Report of the 21st Session of the IOTC Working Party on Tropical Tunas

Donostia-San Sebastian, Spain, 21 - 26 October 2019

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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
RTTP-IO	Regional Tuna Tagging Project in the Indian Ocean
RTSS	RTTP-IO plus small-scale tagging projects
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**).

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EXECUTIVE SUMMARY

The 21st Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT) was held in San Sebastian, Spain from 21 - 26 October 2019. The meeting was opened by the Chairperson, Dr Gorka Merino (EU, Spain) who welcomed participants and Vice-Chair, Dr M. Shiham Adam (Maldives). A total of 68 participants attended the Session (cf. 57 in 2018, 49 in 2017 and 44 in 2016), including an invited expert (Dr. Rishi Sharma, FAO).

The following are a subset of the complete recommendations from the WPTT21 to the Scientific Committee, which are provided at Appendix XI.

Outcomes of the 3rd Technical Committee on Management Procedures

WPTT21.01 (para. 13): The WPTT **NOTED** that the work of the TCAC and TCMP are related; in particular, the outcomes of the deliberations of the TCAC, in relation to the distribution of allocated catches among gear types, will directly influence the predicted performance of management procedures being evaluated by the TCMP. As such the WPTT **RECOMMENDED** that the Commission ensure that these two Technical Committees are well coordinated and that communication between them is assured.

Review of the statistical data available for skipjack tuna

WPTT21.02 (para. 159): The WPTT **EXPRESSED CONCERN** over this consistent increase in FAD associated catch, in particular rapid increase in catches of juvenile yellowfin and bigeye which may hinder the rebuilding of exploited species and **RECOMMENDED** further evaluation of his issue and, where necessary, the identification of which alternative options could be implemented to avoid such adverse impacts on the stock.

Preliminary Indian Ocean yellowfin tuna stock assessment using SS3

WPTT21.03 (para. 219): An extra preparatory meeting may be required well in advance of the assessment, In this context, WPTT **ACKNOWLEDGED** that the procedure of how assessment are conducted needs to be restructured. WPTT **RECOMMENDED** that a data preparation meeting is scheduled well in advance of the assessment meeting so that the assessment meeting can focus on model configuration, diagnostics and advice only, and that data issues should not be reopened at the assessment meeting. This will also allow intersessional work between the data meeting and the assessment meeting to be conducted.

WPTT21.04 (para. 220): The WPTT **NOTED** that there is some model sensitivity to the choice of method used for weighting different data series and the time period in which the recruitment deviates are active. An investigation was undertaken during the WPTT, but the results were insufficiently conclusive to change the structure of the models included in the assessment grid. However, the WPTT **RECOMMENDED** that more intersessional work should be conducted, especially after the revision of the length compositions.

Outcomes of the 2nd joint tuna RFMO FAD Working Group meeting

WPTT21.05 (para. 262): The WPTT **NOTED** that there was little time to discuss FAD issues comprehensively during the WPTT meeting, but these issues are recognised as being of critical importance to the Commission (as acknowledged by the adoption of Rec 19/02). The WPTT therefore **RECOMMENDED** that the IOTC FAD Working Group, which to date has met only once, be reactivated with a clear mandate to discuss IOTC FAD issues.

Revision of the WPTT Program of Work (2020–2024)

WPTT21.06 (paras. 267): The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2020-2024), as provided at Appendix IX.

Review of the draft, and adoption of the report of the 20th session of the WPTT

WPTT21.07 (para. 274): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT20, provided at Appendix XI, 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 2019 (**Figure.14**):

- Bigeye tuna (Thunnus obesus) – Appendix VI
- Skipjack tuna (Katsuwonus pelamis) – Appendix VII

Yellowfin tuna (Thunnus albacares) – Appendix VIII

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

Stock	Indicators		2011	2012	2013	2014	2015	2016	2017	2018	2019	Advice to the Commission
Bigeye tuna *Thunnus obesus*	Catch in 2018: Average catch 2014–2018: MSY (1000 t) (80% CI): F_{MSY} (80% CI): SB_{MSY} (1,000 t) (80% CI): F_{2018}/F_{MSY} (80% CI): SB_{2018}/SB_{MSY} (80% CI): SB_{2018}/SB_0 (80% CI):	93,515 t (81,413 t*) 92,140 t (89,720 t*) 87 (75 – 108) 0.24 (0.18 – 0.36) 503 (370 – 748) 1.20 (0.70 – 2.05) 1.22 (0.82 – 1.81) 0.31 (0.21 – 0.34)						**84%** **			**38%**	A new stock assessment was carried out for bigeye tuna in 2019. The stock status will be characterised from the selected reference grid and catch advice will be developed from the K2SM shown in Table 7 of IOTC-2019-WPTT21-R. This advice will be developed intersessionally and provided to the Scientific Committee in 2019 On the weight-of-evidence available in 2019, the bigeye tuna stock is determined to be **not overfished** but is **subject to overfishing**. If catch remains above the estimated MSY levels, then immediate management measures are required. 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 2018: Average catch 2014–2018: MSY (1000 t) (plausible range): $SSB_{Current}$ / SSB_{MSY} $E_{Current}$ / E_{msy} $Yield_{40\%SSB}$ (1000 t) (80% CI): $E_{2016}/E_{40\%SSB}$ (80% CI): $C_{2016}/C_{40\%SSB}$ (80% CI): SB_{2016} (1000 t) (80% CI): Total biomass B_{2016} (1000 t) (80% CI): $SB_{2016}/SB_{40\%SSB}$ (80% CI): SB_{2016}/SB_0 (80% CI): $E_{40\%SSB}$ (80% CI): SB_0 (80% CI):	607,701 t (606,197 t*) 484,993 t (484,692 t*) 564 (480.4-697.8) 1.61 (1.25-2.35) 0.54 (0.36-0.77) 510.1 (455.9–618.8) 0.93 (0.70–1.13) 0.88 (0.72-0.98) 796.66 (582.65-1,059.40) 910.4 (873.6-1195) 1.00 (0.88–1.17) 0.40 (0.35–0.47) 0.59 (0.53-0.65) 2,015,220 (1,651,230–2,296,135)						**47%** **				No new stock assessment was carried out for skipjack tuna in 2019, thus, stock status is determined on the basis of the 2016 assessment and other indicators presented in 2019.. The 2017 stock assessment model results differ substantively from the previous (2014 and 2011) assessments, for a number of reasons. The final overall estimate of stock status indicates that the stock is at the target biomass reference point and that the current and historical fishing mortality rates are estimated to be below the target. Thus, on the weight-of-evidence available in 2018, the skipjack tuna stock is determined to be **not overfished** and is **not subject to overfishing**. However it should be noted that that total catches in 2018 (607,701 t) were more than 30% higher than the catch limit generated by the Harvest Control Rule (470,029 t) which applies to the years 2018–2020 Given the current status of the fishery and assuming that catch does not exceed prescription from Resolution 16-02, it would be expected that the stock would fluctuate around the target level. However there remains considerable uncertainty in the assessment, and the range of runs analysed illustrate a range of stock status to be between 0.88 and 1.17 of SB_{2016}/SB_0 based on all runs examined. <Click here for full stock status summary>
Yellowfin tuna *Thunnus albacares*	Catch in 2018: Average catch 2014–2018: MSY (1000 t) (plausible range): F_{MSY} (plausible range): SB_{MSY} (1,000 t) (plausible range):	423,815 t (437,422 t*) 404,655 t (407,377 t*) 403 (339–436) 0.15 (0.13–0.17) 1069 (789–1387)					**94%** **	**68%** **		**94%** **		A new stock assessment was carried out for yellowfin tuna in 2019, however, new management advice could not be provided in 2019 due to the complexity of the work, lack of agreement on key model aspects and time constraints during the meeting thus, the stock status is determined on the basis of the 2018 assessment integrated across of grid of 24 model runs. On the weight-of-evidence available in 2017, the yellowfin tuna stock is determined to be **overfished** and **subject to overfishing.**

	F_{2017}/F_{MSY} (plausible range): SB_{2017}/SB_{MSY} (plausible range): SB_{2017}/SB_{0} (plausible range):	1.20 (1.00–1.71) 0.83 (0.74–0.97) 0.30 (n.a.–n.a.)										The stock status determination changed in 2015 as a direct result of the large and unsustainable catches of yellowfin tuna taken over the previous three (3) years since 2012, and the relatively low recruitment levels estimated by the stock assessment model in recent years. Resolution 19/01 *On interim plan for rebuilding the Indian Ocean yellowfin tuna stock in the IOTC area of competence* implements reductions in catches (based on 2014/2015 catch levels), in response to the increased fishing pressure on yellowfin tuna and change in stock status. <Click here for full stock status summary>

* Considering the alternative purse seine log-associated catches for the EU fleet in 2018 as per IOTC-2019-WPTT21-R[E].

**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.

1. Opening of the Meeting

1. The 21st Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT) was held in San Sebastian, Spain from 21 - 26 October 2019. The meeting was opened by the Chairperson, Dr Gorka Merino (EU, Spain) who welcomed participants and Vice-Chair, Dr M. Shiham Adam (Maldives). A total of 68 participants attended the Session (cf. 57 in 2018, 49 in 2017 and 44 in 2016), including an invited expert (Dr. Rishi Sharma, FAO). The list of participants is provided at Appendix I.

2. Adoption of the Agenda and Arrangements for the Session

2. The WPTT **ADOPTED** the Agenda provided in Appendix II. The documents presented to the WPTT21 are listed in Appendix III.

3. The WPTT **ACKNOWLEDGED** a statement made on behalf of the Republic of Mauritius. This statement is included in Appendix XII.

3. The IOTC process: Outcomes, updates and progress

3.1 Outcomes of the 21st Session of the Scientific Committee

4. The WPTT **NOTED** paper IOTC–2019–WPTT21–03 which outlined the main outcomes of the 21st Session of the Scientific Committee (SC21), specifically those related to the work of the WPTT, and **AGREED** to consider how best to progress these issues at the present meeting.

5. The WPTT **NOTED** that in 2018, the SC made a number of requests in relation to the WPTT20 report (noting that updates on Recommendations of the SC21 are dealt with under Agenda item 3.4 below). Those requests are provided here for reference..

Yellowfin tuna stock assessment and development of management advice

- *(Para 103) The SC noted that the 2018 yellowfin tuna assessment indicates that the species is overfished and subject to overfishing and catch reductions required as part of Resolution 18/01 have not been met. The SC further noted that there remain significant uncertainties around the stock assessment inputs and assumptions, such that caveats are required in the interpretation of management advice developed for the species. Acknowledging these concerns, the SC RECOMMENDED that funding be allocated for a workplan (Appendix 38) to systematically address these issues, beginning in January 2019.*
- *(Para 105) The SC noted the usefulness of retrospective analyses to inform management advice, and that informal protocols and expert judgement have been used in the past. However, the SC noted these analyses have not been done in much detail due to a lack of time and resources and suggested that a formal protocol for how these should be undertaken would be beneficial. The SC noted its concern around the likelihood that the current assessment is overestimating F and underestimating B and noted the need to decide whether the retrospective error is significant enough to infer the reliability of B and F estimates. The SC AGREED that development of a protocol to decide whether retrospective errors need to be corrected would be useful.*
- *(Para 108) Noting the current status of the yellowfin tuna stock, the SC ENCOURAGED CPCs utilise the outcomes from the MSE work undertaken by the WPM to develop proposals for candidate Management Procedures for yellowfin tuna. In doing so, CPCs should follow the process outlined in the Commission's Schedule of Work for the development of management procedures, which describes the iterative process that needs to be followed, and the roles of the relevant IOTC committees and sub-committees, in developing Management Procedures.*

- *(Para 109) The SC noted that the decrease in longline CPUE from 2007–2011 may have reflected the redistribution of fishing effort due to piracy and may be causing the model to estimate low recruitment. The SC noted sensitivity trials to test this hypothesis did not reveal the real cause for low recruitment estimates. The SC also noted the model sensitivity exploring PS CPUE included both FAD and free school CPUE rather than the free school CPUE alone as suggested. The SC AGREED that these (and other) uncertainties result in the need to be cautious in the development of management advice.*
- *(Para 111) The SC suggested that more time and flexibility may be required for future joint CPUE analyses, and noted that consultant undertaking the joint CPUE analysis only had access to the data for five days and that it is not possible to replicate their analysis. The SC further noted that there are ongoing challenges with technical transfer and capacity building. The SC AGREED on the need to ensure that in future, sharing of relevant coding is enhanced and tutorials or manuals are produced or provided as part of the consultancy. The SC further AGREED that a protocol for joint CPUE is required for future iterations.*
- *(Para 112) The SC REQUESTED to generate CPUEs for the whole of the Indian Ocean to be used in the current candidate management procedures that are being tested and that basing advice on CPUE that is intended to be representative of the entire stock would be very useful. The SC also REQUESTED the creation maps showing spatial coverage of the joint CPUE analyses.*
- *(Para 113) The SC AGREED to the continuation of CPUE standardization analyses as this is a critical input to the bigeye tuna and yellowfin tuna stock assessments*

Future yellowfin tuna assessments: issues for consideration

- *(Para 121) Noting uncertainty in data and in some biological parameters in the yellowfin tuna assessment, some of which were not captured in the final grid for the assessment, the SC REQUESTED that future assessments capture a broader range of uncertainties.*
- *(Para 122) The SC noted that in the interests of transparency and to enable further exploration of uncertainty, future WPTT reports need to explicitly list all major assumptions.*
- *(Para 123) The SC 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:*
  - *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.*
  - *Tagging data: Further analysis of the tag release/recovery data set.*
  - *Alternative CPUE series: a review of the available data from the Indian tuna longline survey data.*

Review of the implementation of Resolution 18/01 On an interim plan for rebuilding the Indian Ocean yellowfin tuna stock

- *(Para 124) The Commission has an interim plan for the rebuilding the yellowfin stock, with catch limitations based on 2014/2015 levels (Resolution 18/01). Some of the fisheries subject to catch reductions had fully achieved a decrease in catches in 2017 in accordance with the levels of reductions specified in the Resolution; however, these reductions were offset by increases in the catches from some CPCs exempt and some CPCs subject to limitations on their catches of yellowfin tuna (see table 3 below). Thus, while catches for fleets subject to Resolution 18/01 decreased by 1% in 2017 compared* *to the baseline (2014/2015), the total catches of yellowfin in 2017 increased by around 3% from 2014/2015 levels. The Commission should ensure that any revision of the management measure can effectively achieve any prescribed catch reduction to ensure the effectiveness of the management measure.*

- *(Para 125) The SC noted that information on catches from coastal fisheries is particularly limited.*

Review of new information on fisheries and associated environmental data

- *(Para 126) The SC acknowledged the importance of the proposed harmonisation of FOB types and FOB activity definitions and REQUESTED that the concept of harmonisation be taken up by the WPDCS in collaboration with the Scientific Committee with the aim of harmonising IOTC definitions with those used by other tRFMOs in the context of the joint tRFMO Working Group on FADs.*

Review of the statistical data available for skipjack tuna

- *(Para 127) The SC noted that total catches in 2017 (524,282 t) were 12% higher than the catch limit generated by the Harvest Control Rule (470,029 t) which applies to the years 2018–2020, and that there has been an increasing trend in catches over the past 3 years. The SC RECOMMENDED that the Commission consider the urgent need to monitor catches of skipjack in the 2018–2020 period to ensure catches do not exceed the limit.*
    - *The SC noted that Resolution 16/02 does not define exceptional circumstances other than those caused by environmental influences (for example, increases in catch) and REQUESTED the MSE working group and WPM to review the range of exceptional circumstances that may be relevant for skipjack tuna as well as other species. The SC noted 15% implementation error of the TAC was evaluated in the skipjack tuna MSE.*

3.2 Outcomes of the 23rd Session of the Commission

6. The WPTT **NOTED** paper IOTC–2019–WPTT21–04 which outlined the main outcomes of the 23rd 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.

7. The WPTT **NOTED** the 7 Conservation and Management Measures (CMMs) adopted at the 23rd Session of the Commission (consisting of 7 Resolutions and 0 Recommendations) as listed below:

IOTC Resolutions

- Resolution 19/01 *On an interim plan for rebuilding the Indian Ocean yellowfin tuna stock in the IOTC Area of competence.*
- Resolution 19/02 *Procedures on a fish aggregating devices (FADs) management plan, including a limitation on the number of fads, more detailed specifications of catch reporting from fad sets, and the development of improved fad designs to reduce the incidence of entanglement of non-target species*.
- Resolution 19/03 *On the conservation of mobulid species caught in association with fisheries in the IOTC Area of Competence.*
- Resolution 19/04 *Concerning the IOTC Record of Vessels Authorised to operate in the IOTC Area of Competence.*
- Resolution 19/05 *On a ban on discards of bigeye tuna, skipjack tuna, yellowfin tuna, and non-targeted species caught by purse seine vessels in the IOTC Area of Competence*.

- Resolution 19/06 *On establishing a programme for transhipment by large-scale fishing vessels*.
- Resolution 19/07 *On vessel chartering in the IOTC Area of Competence*.

8. The WPTT **NOTED** that these CMMs will become binding 120 days after their distribution to all CPCs. The final versions of the 2019 CMMs will be available at: https://iotc.org/cmms.

9. **NOTING** that the Commission also made a number of general comments and requests on the recommendations made by the Scientific Committee in 2018, which have relevance for the WPTT (details as follows: paragraph numbers refer to the report of the Commission (IOTC–2019–S23–R)), the WPTT **AGREED** that any advice to the Commission would be provided in the relevant sections of this report, below.

   - ***Report of the 20th Session of the Scientific Committee***
     - *(Para. 29): The Commission NOTED the stock status summaries for species of tuna and tuna-like species under the IOTC mandate, as well as other species impacted by IOTC fisheries (Appendix 6) and considered the recommendations made by the Scientific Committee to the Commission. The Commission ENDORSED the Scientific Committee's 2018 list of recommendations as its own.*
   - ***On the status of tropical and temperate tunas***
     - *(Para. 36) The Commission NOTED that the current status of tropical and temperate tunas is as follows (full details are provided in Appendix 6).*

       ***Bigeye tuna**: The stock status is determined on the basis of the 2016 assessment and other indicators presented in 2018. On the weight-of-evidence available, the bigeye tuna stock has been 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.*

       ***Yellowfin tuna**: On the weight-of-evidence available in 2018, the yellowfin tuna stock has been determined to be overfished and subject to overfishing. As a precautionary measure, the Commission should ensure that catches are reduced to end overfishing and allow the SSB to recover to SSBMSY levels. At this stage, specific catch limits are not provided..*

       ***Skipjack tuna**: Stock status is determined on the basis of the 2017 assessment and other indicators presented in 2018. On the weight-of-evidence available, the skipjack tuna stock has been determined to be not overfished and is not subject to overfishing. The Commission needs to ensure that catches of skipjack in the 2018–2020 period do not exceed the agreed limit.*
   - ***Consideration of management measures relevant to tropical and temperate tunas***
     - *(Para. 37) The Commission NOTED the uncertainty in the yellowfin tuna assessment and that the Scientific Committee had not recommended any concrete catch advice due to the uncertainty in the projections and the associated Kobe II strategy matrix (K2SM). The Commission was informed that uncertainty is inherent in all assessments, and is not specific to yellowfin tuna. The Commission NOTED that the Scientific Committee has developed a yellowfin tuna workplan which aims to address and reduce many of the uncertainties in the 2019 assessment. This is expected to result in the provision of more robust advice on stock status and catch forecasts for this species in the future.*
     - *(Para 38) The Commission NOTED the considerable use of estimated data in the yellowfin tuna assessment due to the unavailability of data from CPCs, as is the case for all species. The Commission URGED all CPCs to improve their data collection and reporting.*

3.3 Review of Conservation and Management Measures relating to tropical tunas

10. The WPTT **NOTED** paper IOTC–2019–WPTT21–05 which aimed to encourage participants at the WPTT21 to review the existing CMMs relevant to tropical tunas, noting the CMMs contained in document IOTC–2019–WPTT21–04.

3.4 Progress on the recommendations of WPTT20

11. The WPTT **NOTED** paper IOTC–2019–WPTT21–06 which provided an update on the progress made in implementing the recommendations of the WPTT20, the requests and recommendations of SC21, and decisions of the Commission. The WPTT **AGREED** to consider and revise as necessary, its previous recommendations, and for these to be combined with any new recommendations arising from the WPTT21, noting that these will be provided to the SC for its endorsement.

3.5 Outcomes of the 3rd Technical Committee on Management Procedures

12. The WPTT **NOTED** paper IOTC–2019–WPTT21–07, which informed WPTT21 of the general recommendations to the Commission arising from the 3rd Session of the IOTC Technical Committee on Management Procedures (TCMP03), and those specifically relating to the work of the WPTT, and **CONSIDERED** how best to progress these issues at the present meeting. The recommendations relevant to the WPTT are:

    - *The TCMP NOTED the Operating Models (OM) based on the 2016 WPTmT stock assessment, with data until 2014, and that there is a plan for a new stock assessment for albacore in 2019. The results of the new assessment in 2019 might require, if the results are outside the bounds of the current OM, to recondition the OM and to repeat the simulation of the Management Procedures based on the new OM. The TCMP REQUESTED WPM and Scientific Committee to review the results of the 2019 Albacore assessment and discuss on the need, or not, of reconditioning the OM and repeat the simulations of the Management Procedures based on the new OM, depending on the stock assessment results.*
    - *The TCMP NOTED that the desired Management Procedure (MP) would be one that recovers the stock and keeps it around the target. Most of the MPs tested to date tend to overshoot the target. This may be because the MPs are too simple or the data not sufficiently informative. Additional complexity could be added to the MP design but it is difficult to design a single MP that will achieve the desired MP behaviour with certainty. Another option would be to develop one MP for rebuilding and another one for the time that stock is recovered. The TCMP AGREED to develop an MP for the rebuilding period, which will be updated once recovery is achieved, but the TCMP also REQUESTED that performance statistics are shown for the two periods: tuning objective recovery period, and the 20 years projected period when tuning to the recovery target.*
    - *The TCMP REQUESTED that the first rebuilding time period (5 years) is not used as a tuning objective and instead, 10 and 15 year recovery objectives are used for tuning (Y2 and Y3).*
    - *The TCMP also REQUESTED results that demonstrate how long rebuilding will take if TAC change constraints are limited to 15% (and alternative options of TAC change constraints such as 10% and 20% with some flexibility on the values for the technical developing team).*
    - *The TCMP REQUESTED the Scientific Committee to develop a revised workplan for Management Procedure development as the current plan is due to expire in 2020.*

- *The TCMP RECOMMENDED that the TCMP should continue to function in order to progress on MSE matters and advise on these issues to the Commission.*
- *The TCMP REQUESTED that Intersessional capacity building on MSE be conducted. Additionally attendance at the IOTC Working Party on Methods by national scientists will facilitate the increased understanding of the MSE processes by all CPCs.*
- *The TCMP ENCOURAGED that the deadline for the submission of documents for the TCMP be extended to one month to allow participants to fully consider the information prior to the onset of the meeting. The TCMP also REQUESTED that the questions that require decisions for the progress of the MPs for each species, be distributed prior to the meeting.*
- *The TCMP REQUESTED that a "shiny app" such as that demonstrated during the meeting be developed specifically for the IOTC.*

13. The WPTT **NOTED** that the work of the TCAC and TCMP are related; in particular, the outcomes of the deliberations of the TCAC, in relation to the distribution of allocated catches among gear types, will directly influence the predicted performance of management procedures being evaluated by the TCMP. As such the WPTT **RECOMMENDED** that the Commission ensure that these two Technical Committees are well coordinated and that communication between them is assured.

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

4.1 Review of the statistical data available for tropical tunas

14. The WPTT **NOTED** paper IOTC–2019–WPTT21–08 which provided a review of the statistical data and fishery trends for tropical tunas received by the IOTC Secretariat, in accordance with IOTC Resolution 15/02 *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPCs)*, for the period 1950–2018. 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 supporting information for the WPTT is provided in Appendix IV.
15. The WPTT **THANKED** the IOTC Secretariat for its efforts in the data collation and assessment of the quality of core IOTC datasets, and **ACKNOWLEDGED** the importance of the IOTC Secretariat's role in strengthening the capacity of CPCs in facilitating improvements in the collection, validation and reporting of data to the IOTC.
16. The WPTT **NOTED** that the total catch levels for all tropical tuna combined in 2018 almost reached the same levels as in pre-piracy years (over 1.1 million t) and that this was mainly due to an increase in the catch of skipjack tuna, with catches of yellowfin tuna and bigeye tuna remaining around the same levels recorded over the last five years.
17. Also, the WPTT **NOTED** recent changes in behaviour of the EU (and assimilated) industrial purse seine fishery that, while moderately decreasing total effort with respect to previous years, is now showing a marked expansion of its fishing grounds directed northbound, toward high seas areas in the north-western Indian ocean that were once exploited by industrial longliners before the onset of piracy in the mid-2000s.
18. The WPTT **NOTED** that catches of tropical tunas on free-schools have reached an all-time low in 2018, although recorded trends in log-school and free-school catches in recent years show recurring oscillations in the proportions of catches reported for the two fishing modes for both yellowfin and bigeye tunas.

19. The WPTT **NOTED** recent improvements in Indonesia's capacity to collect detailed catch-and-effort and length-frequency data for its national tuna fisheries, resulting in Indonesia completing the reporting requirements for IOTC Resolution 15/02, and **ACKNOWLEDGED** that while the coverage of logbook data used for this purpose is still low (around 5%) it is further expected to improve in the future.

20. The WPTT **NOTED** that Indonesia is reporting over 24,000 t of tropical tuna catches from a newly developed industrial Purse seine fishery targeting yellowfin and skipjack tuna in 2018, and that this fishery seems to mostly operate within Indonesia EEZ based on the partial catch-and-effort information received.

21. The WPTT also **ACKNOWLEDGED** that a number of previously unreleased biological and operational datasets (size-frequency and standardized CPUEs for tropical and neritic tuna species) are available to research institutions in the Sultanate of Oman, and **ENCOURAGED** the Sultanate of Oman to liaise with the IOTC Secretariat to ensure that such valuable information is shared with the scientific community in the near future.

22. The WPTT **NOTED** with concern that a number of problems with non-reporting and late reporting by several CPCs still persist, and this is problematic for stock assessments.

23. In particular, the WPTT **NOTED** that EU,Italy has not been reporting any information (nominal catch, catch-and-effort, size-frequency data, list of active vessels etc.) for 2018, although a purse seine vessel flagged to EU,Italy was informally known as actively operating in the Indian Ocean during 2018 and 2019.

24. For this reason, the WPTT strongly **ENCOURAGED** all CPCs to report their data in accordance with Resolution 15/02, and **NOTED** that the IOTC Secretariat is liaising with several CPCs (e.g. Pakistan, Oman and I.R. Iran among others) to ensure that all information available at national level is timely and accurately reported in the future.

25. The WPTT **NOTED** that some important revisions to existing nominal catch series for tropical tunas still need to be endorsed and incorporated within the IOTC database (e.g. reconstructed Pakistan gillnet catch series for yellowfin and skipjack tuna) and that the uncertainty caused by this situation might have implications on the Management Strategy Evaluation (MSE) processes for all concerned species.

26. The WPTT **NOTED** that underreporting was very likely to have occurred in earlier years of the time series (1950s-1970s) and that confidence around older data is still low for some species and fisheries.

27. Also, the WPTT **NOTED** that differences in reporting rates and accuracy of all information available (including estimates of catches by gear and species performed by the IOTC Secretariat) could result in biases that may influence stock assessment outcomes, and that this uncertainty has to be properly quantified and minimized as much as possible by ensuring that catch histories are properly reconstructed in recent years as well as in older decades.

4.2 Review new information on fisheries and associated environmental data

French purse seine species composition

28. The WPTT **NOTED** paper IOTC–2019–WPTT21–10 which provided an assessment of the species composition of major tropical tunas in purse seine catches using a new modelling approach applied to the French fleet in the Indian Ocean. The paper included the following abstract:

> *"The precise assessment of the catches by species is a major element in multi-species fisheries, such as the tropical tuna purse seine fisheries. The species composition by set is reported in the logbook, but it has been evidence of large bias mainly for the small individuals in the logbooks, which prevent the direct use of that source for catch estimates. For the major tropical tuna purse seine fisheries operating in the Indian Ocean, the species composition is estimated from sampling operations at landing and thought a statistical*

treatment to interpolate value for nonsampled sets. This method, called the Tropical Tunas Treatment (T3), developed by IRD and IEO in the mid-1990s has been criticized, specifically in the part on the species composition corrections. This document presents the results of a new statistical approach to handle the different shortcomings pointed out using data collected from the French fleet in the Indian ocean. Analyses specifically focus on the spatio-temporal dimension of the catches. Furthermore, the use of more information from the logbook reports are investigated and discussed.."

29. The WPTT **THANKED** the authors for the paper and presentation and **NOTED** the value of such information to inform the work of the WPTT. The WPTT **AGREED** that this approach is more useful than stratified approaches to identify species composition.

30. The WPTT **NOTED** that the paper indicated that there is no difference in species composition for large and small schools/catches, i.e. the size of the catch did not affect the predictive power of the model. The WPTT **ACKNOWLEDGED** that the minimum catch size included in the analysis was 6 tonnes and so species compositions from smaller catches would not have been represented in the analysis. Even though these smaller catches were a small minority of the total sets, the WPTT **SUGGESTED** that the authors could investigate this effect further.

31. The WPTT also **SUGGESTED** that the authors include the set time (hour of catch) in free school sets as a continuous variable in future analyses, as this has been shown to have a significant effect in Pacific Ocean fisheries.

French purse seine statistics

32. The WPTT **NOTED** paper IOTC–2019–WPTT21–11 which described the statistics of the French purse seine fleet targeting tropical tunas in the Indian Ocean (1981-2018) and included the following abstract:

"In 2018, a total of 14 French vessels operated in the eastern Indian Ocean including 12 purse seiners and 2 supplies. The total capacity weighted by the months of activity for each vessel is 11686t. The total nominal effort in 2018 was of 2885 fishing days and 2723 sets with 2463 sets on floating objects and 260 on free schools. In 2018, the percentage of sets on FOB was 90% and the catches reached 91%. The total catch of the French component of the EU purse seine fleet of the Indian Ocean was 84,729 t, being composed of 36%, 58%, and 6% of yellowfin tuna, skipjack tuna, and bigeye tuna respectively. Thus, the most noticeable change in 2018 is the shift of catches from the free school sets, dominated by yellowfin, to the associated school sets, dominated by skipjack. As a consequence, the increase in total catches mainly concerned the skipjack catches."

33. The WPTT **NOTED** that the data reported on FAD and free school sets comes from logbooks, therefore the classification of a FAD or free school set is determined by the Captain.

Spanish purse seine free school fishery trends

34. The WPTT **NOTED** paper IOTC–2019–WPTT21–12 which provided information on free school fishery trends for Spanish tropical purse seiners in the Indian Ocean, and included the following abstract:

"This document provides an update of the statistics of the Spanish purse seine fleet fishing in the Indian Ocean for the period 1990 to 2018, focusing on setting on tuna free schools. Catch and effort statistics, as well as some fishery indicators by species and fishing mode, are included in the analysis. In recent years, there has been a substantial change in the set ratio trends by type of school. This period is coinciding with the establishment of yellowfin tuna stock recovery plan with the aim to reduce their catches by 15% compared to the 2014 level . Thus, in the previous years, there was a ratio around of five sets on log schools for each set on free school. During the last year, this ratio has changed, reaching 25 sets on log schools for each set on free school. This operational change in the behavior of the fleet is an inflection point in the trends from time series"

35. The WPTT **NOTED** an unusual trend in the ratio between sets on FAD and free schools by the Spanish fleet in 2018, with a very large increase in the proportion of sets made on FADs. The WPTT was informed that this was a decision by the Spanish fleet in order to avoid fishing on schools of large yellowfin found in free schools and thereby ensure the catch limit was not reached prematurely. The WPTT was also informed that this change in fleet activity was mirrored by the French fleet in 2017 and 2018 but not in 2019 to date.

36. The WPTT **NOTED** that a switch from free school to FAD sets could explain the increase in small bigeye tuna reported in the catch for 2018, and this matter would likely be relevant in later discussions on the input data to the stock assessment.

Bigeye and yellowfin juveniles misidentification rate

37. The WPTT **NOTED** paper IOTC–2019–WPTT21–13 which provided an assessment of the misidentification rate of (Indian Ocean) bigeye and yellowfin juveniles in brine sampled at Port Victoria, Seychelles, and the consequences for the species composition estimates of landings. The paper included the following abstract:

> *"It is widely accepted that the identification of small to medium sizes of frozen bigeye (Thunnus obesus, BET) and yellowfin (Thunnus albacares, YFT) tunas is an especially difficult task, mainly at fork lengths (FL) under 50 cm. This is due to the fin damage, discoloration, skin abrasion and distortion of crushing during the storage process. For this reason, certain level of misidentification would be expected. The main aim of the current study is to analyze the potential misidentification rates of small YFT and BET during purse seiners sampling at port, in Port Victoria (Seychelles). Our results suggest that Error observed for YFT was almost negligible. However, certain level of misidentification was observed in the case of BET, with about 10% error. Unfortunately, the low number of BETs obtained in sample (3 BET vs. 97 YFT), makes it difficult to draw conclusions. We believe that this type of exercise should be repeated on a larger scale, and with more means for which greater economic investment is required"*

38. The WPTT **THANKED** the authors for this analysis and **SUGGESTED** that the study should be further developed and expanded to include other CPCs where similar misidentification issues may be occurring.

39. The WPTT **NOTED** that it would be important to have a size effect included in the analysis, as the size of the catch could change by season/trip which would affect the results of the analysis.

40. The WPTT also **NOTED** that it is important to ensure the independence of the samplers. The WPTT was informed that the sampling identification was conducted in groups which could affect the analysis. The authors informed the WPTT that there were two independent groups identifying species and that the random factor included in the analysis regarding the samplers was not significant. Therefore, for the above study, the independence of the samplers was not likely to have been an issue.

Catch statistics of the Seychelles purse seine fleet

41. The WPTT **NOTED** paper IOTC–2019–WPTT21–14 which provided statistics of the Seychelles purse seine targeting tropical tunas in the Indian Ocean, and included the following abstract:

> *"In 2018, the Seychelles purse seine fishing fleet was composed of 13 purse seiners and 7 supply vessels. The total annual number of fishing sets reported to be 2,956 which consist of 2,739 positive sets and 217 null sets. A total of 2,784 sets were associated to FOB (combine FADs) and 172 sets associated to free swimming schools (FSC). The total nominal effort in 2018 in term of fishing and searching was about 2,786 and 2,230 days which represent a decreased of 15% and 12% in fishing and searching days compared to 2017. The total catch recorded by Seychelles purse seine fleet operating in the Indian Ocean reached a total of 123,310 Mt representing a slight increase of 1% compared to 2017. Skipjack tuna dominated the Seychelles purse seine catches, accounting for 66% of the total catch followed by yellowfin tuna representing for 28% of the total catch, whilst*

bigeye tuna made up only 5% of the total catch. A total of 119,544 Mt of tuna were caught on FAD representing 97% of the total catch and 3,664 Mt or 3% of the total catch was caught on FSC. This reflects a 15% increase in catches on FAD's associated school and an 80% decrease on free swimming school respectively. Catches on FADs were predominated by skipjack tuna representing 67% of the catch while yellowfin and bigeye tunas represented 27% and 5% of catches, respectively. Catches FSC was dominated by yellowfin tuna representing 60% of the total catch whilst skipjack and bigeye tuna accounted for 27% and 12% of the catch on free swimming schools respectively"

42. The WPTT **THANKED** the authors for the study and encouraged them to continue to provide this information to the WPTT in the future.

43. The WPTT **NOTED** that the number of sets by the Seychelles fleet on both FAD and free schools decreased in 2018, and this was different to the Spanish fleet which saw a decrease in sets on free schools but an increase in sets on FADs.

Tropical tuna fisheries in India

44. The WPTT **NOTED** paper IOTC–2019–WPTT21–15 which provided the status of Indian tropical tuna fisheries in 2018, and included the following abstract:

"Small-scale and artisanal sectors largely contribute to the Indian tropical tuna fishery. This fishery deploys both mechanized and motorized boats using a variety of gears including gillnet, longline, pole and line, troll line and small purse seine. Pole and line fishery is restricted to the Lakshadweep archipelago, wherein artisanal fishermen target surface swimming skipjack tuna schools. The status of tuna and other large pelagics stocks in the Indian seas are constantly monitored employing four research vessels of Fishery Survey of India (FSI). The total catch of tropical tunas by Indian fishery during 2018 was 74,486.19 t. Yellowfin tuna was the principal species caught (50.33% of the total catch), while skipjack (48.85%) and bigeye (0.82%) were the other species of tropical tunas caught by this fishery. Gillnet remained the main gear contributing the tropical tuna catch (37.99%), followed by handline (15.97), pole and line (15.89), longline (11.62) and other gears. More than 60% of the catch was from the west coast (FAO Area 51), while the remaining catch originated from the east coast (FAO Area 57) of India. Results of biological studies of these three species are discussed in brief."

45. The WPTT **NOTED** that the paper included information on length-weight relationships. The WPTT **SUGGESTED** that this information could be compared to the length-weight relationships currently used by the WPTT to examine possible spatial differences in productivity in the Indian Ocean.

46. The WPTT **NOTED** that the paper reported substantial catches by offshore gillnets in 2018 which had not been available previously to the WPTT. The WPTT **ENCOURAGED** India to provide more information on this sector to the IOTC Secretariat.

Tropical tuna fisheries in Pakistan

47. The WPTT **NOTED** paper IOTC–2019–WPTT21–16 which provided the status of tropical tuna fisheries of Pakistan, including the impact of subsurface gillnetting on landings. The paper included the following abstract:

"Tropical tuna is represented by two species in Pakistan; of these yellowfin tuna (Thunnus abacares) contributed16,541m. tons during 2018. Annual landings of skipjack tuna (Katsuwonus pelamis) during 2018were recorded to be 2,318 m. tons. The landings of tropical tuna in 2018 was 46.89 % lower than 2017 which is mainly because of operation of tuna fleet in coastal waters as compared to previous years when the fleet was operating in comparatively deeper and offshore deeper waters. This is because of lower prices of tropical tunas in the neighboring country owing to unprecedented decrease in currency value. In addition, fishermen kept their operation closed during mid May to mid August as compared to normal close season during June and July. The study further revealed that

CPUE of tropical tuna was about 48.81 % higher in subsurface gillnet (2018 data) as compared to surface gear (2013 data).”

48. The WPTT **NOTED** that the IOTC Secretariat conducted a Data Compliance and Support mission to Pakistan in December 2018, which included discussions on revisions to the historical catches submitted by the Government of Pakistan to IOTC in 2016. The IOTC Secretariat has proposed a joint-paper – in collaboration with the Government of Pakistan and WWF-Pakistan – be presented to the WPDCS meeting in 2019 with an evaluation of the revised catch series, before a decision is taken regarding the incorporation of the revised catches in the IOTC database.

49. The WPTT further **NOTED** that Pakistan's revised catches are, in some cases, significantly higher than current IOTC estimates; notably yellowfin tuna are estimated at over 20,000 t in recent years (compared to 7,500 t currently in the IOTC database).

50. The WPTT **NOTED** the effort of the Pakistan fleet to change from surface to sub-surface gillnets which is expected to reduce the bycatch of sensitive species without decreasing the target tuna catch as suggested in Resolution 19/01. However, the completeness of this move to a new setting strategy is not known and the WPTT **REQUESTED** Pakistan to provide details in future meetings.

51. The WPTT **QUESTIONED** the reasons of skipjack catch decreases in certain periods which could be a result of the different areas being fished by Pakistani vessels during the periods of lower skipjack catches. The WPTT **NOTED**, however, that fishery distribution catch/effort data is not available to check this issue.

52. The WPTT also **QUESTIONED** the possible misidentification of species, notably between yellowfin and longtail tuna The WPTT was **INFORMED** that this should not be the case when species are identified by observers, but could be the case when catch is monitored at port.

Tropical tuna landings in Thailand

53. The WPTT **NOTED** paper IOTC–2019–WPTT21–17 which provided information on tropical tuna landing at fishing ports in Thailand during 2016 – 2018, and included the following abstract:

    “Thailand is one of the world's largest exporters of tuna products which are of great important in term of economic value and intensive international trade. During 2016 - 2018, total amount of tuna products exported from Thailand across the world ranged from 563,683 – 633,780 tons per year with an average export of 599,376 tons per year. While, export value of tuna products ranged from 2.50 – 2.66 billion USD per year with an average of 2.60 billion USD per year. The products include canned, pouch, and loin tuna as well as pet food. Since 2016, no Thai-flagged vessel had been operated outside Thai waters because all oversea fishing vessels were recalled to dock in Thailand in order to inspect whether they comply with the regulations under the Royal Ordinance on Fisheries B.E. 2558 (2015). Consequently, no tuna has currently been caught by Thai-flagged vessel. Therefore, all raw materials for tuna products derive from imported tunas. During 2016 – 2018, the total amount of imported tunas ranged from 702,812 - 792,397 tons per year with an average of 748,388 tons per year. Among these numbers, tropical tunas, i.e. bigeye tuna, skipjack tuna, and yellowfin tuna, made up 89.61% - 92.49% of total imported tunas.” – see paper for full abstract.

54. The WPTT **THANKED** the authors for their presentation and **ENCOURAGED** them to continue to provide updates on information from Thailand.

55. The WPTT **NOTED** that only an abstract of the paper was provided for review.

Malaysia tropical tuna catch trends

56. The WPTT **NOTED** paper IOTC–2019–WPTT21–60 on catch trends of tropical tunas by Malaysian tuna longliners in the Indian Ocean 2013 – 2017. The paper included the following abstract:

"Malaysian tuna fisheries had started with tropical tuna fishing since 2005. Malaysian tuna longline vessels were fishing in waters off Madagascar and southwards since the 3rd quarter of 2011. However, in 2012, Malaysia tuna longline vessels had shifted their operation from tropical tuna to albacore tuna fishing. The main species been caught for tropical tunas by Malaysian tuna longliners are Yellowfin tuna, big eye tuna and skipjack. From 2013 to 2017, catches of tropical tunas (comprised of Yellowfin tuna, big eye tuna and skipjack) by Malaysian tuna longliners ranged from 279.94 to 1172.90 tonnes with the average 770.92 363.90 tonnes. In 2017, landing of Yellowfin tuna was decreasing to 60% compare to 2013, meanwhile for bigeye tuna, 60% greater than 2013 landing. Meanwhile, the landing data for skipjack was just started since 2017. The catch trend and species composition during this period have been figured. From the current trend show there was a high demand of these species due to its high quality value for the market."

57. The WPTT **NOTED** that most fishing occurred in the first semester of the year with little activity in the second semester. The authors did not have the data available to determine what is causing this trend in seasonal fishing activity.

Diet and Consumption rates for yellowfin and skipjack tuna

58. The WPTT **NOTED** paper IOTC–2019–WPTT21–18 which described diet and consumption rates of yellowfin and skipjack tunas in the eastern Arabian Sea, and included the following abstract:

"Diet composition, feeding strategies and predator-prey relationships of yellowfin Thunnus albacares (Bonnaterre, 1788) and skipjack Katsuwonus pelamis (Linnaeus, 1758) tunas in the western Indian Exclusive Economic Zone (eastern Arabian Sea) were studied by stomach content analysis. Stomachs of 406 yellowfin tuna specimens in the fork length range of 48 to 165.5 cm caught during exploratory longlining conducted in the eastern Arabian Sea were examined, of which, 15.52% were empty. Purple back flying squid (Sthenoteuthis oualaniensis) was the dominant prey species, followed by the swimming crab (Charybdis smithii), bigeye cigarfish (Cubiceps pauciradiatus) and flyingfishes (family Exocoetidae). Diet breadth index and the Tokeshi graphical analysis showed dominance of few prey species which are available in high densities in the Arabian Sea, indicating opportunistic feeding nature of this apex predator. A total number of 72 skipjack stomachs were studied, of which, 22.22% were empty. Purple back flying squid was the dominant food item, followed by the flyingfish"

59. The WPTT **NOTED** this interesting study and **THANKED** the authors for providing this information. The WPTT **ENCOURAGED** the authors to continue to provide this information to the WPTT.

Tropical tuna catch and effort: Mauritius

60. The WPTT **NOTED** paper IOTC–2019–WPTT21–19 which provided an analysis of catch and effort data of tropical tuna from purse seine and longline fishery in Mauritius, and included the following abstract:

"Catch and effort data obtained from fishing logbooks of the purse seine and longline fisheries were analysed from 2014-2018. It could be observed that there was an increasing trend in the catch of the national purse seiners from 8557t in 2014 to 22405t in 2018. This trend is mainly due to an increase in the fishing effort. The fishing effort was high in 2014 as the active fleet number recorded was highest with a total of 7 purse seiners. The catch composition showed a remarkable increase for yellowfin tuna when compared to skipjack and bigeye tuna. Yellowfin tuna was the dominant species (52.3%), followed by skipjack (39.2%) and bigeye tuna (8.0%). Majority of the catch was made on log school (64.7%) compared to that effected on free school (35.3%). The percentage catch of yellowfin tuna in free school was higher (81.1%) than in log school (36.5%)." – see paper for full abstract.

61. The WPTT **NOTED** the large increase of yellowfin from 2014 to 2018 by Mauritius longliners and purse seiners and that the spatial distribution of FAD catches is showing sets in the eastern

Indian Ocean while official nominal catch has not been reported for this region. The WPTT **REQUESTED** Mauritius to work with the IOTC Secretariat to clarify this matter.

62. The WPTT **QUESTIONED** the reasons for the increase of catch rates for yellowfin tuna in the most recent years. The WPTT **NOTED** this could be explained by larger vessels operating on free schools.

63. The WPTT **NOTED** that the Mauritian purse seiners are operating in similar areas to other purse seiners with similar species proportion of the catch. However, the WPTT **NOTED** that as Mauritian purse seiners are not limited by the yellowfin catch restrictions prescribed in Resolution 18/01, they are focusing more on free schools than on FADs.

64. The WPTT **NOTED** that bigeye tuna composition of FAD sets remains somewhat similar over the years while some other fleets fishing in the same area showed dramatic increases in bigeye tuna proportion.

Japan CPUE for bigeye and yellowfin tuna

65. The WPTT **NOTED** that papers IOTC–2019–WPTT21–20, IOTC–2019–WPTT21–30 and IOTC–2019–WPTT21–46 were presented together.

66. Paper IOTC-2019-WPTT21-20 provided a study on the standardization of bigeye and yellowfin tuna CPUE by Japanese longline in the Indian Ocean which includes cluster analysis, and included the following abstract:

"Standardizations of Japanese longline CPUE for bigeye and yellowfin tuna in multiple Indian Ocean regions were conducted using generalized linear models (GLM) with log normal and delta-lognormal errors. The models incorporated fishing power based on vessel ID where available, and used cluster analysis to account for targeting. The variables year-quarter, vessel ID, latlong5 (five degree latitude-longitude block), cluster and number of hooks were used in the standardization. Dominant species differed depending on clusters. The effects of each covariate differed depending on species and region. The CPUE trends were similar to those estimated using 'traditional' method, though with some differences due to the inclusion of vessel effects and cluster variables"

67. The WPTT **NOTED** paper IOTC–2019–WPTT21–30 which provided the Japanese longline CPUE for bigeye tuna in the Indian Ocean standardized by GLM, and included the following summary:

"Standardization of Japanese longline CPUE for bigeye tuna was conducted up to 2018 by using GLM (generalized linear model, log normal error structured). The effects of season (month or quarter), subarea 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 were observed."

68. The WPTT **NOTED** paper IOTC–2019–WPTT21–46 which describes Japanese longline CPUE for yellowfin tuna in the Indian Ocean standardized by generalized linear model, and included the following abstract:

"Japanese longline CPUE for yellowfin tuna in the Indian Ocean (area aggregated and area-specific) was standardized up to 2018 by GLM mainly based on similar methods used in the previous studies. Basically, standardized CPUEs showed similar trends among areas. CPUE continuously decreased from 1950s to around 1974, and kept in the same level until 1990. Thereafter, it declined to a historically low level and then slightly increased in recent years. Decline in CPUE got less steep by using the vessel effect. There was somewhat difference between the trend of CPUEs in this study and those created in the collaborative analysis (with cluster analysis and vessel ID).."

69. The WPTT **NOTED** the comprehensive work undertaken by the authors on the standardisation of CPUEs for the Japanese longline fleet for both yellowfin and bigeye tuna and **THANKED** them for the presentation.

Taiwanese CPUE for bigeye and yellowfin tuna

70. The WPTT **NOTED** paper IOTC–2019–WPTT21–21 which provided updated CPUE standardizations for bigeye and yellowfin tuna caught by Taiwanese longline fleet in the Indian Ocean, and included the following abstract:

    "Updated Taiwanese longline fishery data to 1979-2018 were used in this analysis. We used cluster analysis to classify longline sets into groups based on the species composition of the catch, to understand whether cluster analysis could identify distinct fishing strategies. Bigeye and yellowfin tuna CPUE were then standardized. 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 2019 in AZTI, Spain.."

71. The WPTT **THANKED** the authors for their presentation.

Joint CPUE analysis for longline fleets in the Indian Ocean

72. The WPTT **NOTED** paper IOTC–2019–WPM10–16 which presented a collaborative study of bigeye and yellowfin tuna CPUE from multiple Indian Ocean longline fleets in 2019, with consideration of discarding. The paper included the following abstract:

    "In April and May 2019 a collaborative study was conducted between national scientists with expertise in Japanese, Korean, Seychelles, and Taiwanese longline fleets, an independent scientist, and an IOTC scientist. The meetings addressed Terms of Reference covering several important issues related to yellowfin and albacore tuna CPUE indices in the Indian Ocean. The study was funded by the Indian Ocean Tuna Commission (IOTC) and the International Seafood Sustainability Foundation." – see document for full abstract

73. The WPTT **THANKED** the authors for this important study and **ACKNOWLEDGED** its utility for the stock assessments of tropical tuna species.

74. The WPTT **NOTED** that the time available to conduct the study was extremely limited and therefore only certain key issues could be examined. In the latest iteration of this study, priority was given to assessing the effects of discards on the CPUE standardisation. As such, issues such as the effect of piracy, or spatial displacement of the fishing effort where only partially addressed.

75. The WPTT **NOTED** that although the effects of piracy were not explicitly included in the standardisation, the model takes into account spatial and temporal factors. The authors clarified that the area affected by piracy was relatively small compared to the entire region; and decreases in effort and associated catch trends in the areas affected by piracy were addressed by taking into account trends in catch rates throughout the entire region. However the large spike in bigeye CPUE from 2011-2012 (immediately following the piracy period) merits further investigation.

76. The WPTT **NOTED** that for certain time periods, the standardised and unstandardized CPUEs were very similar. This was particularly the case for the indices prior to 1979. The WPTT **ACKNOWLEDGED** that for other time periods the difference was much larger. The authors informed the WPTT that for the early time period, data on vessel ID was not available, and this factor had a strong effect on the standardisation. The WPTT were also informed that a project was being undertaken in Japan to recover vessel ID information and this information could be used to improve the CPUE index for the early time period.

77. The WPTT **NOTED** that the discard effect was considered to be minor in the current analysis and that the WPM10 **DISCUSSED** that the information on discarding was limited and so it would be premature to make any definitive statements with regard to its influence. The WPTT **AGREED** that this was the case, but that the analysis had been conducted with the data available, and this had been clearly described.

78. The WPTT **DISCUSSED** the possibility of including other gears and fleets in a joint standardisation of CPUE. The WPTT **NOTED** that that different gear types could not be included in the current analysis, but **AGREED** that such an analysis could be useful in the future, and that this would best be achieved in a parallel but separate process.

79. The WPTT was informed of a recommendation made by the WPM10 that it would be beneficial to coordinate a joint CPUE series workshop with the involvement of all the tuna RFMOs. The WPTT **ENDORSED** the WPM recommendation.

80. The WPTT **NOTED** the regions used for CPUE analysis are common across standardisation processes and are included in **Figures 1** and **2**.

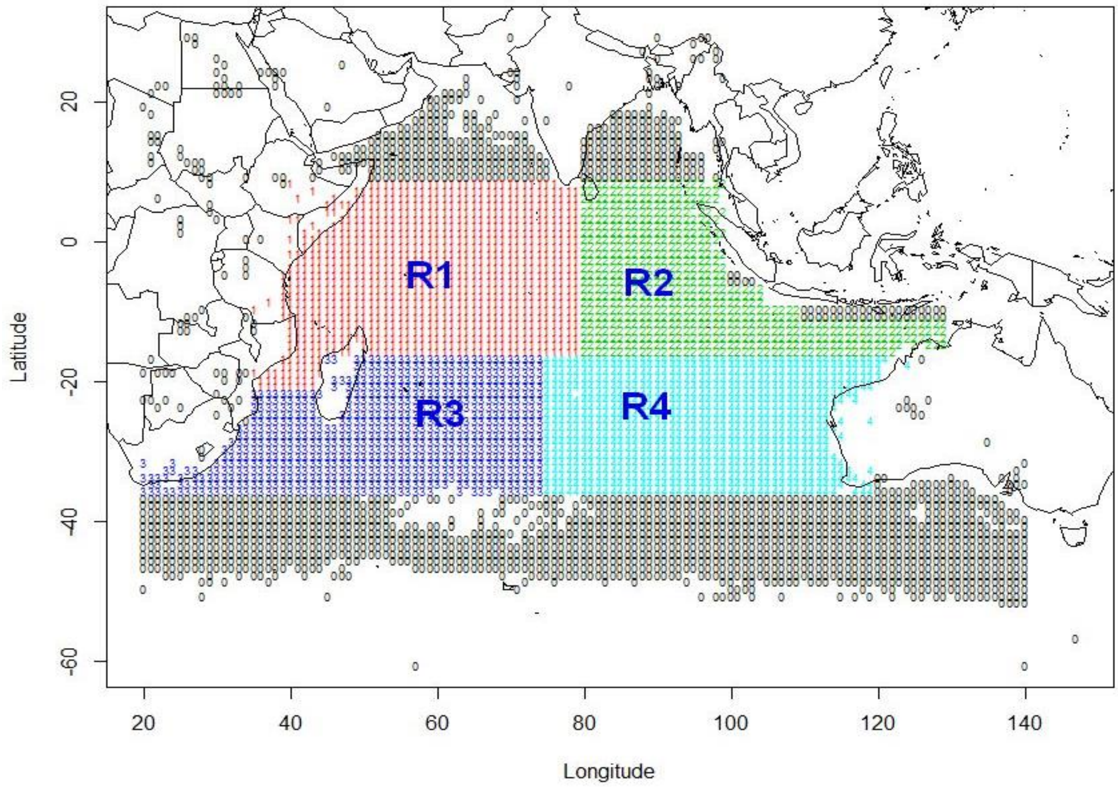


Figure 1: Map of the regional structures used to estimate bigeye tuna CPUE indices

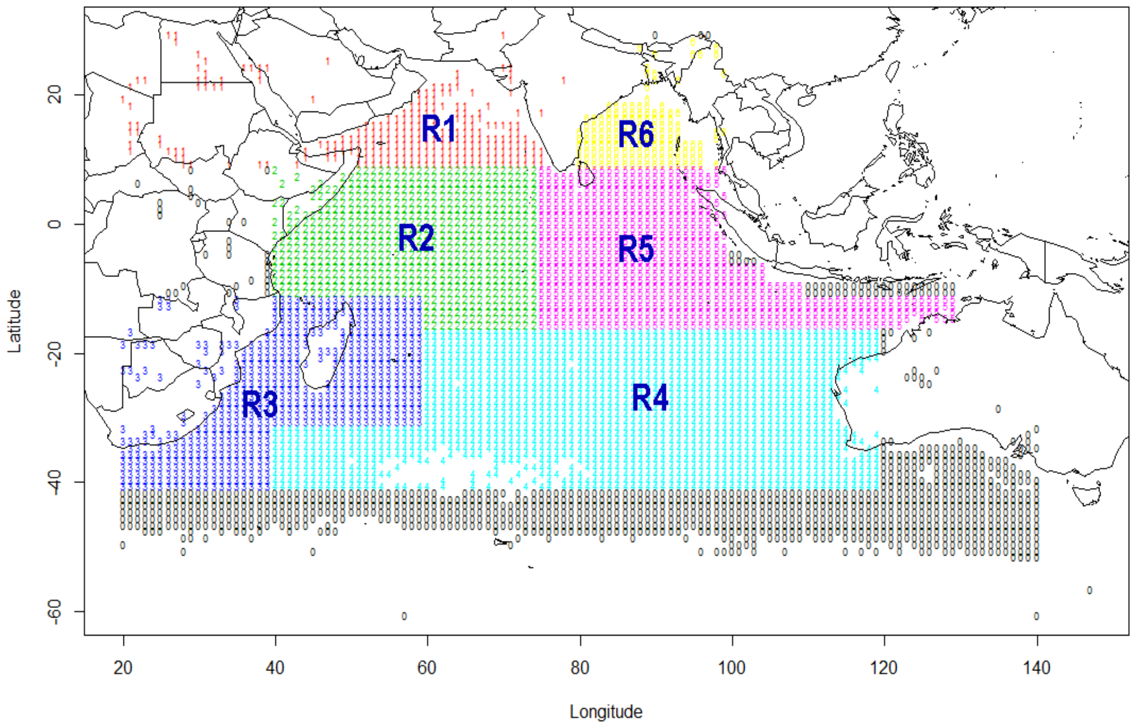


Figure 2: Map of the regional structures used to estimate yellowfin tuna CPUE indices

Tag loss covariates

81. The WPTT **NOTED** paper IOTC–2019–WPTT21–22 which discussed covariates of release mortality and tag loss in large-scale tuna tagging experiments, and included the following abstract:

"The data from tag-recapture experiments, which are used to help understand animal behaviour and dynamics, and to provide input data for population models such as stock assessments, are affected by mortality associated with tagging and by tag shedding. These processes introduce bias and uncertainty into parameters estimated in population models such as tuna stock assessments. The causes and magnitudes of tag shedding and post-release mortality in tuna tagging experiments are not well understood. We analysed data from tuna tagging experiments in the Western Pacific (330,000 releases) and Indian Oceans (168,000 releases) to investigate factors affecting post-release mortality and tag shedding. Tag return rates were modelled as functions of the tagger identity, tagger experience, tagging assistant, tagging station, treatment of the fish, use of oxytetracycline, tuna species, and size at release." – see document for full abstract

82. The WPTT **THANKED** the authors for this presentation which further clarified the methodology used to estimate covariates of release mortality and tag loss.

83. The WPTT **AGREED** that the values of release mortality and tag loss for the three tropical tuna species included in this paper should be adopted for the assessment of the tuna stocks in the Indian Ocean. It was further **NOTED** that new studies are being initiated to re-consider how to utilise tagging data, and the outcomes of this may result in revisions to these values in the future, but the values provided in this paper are the best available estimates currently.

Effort control measures

84. The WPTT **NOTED** paper IOTC–2019–WPTT21–23 which described using effort control measures to implement catch limits in IOTC purse seine fisheries, and included the following abstract:

"In 2016, the IOTC adopted a rebuilding plan in order to address overfishing of the stock of yellowfin tuna (YFT), through the implementation of catch limits for some fisheries and additional measures to reduce the capacity of industrial purse seine fisheries. However, catch controls, while ensuring that overall fishing mortalities are not exceeded, are not implemented properly because some IOTC CPCs exceed targets on a regular basis and not all fisheries are covered by the measures. This is an issue in multi-species fisheries where monitoring of catch in near-real time is complex, especially for industrial tuna purse seine and pole-and-line fisheries, that very often catch juvenile yellowfin tuna and bigeye tuna (BET) when targeting skipjack tuna (SKJ), as those species tend to aggregate forming mixed schools.." – see document for full abstract.

85. The WPTT **THANKED t**he authors for this study on an alternate method to provide management for tropical tuna stocks.

86. The WPTT **NOTED** that for the Spanish fleet, there are difficulties in monitoring vessel catches in real time. The WPTT **NOTED** document IOTC-2019-WPTT21-INF03 which provided the methodology employed for the French and Italian vessels to monitor catches.

87. The WPTT was informed that high catches per vessel and per fishing trip were observed through this monitoring, suggesting that long closures would be necessary to meet the target reduction in yellowfin tuna catches.

88. The WPTT **NOTED** that yellowfin tuna catch limits have only been implemented for 2 years and that more time may be needed to conclude on their efficacy.

89. The WPTT **NOTED** that the method should be updated regularly to account for vessel efficiency. The model uses information on catch and effort from the Spanish purse seine fleet which is regularly updated and so the time period needed for the closure can be revised as necessary. Issues such as effort creep can be monitored and accounted for, provided that fleets provide information on increases in fishing capacity in advance of the fishing season.

90. The WPTT **NOTED** that several combinations of operational tools can be implemented as required to achieve the Commissions objectives. These can include both catch and effort measures, depending on the objectives required, such as limiting effort, catch, or avoiding catches on juveniles. Full seasonal closures may address several of these objectives simultaneously

Area closures

91. The WPTT **NOTED** paper IOTC–2019–WPTT21–59 which made a case for fishery closures to manage purse seine fisheries for tropical tunas in the IOTC Area of Competence. The paper included the following abstract:

"Total Allowable Catches (TAC's) have been implemented for numerous stocks by tRFMO. However, for IOTC's tropical tuna stocks (yellowfin tuna [Thunnus albacares], skipjack tuna [Katsuwonus pelamis] and bigeye tuna [Thunnus obesus]), catch controls, while intended to ensure that overall fishing mortalities are not exceeded, have failed to maintain catches at the desired level because some IOTC CPCs have consistently exceed targets, and other CPCs were excluded from such controls. This document presents a Case for IOTC to consider moving from a system that involves primarily output-based controls to another that relies on input-based controls for its purse seine fishery. It evaluates how successful the different tRFMO have been in managing their tropical tuna stocks showing that input-based controls, as those used in the Pacific Ocean, are more effective than TACs to manage multi-species fisheries for such stocks. Finally, it shows an example of how the decision support tool presented by Sharma & Herrera (2019c) could be used to set seasonal closures for IOTC purse seine fisheries; and demonstrates that the new scheme proposed can assist the IOTC in achieving more effectively its management objectives for tropical tuna stocks."

92. The WPTT **THANKED** the authors for this interesting analysis and **ACKNOWLEDGED** the potential application of this information to improve the management of tropical tunas purse seiner fishery.

93. The WPTT **DISCUSSED** whether the model has evaluated moving the temporal window along with a time-area closure and if the analysis has considered only the evaluation of the FAD component. The WPTT was informed that, considering previous conclusions of a lack of effectiveness of the FAD time-areas closure in the Atlantic Ocean (at least for the specific strata used), only a full closure was evaluated. The authors also confirmed that different windows for time closures were evaluated.

94. The WPTT **NOTED** that the year of the highest catch rate was used as a reference case in the analysis and therefore questioned whether it would be worth undertaking simulations to check the sensitivity of different reference years. The WPTT was informed that the reference year used was the reference year for which the yellowfin catch reduction should be applied.

Indian Ocean Climate and Oceanic conditions

95. The WPTT **NOTED** that paper IOTC–2019–WPTT21–24 providing an outline of climate and oceanic conditions in the Indian Ocean: an update to mid-2019. The paper included the following abstract:

"The trend in climate and oceanic variables was investigated for the recent years (2017-2019). After a neutral phase in 2018, the Southern Oscillation Index entered a negative phase in January 2019, continuing until July 2019. This short event has been qualified as a weak El Niño event. By contrast, a positive dipole (IOD), started in 2017, continued through 2018 and was still observed at a lesser level in August 2019. In line with the IOD, from 2017 to present, warm temperature anomalies prevailed in the WIO whereas sea surface temperature fluctuated around the average in the EIO. The trend in chlorophyll concentration (SSC) was investigated in four ecoregions of the tropical Indian Ocean, distributed between 12°N and 30°S, during 1997-2019. A similar trend is observed in the four ecoregions, with SSC-depleted conditions during 2007-2014 and SSC-enhanced conditions in 2015-2019. A different pattern was observed from 1998 to 2006. Finally, following previous studies, it is shown that the intensity of two important upwelling systems of the tropical Indian Ocean fluctuate in relation to the Dipole/ENSO cycle, however in an opposite way. In the EIO, the SLP anomalies recorded in Darwin can have a predictive power by indicating the status of the Java-Sumatra upwelling in the 3 coming months."

96. The WPTT **THANKED** the author for this comprehensive study on climate and oceanic events and **RECOGNISED** the potential for the information to be used in the work of the WPTT.

97. The WPTT **NOTED** that there is an intention to include climate information into future CPUE standardisations of purse seine data. The WPTT were informed that this could include incorporating chlorophyll data (as a proxy for productivity). The WPTT **AGREED** that this would have to be carefully considered as the trends in the CPUE due to changes in productivity could be lost in the standardisation process if it is confounded with the year effect, and so the proxy parameter of chlorophyll should rather not be included as a factor.

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

5.1 Review of the statistical data available for bigeye tuna

98. The WPTT **NOTED** paper IOTC–2019–WPTT21–08 which provided a review of the statistical data and fishery trends 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 (CPCs)*, for the period 1950–2018. 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 supporting information for the WPTT is provided in Appendix IVb.

99. The WPTT **NOTED** that, while the total catches of bigeye tuna in 2018 were similar to those in 2017 (around 90,000 t), the total was maintained through a marked decrease in catches reported by the longline fisheries and a marked increase in catches reported by the purse seine fisheries (that fish almost exclusively on log-associated schools).

100. For this reason, the WPTT **NOTED** with concern that the recent changes in fishing patterns and gear composition for the bigeye tuna fishery resulted in the estimated average weight of individual fish caught decreasing markedly from 10.7 to 6.2 kg/fish in the last two years (averaged across all gears and fishing modes).

101. The WPTT **NOTED** that 2018 catches of bigeye tuna reported by the EU purse seine fleet alone exceeded the catches recorded by all purse seine fleets in 2017; furthermore, that, in 2018, bigeye tuna was reported by the EU purse seine fleet as the dominant species (in terms of recorded catches) in several grids where the fishery has been operating in conjunction with other PS fleets.

102. The WPTT **NOTED** that the geospatial plots that show the proportion of bigeye tuna catches vs. yellowfin tuna catches recorded over several 1x1 degrees grid by the EU purse seine fleet in 2018 show unusual but distinct characteristics such as regular, large areas with sharp perpendicular edges, and that these correspond to areas in which the proportion of bigeye tuna is markedly higher than yellowfin tuna.

103. As these characteristics are not present in the data reported by other purse seine fleets during the same year, and are not in the data reported by the EU purse seine fleet in years prior to 2018, the WPTT **NOTED** that this feature of the catch might be due to errors or changes related to the estimation of the species composition for catches reported by the EU purse seine fleet in 2018, and **REQUESTED** the EU to clarify the matter and report back to the Scientific Committee in 2019.

104. **ACKNOWLEDGING** that the above matter seems to arise from the Spanish component of the EU purse seine fleet, the WPTT **NOTED** that this could be due to changes introduced in the type of statistical methodologies adopted for the production of final catch statistics by EU,Spain in 2018, (new estimation based on catch per vessel instead of T3) or changes in fishing patterns reported by the fleet during the same year or a combination of both.

105. For this reason, the WPTT **AGREED** that a methodology to revise the bigeye tuna catches reported by EU,Spain in 2018 (limited to their log-associated school component) should be identified and discussed, and that the chosen approach adopted to produce such revision be clearly documented for further reference and reviewed by the WPDCS.

106. The WPTT **REVIEWED** an approach to revising the bigeye tuna catch, which applied the species composition recorded for the log-associated component of EU,Spain purse seine catches in 2017 to the total catches (log-associated) reported in 2018 by the same fleet.

107. For what concerns the first approach, the WPTT **NOTED** that the relative species composition of EU,Spain PS LS catches in 2017 ($pBET_{2017}$, $pSKJ_{2017}$ and $pYFT_{2017}$) was as follows:

- $pBET_{2017} = BET_{2017} : TROP_{2017} \approx 6\%$
- $pSKJ_{2017} = SKJ_{2017} : TROP_{2017} \approx 65\%$
- $pYFT_{2017} = YFT_{2017} : TROP_{2017} \approx 29\%$

with BET_{2017} (7,926 t), SKJ_{2017} (83,426 t) and YFT_{2017} (36,583 t) being the reported catches by species for EU,Spain PS LS in 2017 and $TROP_{2017}$ being the total catches of all tropical tuna species reported for EU,Spain PS LS in 2017 ($TROP_{2017} = BET_{2017} + SKJ_{2017} + YFT_{2017} = 127,936$ t) while in 2018 it was:

- $pBET_{2018} = BET_{2018} : TROP_{2018} \approx 12\%$

- $pSKJ_{2018} = SKJ_{2018} : TROP_{2018} \approx 66\%$
- $pYFT_{2018} = YFT_{2018} : TROP_{2018} \approx 22\%$

with BET_{2018} (24,507 t), SKJ_{2018} (132,709 t) and YFT_{2018} (43,652 t) being the reported catches by species for EU,Spain PS LS in 2018 and $TROP_{2018}$ being the total catches of all tropical tuna species reported for EU,Spain PS LS in 2018 ($TROP_{2018} = BET_{2018} + SKJ_{2018} + YFT_{2018} = 200,239$ t).

108. For this reason, the WPTT **ACKNOWLEDGED** that by applying the same species composition identified for EU, Spain PS LS in 2017 to the total catches reported by the same fleet component in 2018 (200,239 t = $BET_{2018} + SKJ_{2018} + YFT_{2018}$), the resulting revised total catches by species for the fleet and fishing mode in 2018 would be:

- $\mathbf{BET_{2018\_R}} = pBET_{2017} * TROP_{2018} = BET_{2017} * TROP_{2018} : TROP_{2017} =$ **12,405 t**
- $\mathbf{SKJ_{2018\_R}} = pSKJ_{2017} * TROP_{2018} = SKJ_{2017} * TROP_{2018} : TROP_{2017} =$ **130,575 t**
- $\mathbf{YFT_{2018\_R}} = pYFT_{2017} * TROP_{2018} = YFT_{2017} * TROP_{2018} : TROP_{2017} =$ **57,259 t**

with $TROP_{2017} = BET_{2017} + SKJ_{2017} + YFT_{2017}$ and $TROP_{2018} = BET_{2018} + SKJ_{2018} + YFT_{2018}$, in lieu of the currently reported:

- BET_{2018} = 24,507 t,
- SKJ_{2018} = 132,079 t and
- YFT_{2018} = 43,652 t.

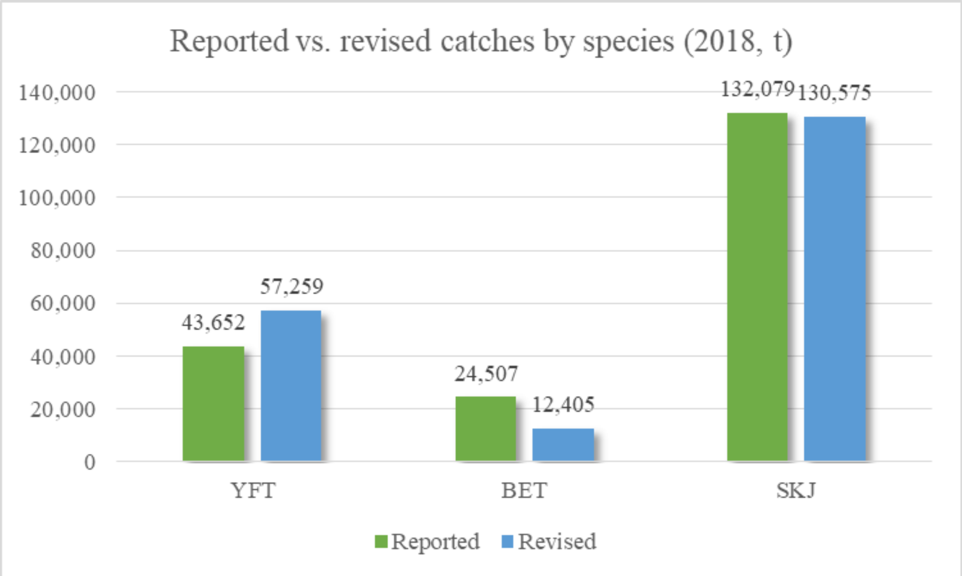


Figure 3: Revised catches of tropical tuna species

109. The WPTT **NOTED** that this approach causes marked reductions in catches of bigeye tuna reported by the EU purse seine fleet component in 2018 by 12,102 t, increasing yellowfin tuna catches by 13,606 t when compared to the official estimates, while leaving skipjack tuna catches basically unaltered (1,504 t less compared to official estimates).

110. Furthermore, the WPTT **ACKNOWLEDGED** that the differences in catches of bigeye tuna and yellowfin tuna introduced by the re-estimation process above do, in turn, produce the following changes to the input data used for the stock assessment of both species (catches by quarter, fleet and area limited to the PS LS fishery), with quarter and area breakdown determined by using the catch-and-effort data available to the IOTC Secretariat:

Year	Quarter	Area	Catches (t)			
			Reported	Revised	Difference	Diff (Area)
2018	**1**	**A2**	15,919	**10,923**	-4,996	-12,102
2018	**2**	**A2**	6,914	**4,755**	-2,158	
2018	**3**	**A2**	7,277	**5,071**	-2,206	
2018	**4**	**A2**	7,415	**4,673**	-2,741	
2018	**1**	**A3**	4,082	**4,082**	-	-
2018	**2**	**A3**	341	**341**	-	
2018	**3**	**A3**	4	**4**	-	
2018	**4**	**A3**	930	**930**	-	

Table 2*:* Revised Bigeye tuna catches by year, quarter, area (2018) for the PS LS fishery

Year	Quarter	Area	Catches (t)			
			Reported	Revised	Difference	Diff (Area)
2018	**1**	**A2**	37,829	**42,248**	4,419	13,405
2018	**2**	**A2**	18,128	**20,442**	2,315	
2018	**3**	**A2**	31,119	**34,762**	3,643	
2018	**4**	**A2**	23,446	**26,474**	3,029	
2018	**1**	**A3**	3,245	**3,322**	76	201
2018	**2**	**A3**	1,134	**1,235**	101	
2018	**3**	**A3**	121	**127**	6	
2018	**4**	**A3**	63	**80**	17	
2018	**1**	**A5**	1,118	**1,118**	-	-
2018	**2**	**A5**	44	**44**	-	
2018	**3**	**A5**	1	**1**	-	
2018	**4**	**A5**	80	**80**	-	

Table 3*:* Revised Yellowfin tuna catches by year, quarter, area (2018) for the PS LS fishery

111. The WPTT **REQUESTED** that the revised catch series for 2018 (PS LS fisheries) be used for assessment and MSE purposes as well as for management advice.

112. The WPTT **ACKNOWLEDGED** that the general, longstanding concerns with longline size data (including inconsistencies between average weights in the periods before and after 2000 and limited representativeness of samples with respect to total reported catches for the fisheries concerned) severely affect the quality of bigeye tuna size-frequency data currently available to the IOTC Secretariat. The WPTT also **NOTED** that a consultancy planned for late 2019 will attempt to improve this situation.

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

113. The WPTT **NOTED** paper IOTC–2019–WPTT21–26, which described growth heterogeneity of Bigeye tuna in the Indian Ocean explored by the mixed effects model. The paper included the following abstract:

"The life history traits including growth, is the fundamental and key process of population dynamics and stock assessment, which gains much attention in recent years. Based on the data collected by Chinese observers onboard from 2013 to 2018, the growth of Bigeye tuna was analyzed, with the spatial-temporal variations. A total of 8,806 individuals were

measured, with fork length ranging from 51 to 203 cm and the gilled & gutted & tailed weight from 2.5 to 138.0 kg. The predicted power length-weight function indicated that the estimate of condition factor a is 1.26 ×10-5 with spatial-temporal ranges 1.20~1.37×10-5, while the estimate of allometric growth parameter b is 3.05..” – see paper for full abstract.

114. The WPTT **ACKNOWLEDGED** that length-weight relationships can vary over space and time, and that a sampling design that is balanced, has a large spatial coverage, and is repeated over several years and among different fishing gears is needed to appropriately capture the patterns of variability. The WPTT **AGREED** that observer programmes may offer the best opportunities to obtain such samples, and **ENCOURAGED** the authors to pursue the collection of samples by the observers.

5.3 Review of new information on the status of bigeye tuna

5.3.1 Nominal and standardised CPUE indices

115. The WPTT **NOTED** paper IOTC–2019–WPTT21–27 which provided an analysis of size frequency and CPUE for Indian Ocean bigeye tuna (*Thunnus obesus*) based on the Chinese longline observer data. The paper included the following abstract:

“This study presents the spatial pattern of length frequency and catch-per-unit-effort (CPUE) for the Indian Ocean bigeye tuna (Thunnus obesus) based on the Chinese longline fishery observer data from 2012 to 2019. Contour lines map and G-statistic method was used to make spatial distribution and autocorrelation analysis of size data, respectively. The standardization of CPUE (annual series as well as quarterly series in number/1000 hooks) was conducted by Generalized Additive Model (GAM) with variables including: year (year-quarter), latitude, longitude, area, target species, and depth of hooks. Spatial strata were defined by an adaptive area stratification used in the previous study. The results of spatial length frequency showed the large size groups (fork length greater than 110 cm) were mainly caught in the Northwest Indian Ocean; while the small size groups (fork length less than 110 cm) were more caught in the Southwest Indian Ocean. Both standardized indices indicate an overall decline, except for an increase in 2017 and decreased again after that. CPUE index mainly distributed in the medium-size group.”

116. The WPTT **WELCOMED** the catch rate standardisation for the Chinese fleet in the Indian Ocean for bigeye tuna (**Figure. 4**).

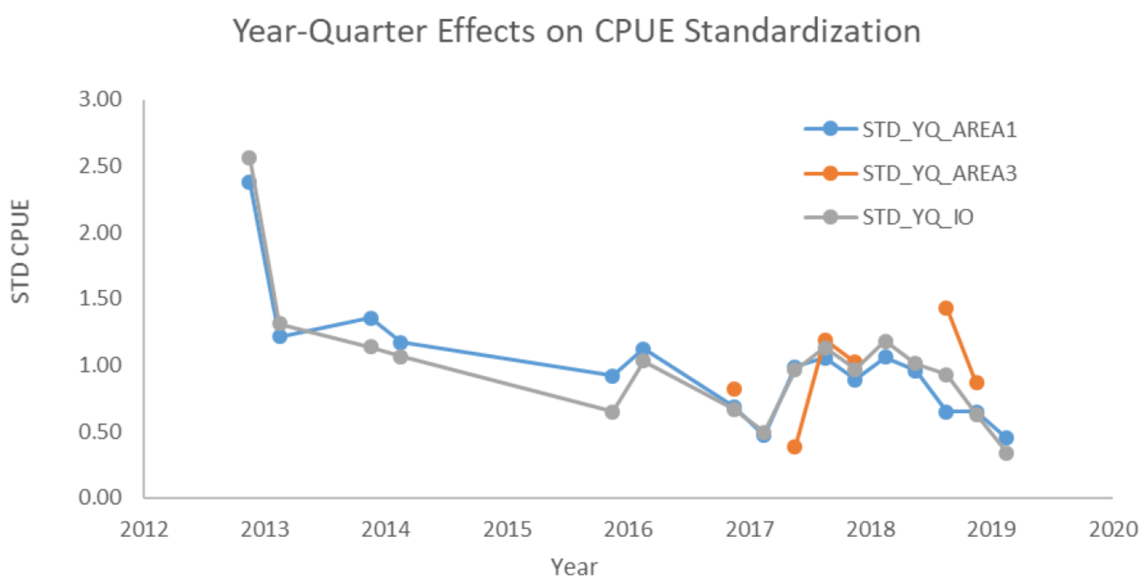


Figure 4: Year-quarter effects of Standardized CPUE of bigeye tuna in region 1, region 3 and the Indian Ocean**.**

117. The WPTT **NOTED** that the Chinese observer catch and effort dataset provides extremely important information because the fleet fishes in an area where other fleets' effort is relatively sparse. The WPTT **NOTED** that the Chinese observer dataset contains information not available in other datasets

118. The WPTT **SUGGESTED** that the Chinese observer dataset should be incorporated into the joint CPUE standardization in the future, and that Chinese scientists collaborate.

119. The WPTT **NOTED** paper IOTC–2019–WPTT21–29 which provided a CPUE standardization of bigeye and yellowfin tuna caught by Korean tuna longline fishery in the Indian Ocean. The paper included the following abstract:

    "In this study we used generalized linear models (GLM) to standardize operational data from Korean tuna longline fisheries in the Indian Ocean to produce CPUE indices for bigeye and yellowfin tuna. The data used for the GLMs were catch (number), effort (number of hooks), number of hooks between floats (HBF), fishing location (5° cell), vessel identifier, and year-quarter. Data were analyzed separately by region. We applied cluster analysis to address concerns about target species change through time. The CPUE was standardized using lognormal constant and delta lognormal approaches, both with and without vessel effects, with the main indices provided by the delta lognormal approach."

120. The WPTT **WELCOMED** the catch rate standardisation for the Korean fleet in the Indian Ocean for bigeye tuna (**Figure. 5**).

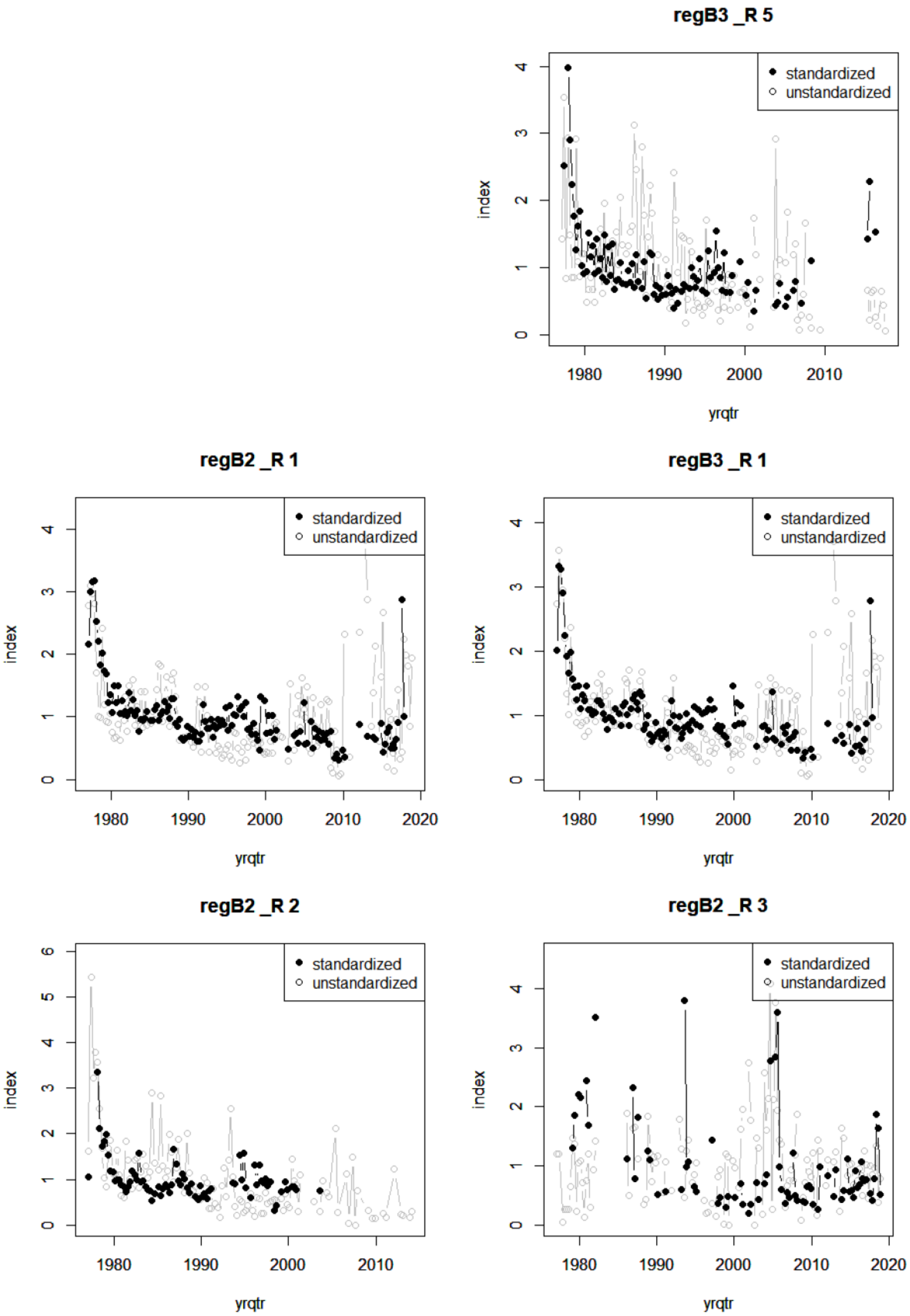


Figure 5: Comparison plot of unstandardized and standardized indices for bigeye in region 1 (western tropical, regB2_R1), region 1S (south-western tropical, regB3_R1) and region 1N (north-western tropical, regB3_R5), region 2 (eastern tropical, regB2_R2) and region 3 (western temperate, regB2_R3).

121. The WPTT **NOTED** paper IOTC–2019–WPTT21–31 which provided CPUE Standardization of Bigeye Tuna, *Thunnus obesus* (Lowe, 1839) from Indonesian Tuna Longline Fishery in Eastern Indian Ocean. The paper included the following abstract:

"Bigeye tuna, Thunnus obesus (Lowe, 1839) is one of the main target species for Indonesian tuna longline fishery in the Eastern Indian Ocean. The tuna longline fishery has begun since 1978 and around 1980, bigeye tuna started as target when deep longline introduced. However, little is known about its abundance, especially in the north eastern area where is the core fishing ground for Indonesian tuna longline fishery. The objective of the study is to provide a preliminary assessment about the abundance indices of bigeye tuna from Indonesian tuna longline fishery. In this paper, four types of Generalized Linear Model (GLM) was used to standardize the catch per unit effort (CPUE) and to estimate the relative abundance indices, i.e. Zero-inflated Negative Binomial (ZINB), Negative Binomial (NB), Tweedie (TW) and Delta-lognormal (DEL). We used two types of data used in this study; the scientific observer data conducted by Research Institute for Tuna Fisheries (RITF) from 2006 to 2018 and national observer program conducted by Directorate General of Capture Fisheries (DGCF) from 2016-2017." – see document for full abstract

122. The WPTT **WELCOMED** the catch rate standardisation for the Indonesian fleet in the Indian Ocean for bigeye tuna (**Figure. 6**).

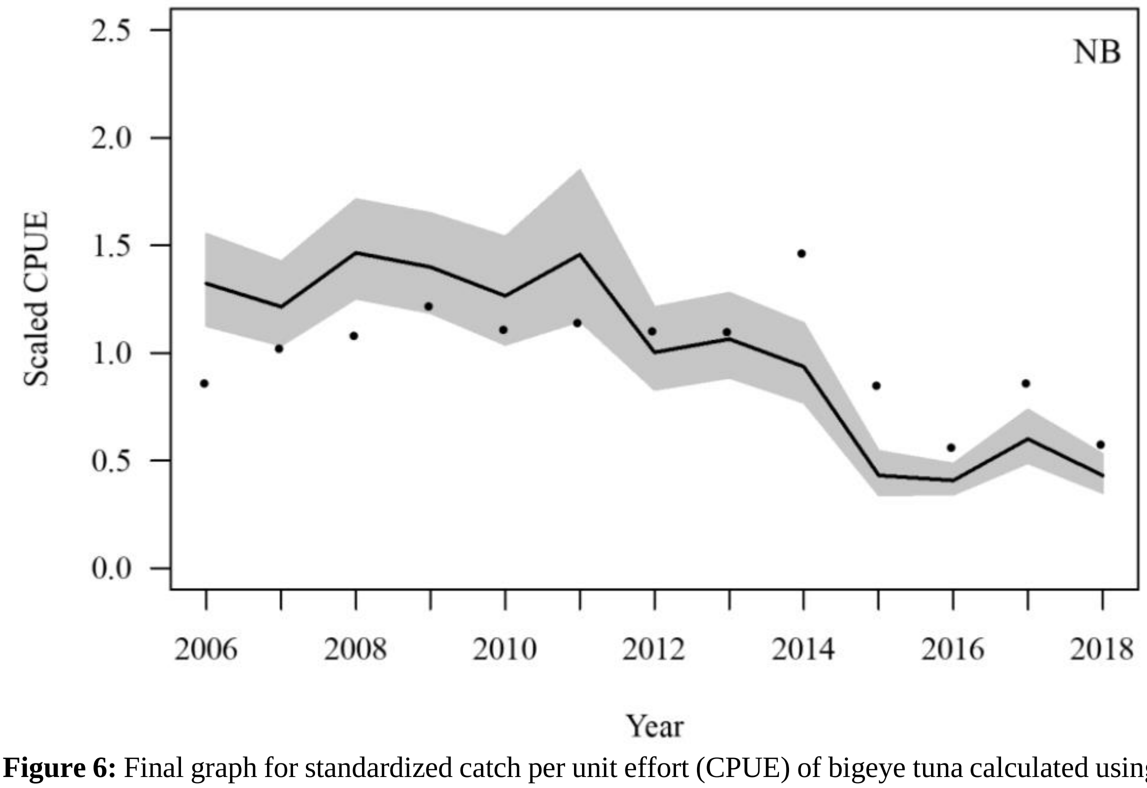


Figure 6: Final graph for standardized catch per unit effort (CPUE) of bigeye tuna calculated using NB model with 95% confidence interval (greyed area). Values were scaled by dividing their means.

5.3.2 Stock assessments

Stock Synthesis

123. The WPTT **NOTED** paper IOTC–2019–WPTT21–61, which provided a preliminary Indian Ocean Bigeye Tuna Stock Assessment 1950-2018 (Stock Synthesis). The paper included the following abstract:

"This report presents a preliminary stock assessment for Indian Ocean bigeye tuna (Thunnus obesus) using Stock Synthesis 3 (SS3). The assessment uses a spatially structured, age-based

model that integrates multiple data sources. The assessment model covers the period 1975–2018 and represents an update and revision of the 2016 assessment model with the inclusion of revised composite longline CPUE indices, the adoption of a new regional weighting scheme, and a refined procedure to process the tag data that is more consistent with recent practice. A range of exploratory models are also presented to explore the impact of key data sets and model assumptions" – see document for full abstract

124. The WPTT **NOTED** the key assessment results for the Stock Synthesis III model (SS3) as shown below (**Table 4**; **Figure 7**).

Table 4. Bigeye tuna: Key management quantities from the SS3 assessment, for the Indian Ocean. Values represent the median and confidence intervals estimated from the results of the 18 model options.

Management Quantity	Aggregate Indian Ocean
Most recent revised catch estimate (t) (2018)	81 413
Mean catch over last 5 years (t) (2014–2018)	89 717
h (steepness)	0.7, 0.8, 0.9
MSY (1,000 t) (80% CI)	87 (75 – 108)
Data period (catch)	1950 – 2018
CPUE series/period	1979 – 2018
F_{MSY} (80% CI)	0.24 (0.18 – 0.36)
SB_{MSY} or B_{MSY} (1,000 t) (80% CI)	503 (370 – 748)
F_{2018}/F_{MSY} (80% CI)	1.20 (0.70 – 2.05)
B_{2018}/B_{MSY} (80% CI)	-
SB_{2018}/SB_{MSY} (80% CI)	1.22 (0.82 – 1.81)
B_{2018}/B_{1950} (80% CI)	-
SB_{2018}/SB_{1950} (80% CI)	0.31 (0.21 – 0.34)
$SB_{2018}/SB_{current, F=0}$ (80% CI)	-

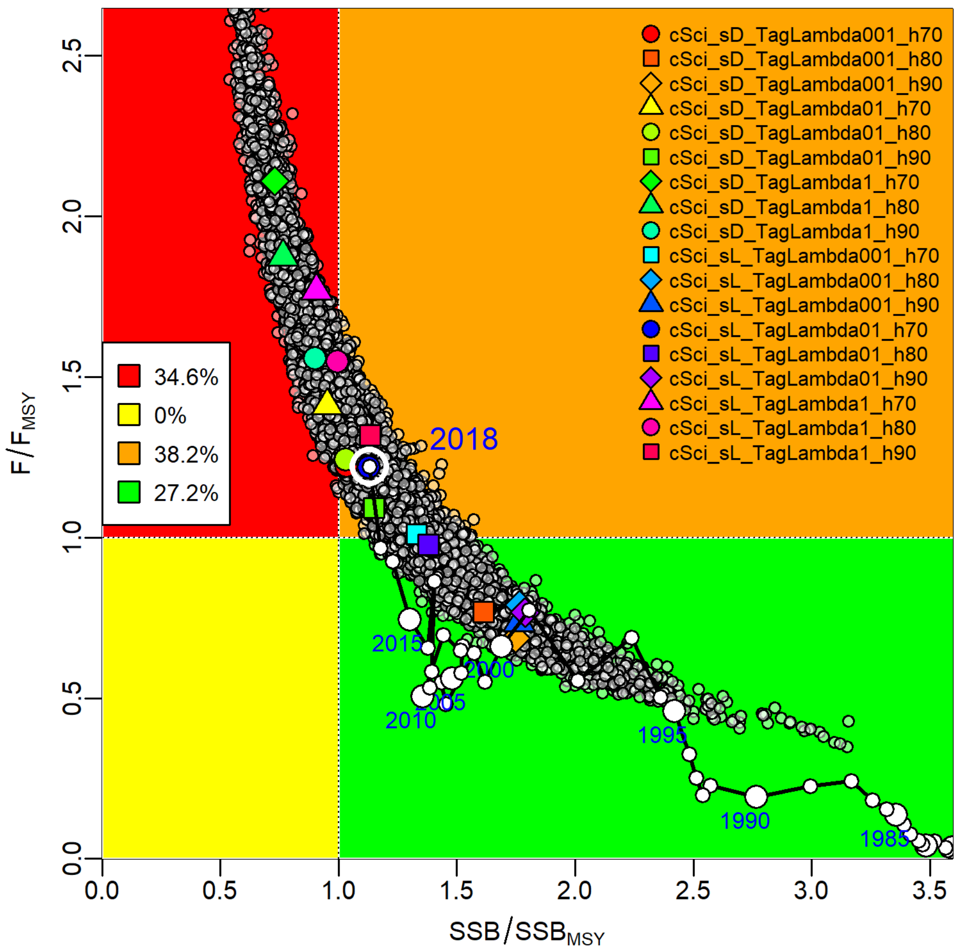


Figure.7. Bigeye tuna: SS3 Aggregated Indian Ocean assessment Kobe plot. The coloured points represent stock status estimates from the 18 model options. The grey points represent 5000 estimates of 2018 stock status from the multivariate normal approximation from the mean and variance-covariance of the 18 model options. The legend indicates the estimated probability of the stock status being in each of the Kobe quadrant.

125. The WPTT **CONGRATULATED** the analyst 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. CPUE catchability assumptions, with separate catchability for LL CPUE before and after 2011
   ii. Relaxing the shared longline selectivity between R1 and R2, and including time-varying selectivity in R2.
   iii. Down-weighting the LL or PSLS size data.
   iv. Simplifying the base growth assumption
   v. Increasing natural mortality to 0.4.
   vi. Changing the spatial structure to 3 regions.

126. The WPTT **NOTED** the following with respect to the input information for the SS3 modelling approach presented at the meeting:
   i. That the peak of high CPUE in 2010-2012 is likely to represent a change in catchability, which the model could be prevented from fitting by increasing the CV associated with that part of the time series.

ii. That there appears to be a conflict within the model between a decline in CPUE and an increase in longline-caught sizes. The WPTT **NOTED** that size data should not be allowed to prevent the model from fitting to the CPUE indices, and that size data weights should be adjusted accordingly.
iii. That rather than being fixed, the CVs on the CPUE could be scaled in proportion to the observation error CVs.
iv. That fits to the size data might be improved by removing the equality constraint between the longline CPUE series in different regions, and changing the selectivity pattern to dome-shaped in regions 1S, 2, and 3.
v. That the assumption of hyperdepletion at the end of the longline CPUE time series is not supported by evidence of low data coverage or change in fishing behaviour. The assumption improves the pattern in the recruitment residuals and is also more consistent with the catch, based on an analysis with constant recruitment. However, assuming hyperdepletion removes the main source of information about abundance trends. The WPTT also noted that the Chinese and Indonesian CPUE series show a similar decline at the end of the time series.
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 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.
viii. That the increase in the Spanish purse seine catch in 2018 caused a large increase in fishing mortality, and that a revised catch estimate should be included in the model.

127. The WPTT **NOTED** that the proposed scenario, assuming “hyper-depletion” caused by decreasing catchability, is one way to resolve the conflict between the observed the CPUE trend and the deterministic expectation about the biomass dynamics as inferred from the presented the ASPM diagnostic (**Figure 8**). However, the WPTT **SUGGESTED** that the hyper-depletion hypothesis currently lacks an explanation from a population dynamics perspective other than improving the model diagnostics. The WPTT also **NOTED** that a short-term hyper-depletion pattern may well be plausible during the initial post-piracy fishing phase in Region 1N, but that this unlikely to explain the more sustained decline that also extends to Region 1S. The WPTT **AGREED** to not include the hyper-depletion hypothesis the Stock Synthesis reference grid considered for providing stock assessment advice.

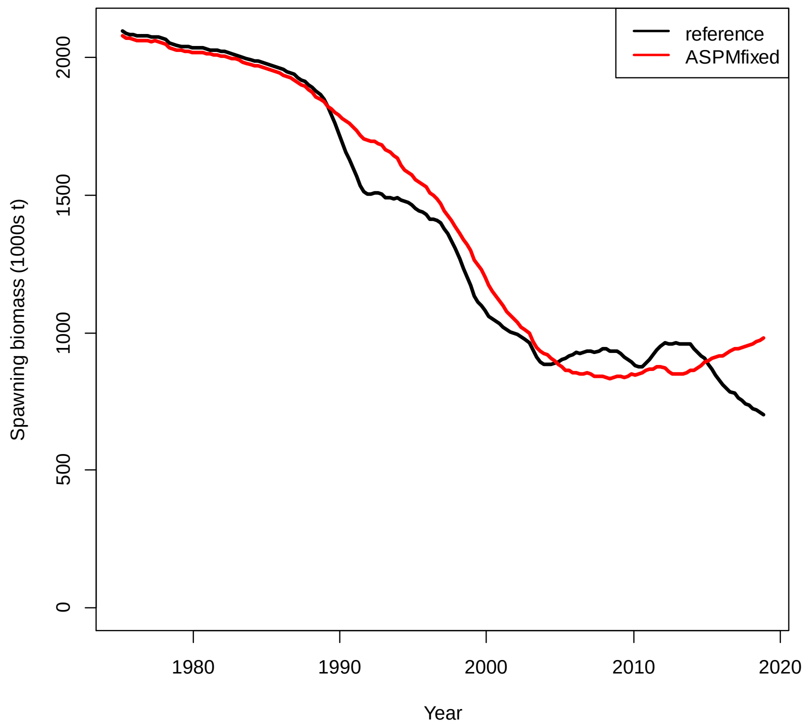


Figure. 8: Estimates of spawning biomass from the ASPM analysis performed to the Reference model.

128. The WPTT **NOTED** that assigning weights to the likelihood functions of CPUE and length composition has followed an iterative, objective process and that the weighting across years is fixed. The WPTT further **NOTED** that the commercial length compositions of some longline fleets show strong systematic patterns in mean lengths, which remains implausible and results in poor residual diagnostics of the Stock Synthesis model fits to these length data. The WPTT noted in particular strong conflicts between the observer length data from Japan and the reported commercial length data from Taiwan,China, which show an inexplicable systematic increase over time. The WPTT **NOTED** that the systematic changes in reported length composition of some fleets caused the poor fits in the Stock Synthesis model.

129. The WPTT **AGREED** that the evaluation of the presented resulted corroborates the relatively low weighting (ESS) of length composition data in the Stock Synthesis scenarios.

130. The WPTT **NOTED** the results of a new set of runs requested with SS3, which included:
    i. A run with the region 1 CPUE series down-weighted in 2011-12. The change resulted in removal of a small peak in the time series. The WPTT **NOTED** that it was appropriate to avoid fitting to a CPUE spike likely to represent a short-term change in catchability, and that this approach should be used in all model runs.
    ii. A run with the CPUE series scaled in proportion to the CPUE observation error CV. The change reduced the size of the peak in 2011-12 and also marginally reduced the amount of decline over the whole time series.
    iii. Dome-shaped selectivity for LL1S, LL2, and LL3. Compare to the reference case, the change substantially improved the fit to the aggregate size data in each longline fishery and increased the seasonal variation in the fit to the LL2 CPUE. It increased the level of recruitment deviates in the period 2009-2015 and reduced their inconsistency with the earlier period (**Figure 9**). It resulted in lower estimates of biomass in all years, and a

greater level of depletion. The WPTT **NOTED** that this approach was plausible and should be included in the grid as an alternative to shared logistic longline selectivity.

iv. An alternative PSLS catch for 2018, based on the assumption that species composition of PSLS catches in 2018 was the same as in 2017. This model had similar biomass to the reference case but substantially lower fishing mortality in 2018. The WPTT considered that the revised time series was should be included in all runs of the grid.

v. The one-area model without tagging data and with constant recruitment gave substantially worse fits to the CPUE indices than the reference case; and increasing rather than decreasing biomass after 2012. The WPTT **NOTED** that, given the current model assumption, catch alone was not sufficient to explain the observed decline in biomass.

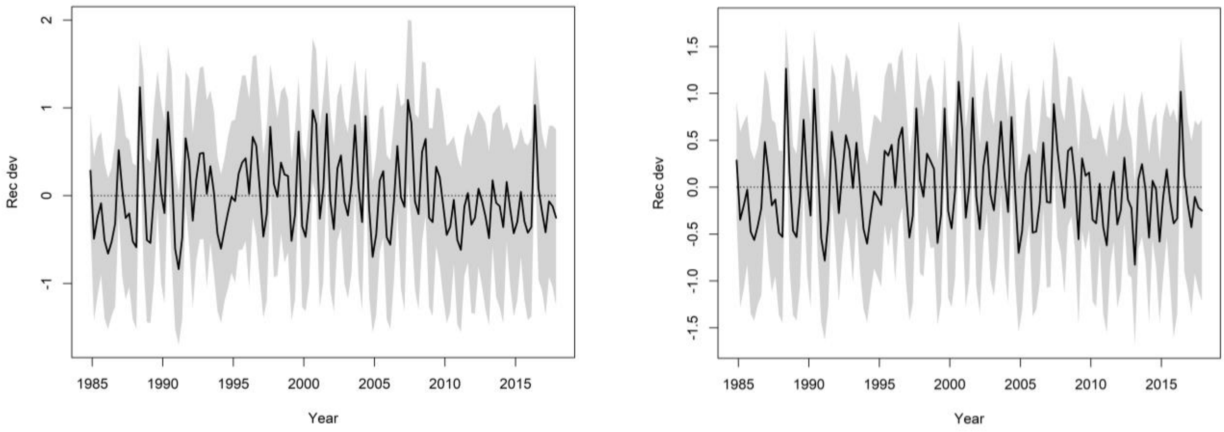


Figure 9: Recruitment time series for the reference case (left) and the model with dome-shaped selectivity in regions LL1S, LL2, and LL3**.**

131. The WPTT **AGREED** that it is in principle desirable to use best scientific catch estimates as input into the stock assessment model, if the reported catches are deemed unreliable. The WPTT **NOTED** however, that there can be unforeseen consequences when changing the catches in an ad hoc manner for stock assessment advice. The WPTT **AGREED** that any changes made to the catch input files must be very clearly documented to ensure reproducibility and continuity of assessment results in the future.

132. The WPTT **NOTED** the following with respect to the input information for the SS3 modelling approach presented at the meeting:

- 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 estimates into the assessment as prior distributions or penalties. This would allow all the data to be used, rather than discarded, due to the mixing period. It would also result in better estimates because fish are still not mixed even after the 12 month mixing period, which results in biased estimates. Also the relatively lower proportion of tags recovered from larger sized fish could produce bias in the tag information when used for the model.
- Inconsistencies were noted between the spatial structure of tagging data analysis and spatial structure of the stock assessment, and that it may be appropriate to model the tagging data independently with a finer spatial scale and then include the tagging/movement data into the stock assessment models.
- There are updated estimates on reporting tag recovery rates, including the longline. The procedure of estimating recovery rates for longline operations is compatible with the Stock Synthesis internal estimation procedure and that the tag recovery rate from Purse Seine operations are generally more influential to the model results.

133. The **WPTT DISCUSSED** the implications of using the tagging data on the spatial population dynamics at length, as this was of relevance for both bigeye and yellowfin Stock Synthesis models. The **WPTT NOTED** the following:

- Changing the weight for likelihood component of tagging has strong influence on the estimated total biomass of the stock, because tagging data are a very strong source of scaling information
- In the case of Indian Ocean bigeye and yellowfin tunas, high weighting tends to result in low absolute biomass estimates, while lower weighting is reducing the influence of the tagging and increasing the influence of the CPUE which is predicting higher biomass levels to fit the data.
- When tags are wrongly assumed to be mixed, they provide misleading scaling information, for example, if fishing is concentrated in areas with high densities of tagged fish biomass estimates will tend to be negatively biased.
- As a result current models may be overestimating productivity and underestimating biomass

134. 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 results from a requested evaluation of alternative CV assumptions for the CPUE indices to reduce influence of the sharp short-term increase in CPUE. The first presented approach used scaling of the assumed CV for the CPUE indices using the estimated CPUE standard error from the Joint-Standardization so that they average to mean CV of 0.2 (or 0.25), while preserving the inter-annual variability, and can assist with objectively dealing "outlier" years or periods of noisy data. The second was to further down-weight the CPUE observations. Both approaches were useful to reduce the reduce influence of sharp short-term increase in CPUE in Area 1N on the model fits the down-weighting by assuming a larger CV specific to this period was more efficient.
ii. The estimated MSY is correlated to the level of steepness used in the model.
iii. That a higher M would result in a more optimistic stock status estimation.
iv. Lowering the weight of tagging data results in a more optimistic stock status.
v. 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 design a more detailed spatial structure.
vi. There may be an overall scaling problem in the assessment. Generally, this information is obtained from tag data or size data.

135. The WPTT **AGREED** to produce management advice from a grid with the following options:

- Either logistic selectivity shared among all longline fisheries; or dome-shaped selectivity for LL1S, LL2, and LL3.
- Tag weighting lambdas of 1, 0.1, and 0.01.
- Stock recruitment steepness values of 0.7, 0.8, and 0.9.

136. Time series of key model estimates from the model grid is shown in **Figure 10**. Key management quantities are summarised in **Table 8** and the Kobe stock status plot in shown in **Figure 7**. A second and subsidiary model grid was prepared with the reported rather than the revised PSLS catch, but the revised catch was preferred for the main model grid. The alternative grid results are provided in Appendix X.

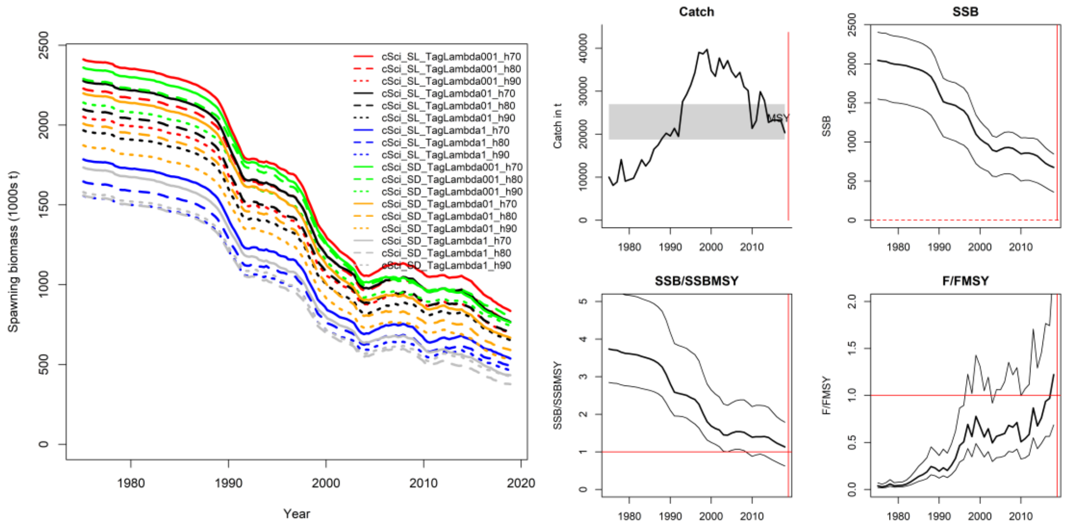
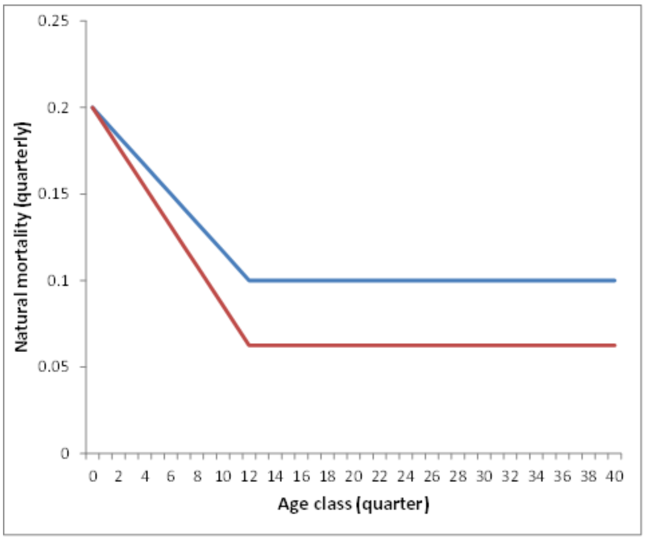


Figure 10. Spawning biomass trajectories of individual models (left), and time series of key management quantities including median and 90% percentiles (right) from the 18 models of the final grid. In the catch plot the shaded area represents 5th and 95th percentiles of estimated MSY (quarterly).

Table 5. 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 $a= 2.217^{-05}$ and $b=3.012$ common to sex
Maturity	Length-specific (50% mature at length 110 cm) – or age-based equivalent[1].

[1] 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)
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

JABBA

137. The WPTT **NOTED** paper IOTC–2019–WPTT21–32, which provided a preliminary stock assessment using JABBA for bigeye tuna in the Indian Ocean. The paper included the following abstract:

"In this study, Bayesian State-Space Surplus Production Model was constructed to assess the status of Bigeye tuna Thunnus obesus stock in the Indian Ocean from 1975 to 2018. This assessment was carried out in the open-source stock assessment environment, JABBA (Just Another Bayesian Biomass Assessment). In the sensitivity analysis, 8 scenarios including joint CPUE (1979-2018) in different regions were tested, and results indicated that model fitting and result, especially for stock status, did not show significant difference. Therefore, joint CPUE in all regions were used for the Base case model. B2018 was estimated to be 607,766 t, while BMSY estimate was 476,817t. Catch in 2018 is 93,515t, while MSY was estimated to be 126,820 (105,576~157,865) t for median and 95% confidence interval." – see document for full abstract

138. The WPTT **WELCOMED** the alternative assessment using the State-Space Bayesian surplus production model assessment software JABBA. The **WPTT NOTED** that the 2018 JABBA assessment result for the Atlantic bigeye were incorporated to provide the stock status advice. The WPTT also **NOTED** that surplus production assessments remain of particularly high relevance for developing model-based harvest controls to test management procedures.

139. The **WPTT NOTED** the key results of JABBA model assessment scenarios (**Figure 11**; **Table 6**) and **THANKED** the authors for exploring alternative reference model specification to improve the diagnostics, which were **SUGGESTED** by the WPM.

140. The **WPTT NOTED** that the JABBA assessment results appeared to be less sensitive to the increase of reported EU FAD catches for 2018 when compared to the Stock Synthesis results, which can be explained by not accounting for differential impacts of the fishing selectivity. The **WPTT also NOTED** the effects of considering alternative CPUE scenarios on the JABBA stock status estimates.

141. The WPTT **NOTED** that this implementation of the JABBA model does not use regional scaling to weight the CPUE time series, but initially gives them equal weights. The model subsequently adjusts the weights of the CPUE series within the model.

142. The WPTT **NOTED** that the JABBA model yields qualitatively different estimates of stock status and productivity than the SS3 model.

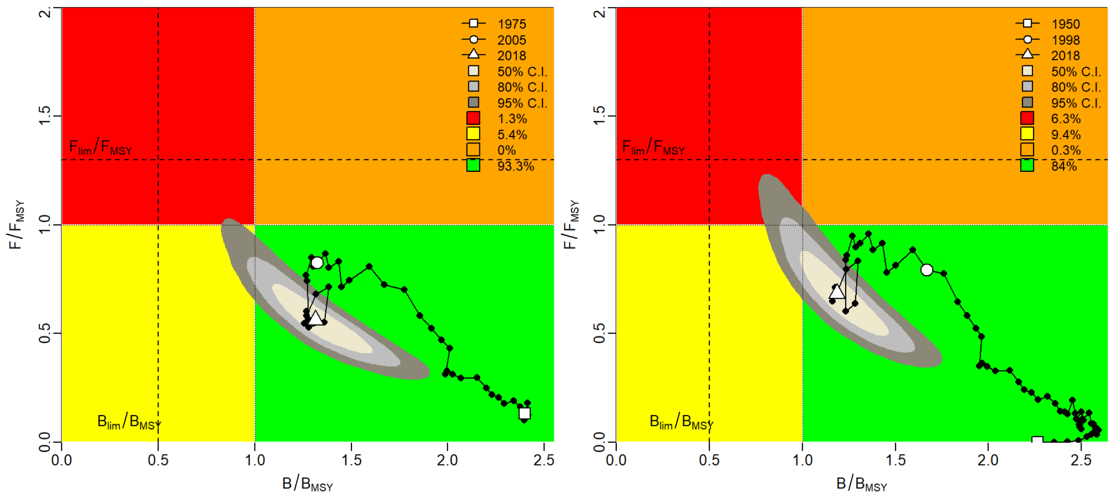


Figure.11. Kobe plots for the original JABBA base-case S1 specification (left) and alternative specification (right) for Bigeye tuna in the Indian Ocean based on suggestion by the WPM.

Table 6. Summary of JABBA **stock assessment results** for the original base-case S1 specification (Model A) and alternative specification (Model B)

	Model A	Model B
C_{2018} (10^6 t)	0.0935	0.0935
mean$C_{2014\text{-}2018}$ (10^6 t)	0.0921	0.0921
MSY (10^6 t)	0.13 (0.10, 0.16)	0.12 (0.09, 0.14)
B_{MSY} (10^6 t)	0.46 (0.32, 0.70)	0.58 (0.39, 0.86)
F_{MSY}	0.28 (0.17, 0.43)	0.2 (0.12, 0.32)
B_{2018}/B_{MSY}	1.30 (0.87, 1.75)	1.19 (0.84, 1.6)
F_{2018}/F_{MSY}	0.57 (0.35, 0.99)	0.68 (0.42, 1.14)
B_{1975}/K	0.81 (0.53, 1.03)	0.83 (0.54, 1.01)
B_{2018}/K	0.48 (0.32, 0.64)	0.44 (0.31, 0.59)

5.3.3 Selection of Stock Status indicators for bigeye tuna

143. The WPTT **AGREED** that the combination of eighteen model scenarios from the SS3 stock assessment would be used for development of management advice for the Scientific Committee's consideration.

144. The WPTT **NOTED** the results of projection and the K2SM (**Figure 12, Table 7**). The WPTT **NOTED** that the uncertainty in the K2SM is characterised using a multivariate normal approximation of the projected stock status from the eighteen model options. The WPTT further **NOTED** the recruitment in the recent years of the assessment model are estimated to be below average levels and these cohorts are projected to cause the stock to decline over the short term, whereas the long term projections are more determined by the assumptions of average recruitment levels over the longer term period, as moderated by the stock-recruitment relationship.

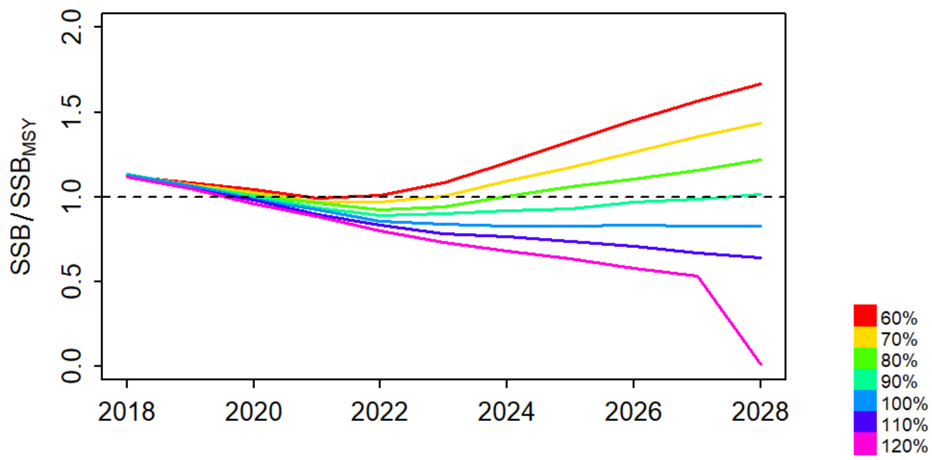


Figure 12. Trajectories of median stock status for constant catch projections 2019–2028 (average catch level from 2018 (93,040t), -10%, -20%, -30%, -40%, +10%, +20%)

Table 7. 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 2018 (93,040t), -10%, -20%, -30%, -40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2018) and weighted probability (%) scenarios that violate reference point**				
	60% (48,848t)	**70%** (56,990t)	**80%** (65,130t)	**90%** (73,272t)	**100%** (81,413t)
$B_{2021} < B_{MSY}$	51.1	53.3	54.2	57.1	58.9
$F_{2021} > F_{MSY}$	7.3	17.8	32	47.9	62.8
$B_{2028} < B_{MSY}$	8	19.5	35.1	49.1	60.8
$F_{2028} > F_{MSY}$	1.1	6.9	19.8	37.7	55.6
Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2018) and probability (%) of violating MSY-based limit reference points (B_{lim} = 0.5 B_{MSY}; F_{Lim} = 1.3 F_{MSY})**				
	60% (48,848t)	**70%** (56,990t)	**80%** (65,130t)	**90%** (73,272t)	**100%** (81,413t)
$B_{2021} < B_{LIM}$	0	0	0	0	0
$F_{2021} > F_{LIM}$	6.0	11.0	17.0	28.0	39.0
$B_{2028} < B_{LIM}$	0.0	0.0	6.0	11.0	22.0
$F_{2028} > F_{LIM}$	0.0	6.0	17.0	22.0	39.0

5.4 Development of management advice for bigeye tuna

145. The WPTT **ADOPTED** the management advice developed for bigeye tuna (*Thunnus obesus*) from the 2018 stock synthesis scenarios agreed and described in section 5.3.3. The stock status will be characterised from the selected reference grid and catch advice will be developed from the K2SM shown in **Table 7**.

146. The WPTT NOTED that the WPTT and SC Chair assisted by the Secretariat will update the draft stock status in the Executive summary for bigeye tuna with the result **AGREED** and the latest 2018 catch data (if necessary), and for the summary to be provided to the SC as part of the draft Executive Summary, for its consideration:
   - Bigeye tuna (*Thunnus obesus*) – Appendix VI

5.5 Update on Management Strategy Evaluation Progress

147. The WPTT **NOTED** papers IOTC–2019–WPM10–11 and IOTC–2019–WPM10–08 were presented together.

148. The WPTT **NOTED** paper IOTC–2019–WPM10–11 which provided an update on the IOTC Bigeye and Yellowfin Management Procedure Evaluation, and included the following summary:
   "This document presents an update of Management Procedure (MP) evaluation results for bigeye and yellowfin tunas since the 2019 IOTC Technical Committee on Management Procedures (TCMP) and Commission meetings, from which we highlight the following points." – see document for full abstract

149. The WPTT **NOTED** paper IOTC–2019–WPM10–08 which provided an update on IOTC bigeye tuna operating model development, October 2019, and included the following summary:
   "IOTC bigeye (BET) Management Strategy Evaluation (MSE) development requests since the 2018 WPTT and WPM were mostly addressed for the IOTC MSE Task Force meeting in Mar 2019 and are documented in a separate information paper (Kolody and Jumppanen 2019a). This paper highlights key changes in the BET reference set OM requested by the IOTC 2019 MSE Task Force meeting and outlines issues to be addressed to progress the bigeye OMs to the next iteration. Issues related to selecting OM ensembles that are relevant to both bigeye and yellowfin are documented in the yellowfin companion paper (Kolody and Jumppanen 2019g). A stand-alone document (attachment 1) summarizes the current state of the bigeye reference set OM as used for MP evaluation in Kolody and Jumppanen (2019c)." – see document for full abstract

150. The WPTT **REQUESTED** the addition of a "recruitment shock" robustness test by reducing future recruitment (e.g. by half for 2 years as in YFT) in the Management Procedure (MP) testing, acknowledging that this kind of robustness scenario has commonly been considered in other RFMOs such as CCSBT and IWC.

151. The WPTT **SUGGESTED** modifying an alternative assumption about spatial differences in longline selectivity patterns into the OM conditioning scenarios to be consistent with the 2019 assessment model grid.

152. The WPTT **NOTED** that the relative contribution of fleets to the total catch has been changing over time (e.g. the increasing trend in the proportions of PS catches), and this has implications for MP evaluations. This relates to a Commission request about alternative allocations. The WPTT recognized that allocations are a political decision and therefore **REQUESTED** guidance from the TCMP on specific scenarios to be tested in the MP evaluations.

153. The WPTT **DISCUSSED** the current specification for conditioning, and the WPTT **AGREED** to use tag lambda (a weight to the likelihood from tag recovery data) as 1, 0.1 and 0.001.

154. The WPTT **NOTED** that there is uncertainty about the reported 2018 catch, as was also discussed during bigeye tuna and yellowfin tuna stock assessment sessions. The WPTT **AGREED** that a single "agreed" 2018 catch scenario is used for new OM conditioning, and MP catch allocation assumptions are the 2017-2018 average. The WPTT further **NOTED** that there are also TAC implementation Robustness tests of 10% over-reporting (with and without reporting), and the MP performance was not very sensitive to these errors.

Table 8: Proposed BET Reference set OM uncertainty dimensions, to be implemented with fractional factorial design (to encompass most of the uncertainty with a greatly reduced number of model runs, as

endorsed by the WPM).

Definition
Stock-recruit function (*h* = steepness) • **Beverton-Holt, *h* = 0.7** • **Beverton-Holt, *h* = 0.8** • **Beverton-Holt, *h* = 0.9**
Natural mortality multiplier relative to reference case M vector • **1.0** • **0.8** • **0.6**
Tag recapture data weighting (tag composition and negative binomial) • **λ = 0.001** • **λ = 0.1** • **λ = 1.0**
Assumed longline CPUE catchability trend (compounded) • **0% per annum** • **1% per annum**
Tropical longline CPUE standardization method • **Hooks Between Floats** • **Cluster analysis**
longline CPUE Regional-scaling factors • **reference case** • **alternate**
Longline fishery selectivity • **Stationary, logistic, shared among areas** • **Stationary, logistic in region 1, double-normal (potentially dome-shaped), in other regions**
Size composition input Effective Sample Sizes (ESS) • **ESS = 10, all fisheries** • **ESS = One iteration of re-weighting from reference case model, capped at 100.**

155. The WPTT **REQUESTED** five bigeye tuna robustness scenarios (all of which assume the reference set OM conditioning):

- What happens if there is a two year recruitment failure (55% of expected + usual stochastic error, as defined for yellowfin tuna)
- What happens if the (annualized aggregate) longline CPUE observation error CV is increased to 30% (auto-correlation 0.5) in projections?
- What happens if there is a consistent 10% future over-catch (accurately reported), equally distributed among fleets?

- What happens if there is a 10% future over-catch (unreported), equally distributed among fleets ?
- What happens if the longline CPUE catchability trend is 2% per year going forward (but remains as in the reference scenario for conditioning)?

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

6.1 Review of the statistical data available for skipjack tuna

156. The WPTT **NOTED** paper IOTC–2019–WPTT20–08 which provided a review of the statistical data and fishery trends 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 (CPCs)*, for the period 1950–2018. 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 supporting information for the WPTT is provided in Appendix IVc.

157. The WPTT **NOTED** that total catches in 2018 (607,701 t) were about 30% higher than the catch limit generated by the Harvest Control Rule[2] (470,029 t, which applies to the years 2018–2020), and that there has been an increasing trend in catches over the past 4 years, including a sudden increase in catches in 2018 (compared to 2017, by over 20% or around 100,000 t).

158. The WPTT **NOTED** that the catch limits being applied to the yellowfin tuna stock might have led to changes in targeting by purse seiners, as demonstrated by a substantial reduction (since 2017) on setting on free schools of large yellowfin tuna. A corresponding increase of targeting of tuna schools associated with FADs has led to changes in the species and size composition of the catch, with higher catches of yellowfin and bigeye juveniles, and increased catches of skipjack, which is the main species on FADs.

159. The WPTT **EXPRESSED CONCERN** over this consistent increase in FAD associated catch, in particular rapid increase in catches of juvenile yellowfin and bigeye which may hinder the rebuilding of exploited species and **RECOMMENDED** further evaluation of this issue and, where necessary, the identification of which alternative options could be implemented to avoid such adverse impacts on the stock.

160. The WPTT **NOTED** that a hotspot exists in fishing grounds in the high seas areas of the South Arabian sea, where catches on log-associated schools reported by the EU purse seine fleet in 2018 show very large proportions of skipjack tuna compared to other tropical tuna species caught in the same areas.

161. Furthermore, the WPTT **NOTED** that an unusual pattern, possibly introduced by the revised species composition estimation process adopted by EU,Spain in 2018, also appears in the same areas as in the case of bigeye tuna, although to less pronounced levels.

162. The WPTT **NOTED** that the reconstructed, official catch series reported by Pakistan for its gillnet fishery is still awaiting endorsement from the WPDCS and SC, but is not expected to result in a major change in the current time series for the species involved.

163. The WPTT **REQUESTED** Pakistan to further examine these data and, and in particular document where there are marked differences in Pakistan's catches compared to those from similar fisheries reported by neighbouring CPCs.

[2] See IOTC-2017-SC20-12 Rev_1 "Calculation of the Skipjack catch limit for the period 2018-2020 using the HCR adopted in Resolution 16/02"

164. The WPTT **NOTED** that the size-frequency data reported for skipjack by I.R. Iran for years between 1992 and 1997 still cannot be used for stock assessments due to the coarseness of the reported size bins (3cm).

165. For this reason, the WPTT **REQUESTED** the IOTC Secretariat that action be taken with scientists from I.R. Iran and work towards obtaining the data at the expected level of resolution (1cm size bins)

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

Iran skipjack tuna fisheries

166. The WPTT **NOTED** paper IOTC–2019–WPTT–21–35 which described Iran's skipjack tuna fisheries, and included the following summary:

> *"The average national catch quantity of tropical and skipjack tuna during the past five-year period, account for 9% of Indian Ocean tuna catch. Iran is the 6th largest country exploit skipjack after Spain, Indonesia, Maldives, Seychelles and Sri Lanka (2014 – 2018). More than 80% of skipjack tuna catches by 6 countries. In the past few years, Islamic republic of Iran carried out the following actions in line with IOTC recommendations and approvals of WPTT, SC and the Commission, which leads to enhancement of compliance to related provisions and regulations from 11% in 2010 to 70% in 2018."*

167. The WPTT **THANKED** the authors for the important data on Iran's tropical tuna fisheries and in particular catches of skipjack. The WPTT **NOTED** that Iran has significant catches of skipjack in the Indian Ocean and encouraged the authors to continue to provide this information to the SC. The WPTT **NOTED** that the skipjack catches reported by similar fisheries by Pakistan are considerably lower and therefore encouraged further studies to investigate these differences.

6.3 Review of new information on the status of skipjack tuna

6.3.1 Nominal and standardised CPUE indices

168. The WPTT **NOTED** paper IOTC–2019–WPTT21–37, which described the use of two data sets for the analysis of catch rates of skipjack tuna (*Katsuwonus pelamis*) in gillnet fishery of Sri Lanka. The paper included the following abstract:

> *"Fourteen years port sampling data (2005-2018) and three years logbook data (2016 - 2018) in the gillnet fishery of Sri Lanka was used to analyze the catch rates of skipjack tuna. Skipjack tuna is the main target species in the Sri Lankan gillnet fishery. All gillnet catches including the catches made by popular gear combinations operated in the gillnet fishery (gillnet–longline and gillnet-ringnet) were considered under the port sampling. Five vessel types operated in the tuna fishery have caught skipjack tuna. Year, month, boat type, gear type, trip duration (in days) and number of net panels used per fishing operation were incorporated for the analysis. Fishing location (5° square) obtained from fisheries logbooks with regard to gillnet fishing operations made during 2016 – 2018 was also considered for this audit. The logbook data exists at present only for multiday fishing vessels." – see document for full abstract*

169. The WPTT **NOTED** that there appears to be an issue with the spatial distribution of skipjack catches as shown in figure 2 (in IOTC–2019–WPTT21–37) as all the catches are located in the northern hemisphere with a clear boundary at the equator. The WPTT suggested that this could be due to the exclusion of a the negative sign in front of the southern hemisphere catch coordinates, effectively assigning them to the North only. The authors confirmed that they are investigating the matter.

6.3.2 Stock assessments

170. The WPTT **NOTED** that as skipjack tuna was not the priority species at WPTT21, no papers were submitted for this agenda item in 2019.

6.3.3 Selection of Stock Status indicators for skipjack tuna

171. The WPTT **AGREED** that as no new stock assessment was carried out for skipjack tuna in 2019, management advice should be based on the range of results from the 2017 assessment and the catch limit for 2018-2020 derived from Res 16/02 and the catches up to 2018.

6.4 Update on Management Strategy Evaluation Progress

172. The WPTT **RECALLED** 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.

173. The WPTT **RECALLED** that the SC had endorsed the WPM09 request for the SKJ HCR be developed into a full Management Procedure. The WPTT **NOTED** that the Secretariat is in the advanced stages of contracting an expert to develop the skipjack tuna MP using funds from an EU Grant.

6.5 Development of management advice for skipjack tuna

174. The WPTT **ADOPTED** the management advice developed for skipjack tuna as provided in the draft stock status summary and **REQUESTED** that the chair, with assistance from the IOTC Secretariat update the draft stock status summary for skipjack tuna with the latest 2018 catch data (if necessary), and for the summary to be provided to the SC as part of the draft Executive Summary, for its consideration:
    - Skipjack tuna (*Katsuwonus pelamis*) – Appendix VII.

7. Yellowfin tuna – Review of New Information on Stock Status

7.1 Review of the statistical data available for yellowfin tuna

175. The WPTT **NOTED** paper IOTC–2019–WPTT21–08 which provided a review of the statistical data and fishery trends 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 (CPCs)*, for the period 1950–2018. 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 supporting information for the WPTT is provided in Appendix IVd.

176. The WPTT **NOTED** ongoing issues with the Taiwanese length frequency data, particularly from early 2000s onwards, and with Japanese length frequency data. Key concerns are that the Taiwanese data may not be representative of the fishery (given in particular the absence of smaller fish despite a large volume of samples) while the Japanese data, although also including information collected by scientific observers, is often below the minimum required value of one fish sampled per metric ton of catch.

177. The WPTT **RECALLED** that results of a consultancy funded in 2019 to identify the causes and overcome the issues inherent with these length-frequency data will be provided at the end of Q1 2020, and that in the meantime one possibility available to scientists is to either fully exclude or down-weight these length-frequency measurements when assessing the status of the species concerned.

178. **ACKNOWLEDGING** that the revised catch series for Yellowfin tuna caught by Pakistan gillnets are not yet incorporated in the IOTC database, the WPTT **NOTED** that these could cause an average increase in catches of 7,100 t per year (in the years between 1994 and 2018) when compared to the scientific estimates currently available to IOTC.

179. The WPTT **NOTED** the update provided by the IOTC Secretariat on the implementation of Resolution 18/01 *On an interim plan for rebuilding the Indian Ocean yellowfin tuna stock*, and that many of the fisheries subject to catch reductions had achieved either a partial or full decrease in catches in 2018 in accordance with the levels of reductions specified in the Resolution.

180. **RECALLING** that Resolution 19/01 superseded Resolution 18/01 in October 2019, the WPTT **ACKNOWLEDGED** that the summary information provided here is still relevant with respect to the new requirements, and that for consistency reasons the catch data series including the revised catches officially provided by the Pakistan government are yet to be endorsed.

181. The WPTT **NOTED** that total catches of yellowfin tuna in 2018 from all fleets subject to Resolution 18/01 decreased by 15% from 2014 / 2015 levels, but that overall catches of yellowfin tuna increased by 10% in the same period (reaching the same levels that were reported in 2007) as the decrease in catches reported by such fisheries was offset by increases in the catches from some fisheries exempt from limitations on their catches of yellowfin tuna (**Table 9** C, D, E, F, G).

Table 9: current status of YFT catches by gear category in relation to the requirements of Resolution 18/01

A) Overall (officially reported catches)

Fleet - Gear		Reduction	2014	2015	2016	2017	2018	Difference with baseline	
								Absolute	%
EU	PS	15%	91405	86149	87075	86893	75375	-16031	-18%
KOR	PS		8852	7509	10347	6362	5415	-3437	-39%
SYC	PS		23463	39072	40014	41694	35023	-4049	-10%
TWN	LL	10%	12285	13921	16958	9115	10845	-1441	-12%
LKA	LL		8625	5933	3939	6448	8554	-71	-1%
IRN	GN	10%	24401	26780	31079	37193	35534	11132	46%
MDV	BB	5%	18481	15796	8550	17500	10749	-7732	-42%
MDV	HL		30246	36300	44385	30563	16704	-13542	-45%
Total			**217759**	**231461**	**242348**	**235767**	**198199**	**-35169**	**-15%**

B) Overall (including revisions to 2018 PS LS)

Fleet - Gear		Reduction	2014	2015	2016	2017	2018	Difference with baseline	
								Absolute	%
EU	PS	15%	91405	86149	87075	86893	88981	-2424	-3%
KOR	PS		8852	7509	10347	6362	5415	-3437	-39%
SYC	PS		23463	39072	40014	41694	35023	-4049	-10%
TWN	LL	10%	12285	13921	16958	9115	10845	-1441	-12%
LKA	LL		8625	5933	3939	6448	8554	-71	-1%
IRN	GN	10%	24401	26780	31079	37193	35534	11132	46%
MDV	BB	5%	18481	15796	8550	17500	10749	-7732	-42%
MDV	HL		30246	36300	44385	30563	16704	-13542	-45%
Total			**217759**	**231461**	**242348**	**235767**	**211805**	**-21563**	**-9%**

C) Purse seine fleets (officially reported)

Purse seine fleets		Reduction	2014	2015	2016	2017	2018	Difference with baseline	
								Absolute	%
Subject to Res. 18/01	EU	15%	91405	86149	87075	86893	75375	-16031	-18%
	KOR		8852	7509	10347	6362	5415	-3437	-39%
	SYC		23463	39072	40014	41694	35023	-4049	-10%
	Sub-tot		**123720**	**132730**	**137437**	**134949**	**115813**	**-23517**	**-17%**
Not subject to Res. 18/01	EGY	N/A			0				
	IDN		5598	5493	5214	5214	9564	3966	71%
	IND		98	76	84	63	120	21	22%
	IRN		4832	3842	3465	1764	3898	-934	-19%
	JOR				0				
	JPN		433	338	422	712	404	-29	-7%
	KEN					73	73	73	
	LKA		2627	3532	1966	5505	2891	264	10%
	MOZ				126				
	MUS		4844	5448	7404	7681	11322	6479	134%
	PHL					73			
	Sub-tot		**18432**	**18729**	**18682**	**21086**	**28272**	**9840**	**53%**
All purse seine fleets			**142152**	**151459**	**156119**	**156034**	**144085**	**-13677**	**-10%**

D) Purse seine fleets (including revisions to 2018 PS LS)

Purse seine fleets		Reduction	2014	2015	2016	2017	2018	Difference with baseline	
								Absolute	%
Subject to Res. 18/01	EU	15%	91405	86149	87075	86893	88981	-2424	-3%
	KOR		8852	7509	10347	6362	5415	-3437	-39%
	SYC		23463	39072	40014	41694	35023	-4049	-10%
	Sub-tot		**123720**	**132730**	**137437**	**134949**	**129419**	**-9910**	**-7%**
Not subject to Res. 18/01	EGY	N/A			0				
	IDN		5598	5493	5214	5214	9564	3966	71%
	IND		98	76	84	63	120	21	22%
	IRN		4832	3842	3465	1764	3898	-934	-19%
	JOR				0				
	JPN		433	338	422	712	404	-29	-7%
	KEN					73	73	73	
	LKA		2627	3532	1966	5505	2891	264	10%
	MOZ				126				
	MUS		4844	5448	7404	7681	11322	6479	134%
	PHL					73			
	Sub-tot		**18432**	**18729**	**18682**	**21086**	**28272**	**9840**	**53%**
All purse seine fleets			**142152**	**151459**	**156119**	**156034**	**157691**	**-70**	**0%**

E) Longline fleets

Longline fleets		Reduction	2014	2015	2016	2017	2018	Difference with baseline	
								Absolute	%
Subject to Res. 18/01	TWN	10%	12285	13921	16958	9115	10845	-1441	-12%
	LKA		8625	5933	3939	6448	8554	-71	-1%
	Sub-tot		**20910**	**19855**	**20896**	**15563**	**19399**	**-1511**	**-7%**
Not subject to Res. 18/01	AUS	N/A	19	73	66	65	38	19	99%
	BLZ		46						
	CHN		1078	1793	1812	2962	4641	3564	331%
	EU		894	732	651	369	331	-563	-63%
	IDN		4009	5077	2826	2353	1606	**-2403**	-60%
	IND		327	669	106	6	7	-320	-98%
	JPN		3639	3140	2967	3291	2999	-641	-18%
	KEN						116	116	100%
	KOR		1557	1674	1374	1802	1575	18	1%
	MDG		59	72	61	28	29	-30	-51%
	MDV		120	63	286	220	106	-15	-12%
	MOZ		1	56	21	89	63	61	4408%
	MUS		15	32	94	266	259	244	1630%
	MYS		77	144	156	384	446	369	477%
	NEICE		4065	3009	418				
	NEIFR		417	451	693				
	OMN		28	205	135	110	177	149	538%
	PHL		69						
	SYC		1616	2395	3247	4313	5678	4062	251%
	THA		187	109					
	TZA		155	108	109				
	ZAF		83	182	183	247	331	248	299%
	Sub-tot		**18463**	**19985**	**15205**	**16504**	**18403**	**-60**	**0%**
All longline fleets			**39373**	**39840**	**36101**	**32067**	**37802**	**-1571**	**-4%**

F) Gillnet fleets

Gillnet fleets		Reduction	2014	2015	2016	2017	2018	Difference with baseline	
								Absolute	%
Subject to Res. 18/01	IRN	10%	24401	26780	31079	37193	35534	11132	46%
	Sub-tot		**24401**	**26780**	**31079**	**37193**	**35534**	**11132**	**46%**
Not subject to Res. 18/01	AUS	N/A	0	0	1	1	1	1	335%
	BHR		1	1	1	0	0	-1	-67%
	COM		16	117	905	547	135	119	739%
	DJI		38	27	34	95	15	-23	-61%
	EGY			0	0				
	IDN		341	334	317	317	252	-89	-26%
	IND		5153	3974	4392	3297	13717	8564	166%
	IRN		16925	11632	4031	8358	6537	**-10388**	-61%
	JOR		0	0	1	5	7	7	1542%
	KEN		54	82	82	157	157	103	191%
	LKA		11246	8559	5469	3142	1479	**-9767**	-87%
	OMN		2268	8145	6914	9646	14184	11916	525%
	PAK		14452	16791	23392	25471	16541	2089	14%
	QAT		93	85	57			-93	-100%
	TMP		0	1	1	0	0	0	-66%
	TZA		3210	3814	3814	3814	3814	603	19%
	YEM		5				18	13	252%
	Sub-tot		**53804**	**53564**	**49409**	**54849**	**56856**	**3053**	**6%**
All gillnet fleets			**78205**	**80344**	**80489**	**92042**	**92390**	**14185**	**18%**

G) All other fleets

Other fleets		Reduction	2014	2015	2016	2017	2018	Difference with baseline	
								Absolute	%
Subject to Res. 18/01	MDV BB	5%	18481	15796	8550	17500	10749	-7732	-42%
	MDV HL		30246	36300	44385	30563	16704	-13542	-45%
	Sub-tot		**48727**	**52096**	**52935**	**48063**	**27453**	**8972**	**49%**
Not subject to Res. 18/01	AUS	N/A	0	0	0	1	0	0	-32%
	COM		1383	1630	4679	4259	3059	**1676**	121%
	EGY			16	15			0	
	EU		291	361	564	445	407	116	40%
	GBRT		2	2	2	3	4	3	158%
	IDN		15327	15041	14278	14278	11319	**-4009**	-26%
	IND		27849	12440	14662	10566	23644	**-4205**	-15%
	IRN		57	345	6535	8806	12682	**12624**	22010%
	JOR		30	29	28	20	17	-13	-44%
	KEN		17	27	27	174	174	157	897%
	LKA		15280	14647	22361	22883	26892	**11612**	76%
	MDG		675	675	675	675	675	0	0%
	MDV BB						6870		
	MDV HL						12256		
	MOZ		4	13	27	80	93	89	2219%
	MUS		50	50	87	69	75	25	50%
	OMN		4912	6833	13935	9693	14281	**9369**	191%
	SYC		0	0	0	57	43	43	10887%
	TMP		3	3	3	3	3	0	0%
	TZA		76	90	90	90	90	14	19%
	YEM		29346	24576	21100	17935	17977	**-11369**	-39%
	ZAF		0						0%
	Sub-tot		**95303**	**76778**	**99067**	**90035**	**130561**	**35259**	**37%**
All other fleets			**144030**	**128874**	**152002**	**138098**	**158015**	**44231**	**31%**

182. The WPTT **NOTED** that there are two main driving factors that can explain the progress with fleets subject to Resolution 18/01: a) an effective reduction in reported catches for some of the concerned fleets and b) a better categorization of the catch components with respect to previous years (e.g. explicitly reported catch components for the offshore baitboats and handlines from Maldives).

183. However, the WPTT **NOTED** that the proposed revisions to species composition for the EU purse seine fleet in 2018 will result in a remarkable degradation of the status of such fleet with respect to Resolution 18/01 (**Table 9** A, B, C, D).

184. Furthermore, the WPTT **NOTED** with concern that several fleets not subject to Resolution 18/01 have sharply increased their catches of yellowfin tuna with respect to the theoretical baseline year (2014) as well as with respect to previous year (2017) therefore reducing the effectiveness of the measures introduced by Resolution 18/01.

185. The WPTT **NOTED** that the information presented in relation to the progress and effectiveness on implementation of Resolution 18/01 was informative and **REQUESTED** the Secretariat to present this information at future WPTT and SC meetings

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

Maldives handline fishing activities

186. The WPTT **NOTED** paper IOTC–2019–WPTT21–38 which provided an identification of fishing activities and time allocation in the Maldives handline yellowfin tuna (*Thunnus albacares*) fishery. The paper included the following abstract:

"Information on the different activities and their time allocation is critical to understand fishing fleets" behavior, to elucidate the unit of fishing effort and to derive informative abundance indices to track changes of fish stocks. The Maldives handline yellowfin tuna fishery, which targets adult and sub-adult yellowfin tuna, is a relatively new fishery that began around mid-2000. This paper aims to reveal the different activities and their time allocation for the fishery using logbook data. Examination of the logbook data for 2017 and 2018 showed bait fishing to require substantial effort in terms of time spent, where around 22% of all daily records reported solely bait fishing. A slightly lower proportion of days were where baiting and fishing both occurred on the same day. About 64% of the days at sea for the entire dataset were where just tuna fishing was reported. The data also contributed to some degree, insights on time allocation for searching/steaming and time spent fishing. The exercise emphasized the importance of studying the dynamics of the handline yellowfin tuna fleet and the importance of widening the observer program and implementing a VMS program that would enable improved understanding of the fleet dynamics."

187. The WPTT **NOTED** the importance of understanding the dynamics of fishing activities in the Maldives yellowfin tuna handline fishery for standardising catch rates in the fishery.

Yellowfin tuna genomic analysis

188. The WPTT **NOTED** paper IOTC–2019–WPTT21–40 which discussed how genomic analysis reveals multiple mismatches between biological and management units for yellowfin tuna (*Thunnus albacares*). The paper included the following abstract:

"The South African (SAF) yellowfin tuna (Thunnus albacares) fishery represents a potential example of misalignment between management units and biological processes. The SAF fishery spans an operational stock with a boundary at 20E, either side of which fish are considered part of Atlantic or Indian Ocean regional stocks. However, the actual recruitment of fish from Atlantic and Indian Ocean spawning populations into SAF waters is unknown. To address this knowledge gap, genomic analysis (11 101 SNPs) was performed on samples from Atlantic and Indian Ocean spawning sites, including SAF sites spanning the current stock boundary. Outlier loci conferred high discriminatory power to assignment tests and revealed that all SAF fish were assigned to the Indian Ocean population and that no Atlantic Ocean fish appeared in the SAF samples. Additionally, several Indian Ocean migrants were detected at the Atlantic spawning site demonstrating asymmetric dispersal and the occurrence of a mixed-stock fishery in Atlantic waters. This study highlights both the spatial inaccuracy of current stock designations and a misunderstanding of interactions between the underlying biological units, which must be addressed in light of local and global declines of the species. Specifically, the entire SAF fishery must be managed as part of the Indian Ocean stock"

189. The WPTT **SUGGESTED** that the authors make contact with relevant project team members from the CSIRO/AZTI/IRD/RITF Indian Ocean stock structure project, as there may be some benefits in linking the results from the two projects.

190. The WPTT **NOTED** that there was no evidence from the analyses to support an isolation by distance hypothesis, but that the large distance between the single Atlantic Ocean sampling site and the Indian Ocean sites makes it difficult to identify the precise location of the boundary between Atlantic and Indian Ocean yellowfin populations.

Yellowfin tuna caught by foreign vessels in Malagasy waters

191. The WPTT **NOTED** paper IOTC–2019–WPTT21–41 which provided statistics of Yellowfin tuna caught by foreign vessels in Malagasy waters (2014 – 2018), including the following summary provided by the authors:

"Yellowfin tuna (Thunnus albacares) is one of the main targeted species for industrial tuna vessels operating in the Malagasy waters. The data used in this paper are from the logbook

of the tuna longliners and purse seiners who operated within the Malagasy EEZ over the last five years (2014-2018). For the length frequency data, the data collected are from the monitoring of the seiners landing at the port of Antsiranana. The individuals are identified, and measured according to the fork length (FL) and to the pre-dorsal length (LD1).The total catch from foreign fleets has been in the order of 47 244 t over the past five years, an average of 9 449 t per year. Yellowfin tuna represents 27% of the catches (12 860 t), which is equivalent to an annual average catch of 2 572 t. 25,546 of Yellowfin were sampled from 2014 to 2018 during the landing of purse seiners at the port of Antsiranana. Collected data shows that the size of Yellowfin caught ranges from 30 cm to 170 cm. The size frequency is dominated by the one between 50 and 60 cm"

192. The WPTT **NOTED** that paper IOTC-2019-WPTT21-41 was not presented.

Pelagic longline fishing operation parameters optimization

193. The WPTT **NOTED** paper IOTC–2019–WPTT21–25, which described Pelagic longline fishing operation parameters optimization and a case study on targeting yellowfin tuna (*Thunnus albacares*) in the Indian Ocean. The paper included the following abstract:

"In longline fishery, in order to improve fishing efficiency, it was necessary to accurately control the depth of hooks to set the hook as far as possible in the preferred water layer of target species. In this paper, the catenary hook depth formula was used to calculate the theoretical depth of the hook. The environmental data, e.g. wind speed (Vw), gear drift velocity (Vg), angle of attack (Qw) (the angle between the prevailing course in deploying the gear and direction that the fishing gear was drifting), the wind angle (γ) (the angle between the direction of the wind and the prevailing course in deploying the gear), and operation parameters, e.g. line shooting speed (V1), vessel speed (V2), the number of hooks between two floats (Nb), and time interval between two hooks (t), were collected and the actual hook depth (Df) were measured on board of the longliners.." – see paper for full abstract.

194. The WPTT **NOTED** that the analytical approach described in this paper has been applied to other tuna and shark species to examine the relationship between hook depth and catch rates, and that these analyses have been published in peer-reviewed journal articles.

7.3 Review of new information on the status of yellowfin tuna

7.3.1 Nominal and standardised CPUE indices

Updated Catch and Effort from Indonesian Longline fishery

195. The WPTT **NOTED** paper IOTC–2019–WPTT21–42, which provided updated information on catch and effort of yellowfin tuna (*Thunnus albacares*) from Indonesian tuna longline fishery. The paper included the following abstract:

"Yellowfin tuna (Thunnus albacares) is one of the main targets for Indonesian tuna longline fishery in the Eastern Indian Ocean. There were two types of data used in this study; first was the skipper's "logbook" data from the state-owned commercial tuna longline vessels based in Benoa Port (1978-1995), and the later was the scientific observer data conducted by Research Institute for Tuna Fisheries (RITF) from 2005 to 2018. Both data then combined to produce nominal catch per unit of effort (CPUE) (no. fish/100 hooks). The result showed that the catch rates of yellowfin tuna is declining over the years. The highest CPUE recorded was in 1982 (0.94), while the lowest was in 2015 (0.03). Efforts distributed mainly within 0-35 oS and 75 – 130 oE. While high average CPUE areas mainly occurred between 5-10 oS and 80-130 oE. We are still in progress of completing the skipper's "logbook" data entry in a hope of presenting the appropriate yellowfin tuna standardized CPUE in the future."

196. The WPTT **THANKED** the authors for their interesting presentation and **ENCOURAGED** them to continue to develop the indices for possible future use in assessments.

Accounting for fishing days without set, fishing concentration and piracy in CPUE standardisation

197. The WPTT **NOTED** paper IOTC–2019–WPTT21–44 which provided a method for accounting for Fishing Days Without Set, Fishing Concentration and Piracy in the CPUE Standardisation of Yellowfin Tuna in Free Schools for the EU Purse Seine Fleet Operating in the Indian Ocean During the 1991-2017 Period. The paper included the following abstract:

    "The time series of EU purse seine fleet catches per unit effort (CPUE) of yellowfin tuna (YFT) from the Indian Ocean were standardized using an extension of the Delta-lognormal GLMM to three components. The aim was to depict the trend in abundance for adult YFT observed in free schools (FSC). The originality of this work relied on the inclusion of i) null sets, considered as presence of YFT FSC, ii) fishing days without set, considered as absence of FSC, iii) EU fishing agreement in the exclusive economic zones driving EU purse seine fleet presence in these areas, iv) time spent by centroid cell by boat by day to constrain detectability, v) the Gulland's index of fishing effort concentration to measure the extent to which a fleet has concentrated its fishing effort in areas with higher than average catch rates and, vi) piracy as a presence absence variable. Standardized CPUE for FSC was thus defined as the product of the number of set (positive and null) by spatio-temporal strata, the proportion of sets with large YFT (>10 kg) and the catch per large YFT set. To detect strata without sets, all activities recorded in captain logbooks were used for the period 1991-2017. This new standardization approach, therefore, represents a significant advance over previous efforts, though there are a number of avenues for future progress."

198. The WPTT **NOTED** that purse seine free school nominal catch rates were very high between 2003 and 2006, so called "golden years". This period was associated with unusual oceanographic conditions, that potentially could have increased abundance and/or purse seine catchability. The inclusion of the Gulland index in the standardization interprets the peak as a catchability effect and the standardization process resulted in a flattening of these anomalous years.

199. The WPTT **NOTED** that Somalian piracy has a smaller effect on the PS effort distribution than longline effort distribution because security personnel reduced the impact of piracy on PS operations.

200. The WPTT **NOTED** that purse seine effort on free school sets is difficult to define and FADs might have an effect on free-school operations and free-school searching behaviour. The authors informed the WPTT that the CPUE on free school focuses only on larger fish that do not associate with FADs. However as the free school sets occur opportunistically between FAD school sets, the FAD effect on the index has been included as a variable in the standardization process.

201. The WPTT **NOTED** the importance of having operational definitions of FADs sets and free school sets to ensure objectivity in assigning catch and effort for those two modes of fishing.

202. The WPTT **NOTED** that the effect of technological improvements needs to be considered carefully. The authors informed the WPTT that most of the technological development in the purse seine fishery is thought to be aimed at improving FAD fishing. It was also **NOTED** that, although the EU PS fleet prefers the more valuable fish associated with free schools, the activity on free schools was substantially lower in 2018.

Novel index of abundance from Echosounder Buoys

203. The WPTT **NOTED** paper IOTC–2019–WPTT21–45 which described a Novel Index of Abundance of Juvenile Yellowfin Tuna in the Indian Ocean Derived from Echosounder Buoys. The paper included the following abstract:

    "The collaboration with the Spanish vessel-owners associations and the buoy-providers companies, has made it possible the recovery of the information recorded by the satellite linked GPS tracking echosounder buoys used by the Spanish tropical tuna purse seiners and associated fleet in the Indian Ocean since 2010. These instrumental buoys inform fishers remotely in real-time about the accurate geolocation of the FAD and the presence

and abundance of fish aggregations underneath them. Apart from its unquestionable impact in the conception of a reliable CPUE index from the tropical purse seine tuna fisheries fishing on FADs, echosounder buoys have also the potential of being a privileged observation platform to evaluate abundances of tunas and accompanying species using catch-independent data. Current echosounder buoys provide a single acoustic value without discriminating species or size composition of the fish underneath the FAD. Therefore, it has been necessary to combine the echosounder buoys data with fishery data, species composition and average size, to obtain a specific indicator. This paper presents a novel index of abundance of juvenile yellowfin tuna in the Indian Ocean derived from echosounder buoys for the period 2010-2018, with the aim of contributing to the 2019 assessment of this stock."

204. The WPTT **ENCOURAGED** further work on this promising new abundance index. Potential avenues for further exploration could include:

- Validation of the biomass estimated by the buoy using catch data.
- Further comparisons by buoy brand and model
- Filtering out the data corresponding to buoy replacement that does not reflect new FAD deployment.
- Consideration of alternative time windows to define "virgin" trajectory segments.

205. The WPTT **NOTED** that the FAD density did not affect the index significantly and suggested that Spanish FAD density may not be a sufficient descriptor of all FADs in the study region.

7.3.2 Stock assessments

206. The WPTT **NOTED** that although 2019 was not designated a yellowfin tuna assessment year, due to the issues with the assessment in 2018, several modelling methods were applied to the assessment of yellowfin tuna in 2019 in accordance with the yellowfin tuna workplan endorsed by the SC in 2018 and Commission in 2019. Each model is summarized in the sections below.

Yellowfin tuna: Summary of stock assessment models in 2018

207. The WPTT **RECALLED** that a quantitative modelling method using SS3 was applied to yellowfin tuna in 2018 and readers are requested to refer to the report of the 20th Session for details (IOTC–2018–WPTT20–R).

Potential impact of catch underreporting on yellowfin stock assessment

208. The WPTT **NOTED** paper IOTC–2019–WPTT21–47 which described the evaluation of the potential impact of catch underreporting on yellowfin stock assessment using exploratory scenarios of catch history. The paper included the following abstract:

"In 2018, a new stock assessment was carried out for yellowfin in the IOTC area. The uncertainty on nominal catches among others, recommended to avoid catch limits recommendation and the development of a workplan to address these uncertainties. One of the objectives of the workplan is to address the potential impact of the uncertainty on catches by exploring alternative scenarios of catch histories for yellowfin. In this study, we carried out a relatively simple exploratory analysis of the potential impact of underreporting of artisanal fisheries. We generated three scenarios of underreporting and re-run the stock assessment model. Our results suggest that the uncertainty in the catch information used in the stock assessment does not produce a noticeable impact on the estimates of stock status. Our results do suggest that changes in catch scenarios produce changes in the estimated productivity of the stock."

209. The WPTT **NOTED** that the yellowfin assessment relative abundance estimates appeared to be very robust to consistent underreporting biases in the artisanal fleets, though MSY estimates

scaled in a predictable manner. The WPTT **NOTED** that trends in catch misreporting are likely to create more complicated biases, and such scenarios may be difficult to derive.

210. The WPTT **NOTED** that some assessment models (including SS), can treat catches as observations with error. However, it was further noted that this can be a dangerous feature to use, because it may result in a significant distortion of the input catch series, to fit some other data which might be very unreliable**.**

An Alternative Assessment for the Indian Ocean Yellowfin Tuna Stock; with Generic Goodness of Fit Diagnostics

211. The WPTT **NOTED** paper IOTC–2019–WPTT21–48 which described an Alternative Assessment for the Indian Ocean Yellowfin Tuna Stock; with Generic Goodness of Fit Diagnostics. The paper included the following abstract:

"•The objective of this work is to assist the IOTC Scientific Committee in providing robust management advice for yellowfin tuna by evaluating alternative assessment methods and scenarios that reflect uncertainty about the assumptions and datasets used in the assessment.

•Specific tasks are to agree datasets (CPUE series and catch series) based on alternative assumptions about mis-reporting, run biomass dynamic based stock assessments. and compare the results to the base case SS3 assessment using a common set of diagnostics.

•The report summarises the analysis and provides a set of diagnostics that can be used for comparison across different modelling platforms

•All scenarios other than 2 (high productivity and the reference case fitted to the estimate of biomass from stock synthesis) indicate that the stock is overfished and experiencing overfishing.
•The work is based on data available on July 8th, 2019."

212. The WPTT **NOTED** that the paper provided examples of diagnostics that can be applied more generally in the IOTC stock assessment process for model validation, i.e. based on prediction skill and runs tests. The models, however, were not intended to provide management advice but to provide insight about uncertainty in IOTC YFT population dynamics. For example estimates of Surplus Production (Walters, et al., 2008) can provide a check of whether predictions of changes in biomass can be reliably made based on catch and current biomass or whether there has been non stationarity in production processes, e.g. are dynamics driven by climate and oceanic conditions (IOTC-2019-WPTT21-24). This is important for the development of MPs in the MSE process..

Preliminary Indian Ocean yellowfin tuna stock assessment using a biomass production model

213. The WPTT **NOTED** paper IOTC–2019–WPTT21–49 which described the stock assessment of Indian Ocean yellowfin using a biomass production model. The paper included the following abstract:

"In 2018, a new stock assessment was carried out for yellowfin in the IOTC area using Stock Synthesis III (SS3), a fully integrated model that is used for the three tropical tuna stocks in the IOTC (bigeye, yellowfin and skipjack). However, the lack of understanding of stock dynamics due to various uncertainties led the IOTC's Scientific Committee (SC) to develop a workplan to address these uncertainties in 2019 before providing management advice. One of the items of this workplan is to characterize model uncertainty by using alternative stock assessment models. Here, we use a relatively simple biomass dynamic model that uses total catch and catch per unit of effort trends to estimate biomass and fishing mortality trajectories and to estimate fishery's reference points. The 2018 SC acknowledged that the uncertainties on this fishery need to be explored and characterized and we do this by generating nine alternative scenarios for this stock assessment." – see document for full abstract

214. The WPTT **NOTED** that this work was undertaken as part of the 2018 SC request to try and improve the 2018 yellowfin stock assessment advice using multiple models. However, the WPTT concluded that the observation-error only production models that were explored did not offer any new insights to improve the current YFT management advice.

Preliminary Indian Ocean yellowfin tuna stock assessment using SS3

215. The WPTT **NOTED** paper IOTC–2019–WPTT21–50 which described the preliminary Assessment of Indian Ocean Yellowfin Tuna 1950-2018 (Stock Synthesis, v3.30). The paper included the following abstract:

"This paper presents a preliminary reference model for the assessment of yellowfin tuna (Thunnus albacares) using the age and length structured integrated assessment model Stock Synthesis (SS) version 3.30.09. In this document we review the reference model that was used for the 2018 assessment as part of the 2019 workplan for yellowfin. The main features of the new model are a proposal for reducing or removing the influence of tagging data and for a reduced number of areas. The analyses that led to this proposal are explained throughout the document. In brief, the analyses and diagnostics of the model suggest that tagging data and environmental data do not contain enough information to estimate the movement between the 4 areas defined within the model: western-tropical, western-temperate, eastern-tropical and western tropical, and that these data make the model unstable." – see document for full abstract

216. The WPTT **NOTED** that the paper represents the culmination of a substantial intersessional collaborative effort to improve the YFT SS stock assessment. This paper formed the base for the modelling work that was undertaken during the WPTT, in which a 36 model grid was defined with the following alternative assumptions used to represent assessment uncertainty:

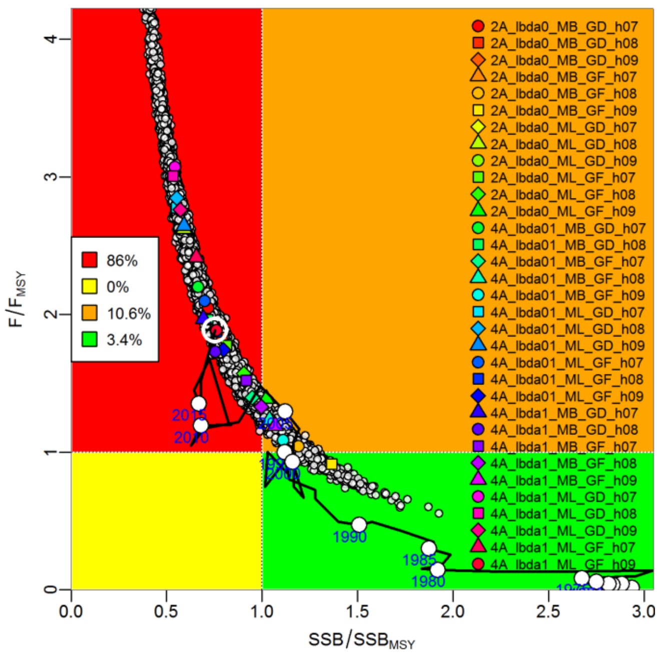
- Spatial structure 1: Four areas defined as in 2018
  - i. 3 X h
  - ii. 2 X M
  - iii. 2 X growth
  - iv. 2 X tag weighting
- Spatial structure 2: Two areas, consisting of merged areas 1&2 and 3&4
  - i. 3 X h
  - ii. 2 X M
  - iii. 2 X growth
- The two spatial options would be weighted equally in the advice
- The assessment was to be based on the alternative 2018 PS catch assumptions derived by the Secretariat during the meeting.

217. The grid was the result of substantial debate among the WPTT participants, in which a number of key points were **AGREED**:

- The reported Spanish purse seine catches in 2018 should be treated as an unlikely event (subject to further investigation), and should be replaced with the new estimate produced by the Secretariat based on historical species composition estimates (Section 7.1).
- Tag induced mortality and immediate shedding (Hoyle et al (2015) and long term shedding assumptions (Gaertner and Hallier 2015) were adopted.
- Tag mixing assumptions are not likely to be met in the 4 area model configuration, and hence tag down-weighting options should be included with equal or higher importance to full tag weight assumptions. Tags should not be included in the 2 area model.

- Purse seine CPUE series would be examined as a sensitivity test.
- M assumptions are based on the Atlantic otolith ageing (and radio-isotope validation), the Then et al. (2015) oldest age method and the shape of the mortality curve that was used in 2018.
- The Dortel et al. (2015) growth equation 2 and the ad hoc Fonteneau (2008) growth curve were used.
- A standard set of diagnostics should be applied to the stock assessment models, or at least a subset of models, including jitter analyses, hindcasting, retrospectives and runs tests (or some method evaluating systematic lack-of-fit). However, limitations of what can be achieved with the diagnostics needs to be recognized – they cannot automate the model selection process.

218. The WPTT **NOTED** the preliminary results generated from the reference grid of models (**Figure 13**). The new grid does not suggest any qualitative difference with the assessment carried out in 2018.



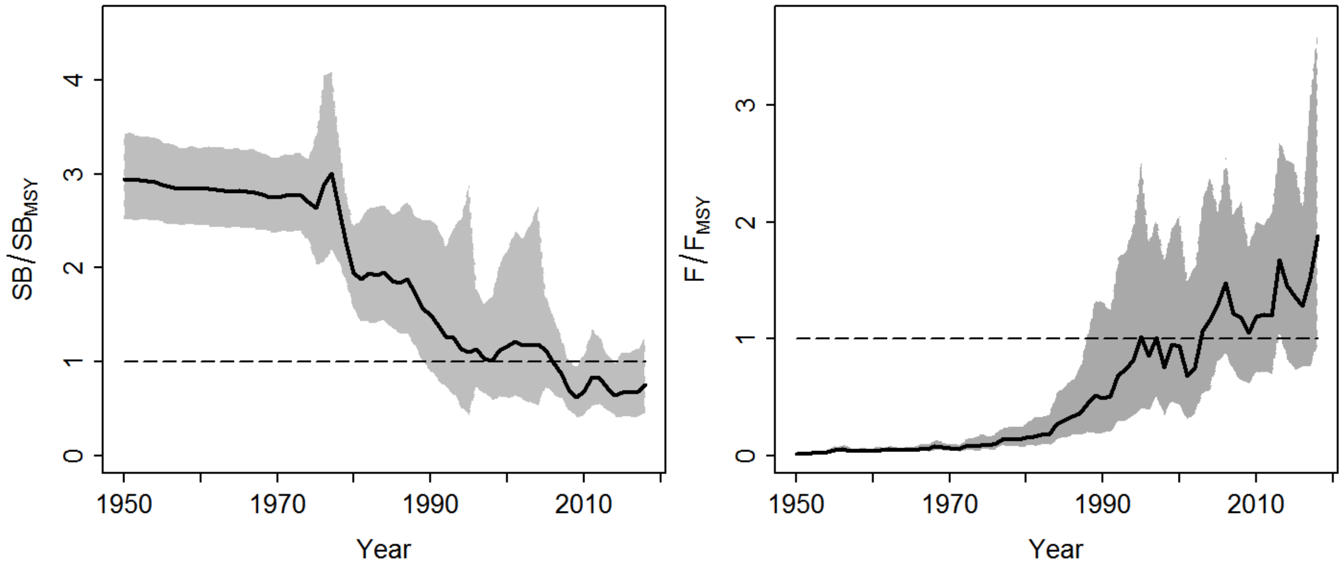


Figure 13: Kobe plot and biomass and F trajectories for the 2019 assessment

219. The WPTT **RECOGNIZED** that the collaborative effort represents an ambitious attempt to improve the assessment, and was successful for increasing the number of people that have a reasonable understanding of Stock Synthesis, the yellowfin assessment issues, and the application of standard model diagnostic techniques. Considerations for future assessments include:

- Comprehensive reviews of size composition data have not yet been completed.
- The WPTT **NOTED** that the Fonteneau (2008) growth curve used in previous assessments cannot be validated and **SUGGESTED** therefore the published Dortel et al (2015) growth curve(s) should be investigated.
- Use of the RTTP-IO tagging data requires further consideration, especially with respect to tag mixing assumption violations. A two stage process may be useful, in which inferences from high resolution modelling can be imported into larger scale models as priors or fixed inputs. Simplification of the biology is the rationale behind the choice of the model without movements (i.e. the 2-area model). Given the defection of tagging design, the information provided by the tagging data in the model are biased and thus not used in the newly developed 2-area model but still in the 4-area model.
- The WPTT workload should be reduced by avoiding multiple tropical tuna stock assessments in the same year.
- Further intersessional yellowfin work should be undertaken to continue the current process.
- Data issues should be addressed at the WPDCS prior to the WPTT
- An extra preparatory meeting may be required well in advance of the assessment, In this context, WPTT **ACKNOWLEDGED** that the procedure of how assessment are conducted needs to be restructured. WPTT **RECOMMENDED** that a data preparation meeting is scheduled well in advance of the assessment meeting so that the assessment meeting can focus on model configuration, diagnostics and advice only, and that data issues should not be reopened at the assessment meeting. This will also allow intersessional work between the data meeting and the assessment meeting to be conducted

220. The WPTT **NOTED** that there is some model sensitivity to the choice of method used for weighting different data series and the time period in which the recruitment deviates are active. An investigation was undertaken during the WPTT, but the results were insufficiently conclusive

to change the structure of the models included in the assessment grid. However, the WPTT **RECOMMENDED** that more intersessional work should be conducted, especially after the revision of the length compositions.

221. The WPTT **NOTED** the potential numeric instability during the projection phase in SS version 3.24 which might cause some of the models to crash during forecast in the 2018 WPTT. This seems to be an issue with SS 3.24 but not with 3.30 as the same phenomenon was not evident in this years projections of yellowfin tuna.

222. The WPTT **NOTED** the substantial work conducted to address the yellowfin tuna workplan, but that there was still work to be completed. As such the WPTT **REQUESTED** that the authors fully document the work conducted prior to, during as well as the work still to be addressed after the meeting, in an information document to be provided to the SC in 2019. This work will be coordinated by the chair of the WPTT.

223. The WPM **NOTED** paper IOTC–2019–WPM10–25 which discussed whether Close-Kin Mark Recapture is Feasible for IOTC yellowfin tuna stock assessment. The following abstract was provided by the authors:

> *"This paper provides (i) brief consideration of options to collect data for improving the IOTC yellowfin stock assessment, (ii) an introduction to the general concept of Close-Kin Mark Recapture (CKMR) - a reasonably new, but proven fisheries assessment tool (e.g. it has been successfully applied to southern bluefin tuna), and (iii) a rough evaluation of the logistical and economic feasibility of applying this tool to the IOTC yellowfin tuna (YFT) population. (See paper for full abstract)"*

224. The WPTT **THANKED** the authors for this interesting study and **AGREED** that this is a novel technique that potentially could avoid several of the problems inherent in the other types of data currently available for stock assessments and the RTTP-IO data. The approach provides information about absolute spawner abundance, total mortality (which can be partitioned into M and F when coupled with catch at age data), and reproductive success by age/size.

225. The WPTT **NOTED** that the current feasibility study indicates that CKMR could be economically viable (e.g. similar in cost to the current IO stock structure project). The WPTT strongly **ENCOURAGED** the authors to develop a design study evaluating all costs and logistical feasibility, to be undertaken before beginning such an application.

7.3.3 Selection of Stock Status indicators for yellowfin tuna

226. The WPTT **NOTED** paper IOTC–2019–WPTT21–51 which described the application of a multivariate lognormal approach to estimate uncertainty about the stock status and future projections for Indian Ocean Yellowfin tuna. The paper included the following abstract:

> "*This paper presents a multivariate lognormal (MVLN) Monte-Carlo approach to produce Kobe phase plots and Kobe II projection matrices for range of fixed catch scenarios from the 2018 Indian Ocean yellowfin tuna reference grid of Stock Synthesis models. First, we present Kobe-phase plots for the current stock status that compare within-model uncertainty estimates for a single reference case model to the structural uncertainty estimates from a reference grid of 24 models. The Kobe phase plot results portrait a more pessimistic stock status for the reference case model (94.3% overfished) compared to the uncertainty grid of 24 Stock Synthesis model configurations (83.9% overfished), which captures a wider range of plausible outcomes along SSB/SSBMSY axis." – see document for full abstract*

227. The WPTT **NOTED** that the approach provides a visual representation of uncertainty within and among models that appears to describe the expected covariance among stock status indicators. The WPTT **REQUESTED** that the approach be used for the usual IOTC summary plots, if future assessments are based on a coarse grid of point estimates that cannot describe management outcome probabilities adequately.

7.4 Development of management advice for yellowfin tuna

228. The WPTT **ACKNOWLEDGED** the efforts made towards improving the 2018 stock assessment but also **AGREED** that new management advice could not be provided in 2019 due to the complexity of the work, lack of agreement on key model aspects and time constraints during the meeting. With regards to the advice on catch limits, the WPTT **NOTED** that the models available at the end of the WPTT need further analyses and exploration before estimating the K2SM.

229. The WPTT **ADOPTED** 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 2018 catch data (if necessary), and for the summary to be provided to the SC as part of the draft Executive Summary, for its consideration:

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

7.5 Update on Management Strategy Evaluation Progress

230. The WPTT **NOTED** paper IOTC–2019–WPM10–09, which provided an update on the development of the operating model for IOTC yellowfin tuna (October 2019). The paper included the following abstract:

“*This paper summarizes progress on the development of Operating Models (OMs) for IOTC yellowfin (YFT) tuna, highlighting priorities for technical feedback. A short stand-alone summary document describing the most recent reference set Operating Model (OM) is included at attachment 1. This paper focuses on OM developments since the IOTC MSE Task Force meeting in March 2019 (Kolody and Jumppanen 2019a,b). MP evaluation updates for yellowfin and bigeye tunas are described in Kolody and Jumppanen (2019c). ” - See paper for full abstract*

231. The WPTT **NOTED** that development work has been undertaken on the model-based MPs with the intention of improving numerical reliability and performance characteristics. The WPTT further **NOTED** that the issue of median biomass over-shooting the yellowfin rebuilding target (as reported to TCMP 2019) has been resolved. The WPTT **SUGGESTED** that production models with process uncertainty might offer further improvements.

232. The WPTT **DISCUSSED** the properties of the production model used in the model-based MP. The WPTT **NOTED** that, in addition to reporting the average performance of a MP across all OM, it is also important to identify when a MP performs and when it fails. For example, in such a model-based MP, the performance may depend on the estimates of shape of the "implicit" production function, the value of r, or the form of process error (variance or frequency) in the OM. Therefore, the WPTT **NOTED** that understanding when an MP fails could help in identifying where resolving uncertainties could improve management performance. The WPTT also **NOTED** that it is worth comparing the true biomass in the OM and estimated biomass by MP in the simulation in addition to the evaluating MP performances.

233. The WPTT **NOTED** that the use of model free cross-validation could potentially identify which data series have good prediction skill and are therefore candidates for use in model free and model base MPs. However, it was further **NOTED** that the MPs (explored to date) pool the regionally-scaled CPUE indices into a single ocean-wide abundance index, and do not use size composition or tag data, so it is not clear how such an analysis would be helpful in this case.

Table 10: Proposed YFT Reference set OM uncertainty dimensions , to be implemented with fractional factorial design (to encompass most of the uncertainty with a greatly reduced number of model runs, as endorsed by the WPM).

YFTRefrence Set OM Assumption

Spatial Structure – Equal weighting on both that are otherwise unbalanced
(Second option to be reviewed intersessionally by MSE Task Force)

- **4 regions**
- **2 regions; merge 1+2, 3+4**

Stock-recruit function (*h* = steepness)

- **Beverton-Holt, *h* = 0.7**
- **Beverton-Holt, *h* = 0.8**
- **Beverton-Holt, *h* = 0.9**

Natural mortality multiplier relative to reference case M vector

- **2019 Base case**
- **2019 Atlantic**
- **Tremblay-Boyer et al. 2017 (WCPO)**

Tag recapture data weighting (tag composition and negative binomial)
(Applies to 2 area structure only)

- **$\lambda = 0.001$**
- **$\lambda = 0.1$**
- **$\lambda = 1.0$**

Growth curve

- **Dortel et al. (2015) – model 2**
- **Dortel et al. (2015) – model 3 with lognormal error**

Assumed longline CPUE catchability trend (compounded)

- **0% per annum**
- **1% per annum**

Tropical longline CPUE standardization method

- **Hooks Between Floats**
- **Cluster analysis**

Longline CPUE error assumption (quarterly observations)

- **$\sigma_{CPUE} = 0.3$**
- **$\sigma_{CPUE} = 0.1$**

longline CPUE Regional-scaling factors

- **reference case**
- **alternate**

Tag mixing period

- **4 quarters**
- **8 quarters**

<u>Longline fishery selectivity</u> • **Stationary, logistic, shared among areas** • **Stationary, double-normal (potentially dome-shaped), shared among regions**
<u>Size composition input Effective Sample Sizes</u> (ESS) • **ESS = 5, all fisheries** • **ESS = One iteration of re-weighting from reference case model (fishery-specific), raised to the power of 0.75, capped at 100.**

234. Five YFT robustness scenarios were requested (all of which assume the reference set OM conditioning):

- What happens if there is a two year recruitment failure (55% of expected + usual stochastic error)
- What happens if the (annualized aggregate) longline CPUE observation error CV is increased to 30% (auto-correlation 0.5) in projections?
- What happens if there is a consistent 10% future over-catch (accurately reported), equally distributed among fleets?
- What happens if there is a 10% future over-catch (unreported), equally distributed among fleets ?
- What happens if the longline CPUE catchability trend is 2% per year going forward (but remains as in the reference scenario for conditioning)?

235. The WPTT **NOTED** paper IOTC–2019–WPM10–19 which provided a schedule of work for the development of management procedures for key species in the IOTC Area. The following abstract was provided by the authors:

> *"At its 21st Session in 2017, the Commission adopted the 'Schedule of work for the development of management procedures for key species in the IOTC Area' (the Schedule). The Schedule ran from 2017 to 2020 and during that time substantial progress has been made to develop management procedures, ranging from early MSE work for swordfish to the consideration of a draft management procedure measure for yellowfin tuna. At its 23rd Session in 2019, the Commission endorsed a request by the Technical Committee on Management Procedures (TCMP) that the Scientific Committee develop a revised work plan for Management Procedure development. This proposed update to the Schedule fulfils this request and is presented for the consideration of relevant scientific working parties and the Scientific Committee in 2019. Based on feedback from the scientific bodies, the update will be revised and submitted for consideration by the TCMP and endorsement by the Commission at their 2020 sessions. This updated Schedule outlines the process that will need to be followed and the decisions that need to be made to develop management procedures for key IOTC species (at the stock or fishery level) in the IOTC area of competence. It provides a guide for the IOTC committees and sub-committes, as well as the Commission, to understand their roles and responsibilities in the process of developing and adopting management procedures. It also provides indicative timeframes for this work, which may be subject to change. The schedule of work is intended to continue to be a 'living' document that the Commission owns and uses (including updating as required) to catalyse, track and confirm its ongoing commitment to the development of management procedures."*

236. The WPTT **NOTED** that this document is a living document providing a proposed plan to guide the work on MPs. The timelines for each species do not preclude an MP being adopted prior to the dates indicated and it acknowledged that unforeseen circumstances can cause delays in the MP development.

237. The WPTT **NOTED** that this plan has been discussed and reviewed by the WPM and supported the observations made during that working party meeting.

238. The WPTT **NOTED** paper IOTC–2019–WPM10–10 which outlined a proposal on a management procedure for yellowfin tuna in the IOTC Area of Competence.

239. The WPTT **ENCOURAGED** the participants to provide further comments to improve the wording of the proposal.

8. FAD INFORMATION

240. The WPTT **NOTED** paper IOTC–2019–WPTT21–52 which provided results of the BIOFAD Project: Testing Designs and Identify Options to Mitigate Impacts of Drifting Fish Aggregating Devices on the Ecosystem. The paper included the following abstract:

" The EU project BIOFAD was launched in August 2017. This 28-months EU project is coordinated by a Consortium comprising three European research centers: AZTI, IRD (Institut de recherche pour le développement) and IEO (Instituto Español de Oceanografía). The International Seafood Sustainability Foundation (ISSF) is also actively collaborating by providing the biodegradable materials needed to test biodegradable dFADs (drifting FADs). Following IOTC, along with other tuna RFMOs, recommendations and resolutions to promote the use of natural or biodegradable materials for dFADs, this project is seeking to develop and implement the use of dFADs with both characteristics, non-entangling and biodegradable, in the IOTC Convention Area. However, there are no technical guidelines on the type of materials and FAD designs to be used." – see document for full abstract.

241. The WPTT **THANKED** the authors for the interesting study and update on the developments of the BIOFAD project (which was formally detailed in Res 18/04).

242. The WPTT **NOTED** paper IOTC–2019–WPTT21–53 which provided a methodology for the monitoring floating object (FOB) and buoy use by French and Italian tropical tuna purse seiners of the Indian Ocean. The paper included the following abstract:

"In this document, we present the methodology adopted by ORTHONGEL and its member fishing companies for the monitoring of FOB and operational buoy use in the Indian Ocean. In particular, we detail updates in purse seine fishing/FOB logbook that will allow a proper collection of information on FOB types and FOB activities and we detail the methodology recently adopted with buoy providers to ensure compliance with existing buoy limitations. We underline the need for a transparent and harmonized control of the number of operational buoys used by purse seiners that would address potential issues of under-reporting through cycles of activation/deactivation. We propose minimum standards of operational buoy monitoring that would ensure that a given vessel does not circumvent buoy limitations with "ghost buoys". "

243. The WPTT **NOTED** the methodology adopted by ORTHONGEL and its member fishing companies for the monitoring of FOB and operational buoy use in the Indian Ocean. The WPTT **NOTED** that this information could be used to inform IOTC discussions on FAD fishing definitions and FAD monitoring options.

244. The WPTT **NOTED** the comments by the authors that this methodology is new; however, the work is expected to be an important resource for the Commission and will be further developed and improved over time.

245. The WPTT **NOTED** the complications inherent in FAD marking. These include both operational problems in reading the mark experienced during the BIOFAD project (markings being underwater), as well as conceptual issues (FAD ownership). No consensus on FAD marking was reached during WPTT discussions.

246. The WPTT **NOTED** the definitions provided by the CECOFAD project and presented in the current paper. The WPTT **NOTED** that some of the definitions which have been adopted by

ICCAT (Rec 16/01), may be an improvement on the current definitions provided in Res 15/08 to ensure the collection of good quality scientific data on floating objects; however, there was not enough time during the meeting to comprehensively discuss them. The WPTT further **NOTED** that the definitions provided by CECOFAD and by Res 15/08 are not using the same classifications and this would need to be addressed by supplementing the CECOFAD definitions or revising the Resolution.

247. The WPTT **AGREED** that further discussions on the definitions would be required if they are to be considered at the Commission level.

248. The WPTT **NOTED** that papers IOTC–2019–WPTT21–54, IOTC–2019–WPTT21–55 and IOTC–2019–WPTT21–56 were presented together.

249. The WPTT **NOTED** paper IOTC–2019–WPTT21–54, a report on biomass estimates obtained from a multi-frequency echosounder buoy model (M3I+), which provided a method to work towards the derivation of fisheries-independent abundance indices for tropical tuna . The paper included the following abstract:

"For several decades, the industrial tropical tuna purse-seiners have employed drifting Fish Aggregating Devices (FAD) worldwide to increase their chances of locating tuna aggregations and catching them. The general objective of this work is to exploit the novel data obtained from the M3I+ buoys in the Indian ocean for deriving novel abundance indices for tropical tuna. The specific objectives of this study are: to obtain biomass estimates from the M3I+ buoy model and assess their accuracy. - to compare the accuracy of M3I+ with other buoy models (mainly M3I)- to compare different metrics (e.g., lifetime of the aggregation and colonization times) obtained from different buoy models (M3I+ and M3I) instrumenting FADs located in the same spatio- temporal strata." – see document for full abstract

250. The WPTT **NOTED** paper IOTC–2019–WPTT21–55, which provided information on aggregation dynamics of tuna under drifting fish aggregating devices (DFADs) assessed through fisher's echosounder buoy in the Indian Ocean. The paper included the following abstract:

"The aggregative behavior of tuna around floating object is widely exploited by the industrial purse-seine fishery, which deploy thousands of floating objects each year in all oceans in order to improve their catches. These fish aggregating devices (FADs) are generally equipped with echosounder buoys that can collect acoustic data, conferring to these devices the status of privileged observation platforms for the fish communities that aggregate. Using a classification model based on supervised learning algorithms trained on M3I buoy data, we were able to translate the acoustic data collected along the trajectories of 5748 drifting FADs newly deployed between 2016 and 2018 in the Indian Ocean into presence or absence of tuna aggregation. Analysis of the resulting time series indicated that drifting FADs are colonized by tuna aggregation over an average of 39 days. The results also revealed, for the first time, that the residence time of a tuna aggregation around a single DFAD is about 6 days and that DFADs spend on average 9 days without tuna. Thus, DFADs appear to be occupied by tuna aggregation about 43 % of their soaking time. We showed that these metrics can manifest spatial and temporal variations."

251. The WPTT **NOTED** paper IOTC–2019–WPTT21–56, which provided information on mapping tuna occurrence under drifting fish aggregating devices from fisher's echosounder buoys in the Indian Ocean. The paper included the following abstract:

"Echosounder buoys data obtained from instrumented drifting FADs represent an unprecedented information source for assessing the spatio-temporal distribution of tropical tuna. Using machine learning algorithms, we transform acoustic data collected from one of the main echosounder buoys models used by the French purse seine fleet (M3I) into presence/absence of tuna aggregations, enabling the measurement of the amount of inhabited FADs on a given spatio-temporal strata. This paper presents the spatial and temporal distribution of the proportion of drifting fish aggregating devices (DFADs) occupied by tuna

aggregations relative to the total number of FADs in the Indian Ocean on a monthly basis, on a 5° grid for year 2016. The perspectives opened up by this new approach in improving estimates of abundance of tropical tuna populations are discussed.”.

252. The WPTT **THANKED** the authors for this innovative study and **ACKNOWLEDGED** the potential application of this information. The WPTT **NOTED** that further collaboration is required to advance these studies - and, because the (EU funded) projects that are currently supporting the work are finishing, further funding will also be needed.

253. The WPTT **NOTED** the findings that both frequencies tested during the study (50 and 200 kHz) were not significantly different in terms of their results. The WPTT **SUGGESTED** that each frequency was sampling different volumes of water and so they were not directly comparable. However, the authors clarified that they used methodology that would in fact allow this comparison.

254. The WPTT also **NOTED** the colonisation times reported for the FADs. Previous tentative studies had indicated colonisation times of between 14 and 15 days whereas in this study, a colonisation time of 39 days was reported. The authors informed the WPTT that this difference may be explained in terms of different buoy models and methodology. The WPTT **SUGGESTED** that perhaps a spatial analysis could be carried out to determine the causes of these differences.

255. The WPTT **NOTED** that the effects of modifications to the raft or object attached to a buoy were not considered in the model,. The WPTT was informed that when modifications are made to the rafts, the buoys are often changed. Because of this, the analysis is difficult to conduct, although it could be interesting to investigate further in the future.

256. The WPTT **NOTED** paper IOTC–2019–WPTT21–58, which provided information the use of Anchored FADs in the Maldives – Notes for a Case Study for Assessing ALDFG. The paper included the following abstract:

“The Maldives has a coastal fishery targeting surface schooling tunas of mainly skipjack and yellowfin. An anchored array of fish aggregation devices (aFADs) deployed around the archipelago has been helping fishermen to locate tuna schools while improving efficiency of their pole- and-line fishing operations. The aFAD deployment program started in early 1980s, initially as a pilot, has grown and established to maintain a permanent array of about 50 aFADs, by re-deploying lost FADs at almost the same location. The aFAD program is managed exclusively by the government and so has maintained detail records of deployment; fabrication methods, marking, and of FAD attachments. More important are records of lost date and information about retrieval and reuse. We present here information for a case study of a well-managed aFAD program, which in general, follows FAO’s Voluntary Guidelines of Marking of Fishing Gear, and the Best Practice Framework for Fishing Gear set out by the Global Ghost Gear Initiative. On average 19 aFADs are lost on an annual basis, which are replaced soon after they are reported lost. Fishermen are financially incentivized to retrieve and return the detached or lost buoys. Roughly 8-10 buoys are returned on an annual basis making annual loss rate at 9-11 buoys. Based on these we estimate that 0.1 aFAD would be lost per 1,000 MT of fish caught in the fishery making this as a fishery with lowest abandoned, lost or otherwise discarded fishing gear (ALDFG) footprint”.

257. The WPTT **NOTED** the interesting study on anchored FADs deployed in the Maldives and **THANKED** the authors for providing this information to the meeting.

258. The WPTT **NOTED** the future developments being planned in the Maldives to better monitor the status of the aFADs, using GPS in combination with vessel based VMS systems and mobile apps to report aFAD status.

8.1 Outcomes of the 2nd joint tuna RFMO FAD Working Group meeting

259. The WPTT **NOTED** paper IOTC–2019–WPTT21–INF02, which provided the WPTT21 with a summary on the outcomes of 2nd joint tuna RFMO FAD working group meeting held in La Jolla, USA in May 2019.

260. The WPTT **NOTED** the presentation of the meeting provided by the Secretariat and **ACKNOWLEDGED** the utility of the joint Tuna RFMO FAD technical working party to address key FAD issues relevant to all tuna RFMOs.

261. The WPTT **NOTED** the list of recommendations provided in Appendix 6 of the document. The WPTT **NOTED** that other tuna RFMOs such as ICCAT, had taken into account some of these recommendations made during the 2nd joint tuna RFMO FAD Working Group meeting and incorporated them into their FAD WG workplans.

262. The WPTT **NOTED** that there was little time to discuss FAD issues comprehensively during the WPTT meeting, but these issues are recognised as being of critical importance to the Commission (as acknowledged by the adoption of Res 19/02). The WPTT therefore **RECOMMENDED** that the IOTC FAD Working Group, which to date has met only once, be reactivated with a clear mandate to discuss IOTC FAD issues.

8.2 FAD category definitions and terminology

263. The WPTT **NOTED** that several presentations were made (eg. IOTC–2019–WPTT21–53, IOTC-2018-WPDCS14-39) with regards to definitions related to FAD fishing and that these definitions are critical to monitoring the fishery as well as facilitating data provision on this sector. Clear definitions have yet to be adopted by the IOTC and so the WPTT **REQUESTED** that this be done under the reactivated IOTC FAD WG.

9. WPTT PROGRAM OF WORK

9.1 Revision of the WPTT Program of Work (2020–2024)

264. The WPTT **NOTED** paper IOTC–2019–WPTT21–09, which provided the WPTT20 with an opportunity to consider and revise the WPTT Program of Work (2020–2024), by taking into account the specific requests of the Commission, Scientific Committee, and the resources available to the IOTC Secretariat and CPCs.

265. 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)

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

267. The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2020–2024), as provided at Appendix IX.

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

268. The WPTT **NOTED** with thanks, the contribution of the invited expert, Dr. Rishi Sharma (FAO), to the WPTT meeting, and which contributed greatly to the group's discussions of tropical tuna data, CPUE standardisation and stock assessment methods.

269. 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 2020, by an Invited Expert:
    - **Expertise**: Stock assessment; including from regions other than the Indian Ocean; size data analysis; and CPUE standardisation.
    - **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: bigeye tuna).

10. OTHER BUSINESS

270. On behalf of the WPTT, the Chairperson **THANKED** all attendees for their constructive and valuable contributions during the intersessional period and throughout the WPTT21 meeting.

10.1 Date and place of the 22nd and 23rd Sessions of the WPTT

271. The WPTT **THANKED** AZTI Tecnalia for hosting the 21st Session of the WPTT and commended Spain on the warm welcome, the excellent facilities and assistance provided to the IOTC Secretariat in the organisation and running of the Session.

272. **NOTING** the discussion on who would host the 22nd and 23rd Sessions of the WPTT in 2020 and 2021 respectively, the WPTT **REQUESTED** that the IOTC Secretariat liaise with CPCs to determine if they would be able to host the 22nd and 23rd sessions of the WPTT respectively (**Table 11**).

273. The Maldives offered to host the 22nd session of the WPTT in 2020 in Malé, Maldives pending confirmation.

Table 11. Draft meeting schedule for the WPTT (2020 and 2021).

Meeting	2020		2021	
	Date	Location	Date	Location
Working Party on Tropical Tunas	Third week in October (6 days)	Maldives	Third week in October (6 days)	TBD

10.2 Review of the draft, and adoption of the Report of the 20th Session of the WPTT

274. The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT21, provided at Appendix XI, 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 2019 (**Figure.14**):
    - Bigeye tuna (*Thunnus obesus*) – Appendix VI
    - Skipjack tuna (*Katsuwonus pelamis*) – Appendix VII
    - Yellowfin tuna (*Thunnus albacares*) – Appendix VIII

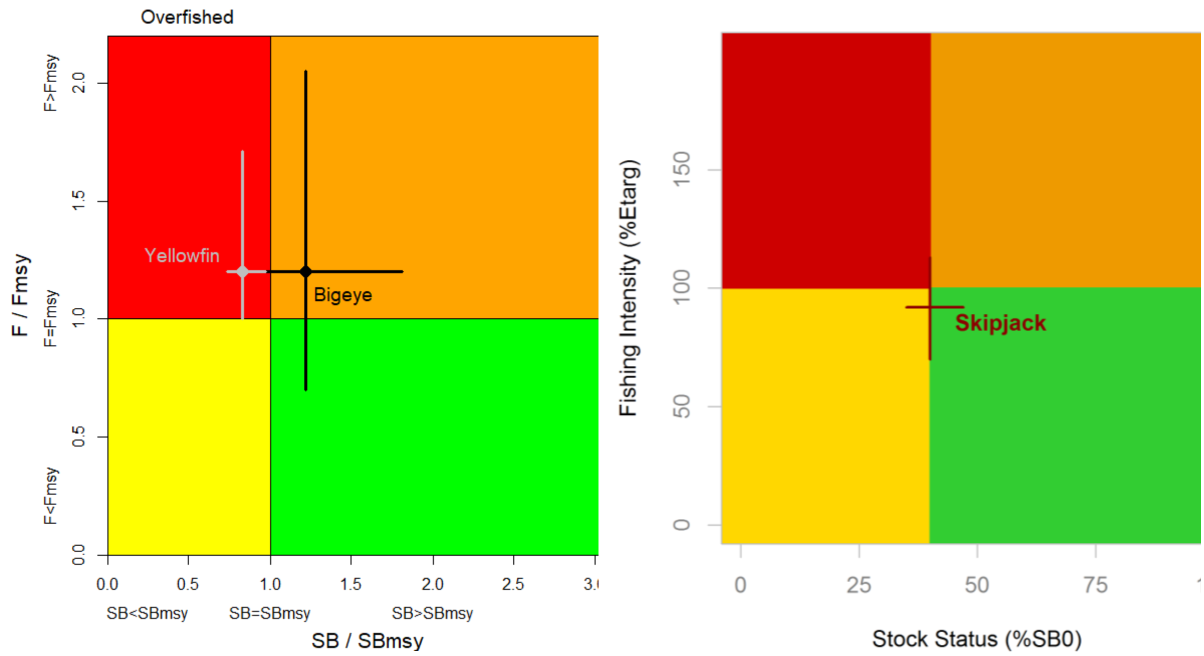


Fig.14. (Left) Combined Kobe plot for bigeye tuna (black: 2019), and yellowfin tuna (grey: 2018) showing the estimates of current stock size (SB) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. (Right) Kobe plot for skipjack tuna showing the estimates of the current stock status. Cross bars illustrate the range of uncertainty from the model runs with a 80% CI.

275. The report of the 21st Session of the Working Party on Tropical Tunas (IOTC–2019–WPTT21–R) was **ADOPTED** on 26th October 2019.

APPENDIX I
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APPENDIX II
AGENDA FOR THE 21ST WORKING PARTY ON TROPICAL TUNAS

Date: 21 – 26 October 2019
Location: Donostia-San Sebastian, Spain
Venue: NH Arranzazu hotel
Time: 09:00 – 17:00 daily
Chair: Dr Gorka Merino (EU,Spain) **Vice-Chair**: Dr Shiham Adam (Maldives)

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

2. **ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION** (Chair)

3. **THE IOTC PROCESS: OUTCOMES, UPDATES AND PROGRESS**
   - 3.1 Outcomes of the 21st Session of the Scientific Committee (IOTC Secretariat)
   - 3.2 Outcomes of the 23rd Session of the Commission (IOTC Secretariat)
   - 3.3 Review of Conservation and Management Measures relevant to tropical tunas (IOTC Secretariat)
   - 3.4 Progress on the recommendations of WPTT20 (IOTC Secretariat)
   - 3.5 Outcomes of the 3rd Technical Committee on Management Procedures (TCMP03)

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)
   - 4.2 Review new information on fisheries and associated environmental data (general CPC papers)

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)
   - 5.3 Review of new information on the status of bigeye tuna (all)
     - Nominal and standardised CPUE indices
     - Stock assessments
     - Selection of Stock Status indicators for bigeye tuna
   - 5.4 Update on Management Strategy Evaluation Progress (OM formulation)
   - 5.5 Development of management advice for bigeye tuna (all)
   - 5.6 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)
   - 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 Update on Management Strategy Evaluation Progress (OM formulation)
   - 6.5 Development of management advice for skipjack tuna (all)
   - 6.6 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)
   - 7.3 Review of new information on the status of yellowfin tuna (all)
     - Nominal and standardised CPUE indices
     - Stock assessments

- Selection of Stock Status indicators for yellowfin tuna

7.4 Update on Management Strategy Evaluation Progress (OM formulation)
7.5 Development of management advice for yellowfin tuna (all)
7.6 Update of yellowfin tuna Executive Summary for the consideration of the Scientific Committee (all)
8.1 Outcomes of the 2nd joint tuna RFMO FAD Working Group meeting (IOTC Secretariat)
8.2 FAD category definitions and terminology
9.1 Revision of the WPTT Program of Work (2020–2024)
9.2 Development of priorities for an Invited Expert at the next WPTT meeting
10.1 Date and place of the 22nd and 23rd Sessions of the WPTT (Chair and IOTC Secretariat)
10.2 Review of the draft, and adoption of the Report of the 21st Session of the WPTT (Chair)

APPENDIX III
LIST OF DOCUMENTS FOR THE 21ST WORKING PARTY ON TROPICAL TUNAS

Document	Title
IOTC–2019–WPTT21–01a	Draft: Agenda of the 21st Working Party on Tropical Tunas
IOTC–2019–WPTT21–01b	Draft: Annotated agenda of the 21st Working Party on Tropical Tunas
IOTC–2019–WPTT21–02	Draft: List of documents for the 21st Working Party on Tropical Tunas
IOTC–2019–WPTT21–03	Outcomes of the 21st Session of the Scientific Committee (IOTC Secretariat)
IOTC–2019–WPTT21–04	Outcomes of the 23rd Session of the Commission (IOTC Secretariat)
IOTC–2019–WPTT21–05	Review of Conservation and Management Measures relevant to tropical tunas (IOTC Secretariat)
IOTC–2019–WPTT21–06	Progress made on the recommendations of WPTT20 (IOTC Secretariat)
IOTC–2019–WPTT21–07	Outcomes of the 3rd Session of the Technical Committee on management Procedures (IOTC Secretariat)
IOTC–2019–WPTT21–08	Review of the statistical data and fishery trends for tropical tunas (IOTC Secretariat)
IOTC–2019–WPTT21–09	Revision of the WPTT Program of Work (2020–2024) (IOTC Secretariat)
IOTC–2019–WPTT21–10	Assessment of the species composition of major tropical tunas in purse seine catches: a new modelling approach for the Tropical Tuna Treatment processing (2). Application to the French fleet in the Indian Ocean. (Duparc A)
IOTC–2019–WPTT21–11	Statistics of the French Purse Seine Fishing Fleet Targeting Tropical Tunas in the Indian Ocean (1981-2018) (Floch L, Depetris M, Dewals P , Duparc A, Lebranchu J, Pernak M and Bach P)
IOTC–2019–WPTT21–12	Free school fishery trends for Spanish tropical purse seiners in the Indian Ocean (Báez J-C and Ramos M-L)
IOTC–2019–WPTT21–13	Assessing the misidentification rate for bigeye and yellowfin juveniles in brine sampled at Port Victoria (Indian Ocean) : consequences for the species composition estimates of landings (Báez J-C, Bach P, Ruiz J, Manzaneque F, Pérez San Juan A, Pernak M, Salgado A, Duparc A, Lucas V, Lucas J and Ramos M-L)
IOTC–2019–WPTT21–14	Statistics of the Seychelles purse seine targeting tropical tunas in the Indian Ocean (Assan C et al.)
IOTC–2019–WPTT21–15	Status of Indian tropical tuna fisheries in 2018 (Mukesh, Varghese S, Pandey S, and Ramalingam L)
IOTC–2019–WPTT21–16	Status of tropical tuna fisheries of Pakistan especially impact of subsurface gillnetting on their landings (M Moazzam)
IOTC–2019–WPTT21–17	Tropical Tuna Landing at Fishing Ports in Thailand during 2016 – 2018 (Noranarttragoon P and Songphatkaew J)
IOTC–2019–WPTT21–18	Diet and consumption rates of yellowfin and skipjack tunas in the eastern Arabian Sea (Varghese S, Mukesh, Pandey S, and Ramalingam L)
IOTC–2019–WPTT21–19	Analysis of catch and effort data of tropical tuna from purse seine and longline fishery in Mauritius (2014-2018) (Kawol D and Sooklall T)
IOTC–2019–WPTT21–20	Standardization of bigeye and yellowfin tuna CPUE by Japanese longline in the Indian Ocean which includes cluster analysis (Matsumoto T et al.)
IOTC–2019–WPTT21–21	Updated CPUE standardizations for bigeye and yellowfin tuna caught by Taiwanese longline fishery in the Indian Ocean. (Yeh Y-M, Tsai W-P, Hoyle S and Chang S-T)
IOTC–2019–WPTT21–22	Covariates of release mortality and tag loss in large-scale tuna tagging experiments (Hoyle S, Leroy B, Nicol S, Hampton J.)
IOTC–2019–WPTT21–23	Using effort control measures to implement catch limits in IOTC purse seine fisheries (Sharma R and Herrera M)
IOTC–2019–WPTT21–24	Outline of climate and oceanic conditions in the Indian Ocean: an update to mid-2019 (Marsac F)

Document	Title
IOTC–2019–WPTT21–25	Pelagic longline fishing operation parameters optimization——A case study on targeting yellowfin tuna (*Thunnus albacares*) in the Indian Ocean (Song L)
IOTC–2019–WPTT21–26	Growth heterogeneity of Bigeye tuna in the Indian Ocean explored by the mixed effects model. (Ma Q, Wang X et al.)
IOTC–2019–WPTT21–27	Analysis of size frequency and CPUE for Indian Ocean bigeye tuna (*Thunnus obesus*) based on the Chinese longline observer data (Wang Y, Zhu J and Dai X)
IOTC–2019–WPTT21–29	CPUE standardization of bigeye and yellowfin tuna caught by Korean tuna longline fishery in the Indian Ocean (Lee S-I)
IOTC–2019–WPTT21–30	Japanese longline CPUE for bigeye tuna in the Indian Ocean standardized by GLM (Matsumoto T)
IOTC–2019–WPTT21–31	CPUE Standardization of Bigeye Tuna, *Thunnus obesus* (Lowe, 1839) from Indonesian Tuna Longline Fishery in Eastern Indian Ocean (Hartaty H, Setyadji B, Nishida T and Fahmi Z)
IOTC–2019–WPTT21–32	Preliminary stock assessment by JABBA for Bigeye tuna in the Indian Ocean (Ma Q et al.)
IOTC–2019–WPTT21–35	Iran's Skipjack Tuna fisheries (Akhondi M)
IOTC–2019–WPTT21–37	Use of two data sets for the analysis of catch rates of Skipjack Tuna (*Katsuwonus pelamis*) in gillnet fishery of Sri Lanka (Haputhantri S)
IOTC–2019–WPTT21–38	Identification of fishing activities and time allocation in the Maldives handline yellowfin tuna (*Thunnus albacares*) fishery (Ahusan M, Shimal M and Adam S)
IOTC–2019–WPTT21–40	Genomic analysis reveals multiple mismatches between biological and management units in yellowfin tuna (*Thunnus albacares*) (Mullins R, McKeown N, Sauer W and Shaw P)
IOTC–2019–WPTT21–41	Statistic of Yellowfin tuna caught by foreign vessels in Malagasy waters (2014 – 2018) (Razafimandimby Y, Jaona G and Joachim D)
IOTC–2019–WPTT21–42	Updated information on catch and effort of yellowfin tuna (*Thunnus albacares*) from Indonesian tuna longline fishery (Hartaty H, Setyadji B and Fahmi Z)
IOTC–2019–WPTT21–44	Accounting for Fishing Days Without Set, Fishing Concentration and Piracy in the CPUE Standardisation of Yellowfin Tuna in Free Schools for the EU Purse Seine Fleet Operating in the Indian Ocean During the 1991-2017 Period (Guéry L, Kaplan D, Marsac F, Floch L, Báez J-C and Gaertner D)
IOTC–2019–WPTT21–45	A Novel Index of Abundance of Juvenile Yellowfin Tuna in the Indian Ocean Derived from Echosounder Buoys (Santiago J, Uranga J, Quincoces I, Orue B, Grande M, Murua H, Merino G, Urtizberea A, Pascual P, Boyra G)
IOTC–2019–WPTT21–46	Japanese longline CPUE for yellowfin tuna in the Indian Ocean standardized by generalized linear model. (Matsumoto T)
IOTC–2019–WPTT21–47	Evaluation of the potential impact of catch underreporting on yellowfin stock assessment using exploratory scenarios of catch history (Merino G, Fu D, Geehan J, Urtizberea A, Santiago J, Murua H)
IOTC–2019–WPTT21–48	An Alternative Assessment for the Indian Ocean Yellowfin Tuna Stock; with Generic Goodness of Fit Diagnostics (Kell L and Sharma R)
IOTC–2019–WPTT21–49	Stock assessment of Indian Ocean yellowfin using a biomass production model (Merino G, Urtizberea A)
IOTC–2019–WPTT21–50	Preliminary Assessment of Indian Ocean Yellowfin Tuna 1950-2018 (Stock Synthesis, v3.30). (Urtizberea A, et al.)
IOTC–2019–WPTT21–51	Application of a multivariate lognormal approach to estimate uncertainty about the stock status and future projections for Indian Ocean Yellowfin tuna (Winker H and Walter J)
IOTC–2019–WPTT21–52	Results of the BIOFAD Project: Testing Designs and Identify Options to Mitigate Impacts of Drifting Fish Aggregating Devices on the Ecosystem (Zudaire I, Tolotti M, Murua J, Capello M, Andrés M, Cabezas O, Krug I, Grande M, Arregui I, Uranga J, Goñi N, Sabarros P, Ferarios J-M, Ruiz J, Baidai Y, Ramos M-L, Báez J-C, Abascal F, Moreno G, Santiago J, Dagorn L, Arrizabalaga H and Murua H)
IOTC–2019–WPTT21–53	Methodology for the monitoring of FOB and buoy use by French and Italian tropical tuna purse seiners of the Indian Ocean (Maufroy A and Goujon M.)
IOTC–2019–WPTT21–54	Towards the derivation of fisheries-independent abundance indices for tropical tuna: Report on biomass estimates obtained from a multi-frequency echosounder buoy model (M3I+). (Diallo A, Baidai Y, Mannocci . and Capello M.)

Document	Title
IOTC–2019–WPTT21–55	Aggregation dynamics of tuna under drifting fish aggregating devices (DFADs) assessed through fisher's echosounder buoy in the Indian Ocean (Baidai Y, Dagorn L, Amande M, Gaertner D, and Capello M)
IOTC–2019–WPTT21–56	Mapping tuna occurrence under drifting fish aggregating devices from fisher’s echosounder buoys in the Indian Ocean. (Baidai Y, Dagorn L, Amande M, Gaertner D, and Capello M)
IOTC–2019–WPTT21–58	Use of Anchored FADs in the Maldives – Notes for a Case Study for Assessing ALDFG (Riyaz A, Jauharee, Adam M S and Azheem M)
IOTC–2019–WPTT21–59	A Case for Fishery Closures to Manage Purse Seine Fisheries for Tropical Tunas in the IOTC Area of Competence (Herrera M)
IOTC–2019–WPTT21–60	Catch Trends of Tropical Tunas by Malaysian Tuna Longliners in the Indian Ocean 2013 – 2017 (Jamaludin N-A, Jamon S, Abdullah E and Abu Halim N-H)
IOTC–2019–WPTT21–61	Preliminary Indian Ocean Bigeye Tuna Stock Assessment 1950-2018 (Stock Synthesis). (Fu D).
IOTC–2019–WPM10–08	Update on IOTC Bigeye Tuna Operating Model Development October 2019 (Kolody D and Jumppanen P)
IOTC–2019–WPM10–09	Update on IOTC Yellowfin Tuna Operating Model Development October 2019 (Kolody D and Jumppanen P)
IOTC–2019–WPM10–10	Proposal on a management procedure for yellowfin tuna in the IOTC Area of Competence (Various)
IOTC–2019–WPM10–11	IOTC Bigeye and Yellowfin Management Procedure Evaluation Progress October 2019 (Kolody D and Jumppanen P)
IOTC–2019–WPM10–16	Collaborative study of bigeye and yellowfin tuna CPUE from multiple Indian Ocean longline fleets in 2019, with consideration of discarding (Hoyle S et al.)
IOTC–2019–WPM10–25	Is Close-Kin Mark Recapture Feasible for IOTC yellowfin tuna stock assessment? (Kolody D and Bravington M)
IOTC–2019–WPTT21–INF01	Report of the Sixth IOTC CPUE Workshop on Longline Fisheries (Anon)
IOTC–2019–WPTT21–INF02	Joint T-RFMO FAD Working Group 2nd Meeting report (Anon)
IOTC–2019–WPTT21–INF03	Information note on the Monitoring of the YFT Tuna Quota Consumption by the French and Italian Purse Seine Fleet in the Indian Ocean (Maufroy A and Goujon M)
IOTC–2019–WPTT21–INF04	Progress in development of Statistical-Catch-At-Size (SCAS) modelling software (Nishida T and Kitakado T)
IOTC–2019–WPTT21–INF05	Residual Diagnostics for Indian Ocean yellowfin tuna Stock Synthesis models (Winker H)
IOTC–2019–WPM10–INF02	Update on IOTC Bigeye Tuna Management Procedure Evaluation March 2019 (Kolody D)
IOTC–2019–WPM10–INF03	Update on IOTC Yellowfin Tuna Management Procedure Evaluation March 2019 (Kolody D)

APPENDIX IV

APPENDIX IVA
STATISTICS FOR TROPICAL TUNAS

(Extracts from IOTC–2019–WPTT21–08)

Fisheries and catch trends for tropical tuna species

- Main species: Skipjack tuna accounts for 49.4% of total catches of tropical tunas, followed closely by yellowfin tuna (41.2%), while catches of bigeye tuna account for the remaining 9.4% of catches (**Fig. 1d**).

- Main fishing gear (2014-18): Purse seiners account for 43% of total catches of tropical tunas, with important catches also reported by handlines and trolling (18%), gillnets (18%), pole-and-line (11%), and longliners (9%), with catches occurring 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**).

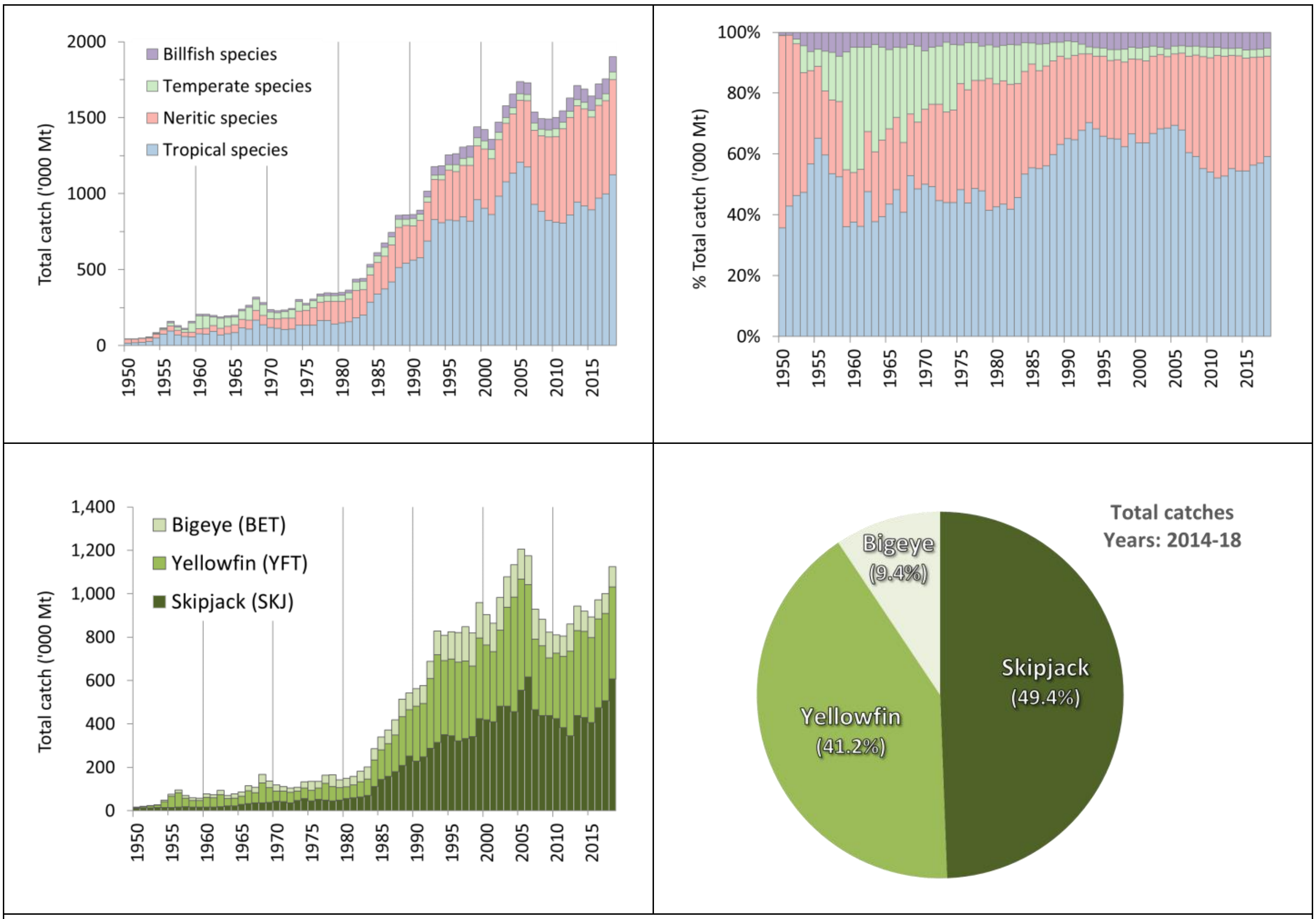
  In recent years the coastal fisheries of five countries (Indonesia, Maldives, Sri Lanka, I.R. Iran, and India) have accounted for 51% of the total catches of tropical tuna species in the Indian Ocean, while the industrial purse seiners and longliners flagged as EU-Spain, Seychelles and EU-France reported a further 33% 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 59% of total catches of all IOTC species, compared to ≈68% over the (pre-piracy) period 1950-2008).

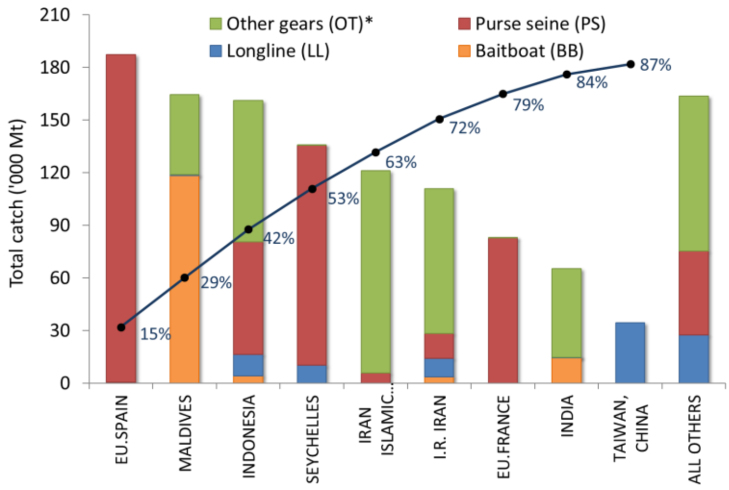
  Since 2012 catches of tropical tunas appear to show signs of recovery – in particular catches from the distant water longline fleets (e.g., Taiwan,China) – as a result of the reduction of the threat of piracy and return of fleets and to the north-west Indian Ocean.

  Total catches of tropical tunas have increased from ≈820,000t during the years of piracy in the late 2000s, to ≈940,000t in 2013 and ≈1,000,000t and over in 2017 and 2018.

- 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 1950-2018 (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, 1950-2018; d. Bottom right: share of tropical tuna catch by species, 2014 – 18)



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

Fig. 2. All tropical tunas: average catches in the Indian Ocean over the period 2014 – 18, by country. Countries are ordered from left to right, according to the importance of catches of tropical tunas reported. The dark 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–2019–WPTT21–08)

Fisheries and main catch trends

Main fishing gear (2014–18)

industrial fisheries account for the majority of catches of bigeye tuna, i.e., deep-freezing and fresh longline (≈42%) and purse seine (≈37%) (**Table 2; Fig. 3**).
In recent years catches by gillnet fisheries have also been increasing, due to major changes for some fleets (e.g., Sri Lanka and I.R. Iran); notably increases in boat size, developments in 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 (2014–18): the four main fleets catching bigeye tuna are Indonesia (fresh / coastal longline, coastal purse seine): 27%; Taiwan,China (longline): 16%; EU-Spain (purse seine): 15%; Seychelles (longline and purse seine): 13% (**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 (2011 and following) 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 20,000t in the 1970s, to over 150,000t 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 (totalling at around 90,000t) still remain far below the 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. Development of a proper industrial purse seine fleet for Indonesia in 2018 resulted in significant catches of bigeye tuna being reported for the first time (around 5,000t).

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**).

As for other tropical tuna species (yellowfin tuna in particular), industrial purse seine catches of bigeye tuna on free-school have shown a steady decline in recent years. Total catches of Bigeye tuna for the purse seine fishery were relatively stable at around 20,000 – 30,000t for all fleets until 2017: catches reported in 2018 show an increase of around 50% compared to previous year (45,000t in total) with over 66% of purse seine catches now being reported by EU,Spain and Seychelles (log school, 53% and 13% of total catches in 2018 vs. 27% and 23% in 2017 respectively).

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.

Catch series

- No major changes to the catch series since the WPTT meeting in 2018.

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 (2009–2018), 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 2019

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
BB	21	50	266	1,536	2,968	5,069	6,874	6,789	6,880	6,886	7,386	6,773	6,517	6,865	6,961	5,295
FS	0	0	0	2,340	4,824	6,196	5,301	3,792	6,222	7,180	4,659	5,000	9,633	2,489	10,242	2,859
LS	0	0	0	4,852	18,315	20,273	24,708	18,486	16,386	10,434	22,809	14,868	15,548	19,330	19,456	42,881
LL	6,488	21,861	30,413	43,079	62,350	71,463	52,077	32,420	36,158	67,451	45,646	35,220	33,712	30,841	26,299	19,452
FL	0	0	218	3,066	26,282	23,490	15,810	9,782	12,031	16,816	16,725	13,650	12,401	7,658	8,892	7,292
LI	43	295	658	2,385	4,273	6,042	8,472	8,769	9,336	9,393	9,086	10,413	11,516	10,655	10,121	7,156
OT	38	64	164	859	1,407	3,658	5,558	5,331	7,361	6,673	6,882	7,131	7,070	9,024	8,892	8,579
Total	**6,589**	**22,269**	**31,720**	**58,118**	**120,418**	**136,191**	**118,801**	**85,368**	**94,374**	**124,833**	**113,193**	**93,055**	**96,396**	**86,861**	**90,863**	**93,515**

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**). Background colour intensity is proportional to the catches by fishery and category (i.e. decade, year)

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 (2009–2018), in tonnes. Catches by decade represent the average annual catch. Data as of September 2019

Area	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
A1	2,478	11,965	17,642	35,960	60,922	80,776	63,459	44,785	47,363	78,818	68,387	52,397	57,173	53,902	58,032	63,847
A2	3,910	7,280	10,271	18,018	45,971	45,397	51,921	36,413	42,918	41,647	40,102	36,556	34,400	29,406	28,505	26,367
A3	202	3,024	3,806	4,139	13,525	10,019	3,421	4,170	4,093	4,369	4,703	4,102	4,824	3,553	4,325	3,300
Total	**6,589**	**22,269**	**31,720**	**58,118**	**120,418**	**136,191**	**118,801**	**85,368**	**94,374**	**124,833**	**113,193**	**93,055**	**96,396**	**86,861**	**90,863**	**93,515**

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. Background colour intensity is proportional to the catches by area and category (i.e. decade, year)

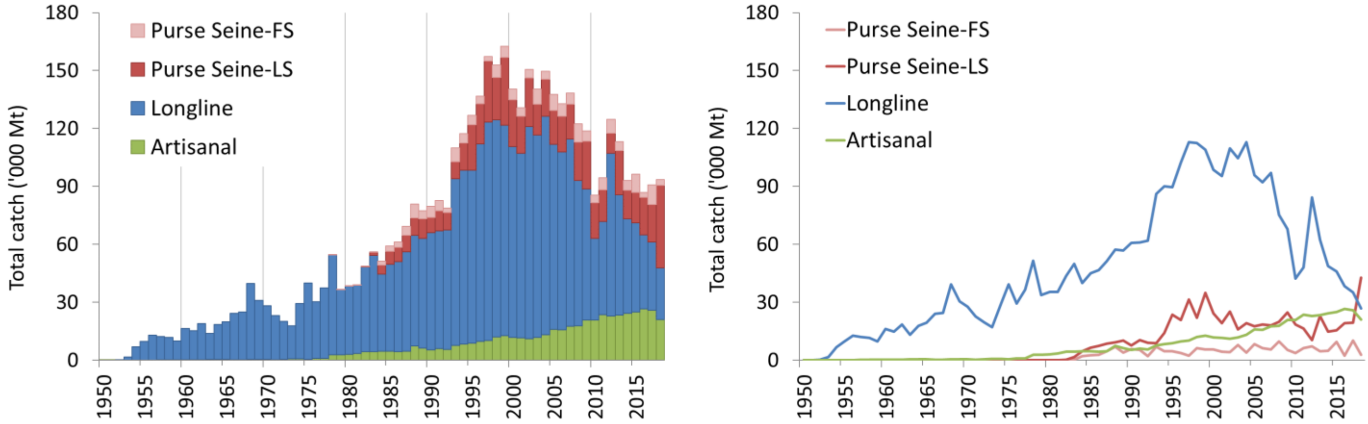


Fig. 3a & b. Annual catches of bigeye tuna by gear (1950–2018). Data as of September 2019.

Gear definitions: Longline (fresh and deep-freezing); Purse seine free-school (FS); Purse seine associated school (LS); Artisanal (pole-and-Line, handline, small longlines, gillnet, trolling & other minor artisanal gears).

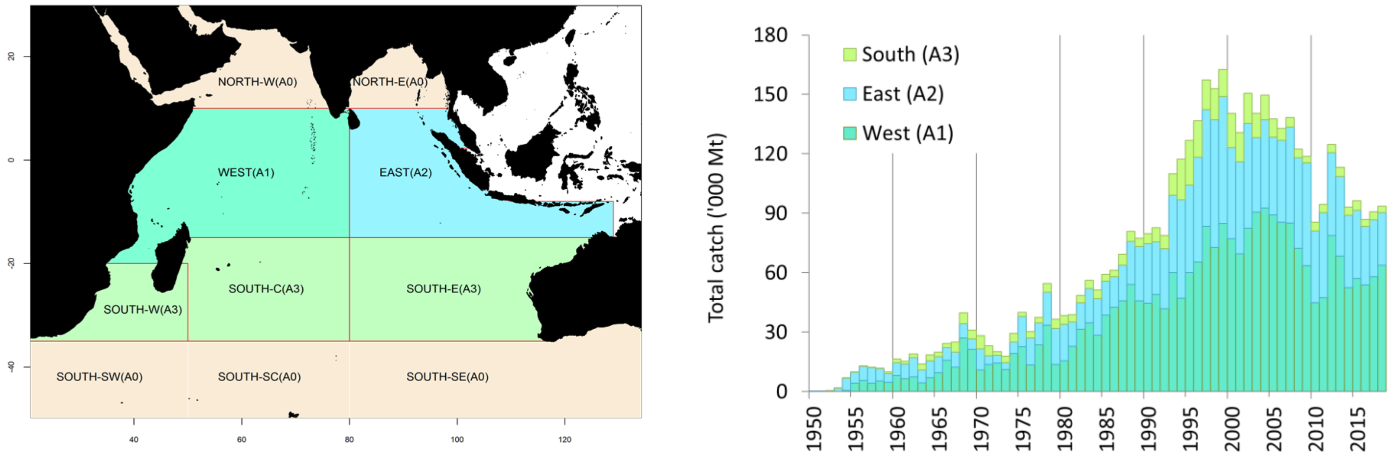


Fig. 4(a-b). Bigeye tuna: Catches of bigeye tuna by (SS3) stock assessment area by year (1950–2018). Catches outside the areas preser in the map were assigned to the closest neighbouring area for the assessment. Data as of September 2019.

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.

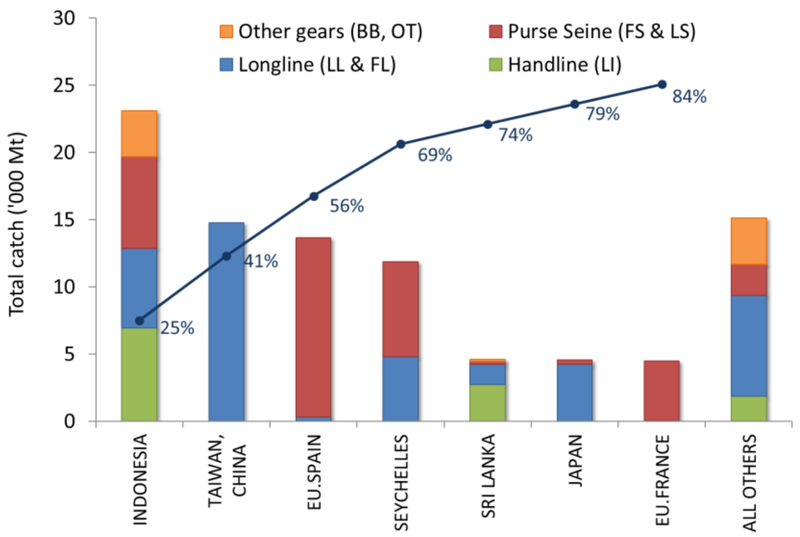


Fig. 5. Bigeye tuna: average catches by country in the Indian Ocean over the period 2014 – 18. Countries are ordered from left to right, according to the importance of catches of bigeye reported. The dark line indicates the (cumulative) proportion of catches of bigeye for the countries concerned, over the total combined catches of this species reported from all countries and fisheries. Data as of September 2019.

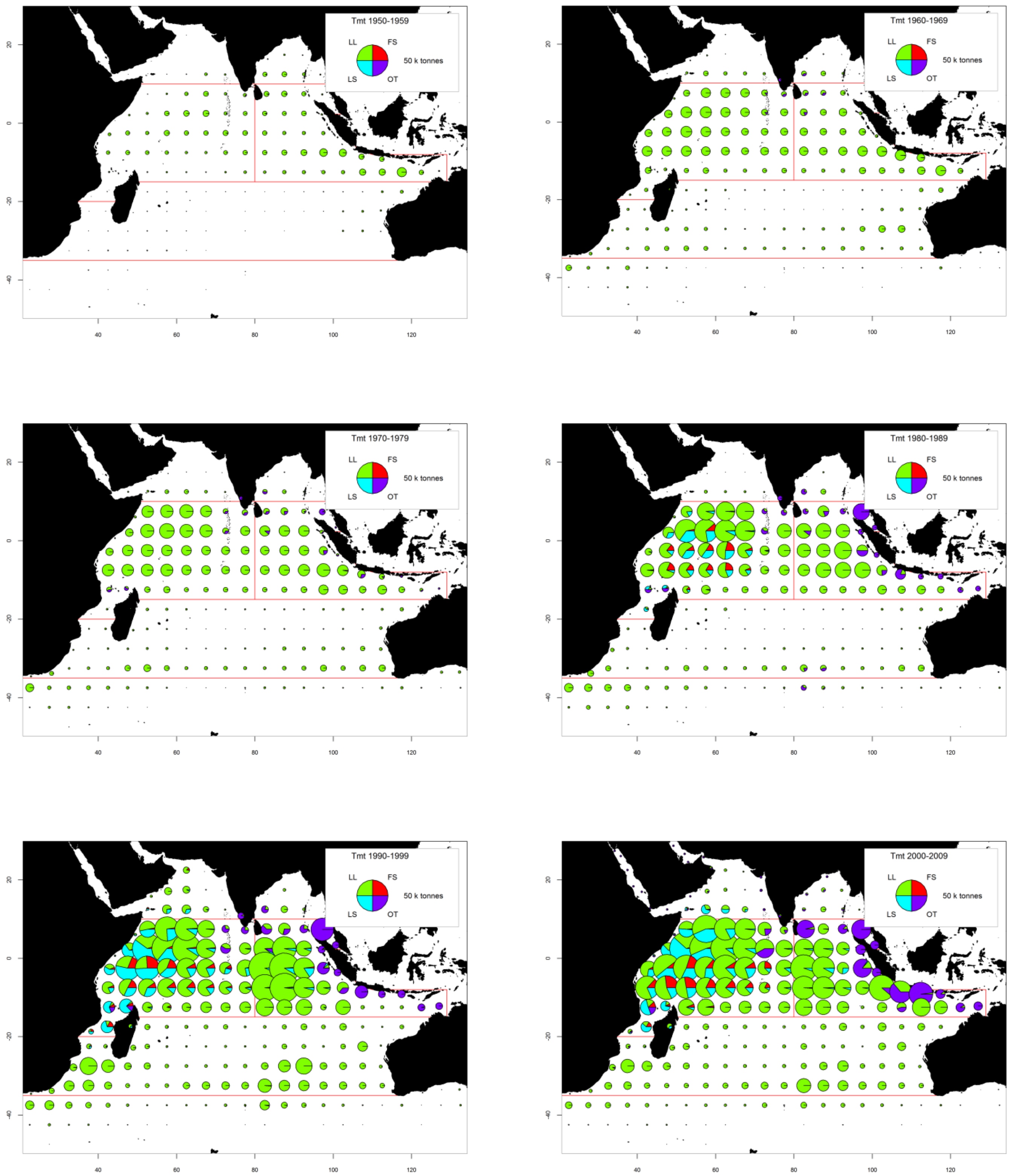


Fig. 6(a-f). Time-area catches (total combined in tonnes) of bigeye tuna estimated for the period 1950–2009, by decade and type of gear. Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), and other fleets (**OT**), including pole-and-line, drifting gillnets,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

Note that the catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded using estimated areas from the CAS data set. This is particularly true for the driftnets of I.R. Iran, gillnet and longline fishery of Sri La and longline and coastal fisheries of Indonesia (OT).

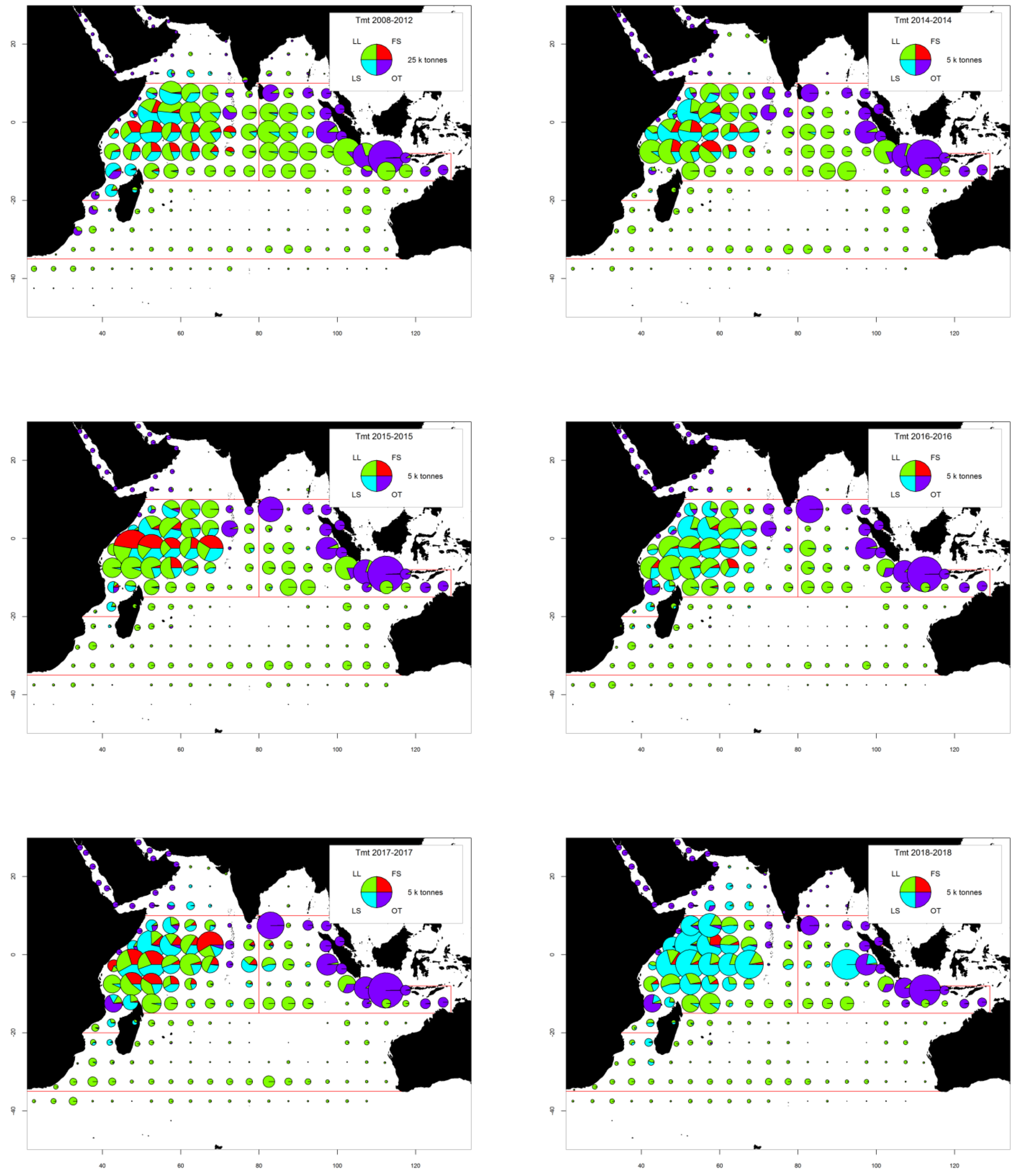


Fig. 7(a-f). Time-area catches (total combined in tonnes) of bigeye tuna estimated for the period 2008–2012 by type of gear and f 2014–18, by year and type of gear. Longline (LL), Purse seine free-schools (FS), Purse seine associated-schools (LS), and other fleets (OT), including pole-and-line, drifting gillnets, and various coastal fisheries.

Note that the catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded using estimated areas from the CAS data set. This is particularly true for the driftnets of I.R. Iran (years before 2007), gillnet and long fishery of Sri Lanka, and longline and coastal fisheries of Indonesia (OT).

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 and Pakistan (before 2012), Sri Lanka (gillnet-longline fishery, before 2014), 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, Malaysia, Oman, and Philippines; improvements in reporting of time-area catches for Indonesian purse seiners were noted in 2018;
    - Artisanal/coastal fisheries: incomplete or missing data for the driftnet fisheries of I.R. Iran (before 2007) 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). In 2019 (using 2018 data), as a consequence of a decrease in catches from longline fleets and a corresponding relevant increase in catches from industrial purse seine fleets (fishing on log-school), the estimated average weight of caught individuals decreased sensibly to an all-time low of around 6 Kg / fish (Indian Ocean wide, all gears) as opposed to over 10 Kg / fish estimated in 2018 (using 2017 data).
- Catch-at-Size (Age) table: data are available, but the estimates are more uncertain for some years and some fisheries due to:
    - 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).
    - lack of size data available for some industrial fleets (NEI, India, Indonesia, I.R. Iran, Sri Lanka).

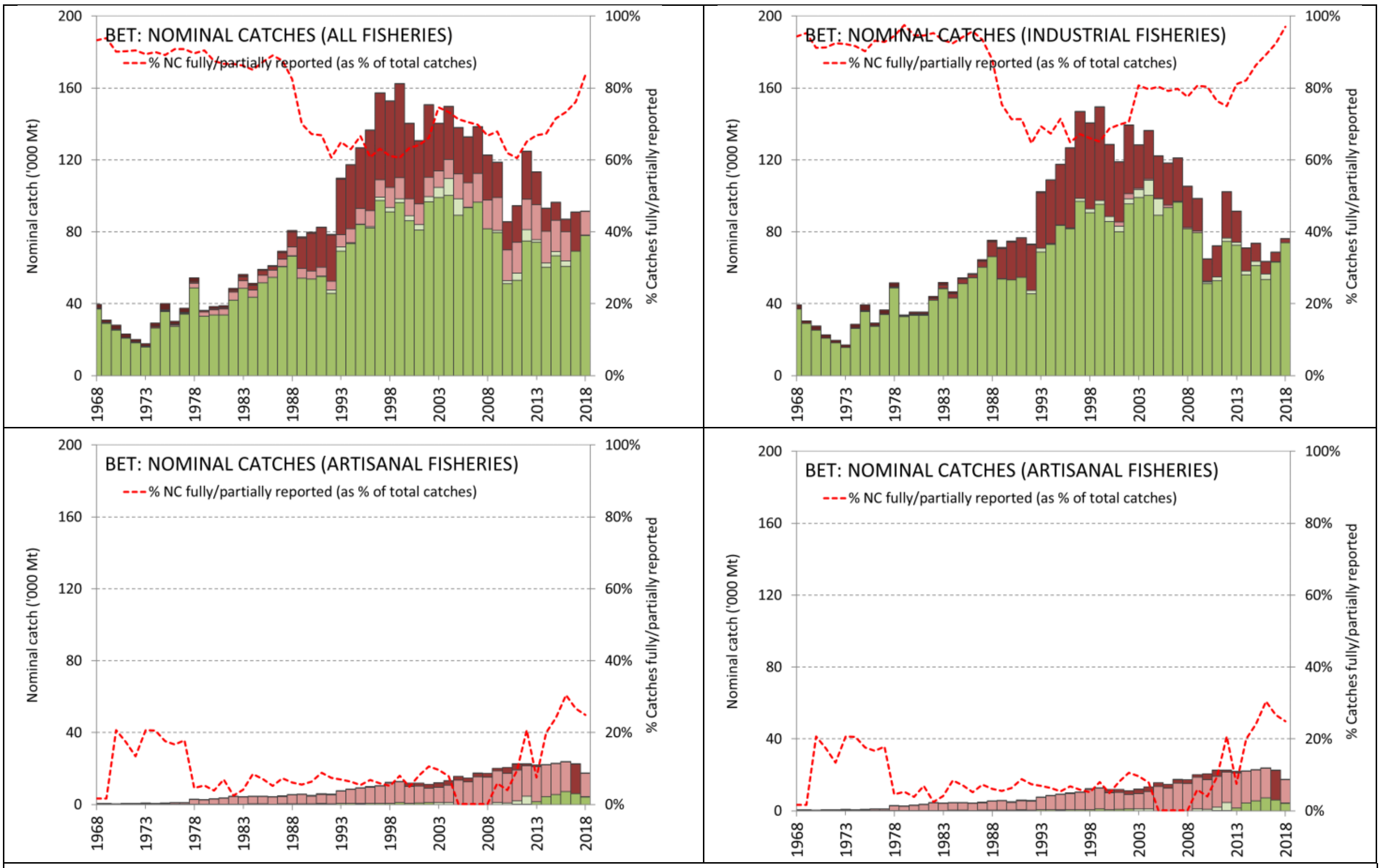


Fig. 8a-d. Bigeye tuna: nominal catches data reporting coverage (1968–2018). The red dotted lines indicate the proportion of catches fully/partially reported according to the IOTC data reporting standards for nominal catches. Data as of September 2019.

Data reporting scores:

	0
	2
	4
	6
	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

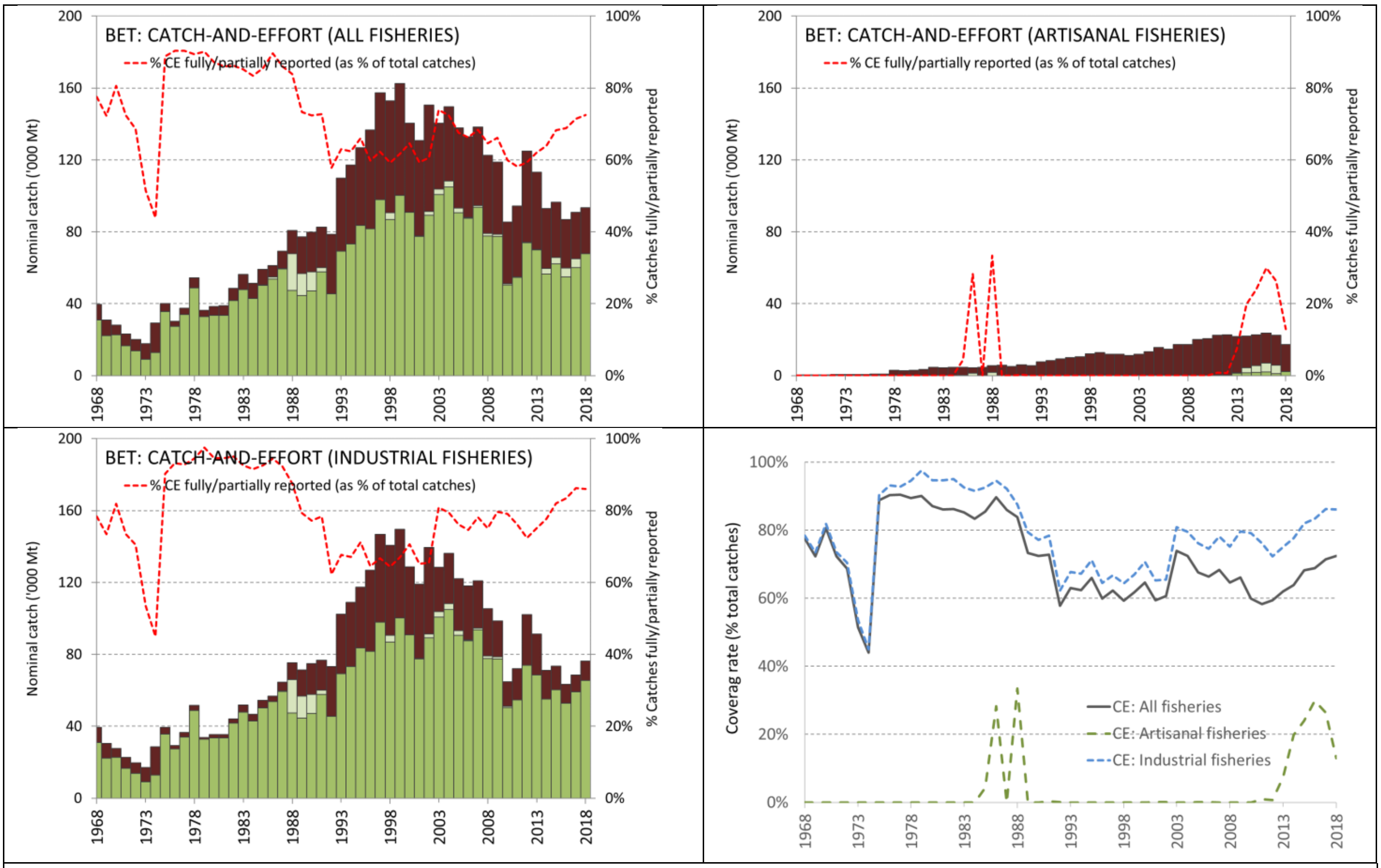


Fig. 8e-h. Bigeye tuna: catch-and-effort data reporting coverage (1968–2018). The red dotted lines indicate the proportion of catches fully/partially reported according to the IOTC data reporting standards for catch-and-effort. Data as of September 2019.

Data reporting scores:

	0
	2
	4
	6
	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

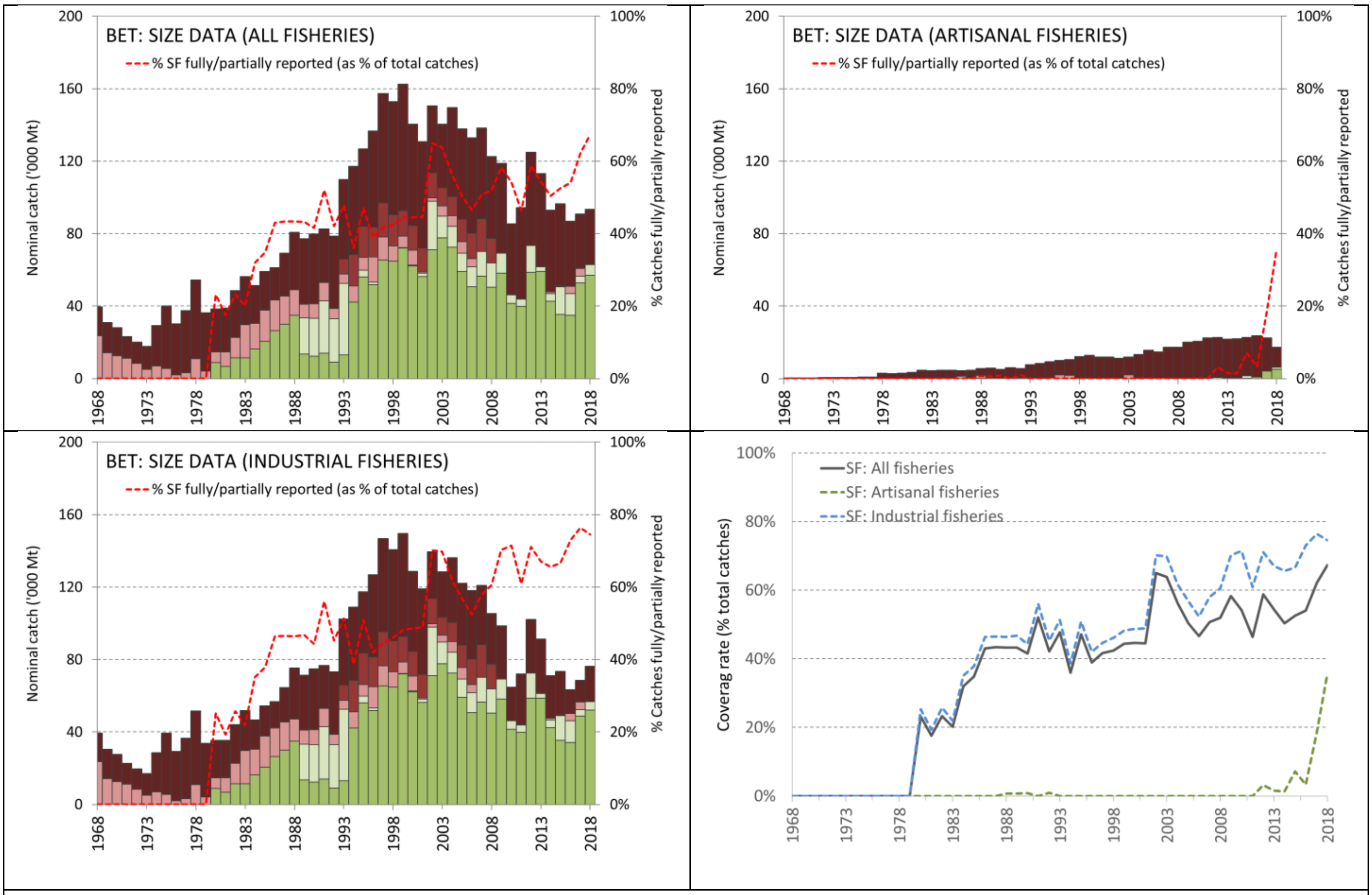


Fig. 8i-l. Bigeye tuna: size frequency data reporting coverage (1968–2018). The red dotted lines indicate the proportion of catches fully/partially reported according to the IOTC data reporting standards for size data. Data as of September 2019.

Data reporting scores:

	0
	2
	4
	6
	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

Bigeye tuna: Tagging data

- A total of 36,001 bigeye tuna (representing 16% of the total number of fish tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP), of which ≈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, 5,833 specimens (16% of releases for this species) have been recovered and reported to the IOTC Secretariat[3]. These tags were mainly reported from the purse seine fleets operating in the Indian Ocean (91%), while 5% were recovered from longline vessels.

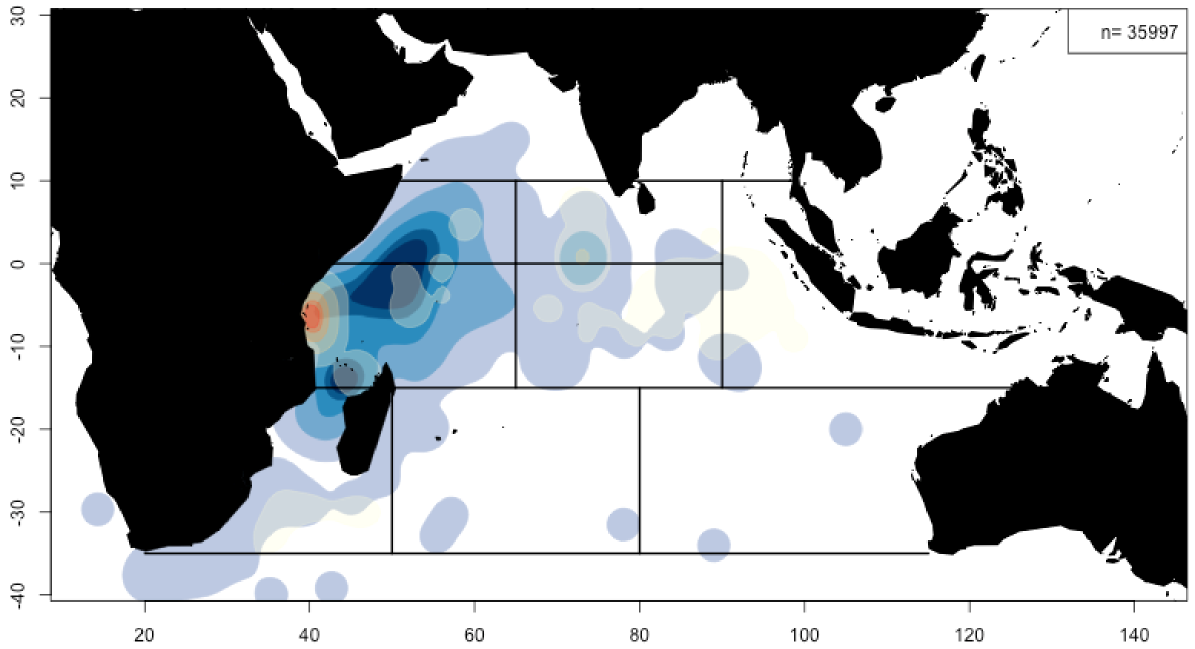


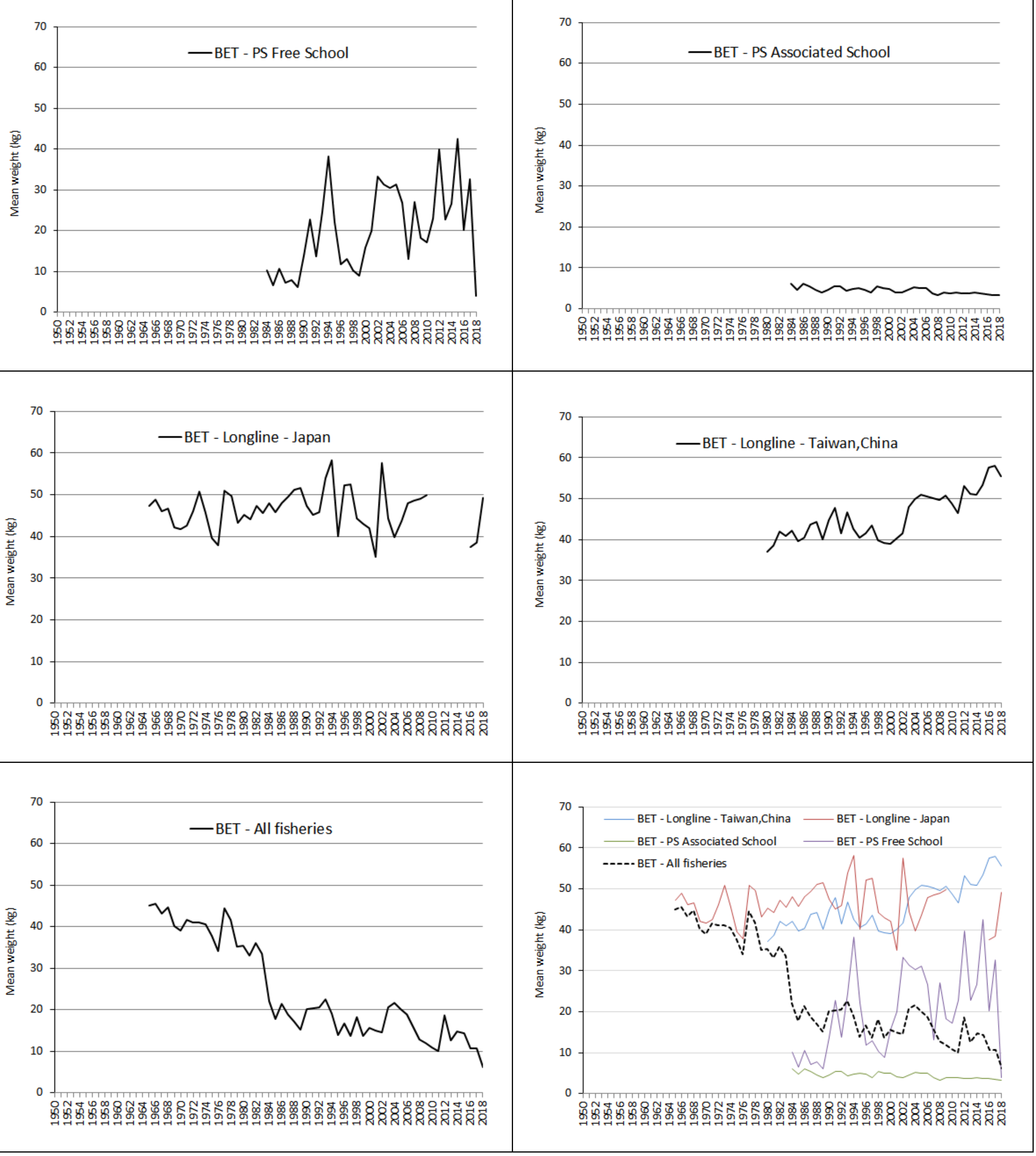
Fig. 9. Bigeye tuna: densities of releases (in red) and recoveries (in blue). The black line represents the stock assessme areas. Includes specimens tagged during the IOTTP and also Indian Ocean (Maldivian) tagging programmes during th 1990s.

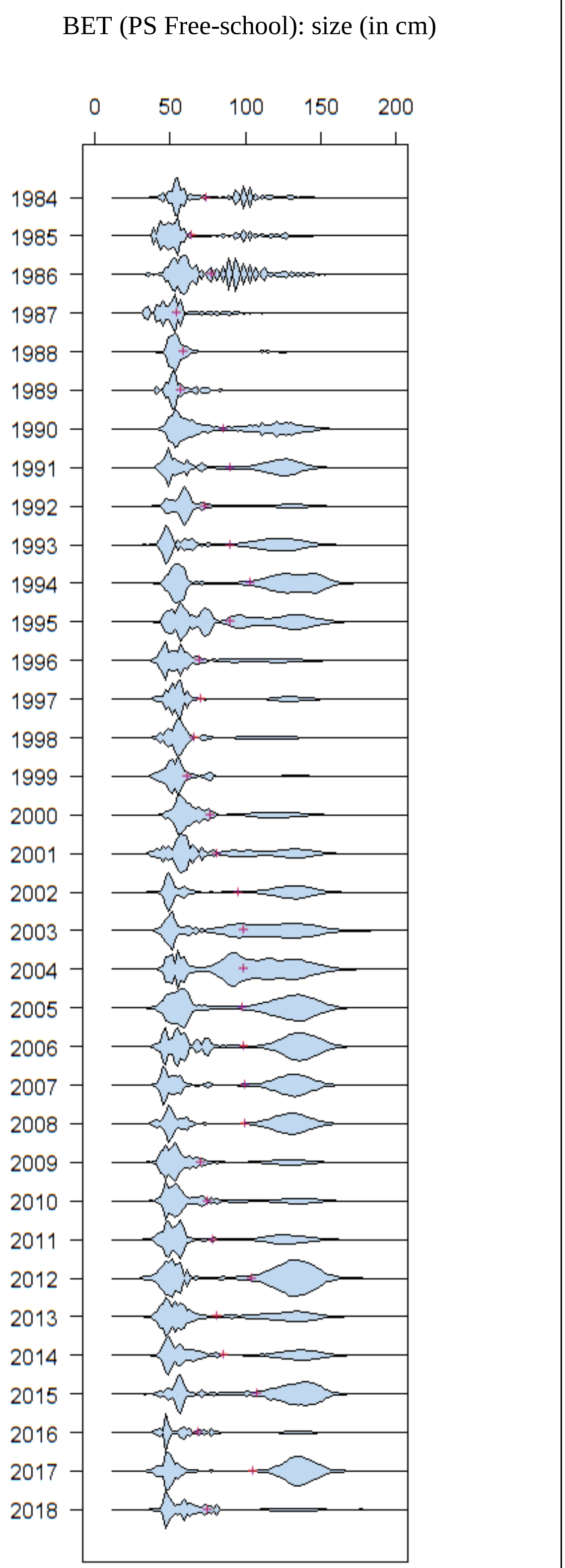
[3] Recoveries by species based on species ID recorded during tagging, prior to release.

Bigeye tuna (BET)

Figure: 10 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)





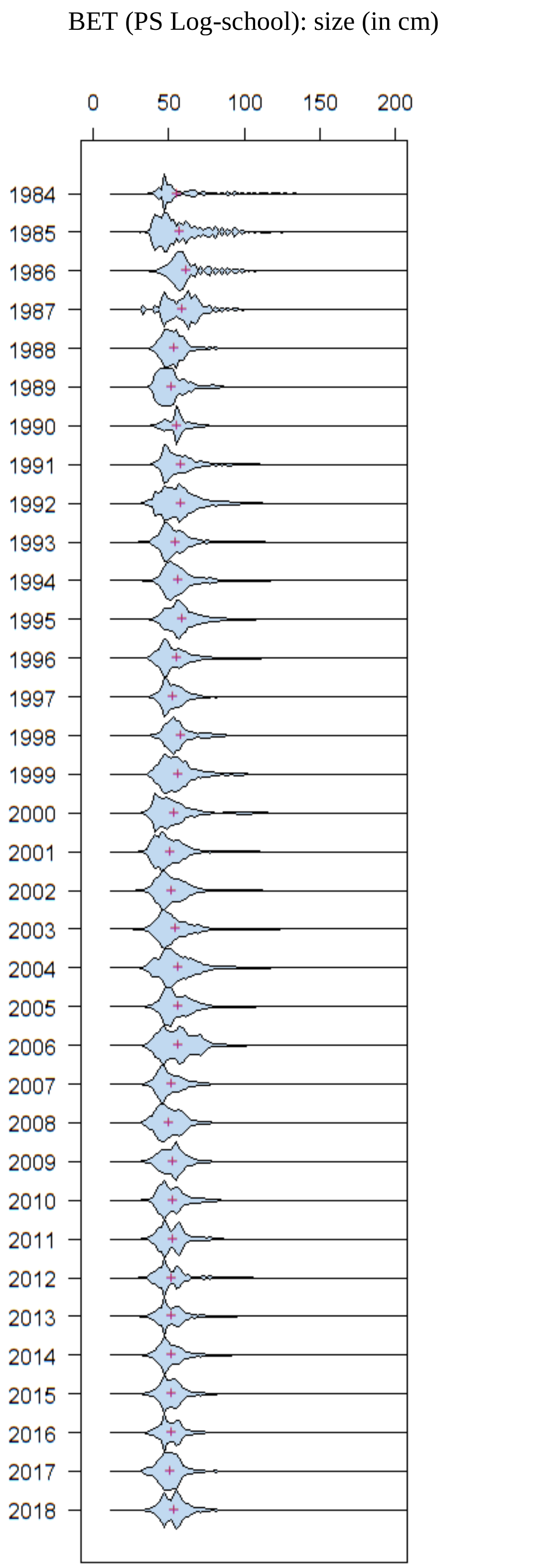


Figure 11. Bigeye tuna (purse seine): **Left:** length frequency distributions for BET PS Free school fisheries (by 2 cm length class). **Right**: Length frequency distributions for BET PS Associated (log) school fisheries (by 2 cm length class). Source: IOTC database.

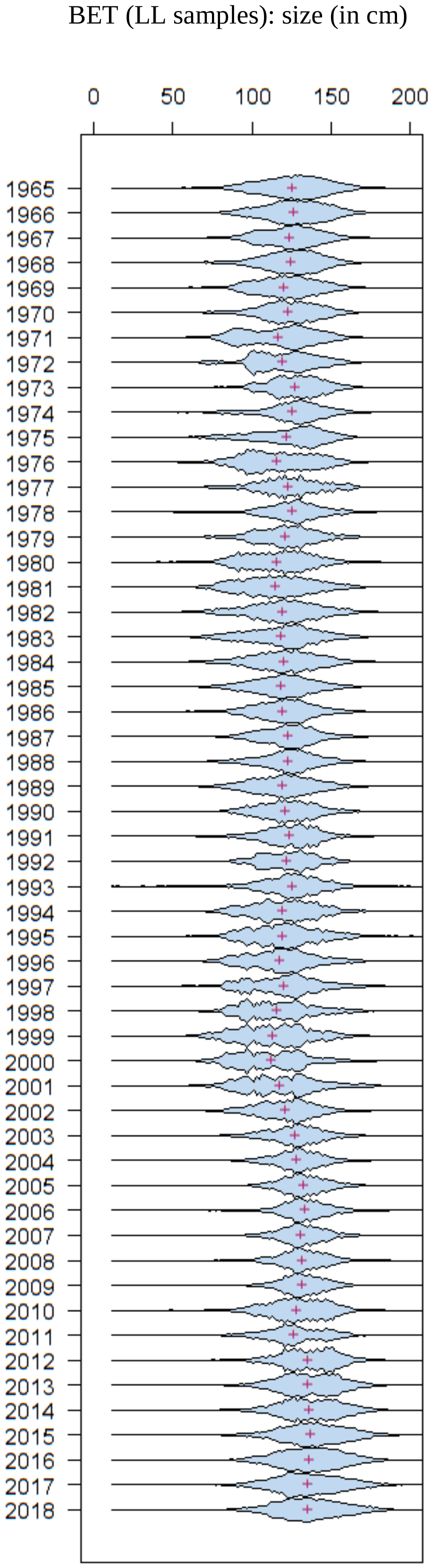


Figure 12; Bigeye tuna (longline): Length frequency distributions for longline fisheries (by 2 cm length class) derived from data available at the IOTC Secretariat. Source: IOTC database.

APPENDIX IVC
MAIN STATISTICS OF SKIPJACK TUNA

(Extracts from IOTC–2019–WPTT21–08)

Fisheries and main catch trends

Main fishing gear (2014–18)

Skipjack tuna are mostly caught by industrial purse seiners (≈49%), gillnet (≈18%) and pole-and-line (≈16%) (**Table 4; Fig. 10**).

Main fleets (and primary gear associated with catches)

Percentage of total catches (2014–18): the five main fleets catching skipjack tuna are EU-Spain (purse seine): 17%; Indonesia (coastal purse seine, troll line, gillnet): 17%; Maldives (pole-and-line): 17%; Seychelles (purse seine): 11% and Sri Lanka (gillnet-longline): 10%; (**Fig. 12**).

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 600,000t in 2006 with the constant increase in catches and catch rates of purse seiners until that year 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 total catches (across all fisheries) have declined to around 340,000t in 2012 – the lowest catches recorded since 1998 – although since 2013 catches have increased sharply and in 2018 reached again a level of 600,000t (around 100,000t more than in 2017) mostly driven by the purse seine (log-school) fisheries.

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 20,000t 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. In 2018 catches from this fishery reached again 100,000t, with the majority of these catches (over 80%) being caught in offshore waters.

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 not fully understood, as time-area catch-and-effort series have been made available for those fleets only in recent years.

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.

Catch series

There have been no major changes to the catch series since the WPTT meeting in 2018.

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 (2009–2018), 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 2019.

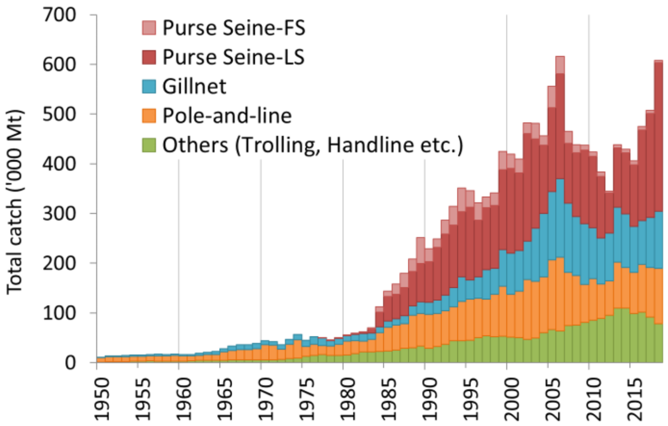
Fishery	By decade (average)						By year (last ten year)									
	1950s	1960s	1970s	1980s	1990s	2000s	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
BB	9,000	12,800	19,275	35,459	67,760	100,496	65,018	71,585	52,489	51,134	72,583	67,301	68,965	68,712	88,617	99,886
FS	0	0	41	15,252	30,776	25,672	10,433	8,774	9,000	2,984	5,742	7,228	7,800	6,888	6,170	4,486
LS	0	0	125	34,457	124,043	163,801	148,135	144,097	123,056	80,989	119,864	122,490	123,997	182,735	208,876	298,786
OT	6,018	14,070	27,476	44,913	97,091	186,281	214,213	199,536	198,653	209,644	239,943	232,144	204,907	216,603	203,831	204,543
Totals	**15,018**	**26,870**	**46,918**	**130,080**	**319,670**	**476,251**	**437,799**	**423,991**	**383,198**	**344,752**	**438,131**	**429,163**	**405,669**	**474,938**	**507,493**	**607,701**

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). Background colour intensity is proportional to the catches by fishery and category (i.e. decade, year)

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 (2009–2018), in tonnes. Catches by decade represent the average annual catch. Data as of September 2019.

Area	By decade (average)						By year (last ten year)									
	1950s	1960s	1970s	1980s	1990s	2000s	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
R1	4,524	9,951	19,330	34,877	80,744	118,318	151,486	154,434	153,882	155,406	171,217	149,052	131,236	116,968	114,413	123,133
R2	1,495	4,119	7,914	59,420	170,502	255,757	220,124	195,836	171,644	135,955	192,493	211,613	204,159	288,380	304,256	384,470
R2b	9,000	12,800	19,674	35,784	68,424	102,176	66,189	73,721	57,672	53,392	74,422	68,498	70,275	69,589	88,825	100,099
Totals	**15,018**	**26,870**	**46,918**	**130,080**	**319,670**	**476,251**	**437,799**	**423,991**	**383,198**	**344,752**	**438,131**	**429,163**	**405,670**	**474,938**	**507,493**	**607,701**

Areas: East Indian Ocean (**R1**); West Indian Ocean, (**R2**); Maldives baitboat (**R2b**). Background colour intensity is proportional to the catches by area and category (i.e. decade, year)



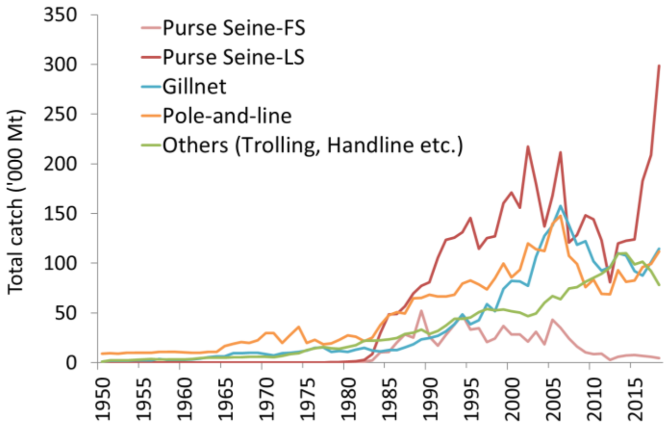


Fig. 10. Annual catches of skipjack tuna by gear (1950–2018). Data as of September 2019.

Gear definitions: 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).

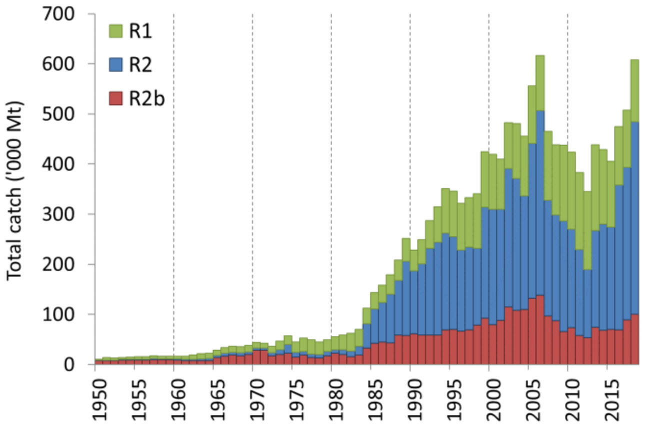


Fig. 11. Skipjack tuna: Catches of skipjack tuna by area by year estimated for the WPTT (1950–2018). **Areas**: East Indian Ocean (**R1**); West Indian Ocean (**R2**); Maldives baitboat (**R2b**). Data as of September 2019.

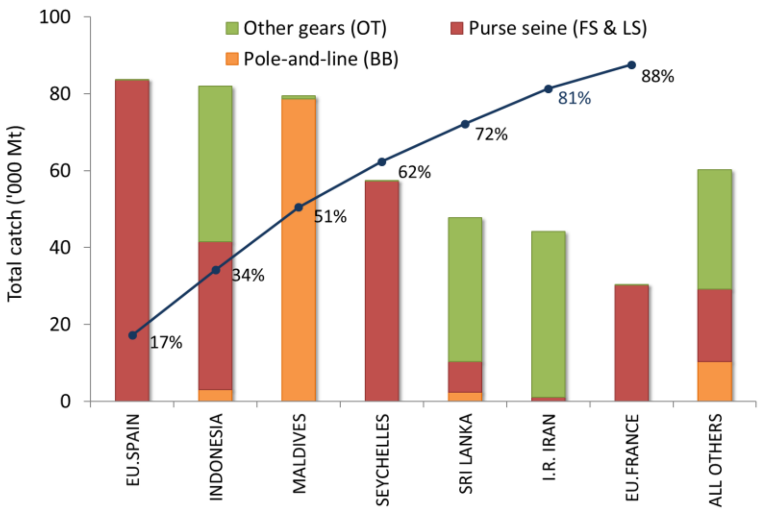


Fig. 12. Skipjack tuna: average catches in the Indian Ocean over the period 2014 – 18, by country. Countries are ordered from left to right, according to the importance of catches of skipjack reported. The dark line indicates the (cumulative) proportion of catches of skipjack for the countries concerned, over the total combined catches of this species reported from all countries and fisheries. Data as of September 2019.

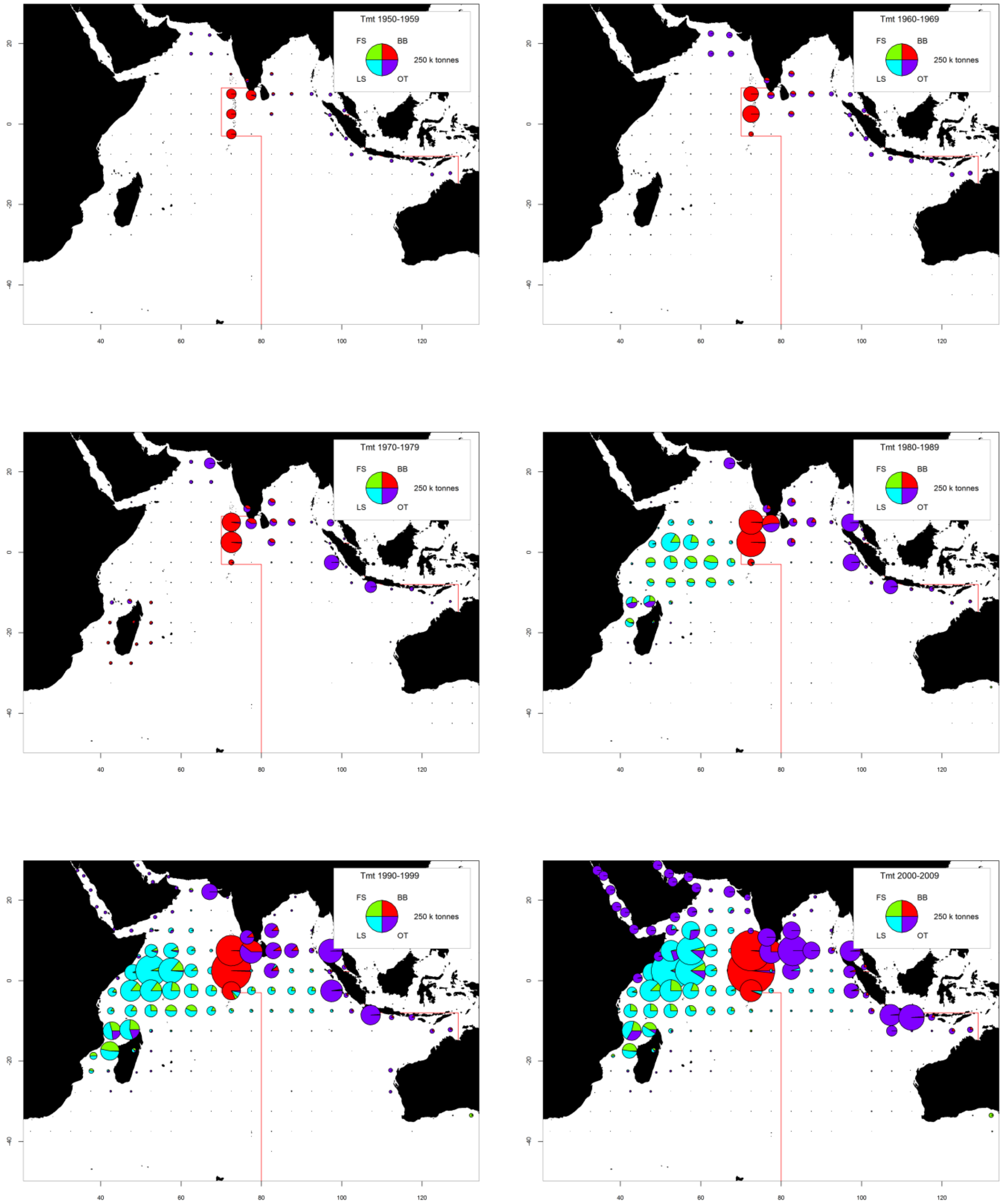


Fig. 13(a-f). Skipjack tuna: Time-area catches (total combined in tonnes) of skipjack tuna estimated for the period 1950–2009, by decade and type of gear. Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including longline,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

Note that the catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded u the estimated areas from the CAS data set. This is particularly true for the driftnets of I.R. Iran, gillnet and longline fishery of Lanka, and longline and coastal fisheries of Indonesia (OT).

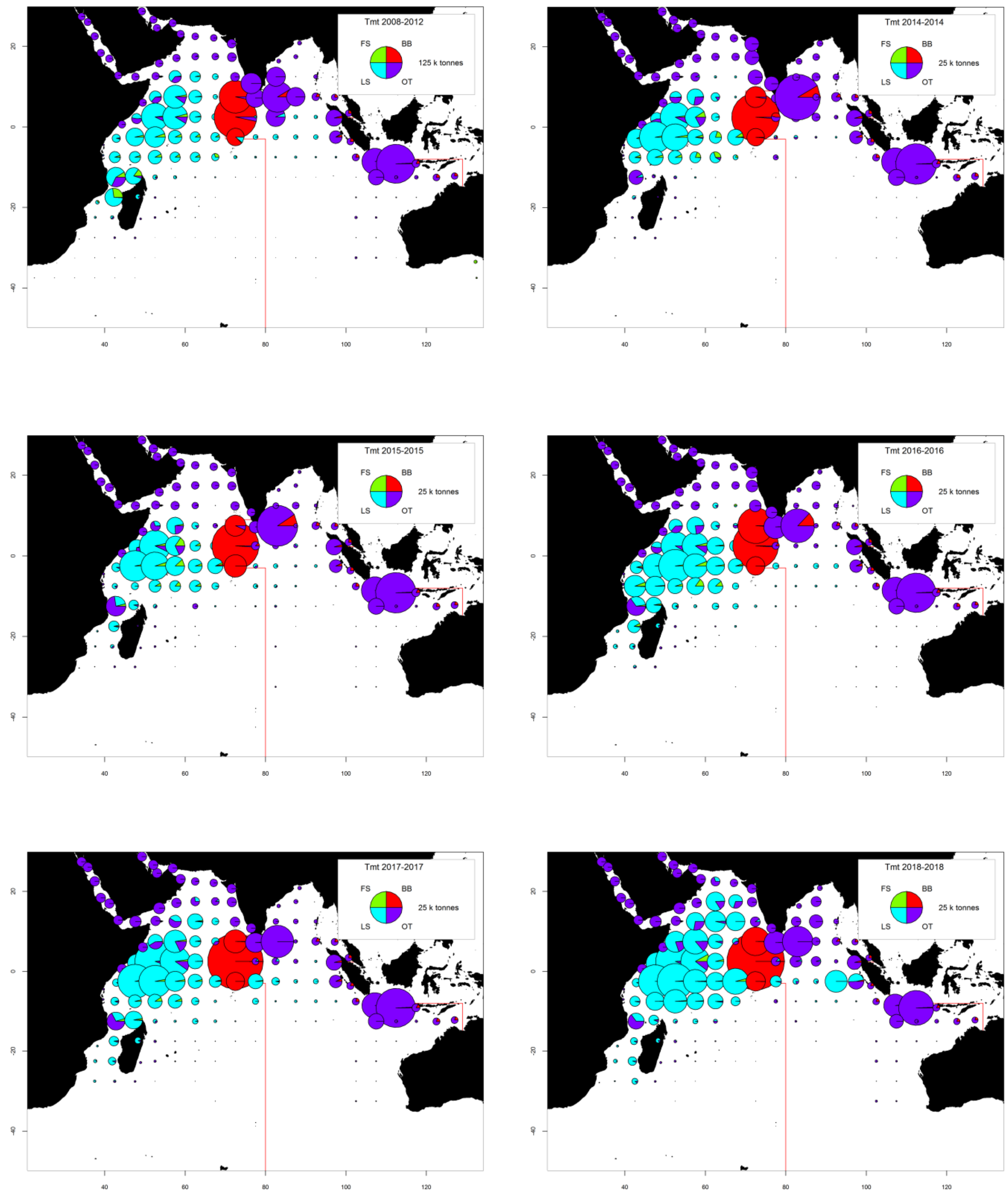


Fig. 14(a-f). Skipjack tuna: Time-area catches (total combined in tonnes) of skipjack tuna estimated for the period 2008–12 by type of gear and for 2014–18, by year and type of gear. Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including longline, drifting gillnets, and various coastal fisheries.

Note that the catches of fleets for which the flag countries do not report detailed time and area data to the IOTC are recorded using the estimated areas from the CAS data set. This is particularly true for the driftnets of I.R. Iran (years before 2007), gillnet and longline fishery of Sri Lanka, and longline and coastal fisheries of Indonesia (OT).

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 (before 2007) 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, since 2014 detailed information by EEZ area (for coastal fisheries) and grid area (for offshore fisheries) and gear started being submitted to the IOTC Secretariat;
  - no catch-and-effort data are available for important coastal fisheries using hand and/or troll lines, in particular Indonesia, India and Madagascar. Time-area catches for handline and troll line fisheries of Indonesia were received in 2018 for the first time.

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) and many gillnet fisheries (e.g., Indonesia, Sri Lanka) – although from 2014 Sri Lanka reported size information for its offshore fisheries.

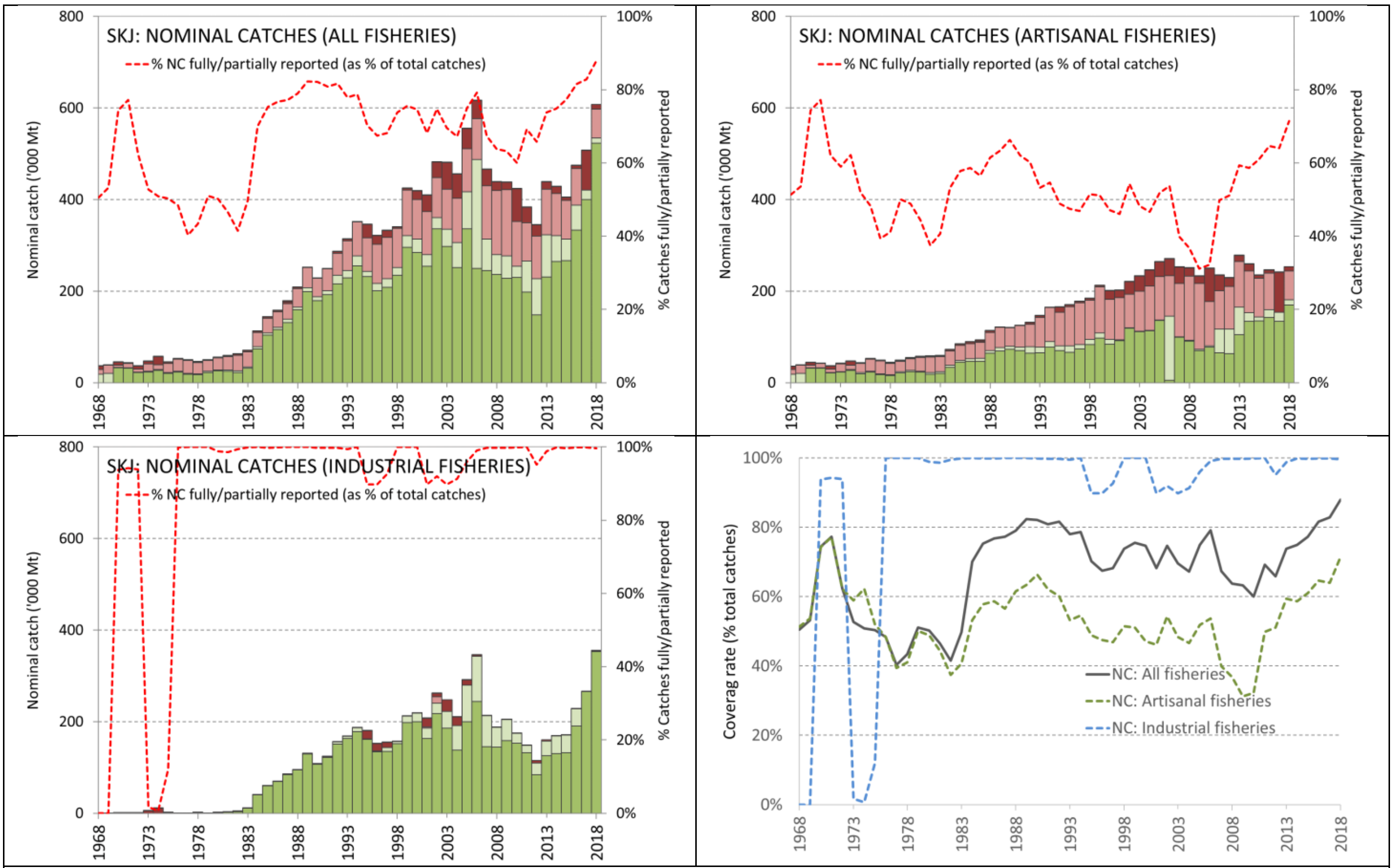


Fig. 15a-d. Skipjack tuna: nominal catches data reporting coverage (1968–2018). The red dotted lines indicated the proportion of catches fully/partially reported according to the IOTC data reporting standards for nominal catches. Data as of September 2019.

Data reporting scores:

	0
	2
	4
	6
	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

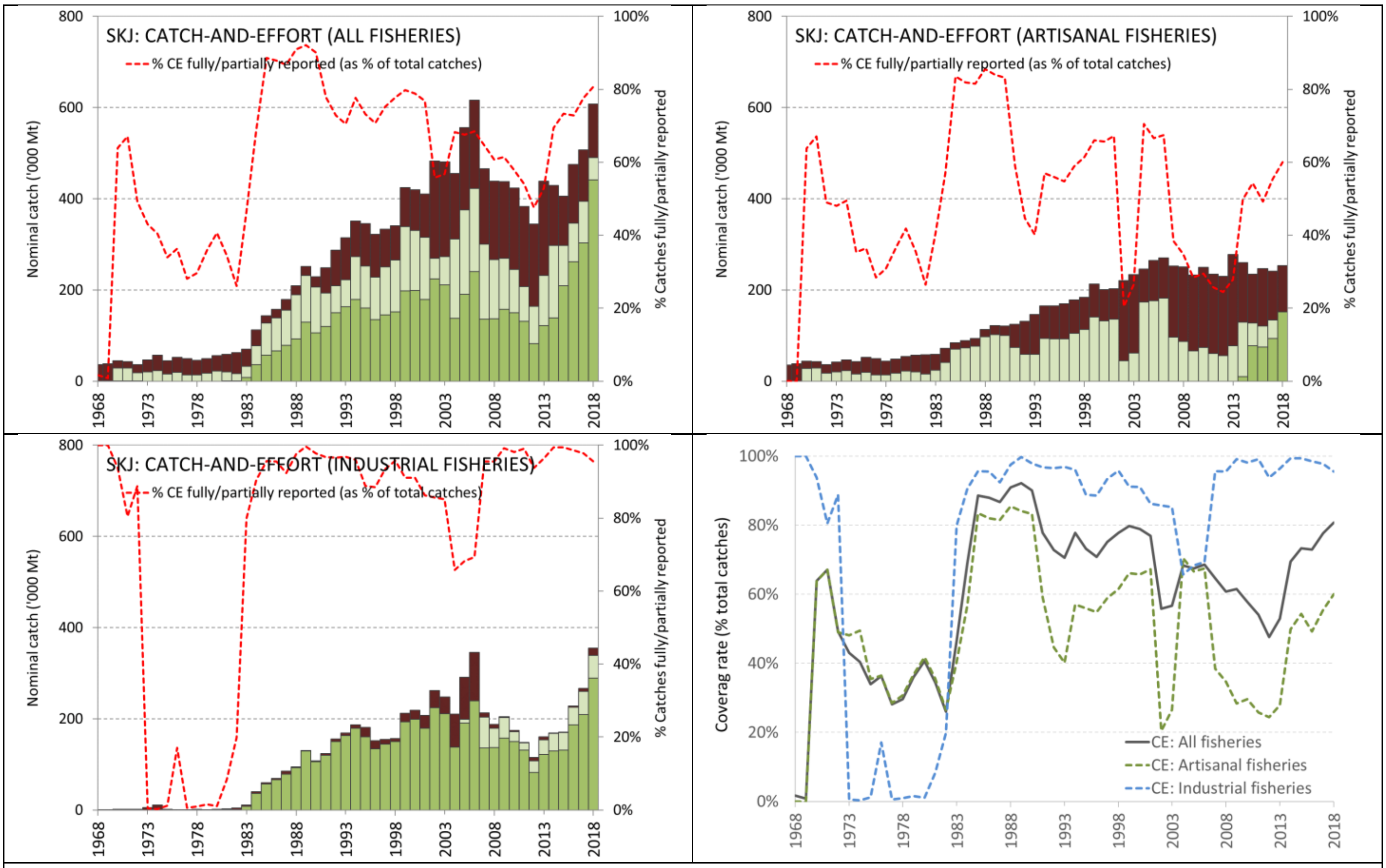


Fig. 15e-h. Skipjack tuna: catch-and-effort data reporting coverage (1968–2018). The red dotted lines indicated the proportion of catches fully/partially reported according to the IOTC data reporting standards for nominal catches. Data as of September 2019.

Data reporting scores:

	0
	2
	4
	6
	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

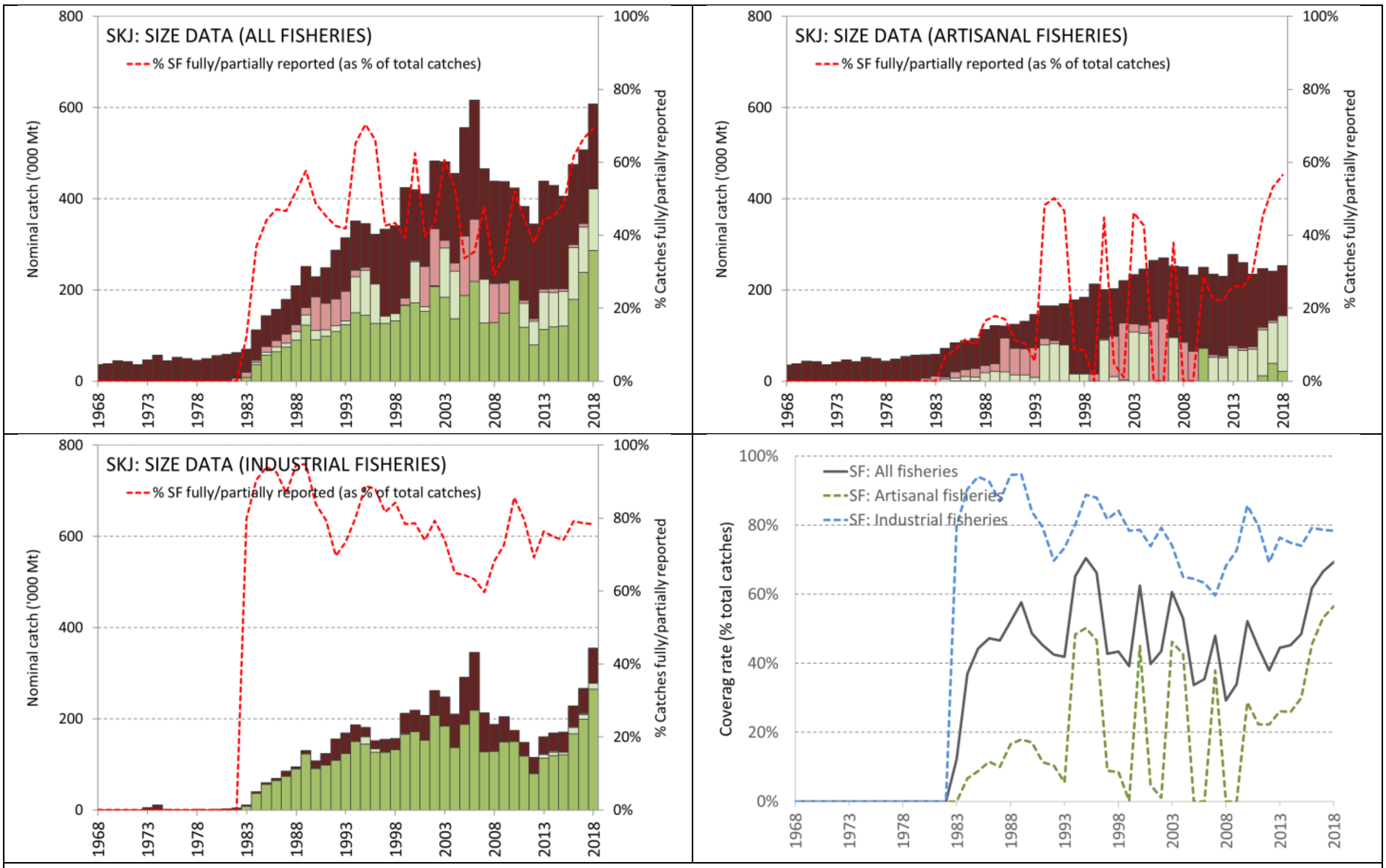


Fig. 15i-l. Skipjack tuna: size frequency data reporting coverage (1968–2018). The red dotted lines indicated the proportion of catches fully/partially reported according to the IOTC data reporting standards for nominal catches. Data as of September 2019.

Data reporting scores:

(green)	0
(light green)	2
(pink)	4
(red)	6
(dark red)	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

Skipjack tuna: Tagging data

- A total of 115,693 skipjack (representing 53% of the total number of fish tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP), of which ≈68% were released during the main Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) 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, 17,669 specimens (15% of releases for this species), have been recovered and reported to the IOTC Secretariat. Around 70% of the recoveries were from the purse seine fleets operating from the Seychelles, and around 29% 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.

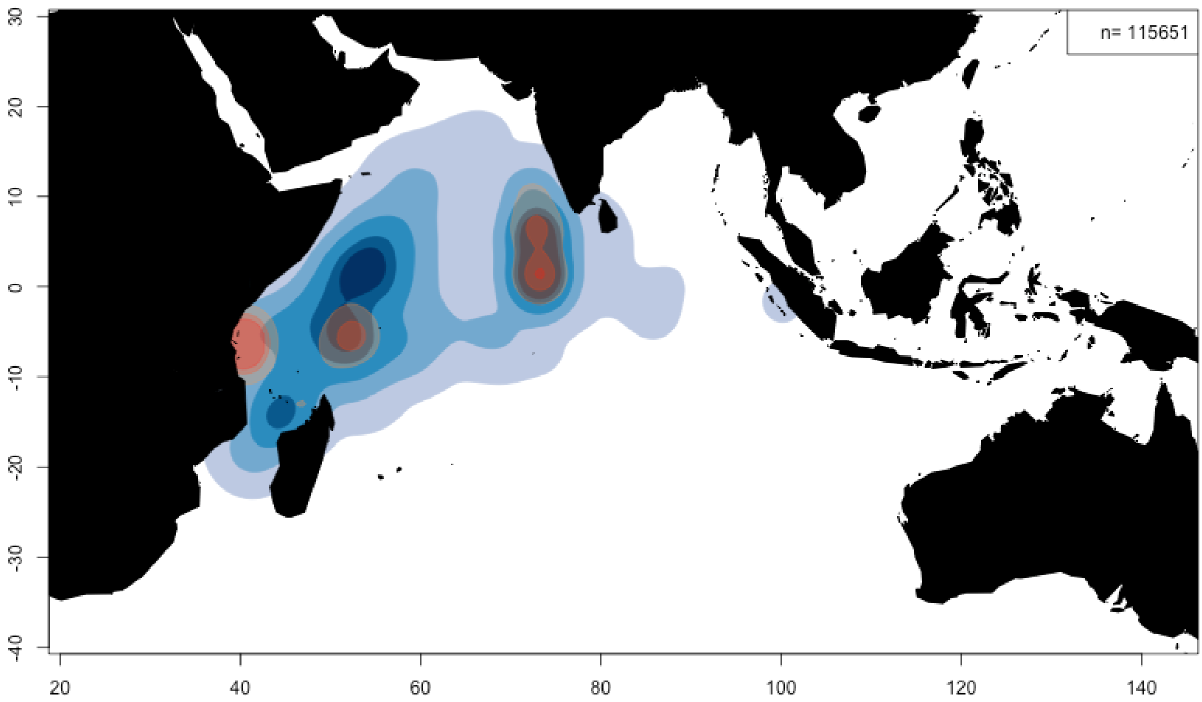
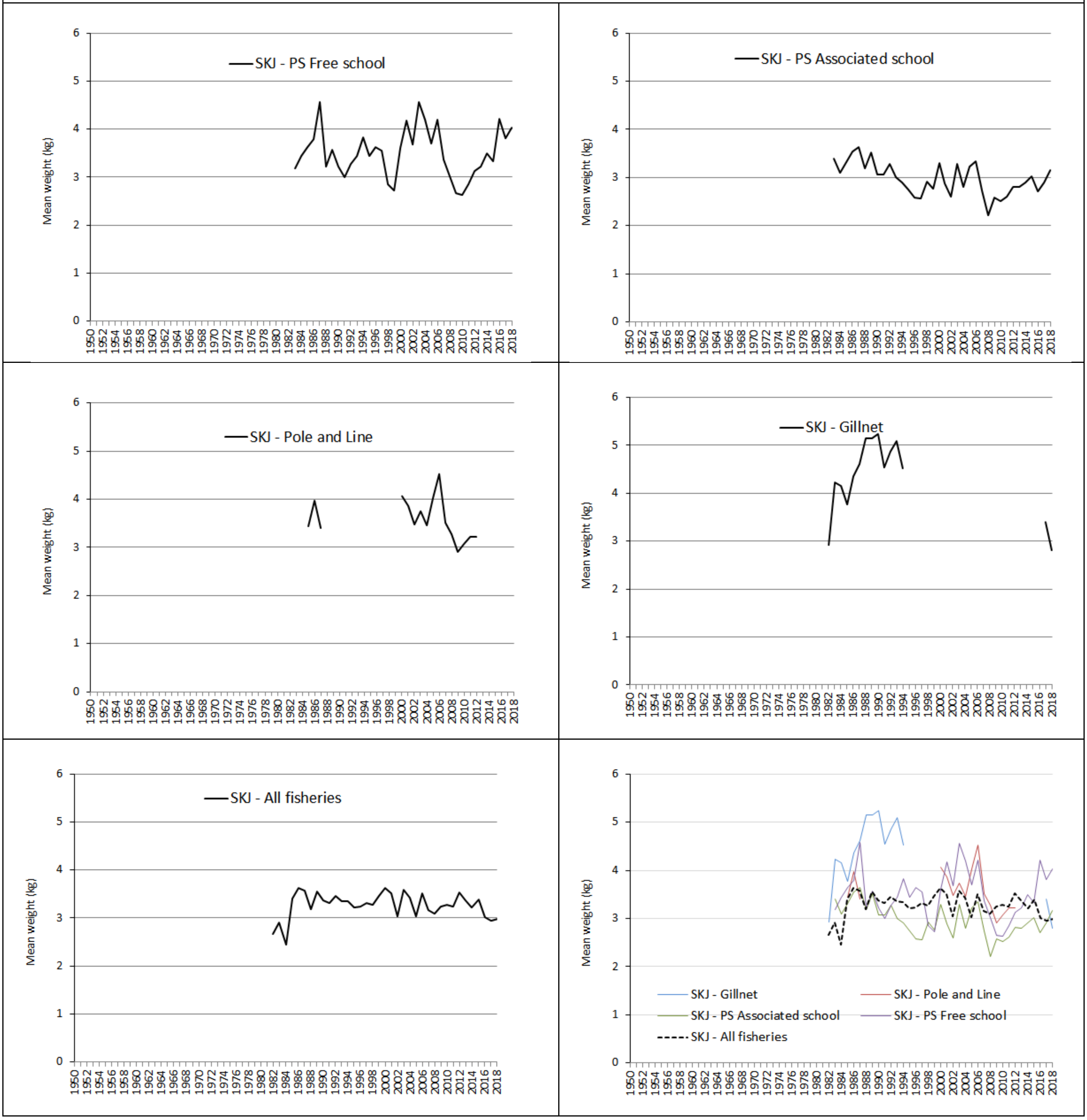


Fig. 16. Skipjack tuna: Densities of releases (in red) and recoveries (in blue). Includes specimens tagged during the IOT and also Indian Ocean (Maldivian) tagging programmes during the 1990s.

Skipjack tuna (SKJ)

Fig. 17. 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)



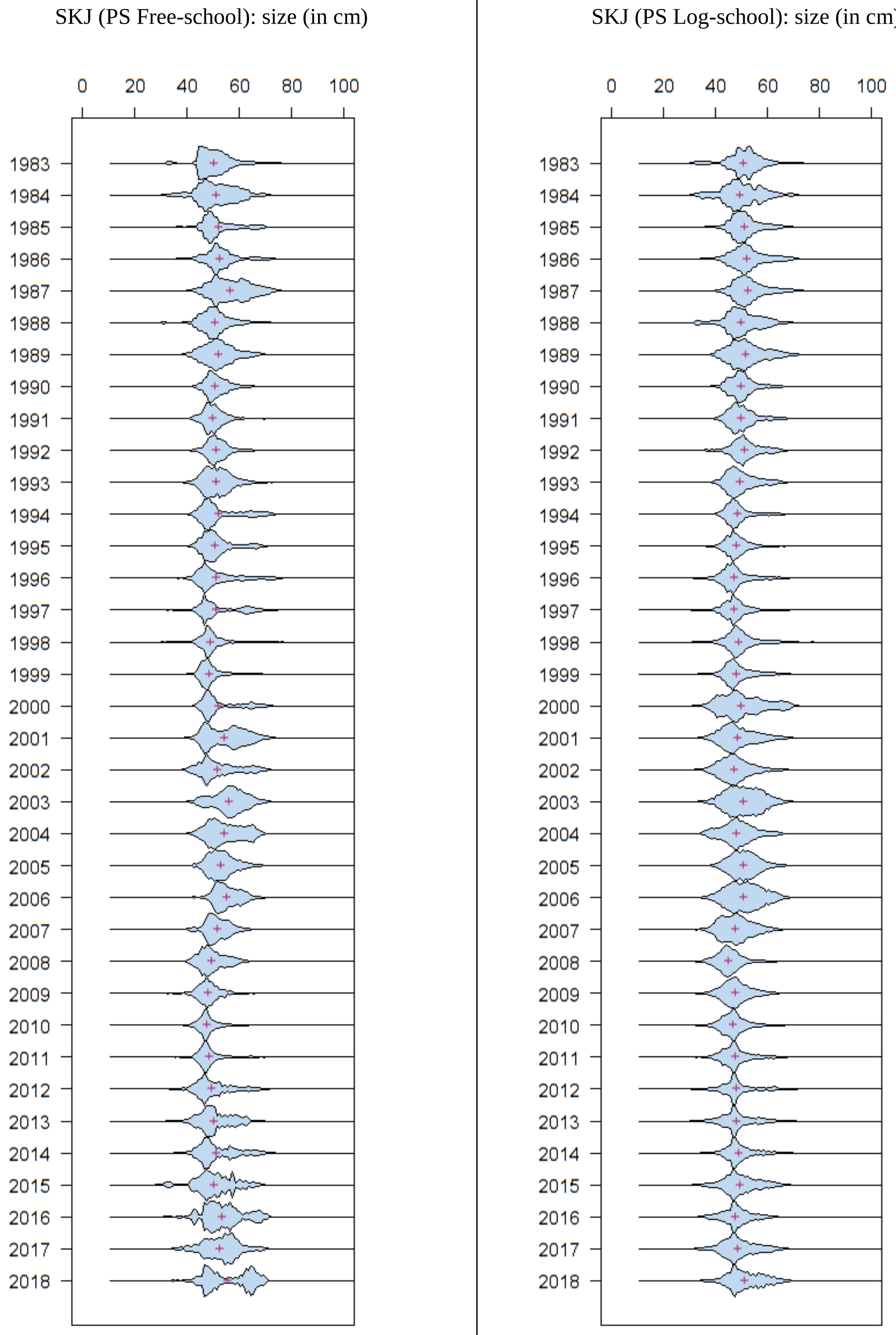


Fig. 18. Skipjack tuna (purse seine): Left: length frequency distributions for SKJ PS Free school fisheries (by 2 cm length class). Right: Length frequency distributions for SKJ PS Associated (log) school fisheries (by 2 cm length class).
Source: IOTC database.

APPENDIX IVD
MAIN STATISTICS OF YELLOWFIN TUNA

(Extracts from IOTC–2019–WPTT21–08)

Fisheries and main catch trends

Main fishing gear (2014-18)

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 40% 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 around 200,000t per annum since 2012. Moreover, the proportion of yellowfin catches from artisanal fisheries has increased from around 30% in 2000 to nearly 50% in recent years.

Main fleets (and primary gear associated with catches)

<u>Percentage of total catches (2014–18):</u> the five main fleets catching yellowfin tuna are EU-Spain (purse seine): 13%; Maldives (handline, pole-and-line): 13%; I.R. Iran (gillnet): 13%; Seychelles (purse seine): 9%; Sri Lanka (gillnet, coastal longliners): 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 30,000t and 70,000t, 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 400,000t by 1993.

Exceptionally high catches were recorded between 2003 and 2006 – with the highest catches ever recorded in 2004 at over 525,000t – 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 current catches over 400,000t recorded.

***<u>Purse seine fishery</u>*:**

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.

As for other tropical tuna species (bigeye in particular), industrial purse seine catches of yellowfin tuna on free-school have shown a steady decline in recent years, reaching an all-time low of around 15,000t in 2018 as opposed to an average of 45,000t recorded for the previous ten years.

<u>Longline fishery</u>:

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, 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.

Catch series

No major changes to the catch series since the WPTT meeting in 2018.

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 (2009–2018), 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 2019.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FS	0	0	18	31,552	64,938	89,204	36,048	32,136	36,453	64,594	34,459	47,427	63,962	49,460	50,700	15,110
LS	0	0	17	17,597	56,279	61,890	51,352	73,382	76,658	66,165	101,900	86,371	78,394	99,267	94,477	116,328
LL	21,990	41,352	29,589	33,968	66,318	56,878	20,000	18,743	20,667	19,667	16,012	15,611	17,850	19,354	18,152	21,190
LF	166	1,258	2,376	7,964	58,997	55,609	49,883	50,485	43,454	44,695	47,271	50,593	40,487	46,278	54,228	68,267
BB	2,111	2,318	5,810	8,295	12,803	16,072	16,827	14,105	14,009	15,513	24,055	20,541	17,642	12,392	18,371	20,029
GI	1,564	4,107	7,928	12,005	39,539	49,393	41,907	51,118	49,326	63,674	56,285	71,286	71,085	64,630	74,105	83,382
HD	622	640	2,920	7,501	19,209	34,465	28,372	34,083	59,401	79,677	70,639	71,918	73,998	86,014	65,488	65,058
TR	1,012	1,833	4,233	7,205	12,064	16,379	15,182	19,981	19,568	28,584	32,471	22,265	16,614	22,064	13,011	19,163
OT	80	193	454	1,871	3,379	5,402	7,360	7,704	7,871	8,223	8,984	11,161	11,497	9,877	12,849	15,291
Total	**27,544**	**51,700**	**53,344**	**127,959**	**333,525**	**385,291**	**266,931**	**301,737**	**327,407**	**390,792**	**392,076**	**397,173**	**391,529**	**409,336**	**401,381**	**423,818**

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**). Background colour intensity is proportional to the catches by fishery and category (i.e. decade, year)

Table 7. Yellowfin tuna: Best scientific estimates of the catches of yellowfin tuna (*Thunnus albacares*) by area by decade (1950–2009) and year (2009–2018), in tonnes. Catches by decade represent the average annual catch. The areas are presented in Fig. 18(a). Data as of September 2019.

Area	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
R1	1,992	4,481	8,634	19,920	74,802	85,040	59,521	70,897	100,816	132,148	119,456	130,395	135,241	144,023	135,498	143,058
R2	12,260	24,036	22,123	73,396	142,282	180,878	99,879	115,229	121,200	145,362	155,461	162,359	164,916	167,338	162,865	161,973
R3	658	7,350	4,283	7,355	21,783	23,501	18,567	18,244	18,960	17,090	20,723	8,768	14,191	18,592	19,735	14,948
R4	918	1,800	1,356	1,086	3,414	2,390	790	1,201	514	504	676	472	991	483	331	1,082
R5	11,716	14,033	16,949	26,201	91,244	93,482	88,174	96,166	85,917	95,688	95,760	95,179	76,190	78,900	82,952	102,757
Total	**27,544**	**51,700**	**53,344**	**127,959**	**333,525**	**385,291**	**266,931**	**301,737**	**327,407**	**390,792**	**392,076**	**397,173**	**391,529**	**409,336**	**401,381**	**423,818**

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**). Background colour intensity is proportional to the catches by area and category (i.e. decade, year)

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**).

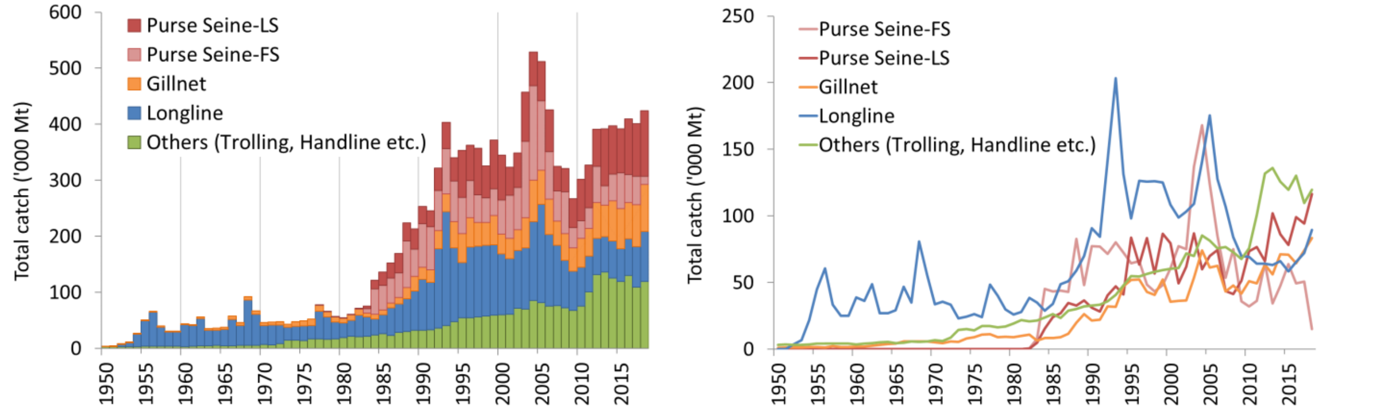


Fig. 17. Annual catches of yellowfin tuna by gear (1950–2018). Data as of September 2019.

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**).

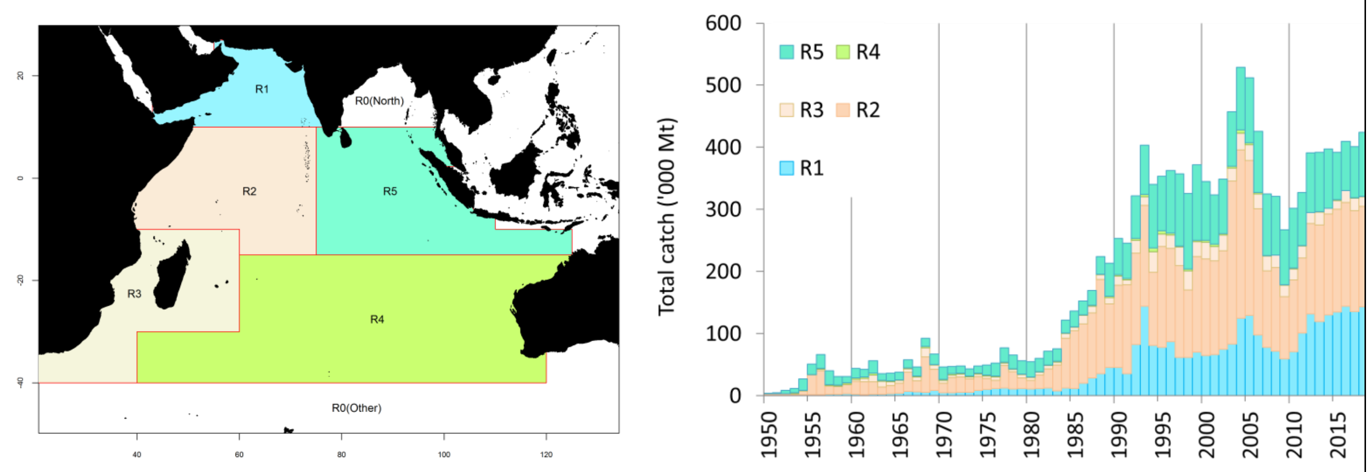


Fig. 18(a-b). Yellowfin tuna: Catches of yellowfin tuna by area by year estimated for the WPTT (1950–2018). Catches in areas R0 were assigned to the closest neighbouring area for the assessment. Data as of September 2019.

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**).

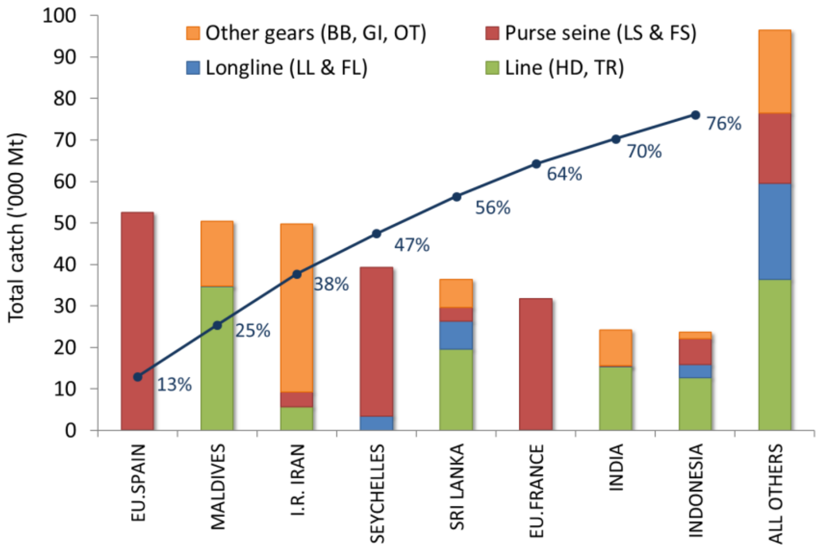


Fig. 19. Yellowfin tuna: average catches in the Indian Ocean over the period 2014 – 18, by country. Countries are ordered from left to right, according to the importance of catches of yellowfin reported. The dark line indicates the (cumulative) proportion of catches of yellowfin for the countries concerned, over the total combined catches of this species reported from all countries and fisheries. Data as of September 2019.

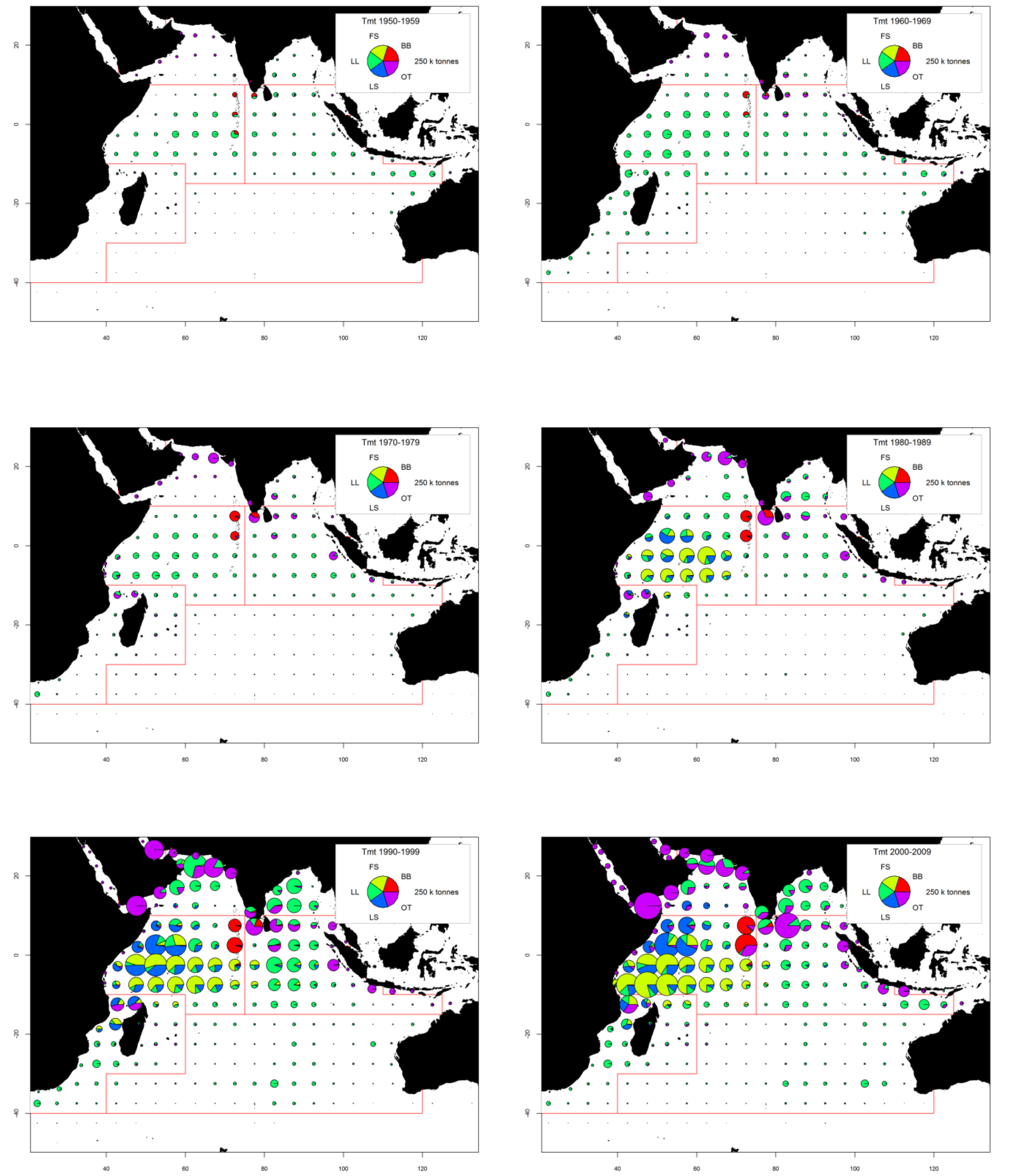


Fig. 20(a-f). Yellowfin tuna: Time-area catches (total combined in tonnes) of yellowfin tuna estimated for the period 1950–2009, by decade and type of gear. Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**),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

Note that 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 (as OT), in particular driftnets of I.R. Iran, gillnet and longline fishery of Sri Lanka, and longline and coastal fisheries of Indonesia.

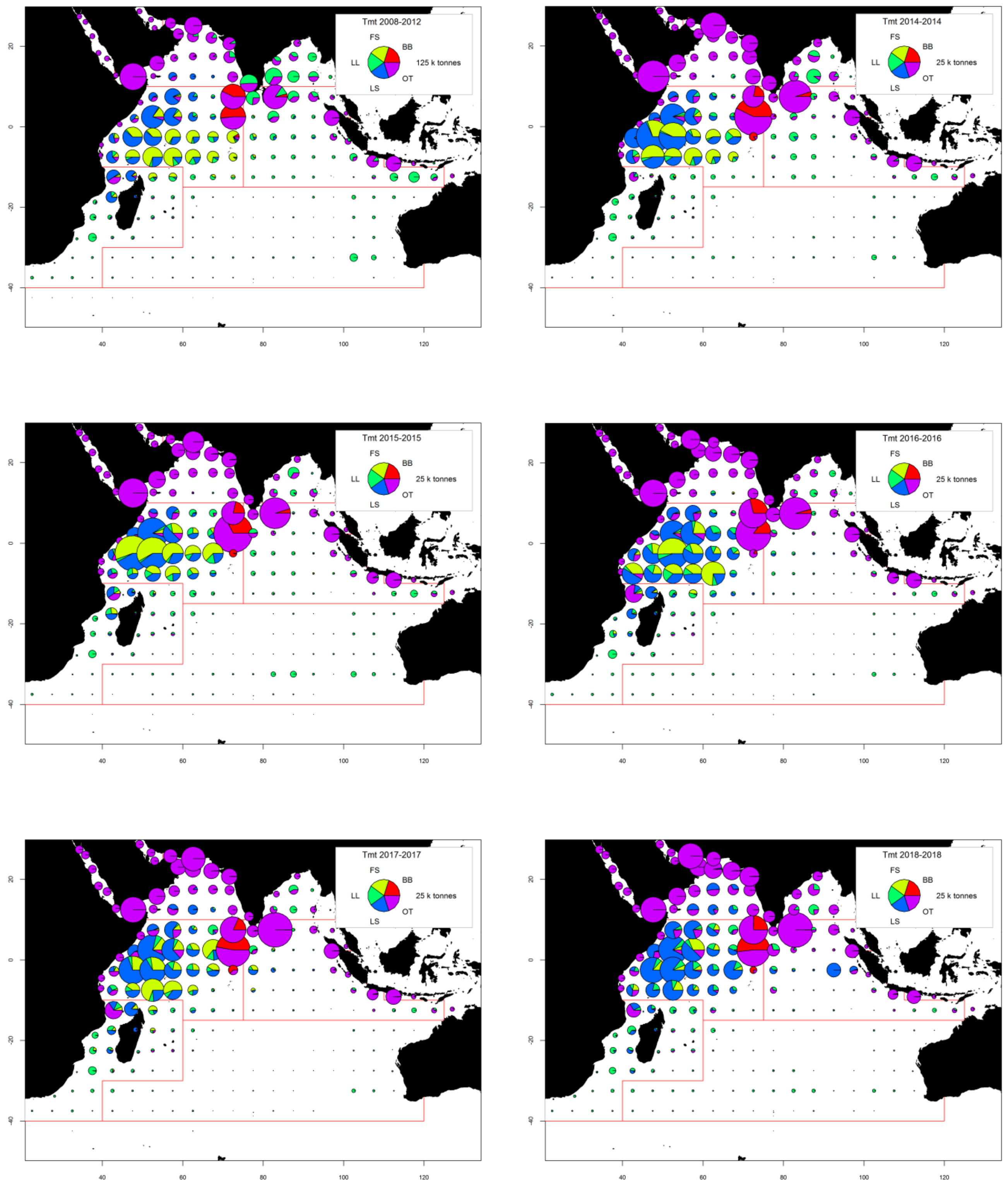


Fig. 21(a-f). Time-area catches (total combined in tonnes) of yellowfin tuna estimated for the period 2008–2012 by type of gear and for 2014–2018, by year and type of gear. Longline (**LL**), Purse seine free-schools (**FS**), Purse seine associated-schools (**LS**), pole-and-line (**BB**), and other fleets (**OT**), including drifting gillnets, and various coastal fisheries.

Note that 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 (as OT), in particular driftnets of I.R. Iran, gillnet and longline fishery of Sri Lanka, and longline and coastal fisheries of Indonesia.

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;
  - the 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:
  - data for the fresh-tuna longline fishery of Taiwan,China are only available since 2006 and partial data for the fresh-tuna longline fishery of Indonesia is available only for 2018;
  - insufficient data for the gillnet fisheries of I.R., Iran (before 2007) and Pakistan;
  - poor quality effort data for the significant gillnet-longline fishery of Sri Lanka (until 2014);
  - no data are available from important coastal fisheries using hand and/or troll lines, in particular Oman, Yemen, Madagascar and Indonesia (until 2018).

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). Data from the artisanal fisheries of Oman (mainly handlines) is known to be available for some years (until 2016) but has not been officially submitted to the IOTC Secretariat.
  - 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).

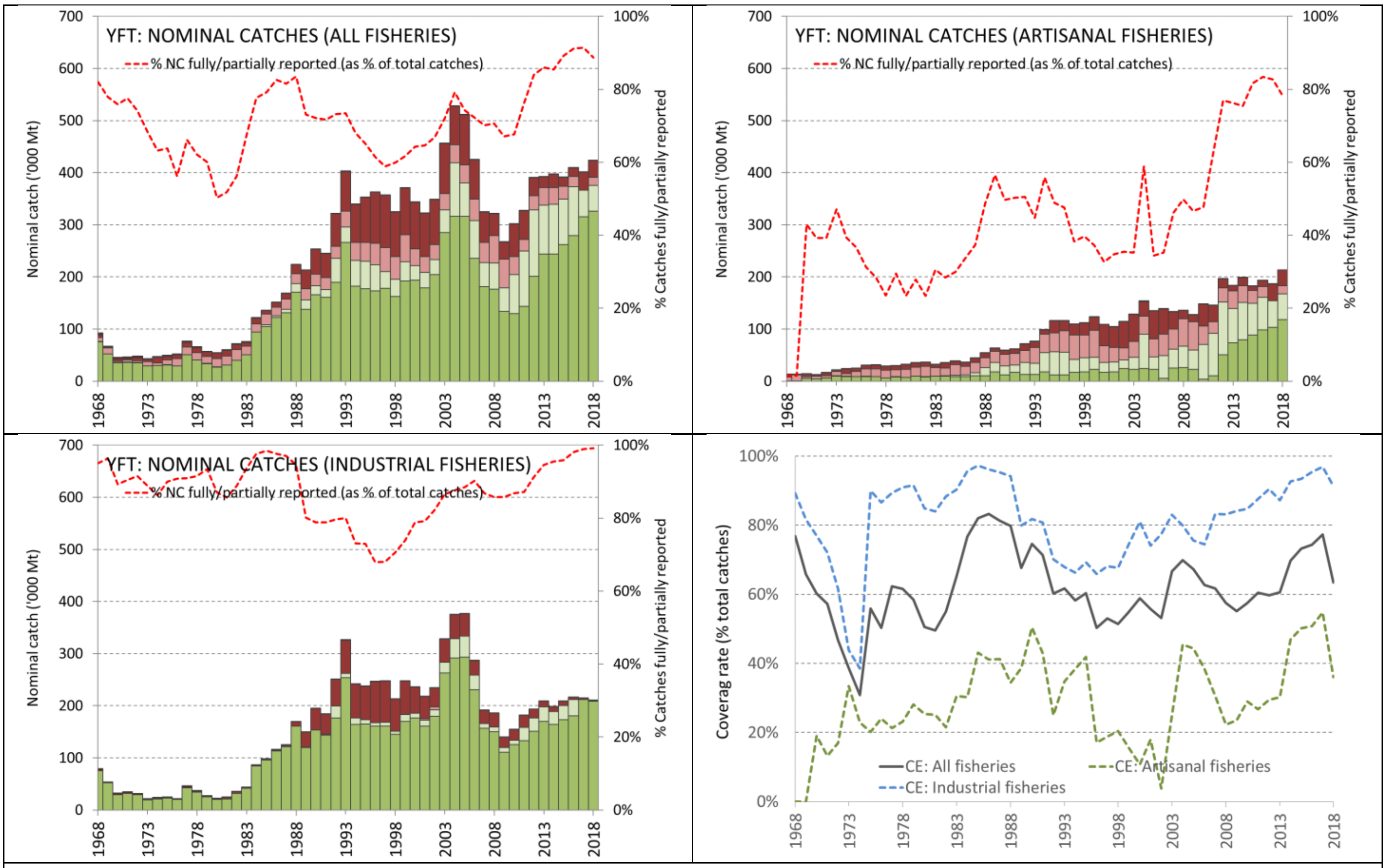


Fig. 22a-d. Yellowfin tuna: nominal catches data reporting coverage (1968–2018). The red dotted lines indicated the proportion of catches fully/partially reported according to the IOTC data reporting standards for nominal catches. Data as of September 2019.

Data reporting scores:

	0
	2
	4
	6
	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

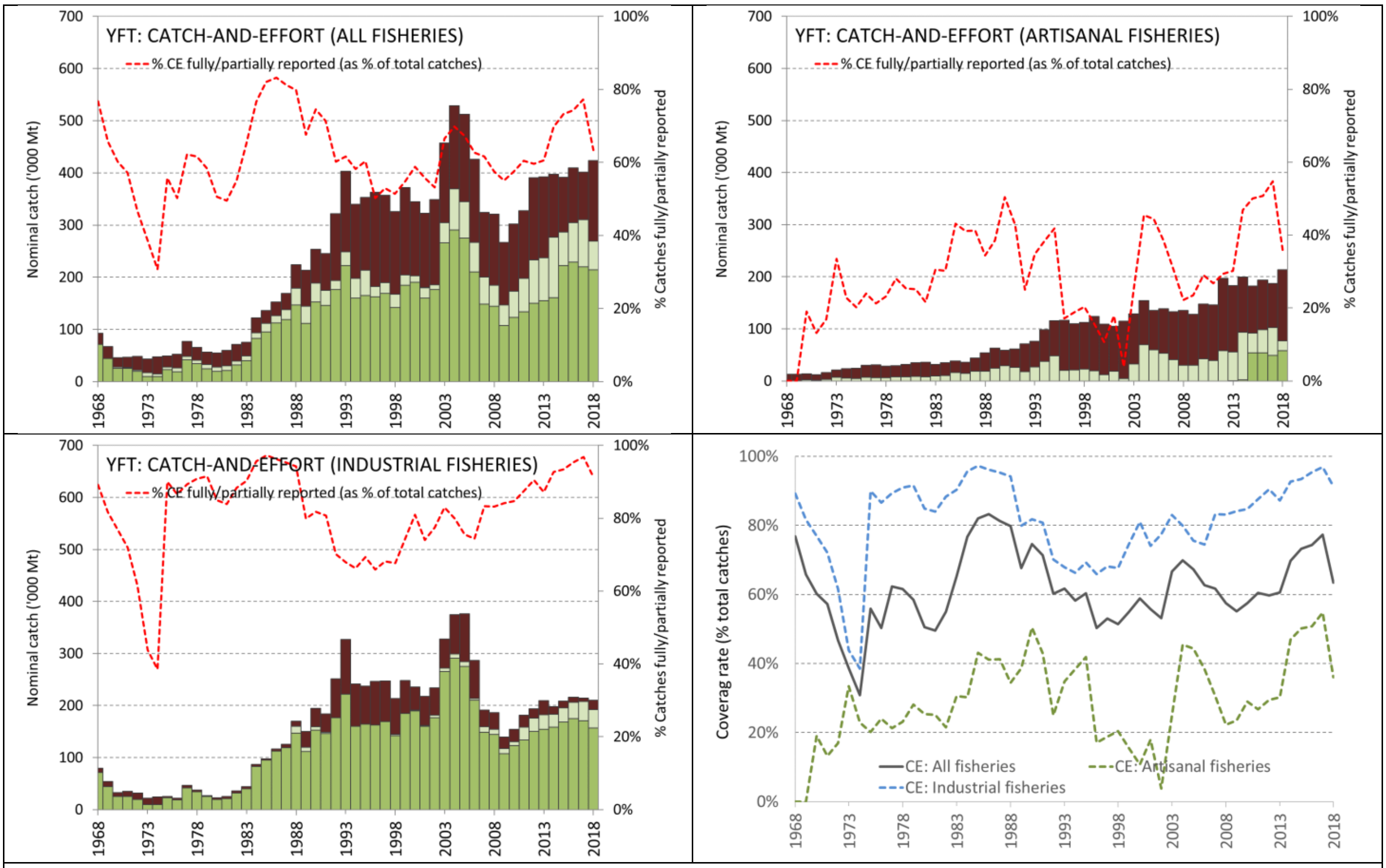


Fig. 22e-h. Yellowfin tuna: catch-and-effort data reporting coverage (1968–2018). The red dotted lines indicated the proportion of catches fully/partially reported according to the IOTC data reporting standards for nominal catches. Data as of September 2019.

Data reporting scores:

(green)	0
(light green)	2
(pink)	4
(red)	6
(dark red)	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

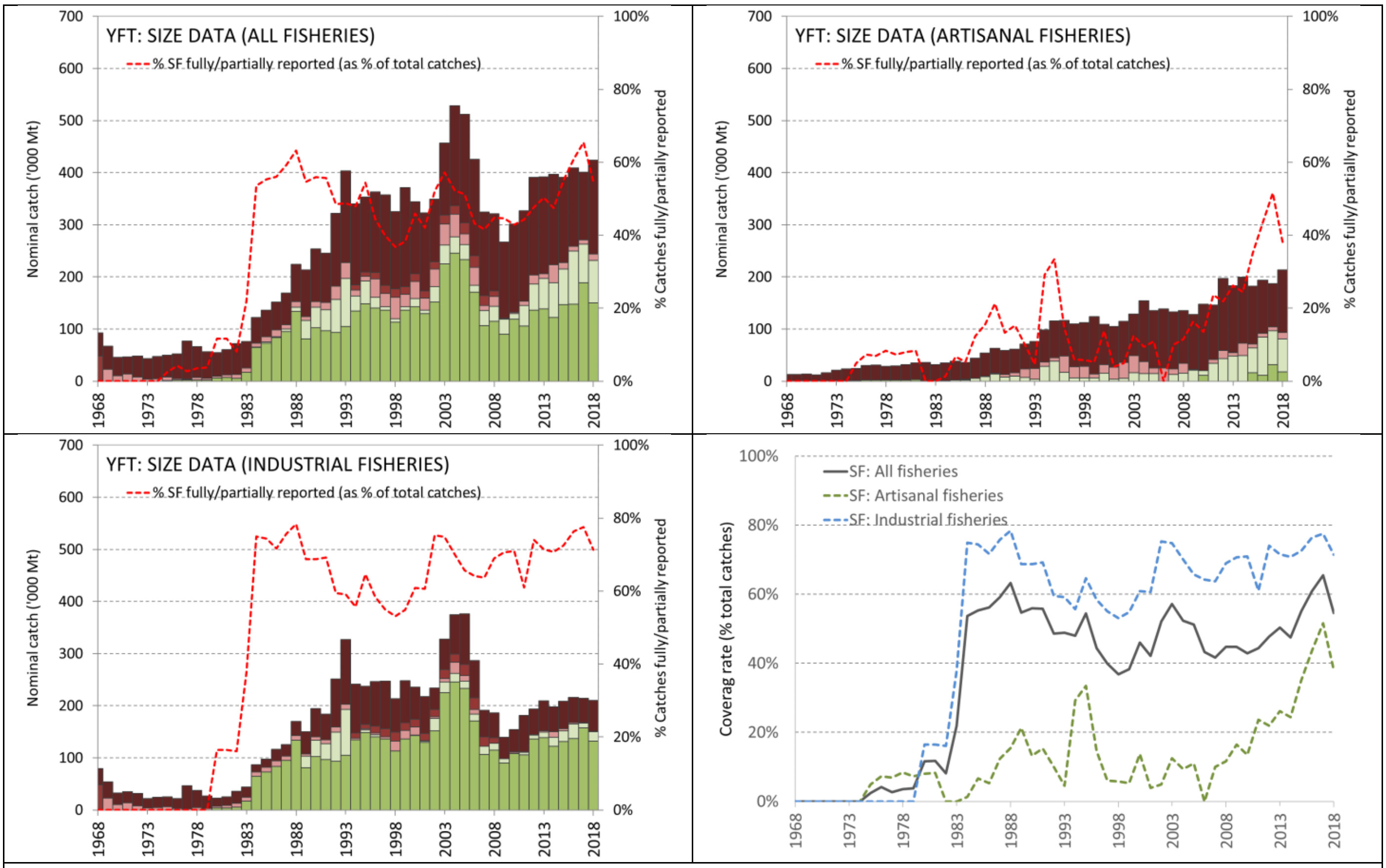


Fig. 22i-l. Yellowfin tuna: size frequency data reporting coverage (1968–2018). The red dotted lines indicated the proportion of catches fully/partially reported according to the IOTC data reporting standards for nominal catches. Data as of September 2019.

Data reporting scores:

	0
	2
	4
	6
	8

Each IOTC dataset (nominal catch, catch-and-effort, and size data) are assessed against IOTC reporting standards, where:

- **Score: 0** indicates the amount of nominal catch associated with each dataset fully reported according to IOTC standards.
- **Score: 2 – 6** indicates the amount of nominal catches associated with each dataset partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat or for any of the other reasons provided in the document).
- **Score: 8** indicates the amount of nominal catches associated that is fully estimated by the IOTC Secretariat (i.e., nominal catches) or data that is not available (i.e., catch-and-effort or size data).

Yellowfin tuna: tagging data

- A total of 66,543 yellowfin tuna (representing 30% of the total number of fish tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP). Most of the tagged specimens (82%) 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 10,842 specimens (16% of releases for this species), have been recovered and reported to the IOTC Secretariat. More than 86% of these recoveries we made by the purse seine fleets operating in the Indian Ocean, while around 9% 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.

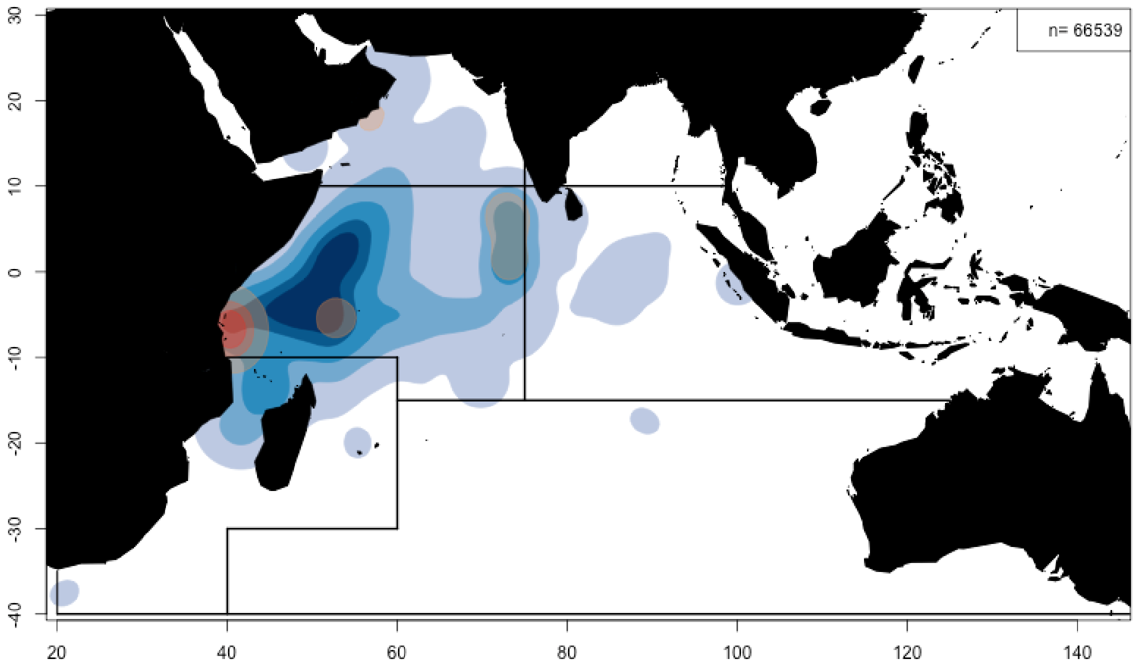
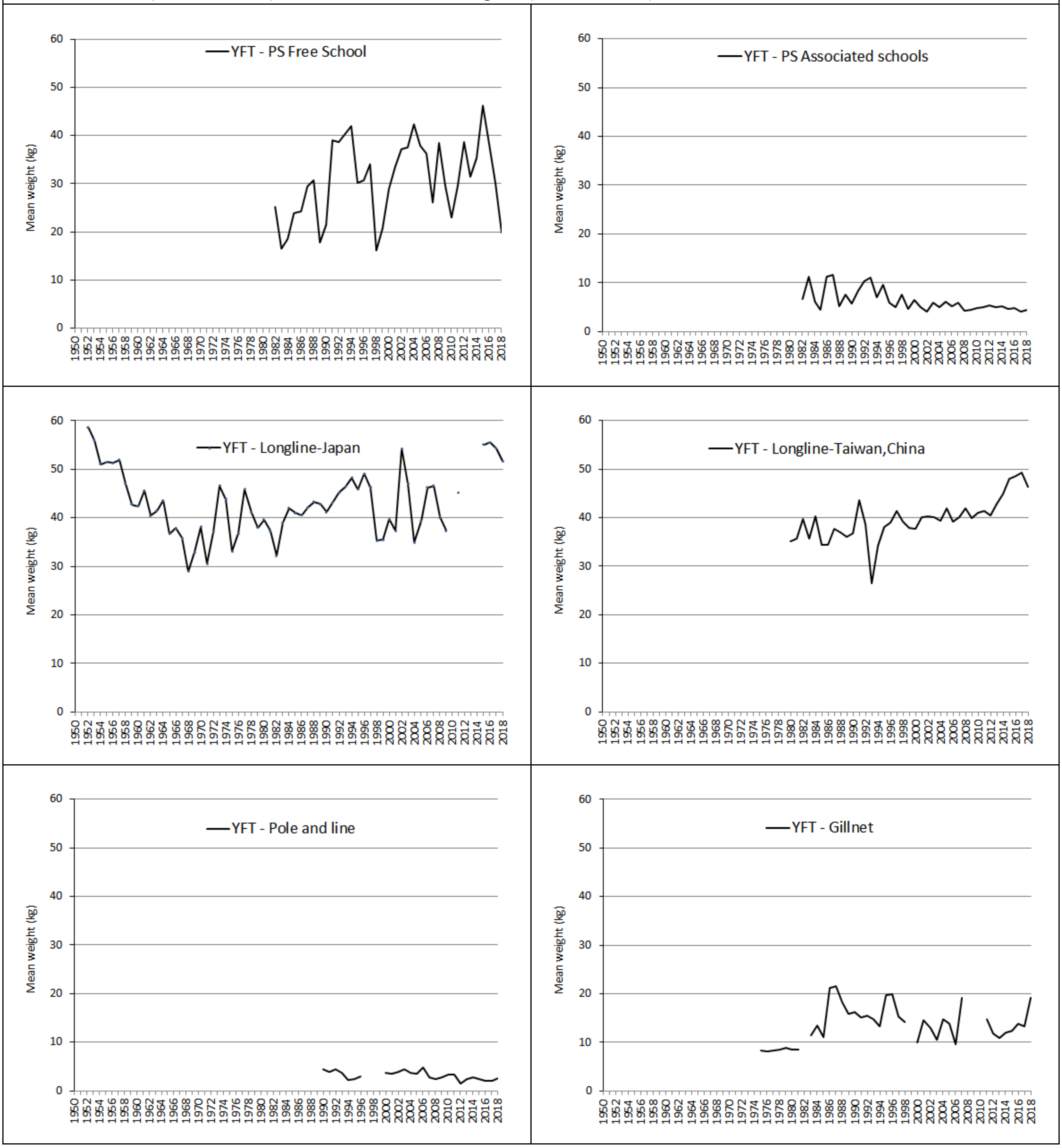


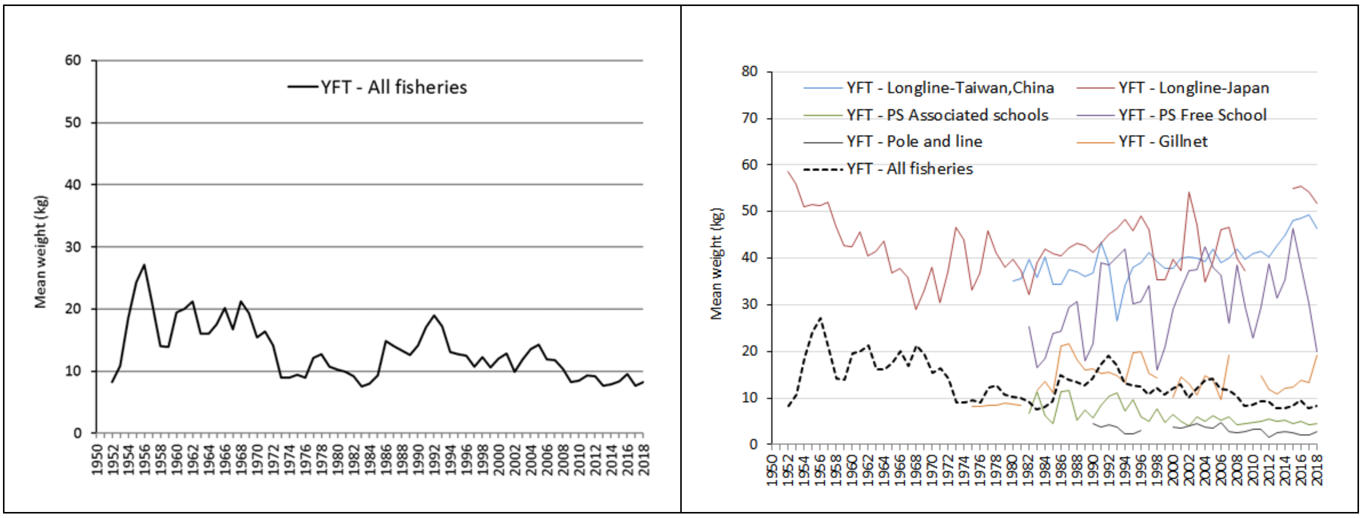
Fig. 23. Yellowfin tuna: Densities of releases (in red) and recoveries (in blue). The black line represents the st assessment areas. Includes specimens tagged during the IOTTP and also Indian Ocean (Maldivian) tagging program during the 1990s.

Yellowfin tuna (YFT)

Fig. 29. 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)




YFT - All fisheries
Mean weight (kg)
YFT - Longline-Taiwan,China
YFT - Longline-Japan
YFT - PS Associated schools
YFT - PS Free School
YFT - Pole and line
YFT - Gillnet
YFT - All fisheries
Mean weight (kg)

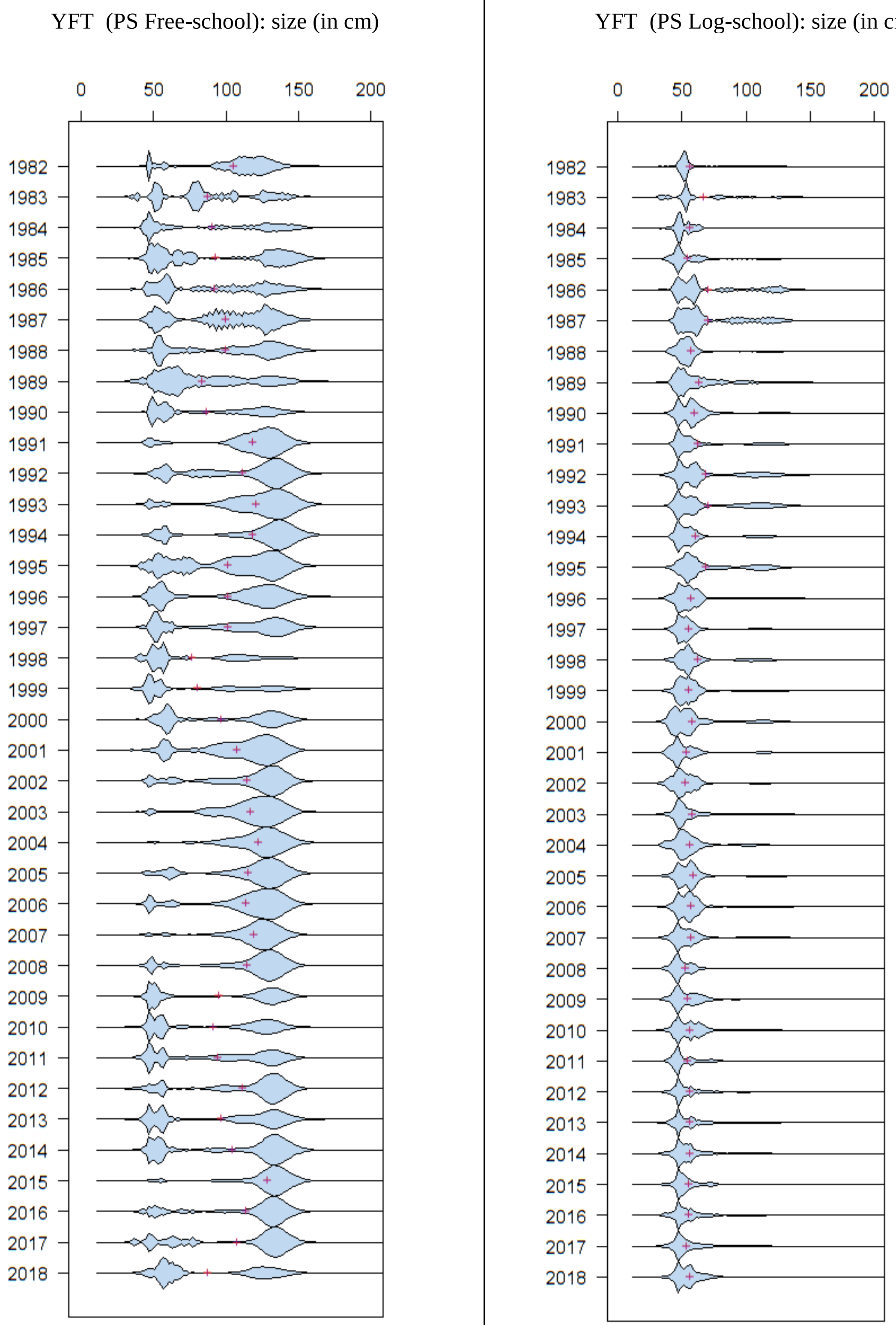


Fig. 30. Yellowfin tuna (purse seine): Left: length frequency distributions for YFT PS Free school fisheries (by 2 cm length class). Right: Length frequency distributions for YFT PS Associated (log) school fisheries (by 2 cm length
class). Source: IOTC database.

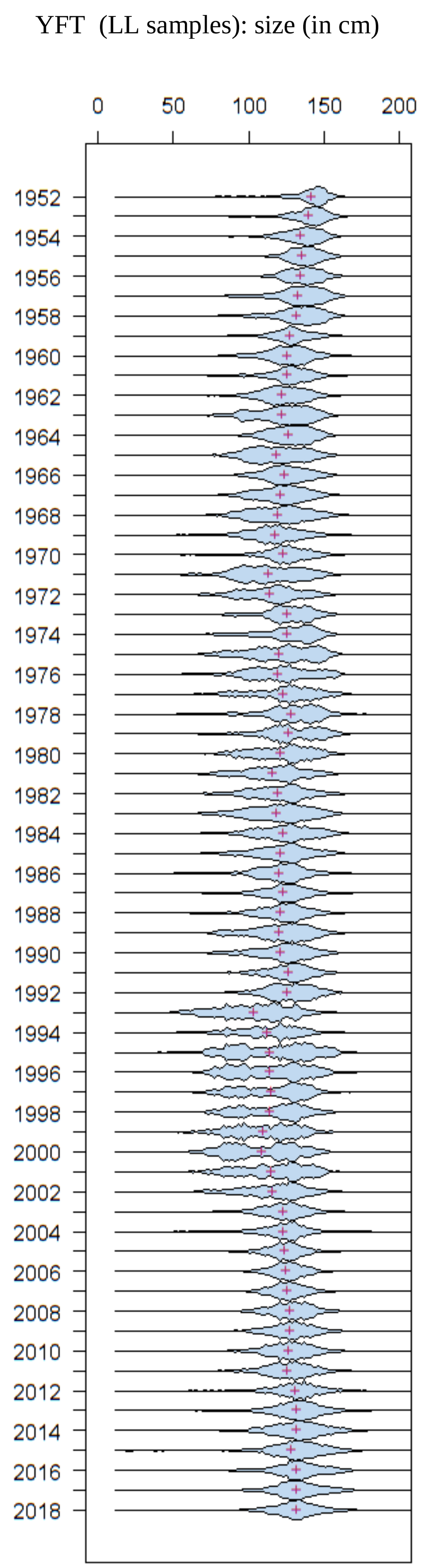


Fig. 31. Yellowfin tuna (longline): Length frequency distributions for longline fisheries (total amount of fish measured by 2 cm length class) derived from data available at the IOTC Secretariat. Source: IOTC database.

APPENDIX V
MAIN ISSUES IDENTIFIED RELATING TO THE STATISTICS OF TROPICAL TUNAS
(Extract from IOTC–2019–WPTT21–08)

The following section 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, for the consideration of the WPTT.

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 revised upwards by around 3,000t – 6,000t 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.
- **Sri Lanka (gillnet-longline)**: Although Sri Lanka has reported catches of bigeye tuna for its 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 I.R. Iran for years prior to 2012 by 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 700t per year), however these 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.

  Since 2016 Pakistan has begun to report official catches on a more regular basis. However, the IOTC Secretariat has noted large revisions to some of the catches for individual species and for this reason the Secretariat is currently liaising with the Ministry of Fisheries and WWF Pakistan to understand, and resolve, the recent inconsistencies in reported catches.
- **Coastal fisheries of Indonesia, Madagascar, Sri Lanka[4] (other than gillnet/longline) and Yemen**: The catches of tropical tunas for these fisheries have been estimated by the IOTC Secretariat in recent years (for Sri Lanka, until 2014) – 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. Currently IOTC estimates are based on FAO data, however the quality of catches remains highly uncertain and 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 and 12 the IOTC Secretariat and 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 5,000t per year instead of 9,000t). The IOTC Secretariat revised estimates of catch for the period 1995 – 2010 using the new estimates.

Discards – all fisheries

The total amount of tropical tunas discarded at sea remains unknown for most fisheries and time periods prior to 2013 (i.e., prior to the introduction of Resolution 13/11, superseded by Resolutions 15/06 and 17/04[5]). Discards of tropical

[4] 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 lead to improvements in the estimate of catch for the coastal fisheries of Sri Lanka for 2012 and subsequent years.

[5] Resolution 17/03 *On a ban on discards of bigeye tuna, skipjack tuna, yellowfin tuna, and non-targeted species caught by purse seine vessels in the IOTC area of competence.*

tunas are thought to be significant during some earlier 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.

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 *IOTC Mandatory statistical requirements* and of limited value in deriving indices of abundance:

- **I.R. Iran (coastal and offshore fisheries)**: I.R. Iran ranks fifth largest in terms of total catches of tropical tunas in 2018 (accounted for mostly by drifting gillnets), however until recently, catch-and-effort have not been reported according to IOTC standards, in particular for vessels operating in offshore waters. Following an IOTC Data Compliance mission in November 2017, I.R. Iran has now begun to submit catch-and-effort data in accordance with the reporting requirements of Resolution 15/02, and this lead to measurable improvements to the data available for the Iranian fisheries in the IOTC database for 2007 and following years.
- **Sri Lanka (gillnet-longline)**: Until 2014 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. For this reason, time-area catches prior to 2014 are considered to be uncertain.
- **Indonesia (longline)**: Several IOTC-OFCF missions were conducted from November 2015 onwards to assist Indonesia with reporting of catch-and-effort, size frequency data and Regional Observer data collected on-board longline vessels. In 2019 (i.e. data for 2018) catch-and-effort data from logbooks covering around 5% of fishing operations for the longline and coastal purse-seine fleet of Indonesia (as well as for some other coastal fisheries) were received by the IOTC Secretariat for the first time as a consequence of the successful implementation of the *One Data* initiative that aims at strengthening data collection processes and coordination at regional and national level.
- **Pakistan (drifting gillnet)**: no catch-and-effort reported for the gillnet fishery, in particular for vessels that operate outside the EEZ of Pakistan. WWF-Pakistan has been a implementing a crew-based observer programme for over three years, which includes information on total enumeration of catches and fishing location (for sampled vessels), and could be used to estimate catch-and-effort for Pakistan gillnet vessels in the absence of a national logbook program. The IOTC Secretariat is currently liaising with WWF-Pakistan to evaluate the quality of the observer data collected and see whether these could be used to cross-verify the revisions to catch series provided in the recent years.
- **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.

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.

  Furthermore, the number of specimens sampled for length on-board longliners flagged in Japan in recent years remains below the minimum of one-fish-per-metric-ton of catch recommended by the IOTC – although size data is now being reported as part of Japan's Regional Observer Scheme data submissions.

  For several years the IOTC Scientific Committee has expressed concern about the poor coverage of length frequency samples for a number of major longline fleets, such as those from Japan, Indonesia, and India, and the potential negative impact this could have on stock assessments.

  In addition, inconsistencies have been noted between the average weights of tropical tunas derived from catch-and-effort and size frequency datasets, particularly for the Taiwanese longline fleet, when comparing data for the same area and time-period.

  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[6].

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

In early 2019 an IOTC consultant was hired to review IOTC's longline size frequency data which, among other tasks, included visits to the national fisheries institutions of the key fleets collecting longline size data. The work is expected to be finalized in early-2020 with the publication of a final report and presentation of the main findings at the IOTC Working Parties and Scientific Committee in 2020.

- **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[7].
- **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°x5° grid) and they refer exclusively to longliners based in ports in this country. In 2019 (i.e. data for 2018) size-frequency data in agreement with the requirements of Resolution 15/02 were received by the IOTC Secretariat for the first time for both the coastal and fresh-tuna longline fleet of Indonesia.
- To date, these countries have not reported size frequency data for their fisheries[8]:
  - Longline: India, Oman and the Philippines (longline);
  - Coastal fisheries: India and Yemen (Indonesia has recently reported data for some of their coastal fisheries in 2018)

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.

  An alternative source of such biological information is the Regional Observer Scheme database, that collates data – including size and weight measurement – recorded by scientific observers and reported to the IOTC Secretariat (in detailed form) as part of the ROS data exchange workflow.

  A first attempt at using ROS data to estimate length-weight relationships for Albacore tuna was made during the WPTmT 2019: a similar approach could be considered for tropical tuna species in the next future, once the extent of the information within the ROS database is deemed adequate enough.

  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.

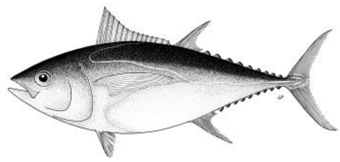
  .

[7] 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 their fisheries.

[8] For the years during which these fisheries were known to operate

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		2019 stock status[3] determination
Indian Ocean[5]	Catch in 2018[2]: Average catch 2014–2018:	93,515 t (81,413 t)[4] 92,140 t (89,720 t)[4]	**38.2%***
	MSY (1,000 t) (80% CI): F_{MSY} (80% CI): SB_{MSY} (1,000 t) (80% CI): F_{2018}/F_{MSY} (80% CI): SB_{2018}/SB_{MSY} (80% CI): SB_{2018}/SB_0 (80% CI):	87 (75-108) 0.24 (0.18-0.36) 503 (370-748) 1.20 (0.70-2.05) 1.22 (0.82-1.81) 0.31 (0.21. – 0.34)	

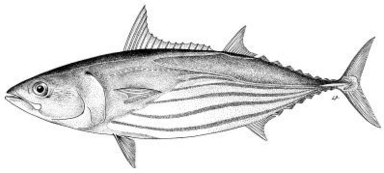
[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[2] Proportion of catch estimated or partially estimated by IOTC Secretariat for catches in 2018: 28%
[3] The stock status refers to the most recent years' data used in the last assessment conducted in 2019.
[4] Considering the alternative purse seine log-associated catch composition for the EU fleet in 2018 as per IOTC-2019-WPTT21-R[E].
[5] Results of management quantities presented here are for the revised catches – see footnote 4.
* 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 ($SB_{year}/SB_{MSY} \geq 1$)
Stock subject to overfishing($F_{year}/F_{MSY} > 1$)	**34.6**	38.2%
Stock not subject to overfishing ($F_{year}/F_{MSY} \leq 1$)	0%	27.2%
Not assessed/Uncertain		

Detailed management advice was not provided during the assessment meeting. This will be done intersessionally and provided and discussed during the 22nd session of the Scientific Committee. Thereafter, this executive summary will be updated and completed

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**		**2017 stock status[4] determination**
Indian Ocean	Catch 2018[2]: Average catch 2014–2018:	607,701 t (606,197 t)[5] 484,993 t (484,692 t)[5]	**47%***
	$Yield_{40\%SSB}$ (1000 t) (80% CI): $C_{2016}/C_{40\%SSB}$ (80% CI): SB_{2016} (1000 t) (80% CI): Total Biomass B_{2016} (1000 t) (80% CI): $SB_{2016}/SB_{40\%SSB}$ (80% CI): SB_{2016}/SB_0 (80% CI): $E^3_{40\%SSB}$ (80% CI): SB_0 (80% CI):	510.1 (455.9–618.8) 0.88 (0.72-0.98) 796.66 (582.65-1,059.29) 910.4 (873.6-1195) 1.00 (0.88–1.17) 0.40 (0.35–0.47) 0.59 (0.53-0.65) 2,015,220 (1,651,230–2,296,135)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[2] Proportion of catch estimated or partially estimated by IOTC Secretariat in 2018: 12%
[3] E is the annual harvest rate.
[4] The stock status refers to the most recent years' data used in the last assessment conducted in 2017.
[5] Considering the alternative purse seine log-associated catches composition for the EU fleet in 2018 as per IOTC-2019-WPTT21-R[E].
* 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 ($SB_{year}/SB_{40\%} < 1$)	Stock not overfished ($SB_{year}/SB_{40\%} \geq 1$)
Stock subject to overfishing($F_{year}/F_{40\%} > 1$)	**38%**	2%
Stock not subject to overfishing ($F_{year}/F_{40\%} \leq 1$)	13%	47%
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. No new stock assessment was carried out for skipjack tuna in 2019, thus, stock status is determined on the basis of the 2017 assessment and other indicators presented in 2019. The 2017 stock assessment model results differ substantively from the previous (2014 and 2011) assessments. The main reasons for this are: (i) the correction of an error in specifying selectivity for small fish in the previous assessments, (ii) the addition of tag-release mortality in the model and (iii) assuming effort creep of 1% per year since 1995 for the standardized European purse seine CPUE. The final overall estimate of stock status indicates that the stock is at the target biomass reference point and that the current and historical fishing mortality rates are estimated to be below the target. Over the history of the fishery, biomass has been well above and the fishing mortality has been well below the established limit reference points. The median value of Catch at the target fishing mortality ($C_{SB40\%}$) from the model runs investigated is 510,090 t with a range between 455,920 and 618,760t. Current spawning stock biomass relative to unexploited levels is estimated at 40% (**Table 1**). Catch in 2018 (≈607,401 t) is in the upper range of the estimated range of $C_{SB40\%}$ (**Table 1**). The average catch over the previous five years (2014–18; ≈ 484,993 t) is at the lower range of the estimated range of $C_{SB40\%}$. Thus, on the weight-of-evidence available in 2017, the skipjack tuna stock is determined to be **not overfished** and is **not subject to overfishing** (**Table 1**).

Outlook. Total catches in 2018 were 29% larger than the resulting catch limit from the skipjack HCR for the period 2018-2020. It should be noted that skipjack catches for most gears have increased from 2017 to 2018 (+43% for purse seine (log-associated), +13% for gillnet and +13% for baitboats). In particular, due to Resolution 19/01, an increase in fishing operations on FADs by purse seine fleets has been increased, with the associated increase in skipjack catch. CPUE fluctuations coincide with environmental signals at inter-annual timescale (e.g., Indian Ocean Dipole). Due to its specific life history attributes, skipjack can respond quickly to ambient foraging conditions driven by ocean productivity. Environmental indicators should be closely monitored to inform on the potential increase/decrease of stock productivity.

Management advice. Based on the results of the stock assessment of skipjack tuna in 2017, the Commission, following Resolution 16/02, adopted an annual catch limit of 470,029 tonnes for the years 2018 to 2020. Total catches in 2018 (607,701 t) were 29% larger than the catch limit generated by the Harvest Control Rule (470,029 t) which applies to the years 2018–2020, and there has been an increasing trend in catches over the past 3 years. The Commission needs to ensure that catches of skipjack in the 2018–2020 period do not exceed the agreed limit.

Following Resolution 16/02, the annual catch limit for the period 2018-2020 was established at 470,029 t.

The SC has included in its programme of work further development of Management Strategy Evaluation (MSE) for the IOTC Skipjack tuna fishery including, but not limited to: refinement of operating model(s) used, specifications for the assessment and data to be used, and alternative management procedures. The aim of this programme of work is to develop the fully specified management procedure (harvest strategy) for Skipjack including the revision of the HCR as may be required.

It should also be noted that:

- **Reference points:** Commission in 2016 agreed to Resolution 16/02 on *harvest control rules for skipjack tuna in the IOTC area of competence;*
- **Fishing mortality**: Current fishing mortality was considered to be below the target reference point, and also below the limit reference point (**Fig. 2**) as per Resolution 15/10;
- **Biomass**: Current spawning biomass was considered to be at the target reference point of 40% of SB_0, and above the limit reference point of $0.2*SB_0$ (**Fig. 2**) as per Resolution 15/10;
- **Main fishing gear** (average catches 2014-18): Purse seine ≈40% (FAD associated school ≈39% and free swimming school ≈1%); Gillnet ≈21%; Pole-and-line ≈19%; Other ≈20% (**Fig. 1(a-c)**);

Main fleets (average catches 2014-18): Indonesia ≈17%; European Union ≈24% (EU-Spain: ≈17%; EU-France: ≈6%); ≈Maldives 16%; Seychelles ≈12%; Sri Lanka ≈10%; ≈I.R. Iran 9%.

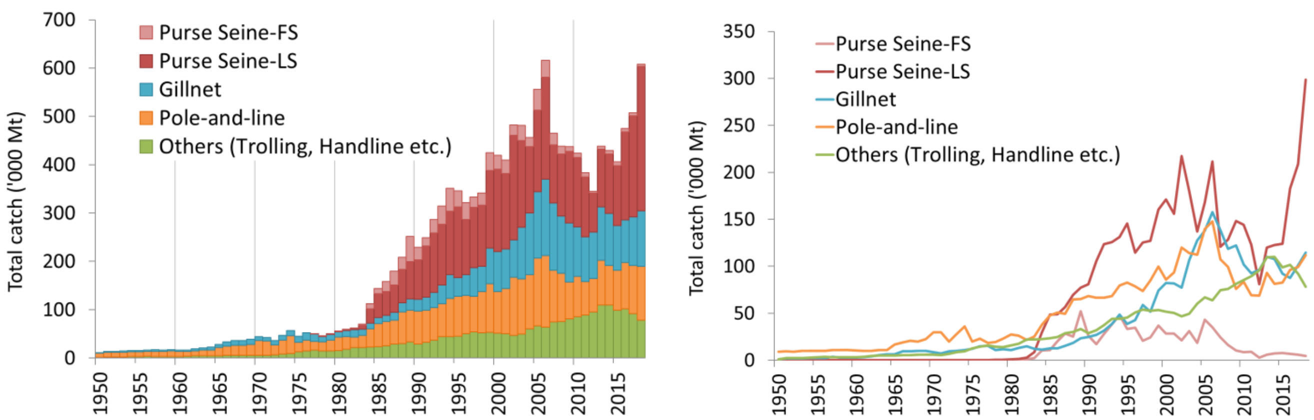


Fig. 1(a-b). Annual catches of skipjack tuna by gear (1950–2018). Data as of October 2019.

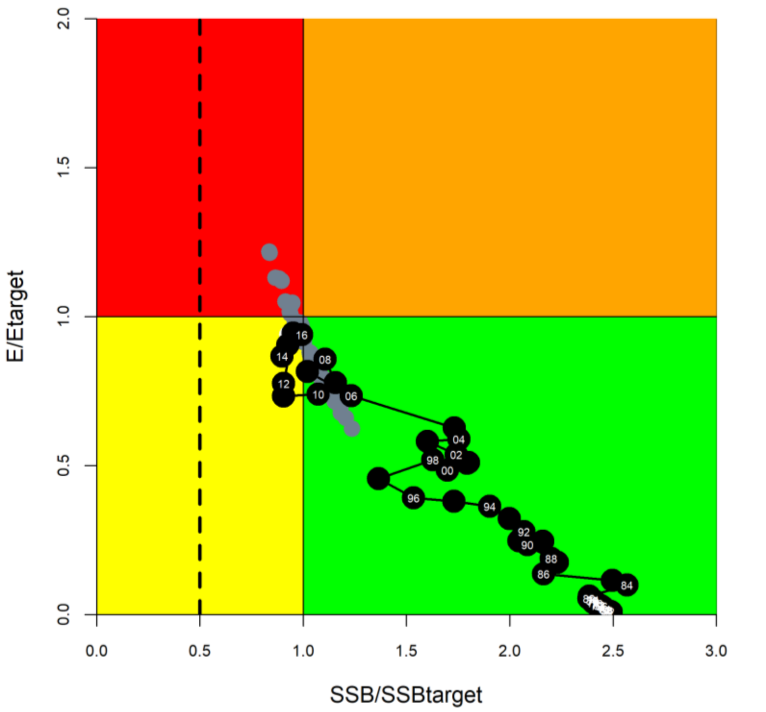
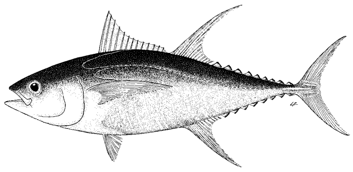


Fig. 2. Skipjack tuna: SS3 Aggregated Indian Ocean assessment Kobe plot of the 2017 uncertainty grid. Black circles indicate the trajectory of the median estimates for the SB/SB_{target} ratio and E/E_{target} ratio across all models of the 2017 uncertainty grid for each year 1950–2016; grey dots are the estimates for year 2016 from individual models. The dashed line indicates SB_{limit} (20% SB_0)

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**		**2019 stock status determination**
Indian Ocean	Catch 2018[2]:	423,815 t (437,422 t)[4]	**94%**
	Average catch 2014–2018:	404,655 t (407,377 t)[4]	
	MSY (1000 t) (80% CI)[3]:	403 (339–436)	
	F_{MSY} (80% CI):	0.15 (0.13–0.17)	
	SB_{MSY} (1,000 t) (80% CI):	1069 (789–1387)	
	F_{2017}/F_{MSY} (80% CI):	1.20 (1.00–1.71)	
	SB_{2017}/SB_{MSY} (80% CI):	0.83 (0.74–0.97)	
	SB_{2017}/SB_0 (80% CI):	0.30 (0.27 – 0.33)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[2] Proportion of catch estimated or partially estimated by IOTC Secretariat for catches in 2018: 11%
[3] Median and quantiles calculated from the uncertainty grid taking into account of weighting on models
[4] Considering the alternative purse seine log-associated catches for the EU fleet in 2018 as per IOTC-2019-WPTT21-R[E].

Colour key	Stock overfished ($SB_{year}/SB_{MSY} < 1$)	Stock not overfished ($SB_{year}/SB_{MSY} \geq 1$)
Stock subject to overfishing($F_{year}/F_{MSY} > 1$)	**94%**	**2%**
Stock not subject to overfishing ($F_{year}/F_{MSY} \leq 1$)	**4%**	**0%**
Not assessed/Uncertain		

The percentages are calculated as the proportion of model terminal values that fall within each quadrant with model weights taken into account

Detailed management advice was not provided during the assessment meeting. This will be done intersessionally and provided and discussed during the 22nd session of the Scientific Committee. Thereafter, this executive summary will be updated and completed

APPENDIX IX
WORKING PARTY ON TROPICAL TUNAS PROGRAM OF WORK (2020–2024)

The following is the Draft WPTT Program of Work (2019–2023) and is based on the specific requests of the Commission and Scientific Committee, and will need to be modified to incorporate topics identified during the WPTT20. The Program of Work consists of the following, noting that a timeline for implementation would be developed by the SC 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 bycatch species in the Indian Ocean.

Topic	Sub-topic and project	Priority ranking	Lead	TIMING				
				2020	2021	2022	2023	2024
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.	(Low) to be finished in 2020	CSIRO/AZTI/IRD/RITF					
	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	Medium						

Topic	Sub-topic and project		Priority ranking	Lead	TIMING 2020	2021	2022	2023	2024
		species distribution, making use of conventional and electronic tagging (P-SAT).							
	1.2.2	Investigation into the degree of local or open population in main fishing areas (e.g,, the Maldives and Indonesia – archipelagic and open ocean) by using techniques such flux in FAD arrays or used of morphological features such as shape of otoliths.	Medium						
2. Biological and ecological information (incl. parameters for stock assessment)	2.1 Biological sampling								
	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.	Funding secured	CPCs directly with secretariat					
	2.1.2	Collect gonad samples from tropical tunas to confirm the spawning periods and location of the spawning area that are presently hypothesised for each tropical tuna species.	High						

Topic	Sub-topic and project	Priority ranking	Lead	TIMING				
				2020	2021	2022	2023	2024
3. Historical data review	3.1 Changes in fleet dynamics need to be documented by fleet							
	3.1.1 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 status of tropical tunas based upon most recent stock assessments.	Medium	CPCs and secretariat					
4 CPUE standardisation	4.1 Develop standardised CPUE series for each tropical tuna fleet/fishery for the Indian Ocean							
	4.1.1 Further development and validation of the collaborative longline CPUE indices using the data from multiple fleets and to provide joint CPUE series for longline fleets where possible	2	SC and consultants					
	4.1.2 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.	Ongoing	CPCs directly					
	4.1.3 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.	Ongoing	CPCs directly					
	4.1.4 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	Ongoing	Japan					

Topic	Sub-topic and project	Priority ranking	Lead	TIMING				
				2020	2021	2022	2023	2024
	and to permit cluster analysis using vessel level data.							
	Bigeye tuna: High priority fleets	High	CPCs directly					
	Skipjack tuna: High priority fleets	High	CPCs directly					
	Yellowfin tuna: High priority fleets	High	CPCs directly					
	4.1.5 Gillnet CPUE standardization including further investigate and use of gillnet CPUE series from Sri Lankan gillnet fishery	High	CPCs directly					
	4.2 That methods be developed for standardising purse seine catch species composition using operational data, so as to provide alternative indices of relative abundance (see Terms of Reference, Appendix IXb IOTC-2017-WPTT19-R).	High	Consultant and CPCs directly					
	4.3 Investigate the potential to use the Indian longline survey as a fishery-independent index of abundance for tropical tunas.	High	Consultant And CPCs directly					
5 Stock assessment / stock indicators	5.1 Develop and compare multiple assessment approaches to determine stock status for tropical tunas 5.2 Scoping of ongoing age composition data collection for stock assessment 5.3 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 IXa IOTC-2017-WPTT19-R). 5.4 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*	Medium Medium Ongoing 1	Consultant and CPCs directly CPC directly Consultant and secretariat					

Topic	Sub-topic and project	Priority ranking	Lead	TIMING				
				2020	2021	2022	2023	2024
	(including recent and historical 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. *Identify approaches for defining appropriate levels of M for inclusion in stock assessments.*							
6 Fishery independent monitoring	6.1 Develop fishery independent estimates of stock abundance to validate the abundance estimates of CPUE series. 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 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:	Ongoing	Consultant and CPCs directly					
	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	Medium Medium						

Topic	Sub-topic and project	Priority ranking	Lead	TIMING				
				2020	2021	2022	2023	2024
	number of commercial sets follow a standardised scientific protocol iii. Aerial surveys, potentially using remotely operated or autonomous drones iv. Studies (research) on flux of tuna around anchored FAD arrays to understand standing stock and independent estimates of the stock abundance. v. Scoping study to investigate genetics-based tagging techniques using recaptured individuals or identification of close-related pairs. Use of Close Kin Mark Recapture (CKMR) methods to study fishery independent methods of generating spawner abundance estimates based on genotyping individuals to a level that can identify close relatives (e.g. parent-offspring or half-siblings). The method avoids many of the problems of conventional tagging, e.g. live handling is not required (only catch needs to be sampled), tag shedding, tag-induced mortality and recovery reporting rates are irrelevant. It has been cost-effective in a successful application to southern bluefin tuna, but it remains unknown how the cost scales with population size. It would be valuable to conduct a scoping exercise to evaluate the applicability to the tropical tuna species vi. Investigate the possibility of conducting ongoing ad hoc, low level tagging in the region	High (3 for point v.)						
7 Target and Limit reference points	7.1 To advise the Commission, on Target Reference Points (TRPs) and Limit Reference Points (LRPs).	High	CPC's directly Under Technical WG					

Topic	Sub-topic and project	Priority ranking	Lead	TIMING				
				2020	2021	2022	2023	2024
	8.1.1 Used when assessing tropical tuna stock status and when establishing the Kobe plot and Kobe matrices							

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

Species	2020	2021	2022	2023	2024
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 X
BIGEYE TUNA SS3 ASSESSMENT MODEL GRID USING REPORTED PSLS CATCHES

The main bigeye tuna SS3 model grid is based on the revised PSLS catch revised PSLS catch (see Section 5.3.2). A second and subsidiary model grid was also prepared with the reported rather than the revised PSLS catch. The alternative grid results are provided below.

Table 1. Bigeye tuna: Key management quantities from the alternative SS3 assessment model grid using reported PSLS catch, for the Indian Ocean. Values represent the median and confidence intervals estimated from the results of the 18 model options.

Management Quantity	Aggregate Indian Ocean
Most recent revised catch estimate (t) (2018)	93 515
Mean catch over last 5 years (t) (2014–2018)	92 138
h (steepness)	0.7, 0.8, 0.9
MSY (1,000 t) (80% CI)	89 (79 – 110)
Data period (catch)	1950 – 2018
CPUE series/period	1979 – 2018
F_{MSY} (80% CI)	0.24 (0.16 – 0.36)
SB_{MSY} or B_{MSY} (1,000 t) (80% CI)	560 (370 – 759)
F_{2018}/F_{MSY} (80% CI)	1.56 (0.90 – 2.48)
SB_{2018}/SB_{MSY} (80% CI)	1.15 (0.73 – 1.82)
SB_{2018}/SB_{1950} (80% CI)	0.32 (0.24 – 0.34)

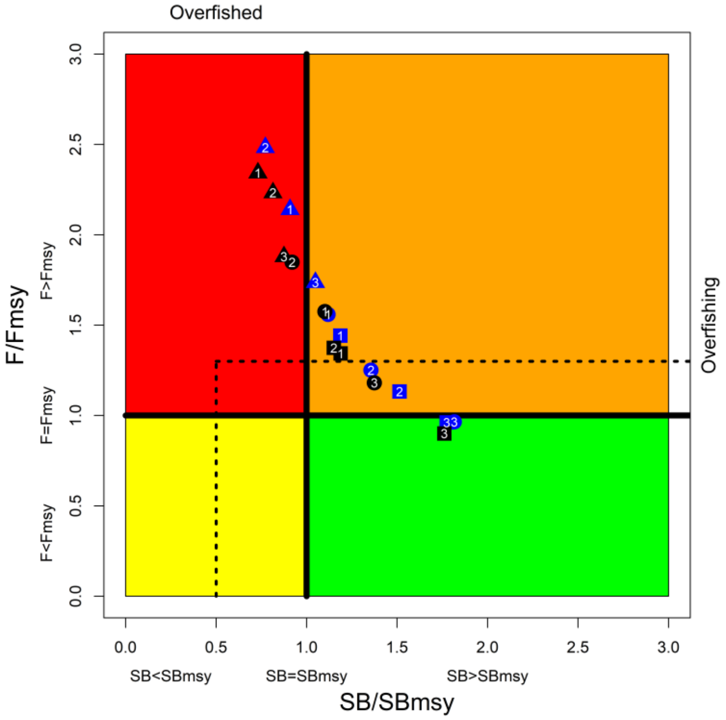


Figure.1. Bigeye tuna: SS3 Aggregated Indian Ocean assessment Kobe plot from the 18 models of the alternative SS3 assessment model grid using reported PSLS catch. Colored symbols represent MPD estimates from individual models (black and blue represent dome-shaped and logistic selectivity options respectively; Triangles, circles, and squares represent tag weighting option lambda of 1, 0.1, and 0.01 respectively; 1,2,3 represent steepness values of 0.7,0,8, and 0.9 respectively). The dashed lines represent limit reference points for IO bigeye tuna (SB_{lim} = 0.5 SB_{MSY} and F_{lim} = 1.4 F_{MSY}).

APPENDIX XI
CONSOLIDATED RECOMMENDATIONS OF THE 21ST SESSION OF THE WORKING PARTY ON TROPICAL TUNAS

Note: Appendix references refer to the Report of the 21st Session of the Working Party on Tropical Tunas (IOTC–2019–WPTT21–R)

Outcomes of the 3rd Technical Committee on Management Procedures

WPTT21.01 (para. 13): The WPTT **NOTED** that the work of the TCAC and TCMP are related; in particular, the outcomes of the deliberations of the TCAC, in relation to the distribution of allocated catches among gear types, will directly influence the predicted performance of management procedures being evaluated by the TCMP. As such the WPTT **RECOMMENDED** that the Commission ensure that these two Technical Committees are well coordinated and that communication between them is assured.

Review of the statistical data available for skipjack tuna

WPTT21.02 (para. 158): The WPTT **EXPRESSED CONCERN** over this consistent increase in FAD associated catch, in particular rapid increase in catches of juvenile yellowfin and bigeye which may hinder the rebuilding of exploited species and **RECOMMENDED** further evaluation of his issue and, where necessary, the identification of which alternative options could be implemented to avoid such adverse impacts on the stock.

Preliminary Indian Ocean yellowfin tuna stock assessment using SS3

WPTT21.03 (para. 218): An extra preparatory meeting may be required well in advance of the assessment, In this context, WPTT **ACKNOWLEDGED** that the procedure of how assessment are conducted needs to be restructured. WPTT **RECOMMENDED** that a data preparation meeting is scheduled well in advance of the assessment meeting so that the assessment meeting can focus on model configuration, diagnostics and advice only, and that data issues should not be reopened at the assessment meeting. This will also allow intersessional work between the data meeting and the assessment meeting to be conducted.

WPTT21.04 (para. 219): The WPTT **NOTED** that there is some model sensitivity to the choice of method used for weighting different data series and the time period in which the recruitment deviates are active. An investigation was undertaken during the WPTT, but the results were insufficiently conclusive to change the structure of the models included in the assessment grid. However, the WPTT **RECOMMENDED** that more intersessional work should be conducted, especially after the revision of the length compositions.

Outcomes of the 2nd joint tuna RFMO FAD Working Group meeting

WPTT21.05 (para. 261): The WPTT **NOTED** that there was little time to discuss FAD issues comprehensively during the WPTT meeting, but these issues are recognised as being of critical importance to the Commission (as acknowledged by the adoption of Rec 19/02). The WPTT therefore **RECOMMENDED** that the IOTC FAD Working Group, which to date has met only once, be reactivated with a clear mandate to discuss IOTC FAD issues.

Revision of the WPTT Program of Work (2020–2024)

WPTT21.06 (paras. 266): The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2020-2024), as provided at Appendix IX.

Review of the draft, and adoption of the report of the 20th session of the WPTT

WPTT21.07 (para. 273): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT20, provided at Appendix XI, 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 2019 (**Figure.14**):

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

APPENDIX XII
STATEMENT BY MAURITIUS

The participant from the Republic of Mauritius reiterates the position conveyed in the statements made by the Republic of Mauritius at the 23rd session of the Indian Ocean Tuna Commission meeting and contained in report 'IOTC-2019-S23-R' in Appendix II.