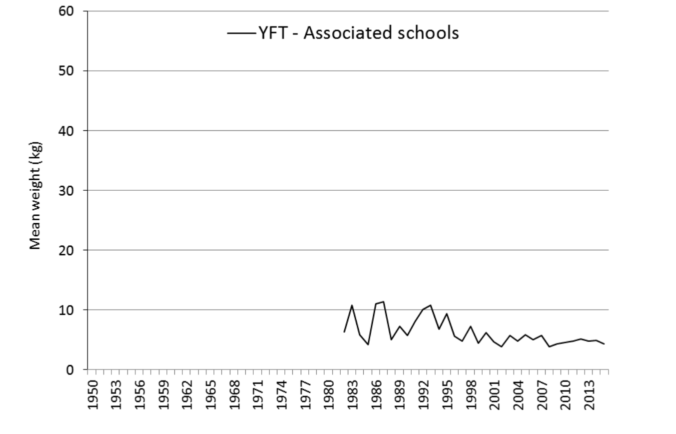
Fig. 23. Yellowfin tuna: Densities of releases (in red) and recoveries (in blue). The black line represents the stock assessment areas. Includes specimens tagged during the IOTTP and also Indian Ocean (Maldivian) tagging programmes during the 1990s. Data as of September 2016.

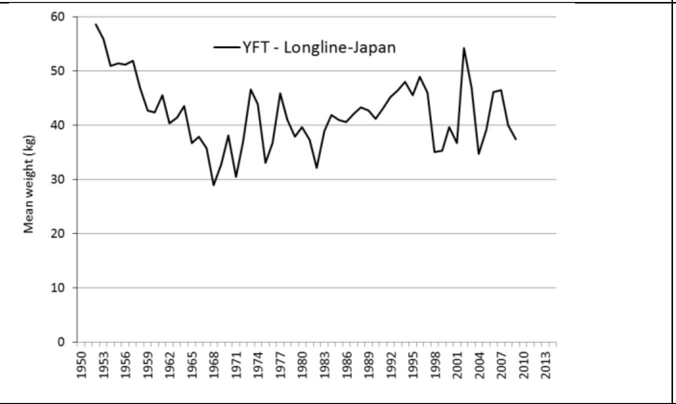
Yellowfin tuna (YFT)

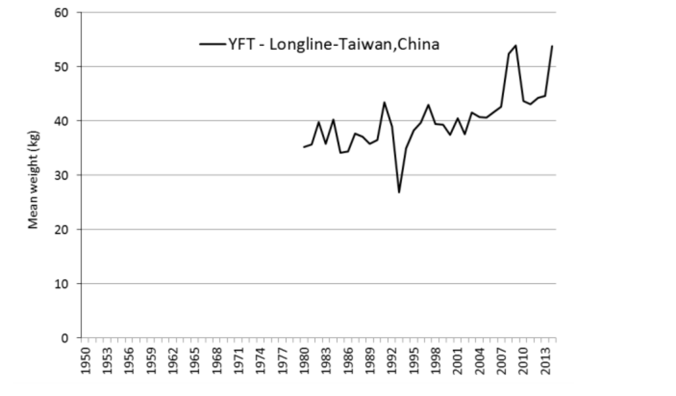
Average weight of yellowfin tuna (YFT) taken by:

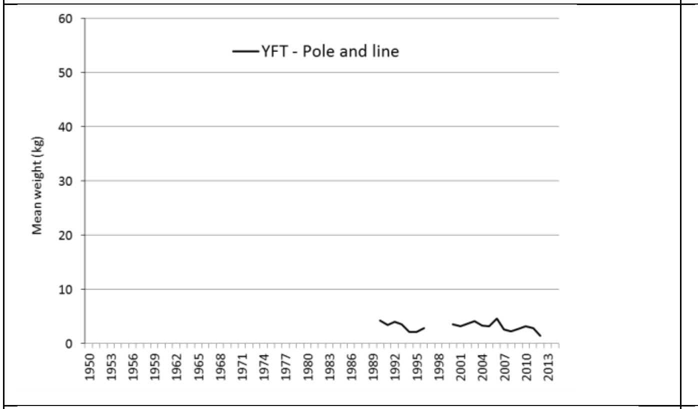
- Purse seine on free (top left) and associated (top right) schools,
- Longlines from Japan (second row left) and Taiwan,China (second row right)
- Pole-and-line from Maldives and India (third row left), and gillnets from Sri Lanka, Iran, and other countries (third row right)
- All fisheries (bottom row left), and all fisheries and main gears (bottom row left)

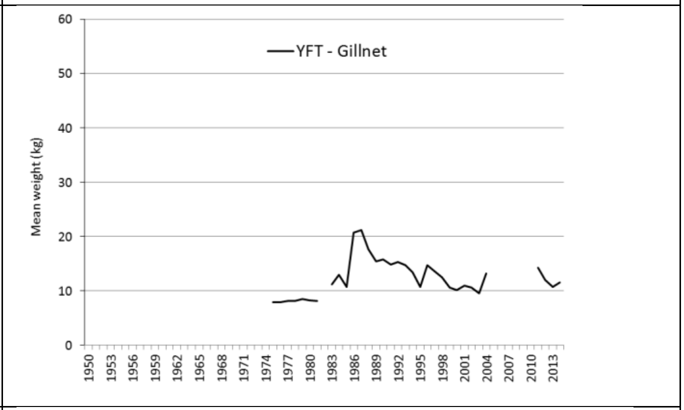


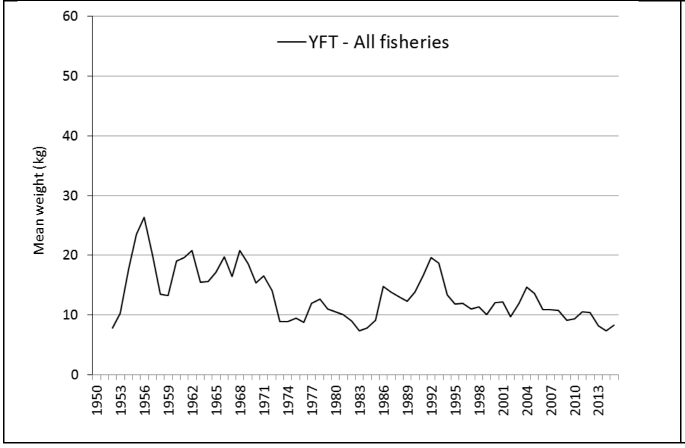


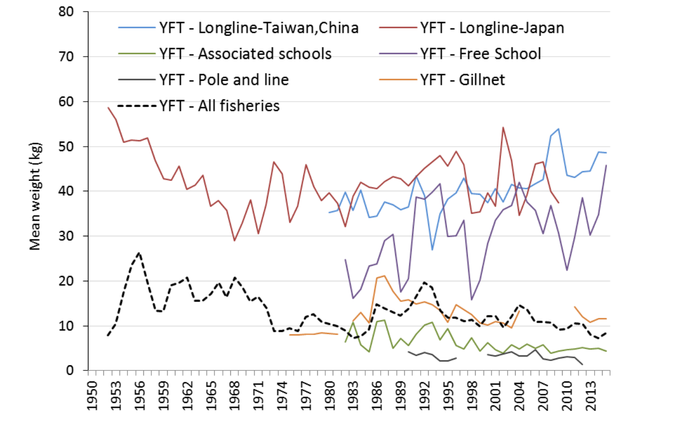


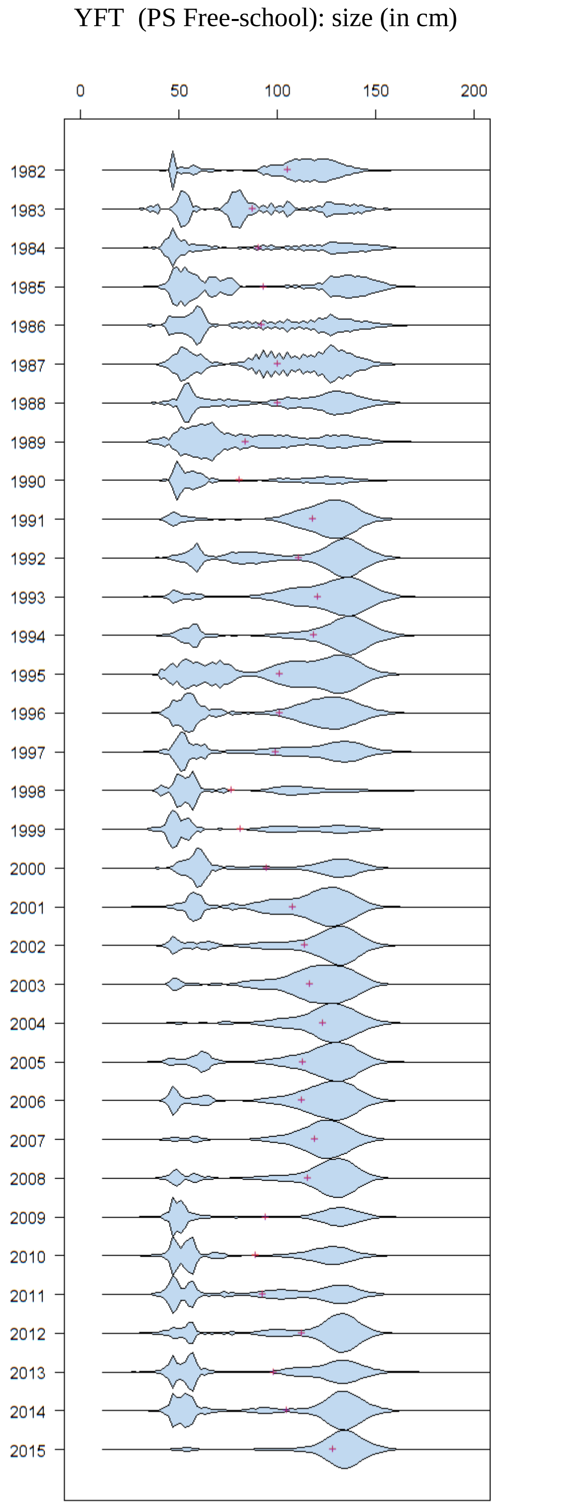


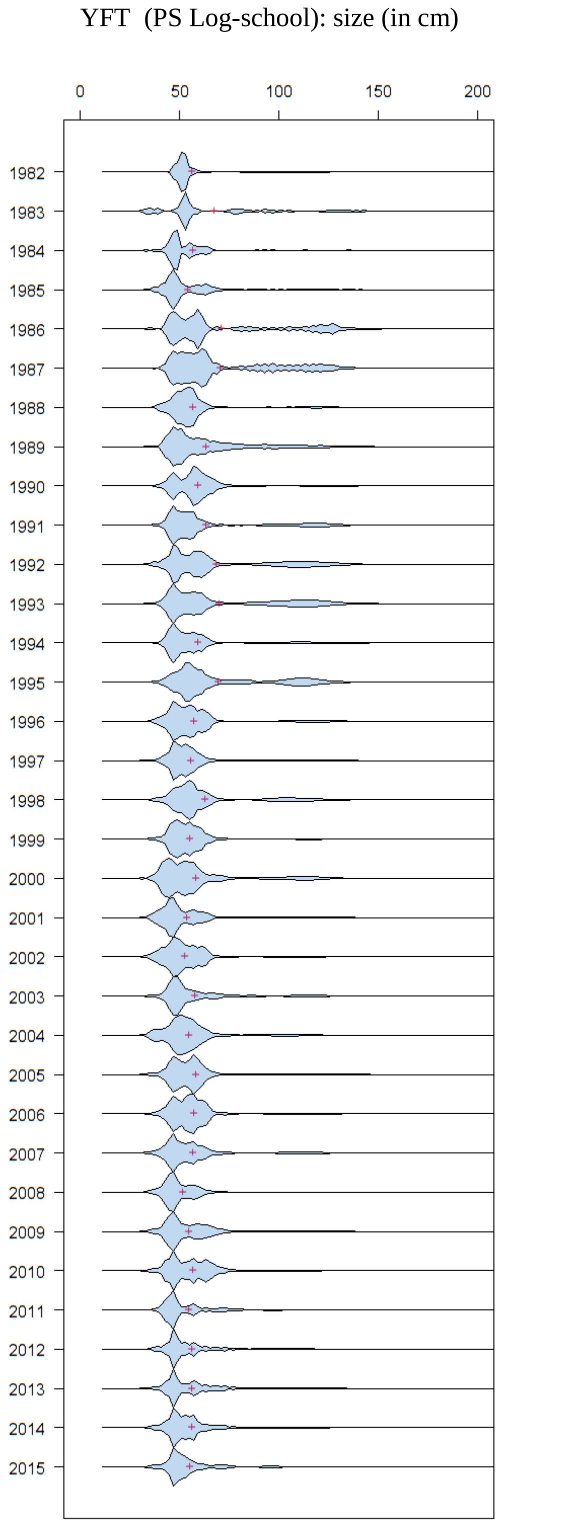






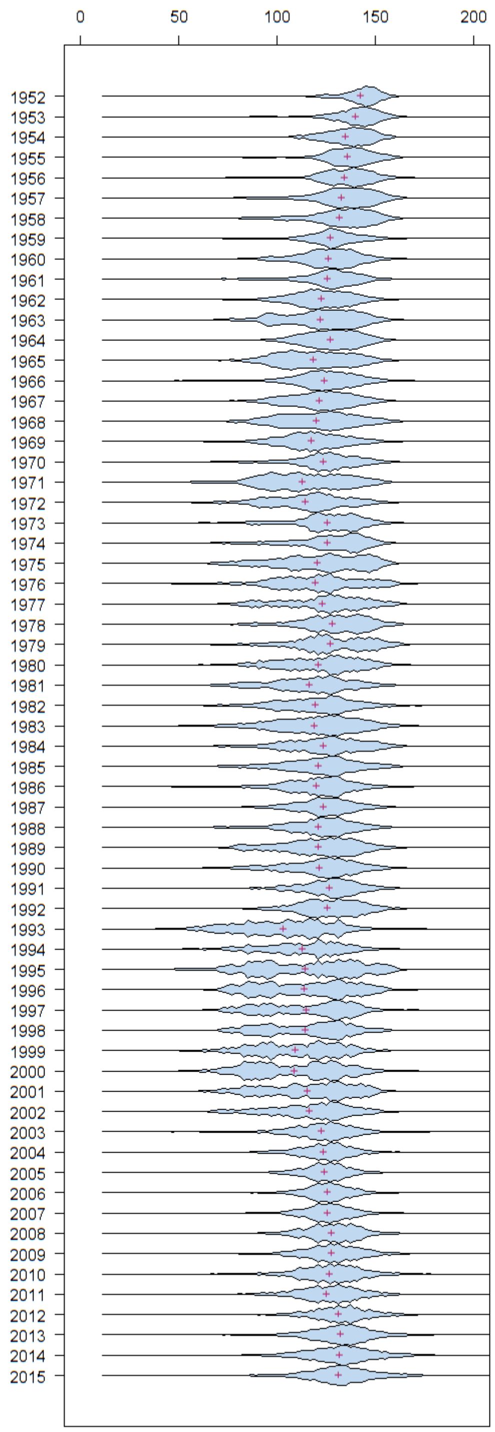




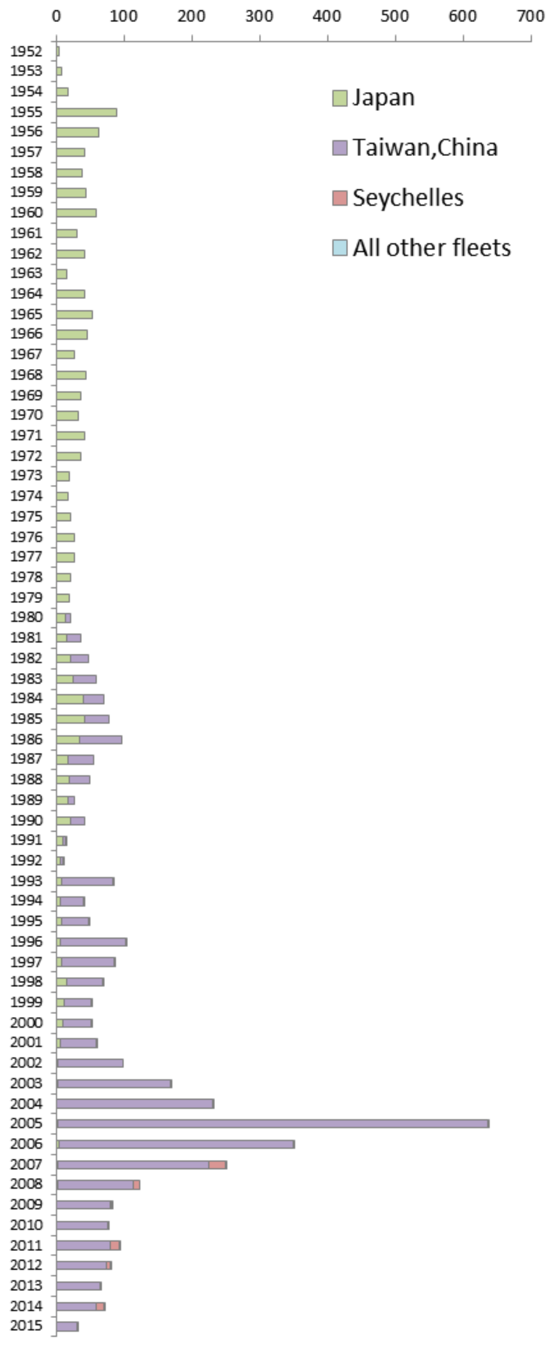


Yellowfin tuna (purse seine): **Left:** length frequency distributions for YFT PS Free school fisheries (by 2 cm length class). **Right**: Length frequency distributions for YFT PS Associated (log) school fisheries (by 2 cm length class). Source: IOTC database.

YFT (LL samples): size (in cm)



YFT (LL): no. of samples ('000)



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

APPENDIX V
MAIN ISSUES IDENTIFIED RELATING TO THE STATISTICS OF TROPICAL TUNAS

(Extract from IOTC–2016–WPTT18–07)

The following list provides a summary of the main issues that the IOTC Secretariat considers to negatively affect the quality of tropical tuna statistics available at the IOTC, by type of dataset and fishery.

1. *Nominal (retained) catches*

- Taiwan,China (longline): inconsistencies have been noted between catches of bigeye tuna originating from the Indian Ocean by the Taiwanese longline fleet – as reported by the nominal catches compared to the Bigeye Statistical Document – as a result of possible of misreporting of catches between the Atlantic and Indian Oceans. Between 2001-2004 the Bigeye Statistical Document has recorded higher catches of Indian Ocean bigeye tuna compared to nominal catches – even after the official nominal catches were been revised upwards by around 3,000 t – 6,000 t per annum. While current bigeye nominal catches in the IOTC database are closer to those reported to the Bigeye Statistical Document, discrepancies still remain and the issue has still not been fully resolved.
- Maldives (pole-and-line): the pole-and-line fishery is known to catch some juvenile bigeye tuna, however up to 2013 catches of yellowfin tuna and bigeye tuna were aggregated and reported to the IOTC Secretariat as yellowfin tuna only. The IOTC Secretariat has previously used the proportion of bigeye tuna collected in the Maldives in previous sampling programs to disaggregate the catches of yellowfin tuna, per year – with average catches of bigeye tuna estimated at around 850 t per year.

  While Maldives has made some progress in improving the accuracy of catches by species, notably with the introduction of logbooks since 2012, estimates of bigeye tuna still remain uncertain for earlier years and further work is needed to improve the accuracy of catches for the historical series.
- Sri Lanka (gillnet-longline fishery): Although Sri Lanka has reported catches of bigeye tuna for it's gillnet/longline fishery, catches are considered to be too low, possibly due to the mislabelling of catches of bigeye tuna as yellowfin tuna.
- I.R. Iran (drifting gillnet): In 2013 I.R. Iran reported catches of bigeye tuna for its drifting gillnet fishery for the first time, (i.e., data for year 2012). The IOTC Secretariat has estimated caches of bigeye tuna for Iran for years before 2012, assuming various levels of activity of vessels using driftnets on the high seas, depending on the year, and catch ratios between bigeye tuna and yellowfin tuna recorded for industrial purse seiners on free-swimming tuna schools in the northwest Indian Ocean. Catches of bigeye tuna have been estimated for the period 2005–2011 (at around 700 t per year), however estimates remain uncertain.
- Pakistan (drifting gillnet): Up to 2016, Pakistan has not reported catches of bigeye tuna for its gillnet fishery, although a component of the fleet is known to operate on the high seas, where catches of bigeye tuna are reported by other fleets operating the same area.
- Coastal fisheries of Indonesia, Madagascar, Sri Lanka[8] (other than gillnet/longline) and Yemen: The catches of tropical tunas for these fisheries have been estimated by the IOTC Secretariat in recent years – although the quality of the estimates is thought to be very poor due to the lack of information available about the fisheries operating in these countries.
  - ➢ *Update*: In 2016, IOTC catch estimates for Yemen were updated – based on FAO data – however the quality of catches remains highly uncertain. A more substantial review of catches is still required.
- Indonesia (longline): has not reported catches for longliners under their flag that are not based in their ports.
- Comoros (coastal fisheries): In 2011-12 the IOTC and the OFCF provided support to the strengthening of data collection for the fisheries of Comoros, including a Census of fishing boats and the implementation of sampling to monitor the catches unloaded by the fisheries in selected locations over the coast. The IOTC Secretariat and the *Centre National de resources Halieutiques* of Comoros derived estimates of catch using the data collected and the new catches estimated are at around half the values reported in the past by Comoros (around 5,000 t per year

[8] In 2012-13 the Ministry of Fisheries and Aquatic Resources Development of Sri Lanka received support from IOTC, the OFCF and BOBLME to strengthen its data collection and processing system, which should lead to improvements in the estimate of catch for the coastal fisheries of Sri Lanka for 2012 and subsequent years.

instead of 9,000 t). The IOTC Secretariat revised estimates of catch for the period 1995-2010 using the new estimates.

2. *Discards – all fisheries*

- The total amount of tropical tunas discarded at sea remains unknown for most fisheries and time periods. Discards of tropical tunas are thought to be significant during some periods of industrial purse seine fisheries using fish aggregating devices (FADs) and may also be high due to depredation of catches of longline fisheries, by sharks or marine mammals, in tropical areas.
  - *Update*: The IOTC Secretariat is actively working with CPCs to develop the Regional Observer Scheme, which will lead to improvements in the estimates of discards of tropical tunas. However, for the moment, estimates of discards remain highly uncertain.

3. *Catch-and-effort*

For a number of fisheries important for catches of tropical tuna, catch-and-effort remains either unavailable, incomplete (e.g., missing catches by species or gear), or only partially reported according to the standards of IOTC Resolution 15/02 and of limited value in deriving indices of abundance:

- I.R. Iran (coastal and offshore fisheries): I.R. Iran ranks sixth largest in terms of total catches of tropical tunas (accounted for mostly by drifting gillnets), however catch-and-effort have not been reported according to IOTC standards, in particular for vessels operating outside of its EEZ. No information is reported on effort, while catches are provided by province rather than 5° grid area.
- Sri Lanka (gillnet-longline): In previous years Sri Lanka has not reported catch-and-effort data as per the IOTC standards, including separate catch-and-effort data for gillnet-longline and catch-and-effort data for those vessels that operate outside its EEZ.
  - *Update*: In 2014 Sri Lanka provided more detailed catch-and-effort for the first time, which the IOTC Secretariat is currently reviewing.
- Indonesia (longline): To date, Indonesia has not reported catch-and-effort data for its longline fishery.
  - *Update*: An IOTC-OFCF mission was conducted in November 2015 to assist Indonesia with reporting of catch-and-effort, size frequency data and Regional Observer data collected on-board longline vessels. Although no catch-and-effort has still not been reported, Indonesia is planning to begin reporting data in 2017.
- Pakistan (drifting gillnet): no catch-and-effort reported for the gillnet fishery, in particular for vessels that operate outside the EEZ of Pakistan.
- India (longline): catches and catch-and-effort data have been reported for its commercial longline fishery for activities inside of the EEZ of India. However, India has not reported catches of tropical tunas or other species for longline vessels under its flag, operating offshore.

4. *Size data (all fisheries)*

- Japan and Taiwan,China (longline fisheries): In 2010, the IOTC Scientific Committee identified several issues concerning the size frequency statistics available for Japan and Taiwan,China, which remain unresolved. In 2013 the IOTC Secretariat presented a paper to WPTT-15 documenting the current data quality issues and inconsistences between the length frequency data and catch-and-effort reported in particular by Taiwan,China since the mid-2000s[9].

  The WPTT recommended an inter-sessional meeting attached to the WPDCS and WPM on *data collection and processing systems for size data from the main longline fleets in the Indian Ocean*, be carried out in early 2014. Unfortunately arrangements for the inter-sessional meeting were never taken forward.

[9] See IOTC Secretariat, IOTC-2013-WPTT15-41 Rev_1, for more details.

- *Update*: Collaboration between the IOTC Secretariat, Japan, and Taiwan,China is on-going and progress will be reported to the WPDCS, WPTT and SC in due course. Japan is due to present an update at WPDCS in 2016.

- In addition, the number of specimens sampled for length on-board longliners flagged in Japan in recent years remains below the minimum recommended by the IOTC (i.e., 1 fish per metric ton of catch measured for length).
- I.R. Iran and Pakistan (gillnet): although both countries have reported size frequency data gillnet fisheries in recent years, data have not been reported by area and the number of samples are below the minimum sample size recommended by the IOTC.
- Sri Lanka (gillnet-longline): Although Sri Lanka has reported length frequency data for tropical tunas in recent years, sampling coverage is below recommended levels and lengths are not available by gear type or fishing area[10].
  - *Update*: In 2014 Sri Lanka provided more detailed catch-and-effort for the first time, which the IOTC Secretariat is currently reviewing.
- Indonesia (longline): size frequency data have been reported for its fresh-tuna longline fishery in previous years (e.g., 2002-2003), however samples cannot be fully broken fishing area (i.e., 5° degree grid) and they refer exclusively to longliners based in ports in those countries.
  - *Update*: An IOTC-OFCF mission was conducted in November 2015 to assist Indonesia with reporting of catch-and-effort, size frequency data and Regional Observer data collected on-board longline vessels. Size data collected by the observers was submitted for the first time in 2016.
- To date, these countries have not reported size frequency data for their fisheries:
  - Longline: India, Oman and the Philippines (longline);
  - Coastal fisheries: India, Indonesia and Yemen (coastal fisheries).

5. Biological data for all tropical tuna species

- Surface and longline fisheries, in particular Taiwan,China, Indonesia, Japan, and China:

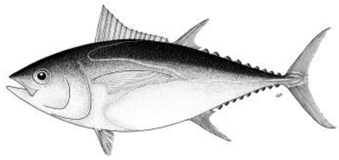
  The IOTC database does not contain enough data to allow for the estimation of statistically robust length-weight keys or non-standard size to standard length keys for tropical tuna species, due to the general lack of biological data available from the Indian Ocean.

  A summary of the current biological length-weight equations and availability of alternative sources are documented in Appendix II for the consideration of the WPTT, following the recommendation of the WPDCS.

[10] In 2012-13 the Ministry of Fisheries and Aquatic Resources Development of Sri Lanka received support from IOTC, the OFCF and BOBLME to strengthen its data collection and processing system, including collection of more length frequency data from the fisheries.

APPENDIX VI
DRAFT RESOURCE STOCK STATUS SUMMARY – BIGEYE TUNA

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



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

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

Area[1]	Indicators		2016 stock status[2] determination
Indian Ocean	Catch in 2015: Average catch 2011–2015:	92,736 t 101,515 t	**83.7 %**
	MSY (1,000 t) (80%): F_{MSY} (80%): SB_{MSY} (1,000 t) (80%): F_{2015}/F_{MSY} (80%): SB_{2015}/SB_{MSY} (80%): SB_{2015}/SB_0 (80%):	104 (87-121) 0.17 (0.14-0.20) 525 (364-718) 0.76 (0.49-1.03) 1.29 (1.07-1.51) 0.38 (n.a. – n.a.)	

[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 in the assessment (2015).

Colour key	Stock overfished ($SB_{year}/SB_{MSY}< 1$)	Stock not overfished ($SB_{year}/SB_{MSY}\geq 1$)
Stock subject to overfishing($F_{year}/F_{MSY}> 1$)	**2.1%**	13.8%
Stock not subject to overfishing ($F_{year}/F_{MSY}\leq 1$)	0.4%	83.7%
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. In 2016, six models were applied to the bigeye tuna stock in the IOTC area of competence (ASAP, BDM, ASPIC, SCAA, BSPM and SS3). The reported stock status is based on the SS3 model formulation using a grid designed to capture the uncertainty on stock recruitment relationship and the influence of tagging information. Spawning stock biomass in 2015 was estimated to be 38% of the unfished levels (Table 1) and 129% (107–151%) of the level that can support MSY. The assessment is qualitatively similar to the 2013 stock assessment but with a lower relative biomass (from 144 to 129% SB/SB_{MSY}) and higher relative fishing mortality (from 42 to 76% F/F_{MSY}). Considering the quantified uncertainty, which is conservative, the assessment indicates that, with high likelihood, SB_{2015} is above SB_{MSY} and F_{2015} is below F_{MSY}. The median value of MSY from the model runs presented with SS3 was 104,000 t with a range between 87,000 and 121,000 t (a median level 22% lower than the estimate in 2013). Catches in 2015 (≈92,736 t) remain lower than the estimated MSY values from the 2015 stock assessments (Table 1). The average catch over the previous five years (2011–15; ≈101,515 t) also remains below the estimated MSY. Thus, on the weight-of-evidence available in 2016, the bigeye tuna stock is determined to be **not overfished** and is **not subject to overfishing** (Table 1).

Outlook. Declines in longline effort since 2007, particularly from the Japanese, Taiwan, China and Rep. of Korea longline fleets 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 in the near future. The Kobe strategy matrix based on the plausible model runs from SS3 in 2016 illustrates the levels of quantified risk associated with varying catch levels over time and could be used to inform future management actions (Table 2). The SS3 projections from the 2016 assessment show that there is a low risk of exceeding MSY-based reference points by 2018, and 2025 if catches are maintained at current catch levels of 92,736 t (Table 2).

Management advice. The stock status determination did not qualitatively change in 2016, but is somewhat less optimistic than in 2013. If catch remains below the estimated MSY levels estimated for the current mix of fisheries, then immediate management measures are not required. However, increased catch or increases in the mortality on immature fish will likely increase the probabilities of breaching reference levels in the future. Continued monitoring and improvement in data collection, reporting and analysis is required to reduce the uncertainty in assessments (Table 2).

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY):** estimate for the whole Indian Ocean is 104,101 t with a range between 87,000–121,000 t for SS3 (Table 1). The average 2011-2015 catches ≈101,515 (t) since 2011 were below the MSY level.
- **Interim reference points**: Noting that the Commission in 2015 agreed to Resolution 15/10 *on target and limit reference points and a decision framework*, the following should be noted:
    - **Fishing mortality**: Current fishing mortality is considered to be at 76% of the interim target reference point of F_{MSY}, and 54% of the interim limit reference point of 1.3*F_{MSY} (Fig. 1).
    - **Biomass**: Current spawning biomass is considered to at 129% of the interim target reference point of SB_{MSY} and well above the interim limit reference point of 0.5*SB_{MSY} (Fig. 1).
- **Main fishing gear** (Average catch 2012–15): Longline ≈57.0% (frozen ≈43%, fresh ≈14%); Purse seine ≈19% (FAD associated school ≈13%; free swimming school ≈6%); Line other ≈8%; Other ≈16%.
- **Main fleets** (Average catch 2012–15): Indonesia ≈26%; Taiwan,China ≈22%; European Union ≈14% (EU,Spain: ≈10%; EU,France: ≈4%); Seychelles ≈11; Japan ≈5%; All other fleets ≈18%.

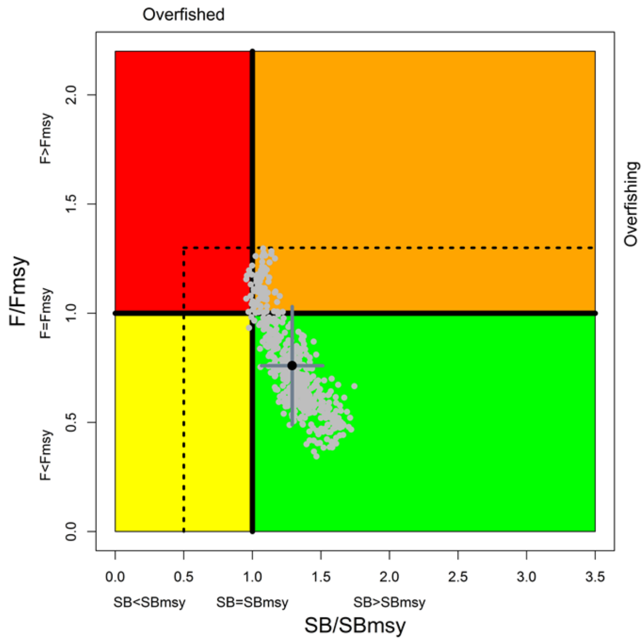


Figure. 1. Bigeye tuna: SS3 Aggregated Indian Ocean assessment Kobe plot. Dotted black lines are the interim limit reference points adopted by the Commission via Resolution 15/10. The grey points represent 500 estimates of 2015 stock status from the six model options. The black point represents the average of the six model options with associated 80% confidence interval.

TABLE 2. Bigeye tuna: Stock Synthesis base case Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (relative to catches from 2015 (93,040t), ± 20%, + 40%) projected for 3 and 10 years.

Reference point and projection timeframe	Alternative catch projections (relative to the catch level from 2015) and weighted probability (%) scenarios that violate reference point

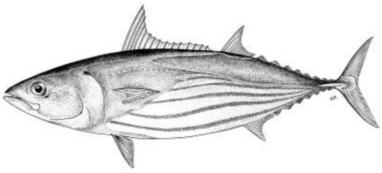
	80% (74,432t)	**100%** (93,040t)	**120%** (111,648t)	**140%** (130,256t)
$B_{2018} < B_{MSY}$	11	20	30	40
$F_{2018} > F_{MSY}$	2	19	40	61
$B_{2025} < B_{MSY}$	6	25	49	60
$F_{2025} > F_{MSY}$	1	19	42	53

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.5\ B_{MSY}$; $F_{Lim} = 1.3\ F_{MSY}$)**			
	80% (74,432t)	**100%** (93,040t)	**120%** (111,648t)	**140%** (130,256t)
$B_{2018} < B_{LIM}$	0	0	0	0
$F_{2018} > F_{LIM}$	0	4	18	37
$B_{2025} < B_{LIM}$	0	1	12	33
$F_{2025} > F_{LIM}$	0	9	30	48

** Minor differences in the 2015 catch estimates between the Kobe II Strategy Matrix and management quantities in Table 1, are due to updates in the nominal catch published prior to the Working Party on Tropical Tunas.*

APPENDIX VII
DRAFT RESOURCE STOCK STATUS SUMMARY – SKIPJACK TUNA

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



Status of the Indian Ocean skipjack tuna (SKJ: *Katsuwonus pelamis*) resource

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

Area[1]	**Indicators**		**2016 stock status determination**
Indian Ocean	Catch 2015: Average catch 2011–2015:	393,954 t 394,320 t	
	MSY (1,000 t) (80% CI): F_{MSY} (80% CI): SB_{MSY} (1,000 t) (80% CI): C_{2013}/C_{MSY} (80% CI): SB_{2013}/SB_{MSY} (80% CI): SB_{2013}/SB_0 (80% CI):	684 (550–849) 0.65 (0.51–0.79) 875 (708–1,075) 0.62 (0.49–0.75) 1.59 (1.13–2.14) 0.58 (0.53–0.62)	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.

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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. No new stock assessment was carried out for skipjack tuna in 2016, thus, stock status is determined on the basis of the 2014 assessment and other indicators presented in 2016. The 2014 stock assessment model results did not differ substantively from the previous (2012 and 2011) assessments; however, the final overall estimates of stock status differ somewhat due to the revision of the input parameters and updated standardised CPUE indices. All the runs carried out in 2014 indicate the stock is above a biomass level that would produce MSY in the long term (i.e. $SB_{2013}/SB_{MSY} > 1$) and in all runs that the current proxy for fishing mortality is below the MSY-based reference level (i.e. $C_{current}/C_{MSY} < 1$) (Table 1 and Fig. 1). The median value of MSY from the model runs investigated was 684,000 t with a range between 550,000 and 849,000 t. Current spawning stock biomass was estimated to be 57% (Table 1) of the unfished levels. Catches in 2015 (≈393,954 t) remain lower than the estimated MSY values from the 2014 stock assessments (Table 1). The average catch over the previous five years (2011–15; ≈394,320 t) also remains below the estimated MSY. Thus, on the weight-of-evidence available in 2016, the skipjack tuna stock is determined to be **not overfished** and is **not subject to overfishing** (Table 1).

Outlook. The recent declines in total overall catch of skipjack for both BB and PS, the decline in catch per set on FADs (in parallel to the overall increase in number of FADs deployed at sea and number of supply vessels), and the decrease on free school catches of skipjack tuna are thought to be of some concern, particularly as the causes of these indicators are currently not fully understood. These indicators may suggest some increase in fishing mortality or school fragmentation due to the strong associative behaviour of the species. In addition, the marked decline in the relative proportion of skipjack in FAD catches, should be further investigated and explained.

These indicators should be updated and at least considered in parallel, or whenever possible, incorporated to the formal SKJ stock assessment that will be conducted in 2017.

There remains considerable uncertainty in the assessment, and the range of runs analysed illustrate a range of stock status to be between 0.73–4.31 of SB_{2013}/SB_{MSY} based on all runs examined. 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 conducted in 2014, there is a low risk of exceeding MSY‑based reference points by 2016 and 2023 if catches are maintained at 2013 levels of ≈425,000 t (< 1 % risk that $B_{2016} < B_{MSY}$ and 1 % risk that C_{2023}>MSY as proxy of $F > F_{MSY}$).

Management advice. If catch remains below the estimated MSY levels, 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.

The following key points should also be noted:

- Maximum Sustainable Yield (MSY): The median MSY value from the model runs investigated was 684,000 t with a range between ≈550,000 and ≈849,000 t (Table 1); However, MSY reference levels from these models were not well determined. Historically, catches in excess of 600,000 t were estimated to coincide with the time that the stock fell below 40% of the unfished level, which maybe a more robust proxy for MSY in this case. Considering the average catch level from 2010–2014 was ≈402,000 t, the stock appears to be in no immediate threat of breaching target and limit reference points. Current stock size is above $SB_{40\%}$ and predicted to increase on the short term. Catches at the level of ≈425,000 t have a low probability of reducing the stock below $SB_{40\%}$ in the short term (3–5 years) and medium term (10 years). However, taking into account the uncertainty related to current skipjack assessment as well as other indicators such the low catch rates of FADs and increased effort, it is recommended that annual catches of skipjack tuna should not exceed the lower value of MSY of the range (≈550,000 t) in order to ensure that stock biomass levels could sustain catches at the MSY level in the long term.
- 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.
- **Interim reference points:** Noting that the Commission in 2015 agreed to Resolution 15/10 *on target and limit reference points and a decision framework*, the following should be noted:
  - **Fishing mortality**: Current fishing mortality is considered to be below the interim target reference point of F_{MSY}, and therefore below the interim limit reference point of $1.5*F_{MSY}$ (Fig. 1). Based on the current assessment there is a very low probability that the interim limit reference points of $1.5*F_{MSY}$ at the current catch levels will be exceeded in 3 or 10 years.
  - **Biomass**: Current spawning biomass is considered to be above the interim target reference point of SB_{MSY}, and therefore above the interim limit reference point of $0.4*SB_{MSY}$ (Fig. 1). Based on the current assessment, there is a low probability that the spawning stock biomass, at the current catch levels, will be below the interim limit reference point of $0.4*SB_{MSY}$ in 3 or 10 years.
- **Main fishing gear** (Average catch 2012–15): Purse seine ≈30% (FAD associated school ≈28% and free swimming school ≈2%); Gillnet ≈26%; Pole-and-line ≈21%; Other ≈24%.
- **Main fleets** (Average catch 2012–15): Indonesia ≈21%; European Union ≈19% (EU,Spain: ≈15%; EU,France: ≈4%); ≈Maldives 17%; Sri Lanka ≈15%; ≈I.R. Iran 9%; Seychelles ≈8%; India ≈7%.

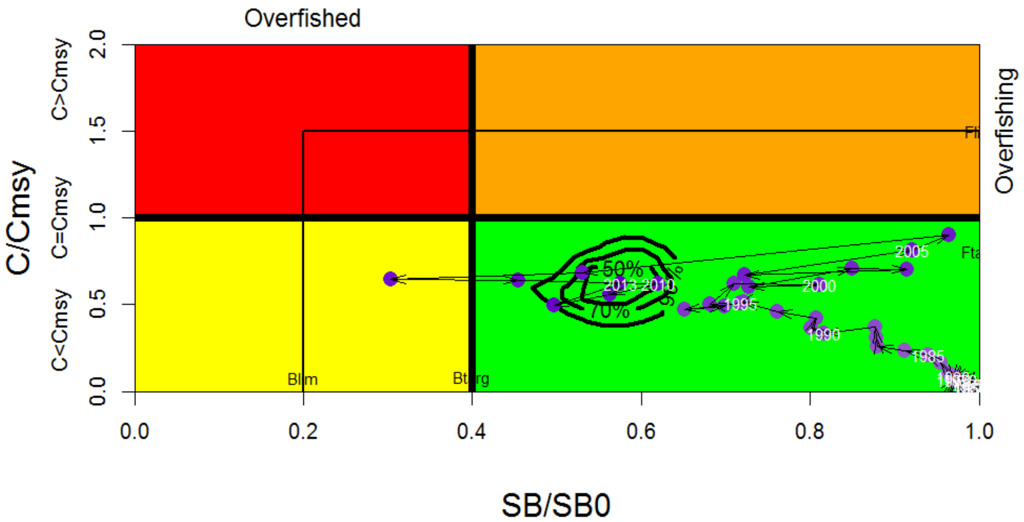


Fig. 1. Skipjack tuna: SS3 Aggregated Indian Ocean assessment Kobe plot (contours are the 50, 70 and 90 percentiles of the 2013 estimate). Blue circles indicate the trajectory of the point estimates for the SB/SB0 ratio and F proxy ratio for each year 1950–2013 estimated as C/C_{MSY}. Interim target (Ftarg and SBtarg) and limit (Flim and SBlim) reference points, are based on 0.4 (0.2) B_0 and C/C_{MSY}=1 (1.5) as suggested by WPTT.

TABLE 2. Skipjack tuna: SS3 aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for nine constant catch projections (relative to the catch level from 2013 (424,580 t)*, ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

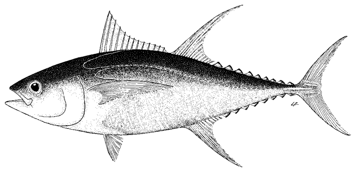
Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2013*) and probability (%) of violating MSY-based target reference points ($SB_{targ} = SB_{MSY}$; $F_{targ} = F_{MSY}$)**								
	60% (254,748 t)	**70%** (297,206 t)	**80%** (339,664 t)	**90%** (382,122 t)	**100%** (424,580 t)	**110%** (467,038 t)	**120%** (509,496 t)	**130%** (551,954 t)	**140%** (594,412 t)
$B_{2016} < B_{MSY}$	0	n.a.	1	n.a.	1	n.a.	1	n.a.	9
$F_{2016} > F_{MSY}$	0	n.a.	1	n.a.	1	n.a.	5	n.a.	12
$B_{2023} < B_{MSY}$	0	n.a.	1	n.a.	1	n.a.	6	n.a.	25
$F_{2023} > F_{MSY}$	0	n.a.	1	n.a.	1	n.a.	5	n.a.	20

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2013*) and probability (%) of violating MSY-based limit reference points ($SB_{lim} = 0.4\ SB_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	60% (254,748 t)	**70%** (297,206 t)	**80%** (339,664 t)	**90%** (382,122 t)	**100%** (424,580 t)	**110%** (467,038 t)	**120%** (509,496 t)	**130%** (551,954 t)	**140%** (594,412 t)
$B_{2016} < B_{Lim}$	0	n.a.	0	n.a.	0	n.a.	0	n.a.	0
$F_{2016} > F_{Lim}$	1	n.a.	1	n.a.	1	n.a.	1	n.a.	1
$B_{2023} < B_{Lim}$	0	n.a.	0	n.a.	0	n.a.	0	n.a.	0
$F_{2023} > F_{Lim}$	0	n.a.	1	n.a.	1	n.a.	1	n.a.	6

*** *Catches for 2013, at the time of the last skipjack tuna assessment conducted in 2014.*

APPENDIX VIII
DRAFT RESOURCE STOCK STATUS SUMMARY – YELLOWFIN TUNA

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



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

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

Area[1]	Indicators		2016 stock status determination
Indian Ocean	Catch 2015: Average catch 2011–2015:	407,575 t 390,185 t	**67.6%**
	MSY (1000 t) (80% CI): F_{MSY} (80% CI): SB_{MSY} (1,000 t) (80% CI): F_{2015}/F_{MSY} (80% CI): SB_{2015}/SB_{MSY} (80% CI): SB_{2015}/SB_0 (80% CI):	422 (406-444) 0.151 (0.148-0.154) 947 (900-983) 1.11 (0.86-1.36) 0.89 (0.79-0.99) 0.29 (n.a.-n.a.)	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
*Estimated probability that the stock is in the respective quadrant of the Kobe plot (shown below), derived from the confidence intervals associated with the current stock status. The confidence intervals for SB_{2015}/SB_0 were not estimated for the models used.

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)	67.6%	3.7%
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	27.3%	1.4%
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. In 2016, two models were applied to the yellowfin tuna stock in the IOTC area of competence to update the stock status undertaken in 2015: a Biomass Dynamic Model (BDM) and Stock Synthesis III (SS3) model, which gave qualitatively similar results. Stock status and management advice was based on the SS3 model formulation. Spawning stock biomass in 2015 was estimated to be 28.9% of the unfished levels (Table 1) and 89% (79–99%) of the level which can support MSY. The assessment is somewhat more optimistic than the 2015 assessment mainly due to the use of a new composite LL CPUE series, which results in a lower estimate of fishing mortality in the NE Indian Ocean. In addition, the catch series revised in 2016 reduced the catch data for 2014 by 5.1% (from 430,327 to 408,497, although the impact of this revision on status determination was minor. According to the information available for the stock assessment, the total catch has remained relatively stable at levels somewhat lower than the estimated MSY since 2012 (407,575 t in 2015, 408,497 in 2014, 405,048 in 2013 and 400,502 in 2012). The inclusion of revised and new data into the updated assessment using the model structure applied in the 2015 assessment, resulted in a higher estimated biomass in 2014 and lower estimated F/F_{MSY} than the corresponding estimates from the 2015 stock assessment. Nonetheless, the updated assessment estimates SB_{2015}/SB_{MSY} at 0.89 (0.79-0.99) and F_{2015}/F_{MSY} at 1.11 (0.86-1.36). The quantified uncertainty in these estimates is an underestimate of the underlying uncertainty of the assessment. On the weight-of-evidence available in 2016, the yellowfin tuna stock is determined to remain **overfished** and subject to **overfishing** (Table 1 and Fig. 1).

Outlook. The increase in longline, gillnet, handline and purse seine effort and associated catches in recent years has substantially increased the pressure on the Indian Ocean stock as a whole, with recent fishing mortality exceeding the MSY-related levels. There is a risk of continuing to exceed the MSY-based biomass reference point if catches increase or remain at current levels (2015) until 2018 (88% risk that SB < SB_{MSY}) (Table 2). The modelled probabilities of the stock attaining levels consistent with the Commission's current management objective (e.g. SB > SB_{MSY}) are shown in the K2MSM, which provides a range of options for reducing catches and the probabilities of the yellowfin tuna stock recovering to the MSY target levels (Table 2).

Management advice. The stock status determination did not change in 2016, but does give a somewhat more optimistic estimate of stock status than the 2015 assessment as a direct result of the use of more reliable information on catch rates of longline fisheries and updated catch up to 2015. The stock status is driven by unsustainable catches of yellowfin tuna taken over the last four (4) years, and the relatively low recruitment levels estimated by the model in recent years. The Commission has an interim plan for the rebuilding of this stock (Resolution 16/01, which is yet to be evaluated) to achieve the recovery of yellowfin stock, with catch limitations beginning January 1 2017. The projections produced to advise on future catches are, in the short term, driven by the below average recruitment estimated for in recent years since these year classes have yet to reach maturity and contribute to the spawning biomass (see Table 2).

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY):** estimate for the whole Indian Ocean is estimated at 422,000 t with a range between 406,000-444,000 t (Table 1). The 2011-2015 average catches (390,185 t) were below the estimated MSY level.
- **Interim reference points**: Noting that the Commission in 2015 agreed to Resolution 15/10 *on target and limit reference points and a decision framework*, the following should be noted:
  - **Fishing mortality**: Current fishing mortality is considered to be 11% above the interim target reference point of F_{MSY}, and below the interim limit reference point of $1.4*F_{MSY}$ (Fig. 1).
- **Biomass**: Current spawning biomass is considered to be 11% below the interim target reference point of SB_{MSY}, however above the interim limit reference point of $0.4*SB_{MSY}$ (Fig. 1).
- **Main fishing gear** (Average catch 2012–15): Purse seine ≈34% (FAD associated school ≈20%; free swimming school ≈13%); Longline ≈19%; Handline ≈19%; Gillnet ≈16%; Trolling ≈7%; Pole-and-line ≈5%; ≈Other 2%).
- **Main fleets** (Average catch 2012–15): European Union ≈21% (EU,Spain ≈15%; EU,France ≈7%); Maldives ≈12%; Indonesia ≈10%; I.R. Iran ≈10%; Sri Lanka ≈9%; Yemen ≈8%; India ≈7%.

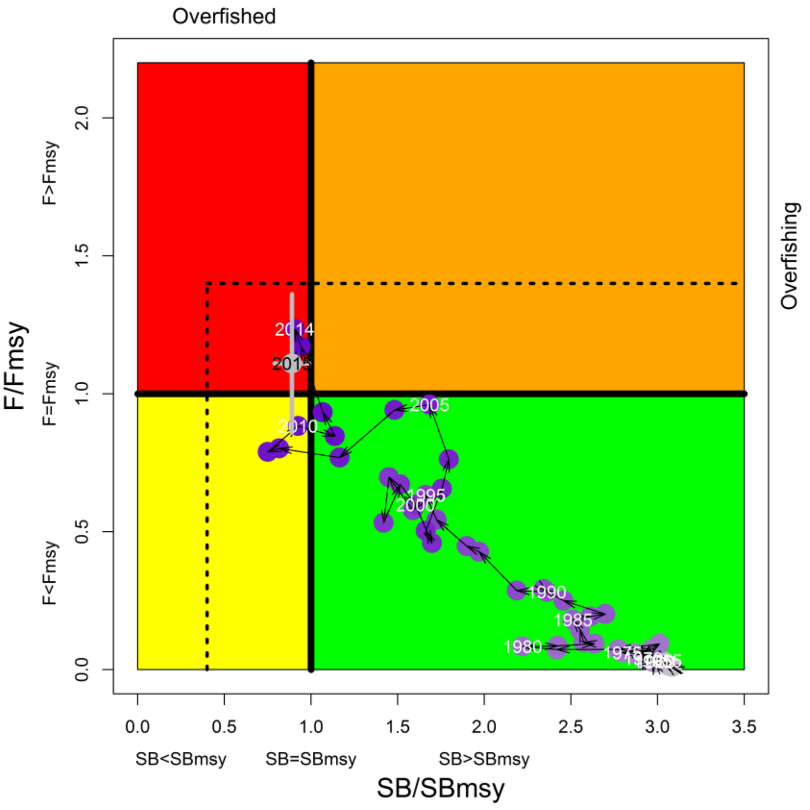


Fig. 1. Yellowfin tuna: Stock synthesis Kobe plot. Blue dots indicate the trajectory of the point estimates for the B/B_{MSY} ratio and F_{MSY} proxy ratio for each year 1950–2015. The grey line represents the 80% confidence interval associated with the 2015 stock status. Dotted black lines are the interim limit reference points adopted by the Commission via Resolution 15/10.

TABLE 2. Yellowfin tuna: Stock synthesis assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (relative to the catch level from 2015 (407,575t), -30%, - 25%, ± 20%, -15%,± 10%, -5%), projected for 3 and 10 years), projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**								
	70% (285,302t)	75% (305,680t)	80% (326,059t)	85% (346,438t)	90% (366,816t)	95% (387,195t)	100% (407,574t)	110% (448,331t)	120% (489,089t)
$B_{2018} < B_{MSY}$	53	61	67	77	80	88	88	97	99
$F_{2018} > F_{MSY}$	2	7	23	47	65	73	100	100	100
$B_{2025} < B_{MSY}$	6	n.a.	20	37	60	100	100	100	100
$F_{2025} > F_{MSY}$	0	n.a.	10	40	57	100	100	100	100
Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2015) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.4\ B_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	70% (285,302t)	75% (305,680t)	80% (326,059t)	85% (346,438t)	90% (366,816t)	95% (387,195t)	100% (407,574t)	110% (448,331t)	120% (489,089t)
$B_{2018} < B_{Lim}$	2	1	2	4	6	6	12	21	38
$F_{2018} > F_{Lim}$	0	0	1	10	32	52	100	100	100
$B_{2025} < B_{Lim}$	0	n.a.	1	7	30	>30*	>30*	>30*	>30*
$F_{2025} > F_{Lim}$	0	n.a.	0	11	53	>30*	>30*	>30*	>30*

** At least one fishery not able to take the catch due to absence of vulnerable fish in the projection period. The probability levels are not well determined, but likely progressively exceed 30% as the catch level increases beyond 90%.*

APPENDIX IX
WORKING PARTY ON TROPICAL TUNAS PROGRAM OF WORK (2017–2021)

The WPTT Program of Work (2017–2021) consists of the following, noting that a timeline for implementation would be refined by the Scientific Committee once it has agreed to the priority projects across all of its Working Parties:

- **Table 1**: Priority topics for obtaining the information necessary to develop stock status indicators for tropical tunas in the Indian Ocean;
- **Table 2**: Stock assessment schedule.

Table 1. Priority topics for obtaining the information necessary to develop stock status indicators for tropical tunas in the Indian Ocean.

Topic	Sub-topic and project	Priority ranking	Lead	Est. budget (potential source)	TIMING				
					2017	2018	2019	2020	2021
1. Stock structure (connectivity and diversity)	1.1 Genetic research to determine the connectivity of tropical tuna species throughout their distribution (including in adjacent Pacific Ocean waters as appropriate) and the effective population size.	MED (on-going)	CSIRO/AZTI/IRD/RITF	1.3 m Euro: (European Union; 20% additional co-financing)					
	1.1.1 Next Generation Sequencing (NGS) to determine the degree of shared stocks for tropical tuna species in the Indian Ocean. Population genetic analyses to decipher inter- and intraspecific evolutionary relationships, levels of gene flow (genetic exchange rate), genetic divergence, and effective population sizes.								
	1.1.2 Nuclear markers (i.e. microsatellite) to determine the degree of shared stocks for tropical tuna species in the Indian Ocean with the Pacific Ocean, as appropriate.								
	1.2 Connectivity, movements and habitat use								
	1.2.1 Connectivity, movements, and habitat use, including identification of hotspots and investigate associated environmental conditions affecting the tropical tuna species distribution, making use of conventional and electronic tagging (P-SAT).	MED		US$?? (TBD)					
2. Biological	2.1 Age and growth								

Topic	Sub-topic and project		Priority ranking	Lead	Est. budget (potential source)	TIMING				
						2017	2018	2019	2020	2021
and ecological information (incl. parameters for stock assessment)	2.1.1	Design and develop a plan for a biological sampling program to support research on tropical tuna biology. The plan would consider the need for the sampling program to provide representative coverage of the distribution of the different tropical tuna species within the Indian Ocean and make use of samples and data collected through observer programs, port sampling and/or other research programs. The plan would also consider the types of biological samples that could be collected (e.g. otoliths, spines, gonads, stomachs, muscle and liver tissue, fin clips etc), the sample sizes required for estimating biological parameters, and the logistics involved in collecting, transporting and processing biological samples. The specific biological parameters that could be estimated include, but are not limited to, estimates of growth, age at maturity, fecundity, sex ratio, spawning season, spawning fraction and stock structure.	High	CPCs directly	US$?? (TBD)					
	2.2 Age-at-Maturity									
	2.2.1	CPCs to provide further research reports on tropical tuna biology, namely age and growth studies including using through the use of fish otoliths, either from data collected through observer programs or other research programs.	High	CPCs directly	US$?? (TBD)					
3. Ecological information	3.1 Spawning time and locations									
	3.1.1	Collect gonad samples from tropical tunas to confirm the spawning time and location of the spawning area that are presently hypothesised for each tropical tuna species.	Med		US$?? (TBD)					
4. Historical data review	4.1 Changes in fleet dynamics need to be documented by fleet									
	4.1.1	Provide an evaluation of fleet-specific fishery impacts on the stock of bigeye tuna, skipjack tuna and yellowfin tuna. Project potential impact of realizing fleet development plans on the	Med	Consultant	US$30K					

Topic	Sub-topic and project	Priority ranking	Lead	Est. budget (potential source)	TIMING 2017	2018	2019	2020	2021
	status of tropical tunas based upon most recent stock assessments.								
5. CPUE standardisation	5.1 Develop standardised CPUE series for each tropical tuna fleet/fishery for the Indian Ocean								
	5.1.1 Further development and validation of the collaborative longline CPUE indices using the data from multiple fleets (see Terms of Reference, Appendix IXa below).	High (on-going)	SC and consultants	US$40K (IOTC)					
	5.1.2 That standardised CPUE index for juvenile yellowfin tuna and bigeye tuna caught by the EU purse seiner fleets, be estimated and submitted to the WPTT before the next round of stock assessments of tropical tunas.		CPCs directly	US$?? (TBD)					
	5.1.3 Development of minimum criteria (e.g. 10% using a simple random stratified sample) for logbook coverage to use data in standardisation processes; and 2) identifying vessels through exploratory analysis that were misreporting, and excluding them from the dataset in the standardisation analysis.		CPCs directly	US$?? (TBD)					
	5.1.4 Vessel identity information for the Japanese fleets for the period prior to 1979 should be obtained either from the original logbooks or from some other source, to the greatest extent possible to allow estimation of catchability change during this period and to permit cluster analysis using vessel level data.		Japan	US$?? (TBD)					
	5.1.5 The standardisation of purse seine CPUE be made where possible using the operational data on the fishery.		CPCs directly	US$?? (TBD)					
	Bigeye tuna: High priority fleets	High	CPCs directly	US$?? (TBD)					
	Skipjack tuna: High priority fleets	High	CPCs directly	US$?? (TBD)					
	Yellowfin tuna: High priority fleets	High	CPCs directly	US$?? (TBD)					

Topic	Sub-topic and project	Priority ranking	Lead	Est. budget (potential source)	TIMING				
					2017	2018	2019	2020	2021
	5.1.6 That methods be developed for standardising purse seine catch species composition using operational data, so as to provide alternative indices of relative abundance.	High	Consultant and CPCs directly	US$?? (TBD)					
	5.1.7 Investigate the potential to use the Indian longline survey as a fishery-independent index of abundance for tropical tunas.	High	Consultant And CPCs directly	US$30K (TBD)					
6. Stock assessment / stock indicators	6.1 Develop and compare multiple assessment approaches to determine stock status for tropical tunas	Med	Consultant and CPCs directly	US$?? (TBD)					
	6.2 Scoping of ageing studies of tropical tunas to provide information on population age structure (based on species and age composition of sampled catches)	Med							
	6.3 Develop a high resolution age structured operating model that can be used to test the spatial assumptions including potential effects of limited tags mixing on stock assessment outcomes (see Terms of Reference, Appendix IXb below).	Med		US$60K					
	6.4 Stock assessment priorities – detailed review of the existing data sources, including: i. Size frequency data: Evaluation of the reliability of length composition from the longline fisheries (including recent and historical data), review of anomalies in the (EU) PS length composition data, and the need for a thorough review of the size frequency data held by IOTC, in collaboration with the fleets involved, to improve the utilization of these data in tropical tuna stock assessments. ii. Tagging data: Further analysis of the tag release/recovery data set. iii. Alternative CPUE series: a review of the available data from the Indian tuna longline survey data.	Med		US$?? (TBD)					
7. Fishery independent monitoring	7.1 All of the tropical tuna stock assessments are highly dependent on relative abundance estimates derived from commercial fishery catch rates, and these could be substantially biased despite efforts to		CPCs directly	US$?? (TBD)					

	Topic	Sub-topic and project	Priority ranking	Lead	Est. budget (potential source)	TIMING 2017	2018	2019	2020	2021
		standardise for operational variability (e.g. spatio-temporal variability in operations, improved efficiency from new technology, changes in species targeting). Accordingly, the IOTC should continue to explore fisheries independent monitoring options which may be viable through new technologies. There are various options, among which some are already under test. Not all of these options are rated with the same priority, and those being currently under development need to be promoted, as proposed below:	High							
		i. Acoustic FAD monitoring, with the objective of deriving abundance indices based on the biomass estimates provided by echo-sounder buoys attached to FADs	High							
		ii. Longline-based surveys (expanding on the Indian model) or “sentinel surveys” in which a small number of commercial sets follow a standardised scientific protocol	Med							
		iii. Aerial surveys, potentially using remotely operated or autonomous drones	Med							
		iv. Genetics-based tagging techniques using recaptured individuals or identification of closely-related pairs								
8	Target and Limit reference points	8.1 To advise the Commission, on Target Reference Points (TRPs) and Limit Reference Points (LRPs).								
		8.1.1 Used when assessing tropical tuna stock status and when establishing the Kobe plot and Kobe matrices	High	CPCs directly	US$?? (TBD)					

Table 2. Assessment schedule for the IOTC Working Party on Tropical Tunas (WPTT)

Species	2017	2018	2019	2020	2021

Working Party on Tropical Tunas					
Bigeye tuna	Indicators	Indicators	**Full assessment**	Indicators	Indicators
Skipjack tuna	**Full assessment**	Indicators	Indicators	**Full assessment**	Indicators
Yellowfin tuna	Indicators	**Full assessment**	Indicators	Indicators	**Full assessment**

APPENDIX IXa. TERMS OF REFERENCE FOR THE PROVISION OF SCIENTIFIC SERVICES TO THE IOTC: COLLABORATIVE ANALYSIS TO PREPARE CPUE INDICES

Background

Indian Ocean longline data held by Japan, Korea, and Taiwan,China have been analysed in collaborative workshops in 2015 and 2016. The workshops have developed methods for joint standardization of the data, in order to provide abundance indices, which were used in 2016 assessment of bigeye, yellowfin, and albacore tunas. The assessments would benefit from further development of the analysis methods.

The 2016 IOTC-WPM07 **NOTED** the research priorities identified in the presentation of the CPUE standardization, ranked as follows: (i) improve the understanding of the fishery including the discontinuity of CPUE 1976-80 and size data, (ii) explore the spatial variation and time-area interactions within regions, (iii) prepare indices for each fleet separately, (iv) set up hardware and software for grid computation to speed up the analysis, (v) develop a simulator to allow development and testing of code while joint data are unavailable, and (vi) the analysis of factors affecting changes in targeting.

Scientific Services to be provided:

Following the application in 2016 of methods for joint standardization of catch and effort data to develop indices of abundance for bigeye, yellowfin, and albacore tunas, the IOTC requires a short term consultancy for the following activities.

COLLABORATIVE ANALYSES TO PREPARE CPUE INDICES

- Validate and improve methods for developing indices of abundance for tropical and albacore tunas.
- Provide indices of abundance for bigeye and yellowfin tunas and draft working papers to be presented at the WPTT19 and WPM08 (October/November 2017 (TBC)).
- Provide support and training to national scientists in their analyses of catch and effort data.
- The analyses will consider data to be provided by Japanese, Taiwanese, Korean, and potentially Seychelles research agencies.
- Analyses will be carried out in a series of meetings. After preliminary meetings between the consultant and some of the participating data providers to prepare each dataset and develop methods, there will be a joint meeting between all participating countries and the consultant.

Tasks will include the following, to the extent possible in the available time:

- Work with the IOTC Stock Assessment Expert to coordinate a series of meetings between data holders and the consultant.
- Load, prepare, and check each dataset, given that data formats and pre-processing often change between years and data extracts, and important changes to fleets and reporting sometimes occur in new data. The Seychelles data have not previously been included in the analyses and will require additional preparation.
- Prepare plots to explore relationships among covariates available in the logbook data, to identify patterns and increase understanding of the fisheries. Analyses will focus on the late 1970s in the Japanese dataset, and the recent Somalian piracy period in all datasets.
- Conduct the following analyses to improve CPUE methods:
    - Explore alternative modelling and data transformation methods in order to normalise residuals and to accommodate strata with no zero catches.
    - Explore spatial and temporal patterns in residuals by fleet and cluster, in order to better understand the factors driving CPUE changes.
    - Identify appropriate subareas for modelling time-area interactions within regions, by region and species. Prepare CPUE indices using models that include time-subarea interactions.
- Apply cluster analyses and bigeye and yellowfin CPUE standardization using reliable data from each CPC. Prepare separate indices for each fleet, and joint indices.

- The following tasks will be carried out using data held by the IOTC Secretariat:
  - Increase understanding of the fisheries that provide the CPUE by exploring the size data associated with each fleet, if possible with size data at the vessel set level.
  - Standardize size data from each longline fleet in order to identify spatial and temporal patterns.
- Prepare a simulator to generate datasets that can be used to test the code used in the joint CPUE standardization.
- Prepare and test computer hardware and software that will facilitate the fast and efficient running of large numbers of computer-intensive analyses.
- All work using Japanese, Korean, Taiwanese and Seychellois longline data is subject to the agreement of the respective fisheries agencies to make the data available.
- To document the analyses in accordance with the IOTC "*Guidelines for the presentation of CPUE standardisations and stock assessment models*", adopted by the IOTC Scientific Committee in 2014; and to provide the final report to the IOTC Secretariat no later than 15 days prior to the meeting of the WPTT19, i.e., in mid-October 2017.
- To undertake any additional analyses deemed relevant by the WPTT18 or the IOTC Secretariat up to 60 days after the start date of the contract.

Conditions and payment

In total this Service will require (TBA) days of work.

Honorarium is determined by FAO based on previous earnings and pre-approved consultant daily rates in Category A.

The IOTC Secretariat will pay the cost of return airfares (based on FAO travel regulations) from the contractor's home to the meetings. A Daily Subsistence Allowance will also be paid in accordance with FAO procedures for attendance at the WPTT and WPM Working Party meetings.

APPENDIX IXb. TERMS OF REFERENCE FOR THE PROVISION OF SCIENTIFIC SERVICES TO THE IOTC: TAG MODELLING PROJECT

Aim: To develop a preliminary spatially explicit operating model of the tropical tuna population for potential use in evaluating assessment bias

Objectives:

1. **To develop a spatially explicit operating model of the tropical tuna population.**
2. **To use the model to simulate data sets for evaluating assessment bias.**

Scientific Methods:

The extent and nature of bias resulting from mixing and movement assumptions in tag data remains a key uncertainty in stock assessment. In particular, it has been recommended that plausible spatial movement models be developed in order to address concerns about the level and nature of the bias that could result from non-homogeneous mixing assumptions of tagged fish.

Dunn & Rasmussen developed a generalised spatially explicit Bayesian statistical catch-at-age population dynamics model for developing and investigating plausible spatial movement models (SPM Manual). Mormede et al. (2014) applied this model to Antarctic toothfish in the Ross Sea as an age and maturity state spatial movement model.

The Project is proposing a similar approach, applied to tropical tunas, dependent on the availability of biological parameters for the tuna species of interest as well as the following data layers:

- Environmental predictor layers (e.g., surface temp, depth of mixed layer, currents, chlorophyll, etc.) by cell for developing preference functions.
- Historical catch history by cell
- Historical CPUE by cell
- Historical tag releases and recaptures by cell
- Age (length?) composition by cell??

Indicative costs and timing

~400 hours (approx. US$70-80k, excluding travel costs) to design a preliminary model up and testing – dependent on on the environmental layers and other data layers being readily available.

Timescale

July – November 2017

APPENDIX X
CONSOLIDATED RECOMMENDATIONS OF THE 18TH SESSION OF THE WORKING PARTY ON TROPICAL TUNAS

Note: Appendix references refer to the Report of the 18th Session of the Working Party on Tropical Tunas (IOTC–2015–WPTT18–R)

Review of the statistical data available for bigeye tuna

WPTT18.01 (para. 63): The WPTT **NOTED** that in the case of the Maldives and other coastal fisheries, juveniles of bigeye tuna often account for an appreciable amount of the total catch but are either not reported or assigned to an 'Other' species category and **RECOMMENDED** the IOTC Secretariat and Maldives collaborate to improve reliability of catches of bigeye tuna – particularly for historical catch series prior to the introduction of logbooks in 2010.

Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets

WPTT18.02 (para. 85): **NOTING** paragraph 84, the WPTT **RECOMMENDED** continued work on joint analysis of operational catch and effort data from multiple fleets, to further develop methods and to provide indices of abundance for IOTC stock assessments, and **NOTED** that ISSF would be willing to contribute support for future activities, with the aim of normalizing the process of joint analysis of the operational catch and effort data within the IOTC.

Bigeye tuna CPUE summary discussion

WPTT18.03 (para. 88): The WPTT **RECOMMENDED** that the multi-nation CPUE standardisation collaboration continue their efforts to improve the understanding of commercial CPUE as relative abundance indices, and expand future work to include other fleets, including the Seychelles longline fleet.

Yellowfin tuna CPUE Summary discussion

WPTT18.04 (para. 165): The WPTT **RECOMMENDED** that efforts to develop abundance indicators using PS data should be continued. Given the difficulty of defining effort in PS fisheries, and the importance of obtaining an abundance index for skipjack, alternative methods such as those based on ratio methods and standardized species composition should also be considered.

Stock Synthesis III (SS3) assessment of yellowfin tuna

WPTT18.05 (para. 181): **NOTING** the discussions on the tagging mixing period during previous WPTT meetings, related to the assessment of yellowfin and other tropical tuna stocks, the WPTT **RECOMMENDED** that additional work to be conducted to elucidate the most appropriate approach to tag modelling in IOTC stock assessments[11].

Parameters for future analyses: Yellowfin tuna CPUE standardisation and stock assessments

WPTT18.06 (para. 191): The WPTT **RECOMMENDED** that development of the next stock assessment of yellowfin tuna should include a detailed review of the existing data sources (conducted by the stock assessment consultant, in collaboration with the IOTC Secretariat and main longline and purse seine fleets), including:

[11] See Appendix IV, Program of Work, Topic 6 for more details.

v. Size frequency data: Evaluation of the reliability of length composition from the longline fisheries (including recent and historical data), review of anomalies in the (EU) PS length composition data, and the need for a thorough review of the size frequency data held by IOTC, in collaboration with the fleets involved, to improve the utilization of these data in tropical tuna stock assessments.

vi. Collaborative longline CPUE: Further refinement of the procedures to standardize the composite longline logsheet data sets to develop the longline CPUE indices;

vii. Tagging data: Comprehensive analysis of the tag release/recovery data set;

viii. Alternative CPUE series: a review of the available data from the Indian tuna longline survey data.

Revision of the WPTT Program of Work (2017–2021)

WPTT18.07 (para. 201): The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2017–2021), as provided at Appendix IX.

Election of a Chair and Vice-Chairperson of the WPTT for the next biennium

WPTT18.08 (para. 209): The WPTT **RECOMMENDED** that the SC note that Dr. M. Shiham Adam (Maldives) and Mr. Gorka Merino (Spain) were re-elected as Chairperson and Vice-Chairperson, respectively, of the WPTT for the next *biennium*.

Review of the draft, and adoption of the Report of the 18th Session of the WPTT

WPTT18.09 (para. 212): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT18, provided at Appendix X, as well as the management advice provided in the draft resource stock status summary for each of the three tropical tuna species under the IOTC mandate, and the combined Kobe plot for the three species assigned a stock status in 2016 (Fig. 15):

- Bigeye tuna (*Thunnus obesus*) – Appendix VI
- Skipjack tuna (*Katsuwonus pelamis*) – Appendix VII
- Yellowfin tuna (*Thunnus albacares*) – Appendix VIII

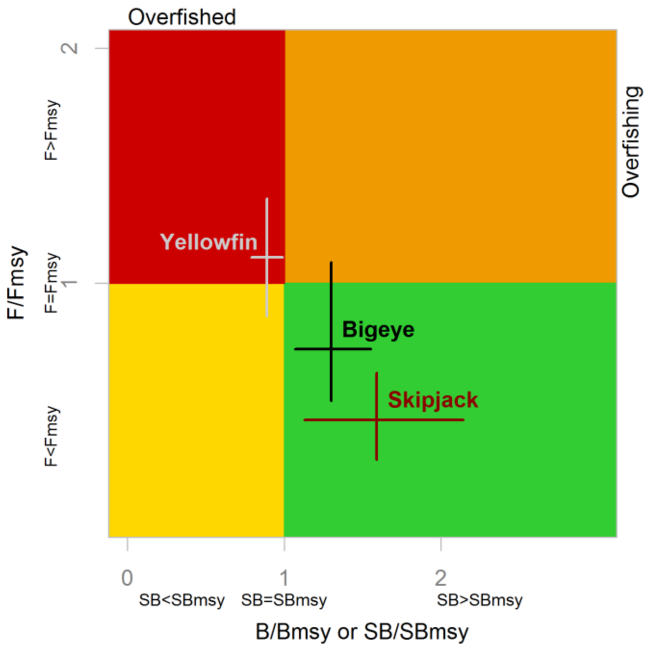


Fig.15. Combined Kobe plot for bigeye tuna (black: 2016), skipjack tuna (brown: 2014) and yellowfin tuna (grey: 2016) showing the estimates of current stock size (SB) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs. Note that for skipjack tuna, the estimates are highly uncertain as F_{MSY} is poorly estimated, and as suggested for stock status advice it is better to use B_0 as a biomass reference point and C(t) relative to C_{MSY} as a fishing mortality reference point.