Report of the 22nd Session of the IOTC Working Party on Tropical Tunas, Stock Assessment Meeting

Virtual Meeting, 19 - 23 October 2020

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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_0	The estimate of the unfished spawning stock biomass
B_{curr}	The estimate of current spawning stock biomass
B_{MSY}	Biomass which produces MSY
B_{thresh}	Threshold level, the percentage of B0 below which reductions in fishing mortality are required
CE	Catch and effort
CI	Confidence Interval
C_{max}	Maximum catch limit
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.
D_{max}	Maximum change in catch limit
EEZ	Exclusive Economic Zone
ENSO	El Niño–Southern Oscillation
E_{targ}	The estimate of the equilibrium exploitation rate associated with sustaining the stock at B_{targ}.
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
I_{max}	Maximum fishing intensity
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 22nd Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT), Stock Assessment Meeting was held online using the Microsoft Teams online platform from 19 - 23 October 2020. The meeting was opened by the Chairperson, Dr Gorka Merino (EU, Spain) who welcomed participants and Vice-Chair, Dr M. Shiham Adam (IPNLF). A total of 111 participants attended the Session (cf. 68 in 2019, 57 in 2018, and 49 in 2017). The list of participants is provided at Appendix I.

The following are the recommendations from the WPTT22 to the Scientific Committee, which are provided at Appendix XI.

Stock Assessment Result

WPTT22.01 (para. 37): The WPTT **RECOMMENDED** additional analyses and a workshop, to further progress CPUE standardization efforts, evaluate evidence related to CPUE catchability trends, and make specific recommendations for time series and assumptions to use in future assessments and Operating Model (OM) conditioning.

Revision of the WPTT Program of Work (2021–2025)

WPTT22.02 (paras. 159): The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2021–2025), as provided in Appendix IX.

Date and place of the 23rd and 24th Sessions of the WPTT (Chair and IOTC Secretariat)

WPTT22.03 (paras. 162): The WPTT **NOTED** that the global Covid-19 pandemic has resulted in international travel being almost impossible and with no clear end to the pandemic in sight, it was impossible to finalise arrangements for the meeting in 2021. The Secretariat will continue to liaise with CPCs to determine their interest in hosting these meetings in the future when this once again becomes feasible. The WPTT **RECOMMENDED** the SC consider late October 2021 as a preferred time period to hold the WPTT22 Assessment meeting in 2021 with a Data Preparatory meeting to be held in the first half of 2021 to prepare for the YFT assessment.

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

WPTT22.04 (para. 164): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT22, 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 2020 (Figure 2):

- 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		2012	2013	2014	2015	2016	2017	2018	2019	2020	Advice to the Commission
Bigeye tuna *Thunnus obesus*	Catch in 2019 (MT) Average catch 2015–2019 (MT) MSY (1,000 MT) (80% CI) F_{MSY} (80% CI) SB_{MSY} (1,000 MT) (80% CI) F_{2018} / F_{MSY} (80% CI) SB_{2018} / SB_{MSY} (80% CI) SB_{2018} / SB_0 (80% CI)	73,165* 88,303* 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%**		No new stock assessment was conducted in 2020 and so the advice is based on the 2019 assessment. The reported stock status is based on the SS3 model formulation using a grid of 18 model configurations designed to capture the uncertainty on stock recruitment relationship, the influence of tagging information and selectivity of longline fleets. The stock status determination changed qualitatively in 2019 to **not overfished** but **subject to overfishing**. If catches remain at current levels there is a risk of breaching MSY reference points with 58.9% and 60.8% probability in 2021 and 2028. Reduced catches of at least 10% from current levels will likely reduce the probabilities of breaching reference levels to 49.1% in 2028. Continued monitoring and improvement in data collection, reporting and analyses is required to reduce the uncertainty in assessments. <Click here for full stock status summary>
Skipjack tuna *Katsuwonus pelamis*	Catch in 2019 (MT): Average catch 2015-2019 (MT): $C_{40\%SSB0}$ (MT): $C_{2019} / C_{40\%SSB0}$ (MT): $E_{40\%SSB0}$ (MT)***: $E_{2019} / E_{40\%SSB0}$ SSB_0 (MT) SSB_{2019} (MT) $SSB_{40\%SSB0}$ (MT) $SSB_{20\%SSB0}$ (MT) SSB_{2019} / SSB_0 $SSB_{2019} / SSB_{40\%SSB0}$ SSB_{2019} / SSB_{MSY}	547,248 506,555 535,964 (461,995–674,536) 1.02(0.81–1.18) 0.59 (0.53–0.66) 0.92 (0.67-1.21) 1,992,089 (1,691,710–2,547,087) 870,461 (660,411–1,253,181) 794,310 (672,825–1,019,056) 397,155 (336,412–509,528) 0.45 (0.38-0.5) 1.11 (0.95-1.29) 1.99 (1.47-2.63)						**47%** **			**60%** **	A new stock assessment was carried out for skipjack tuna in 2020 using Stock Synthesis with data up to 2019. The outcome of the 2020 stock assessment model does not differ substantially from the previous assessment (2017) despite the large catches recorded in the period 2018-2019, which exceeded the catch limits established in 2017 for this period. The final overall estimate of stock status indicates that the stock is above the adopted target for this stock and that the current exploitation rate is just below the target. Also, the models estimate that the spawning biomass remains above its SSB_{MSY} and the fishing mortality remains below E_{MSY} (E is the annual harvest rate) with very high probability. Over the history of the fishery, biomass has been well above the adopted limit reference point (0.2*SSB_0). The recent catches have been within the range of estimated target yield. Current spawning stock biomass relative to unexploited levels is estimated at 45%. Thus, on the weight-of-evidence available in 2020, the skipjack tuna stock is determined to be: to (i) **not overfished** (SSB2019>SSB40%SSB0); and (ii) **not subject to overfishing** (E2019<E40%SSB0).

	MSY (MT) E_{2019} / E_{MSY}	601,088 (500,131–767,012) 0.48 (0.35-0.81)										The catch limit will be calculated applying the HCR specified in Resolution 16/02 for the SC Meeting. The Commission needs to ensure that catches of skipjack tuna in the 2021–2023 period do not exceed the agreed limit. <Click here for full stock status summary>
Yellowfin tuna *Thunnus albacares*	Catch in 2019 (MT) Average catch 2015–2019 (MT) MSY (1000 MT) (plausible range) F_{MSY} (plausible range) SB_{MSY} (1,000 MT) (plausible range) F_{2017} / F_{MSY} (plausible range) SB_{2017}/ SB_{MSY} (plausible range) SB_{2017} / SB_0 (plausible range)	427,240* 424,104* 403 (339–436) 0.15 (0.13–0.17) 1069 (789–1387) 1.20 (1.00–1.71) 0.83 (0.74–0.97) 0.30 (n.a.–n.a.)				**94%** **	**68%** **		**94%** **			No new stock assessment was carried out for yellowfin tuna in 2020. New management advice could also 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.** 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.

***E is the annual harvest rate

1. Opening of the Meeting

1. The 22nd Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT), Stock Assessment Meeting was held online using the Microsoft Teams online platform from 19 - 23 October 2020. The meeting was opened by the Chairperson, Dr Gorka Merino (EU, Spain) who welcomed participants and Vice-Chair, Dr M. Shiham Adam (IPNLF). A total of 111 participants attended the Session (cf. 68 in 2019, 57 in 2018, and 49 in 2017). 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 WPTT22(AS) are listed in Appendix III.
3. The participant from Mauritius reiterated the positions conveyed in the statements made by the Republic of Mauritius at the 23rd Session of the Commission meeting and contained in the report 'IOTC-2019-S23-R_Rev1[E]. The participant from France OT reserved the right to respond. The WPTT **NOTED** that in the future, position statements should not be made at WP meetings, but rather at higher level forums such as the SC and Commission. .

3. Update of Any New Data Available at the Secretariat for Tropical Tuna Species Since the Data Preparatory Meeting

4. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–03 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 on Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPCs), for the period 1950–2019. 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 mark-recapture (tagging) data, and a summary of supporting information for the WPTT is provided in Appendix IV.
5. The WPTT **ACKNOWLEDGED** that the information presented in this paper includes official data for 2019 (submitted by most CPCs by the deadline of June 30th 2020) that were not originally available during the data preparatory meeting held in June 2020.
6. The WPTT **NOTED** again that the revision of Pakistan catch series substantially affects the catch levels of yellowfin tuna from 2000 onwards, with yearly differences ranging from 8,000 to 20,000 MT. Skipjack tuna is only marginally affected by the revision while bigeye tuna continues to be not reported at all by the fishery.
7. The WPTT **NOTED** an 8% decrease in total catch levels for all tropical tuna species between 2018 and 2019, and that bigeye tuna and skipjack tuna are the species for which the highest decrease is recorded, with yellowfin tuna catches remaining almost stable compared to previous year.
8. The WPTT **NOTED** that catches of tropical tunas on free-schools have reached an all-time low in 2018, to the point that 99% of skipjack catches were recorded on log school during that year, and **ACKNOWLEDGED** that in 2019 a relatively marked increase in free-school catches becomes evident.
9. The WPTT **NOTED** that the species composition of reported catches for the EU,Spain purse seine fishery for 2019 shows the proportion of each tropical tuna species as being more consistent with what reported in years prior to 2018 for that fishery (as well as the other components of the western Indian Ocean purse seine fishery, namely the fleets from Seychelles, Mauritius and EU,France).

10. The WPTT **RECALLED** that no documentation has yet been provided to the IOTC Secretariat to describe the method used to estimate the species composition of the EU,Spain purse seine fishery in 2018 despite the major change reported in species composition for that year and the concerns raised at the 21st session of the WPTT, the 15th session of the WPDCS in 2019 and at the WPTT Data Preparatory meeting in 2020.

11. **NOTING** that the EU scientists are currently analysing and assessing the methodology used to process the EU purse seine fisheries data and that this activity requires some time as adjustments in the method are expected to have some impact on the historical time series, the WPTT **REQUESTED** the EU to present the progress and findings of the activity to the next sessions of the WPTT and/or WPDCS.

12. The WPTT **NOTED** some potential anomalies in the recently provided (2017-2019) size-frequency data for yellowfin tuna as reported by the purse seine fisheries of EU,Spain, EU,France and Seychelles, with either a very large number of small individual recorded in free-school samples (EU,Spain 2019, Seychelles 2017-2019) or a higher than usual number of large individuals recorded in log-school samples (EU,Spain 2018, EU,France 2019), and **ACKNOWLEDGED** that this information comes from a mix of "raw" (unraised) and "estimated" (raised to total catches) size frequency data which might potentially have an impact on future assessment of the species.

13. The WPTT **NOTED** that there are no specific requirements in the IOTC Resolution 15/02 about whether the size data should be submitted to the Secretariat in raised and unraised format and **ENCOURAGED** all CPCs to provide a description of the methodology used for generating the size data as described in IOTC Res. 15/02 as such description currently lacks for most CPCs.

14. The WPTT **RECALLED** that the major uncertainties existing in the catch, effort, and size data sets available for some fisheries (Appendix V) may impair the quality of the assessment of the stock status and **ENCOURAGED** all CPCs to report their data in accordance with Resolution 15/02, **NOTING** 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.

15. 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.

16. Furthermore, the WPTT **RECALLED** that due to the CoViD-19 pandemic crisis, almost no size sample has been collected since March 2020 in Port Victoria for the Seychelles and EU purse seine fleets, so the processing for 2020 purse seine data might prove to be particularly difficult and require estimation procedures relying on alternative strata (substitution scheme), and that this situation might be common to other fleets and fisheries as well.

17. The WPTT **ACKNOWLEDGED** that the uncertainty in the catches described by poor quality scores is currently not accounted for in the stock assessments and that the production of alternative catch series to account for bias through sensitivity runs as well as definition of confidence intervals to describe the extent of the uncertainty is very difficult in the absence of ancillary information.

18. The WPTT **NOTED** that the most recent version of the Stock Synthesis modelling platform can account for some variability in the landings and that a standard deviation has been fixed throughout the whole time series in the case of yellowfin tuna but that it could be set to vary with time. The WPTT further **NOTED** that catch is one of the fundamental inputs anchoring the assessment, such that it is doubtful whether model assumptions and other data should be expected to be informative about the catch series uncertainty.

19. The WPTT **NOTED** that the extent and temporal variability to be considered in the landings could be addressed during future Data Preparatory meetings and the impact of historical reporting

uncertainty could be explored with MSE or throughout the assessment, for example with alternative catch history time series derived using different methods..

4. Skipjack Stock Assessment

4.1 Review any New Information on Skipjack Biology, Stock Structure, Fisheries and Associated Environmental Data Since the Data Preparatory Meeting

20. WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–08 on Reproductive Biology of Skipjack Tuna (*Katsuwonus pelamis*) in Indonesian Exclusive Economic Zone, including the following abstract:

> *"Skipjack tuna (Katsuwonus pelamis) is a tropical tuna species and has been a historically exploited in the south and western part of Indonesia waters (south eastern Indian Ocean). The objective of this study was to determine length at first maturity (Lm50) of female skipjack obtained from area south of Bali. Samples were collected from April to September 2018, and April to October 2019. A total of 230 ovaries with length ranged between 33-72 cm FL. Fresh ovaries were immediately fixed using a 10% buffer-formalin solution then histologically prepared using the paraffin method and HE staining (Harris-Haemotoxylin and Eosin). Ovaries containing advanced yolked, migratory nucleus or hydrated oocytes and/or POFs were classed as mature, and ovaries with unyolked or early yolked oocytes as the MAGO but with maturity markers present were classed as mature as well. Ovaries containing unyolked and early yolked oocytes as the MAGO but no POFs, atresia or maturity markers were classed as immature. Size at first maturity (Lm50) of female skipjack in Indian Ocean southern Bali was 42 cm FL (41 - 42.9 cm FL)."*

21. The WPTT **NOTED** that all fish sampled during this study came from handline fisheries around Bali which all only fish around FADs.

4.2 Update on the Nominal and Standardised CPUE Indices Presented at the Data Preparatory Meeting

22. The WPTT **NOTED** paper IOTC–2020–WPTT22(DP)–INF05 which provided an addendum to the Paper IOTC-2020-WPTT22(DP)-11 (Bayesian Skipjack and Yellowfin Tuna CPUE Standardisation Model for Maldives Pole and Line 1970-2019) presented at the IOTC–2020–WPTT22(DP) Meeting.

23. The WPTT **THANKED** the authors for this updated analysis and NOTED its usefulness for inclusion in the skipjack assessment.

4.3 Stock Assessment Result

24. The WPTT **NOTED** paper IOTC-2020-WPTT22(AS)-10_Rev1 which provided a stock assessment of skipjack tuna in the Indian Ocean using Stock Synthesis III, including the abstract:

> *"This report presents a preliminary stock assessment for Indian Ocean Skipjack tuna (Katsuwonus pelamis) using Stock Synthesis 3 (SS3). The assessment uses a spatially aggregated and seasonally structured model that integrates several sources of fisheries and biological data. An alternative, spatially explicit model is also considered in the final model ensemble. The assessment model covers the period 1950–2019 and represents an update and revision of the 2017 assessment model with the inclusion of updated CPUE indices, and a revised fishery structure. A range of sensitivity models are presented to explore the impact of key data sets and model assumptions (See paper for full abstract)."*

25. The WPTT **THANKED** the author for a clear presentation and **NOTED** that the preliminary assessment addressed many of the key uncertainties and fit most of the key features of the data.

26. The WPTT **NOTED** that the assessment separated out the gillnet, handline, and longline fisheries (which were amalgamated into one composite fishery in the previous assessment) to reduce the bias in the selectivity estimates as these fisheries have distinctive size compositions.
27. The WPTT **NOTED** that the extremely low recovery rate of data from small-scale tagging by the purse seine fishery (possibly due to low mixing or high post release tag mortality) is likely to induce bias into the model estimates and **AGREED** that the final assessment grid dropped the option of including the small-scale tagging data.
28. The WPTT **NOTED** that the assessment failed to fit the very large skipjack tunas reported in the longline fishery as reported in previous IOTC assessments and in other oceans. This issue is thought to arise from a limitation in the growth model rather than a data reporting bias. These very large fish represent a negligible proportion of the total catch and the WPTT **NOTED** that they are assumed to represent a trivial proportion of the total population, that can be ignored in the stock assessment advice.
29. The WPTT **NOTED** that there was a systematic lack of fitting to tagging data in the first quarter following a 3-quarter mixing period, and **AGREED** dropping this option from the final grid, while retaining the 4-quarter mixing option, which should be less biased.
30. The WPTT **EXAMINED** likelihood profiles on the natural mortality vector M in the reference case and did not find strong justification for including an alternative M option in the assessment grid.
31. The WPTT **NOTED** that both the PL and PSLS CPUE series have potential standardization problems, including limited spatial extent in the PL CPUE and potential hyperstability issues in the PSLS CPUE and no consensus was reached in favouring one over the other. Trends in the two series conflict somewhat when included in a single area model, but the conflict is substantially reduced in the two-area structure. The WPTT **ADVISED** maintaining both spatial structure options with equal balance in the final grid.
32. The WPTT **NOTED** that the preliminary grid assumed stationary catchability for the PSLS CPUE, even though the standardized CPUE trend was very similar to the nominal. The group **RECALLED** the WPTT20 (2018) statement "[…] in the absence of other information, catchability trends of at least 1.25% per year should be used as the minimum in the next assessment of skipjack tuna" (para 135). This recommendation was based on a proof-of-concept analysis that estimated PS catchability from bigeye and yellowfin tuna assessments that were modified to include PSLS CPUE in an uninformative way (IOTC-2018-WPTT20-32). The WPTT **AGREED** to include PSLS catchability trends of 0 and 1.25% per year in the final grid.
33. The WPTT **NOTED** that a suite of model diagnostics that describe model internal consistency and hindcasting skill were slightly more supportive of the PSLS CPUE catchability trend.
34. The WPTT **NOTED** that the total catches exceeded the HCR recommendation in the past 3 years, during which CPUE also increased. The WPTT **NOTED** that skipjack CPUE trends and abundance estimates show large multi-year oscillations that appear to correlate with environmental conditions, notably chlorophyll-a in the western equatorial Indian Ocean. The WPTT further **NOTED** that recent high catches may not be sustainable if oceanographic conditions revert to average, or low productivity conditions.
35. The WPTT **NOTED** that the PSLS catchability trend assumption was much less important than the tag data weighting option in influencing the stock status estimates in the final assessment grid and that the full tag weighting was associated with the most pessimistic outcomes.
36. While the PSLS catchability trend option from the grid was not the major driver of the stock status, the WPTT **NOTED** that the participants did not reach a consensus on how this assumption should be represented in the assessment:
    - Some participants felt that the 0% per year PSLS catchability option was sufficient because:

    - The PSLS CPUE standardization analysis should have removed the catchability trend;
    - Acoustic FAD uptake was very rapid in the Spanish fleet with almost 100% usage since 2013;
    - The acoustic FAD technology has not improved since ~2014;
    - The number of FADs deployed per vessel has been decreasing in recent years as has the use of support vessels;
    - The independent echosounder indices in the most recent years resemble the large PSLS CPUE increase, and should be given additional consideration in the future, as they operate consistently over time.
- The opposing participants thought that the 1.25% per year catchability trend should have been adopted as a minimum, because:
    - The PSLS standardized CPUE series closely resembles the nominal CPUE series, despite decades of technological development in the fishery. Furthermore, it is not theoretically clear why catch per set should be interpreted analogously to catch per unit effort, since there is no link to search effort, and a set would not be undertaken without prior acoustic evidence of the presence of fish;
    - Studies on the French fleet indicate a 10% increase in catch per set associated with echosounder use, and 1.7 – 4.0 % increase in efficiency arising from fishing owned FOBs (and this practice has increased in recent years);
    - The 2018 analysis (IOTC-2018-WPTT20-32) confirmed that the standardized 2018 PSLS CPUE (which closely resembles the most recent series) must have long term increasing catchability trends to be internally consistent with the bigeye and yellowfin tuna assessments at the time. 1.25% per year was an initial estimate derived from yellowfin, while the equivalent estimate for bigeye was 4.1%. These increasing catchability trends are qualitatively consistent with similar results from the Pacific Ocean;
    - If one accepts the BET and YFT assessments and the analysis outlined in IOTC-2018-WPTT20-32, but assumes that standardized PSLS catchability has not changed, it implies that the LL fisheries must have become increasingly less effective over the past several decades. The WPTT and WPM have endorsed 1% per year increasing catchability trends in the LL fisheries as plausible assumptions in bigeye and yellowfin MSE Operating Models, due to factors that the standardization is not expected to be able to address. If correct, this would imply an even greater catchability trend in the PSLS fishery;
    - The catchability trend should have been introduced from the start of the time series (~1990), rather than 1995 as was requested from the WPTT in 2017 and repeated in 2020.

37. The WPTT **RECOMMENDED** additional analyses and a workshop, to further progress CPUE standardization efforts, evaluate evidence related to CPUE catchability trends, and make specific recommendations for time series and assumptions to use in future assessments and Operating Model (OM) conditioning.

38. The WPTT **NOTED** the utility of objectively incorporating expert opinion on the degree of increase in fishing efficiency, similar to what has been done for the Maldives PL CPUE standardization. Given that certain Purse seine fleets are undergoing MSC assessment, such workshops may easily be conducted. The Group **ENCOURAGED** relevant CPC scientists to pursue such an approach in the future

39. The WPTT **ADOPTED** the final assessment grid as defined in Table 2.

Table 2. Final skipjack tuna assessment model grid used to provide stock assessment advice in 2020 and run the Harvest Control Rule

Model options	**Description**
Spatial structure	io – whole Indian Ocean one area model
	io2 – East and western Indian Ocean two area model
Steepness	h70 – Stock-recruitment steepness parameter 0.7
	h80 – Stock-recruitment steepness parameter 0.8
	h90 – Stock-recruitment steepness parameter 0.9
Tag weighting	TagLamda01 – Tag lambda = 0.1 for both components of tag likelihood
	TagLamda1 – Tag lambda = 1 for both components of tag likelihood
PSLS catchability	q0 – 0% catchability change
	q1 – 1.25% catchability change per annum from 1995 to 2019

40. The WPTT **NOTED** the key assessment results for Stock Synthesis (SS3) as shown below (Table 3; Fig. 1) for which estimates from the final assessment model grid are reported.

Table 3. Estimated status of Indian Ocean skipjack tuna from the final model ensemble (median and 80% confidence interval)

Catch in 2019 (MT)	547,248
Average catch 2015–2019 (MT)	506,555
$Yield_{40\%SSB}$ (MT)	535,964 (461,995–674,536)
MSY (MT)	601,088 (500,131–767,012)
$F_{40\%SSB}$	0.59 (0.53–0.66)
SB_0 (MT)	1,992,089 (1,691,710–2,547,087)

SB_{2019} (MT)	870,461 (660,411–1,253,181)
$SB_{40\%SB0}$ (MT)	794,310 (672,825–1,019,056)
$SB_{20\%SB0}$ (MT)	397,155 (336,412–509,528)
SB_{2019}/SB_0	0.45 (0.38-0.5)
SB_{2019} / $SB_{40\%SB0}$	1.11 (0.95-1.29)
SB_{2019} / SB_{MSY}	1.99 (1.47-2.63)
F_{2019} / $F_{40\%SB0}$	0.92 (0.67-1.21)
F_{2019} / F_{MSY}	0.48 (0.35-0.81)

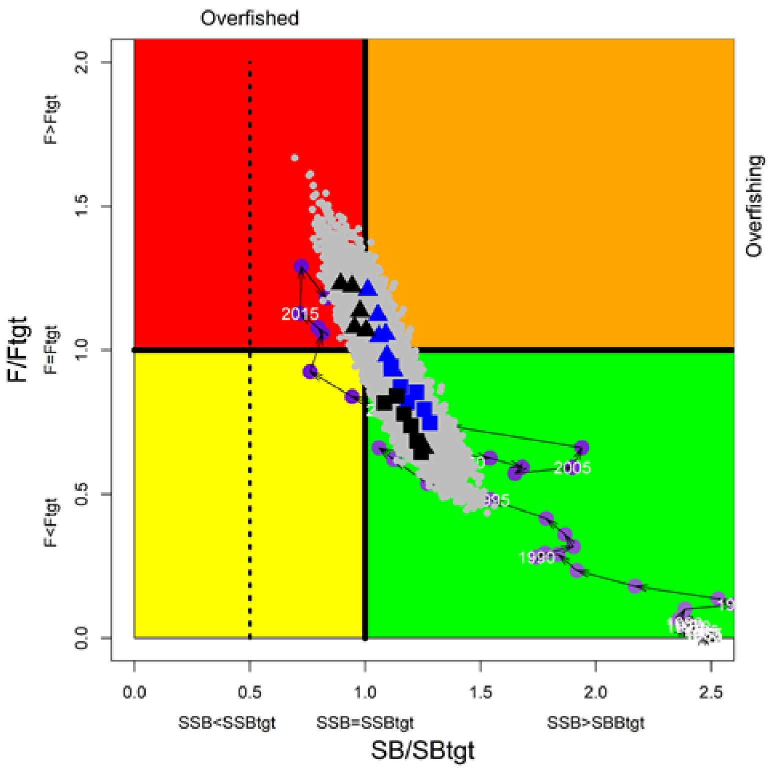

Fig. 1. Current stock status of Indian Ocean skipjack tuna, relative to $SB_{40\%SSB0}$ (x-axis) and $F_{40\%SSB0}$ (y-axis) reference points for the final assessment grid, as well as time series of historical stock status for the reference model (io_h80_q1_tagLamda1). Symbols represent Maximum Posterior Density (MPD) estimates from individual models (blue, *q0*; black, *q1*; triangle, *tagLamda1*; square, *tagLamda01*). Grey dots represent

uncertainty from individual models. The dashed lines represent limit reference points for IO skipjack (SSB_{lim} = $SSB_{20\%}SSB_0$).

4.4 *Selection of Stock Status Indicators for skipjack*

41.The WPTT **AGREED** that the final grid of 24 model runs from the SS3 stock assessment would be used for the development of management advice for the Scientific Committee's consideration.

42.The WPTT **AGREED** on presenting results disaggregated for each factor of the grid when being presented to the SC.

43.The WPTT briefly **DISCUSSED** the best way to report on skipjack stock status. Skipjack is above the Target Reference Point but the probability associated to being overfished remains high. This is because the plot used to represent stock status has been adapted from MSY-based Kobe plots. The WPTT **NOTED** that it seems incompatible to maintain the stock fluctuating around the biomass TRP with high probability while achieving a low probability of not being overfished, if this is defined as being below the TRP. Currently, the stock is considered at values well above the SSB_{MSY} but the definition used to define the "overfished" stock is to be below the TRP. The WPTT **DISCUSSED** if a different representation would be more suitable for this stock. In this regard, the WPTT **AGREED** that the Ad Hoc Reference Point Working Group should continue its efforts to identify more appropriate stock status descriptors.

44.The WPTT **AGREED** to add a dashed line to the Kobe plot indicating the Limit Reference Point.

45.The WPTT **ADOPTED** the management advice developed for skipjack tuna as provided in the draft resource stock status summary and **REQUESTED** that the IOTC Secretariat update the draft stock status summary for skipjack tuna with the latest 2019 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

4.5 UPDATE ON MANAGEMENT STRATEGY EVALUATION PROGRESS

46.The WPTT **NOTED** paper IOTC-2020-WPM11-9, which describes the potential use of a biomass dynamic model for use in future skipjack Management Procedures, including the following abstract excerpt:

> *"An MP includes the assessment or estimation method on which the HCR is based, as well as the data inputs and the HCR itself. To be fully specified therefore, a suitable assessment method is required: one that is capable of forming the basis for implementation of the HCR but simple enough to simulation test. A biomass dynamic model could fulfill these requirements. Developing such a model provides the motivation and basis for the current work. (See paper for full abstract)"*

47.The WPTT **NOTED** paper IOTC-2020-WPM11-10, which describes progress in the development of a new Operating Model for evaluating candidate skipjack tuna Management Procedures, including the following abstract excerpt:

> *"An MP includes the assessment or estimation method on which the HCR is based, as well as the data inputs and the HCR itself. Simulation evaluation requires an operating model (OM), to describe dynamics of the resource and how it responds to harvesting, plus a computational framework that will generate artificial observations, apply the MP to estimate a management recommendation, and then simulate the implementation of that*

recommendation in a closed loop forward projection. The current report describes initial developments of such a framework, specifically implementing Stock Synthesis III as the OM. Closed loop simulation evaluations of the current HCR are performed so as to demonstrate the framework's functionality. (See paper for full abstract)"

48.The WPTT **DISCUSSED** the role of stock assessment within the context of an adopted Management Procedure (MP), **NOTING** that:

- The proposed triennial application of an MP should be a simple mechanical process relative to a full stock assessment, because all of the analyses and data inputs are pre-defined (the requisite MP data analyses do need to be updated);
- The MP is adopted within a broader management framework of meta-rules that includes ongoing monitoring for "exceptional circumstances", i.e. evidence for circumstances beyond which the MP was tested (e.g. a sustained recruitment failure, or loss of essential input data, evidence that OM may have failed to capture an important population dynamics feature), in which case the MP may be suspended, retested and revised;
- There is also a pre-specified plan for MP performance review (e.g. every 5-10 years), in which a full stock assessment would be expected, to evaluate whether the MP is meeting the original or revised management objectives. This might initiate a new cycle of OM and MP revision.

5. OTHER TROPICAL TUNAS

49.The WPTT **NOTED** a suite of papers produced by the Stock Structure Project for IOTC species and sharks (PSTBS-IO) which was completed in May 2020, combining next generation sequencing techniques (genetics) and otolith microchemistry. Results for bigeye, skipjack and yellowfin tunas were presented sequentially.

50.The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–05_Rev1 on Investigating early stages of skipjack tuna (*Katsuwonus pelamis*) in the Indian Ocean using otolith chemistry, including the following abstract:

"Trace elements (Ba, Sr) and stable isotopes (δ13C and δ18O) of otoliths from young-of-year (YOY) skipjack tuna were examined to determine whether there is sufficient distinction of chemical signatures among three main nursery areas of the equatorial Indian Ocean (West, Central and East) to retrospectively determine individual´s natal origin. Higher δ 18O values in the otolith material deposited during the first fourth months of life were observed in YOY skipjack tuna captured in the western Indian Ocean nursery, but, in general, the chemical signatures of the three nursery areas largely overlapped. Random forest cross-validated classification success of fish to their nursery area was low (46%). This may suggest (1) that early life history stage skipjack tunas from the three different nursery areas lived in a chemically homogenous environment or (2) that fish moved between nursery areas in the first months of life. Our results suggest the use of these otolith signatures alone are not sufficient to understand skipjack stock structure in the Indian Ocean. Future research should explore larvae or younger skipjack tuna, ideally sampling at finer scale temporal stratification (i.e. by monsoon and year) to resolve questions regarding skipjack stock structure in the Indian Ocean."

51. The WPTT **NOTED** that, because of the large overlap in the chemical signature of the young-of-the-year skipjack tuna in the different sampling locations, it was impossible to predict the nursery origin of older individuals.

52. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–06_Rev1 on Otolith δ18O as a tracer of yellowfin tuna (*Thunnus albacares*) origin in the Indian Ocean, including the following abstract:

> *"Oxygen stable isotope in otoliths (δ 18O) was used to investigate stock structure of yellowfin tuna (Thunnus albacares) across the Indian Ocean. Differences in otolith δ 18O signatures among young of the year (YOY) yellowfin tuna were examined to determine whether there was sufficient distinction among three main nursery areas of the equatorial Indian Ocean (West, Central and East), to establish a reference isotopic signature (a baseline). The nursery origin of juvenile yellowfin (47-75 cm fork length (FL)) tuna from Reunion and Pakistan was then compared with these nursery signals. Juvenile fish from Reunion show δ18O signatures comparable with those of the nearest nursery area (West nursery), but juvenile fish from the Pakistan show distinctive δ18O composition compared to any of the nursery areas described. Therefore, samples from Pakistan were considered as an additional baseline signature for adult assignment purposes. Quadratic discriminant function analysis was used to assign adult individuals to one of the four areas in our baseline. Results indicate that western nursery was contributing the most to the fish analysed (24 adult out of 39 were predicted to this nursery) with a minor contribution from Pakistan (5 individuals). No Central or East nursery origins were detected among the adult sample. A fraction of yellowfin tuna (11 individuals) was left unclassified. This is an important first step towards understanding the mixing rates and the connectivity of yellowfin tuna in the Indian Ocean."*

53. The WPTT **NOTED** the revelation concluded by this study of the existence of a possible nursery area in the Arabian Sea (Pakistan) due to its particular chemical signature and oceanographic processes, in addition to the other nursery areas (West, Central and East).

54. The WPTT also **NOTED** that no fish from the Central or East nurseries were detected in the adult mixed samples of the three southern locations, which may imply limited movements outside this nursery areas, or movements towards feeding grounds in northern latitudes (i.e. Arabian Sea, Bay of Bengal) not sampled in this study.

55. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–07 on Co-occurrence of genetically isolated groups of skipjack tuna (*Katsuwonus pelamis*) within the Indian Ocean, including the following abstract:

> *"In order to resolve the population connectivity of skipjack (Katsuwonus pelamis) within the Indian Ocean, we analyzed thousands of genome-wide markers of individuals from a broad geographic area of the Indian Ocean, as well as from one location in the Atlantic Ocean. Our results support a complex stock structure with multiple genetically isolated populations co-occurring in most locations, and claim for additional analyses to further understand the population structure of skipjack tuna within the Indian Ocean."*

56. The WPTT **NOTED** that a differentiation exists between the North Indian Ocean and the rest of the Indian Ocean, however that mixing is occurring across the genetic groups throughout the oceanic basin.

57. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–11 on Investigating population structure of bigeye tuna in the Indian Ocean using otolith chemistry, including the following abstract excerpt:

"Natal origin and stock structure of bigeye tuna (Thunnus obesus) in the Indian Ocean were investigated using trace elements in otoliths. Otoliths were collected from (i) young of the year (YOY) bigeye caught in the west central and north east regions of the Indian Ocean, which are known to be spawning areas, and (ii) older fish in the south west and south east regions of the Indian Ocean. Otoliths were analysed by LA-ICP-MS at two points: near the core and at the edge, providing an elemental signal from material deposited while the fish were close to their spawning grounds and from material deposited while they were in or close to their capture areas, respectively. Twelve elemental isotopes were measured: Li, Na, Mg, P, K, Mn, Fe, Cu, Zn, Rb, Sr, Ba. Core and edge signatures for the same otolith were significantly different for most elements. Core signatures did not differ significantly for YOY bigeye in the west and east northern locations; this suggests that the ocean chemistry did not differ significantly between these locations. The core signatures for older fish in the west and east southern locations did not differ significantly from each other, but they did differ significantly from the core signatures observed for fish from the northern spawning locations. (See paper for full abstract)"

58. The WPTT **NOTED** that while otolith chemistry can be used as a tool to differentiate groups of fish, temporal variability in otolith elemental chemistry may confound spatial structure information.

59. The WPTT **NOTED** that the study of elemental signatures of young-of-the-year bigeye tuna in the Indian Ocean failed to retrospectively determine the natal origin of adults, with which to infer stock structure and connectivity of this species in the Indian Ocean.

60. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–12_Rev1 on Genetic population connectivity of yellowfin tuna within the Indian Ocean, including the following abstract excerpt:

"Yellowfin tuna are a high value pantropically distributed tuna species managed as a single stock within the Indian Ocean. While studies to date have not provided evidence that a revision to this single stock assumption is warranted, further exploring and understanding the level of population heterogeneity is a priority for sustainable management of these fisheries. This paper presents results from a recent investigation of population structure of yellowfin tuna using cutting-edge sequencing technology as part of a larger collaborative project "Population Structure of IOTC species and sharks of interest in the Indian Ocean (PSTBS-IO)". A total of 1206 individuals from 9 Indian Ocean areas and two outlier locations (east Atlantic Ocean and southwest Pacific Ocean) were collected. The samples consist of a mix of YoY fish and mature adults, with predominantly YoY in the equatorial regions and adult fish in the sub-tropical and temperate regions. A total of 664 samples, matched to the intended sampling design of the study, were chosen to be sequenced using DArTSeq and included in the analysis of population structure and examination of population connectivity. Model selection criteria using StockR indicate that 2 genetic groupings within the Indian Ocean are more likely than 1, with the likelihood for 1 and 3 groups being similar. (See paper for full abstract)."

61. The WPTT **NOTED** that yellowfin tuna from the Indian Ocean is genetically isolated from the Atlantic and Pacific Oceans.

62. The WPTT also **NOTED** that two genetic groupings in the Indian Ocean were most likely, with the Arabian Sea grouping showing clear differences compared to the other sites investigated. However, it was not possible to discard the assumption of three groupings, composed of two groups north of the equator and one group south of the equator.

63. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–16 on Evidence of connectivity of bigeye tuna (*Thunnus obesus*) throughout the Indian Ocean inferred from genome-wide genetic markers, including the following abstract:

> *"In order to resolve the population connectivity of bigeye tuna (Thunnus obesus) within the Indian Ocean, we analyzed thousands of genome-wide markers of individuals from a broad geographic area of the Indian Ocean as well as from locations in the Pacific and Atlantic Oceans. Our results support a single panmictic population of bigeye tuna within the Indian Ocean isolated from the Atlantic and Pacific Oceans."*

64. The WPTT **NOTED** that a strong differentiation exists between samples from the three oceans, but the results do not suggest any intra-oceanic structure within the Indian Ocean, even when including only samples from the Indian Ocean.
65. The WPTT **NOTED** that it is very difficult to determine the generational time or degree of separation of populations as this depends on many factors including the size of the populations and the length of time for which they have been separated but also that the degree of separation is generally considered to be low due to the high rates of migration.
66. The WPTT **NOTED** that if genetic differences are observed it is likely that the separate populations will act differently to each other potentially due to adaptations to environmental effects even in cases where the populations coexist spatially.
67. The WPTT **NOTED** that further work is required to fully determine the connectivity of tropical tuna populations, particularly for skipjack and yellowfin tuna, to determine whether all populations spawn together spatially or temporally.
68. Finally, as a summary for the three species, the WPTT **NOTED** the Indian Ocean can be considered as separate from the Atlantic and Pacific Oceans for fisheries management purposes, with evidence of genetic structuring within the Indian Ocean for skipjack tuna and yellowfin tuna, but not for bigeye tuna.
69. The WPTT **ACKNOWLEDGED** that additional analyses based on more samples from more years, including larvae, juveniles and adults, are needed to better match otolith early life stage signatures from older fish, to resolve the inherent complexity of the genetic structure of skipjack and yellowfin tunas within the Indian Ocean and to understand the role of ecological niches in the spatial connectivity.
70. The WPTT **THANKED** the international group of scientists who have been conducting the PSTBS-IO project and **ENCOURAGED** them to continue to provide any additional information resulting from further analyses to the WPTT in the future.
71. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–09 on a Plan of trilateral collaborative study among Japan, Korea and Taiwan,China for producing joint abundance index with longline fisheries data for the tropical tuna species in the Indian Ocean, including the following abstract:

> *"Three distant-water tuna longline fleets, Japan, Korea and Taiwan,China have started a collaborative study for improving the joint abundance index using integrated fishery data of these fleets for tropical tuna species in the Indian and Atlantic Oceans. In addition to some preliminary steps to confirm similarity and dissimilarity of fishery operation, nominal CPUE, length frequency and spatio-temporal coverage, we planned three tasks to produce the joint CPUE; 1) investigation of better approaches to account for changes in target within each country; 2) analyses using conventional regression models with geographical, environmental and fishery (including target) information; and 3) analysis using an advanced spatio-*

temporal model (e.g. VAST) for developing abundance indices with additional consideration of spatio-temporal correlations. Although we have started with some coding work for bigeye tuna in the Atlantic Ocean, we will also apply the methods to yellowfin tuna in the Indian Ocean in a parallel way. A final set of results on the IO yellowfin tuna will be submitted to the Working Party on Methods and Working Party on Tropical Tuna next year for use as inputs for the update of its stock assessment. The work can also be extended for the IO albacore for its future stock assessment."

72. The WPTT **RECALLED** that this work is important as future assessments will be based on these indices.
73. The WPTT **ENCOURAGED** the authors to provide a small ensemble of CPUE series that encompass relative abundance index uncertainties for inclusion in future MSE work (e.g. potentially including species clustering as an alternative method for accounting for targeting, alternative regional-scaling factors, etc.).
74. The WPTT further **NOTED** that the authors intend to continue with previous methodologies for calculating CPUE indices for consistency but they will also look for ways to improve CPUE quality.
75. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–13 on an Improved version of the tropical tuna treatment process: new perspectives for catch estimates of tropical purse seine fishery, including the following abstract:

"The Tropical Tuna Treatment is a process created at the end of the 90s by EU scientists to estimate catch of the tropical tuna purse seine fishery, for which logbook declarations were known biased. His main purpose is to provide the best estimations for nominal catch and catch effort spatially represented, to the RFMOs. However, the evolution of fishing practices and the extension of the fishing grounds have challenged the T3 methodology in some parts of it processing. Thus, the used of too large spatio-temporal sampling strata was specifically pointed out as the major cause of biases in the catch estimated. This paper presents the new methodology developed to fix this issue and implications on the output estimations compared to the previous version and logbook declarations. Finally, future improvements were discussed."

76. The WPTT **CONGRATULATED** the authors for the progress made on the improvements of the method that reduces some of the sharp spatial changes in species composition due to boundary effects (occurring due to the previous post-stratification) and provides estimates of confidence intervals on the catch, although those do not account for all sources of uncertainty.
77. The WPTT **NOTED** that the discrepancies between the species composition reported in the purse seiners' logbooks and derived from the samples have been reduced over time, particularly in recent years, likely due to improved efforts in reporting by fishermen in the context of the monitoring of the yellowfin tuna catch limit.
78. The WPTT **NOTED** that the length-weight relationship data are thought to be more up to date in the Indian Ocean compared with the Atlantic Ocean and that more standardized data collection processes are required as the period of validity for these data and relationships are not well known. The WPTT **NOTED** the intention of the authors to investigate this for both IOTC and ICCAT.
79. The WPTT **NOTED** that in the past there have been issues related to the stratification of the processing based on weight categories (<10 kg and >10 kg) due to the reliance on data from logbooks that were not thought to be very reliable for some components of the purse seine fishery, and that this introduced some large bias in the results.

80. The WPTT **NOTED** that the new version still includes the stratification in weight categories but that future work, based in particular on the collection of new data (e.g. super-sampling operations), will explore the best approach to improve the estimates in relation with the accuracy of the data available.

81. The WPTT **NOTED** the necessity to re-estimate the historical series of purse seine catch when the new version of T3 is finalized and validated to ensure the consistency and continuity of the catch series for the stock assessments.

82. The WPTT **ACKNOWLEDGED** the potential issues in regulation compliance associated with the expected changes in catch estimates and **ENCOURAGED** the authors to further investigate these consequences.

83. The WPTT **NOTED** that the R scripts for this work developed by IRD are publicly available online (https://github.com/OB7-IRD/t3) and have since been discussed with Spain and Seychelles in technical meetings, and that data will be shared to test the behaviour of the model.

84. The WPTT **ENCOURAGED** the participation by all scientists interested in this work including at a planned workshop on T3 development.

85. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–14 discussing: Are sets on tropical tuna not associated with floating objects really free schools sets? Implications on fishing effort, including the following abstract:

> *"Since starting up the Spanish purse seiner's fishery in the Indian Ocean, the concentration of tuna schools under natural floating objects adrift has been exploited. Thus, two different mode sets are performed: associated school sets (sets on Floating Objects or FOBs), and free school sets (Free sets). The number of sets on FOBs has been consistently increasing from the early period, and associated with this, the space-time frame between FOB sets performed is rapidly approaching. For this reason, we wonder if still an exhaustive searching and targeting fisheries is performed on free schools, or on the contrary, the current sets on free schools are opportunistic because the vessels are focusing on their own FADs (Fishing Aggregating Devices). Thus, we performed a relationship between the possible causal effect of the dFADs (drifting FADs) abundance per 5x5 grid, quarter and year on the number of total sets per 5x5 grid, quarter and year, on YFT non-associated. We obtained significant and explicative models, which established a direct relationship between the dFADs abundance per 5x5 grid, quarter and year on the number of total sets per 5x5 grid, quarter and year, on YFT non-associated. In this context, we hypothesize that the mentioned fishery's effort revolves mainly around their own dFADs, and if among them they observe a free school of YFT, the fishermen will fish on it. For the future it may be interesting to extend this analysis to the distribution of size, mainly in the case of YFT."*

86. The WPTT **NOTED** that the hypothesis of the study is that the massive increase in drifting FADs in the western Indian Ocean may have resulted in a change in fishermen behaviour who would not target free-swimming schools but mostly catch them when in transition between FADs.

87. The WPTT was **INFORMED** that similar work has been recently conducted in the Pacific Ocean and preliminary results indicated that most free schools could still be considered to be associated with FADs, due to the large number of FADs in the surroundings.

88. The WPTT **RECALLED** the hypothesis that a higher density of drifting FADs occurring at sea may cause a lesser occurrence of free schools, an assumption already discussed at the WPTT19 and termed as "school fragmentation".

89. The WPTT **NOTED** that the size distribution of the fish in the schools, which was not considered in the study, could provide a fair indication of the school category, knowing that free school fishes are generally larger in size than those associated with drifting FADs.

90. The WPTT **NOTED** that the inclusion of additional factors in the model could be useful to identify other reasons to explain the observed pattern and **ENCOURAGED** the authors to continue the work and extend the analyses.

91. The WPTT **NOTED** the unusual size distribution reported by EU,Spain from sets on free schools and considered that this may be a consequence of the results shown in this paper. The WPTT further **NOTED** that it is necessary to continue to analyse this as available data show increases in size distribution of fish caught in FAD associated schools reported by EU,Spain.

92. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–15 on the Combined effect of PDO/ENSO on YFT catches in Indian Ocean: the case of Spanish purse seiner fisheries, including the following abstract:

> *"In a recent study, the authors concluded that there is a lagged effect modulated mainly by PDO-SOI, which could be related to a good recruitment, larval survival, or improved spawning, after analyzing the combined effect of the main atmospheric teleconnections affecting the Indian Ocean (i.e. South Oscillation Index -SOI-, Pacific Decadal Oscillation -PDO-, and Indian Ocean Dipole -IOD-) on YFT catches of Spanish purse seine freezer fleet operating in the Indian Ocean, they. Thus, negative PDO phase (or positive SOI phase) lagged between 3 and 6 years could favor future stock abundance, while positive PDO phase (or negative SOI phase) lagged 3 or 6 years could negatively affect future stock abundance. However, the authors analyzed the total YFT catches per year without separating by type of schools. Moreover, they analyzed all the climatic oscillations in combination. The main aim of this study is to test the effect of the main teleconnections (i.e. PDO, SOI and IOD) of the Indian Ocean, using different lags (until 6 years lagged), separately and independently of the YFT catches on free schools. The final objective was to find the main climatic oscillations and lags, most influential on the YFT catches on non-associated. A total of twenty-one GLM models were fitted using PDO, SOI and IOD as independent variables and The YFT not associated schools catches was standardized by searching days, as a dependent variable. According its AUC, the more important variables are: SOI 1 year lag, SOI 4 years lag, and PDO 1 year lag. We found that lagging SOI and PDO could better explain the variations presented in the series than IOD."*

93. The WPTT **QUESTIONED** the choice of using annually-averaged values for both catch per day and climatic indices, because of seasonal patterns for the former and time patterns in the development of the signals for the latter.

94. The WPTT **NOTED** that determining appropriate time windows depicting the full development of a climatic signal should be attempted to better understand what is driving the catch response, since the lags resulting from the study were only correlations not discussed in relation to any physical or biological process.

95. The WPTT **NOTED** that, although the approach of using climatic indices to explain variability in fisheries has proven useful in previous studies, it must be applied in relation to spatial oceanic conditions because of the dipole-like patterns associated with climatic oscillations which generate opposing situations from one region to another. The WPTT further **NOTED** that the effects of climatic changes on recruitment are still unclear and further work is required to improve knowledge of these effects.

96. The WPTT **NOTED** that it would be valuable to look at local dynamics as well as larger scale global impacts to better explain stock variability.

97. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–17, with the following excerpt of an abstract of an article accepted for publication in *ICES Journal of Marine Science*:

> *"We analysed catch data from the French purse seine fleet for the period 2010 to 2017 in the Indian Ocean to assess the impact of this fleet's switch to echosounder buoys around 2012. Results indicate that echosounders do not increase the probability to have a successful set, they have a positive effect on catch per set, with catches on average increasing by about 2-2.5 tonnes per set (~10%) when they are made on their own dFADs equipped with an echosounder buoy. Increases were due to a decrease in sets below (~25 tonnes and an increase of those greater than ~25 tonnes, with a non-linear transition around this threshold. This increase explains the considerable investment of purse seiners in echosounder buoys, but also raises concerns about bias in recent stock size estimates based on CPUE if we do not correct for this increase in fishing efficiency."*

98. The WPTT **NOTED** that between 2014 and 2017 there was a net increase in sets on Floating Objects (FOBs) per French purse seine vessel per year of 29%.

99. The WPTT **NOTED** that the use of echosounder buoys in the EU,France purse seine fleet has resulted in an increase of between 1.7% and 4.0% in the mean catch per set relative to the period prior to the introduction of echosounder buoys in 2012, while other factors increasing efficiency, for instance in locating tuna schools, were not considered in the study.

100. The WPTT **NOTED** that the relative increase observed in the proportion of skipjack tuna on floating objects equipped with the vessels' own echosounders remains difficult to explain but that it was concurrent with the increasing use of FADs by the French purse seine fleet, possibly reflecting some learning process associated with the use of buoys to detect specific types of fish schools (either in species composition, size or depth profile) since 2010.

101. The WPTT **NOTED** that the proportion of skipjack tuna in the catch was derived from T3 reprocessed species composition data based on the size samples for large spatio-temporal strata but that this was not expected to affect the results.

102. The WPTT **NOTED** that there is information sharing in the French purse seine fishery between fishers on buoys but that this level of information sharing varies between companies, vessels, and skippers. The WPTT further **NOTED** that all buoys drifting east of 80°E are shared among all French and associated purse seiners.

103. The WPTT **NOTED** that the French and Spanish fisheries have had different fishing strategies with regards to the use of buoys and FADs since the 1990s, which is expected to result in different changes in efficiency over time and eventually in different time series of fishing power creep.

104. The WPTT **NOTED** that the number of buoys in use by EU,Spain has decreased by 40% since 2015, and the number of support vessels has also decreased and technological improvement in the buoys models in use in the fleet has been relatively modest in recent years. Though consistent with the small changes in efficiency for this component of the purse seine fishery during 2015-2019, data are not available to estimate the extent to which changes in fishing strategy (e.g., sharing of buoys among fishing vessels and companies) compensate for the decrease in the number of active buoys and there is no indication that the number of EU,Spain FOB sets per vessel has decreased as a result of these changes.

105. The WPTT **ENCOURAGED** EU,Spain to conduct analyses to assess both the changes in ownership and sharing of the buoys attached to the floating objects fished as well as the variations in the catch per set according to the buoy features and ownership.

106. The WPTT **RECALLED** the consistency between the CPUE time series derived from fishery-dependent data and acoustic data collated from echosounder buoys and **ACKNOWLEDGED** the promising aspects of these latter data sets in reducing the influence of fishing strategies and changes in fishing power for deriving unbiased, fishery-independent indices of abundance for tropical tuna stock assessments.

107. The WPTT **NOTED** that the 10% increase in efficiency observed in the French purse seine fishery when fishing on echosounder buoys may have occurred previously in the Spanish fishery that is presumed to fish primarily on their own buoys and that the distribution of this increase over the last decade would result in a ~1% annual increase, in line with the conservative level of increased catchability of 1.25% per year estimated for the purse seine fishery on associated schools over the period 1985-2015 from the yellowfin tuna stock assessment (IOTC–2018–WPTT20–32).

108. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–INF02 on Statistics of the French Purse Seine Fishing Fleet Targeting Tropical Tunas in the Indian Ocean (1981-2019).

YELLOWFIN TUNA

5.1 Update on the yellowfin tuna assessment and YFT workplan

109. The WPTT **NOTED** the update given by the Chair on the activities of the yellowfin workplan, which summarised the progress made on the yellowfin assessment. The WPTT **RECALLED** the yellowfin workplan came out in 2019 to address issues related to the projections found in the 2018 stock assessment which led to the WPTT being unable to provide advice on catch levels in 2019 and the work continues in 2020 to improve the assessment methodology in order to decide whether the catch advice requires any changes.

110. The WPTT **NOTED** that following the work with the yellowfin stock assessment model, the analysts encountered a potential problem with the projections that were run in 2018 to build the K2SM that is currently in the YFT Executive Summary. This preliminary presentation indicated that the way in which total recruitment is allocated between two of the four areas of the model may be causing the models to crash and therefore potentially producing bias in the probabilities estimated for the K2SM. The WPTT **NOTED** that the group of analysts will continue looking at this issue more carefully and report to the group when they have more definitive conclusions.

111. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–18 on Developing management advice to rebuild the Indian Ocean yellowfin tuna (*Thunnus albacares*) stock in two generations, including the following abstract excerpt:

> *"Naunet Fisheries Consultants was commissioned by the GTA to develop management advice for the Indian Ocean yellowfin tuna that would rebuild the stock in two generations. In order to meet the assignment, a desk-based study was undertaken. Relevant reports have been consulted and a series of interviews with stock assessment experts, fisheries managers, NGO representatives and other stakeholders have been held. Major concerns for the stock assessment are the uncertainties in data inputs (reported nominal catch data, CPUE indices, size-frequency data, tagging data, etc.) and stock assessment model assumptions (stock distribution, growth, natural mortality, maturity at size/age, steepness of the stock-recruitment relationship) which jeopardise the stock assessment results"* – see document for full abstract

112. The WPTT **NOTED** that many retailers who have signed up to the Global Tuna Alliance have begun to boycott yellowfin tuna caught in Indian Ocean fisheries due to concerns over the status of this stock, a lack of robust management and concerns about compliance with existing measures.

113. The WPTT **THANKED** the author for the interesting presentation and **ENCOURAGED** the seafood market to continue to be engaged with these meetings. However, the WPTT **NOTED** that these working parties are not the correct fora for these discussions as they relate to management decisions that the Commission will be called upon to make. The WPTT also **NOTED** that several conclusions in the presentation were made with reference to the 2018 yellowfin stock assessment projections which were not endorsed by the Scientific Committee.

114. The WPTT **NOTED** the market hope for strong management advice to be recommended and endorsed by experts in these meetings but in the absence of this, the market will generate advice themselves to present at these meetings. The WPTT **NOTED** that the market intends to use their influence to encourage the introduction of robust management strategies.

115. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–20 on Stock Trajectory of Yellowfin Tuna exploited by Iranian fisheries in the Sea of Oman. The following abstract was provided by the authors:

> *"Over the last decades, views on fisheries management have oscillated between alarm and trust in the management process. The predominant policy for remedying the world fishing crisis aims at maximum sustainable yield (MSY) by adjusting gear selectivity and fishing effort to meet sustainable stock levels. The yellowfin tuna fishery in the Sea of Oman has experienced intense increases in removals since 1980, with particularly high levels since the 1990s. Here we provide an analysis of the fisheries and a preliminary evaluation of stock status for yellowfin tuna in the Sea of Oman since the start of the fishery in 1950 to 2019. "* – see document for full abstract

116. The WPTT **THANKED** the authors for their study.

117. The WPTT **NOTED** IOTC–2020–WPTT22(AS)–21: Preliminary Stock Assessment for Yellowfin Tuna in the Indian Ocean: Hypothesis and Diagnostics, including the following abstract:

> *"In 2018 the advice of yellowfin tuna in the Indian Ocean (YFT) was based on a grid of 24 models, where all models were based on the age and length structured integrated assessment model Stock Synthesis (SS). However, due to several issues in the data inputs and model assumptions, the Science Committee of IOTC (SC) recommended a workplan to improve the YFT assessment. Therefore, in this document, based on the comments of the WPTT21, two different processes were conducted: i) some of the basic assumptions on the assessment model were analyzed in details and ii) a new procedure on how to select the models to be included in the final grid used for the advice is presented."* – see document for full abstract

118. The WPTT **RECALLED** that several modelling methods were applied to improve the yellowfin assessment methodology. The WPTT **THANKED** the yellowfin assessment team for their excellent work and efforts to improve the assessment model for providing management advice.

119. The WPTT **NOTED** the analysis done to convert the model structure from a quarterly model () to an annual-season model in order to simplify diagnostics. The WPTT also **NOTED** that the annual season model allows the estimation of seasonal movement effects directly within the model, thus eliminating the need to include the complex environmental data.

120. The WPTT **NOTED** that these are preliminary results and it is still unclear how the models will fit to the tagging data and that going forward with a seasonal model when the effects of the tagging data are not well understood could cause problems. The WPTT **AGREED** that there is a need to compare the tag release distribution between the two approaches. The seasons-as-years model

was originally adopted because it has more flexibility for representing the true tag release design, while the new years-with-seasons model is equivalent or preferable in all other respects..

121. The WPTT **NOTED** that the proposed grid (based on what was established in 2019) included 4-area and 2-area regional structures, and alternative values on growth, natural mortality, steepness, and tag weighting. The WPTT **NOTED** that each model in the grid was ranked according to performance against a set of diagnostics (through the *SSdisag* package), and a 60/70% performance score cut-off was applied to select the final models. The WPTT **NOTED** that 18-32 models would remain for test runs using this 60/70% cut-off point.

122. The WPTT **NOTED** the proposed 60/70% cut-off was an arbitrary level which was intended to serve as a starting value to illustrate the contrast in model performance and to enable the incorporation of most grid factor combinations. However, the WPTT **NOTED** that some poorly performing models discounted by the cut-off score may in fact better depict the actual dynamics so the selection should be done with caution.

123. The WPTT **AGREED** that there is no perfect way to select a range of models and that the group is learning a lot through this process about evaluation criteria for determining a range of plausible models. The WPTT **NOTED** that the proposed methodology for evaluating models through assessing their fitting to data, prediction skills and by running retrospective analyses is thought to be comprehensive. The WPTT **AGREED** that a full range of options should be left open for future assessments and for the assessments of other species and that the incorporation of further diagnostics should be considered.

124. The WPTT **ENDORSED** this preliminary method of evaluation of the model framework but not of the criteria outlined in the paper. The WPTT **NOTED** that there is a need to reach an interim agreement on how to properly use the evaluation criteria. The WPTT **NOTED** that there is a limited amount of time to decide on how to proceed and that it will not be possible to bring this proposal to the Commission this year so next year will be the most appropriate time to conclude this issue ahead of the yellowfin assessment.

125. The WPTT **NOTED** that a hindcast analysis was built for the composition data but there is a need to check its consistency which is not possible at the moment as the model does not have updated size data. The WPTT **NOTED** the size data are expected to be updated ahead of the full assessment.

126. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–22 which described an application of length-based assessment methods to Indian Ocean fisheries for yellowfin tuna between 1955 and 2015 with implications for sustainable fisheries management, including the following abstract excerpt:

> *"Five length-based assessment methods were applied to size frequency data for T.albacares caught using five fishing methods every five years between 1955 and 2015. The results suggest that different fisheries are likely to have different impacts on the stock. Longline, hand line and trolling lines fisheries closely corresponded to the target reference points for sustainable fishing. Pole and line and purse seine fisheries generated the least favourable results for all five simple assessment methods. Equipped with such knowledge fishery managers can formulate locally appropriate harvest control management tools to reduce a fishery's impact on the stock. Extrapolating from the results suggests that 207,170 MT of the T. albacares harvested in 2015 (407,573 MT) were immature and only 47,147 MT were caught at optimum length. The annual yield of YFT in 2015 was numerically similar to the IOTC's estimate of MSY (403,000 MT), but given the composition of the catch (i.e. 52% immature / 12% optimum length) it is unlikely that this yield was sustainable. The results cast doubt on whether the harvest control management tools proposed by analyst's and lobbyist to improve the status of the stock proposed (i.e. catch reductions of 5% - 25%) will be*

effective, if the impact of fisheries that harvest IO YFT remains unchanged. (See paper for full abstract)"

127. The WPTT **NOTED** that there are many issues with the size frequency data held in IOTC databases which were used for these analyses and that these issues are described in detail in paper IOTC–2020–WPTT22(AS)–03. The WPTT **ENCOURAGED** the authors to liaise with the IOTC Secretariat regarding the quality and utility of the raw size data for future analysis.

128. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–19 on Development of spatially explicit operating models for yellowfin tuna populations in the Indian Ocean, including the following abstract:

"A preliminary operating model for Indian Ocean yellowfin tuna was successfully developed with the stock assessment package SPM. The model was spatially explicit at the 5° cell level with a quarterly (3-month) time step. The model was age-structured with many of the same biological characteristics as the 2018 IOTC Stock Synthesis assessment. Fish movements were estimated using preference functions based on distance and time-varying SST and chlorophyll, with independent preference functions for mature and immature fish. The model was fitted with catch, size, CPUE and tagging data. Initial biomass was fixed because biomass scale appeared to be confounded with movement rates. This preliminary model can be considered a proof of concept for spatially explicit operating models of pelagic species and their potential utility. As an example of its use, the MPD estimate of the SPM operating model was used to simulate randomised observational data for size, CPUE and tag recoveries, and these observational data were reformatted and loaded into a Stock Synthesis model based on the 2018 IOTC YFT stock assessment" – see document for full abstract

129. The WPTT **CONGRATULATED** the authors for the progress made in the development of a preliminary spatially-explicit OM for yellowfin tuna and **NOTED** the interest in taking this approach to evaluate some key elements of the assessment such as the influence of the tag mixing period which is difficult to analyze outside the assessment model, the steep decline (i.e. breakpoint) observed in the time series of spawning stock biomass when the size data become available and some model assumptions such as the stability in selectivity of some fisheries over time.

130. The WPTT **NOTED** that one of the assumptions when using tagging data is that fishing mortality is distributed evenly across the tagged fish but in some cases this assumption is violated which can cause bias in assessments. The WPTT **AGREED** that tagging data are valuable, but it is important not to use them for the wrong purposes which could bias within the results.

131. The WPTT **NOTED** that this is a preliminary model and further work is required to refine the details. The WPTT **NOTED** that lots of diagnostics that are required to compare input data with the OM have not yet been generated but this would be useful future work.

132. The WPTT **NOTED** that the OM will be further developed and presented at a 3-day workshop on the approaches to modelling spatial data which is planned for after the World Fisheries Congress, initially scheduled in 2020 and postponed to 2021 due to the Covid-19 pandemic.

133. The WPTT **NOTED** that issues may be resulting from the fact that all fisheries are assumed to have the same selectivity in the model which is unlikely to be accurate due to the different effort distributions with regards to differing size distributions of fish. The WPTT **NOTED** that this should be examined to find a more flexible way to specify selectivities of the individual fisheries and it was suggested that it may be better to aggregate the fleets then focus on the selectivities needed to match with available CPUE series' to reduce the complexity while allowing selectivity that varies with time.

134. The WPTT **NOTED** that the first step is to get the fine-scale model to fit the data to generate a plausible estimate of population dynamics and it is useful to look at the diagnostics to determine how well the model works in terms of replicating the real data. However, if the OM is not consistent with the real YFT data, it is not clear how transferable the simulation inferences will be for improving the real YFT assessment.

135. The WPTT **NOTED** that although possible, the work has not focused on fitting the different data sets available to the model as this was not a priority of the work and there are currently not many diagnostics implemented in the OM to assess the quality of the fit.

136. The WPTT **NOTED** that preliminary results suggested that a minimum of 8 quarters was required for the tags to be mixed within the population and **ENCOURAGED** the authors to further explore this question and apply the approach to the two other tropical tuna species, **NOTING** that considering a 8-quarter mixing period would result in the removal of most tags from the model in the case of skipjack tuna. The WPTT **NOTED** that it is thought that few tags would remain after 8 quarters for yellowfin but that the remaining tags can still impact the biomass compared to when tagging data are completely excluded. The WPTT **NOTED** a study that included tag mixing over a period of 4 quarters led to 75% of tag recoveries being included in analyses.

137. The WPTT further **NOTED** that these results are encouraging as they are in agreement with previous analyses.

5.2 Update on Management Strategy Evaluation Progress

138. The WPTT **NOTED** paper IOTC–2020–WPM11–12 on Indian Ocean Yellowfin Tuna Management Procedure Evaluation Update April 2020, including the following abstract excerpt:

> *"This working paper describes developments on the Indian Ocean Tuna Commission (IOTC) yellowfin (YFT) reference set and robustness test operating models (OMs), since the 2019 Working Party on Tropical Tunas (WPTT) and Working Party on Methods (WPM). In the following (for historical reasons), we mostly use the term MP and Management Strategy (MS) interchangeably, though we subscribe to the specific definition of MP as a subset of MS (as defined in the CCSBT and IWC, in which the MP aims for full specification and simulation testing of data collection and analytical methods). Management Strategy Evaluation (MSE) is the simulation testing process, using complex operating models, for evaluating performance of alternative MSs (or MPs). The intent was to obtain feedback on presentation requirements for the 2020 Technical Committee on Management Procedures (TCMP) meeting, and recommendations on further analyses and revisions for the OMs in preparation for the WPM and WPTT 2020 (but priorities changed due to the Covid-19 pandemic and remain uncertain). (see paper for full summary)"*

139. The WPTT **CONGRATULATED** the authors for the work and **NOTED** that the development of the MSE within ICCAT faces challenges similar to IOTC, including the difficulties associated with securing funding and the limited availability of technically-skilled people involved in the work.

140. The WPTT **AGREED** the reference set OM as defined in Table 4, subject to the caveats on spatial issues below.

141. The WPTT **NOTED** that a very high fishing mortality was estimated for some age/region/quarter strata in the previous OM iteration, and this is expected to recur. The problem manifests on a continuum, such that there is no obvious criterion for model retention/rejection. It remains unclear the extent to which this represents i) a genuine problem that has serious effects on inferences, ii) a genuine situation with a trivial effect on inferences, or iii) an artefact of misleading

labels in Stock Synthesis or r4ss outputs. Additional plausibility constraints will likely need to be applied, perhaps in parallel with new insights from the 2021 YFT assessment

142. The WPTT **NOTED** that different spatial structures (2-area and 1-area models) have been explored as alternatives to the 4-area model in the yellowfin tuna stock assessment (the 1 area model was not retained for management advice). However, the OM for the yellowfin MP development currently retains the 4-area model structure only. The WPTT **AGREED** to retain the 4-area model structure in the OM, noting that the current MSE software would require modification to support multiple spatial structures. The WPTT **AGREED** to explore the potential to include the 2-area model in future OMs, pending the outcome of further comparison of the 2 area and 4 area models to determine whether important inferences and challenges for candidate MPs actually exist, and if so, whether they depend on the spatial structure or other confounding factors (e.g. differing use of tags, restriction of east-west movement and/or interpretation of CPUE regional scaling factors).

143. The WPTT **NOTED** that the spatial population model (SPM) presented in paper IOTC–2020–WPTT22(AS)–19 might be useful for helping to define the appropriate spatial assumptions of the OM (and stock assessments) in future iterations.

144. The WPTT **NOTED** the difficulty in running diagnostics on all models in the OM and the redundancy that arises from having a large number of models in the OM in the centre of the model distribution. The WPTT **NOTED** the value in running diagnostics on the models at the ‘corners’ of the OM domain, rather than across all models in the OM, to identify the plausibility of different models. This can assist with objective elimination of the least plausible Operating Models based on three quantifiable criteria: (1) fit to the data, (2) model internal consistency and (3) prediction skill.

145. The WPTT **NOTED** that the high natural mortality scenario recommended in 2019 for the OM (but not used in previous OM iterations), which has also been used until recently in the WCPFC yellowfin stock assessment, was derived from an eastern Pacific study in the 1960s (Hennemuth, 1961). A recent meta-analysis (Vincent et al. 2019) of yellowfin M estimates from life-history theory and empirical relationships provided an estimate of around 0.52 which was used in the last WCPFC yellowfin stock assessment, is close to the base case used in the OM, and is consistent with recent estimates of maximum observed age of yellowfin from annual increments in otoliths. Accordingly, the high M option was dropped from the OM grid.

146. The WPTT **NOTED** that the low estimates of natural mortality of yellowfin tuna were very similar between the Atlantic and Indian Ocean and **AGREED** to use the values from the Indian Ocean for consistency.

147. The WPTT **AGREED** to retain the 0% and 1% longline catchability trends, and both the Fonteneau and Dortel model 3 (lognormal error) in the OM (despite the poor representation of variance-at-age that can be achieved within Stock Synthesis), and to remove the alternative error assumption scenarios for the longline CPUE standardisations.

148. The WPTT **NOTED** the importance of the longline CPUE indices for the OM and the need to adequately capture the uncertainty in the CPUE time series. The WPTT **REQUESTED** that the Joint CPUE Working Group provide recommendations on how to best capture the uncertainty in the longline CPUE series for the OMs and identifies a small number of alternate CPUE series that encompasses an appropriate range of uncertainty in relative abundance to be represented in Management Strategy Evaluation. The WPTT **NOTED** that these alternatives could include alternative analytical approaches such as targeting (cluster vs. hooks between floats), alternative regional scaling factors, and/or unaccounted catchability trend hypotheses.

149. The WPTT **NOTED** that the inclusion of purse seine CPUE in the yellowfin OM models would require significant changes to the code and would also create a conflict with longline CPUE due

to assumptions about catchability trends in the PS CPUE. The WPTT therefore **AGREED** not to include the PS CPUE in the yellowfin OM at this stage, but it could be considered in future iterations when more information on purse seine catchability trends is available.

150. The WPTT **NOTED** that the two robustness scenarios for catch implementation error (10% overcatch reported; 10% overcatch not reported) may not represent likely scenarios and **SUGGESTED** using an additional robustness scenario that includes both 5% overcatch reported and 5% overcatch not reported.

151. The WPTT **NOTED** that the YFT OM (and current YFT assessments) use seasons as years configuration, while annual models with seasons are under investigation for future assessments (see WPTT22(AS)-21) and that potential complexities may arise in moving the OM to an annual model with seasons. The WPTT **AGREED** that the model structures for the OM and stock assessment do not necessarily need to align as they each have a different purpose, with the main requirement being that the OM to encompasses a broader range of uncertainty than the stock assessment.

Table 4. YFT Reference set OM uncertainty grid (to be implemented with fractional factorial design). The balance will change with respect to tag assumptions if the 2 area model is added)

Definition
Spatial Structure – 4 regions **(2 region option to be further investigated for potential inclusion)**
Stock-recruit function (*h* = steepness) Beverton-Holt, *h* = 0.7, 0.8, 0.9
Natural mortality (multiplier relative to reference case M vector M10) 1.0, 0.8, 0.6
Tag recapture data weighting (tag composition and negative binomial) λ = 0.001, λ = 0.1, λ = 1.0 if 2 area model is added, tag λ = 0, and 4 Area λ = 0.001 will be dropped
Growth curve Fonteneau (2008) Dortel et al. (2014) model 3 (as approximated in 2020 YFT Management advice paper)
Assumed longline CPUE catchability trend (compounded) 0% per annum 1% per annum
Tropical longline CPUE standardization method Hooks Between Floats only
Longline CPUE error assumption (quarterly observations) σ_{CPUE} = 0.1, 0.3

Tag mixing period 4 quarters 8 quarters

BIGEYE TUNA

5.3 Update on Management Strategy Evaluation Progress

152. The WPTT **NOTED** paper IOTC–2020–WPM11–11 and IOTC–2020–WPM11–13, which were also presented to the WPM, and provide an update on IOTC bigeye tuna management procedure evaluation (October 2020) and a candidate Management Procedure based on a Pella-Tomlinson Random Effects model. The papers included the following summary:

    IOTC-2020-WP11-11 "This working paper describes developments on the Indian Ocean Tuna Commission (IOTC) bigeye (BET) reference set and robustness test operating models (OMs), with key Management Procedure (MP) evaluation results, since the 2019 Working Party on Tropical Tunas (WPTT) and Working Party on Methods (WPM)." – see document for full abstract

    IOTC-2020-WP11-13 "In this paper, we explore a Pella-Tomlinson Random Effects surplus production model (PTRE) that admits joint process and observation error, as a potential estimation model for use within IOTC Management Procedures." – see document for full abstract

153. The WPTT **NOTED** that some of the OMs appear to have unrealistically high fishing mortality in a small number of age/region/quarter strata as described for yellowfin (para 141), though to a lesser extent.

154. The WPTT **AGREED** the BET reference set OM as defined in Table 5 (as applied in IOTC-2020-WP11-11), for the provision of MP results to the TCMP 2021.

155. The WPTT **NOTED** the improved performance of the MP based on a Pella-Tomlinson Random Effects model developed in Template Model Builder and SUPPORTED a continuation in the development of this MP.

156. Similar to the discussion for yellowfin tuna, the WPTT **SUGGESTED** using an additional robustness scenario for bigeye that includes both 5% overcatch reported and 5% overcatch not reported.

Table 5. BET reference set OM

Definition
Stock-recruit function (*h* = steepness) ● Beverton-Holt, *h* = 0.7, 08 and 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
longline CPUE Regional-scaling factors ● reference case
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.

6. WPTT PROGRAM OF WORK

6.1 Revision of the WPTT Program of Work (2021–2025)

157. The WPTT **NOTED** paper IOTC–2020–WPTT22(AS)–04, which provided the WPTT20 with an opportunity to consider and revise the WPTT Program of Work (2021–2025), by taking into account the specific requests of the Commission, Scientific Committee, and the resources available to the IOTC Secretariat and CPCs.

158. 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)*

159. 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.

160. The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2021–2025), as provided in Appendix IX.

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

161. The WPTT **NOTED** with thanks, the contribution of the invited expert, Dr. Michael Schirripa (NOAA), to the WPTT meeting, and which contributed greatly to the group's discussions of tropical tuna stock assessment methods.

162. 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.

7. OTHER BUSINESS

7.1 Date and place of the 23rd and 24th Sessions of the WPTT (Chair and IOTC Secretariat)

163. The WPTT **NOTED** that the global Covid-19 pandemic has resulted in international travel being almost impossible and with no clear end to the pandemic in sight, it was impossible to finalise arrangements for the meeting in 2021. The Secretariat will continue to liaise with CPCs to determine their interest in hosting these meetings in the future when this once again becomes feasible. The WPTT **RECOMMENDED** the SC consider late October 2021 as a preferred time period to hold the WPTT23 Assessment meeting in 2021 with a Data Preparatory meeting to be held in the first half of 2021 to prepare for the YFT assessment.

164. As usual it was also **AGREED** that the WPTT Assessment meeting should continue to be held back-to-back with the WPM, with the WPM taking place before the WPTT in 2021.

7.2 Review of the draft, and adoption of the Report of the 22nd Session of the WPTT(AS) (Chair)

165. The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT22, 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 2020 (Figure 2):

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

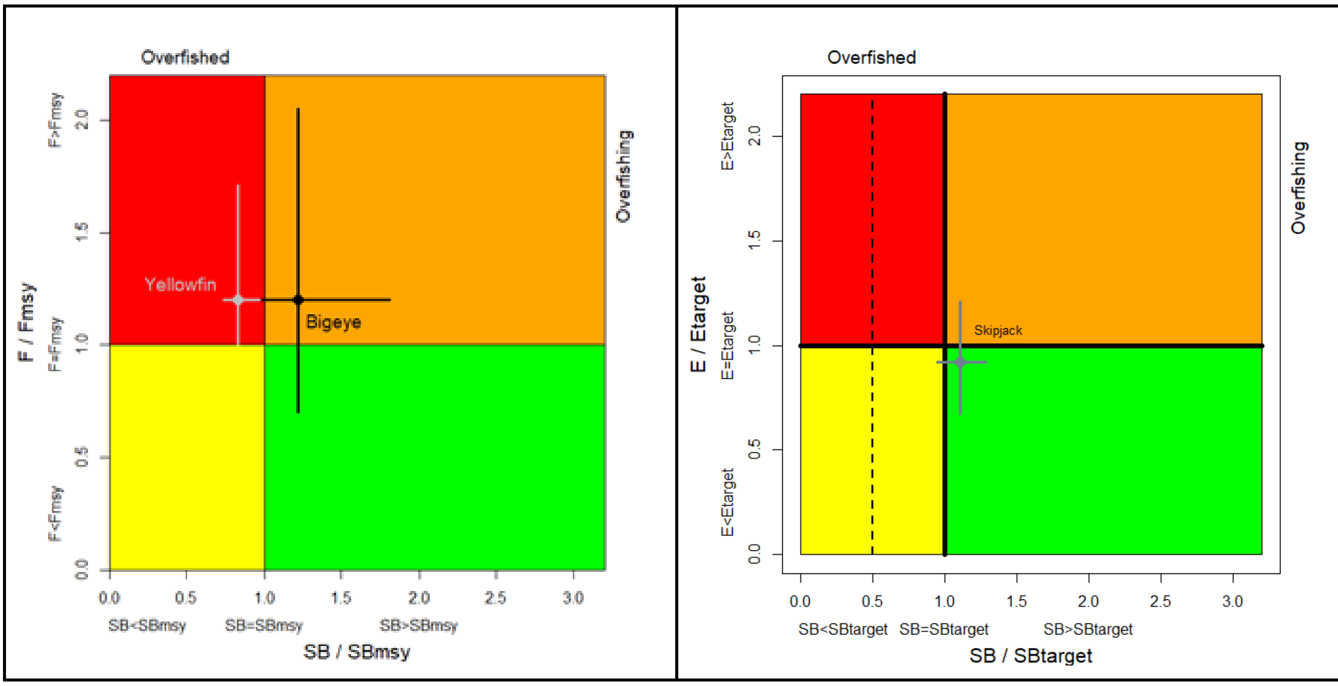

Figure 2. (Left) Combined Kobe plot for bigeye tuna (black: 2019), and yellowfin tuna (grey: 2018) showing the estimates of current stock size (SB) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. (Right) Kobe plot for skipjack tuna showing the estimates of the current stock status (The dashed line indicates the limit reference point at 20%SB0). Cross bars illustrate the range of uncertainty from the model runs with a 80% CI.

166. The report of the 22nd Session of the Working Party on Tropical Tunas Assessment Meeting (IOTC–2020–WPTT22(AS)–R) was **ADOPTED** by correspondence.

APPENDIX I
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APPENDIX II

AGENDA FOR THE 22ND WORKING PARTY ON TROPICAL TUNAS, ASSESSMENT MEETING

Date: 19 - 23 October 2020

Location: Online

Platform: Microsoft Teams

Time: 12:00 – 16:00 daily (Seychelles time)

Chair: Dr Gorka Merino (EU); **Vice-Chair:** Dr Shiham Adam (IPNLF)

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

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

3. **UPDATE OF ANY NEW DATA AVAILABLE AT THE SECRETARIAT FOR TROPICAL TUNA SPECIES SINCE THE DATA PREPARATORY MEETING (**IOTC Secretariat**)**

4. **SKIPJACK STOCK ASSESSMENT** (Chair)
   - 4.1 Review any new information on skipjack biology, stock structure, fisheries and associated environmental data since the data preparatory meeting (all)
   - 4.2 Update on the nominal and standardised CPUE indices presented at the data preparatory meeting
   - 4.3 Stock assessments results
     - Stock Synthesis (SS3)
     - Other models
   - 4.4 Selection of Stock Status indicators for skipjack
   - 4.5 Update on Management Strategy Evaluation Progress
   - 4.6 Development of management advice for skipjack tuna (all)
   - 4.7 Update of skipjack tuna Executive Summary for the consideration of the Scientific Committee (all)

5 **OTHER TROPICAL TUNAS**

Yellowfin

- 5.1 Update on the yellowfin tuna assessment and YFT workplan
- 5.2 Update on Management Strategy Evaluation Progress

Bigeye

- 5.3 Update on Management Strategy Evaluation Progress

6 **WPTT PROGRAM OF WORK**

- 6.1 Revision of the WPTT Program of Work (2021–2025)
- 6.2 Development of priorities for an Invited Expert at the next WPTT meeting

7 **OTHER BUSINESS**

- 7.1 Date and place of the 23rd and 24th Sessions of the WPTT (Chair and IOTC Secretariat)
- 7.2 Review of the draft, and adoption of the Report of the 22nd Session of the WPTT(AS) (Chair)

APPENDIX III
LIST OF DOCUMENTS FOR THE 22ND WORKING PARTY ON TROPICAL TUNAS

Document	Title
IOTC–2020–WPTT22(AS)–01a	Draft: Agenda of the 22nd Working Party on Tropical Tunas (Assessment Meeting)
IOTC–2020–WPTT22(AS)–01b	Draft: Annotated agenda of the 22nd Working Party on Tropical Tunas (Assessment Meeting)
IOTC–2020–WPTT22(AS)–02	Draft: List of documents for the 22nd Working Party on Tropical Tunas (Assessment Meeting)
IOTC–2020–WPTT22(AS)–03	Review of the statistical data and fishery trends for tropical tunas (IOTC Secretariat)
IOTC–2020–WPTT22(AS)–04	Revision of the WPTT Program of Work (2021–2025) (IOTC Secretariat)
IOTC–2020–WPTT22(AS)–05	Investigating early stages of skipjack tuna (*Katsuwonus pelamis*) in the Indian Ocean using otolith chemistry (Artetxe-Arrate I, Fraile I, Rodríguez-Ezpeleta N, Farley J, Darnaude A M, Clear N, Dettman D, Pécheyran C, Eveson P, Krug I, Nikolic N, Médieu A, Landsdell M, Ahusan M, Proctor C, Priatna A, Lestari P, Taufik M, Usmani H, Zehra K, Khan M, Shahid M, Kazmi S, Islam S, Tariq M, Zafar S, Zaidi J, Marsac F, Davies C, and Murua H)
IOTC–2020–WPTT22(AS)–06	Otolith δ18O as a tracer of yellowfin tuna (*Thunnus albacares*) origin in the Indian Ocean (Artetxe-Arrate I, Fraile I, Farley J, Clear N, Darnaude AM, Dettman D, Eveson P, Krug I, Nikolic N, Médieu A, Ahusan M, Landsdell M, Proctor C, Priatna A, Lestari P, Taufik M, Parker D, Usmani H, Zehra K, Khan M, Shahid U, Kazmi S, Islam S, Tariq M, Zafar S, Zaidi J, Davies C, Marsac F and Murua H)
IOTC–2020–WPTT22(AS)–07	Co-occurrence of genetically isolated groups of skipjack tuna (*Katsuwonus pelamis*) within the Indian Ocean (Rodríguez-Ezpeleta N, Artetxe-Arrate I, Mendibil I, Díaz-Arce N, Krug I, Ruiz J, Nikolic N, Medieu A, Pernak M, Farley J, Grewe P, Lansdell M, Aulich J, Clear N, Proctor C, Wudianto, Ruchimat T, Fahmi Z, Satria F, Lestari P, Taufik M, Priatna A, Zamroni A, Davies C, Marsac F, Fraile I, Murua H)
IOTC–2020–WPTT22(AS)–08	Reproductive Biology of Skipjack Tuna (*Katsuwonus pelamis*) in Indonesian Exclusive Economic Zone (Hartaty H, Setyadji B and Fahmi Z)
IOTC–2020–WPTT22(AS)–09	Plan of trilateral collaborative study among Japan, Korea and Taiwan for producing joint abundance index with longline fisheries data for the tropical tuna species in the Indian Ocean (Kitakado T, Satoh K, Matsumoto T, Yokoi H, Okamoto K, Lee S-I, Kyung Lee M, Lim J-H, Wang S-P , Su N-J, Tsai W-P and Chang S-T)
IOTC–2020–WPTT22(AS)–10	Preliminary Indian Ocean Skipjack Stock Assessment (Stock Synthesis) (Fu D)
IOTC–2020–WPTT22(AS)–11	Investigating population structure of bigeye tuna in the Indian Ocean using otolith chemistry (Clear N, Eveson P, Darnaude AM, Labonne M, Artetxe-Arrate I, Fraile I, Farley J, Grewe P, Lestari P, Taufik M, Zamroni A, Priatna A, Aulich J, Lansdell M, Lozano-Montes H, Danyushevsky L, Fahmi Z, Wudianto, Murua H, Marsac F and Davies C)
IOTC–2020–WPTT22(AS)–12	Genetic population connectivity of yellowfin tuna within the Indian Ocean (Grewe P, Feutry P, Foster S, Aulich J, Lansdell M, Cooper S, Clear N, Farley J, Nikolic N, Krug I, Mendibil I, Ahusan M, Parker D, Wudianto, Ruchimat T, Satria F, Lestari P, Taufik M, Fernando D, Priatna A, Zamroni A, Rodríguez-Ezpelet N, Artetxe-Arrate I, Fahmi Z, Murua H, Marsac F, Davies C)
IOTC–2020–WPTT22(AS)–13	Improved version of the tropical tuna treatment process: new perspectives for catch estimates of tropical purse seine fishery (Duparc A., Depetris M., Cauquil P., Floch L., Lebranchu J.)
IOTC–2020–WPTT22(AS)–14	Are sets on tropical tuna not associated with floating objects really free schools sets? Implications on fishing effort (Báez J-C, González-Carballo M, Lourdes Ramos M and Deniz S)

Document	Title
IOTC–2020–WPTT22(AS)–15	Combined effect of PDO/ENSO on YFT catches in Indian Ocean: the case of Spanish purse seiner fisheries (Báez J-C, Ramos M, González-Carballo M and Czerwinski I)
IOTC–2020–WPTT22(AS)–16	Evidence of connectivity of bigeye tuna (*Thunnus obesus*) throughout the Indian Ocean inferred from genome-wide genetic markers (Díaz-Arce N, Grewe P, Krug I, Artetxe I, Ruiz J, Nikolic N, Medieu A, Pernak M, Lansdell M, Aulich J, Clear N, Proctor C, Wudianto, Ruchimat T, Fahmi Z, Satria F, Lestari P, Taufik M, Priatna A, Zamroni A, Farley J, Davies C, Marsac F, Fraile F, Murua H, Rodríguez-Ezpeleta N)
IOTC–2020–WPTT22(AS)–17	Quantifying the increase infishing efficiency due to the use of drifting FADs equipped with echo-sounders in tropical tuna purse seine fisheries (Kaplan D, Wain G, Guery L, and Gaertner D)
IOTC–2020–WPTT22(AS)–18	Developing management advice to rebuild the Indian Ocean yellowfin tuna (*Thunnus albacares*) stock in two generations (Global tuna alliance)
IOTC–2020–WPTT22(AS)–19	Development of spatially explicit operating models for yellowfin tuna populations in the Indian Ocean (Dunn A, Hoyle S and Datta S)
IOTC–2020–WPTT22(AS)–20	Stock Trajectory of Yellowfin Tuna exploited by Iranian fisheries in the Sea of Oman (Eighani M)
IOTC–2020–WPTT22(AS)–21	Preliminary Stock Assessment for Yellowfin Tuna in the Indian Ocean: Hypothesis and Diagnostics (Urtizberea A, Cardinale M, Methot R, Fu D, Fernández C, Winker H, Kitakado T, Merino G).
IOTC–2020–WPTT22(AS)–22	An application of length-based assessment methods to Indian Ocean fisheries for yellowfin tuna (*Thunnus albacores*) between 1955 and 2015: implications for sustainable fisheries management (Creech S and Gunasekera E)
IOTC–2020–WPM11–09	Applications of a Bayesian biomass dynamic model to Indian Ocean Skipjack Tuna (Edwards C)
IOTC–2020–WPM11–10	Developments toward an MSE framework for Indian Ocean skipjack
IOTC–2020–WPM11–11	Indian Ocean Bigeye Tuna Management Procedure Evaluation Update March 2020 (Kolody D, Jumppanen P and Day J)
IOTC–2020–WPM11–12	Indian Ocean Yellowfin Tuna Management Procedure Evaluation Update April 2020 (Kolody D, Day J and Jumppanen P)
IOTC–2020–WPM11–13	A candidate Management Procedure based on a Joint Process and Observation Error Random Effects Production Model (Kolody D and Jumppanen P)
IOTC–2020–WPTT22(AS)–INF01	Summary of activities of the yellowfin tuna workplan (Merino G et al)
IOTC–2020–WPTT22(AS)–INF02	Statistics of the French Purse Seine Fishing Fleet Targeting Tropical Tunas in the Indian Ocean (1981-2019) (Floch L, Depetris M, Duparc A, Kaplan D, Lebranchu J, Marsac F, Pernak M and Bach P)
IOTC–2020–WPTT22(AS)–INF03	Development of the SCAS (Statistical-Catch-At-Size) software (Nishida T, Kitakado T and Odaira Y)
IOTC–2020–WPTT22(DP)–INF04	Standardized purse seine CPUE of skipjack in the Indian Ocean for the European fleet (Guery L)
IOTC–2020–WPTT22(DP)–INF05	Addendum to the Paper IOTC-2020-WPTT22(DP)-11 (Bayesian Skipjack and Yellowfin Tuna CPUE Standardisation Model for Maldives Pole and Line 1970-2019) Presented at the IOTC–2020–WPTT22(DP) Meeting (Medley P, Ahusan M and Adam MS)

APPENDIX IVA

MAIN STATISTICS FOR TROPICAL TUNAS

(Extracts from IOTC–2020–WPTT22(AS)–03_Rev3)

Fisheries and catch trends (2015-2019) for tropical tuna species

Main species

Tropical tuna species account for roughly two thirds of total catches of IOTC species in recent years. Skipjack tuna, in particular, accounts for almost 50% of total catches of tropical tunas, followed by yellowfin tuna (41.6%), while catches of bigeye tuna account for the remaining 8.7% (**Fig. A1c-d**).

Main fisheries

Purse seine accounts for 44% of total catches of tropical tunas, with important catches also reported by handline, coastal longline and trolling (18%), gillnet (18%), pole-and-line (11%), and longline (7%) with catches occurring in both coastal waters and the high seas (**Fig. A2a-d**).

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

Tropical tunas are caught by both coastal countries in the Indian Ocean and distant water fishing nations (**Fig. A3**).

In recent years the coastal and industrial fisheries of five countries (Indonesia, Maldives, Sri Lanka, I.R. Iran and India) have accounted for almost 50% of the total catches of tropical tuna species in the Indian Ocean, while the industrial purse seiners and longliners flagged by EU,Spain, Seychelles and EU,France contributed a further 34% to total catches for these species.

Retained catch trends

Total catches of tropical tunas steadily increased from the ‘50s to reach a maximum of more than 1.2 million MT in 2005, accounting for 70% of the total catch of all species under the IOTC mandate in that year (**Fig. A1a-b**). The catches then decreased to around 809,000 MT in 2011 in relation to the piracy threat before re-increasing to more than 1.1 million MT in 2018. In 2019, the catches of tropical tunas have been estimated at 1,047,653 MT, almost to the same levels as the previous year, reaching 60% of catches of all IOTC species combined.

The importance of tropical tunas to the total catches of IOTC species in the Indian Ocean has changed over the years, in particular following the arrival of industrial purse seine fleets targeting tropical tunas in the early ’80s (**Fig. A1a-b**). With the onset of piracy in the late ’00s, the activities of fleets operating in the Northwest Indian Ocean have been displaced or reduced – particularly the Asian distant-water longline fleets – leading to a relative decline in the proportion of catches from tropical tunas that went down to around 55% of total catches of all IOTC species during 2008-2019, compared to around 65 % during the pre-piracy period (1996-2007). Other factors such as the concurrent development of gillnet fisheries catching neritic tunas and billfish species might explain the decline in the contribution of tropical tunas to catches of all IOTC species observed in the last decade.

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 canning factories in the Indian Ocean region or abroad (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 retained by the fishermen for direct consumption.

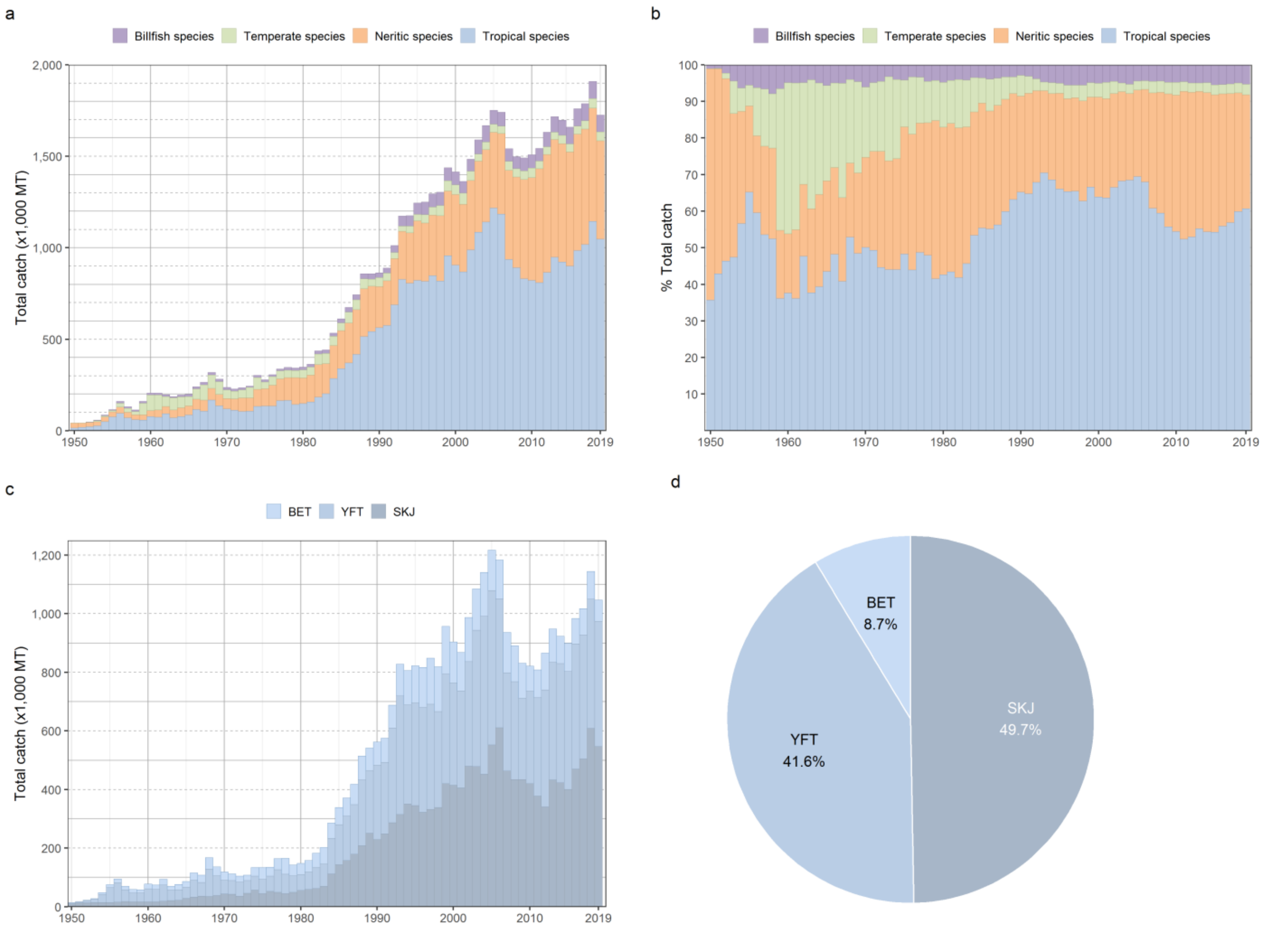


Fig. A1. Top: contribution of tropical tunas to the total catches of IOTC species in the Indian Ocean over the period 1950-2019. (a) Annual nominal catches (MT) by group of species; (b) Percentage of the annual nominal catches by group of species. **Bottom**: Contribution of each tropical tuna species to the total combined catches of tropical tunas; (c) Annual nominal catches by species in MT, 1950-2019; (d) Percentage of the average annual catch by species, 2015-2019

TABLE A1. Best scientific estimates of the annual nominal catches (MT) of all tropical tunas by fishery for the period 1950–2019. Colour codes (yellow = lower, green = higher) describe the intensity of captures by fishery across decades (left) and years (right). 'Purse seine' includes industrial purse seiners only, while 'Other' includes all remaining fishing gears not explicitly listed

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Baitboat	12,138	17,516	30,604	50,250	90,250	126,640	98,379	84,047	85,049	117,409	102,414	100,574	109,503	118,062	132,333	116,698
Gillnet	3,900	10,918	19,178	27,156	83,143	172,011	165,751	149,800	168,997	174,285	187,309	173,989	170,498	199,555	209,535	172,499
Line	4,257	8,314	19,066	35,695	68,750	95,407	111,565	138,637	168,568	174,557	188,137	163,325	199,404	170,339	184,299	192,191
Longline	28,673	63,595	60,901	84,678	208,361	202,441	104,821	106,815	149,158	122,690	88,778	86,748	75,261	67,992	65,875	67,238
Purse Seine	0	32	1,405	115,923	317,309	399,348	328,453	317,427	281,335	345,463	343,553	363,187	418,061	451,203	542,176	487,651
Other gears	184	466	828	2,522	4,725	8,860	12,242	12,253	12,395	13,646	12,989	12,156	12,016	11,023	10,035	11,376
Total	**49,152**	**100,841**	**131,982**	**316,224**	**772,538**	**1,004,707**	**821,211**	**808,979**	**865,502**	**948,050**	**923,180**	**899,979**	**984,743**	**1,018,174**	**1,144,253**	**1,047,653**

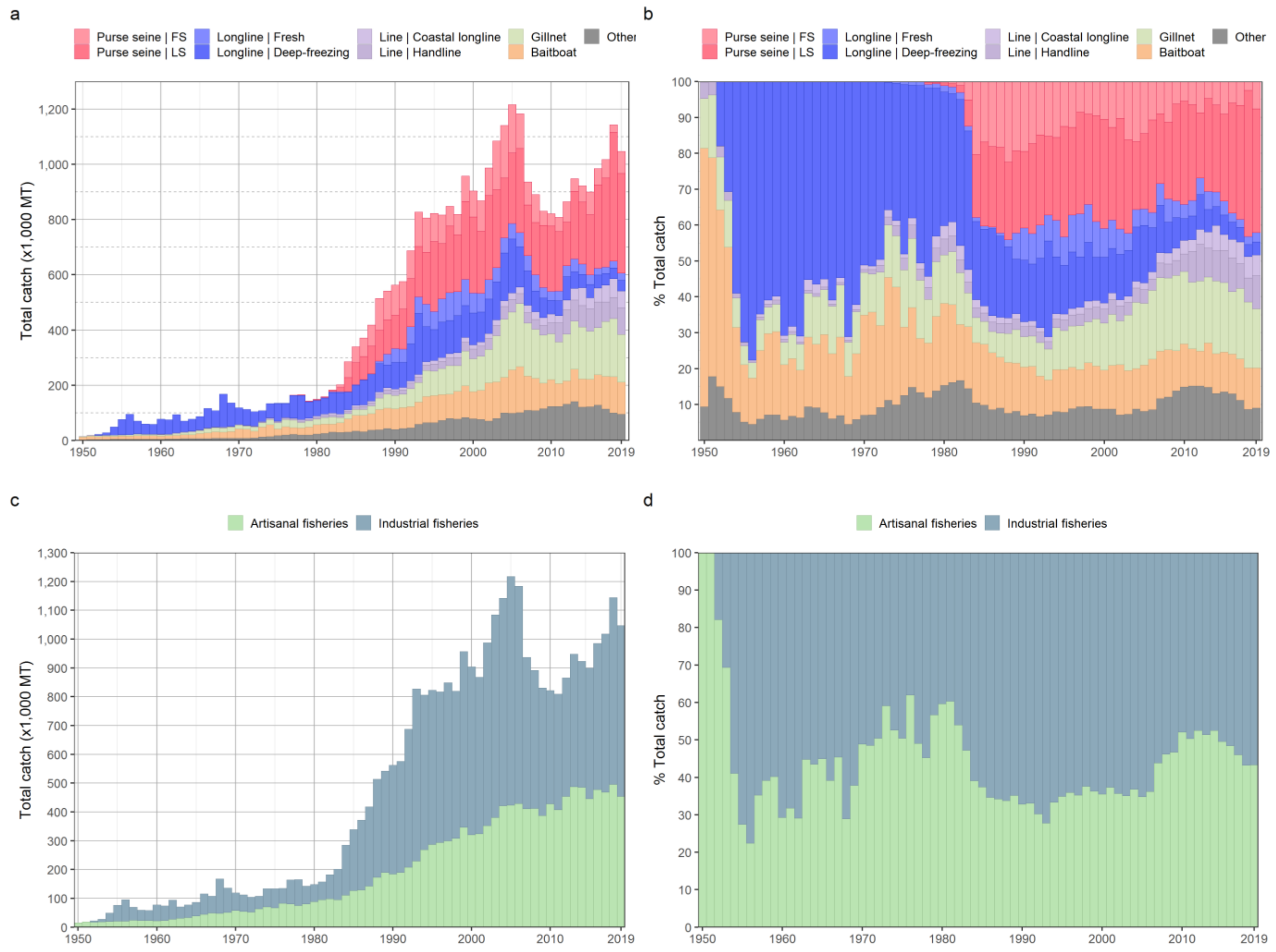


Fig. A2. Annual time series of bigeye tuna during 1950-2019 (a) cumulative nominal catches (MT) by gear; (b) percentage share of all tropical tuna catches by gear; (c) cumulative nominal catches (MT) by fishery type and (d) percentage share by fishery

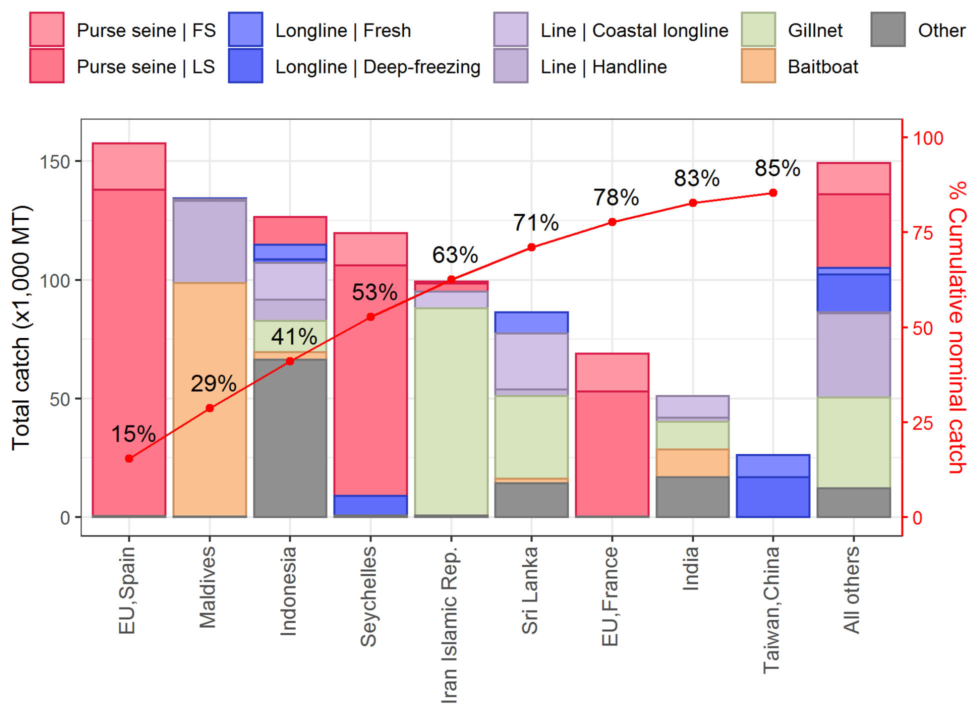


Fig. A3. Average nominal catches (MT) of tropical tunas over the period 2015–2019, by gear group and CPC ordered according to the importance of catches. The red solid line indicates the cumulative percentage of the total combined catches of the species for the CPCs concerned

APPENDIX IVB
MAIN STATISTICS FOR BIGEYE TUNA

(Extracts from IOTC–2020–WPTT22(AS)–03_Rev3)

Fisheries and main catch trends (2015-2019)

Main fishing gears

Industrial fisheries accounted for the majority of catches of bigeye tuna during 2015–2019, with about 40% of the total catch taken by deep-freezing and fresh longline and about 34% by purse seine (**Table A2; Fig. A5**). Catches of bigeye tuna by coastal fisheries were dominated by coastal longline (10%) and coastal purse seine (6%), and a mix of other gears composed of liftnet, coastal gillnet, trolling, and handline.

In recent years catches by gillnet fisheries have 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. Gillnet fisheries represented 35% of the catches of the 'Other' gear group during 2015-2019 (**Table A2**).

Main fleets (and primary gear associated with catches)

Percentage of total catches (2015–19): the four main fleets catching bigeye tuna are Indonesia (fresh / coastal longline, coastal purse seine): 23%; EU,Spain (purse seine): 16%; Taiwan,China (longline): 16%; Seychelles (longline and purse seine): 13% (**Fig. A5**).

Main fishing areas

- **Primary**: Western Indian Ocean, in waters off Somalia;
- **Secondary**: Eastern Indian Ocean.

In contrast to yellowfin tuna and skipjack tuna, where the majority of catches are taken in the western Indian Ocean, bigeye tuna is also exploited in the eastern Indian Ocean, particularly since the late '90s 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 '70s, from around 20,000 MT in the '70s, to over 150,000 MT by the late '90s, going through the development of the industrial longline fisheries and arrival of European purse seiners in the '80s. Since 2007 catches of bigeye tuna by longliners have been relatively low, less than half of the catch levels recorded before the onset of piracy in the northwest Indian Ocean (e.g., ≈50,000 MT).

- Longline fisheries: bigeye tunas have been caught by industrial longline fleets since the early '50s, but before 1970 only represented incidental catches. After 1970, the introduction of fishing practices that improved catches of bigeye tuna, and the emergence of a sashimi market, resulted in bigeye tuna becoming a primary target species for the industrial longline fleets. Large bigeye tunas (averaging just above 40 kg) are primarily caught by longliners, in particular deep-freezing ones.

  Since the late '80s, Taiwan,China has been the major longline fleet targeting bigeye tuna in the Indian Ocean, accounting for more than 40% of the total longline catch in the Indian Ocean in recent years (**Fig. A5**).

  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. Current catches (totaling at around 73,000 MT) still remain far lower than the levels recorded from the late '90s through the mid '00s (**Table A2** and **Fig. A5**).

- Purse seine fisheries: since the late '70s, bigeye tuna has been caught by purse seine vessels fishing on tunas aggregated on floating objects and, to a lesser extent, associated with free swimming schools of yellowfin tuna (**Fig. A5a**). Purse seiners under the flags of EU countries and Seychelles account for the majority of purse seine catches of bigeye tuna in the Indian Ocean (**Fig. A6**) – mainly small juvenile bigeye (averaging around 5 kg) compared to longliners which catch much larger sized fish (40-60 kg) (**Fig. AA3**). 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 5,000 MT). The catch reported by Indonesia for this fleet component however declined to less than 600 MT in 2019.

  While the activities of purse seiners were also affected by piracy in the northwest Indian Ocean during 2008-2011, the decline in catches of tropical tunas has 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.

  Total catches of bigeye tuna for the purse seine fishery were relatively stable at around 20,000 – 30,000 MT for all fleets until 2017: catches reported in 2018 showed a major increase of around 50% compared to previous year (45,000 MT in total) with over 66% of purse seine catches being reported by EU,Spain and Seychelles. This increase can potentially be explained by the revisions introduced in the species composition estimation by one component of the EU purse seine fleet, and is still subject to further discussion and analysis. In 2019, the total purse seine catches of bigeye were back to levels similar to what was observed in 2016-2017, with a total catch of 26,000 MT, of which more than 70% was taken on associated schools.

Discard levels

Discard levels are thought to be low, although estimates of discards are unknown for most industrial fisheries, excluding industrial purse seiners flagged in EU countries and the Seychelles for the period 2003–2017. The existence of the practice of high-grading (discarding of small fish) in some longline fisheries has been raised as a potential issue for the accuracy of Catch Per Unit Effort (CPUE) time series but it is not considered to be a big issue for bigeye tuna as there is a market for small-sized fish.

Catch series

No major change has occurred in the nominal catch series of bigeye tuna since the WPTT meeting in 2019. The revised Pakistan gillnet catches from 1987 onwards (incorporated in the IOTC database in December 2019) do not include reports of bigeye tuna catches at all, introducing a total reduction in bigeye tuna catches of 3,925 MT (123 MT / year) in the years concerned (1987-2018) when compared to the data available at the WPTT21 (**Fig. A4**).

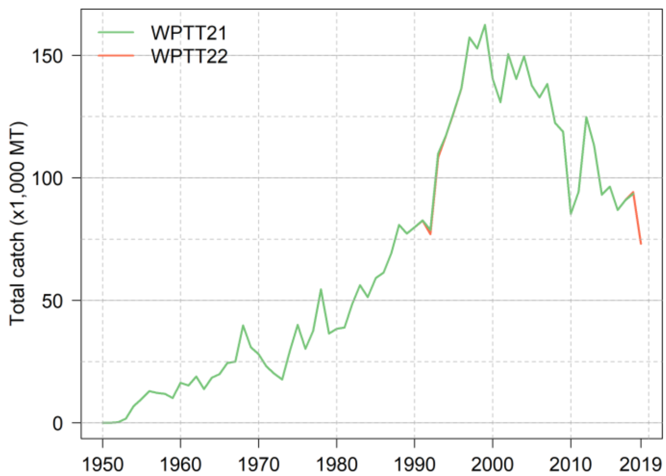


Fig. A4. Comparison of annual time series of total catches (MT) of Indian Ocean bigeye tuna available at the 21st (WPTT21, 2019) and 22nd (WPTT22, 2020) sessions of the IOTC Working Party on Tropical Tunas

TABLE A2. Best scientific estimates of the annual nominal catches (MT) of bigeye tuna by fishery for the period 1950–2019. Colour codes (yellow = lower, green = higher) describe the intensity of captures by fishery across decades (left) and years (right). 'Purse seine' includes industrial purse seiners only and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Purse seine | FS	0	0	0	2340	4824	6196	3,792	6,222	7,180	4,659	5,000	9,633	2,489	10,242	3,634	7,078
Purse seine | LS	0	0	0	4852	18315	20273	18,486	16,386	10,434	22,809	14,882	15,547	19,330	19,456	42,965	18,934
Longline | Fresh	0	0	218	3066	26282	23490	9,782	12,031	16,816	16,725	13,650	12,401	7,658	8,892	7,147	6,874
Longline | Deep-freezing	6488	21861	30413	42972	61577	70308	31,199	34,206	65,015	44,320	33,768	32,153	29,706	25,300	18,705	19,315
Line | Coastal longline	33	287	548	2204	4111	5786	7,662	7,676	7,087	8,949	9,578	9,897	9,392	9,581	6,849	6,415
Line | Handline	9	8	110	181	162	226	1,096	1,742	2,308	151	836	1,648	1,282	552	331	1,591
Other	58	114	430	2502	4759	9908	13,352	16,111	15,920	15,580	15,345	15,118	16,993	16,840	14,610	12,957
Total	**6588**	**22270**	**31719**	**58117**	**120030**	**136187**	**85,369**	**94,374**	**124,760**	**113,193**	**93,059**	**96,397**	**86,850**	**90,863**	**94,241**	**73,164**

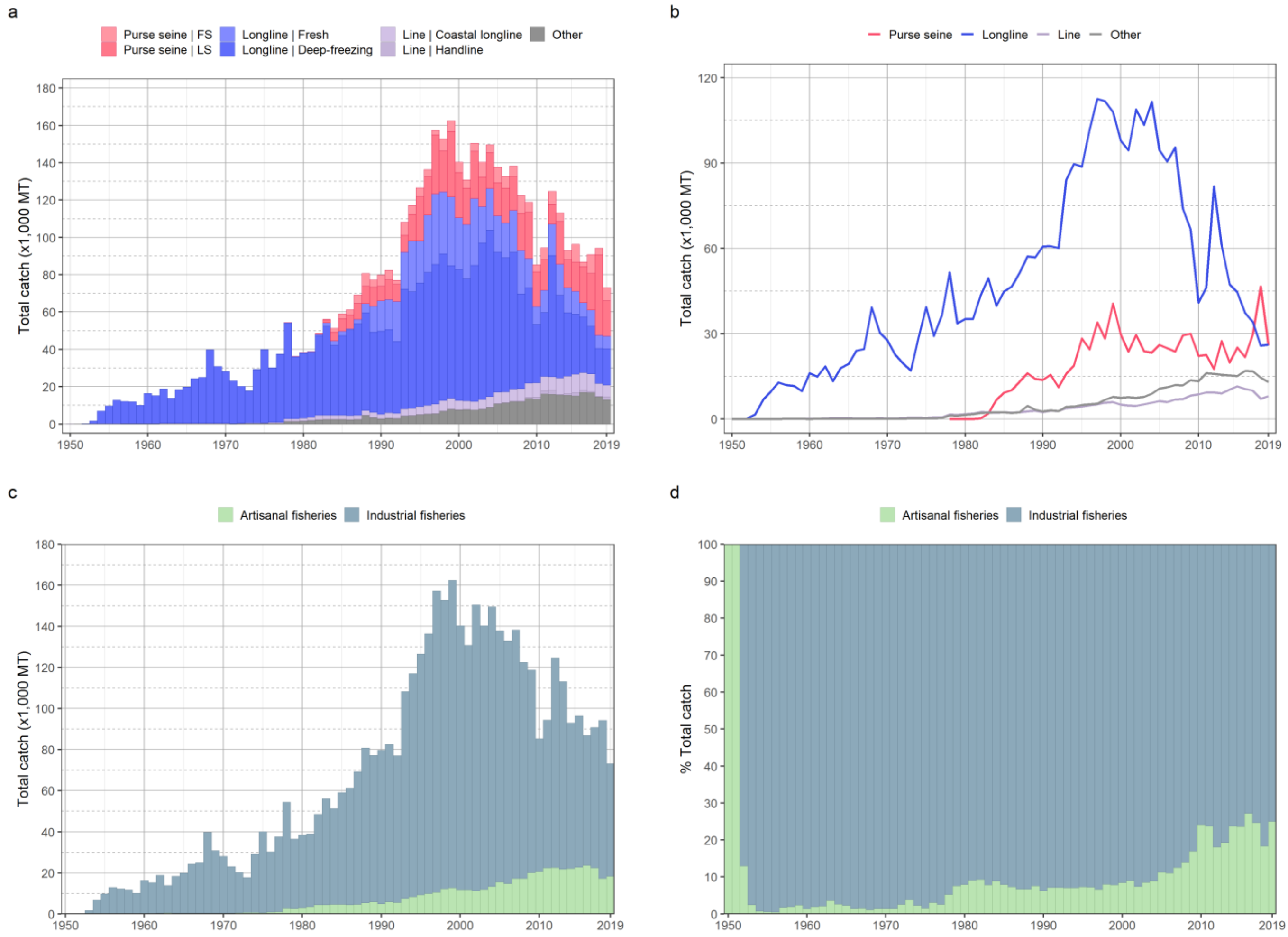


Fig. A5. Annual (1950–2019) time series of bigeye tuna (a) cumulative nominal catches (MT) by gear; (b) individual nominal catches (MT) by gear group; (c) cumulative nominal catches (MT) by fishery type and (d) percentage share by fishery type. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

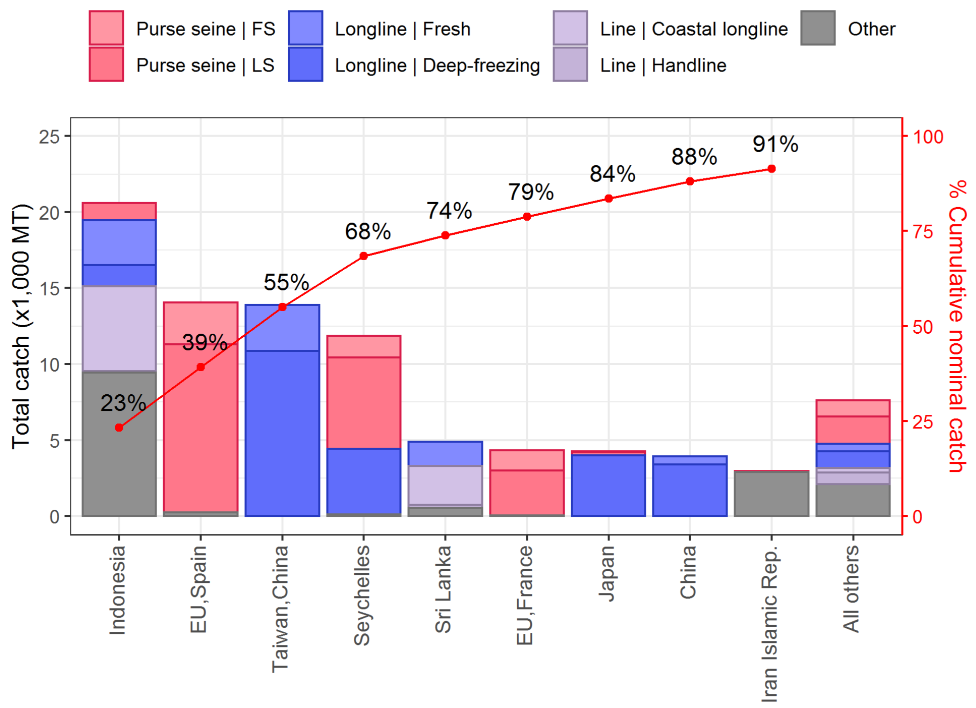


Fig. A6. Average nominal catches (MT) of bigeye tuna over the period 2015–2019, by gear group and CPC ordered according to the importance of catches. The red solid line indicates the cumulative percentage of the total combined catches of the species for the CPCs concerned. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

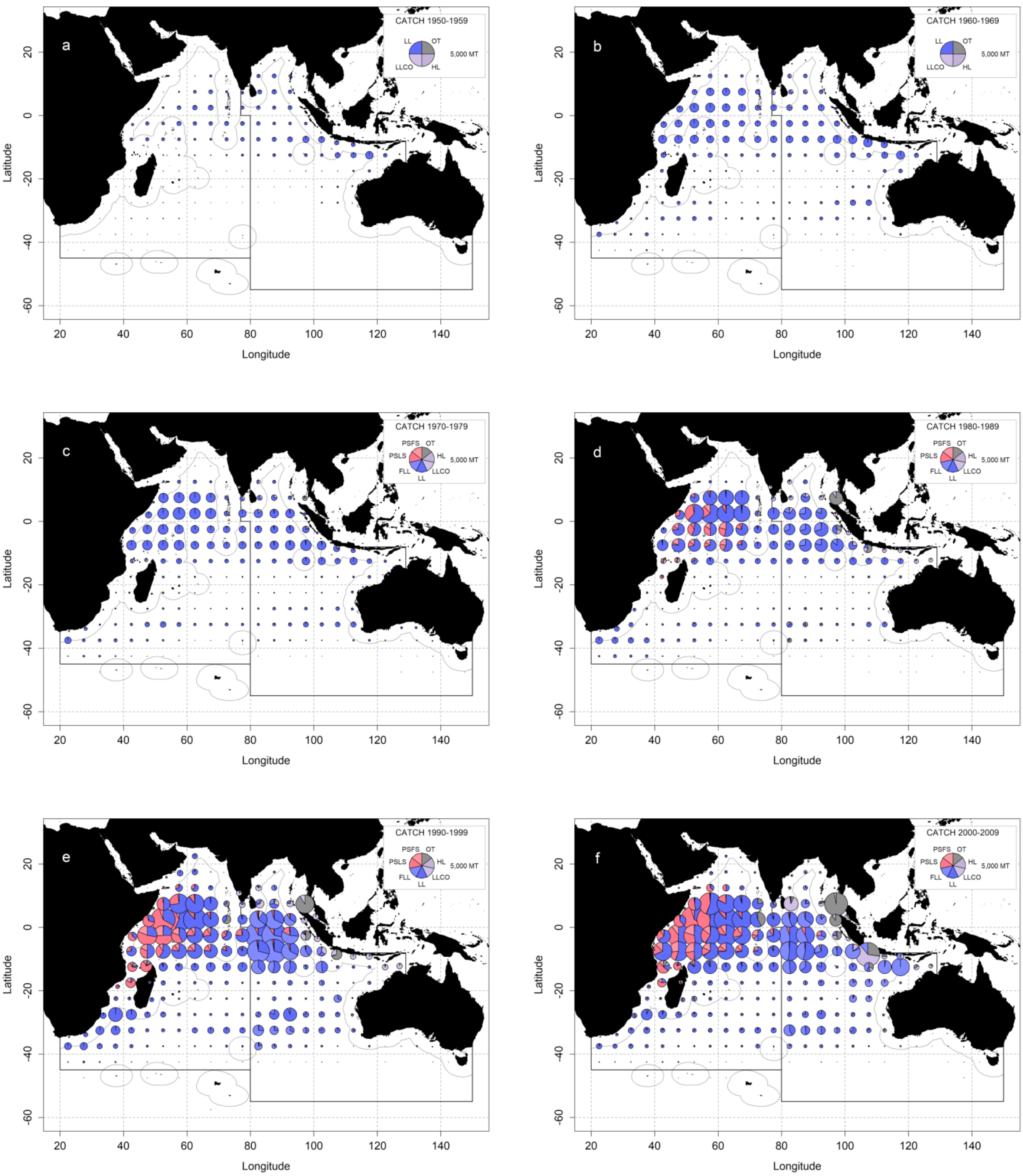


Fig. A7. Estimated average annual time-area catches (MT) of bigeye tuna for the period **1950–2009** by decade and type of gear. Black solid lines represent the IOTC areas. **PSLS** = purse seine (log/FAD school); **PSFS** = purse seine (free school); **FLL** = longline (fresh); **LL** = longline (deep-freezing); ***HL** = line (coastal longline, handline); **OT** = all remaining gears

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

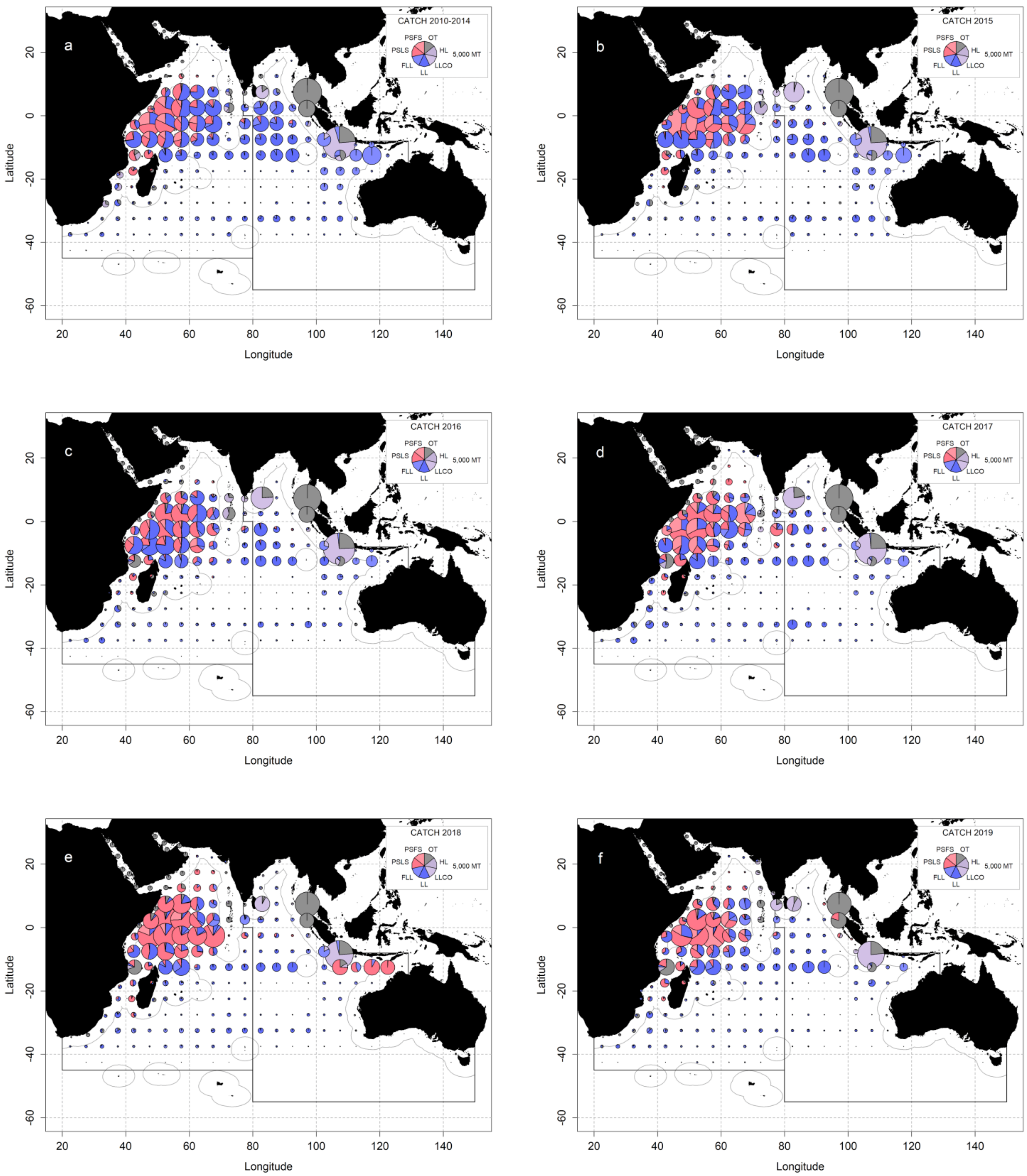


Fig. A8. Estimated average annual time-area catches (MT) of bigeye tuna for the period **2015**–**2019** by type of gear and for **2015**–**19**, by year and type of gear. Black solid lines represent the IOTC areas. **PSLS** = purse seine (log/FAD school); **PSFS** = purse seine (free school); **FLL** = longline (fresh); **LL** = longline (deep-freezing); **HL** = line (coastal longline, handline); **OT** = all remaining gears

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 a relatively low proportion of catches estimated, or adjusted, by the IOTC Secretariat (**Fig. A9a**).
- Catches of bigeye tuna in the industrial purse seine fishery are estimated from large numbers of size samples collected at unloading and a data processing procedure that relies on large, fixed time-area strata which date back to the '90s and are currently being assessed and revised.
- 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: until 2012, pole-and-line fishery of Maldives, drifting gillnet fisheries of I.R. Iran and Pakistan; until 2014, gillnet-longline fishery of Sri Lanka; artisanal fisheries of 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) and industrial purse seine fisheries (EU, Seychelles, Mauritius) but these latter are generally not considered as reliable proxies of tuna abundance due to the difficulties associated with the definition of fishing effort in purse seine fisheries.

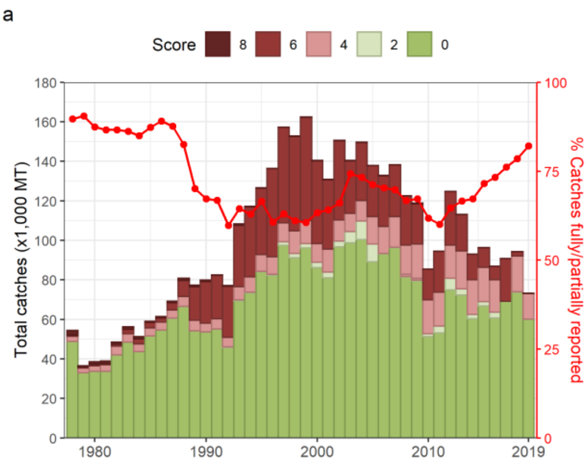
  For most other fisheries, catch-and-effort are either not available (**Fig. A9b**), or are considered to be of poor quality – especially since the early '90s and for the following fisheries/fleets:

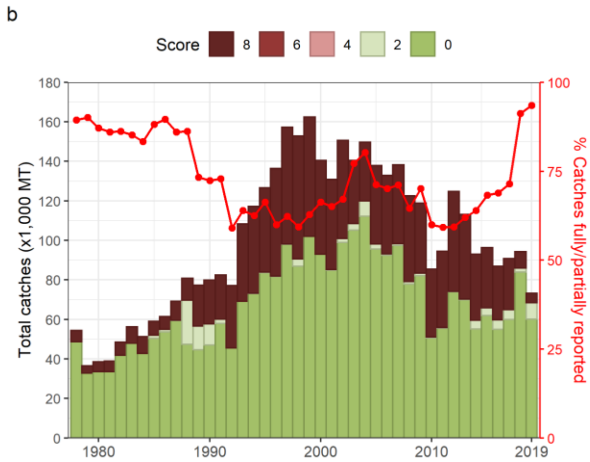
  - NEI purse seine and longliners: no data available;
  - Fresh-tuna longline fisheries: no data are available for the fresh-tuna longline fishery of Indonesia, while data for the fresh-tuna longline fishery of Taiwan,China have only been available since 2006;
  - Other industrial fisheries: uncertain 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 2018-2019 but the coverage of the geo-referenced data remains low;
  - 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. A9c**) or of poor quality for most fisheries before the mid '80s and for some fleets in recent years (e.g. Japan and Taiwan,China longline). In 2018-2019, 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-schools), the estimated average weight of caught individuals decreased sensibly to an all-time low of less than 4.5 Kg / fish (Indian Ocean wide, all gears) as opposed to about 10 Kg / fish estimated during 2013-2017 (**Fig. AA3**).
- 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 '70s up to the mid80s and in recent years (Japan and Taiwan,China), with some inconsistencies between observer and crew-based samples as well as with average weights derived from logbooks when catches are reported in both numbers and weights.
  - Lack of size data available for some industrial fleets (NEI, India, Indonesia, I.R. Iran, Sri Lanka).

Data quality (by dataset)





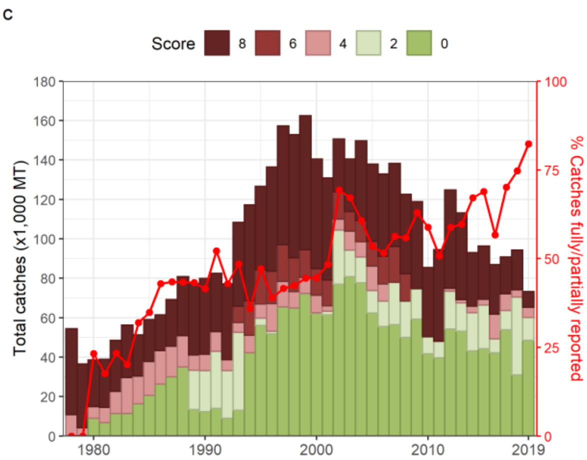


Fig. A9. Annual nominal catches (MT) of bigeye tuna estimated by quality score (barplot) and percentage of nominal catch fully/partially reported to the IOTC Secretariat (red line with circles) for all fisheries (1978–2019) for (a) Nominal Catch; (b) Catch-Effort and (c) Size-Frequency data

Each IOTC dataset is assessed against IOTC reporting standards, where:

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

Key to IOTC Scoring system

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

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

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

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

Key to colour coding

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

Tagging data

- A total of 35,948 bigeye tuna (representing 16.5% of the total number of fish tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP), of which about 96% 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. A10**). 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 southwest and the eastern Indian Ocean.
- To date, 5,781 specimens (16% of releases for this species) have been recovered and reported to the IOTC Secretariat. These tags were mainly reported from the purse seine fleets operating in the Indian Ocean (91%), while 5% were recovered from longline vessels.

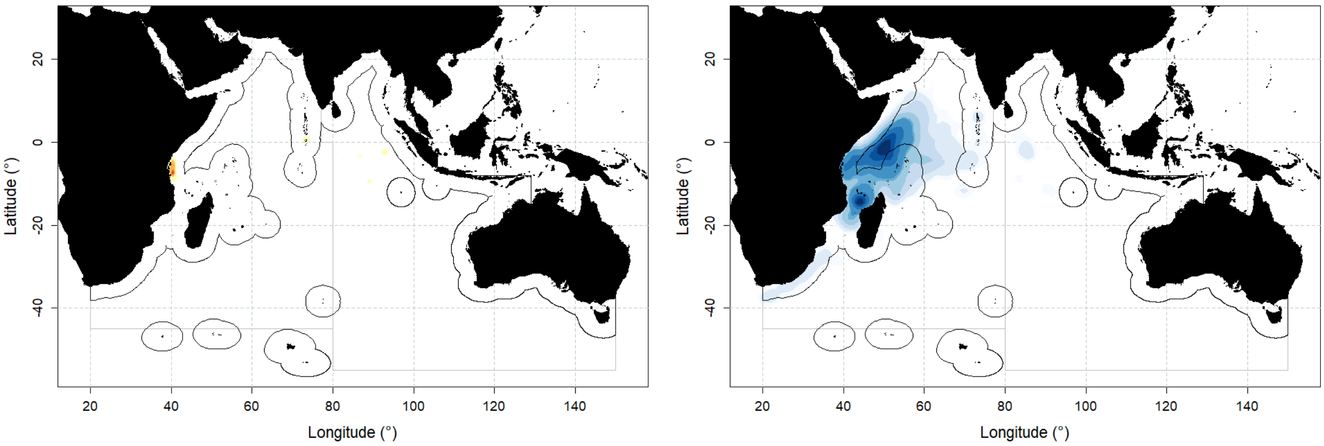


Fig. A10. Density distribution of (left panel) releases and (right panel) recoveries of bigeye tuna tagged during the during the Maldivian and Indian Ocean Tuna Tagging programmes

Average weights

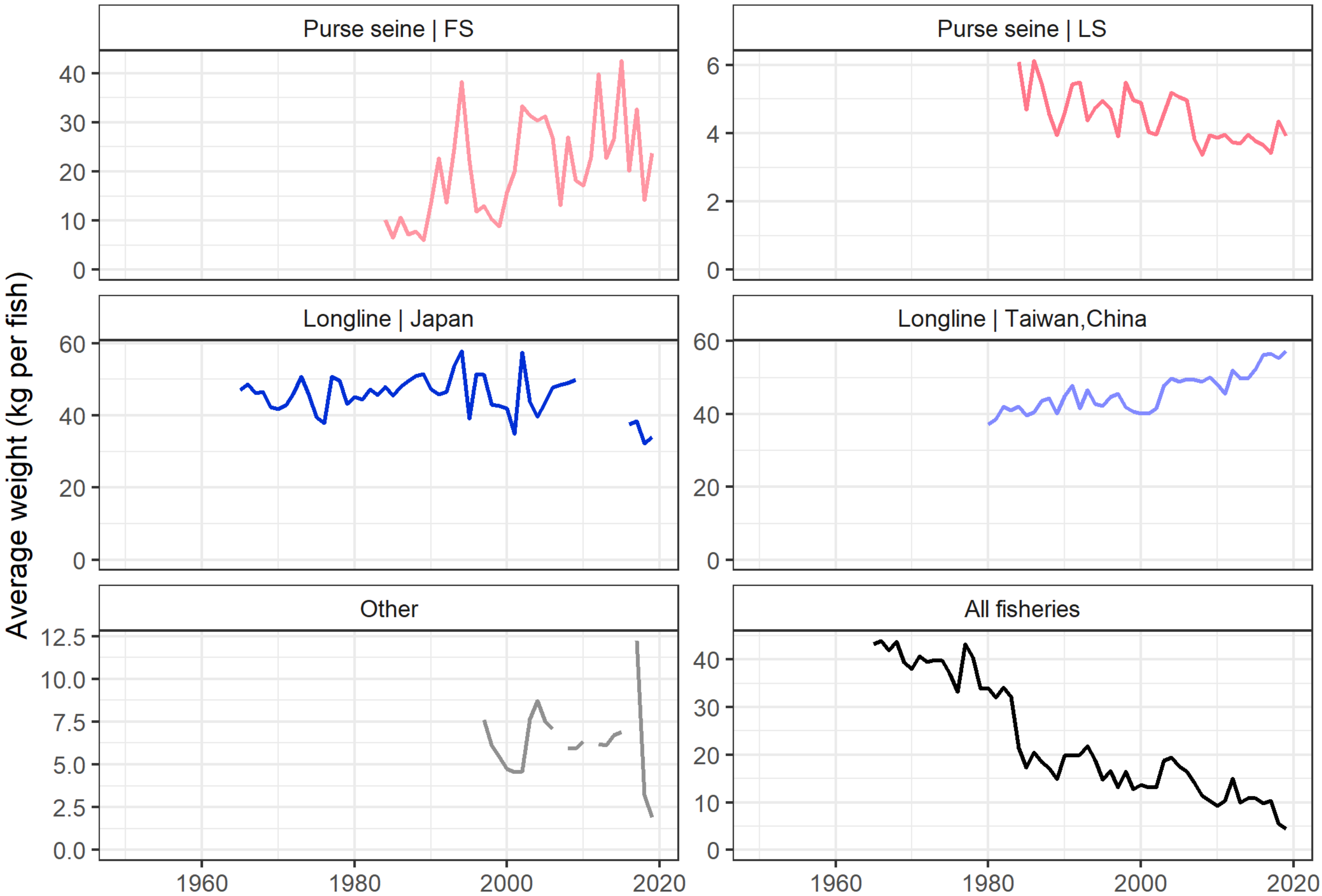


Fig AA3. Annual time series of estimated average weight (kg) of bigeye tuna caught with (top left panel) purse seine on free schools (FS), (top right panel) log/FAD-associated schools (LS), (middle left panel) longline from Japan and assimilated[1], (middle right panel) longline from Taiwan,China and assimilated[2], (bottom left panel) gears from all remaining fisheries, (bottom right panel) all gears from Indian Ocean fisheries. Source: estimated raised catches in weight and number (1950-2019). Data are only shown for those years for which the original size samples cover strata with reported catches by year and fishery higher than 50 MT

[1] Japan, Rep. of Korea, and Thailand
[2] Taiwan,China and all other longline fleets not flagged by Japan, Rep. of Korea, and Thailand

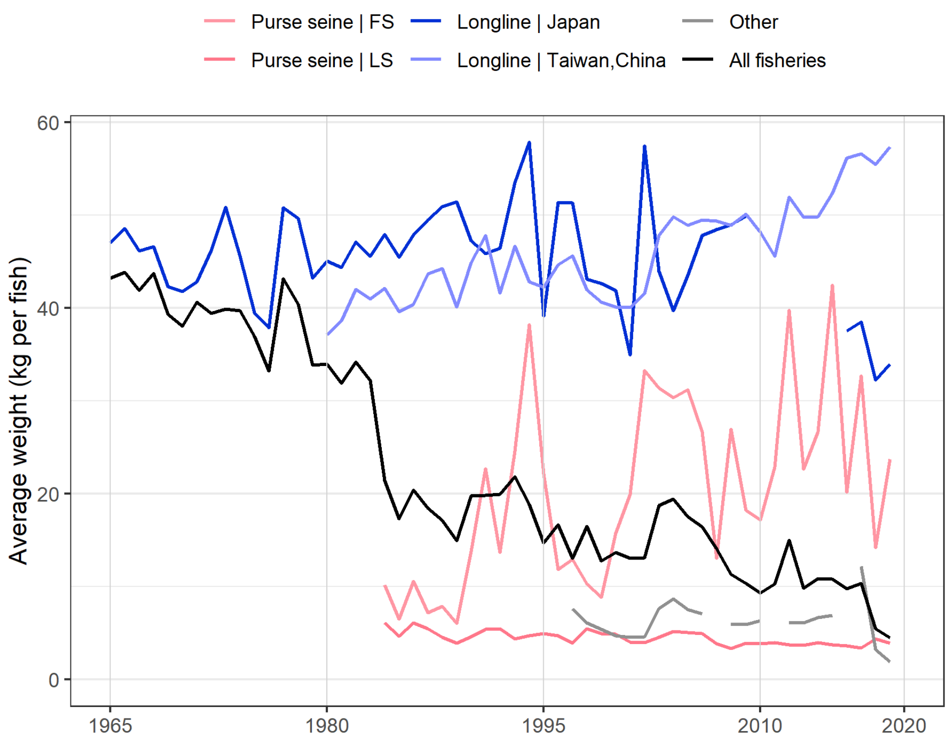


Fig AA4. Comparison of annual time series of estimated average weight (kg) of bigeye tuna caught by the major fleets with different fishing gears and for all fisheries combined. Source: estimated raised catches in weight and number (1965-2019). Data are only shown for those years for which the original size samples cover strata with reported catches by year and fishery higher than 50 MT

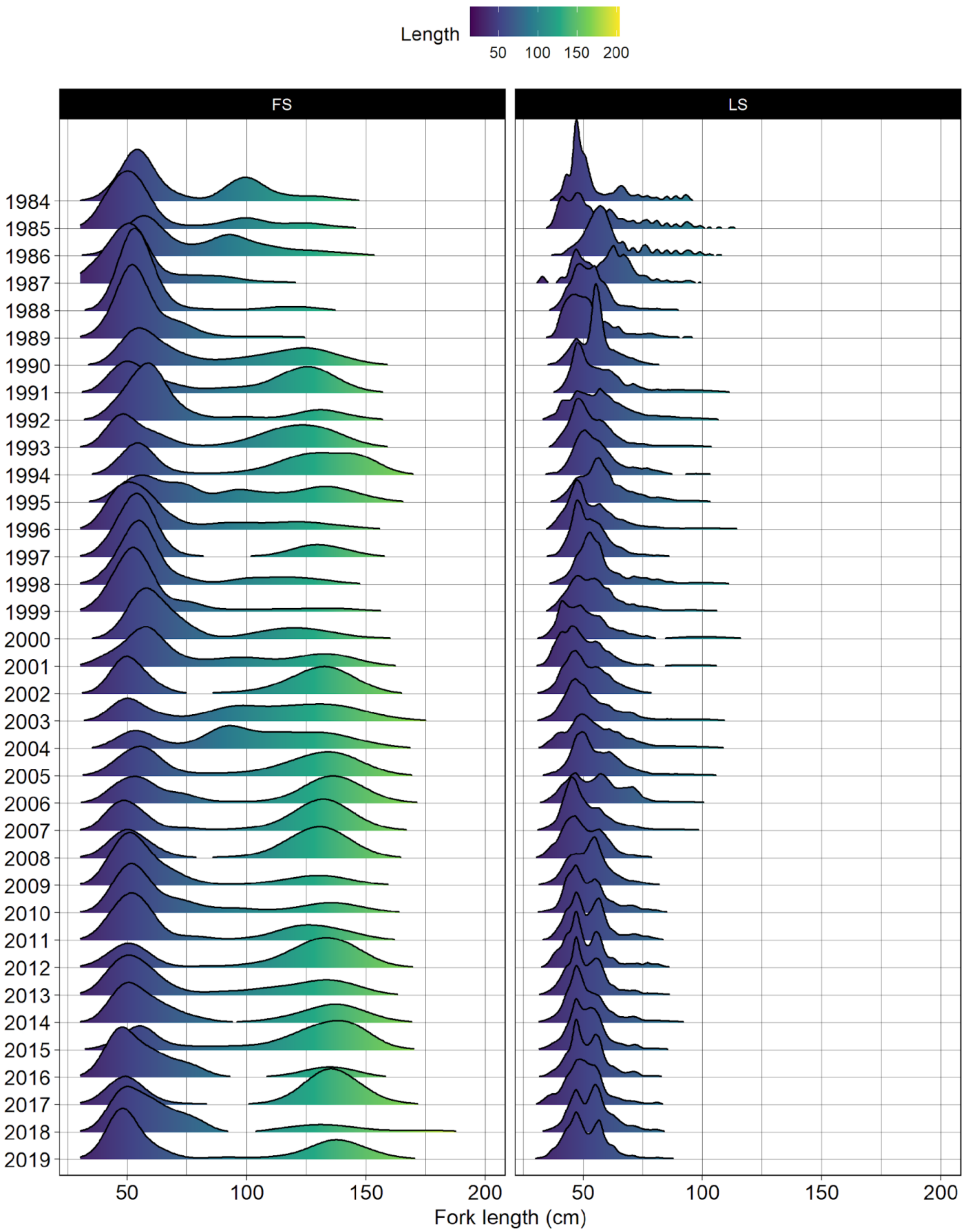


Fig. AA5. Length frequency distributions (by 2 cm length class) of bigeye tuna caught with industrial purse seine on (left) free schools (FS) and (right) on log/FAD-associated schools (LS) during 1984-2019

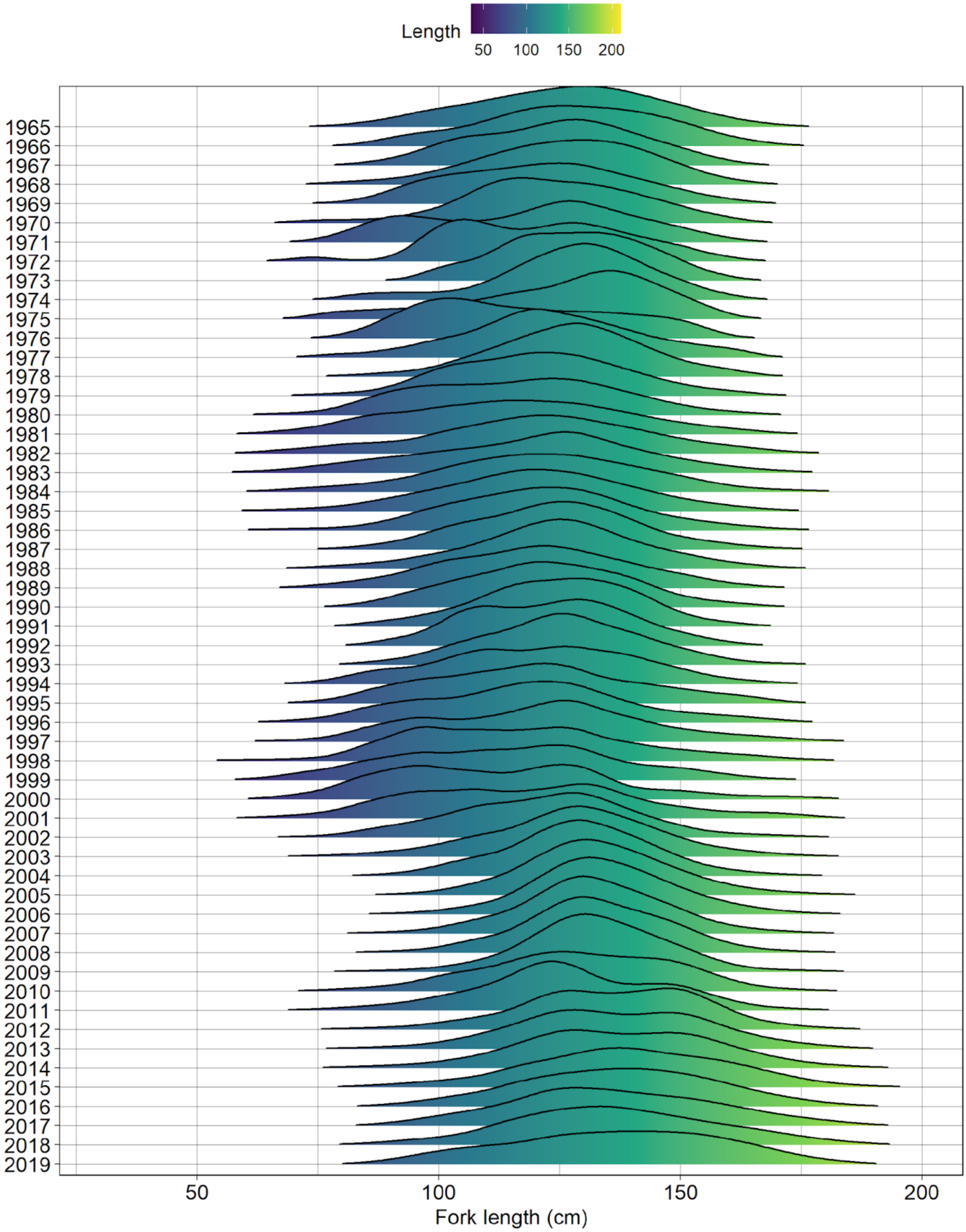


Fig. AA6. Length frequency distributions (by 2 cm length class) of bigeye tuna caught with deep-freezing longline during 1965-2019

APPENDIX IVC
MAIN STATISTICS FOR SKIPJACK TUNA

(Extracts from IOTC–2020–WPTT22(AS)–03_Rev3)

Fisheries and main catch trends (2015–19)

Main fishing gears

Skipjack tuna are mostly caught by industrial purse seine (44%) while pole-and-line and gillnet have the same level of contribution (19%) (**Table A3**; **Fig. A12**).

Main fleets (and primary gear associated with catches)

The five main fleets catching skipjack tuna are EU,Spain (purse seine): 19%; Maldives (pole-and-line): 16%; Indonesia (coastal purse seine, troll line, gillnet): 16%; Seychelles (purse seine): 13% and I.R. Iran (gillnet): 9% (**Fig. A13**).

Main fishing areas

- **Primary**: Western Indian Ocean, in waters off Somalia and north of the Mozambique Channel and in the Maldives;
- **Secondary**: Waters off Sri Lanka, western Australia, and Indonesia.

Retained catch trends

- Purse seine fisheries: the increase in catches of skipjack tuna in the last 40 years has largely been driven by the arrival of purse seiners in the early ‘80s, and the development of the fishery in association with FADs since the early to mid ’90s. Following the major decrease in purse seine effort related to the piracy threat during 2008-2012, the catches of skipjack tuna have steadily increased to exceed 300,000 MT in 2018, with more than 95% caught on schools associated with drifting FADs and logs (**Table A3**; **Fig. A12**).

  In 2019, the purse seine catches of skipjack tuna were larger than 280,000 MT, with more than 12% of the catches coming from free schools (34,668 MT) while the mean annual percentage contribution of free schools to the skipjack purse seine catch was around 5% during 2010-2016 and less than 3% during 2017-2018.

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

  Catches of skipjack tuna reported by Maldivian pole-and-liners then declined to as low as 55,000 MT in 2012, i.e. 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. Catches of skipjack tuna with pole-and-line increased to reach 100,000 MT in 2018, with most of these catches (over 80%) being caught by larger vessels with overall length above 24m. In 2019, the catches reported for the fishery were close to 90,000 MT.

- 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 about 20% of the total catches of skipjack tuna in the Indian Ocean (**Table A3**; **Fig. A12**). 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 vessels may use a mix of gillnet and longline fishing gears and time-area catch-and-effort series have been made available for those fleets only in recent years.

Discard levels

Discard levels are thought to be low, although estimates of discards are unknown for most fisheries, except for the industrial purse seine fishery for 2003-2017. Discards may also occur in the driftnet fishery of I.R. Iran, as this species has no commercial value in this country.

Catch series

No major change has occurred in the nominal catch series of skipjack tuna since the WPTT meeting in 2019. The revised Pakistan gillnet catches from 1987 onwards (incorporated into the IOTC database in December 2019) introduced a total reduction in skipjack tuna catches of 69,277 MT (2,165 MT / year) in the years concerned (1987-2018) when compared to the data available at the WPTT21 (**Fig. A11**).

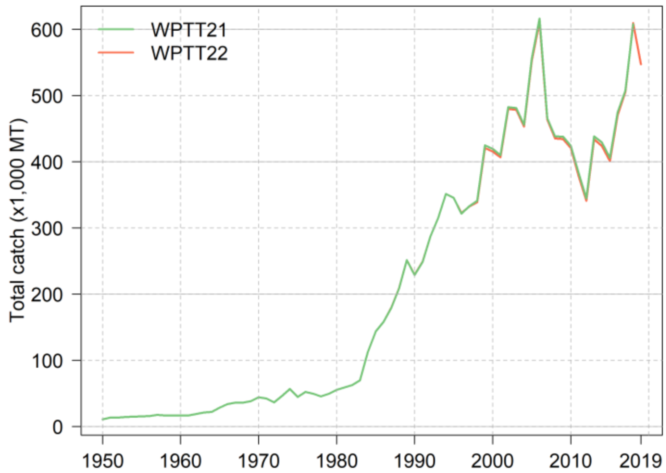


Fig. A11. Comparison of annual time series of total catches (MT) of Indian Ocean skipjack tuna available at the 21st (WPTT21, 2019) and 22nd (WPTT22, 2020) sessions of the IOTC Working Party on Tropical Tunas

TABLE A3. Best scientific estimates of the annual nominal catches (MT) of skipjack tuna by fishery for the period 1950–2019. Colour codes (yellow = lower, green = higher) describe the intensity of captures by fishery across decades (left) and years (right). 'Purse seine' includes industrial purse seiners only and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Purse seine | FS	0	0	41	15,252	30,776	25,672	8,774	9,000	2,984	5,742	7,228	7,800	6,888	6,170	6,235	34,268
Purse seine | LS	0	0	125	34,457	124,043	163,801	144,097	123,056	80,989	119,864	122,490	123,994	182,735	208,876	301,570	247,687
Baitboat	10,007	15,148	24,684	41,705	76,903	109,571	83,506	69,404	68,821	93,010	81,568	82,748	96,268	99,423	111,867	97,516
Gillnet	2,310	6,775	11,173	14,524	43,159	111,700	98,919	87,724	92,570	105,673	102,900	87,419	82,796	99,663	111,983	88,941
Other	2,697	4,943	10,894	24,183	44,250	62,238	85,399	89,266	95,566	109,547	109,873	98,712	101,499	91,354	77,524	78,837
Total	**15,014**	**26,866**	**46,917**	**130,121**	**319,131**	**472,982**	**420,695**	**378,450**	**340,930**	**433,836**	**424,059**	**400,673**	**470,186**	**505,486**	**609,179**	**547,249**

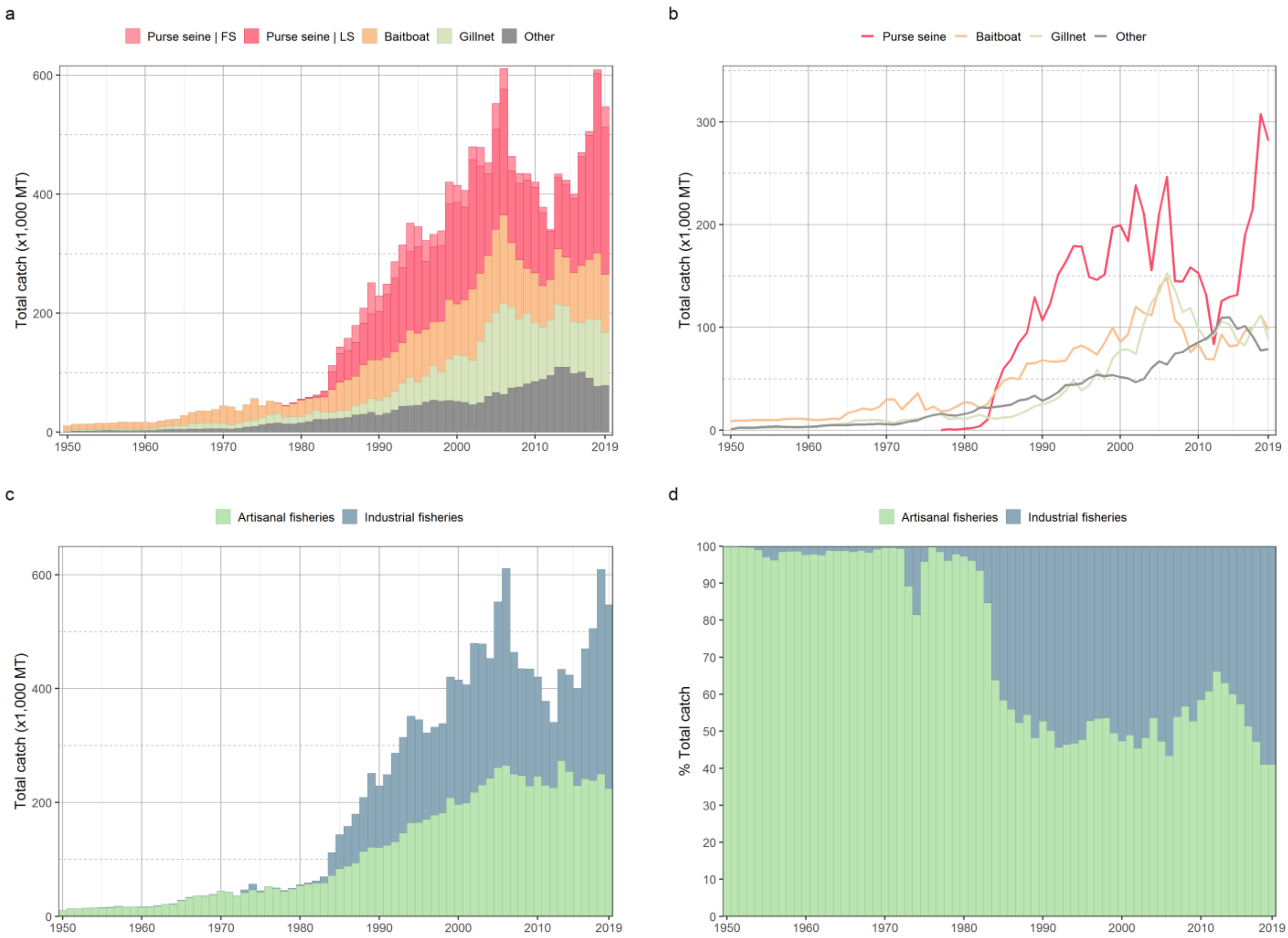


Fig. A12. Annual time series of skipjack tuna during 1950-2019 (a) cumulative nominal catches (MT) by gear; (b) individual nominal catches (MT) by gear group for skipjack tuna; (c) cumulative nominal catches (MT) by fishery type and (d) percentage share by fishery type. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

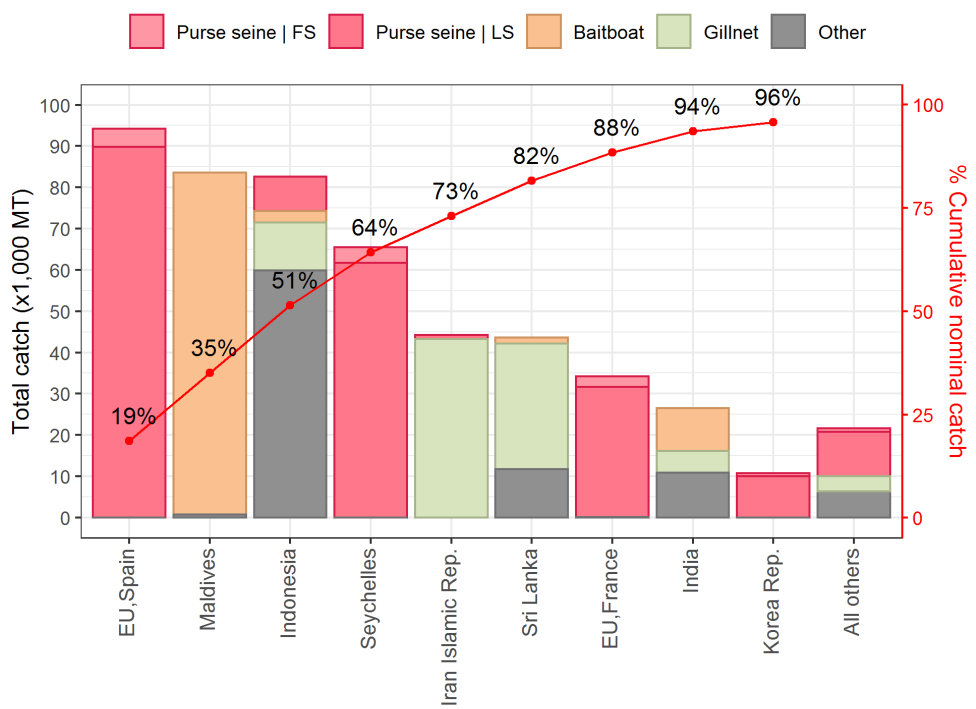


Fig. A13. Average nominal catches (MT) of skipjack tuna over the period 2015–2019, by gear group and CPC ordered according to the importance of catches. The red solid line indicates the cumulative percentage of the total combined catches of the species for the CPCs concerned. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

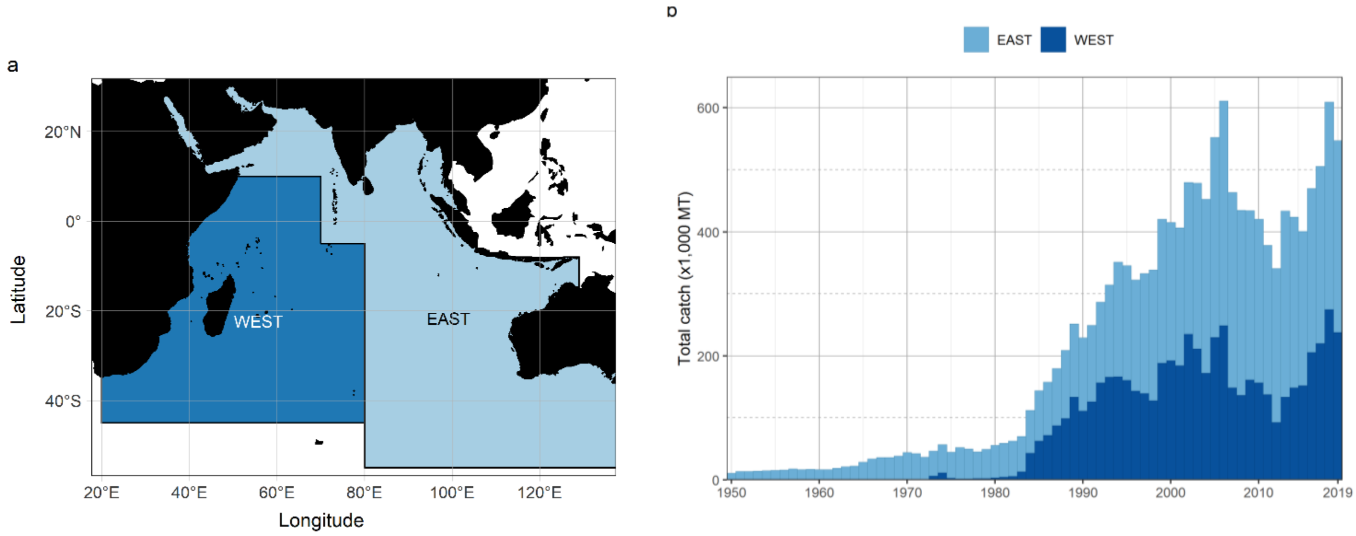


Fig. A14. (a) Map of areas used for some configurations of the assessment model of skipjack tuna in 2020 (see Document IOTC-2020-WPTT-22(AS)-10) and (b) annual time series of nominal catches (MT) of skipjack tuna for each assessment area

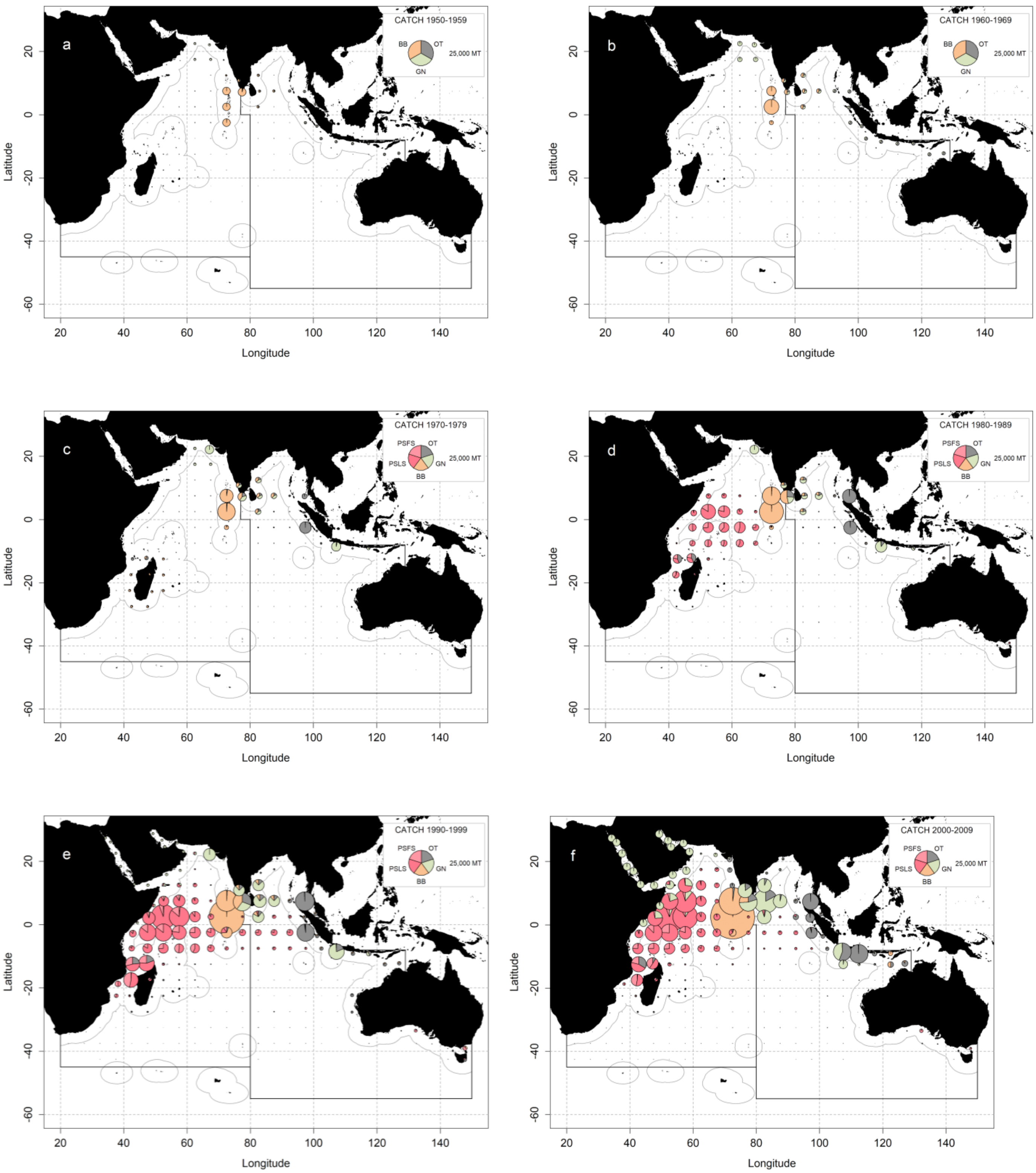


Fig. A15. Estimated average annual time-area catches (MT) of skipjack tuna for the period **1950–2009** by decade and type of gear. Black solid lines represent the IOTC areas. **PSLS** = purse seine (log/FAD school); **PSFS** = purse seine (free school); **GN** = gillnet; **BB** = baitboat / pole-and-line; **OT** = all remaining gears

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

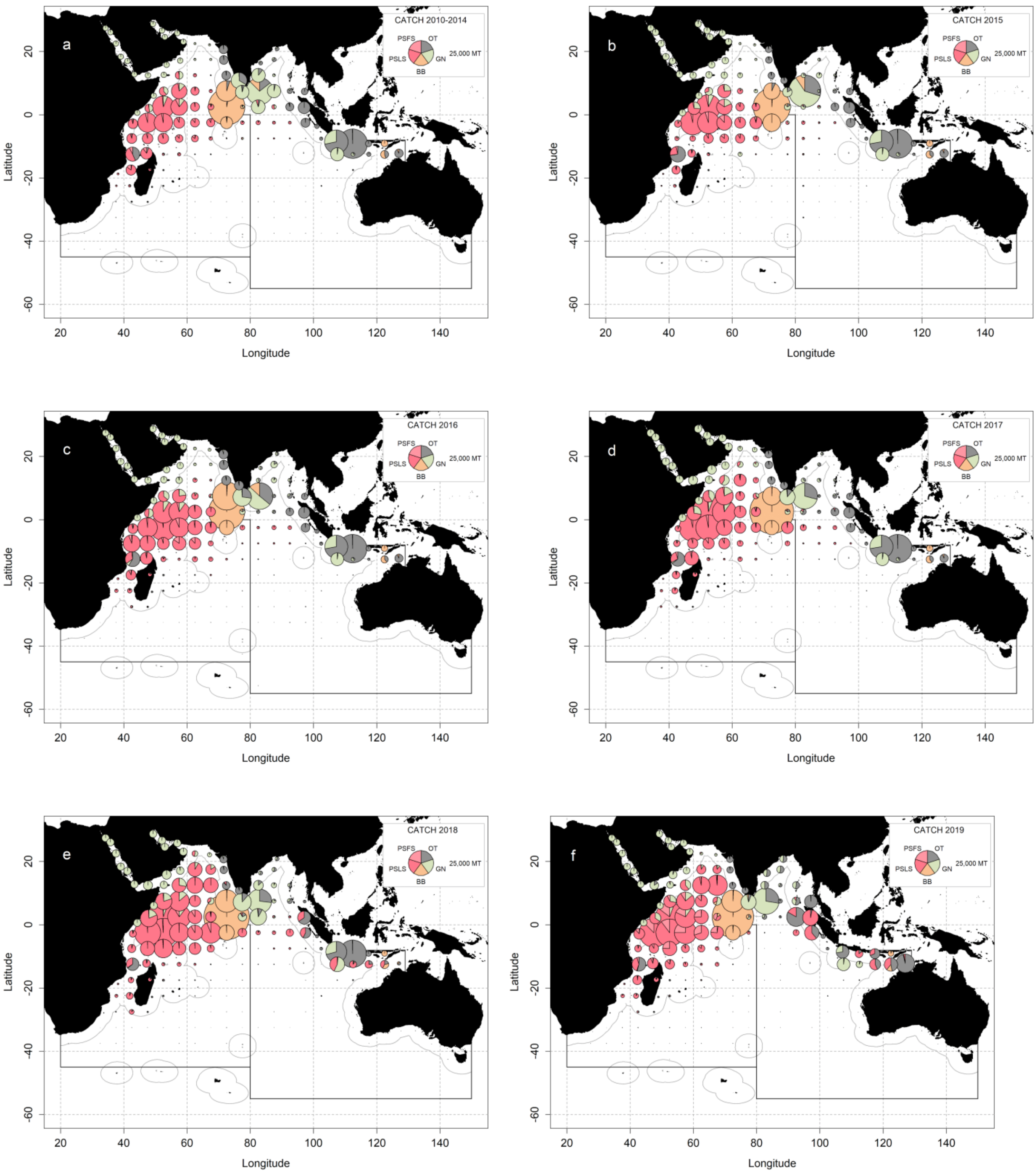


Fig. A16. Estimated average annual time-area catches (total combined in tonnes) of skipjack tuna for the period **2010–2014** by type of gear and for **2015–19**, by year and type of gear. Black solid lines represent the IOTC areas. **PSLS** = purse seine (log/FAD school); **PSFS** = purse seine (free school); **GN** = gillnet; **BB** = baitboat / pole-and-line; **OT** = all remaining gears

Data availability and related data quality issues

Retained catches

- Retained catches are considered to be generally well known for the major industrial fleets, with a low proportion of catches estimated, or adjusted, by the IOTC Secretariat (**Fig. A17a**). Catches are less certain for many artisanal fisheries for several 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

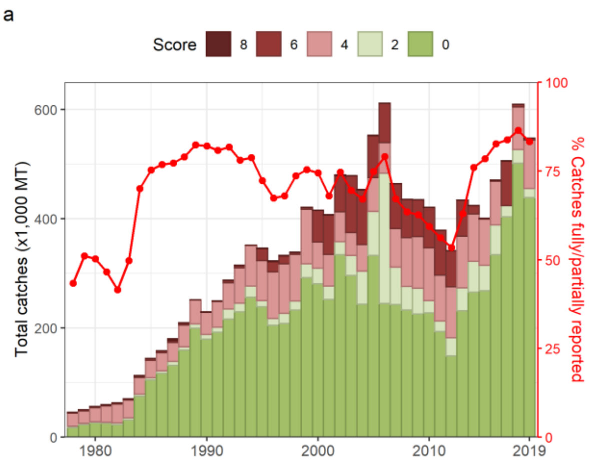
- Catch-and-effort series are available for the various industrial and artisanal fisheries (e.g., Maldives pole-and-line fishery, EU,France purse seine).

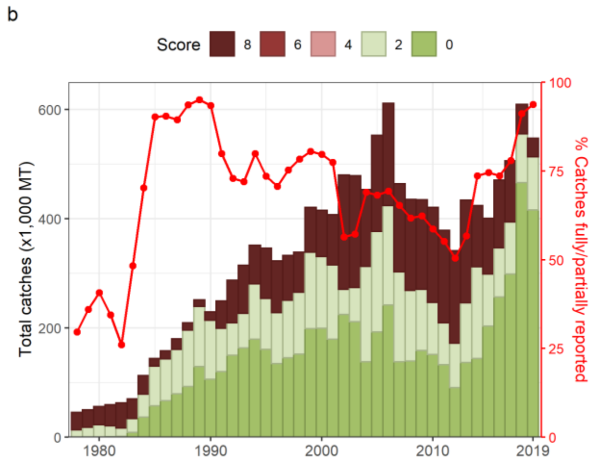
  However, for several other important fisheries catch-and-effort are either not available, or are considered to be of poor quality (**Fig. A17b**), notably:
  - insufficient data available for the gillnet fisheries of I.R. Iran (before 2007) and Pakistan;
  - poor quality effort data for the gillnet-longline 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, and again in 2019, although with very low levels of coverage.

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 ’80s and are also incomplete for most artisanal fisheries, namely hand lines, troll lines and many gillnet fisheries (e.g., Indonesia) (**Fig. A17c and AA7**).
- Catch-at-Size (Age) table: Available but the estimates are uncertain for some years and fisheries due to:
  - general lack of size data before the mid ’80s, for all fleets/fisheries;
  - lack of size data available for some artisanal fisheries, notably most hand lines and troll line fisheries (e.g., Madagascar), many gillnet (e.g., Indonesia, Sri Lanka) and small purse seine fisheries – although Indonesia reported good size information for its small purse seine fishery in 2019. It is noteworthy that size data reported by Sri Lanka for its coastal and offshore gillnet fisheries in 2017 and 2019 were found to be identical to the data reported for 2016.

Data quality (by dataset)





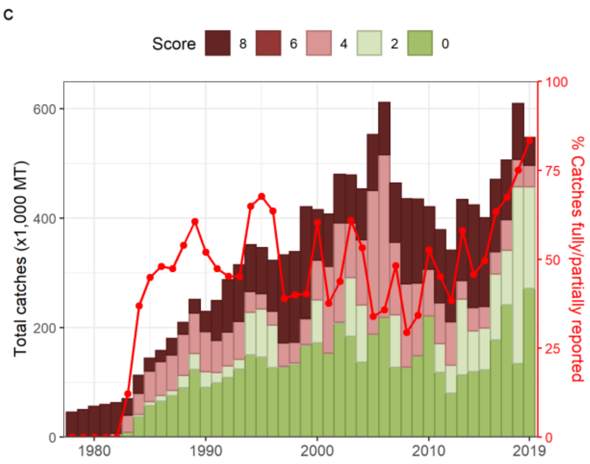


Fig. A17. Annual nominal catches (MT) of skipjack tuna estimated by quality score (barplot) and percentage of nominal catch fully/partially reported to the IOTC Secretariat (red line with circles) for all fisheries (1978–2019) for (a) Nominal Catch; (b) Catch-Effort and (c) Size-Frequency data

Each IOTC dataset is assessed against IOTC reporting standards, where:

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

Key to IOTC Scoring system

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

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

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

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

Key to colour coding

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

Tagging data

- A total of 101,353 skipjack tunas (representing 46% of the total number of fish tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP), of which ≈77% (n = 78,324) 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. A18**). The remaining fish (n = 23,029) were tagged during small-scale tagging projects, and by other institutions with the support of IOTC around the Maldives, India, and in the southwest and the eastern Indian Ocean. The past tagging projects conducted in the Maldives in the '90s added 14,506 tagged skipjack tunas to the database.
- To date, 17,835 specimens (12.8% of releases for this species), have been recovered and reported to the IOTC Secretariat: 1,960 as part of the historical tagging projects in the Maldives and 15,875 throughout the IOTTP. 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.

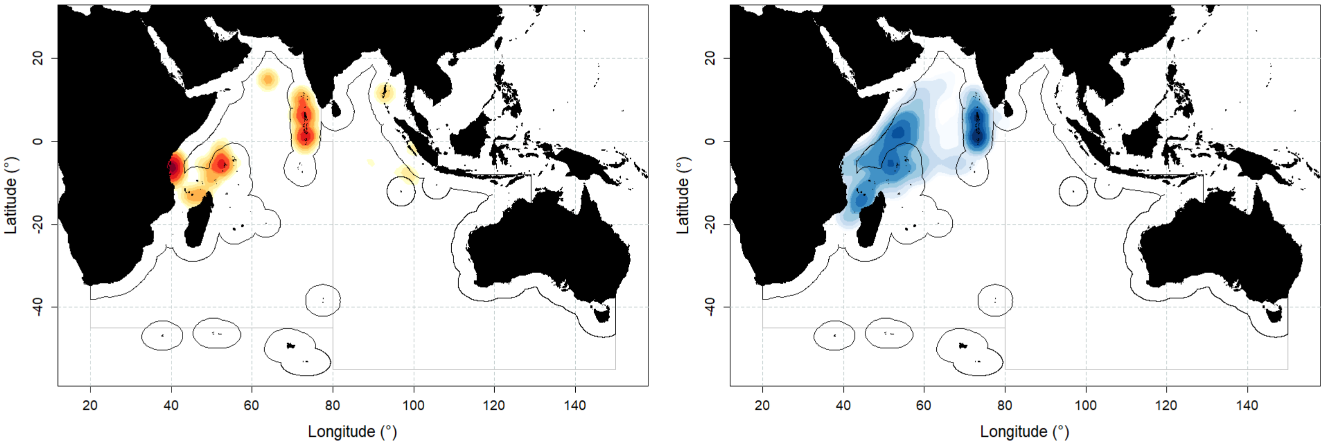


Fig. A18. Density distribution of (left panel) releases and (right panel) recoveries of skipjack tuna tagged during the during the Maldivian and Indian Ocean Tuna Tagging programmes

Average weights

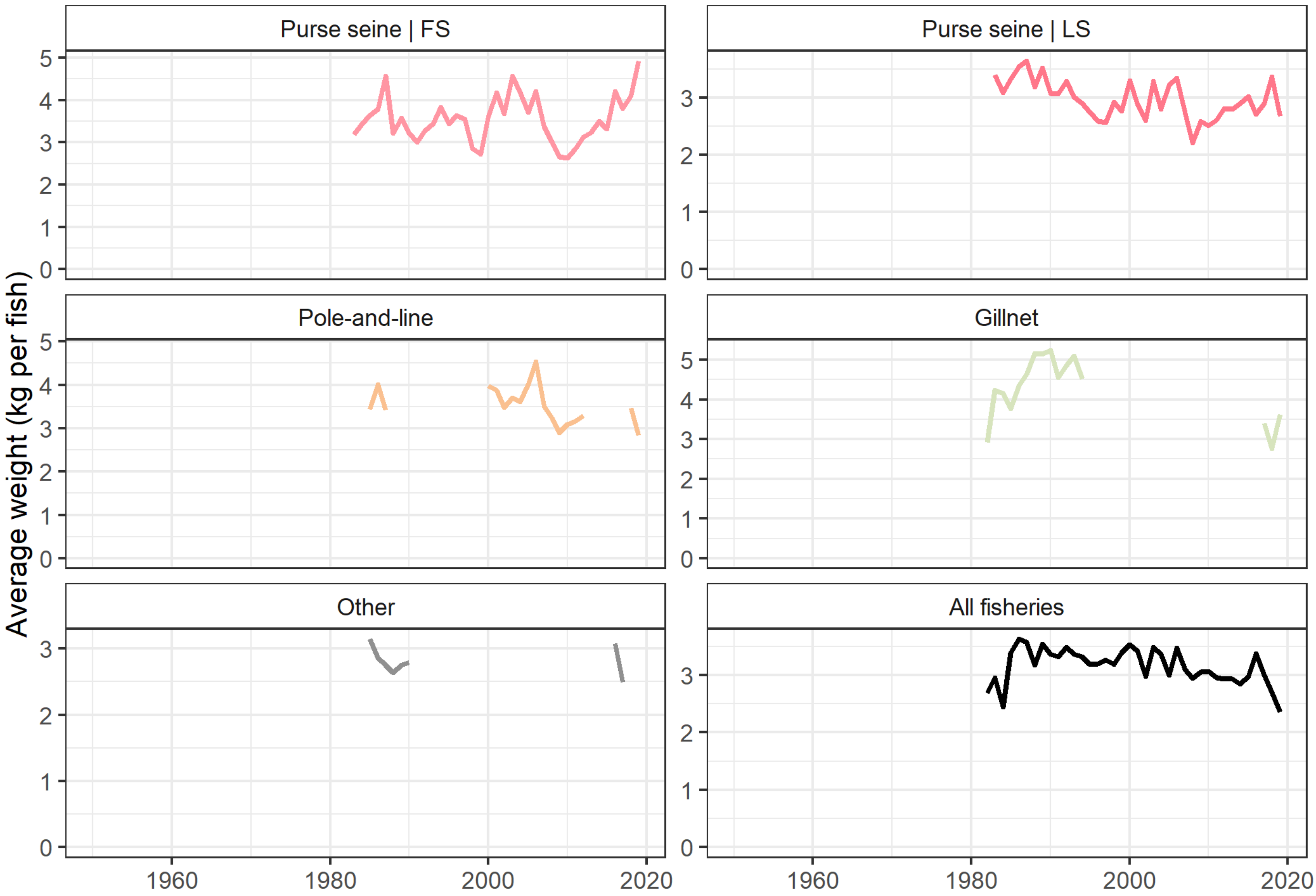


Fig. AA7. Annual time series of estimated average weight (kg) of skipjack tuna caught with (top left panel) purse seine on free schools (FS), (top right panel) log/FAD-associated schools (LS), (middle left panel) pole-and-line from Maldives and India, (middle right panel)gillnet from Sri Lanka, (bottom left panel) gears from all remaining fisheries, (bottom right panel) all gears from Indian Ocean fisheries. Source: estimated raised catches in weight and number (1950-2019). Data are only shown for those years for which the original size samples cover strata with reported catches by year and fishery higher than 50 MT

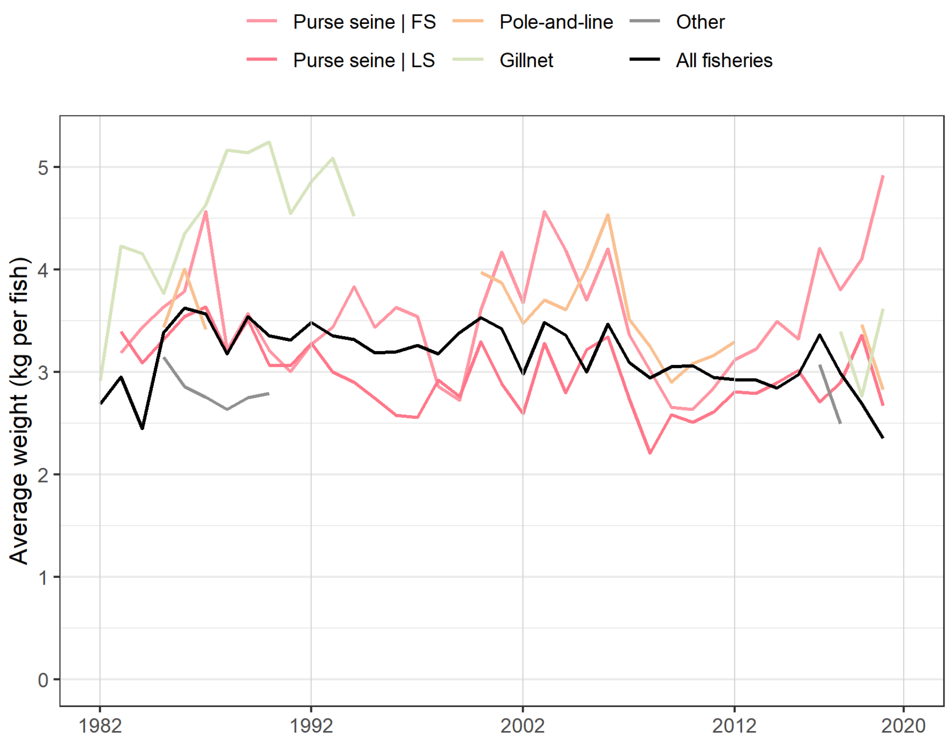


Fig. AA8. Comparison of annual time series of estimated average weight (kg) of skipjack tuna caught by the major fleets with different fishing gears and for all fisheries combined. Source: estimated raised catches in weight and number (1965-2019). Data are only shown for those years for which the original size samples cover strata with reported catches by year and fishery higher than 50 MT

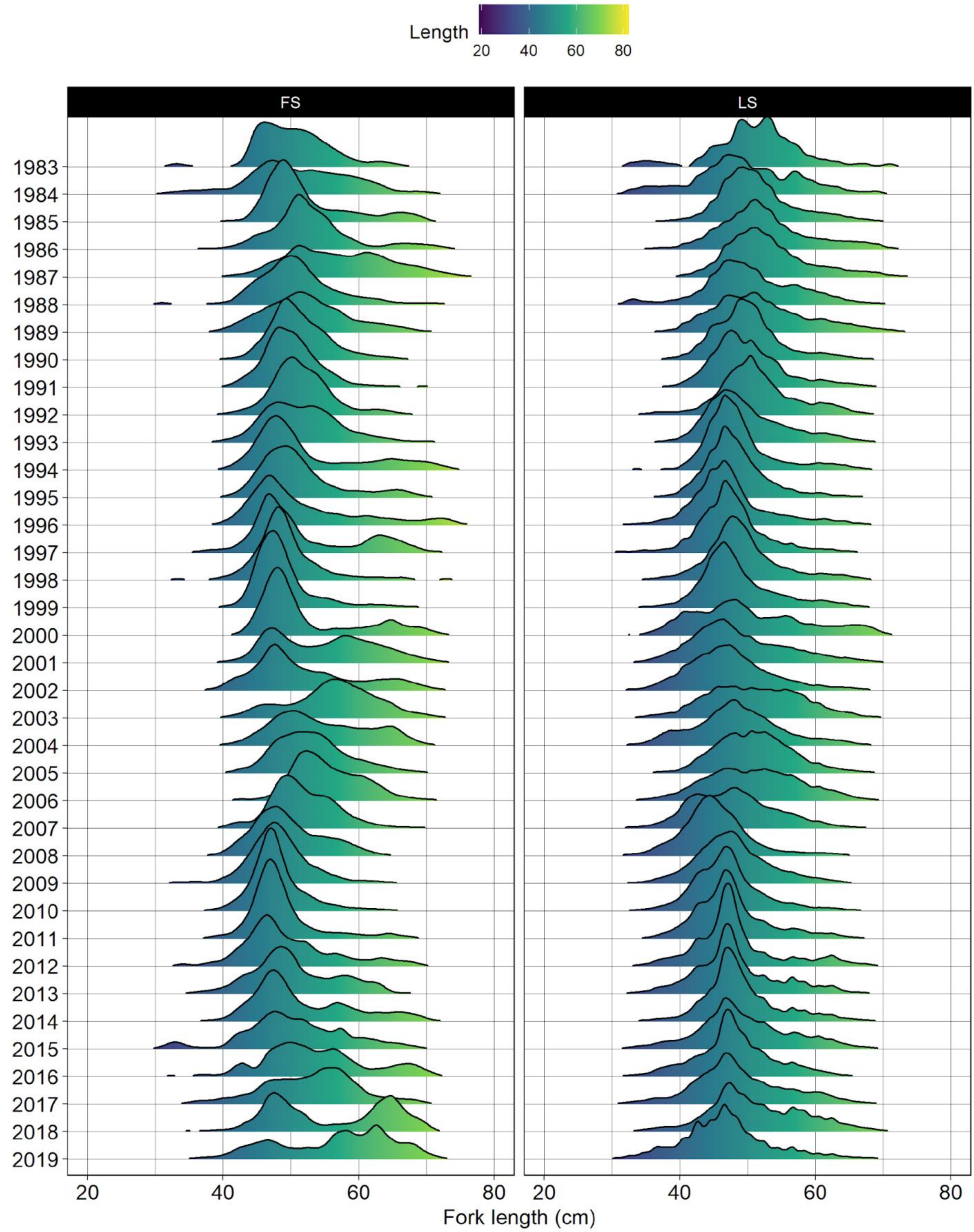


Fig. AA9. Length frequency distributions (by 1 cm length class) of skipjack tuna caught with industrial purse seine on (left) free schools (FS) and (right) on log/FAD-associated schools (LS) during 1983-2019

APPENDIX IVD
MAIN STATISTICS FOR YELLOWFIN TUNA

(Extracts from IOTC–2020–WPTT22(AS)–03_Rev3)

Fisheries and main catch trends (2015-2019)

Main fishing gears

In recent years catches have been evenly split between industrial and artisanal fisheries, with a mean annual catch of about 210,000 MT for each component during 2015-2019. 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 ‘80s (**Table A4**; **Fig. A20**).
Contrary to other oceans, the artisanal fishery component of yellowfin catches in the Indian Ocean is substantial, accounting for catches of around 200,000 MT per annum since 2012. Moreover, the percentage of yellowfin catches from artisanal fisheries has increased from around 30% in 2000 to nearly 50% of the total catch of yellowfin in the same period.

Main fleets (and primary gear associated with catches)

Percentage of total catches (2015–19): the five main fleets catching yellowfin tuna, described by similar catch levels for the three first ones, are I.R. Iran (gillnet): 12%; Maldives (handline, pole-and-line): 12%; EU-Spain (purse seine): 12%; Seychelles (purse seine): 8%; Sri Lanka (gillnet, coastal longliners): 8% (**Fig. A21**).

Main fishing areas

- **Primary**: Western Indian Ocean, around Seychelles and waters off Somalia, and Mozambique;
- **Secondary**: Maldives and along the coasts of India and Sri-Lanka.

Retained catch trends

Catches of yellowfin tuna remained stable between the mid ’50s and the early ’80s, ranging from between 30,000 MT and 70,000 MT, with longliners and gillnetters as the main fisheries. Catches increased rapidly in the early ’80s with the arrival of the purse seiners and increased activity of longliners and other fleets, reaching over 400,000 MT by 1993. Exceptionally high catches were recorded between 2003 and 2006 – with the highest catches ever recorded in 2004 at over 525,000 MT – 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 was 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 increased from 400,000 MT to around 420,000 MT in recent years, although the catches of 440,00 MT reported for 2018 might be under-estimated to some extent in relation to the change in data processing methodology by EU,Spain for its purse seine fleet for that year (see section on data quality issues).

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

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

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 18,000 MT in 2018 as opposed to an average of 45,000 MT recorded for the previous ten years. In 2019, the catches of large yellowfin tuna on free schools re-increased to almost 40,000 MT.

- Longline fishery: the longline fishery started in the early '50s and expanded rapidly 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

Discard levels are thought to be low, although estimates of discards are unknown for most industrial fisheries, excluding industrial purse seiners flagged in EU countries for the period 2003–17.

Catch series

Some changes have occurred in the nominal catch series of yellowfin tuna since the WPTT meeting in 2019 although they have not modified the general pattern of the time series. The revised Pakistan gillnet catches from 1987 onwards (incorporated in the IOTC database in December 2019) introduced a total increase in yellowfin tuna catches of 209,441 MT (6,545 MT / year) in the years concerned (1987-2018) when compared to the data available at the WPTT21 (**Fig. A19**).

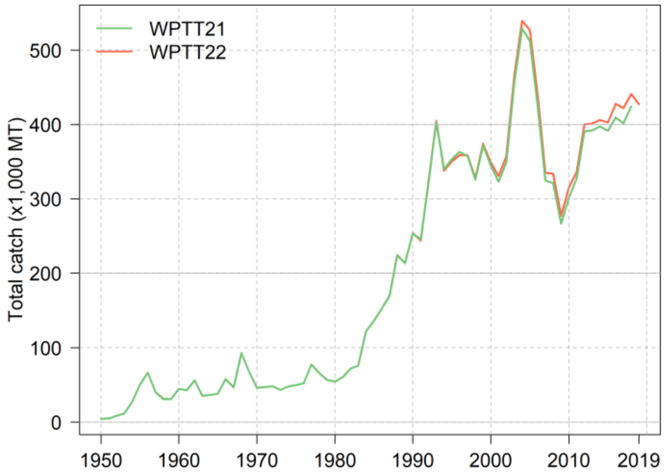


Fig. A19. Comparison of annual time series of total catches (MT) of Indian Ocean yellowfin tuna available at the 21st (WPTT21, 2019) and 22nd (WPTT22, 2020) sessions of the IOTC Working Party on Tropical Tunas

TABLE A4. Best scientific estimates of the annual nominal catches (MT) of yellowfin tuna by fishery for the period 1950–2019. Colour codes (yellow = lower, green = higher) describe the intensity of captures by gear group across decades (left) and years (right). Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Purse seine | FS	0	0	18	31,552	64,938	89,204	32,135	36,453	64,593	34,459	47,426	63,963	49,460	50,700	17,944	38,588
Purse seine | LS	0	0	17	17,597	56,278	61,890	73,383	76,659	66,166	101,898	86,417	78,395	99,268	94,479	121,699	94,111
Longline | Fresh	0	0	615	4,286	47,612	34,150	23,240	22,709	17,808	28,981	23,763	21,987	16,749	13,915	16,506	19,235
Longline | Deep-freezing	21,990	41,352	29,589	33,770	66,039	56,661	17,859	19,812	18,847	15,014	14,518	16,601	17,731	16,476	19,366	18,856
Line | Coastal longline	168	1,262	1,771	3,489	6,161	11,107	15,470	11,255	15,167	13,245	34,072	20,866	30,484	40,560	52,555	44,312
Line | Handline	621	641	2,948	7,861	19,803	34,368	33,397	58,071	78,568	70,018	71,490	73,907	86,025	65,557	72,959	89,656
Gillnet	1,575	4,118	7,928	12,034	39,199	58,819	64,529	58,074	72,912	65,326	80,484	82,650	82,967	94,515	92,437	80,268
Baitboat	2,111	2,318	5,810	8,295	12,803	16,072	14,105	14,009	15,512	24,055	20,542	17,642	12,391	18,370	20,030	18,551
Other	1,084	2,014	4,647	9,101	20,546	33,268	41,030	39,112	50,239	48,027	27,349	26,902	32,631	27,253	27,338	23,662
Total	27,549	51,705	53,343	127,985	333,379	395,539	315,148	336,154	399,812	401,023	406,061	402,913	427,706	421,825	440,834	427,239

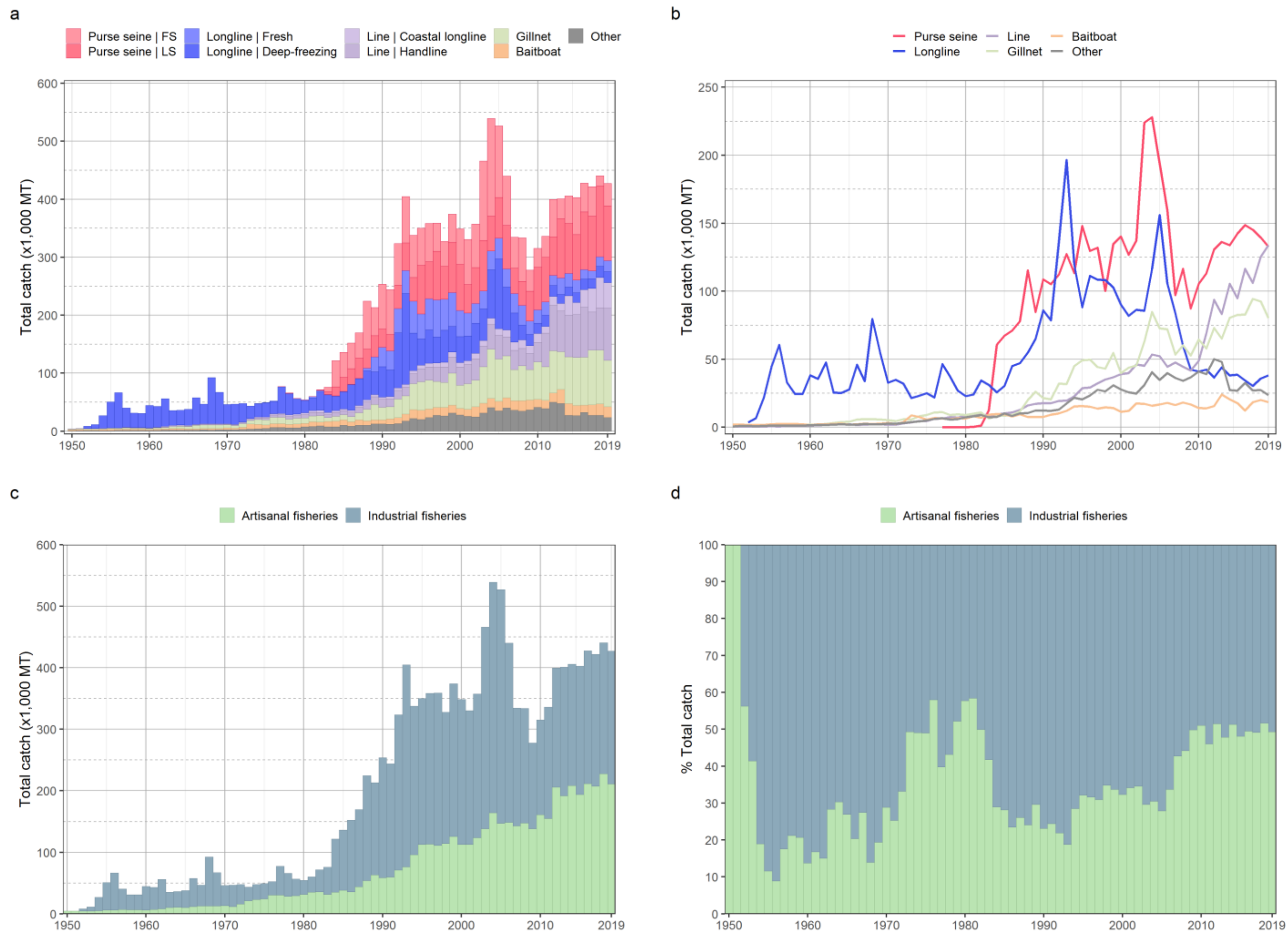


Fig. A20. Annual (1950–2019) time series of yellowfin tuna (a) cumulative nominal catches (MT) by gear; (b) individual nominal catches (MT) by gear group; (c) cumulative nominal catches (MT) by fishery type and (d) percentage share by fishery type. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

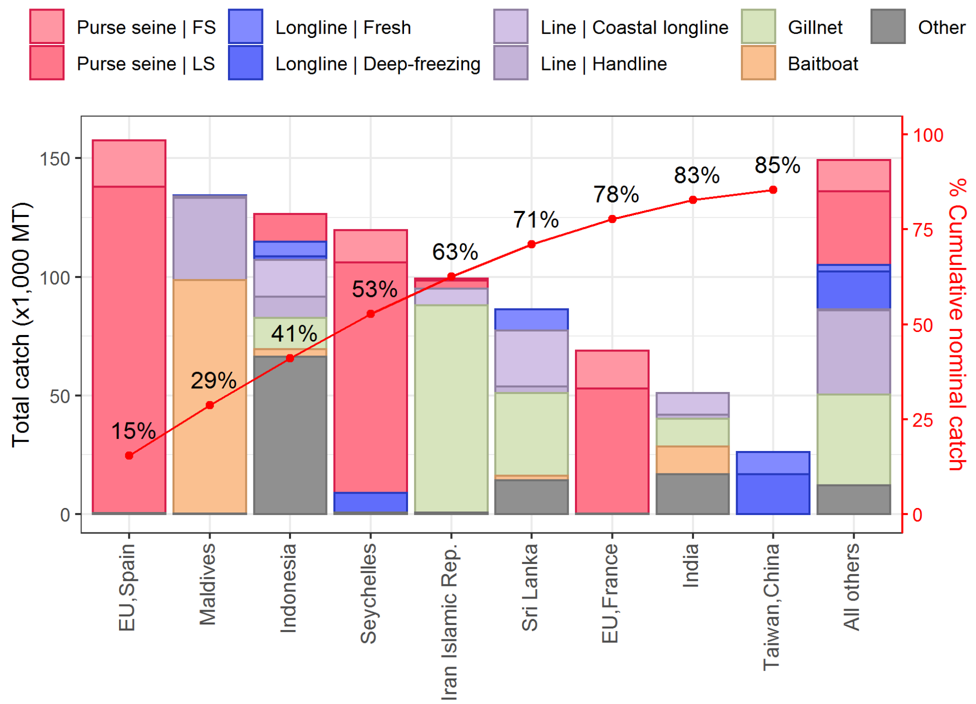


Fig. A21. Average nominal catches (MT) of yellowfin tuna over the period 2015–2019, by gear group and CPC ordered according to the importance of catches. The red solid line indicates the cumulative percentage of the total combined catches of the species for the CPCs concerned. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

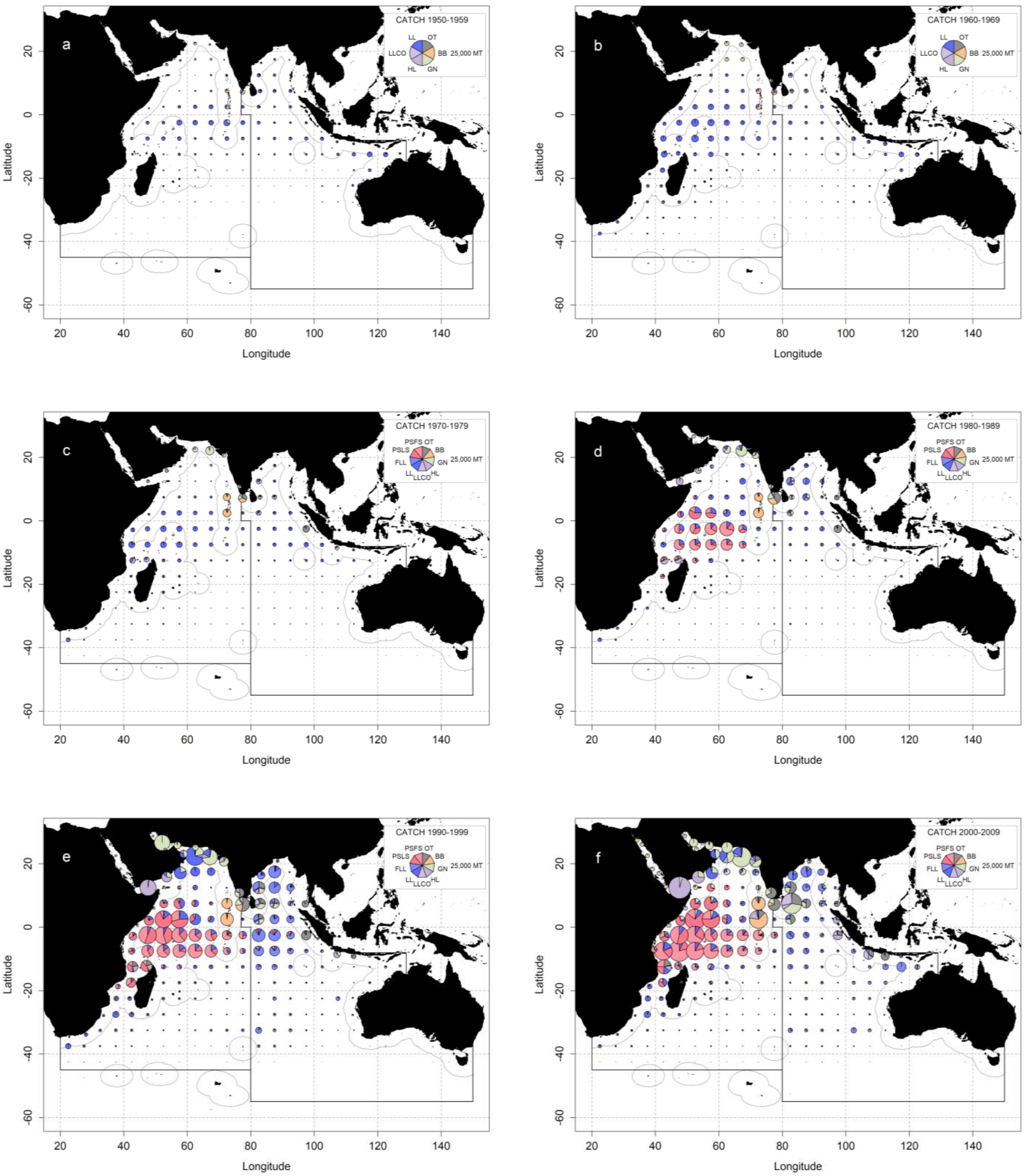


Fig. A22. Estimated average annual time-area catches (MT) of yellowfin tuna for the period **1950**–**2009** by decade and type of gear. Black solid lines represent the IOTC areas. **PSLS** = purse seine (log/FAD school); **PSFS** = purse seine (free school); **FLL** = longline (fresh); **LL** = longline (deep-freezing); **HL** = line (coastal longline, handline); **GN** = gillnet, **BB** = baitboat / pole-and-line; **OT** = all remaining gears

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

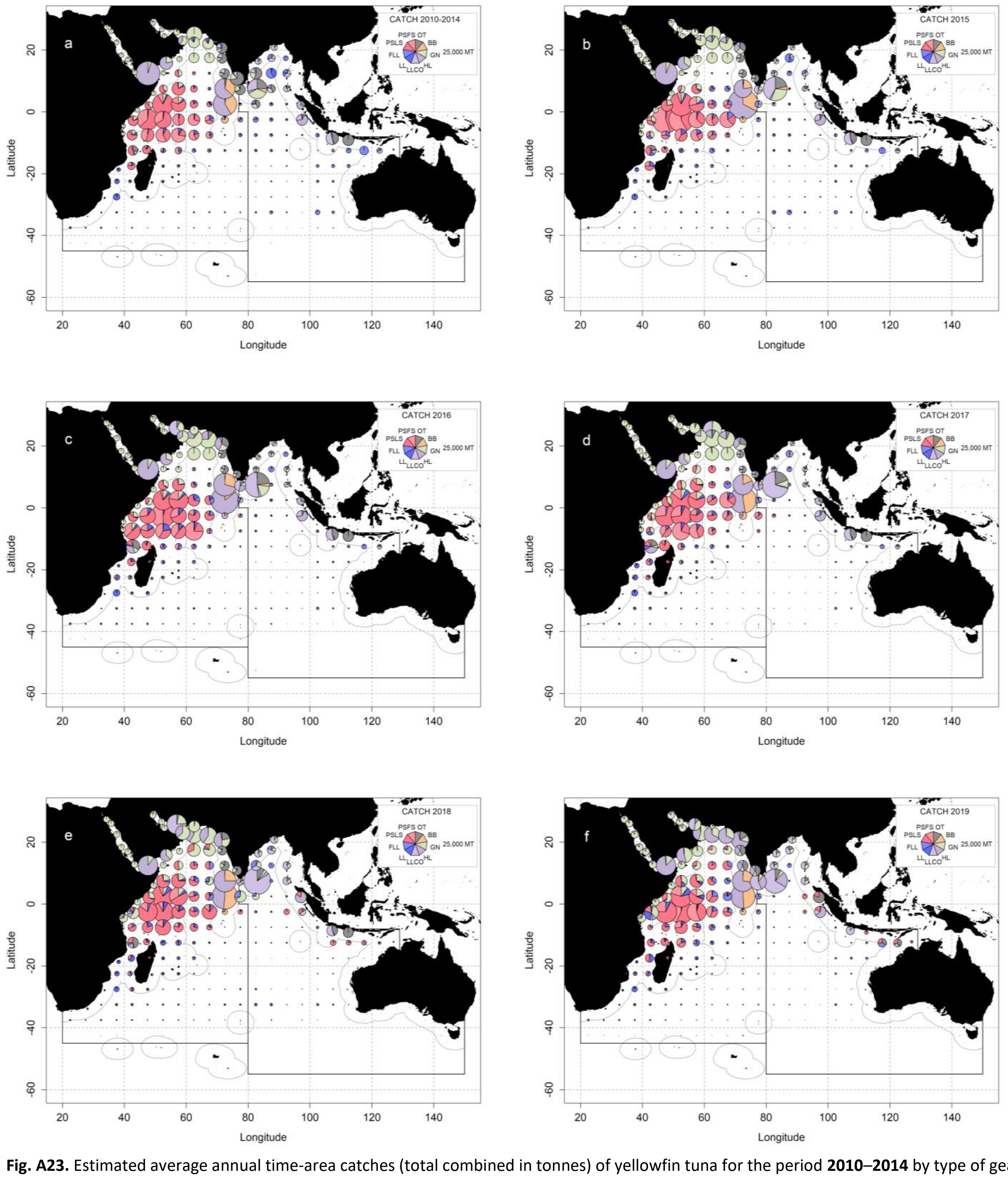


Fig. A23. Estimated average annual time-area catches (total combined in tonnes) of yellowfin tuna for the period **2010**–**2014** by type of gear and for **2015**–**19**, by year and type of gear. Black solid lines represent the IOTC areas. **PSLS** = purse seine (log/FAD school); **PSFS** = purse seine (free school); **FLL** = longline (fresh); **LL** = longline (deep-freezing); **HL** = line (coastal longline, handline); **GN** = gillnet; **BB** = baitboat / pole-and-line; **OT** = all remaining gears

Data availability and related data quality issues

Retained catches

- Data are considered to be generally well known for the major industrial fisheries, with a relatively low proportion of catches estimated, or adjusted, by the IOTC Secretariat (**Fig. A24a**).
  - The new methodology used by EU,Spain for the processing of purse seine fisheries data for 2018 resulted in a 17% reduction in the reported catch of yellowfin tuna between 2017 and 2018 when the catches of skipjack and bigeye tunas increased by 58% and 112%, respectively. The percentage of yellowfin tuna caught on associated schools reported by EU,Spain for that year was 21.8%, while it varied between 32% and 43% during 2012-2016 (i.e. prior to IOTC Resolution 16/01). Between 2018 and 2019, the percentage of bigeye tuna in the Spanish purse seine catch caught on associated schools decreased from 12.8% to 6.5% but the percentage of yellowfin tuna (23%) was still much lower than observed in the Seychelles (29.1%) and EU,France (33.5%) purse seine fisheries. Notwithstanding the request from the last WPTT, no information has yet been provided by EU,Spain on the rationale behind the exceptional species composition reported for 2018 and the methodology used for processing the data for both 2018 and 2019. Therefore, the original data set for 2018 is still within the IOTC database.
- Catches are less certain for the following fisheries/fleets:
  - many coastal fisheries, notably those from Indonesia, Sri Lanka, Yemen, and Madagascar;
  - gillnet fishery of Pakistan;
  - non-reporting industrial purse seiners and longliners (NEI), and longliners of India.

Catch-per-unit-effort (CPUE) trends

- Availability: Catch-and-effort series are available for the major industrial and artisanal fisheries (e.g., Japan longline, Taiwan,China) (**Fig. A24b**).

  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 are 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).

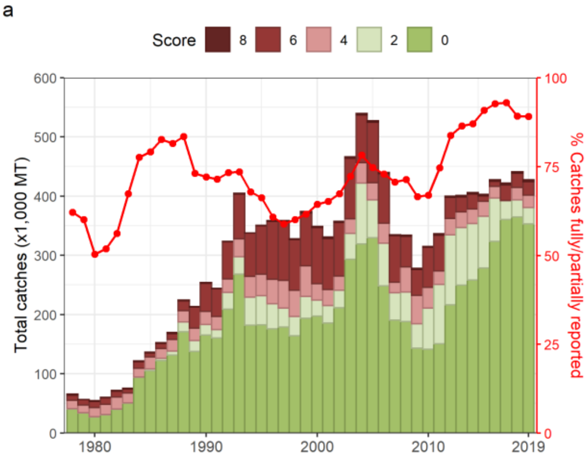
Fish size or age trends (e.g., by length, weight, sex and/or maturity)

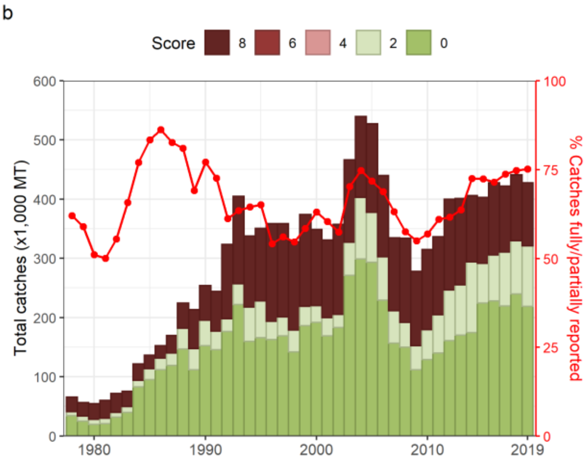
- Average fish weight: trends in average weight can be assessed for several industrial fisheries but they are very incomplete or of poor quality for some fisheries, namely hand lines (Yemen, Comoros, Madagascar), troll lines (Indonesia) and many gillnet fisheries (**Fig. A24c**).
  - Purse seine vessels 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 (**Fig. AA9**);
  - 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 (**Fig. AA10**).

- Catch-at-Size (Age) table: data are available, although the estimates are more uncertain in some years and 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 ’60s up to the mid ’80s, and in recent years (Japan and Taiwan,China), with some inconsistencies between observer and crew-based samples as well as with average weights derived from logbooks when catches are reported in both numbers and weights;
- the paucity of catch by area data available for some industrial fleets (NEI fleets, I.R. Iran, India, Indonesia, Malaysia).

Data quality (by dataset)





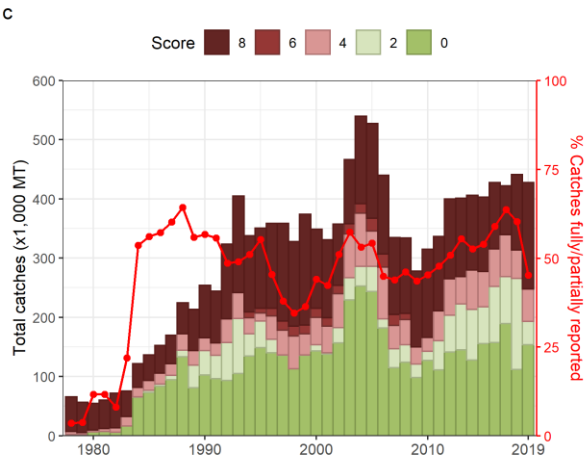


Fig. A24. Annual nominal catches (MT) of yellowfin tuna estimated by quality score (barplot) and percentage of nominal catch fully/partially reported to the IOTC Secretariat (red line with circles) for all fisheries (1978–2019) for (a) Nominal Catch; (b) Catch-Effort and (c) Size-Frequency data.

Each IOTC dataset is assessed against IOTC reporting standards, where:

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

Key to IOTC Scoring system

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

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

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

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

Key to colour coding

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

Tagging data

- A total of 101,353 yellowfin tunas (representing 46% of the total number of fish tagged) were tagged during the Indian Ocean Tuna Tagging Programme (IOTTP), of which ≈77% (n = 78,324) 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. A18**). The remaining fish (n = 23,029) were tagged during small-scale tagging projects, and by other institutions with the support of IOTC around the Maldives, India, and in the southwest and the eastern Indian Ocean. The past tagging projects conducted in the Maldives in the '90s added 14,506 tagged yellowfin tunas to the database.
- To date, 17,835 specimens (12.8% of releases for this species), have been recovered and reported to the IOTC Secretariat: 1,960 as part of the historical tagging projects in the Maldives and 15,875 throughout the IOTTP. 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.

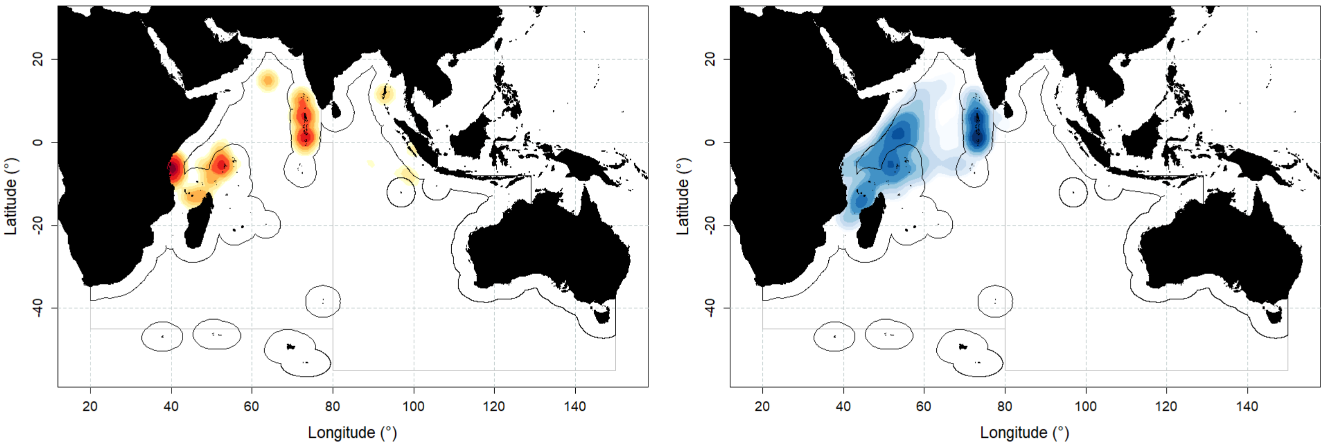


Fig. A18. Density distribution of (left panel) releases and (right panel) recoveries of yellowfin tuna tagged during the during the Maldivian and Indian Ocean Tuna Tagging programmes

Average weights

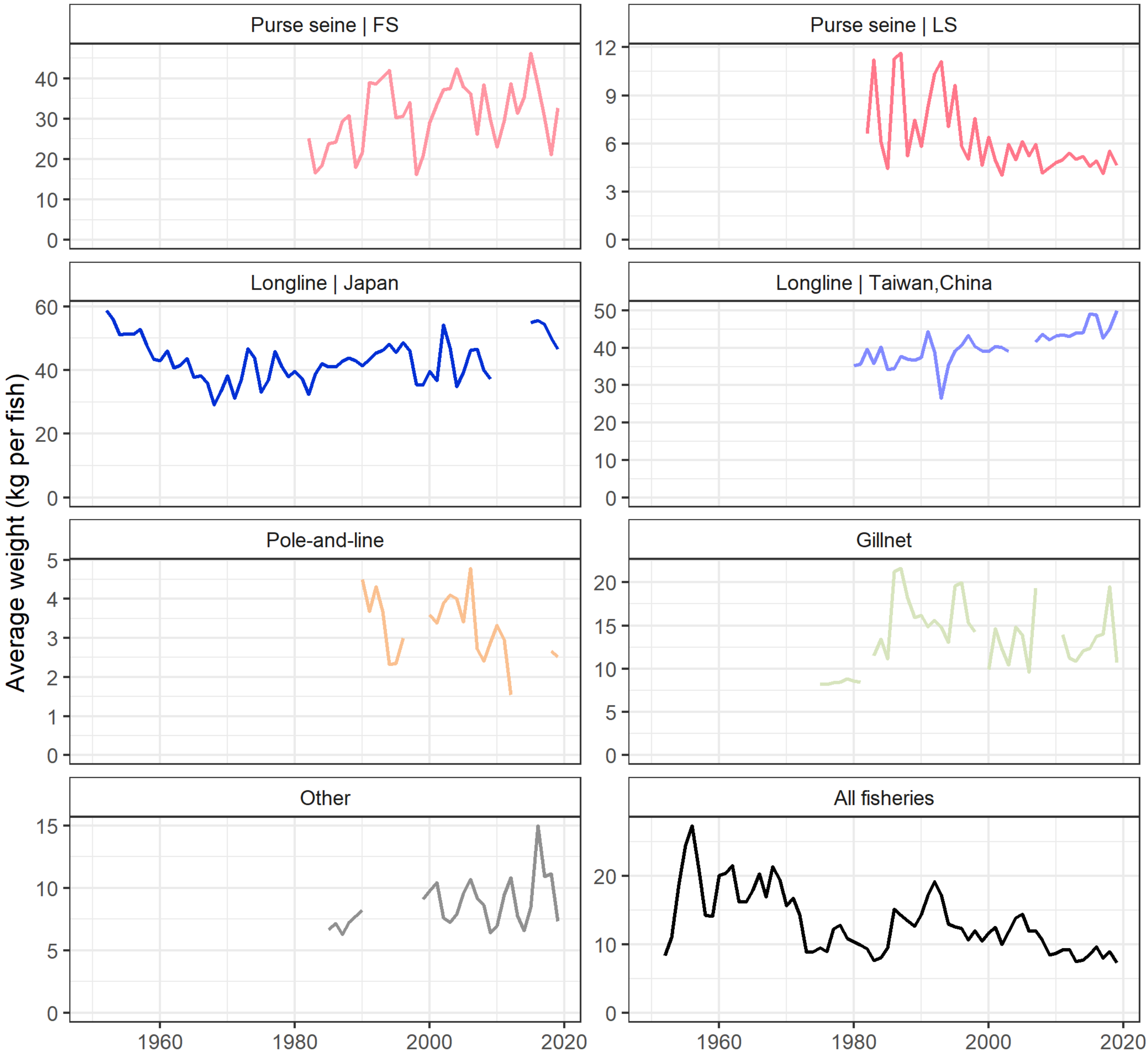


Fig. AA10. Annual time series of estimated average weight (kg) of yellowfin tuna caught with (top left panel) purse seine on free schools (FS), (top right panel) log/FAD-associated schools (LS), (upper middle left panel) longline from Japan and assimilated[3], (upper middle right panel) longline from Taiwan,China and assimilated[4], (lower middle left panel) pole-and-line from Maldives and India, (lower middle right panel) gillnet from Sri Lanka, I.R. Iran, and other countries, (bottom left panel) gears from all remaining fisheries, (bottom right panel) all gears from Indian Ocean fisheries. Source: estimated raised catches in weight and number (1950-2019). Data are only shown for those years for which the original size samples cover strata with reported catches by year and fishery higher than 50 MT

[3] Japan, Rep. of Korea, and Thailand
[4] Taiwan,China and all other longline fleets not flagged by Japan, Rep. of Korea, and Thailand

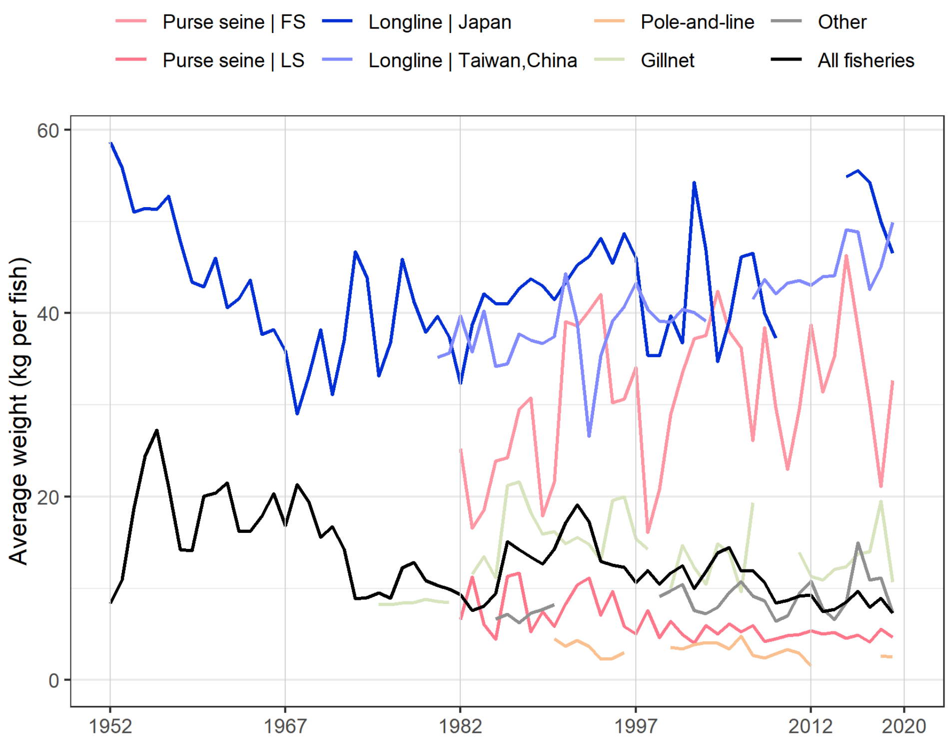


Fig. AA11. Comparison of annual time series of estimated average weight (kg) of yellowfin tuna caught by the major fleets with different fishing gears and for all fisheries combined. Source: estimated raised catches in weight and number (1965-2019). Data are only shown for those years for which the original size samples cover strata with reported catches by year and fishery higher than 50 MT

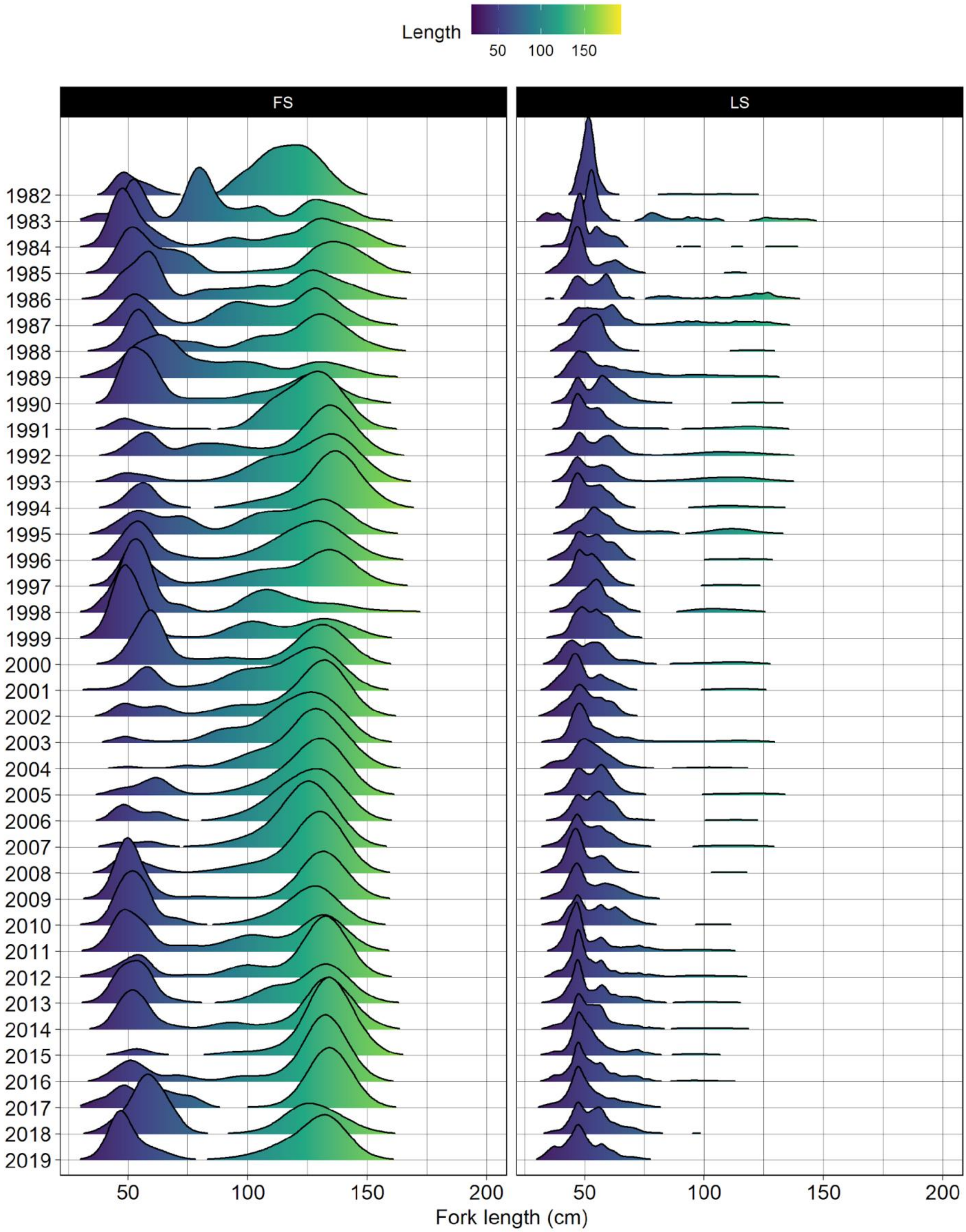


Fig. AA12. Length frequency distributions (by 2 cm length class) of yellowfin tuna caught with industrial purse seine on free schools (FS) and (right) on log/FAD-associated school (LS) during 1982-2019

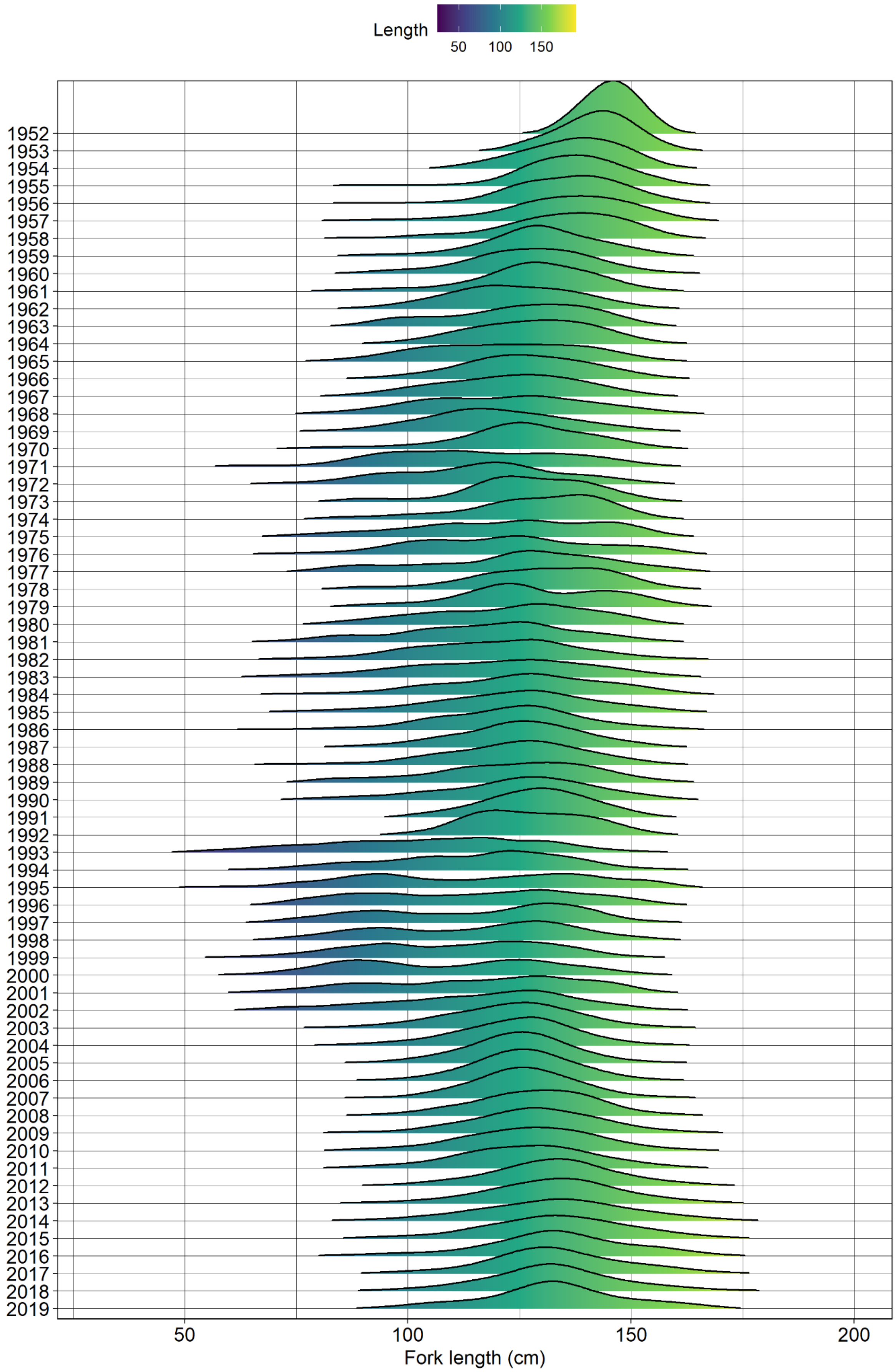


Fig. AA13. Length frequency distributions (by 2 cm length class) of yellowfin tuna caught with deep-freezing longline during 1952-2019

APPENDIX V

MAIN ISSUES IDENTIFIED RELATING TO THE STATISTICS OF TROPICAL TUNAS

(Extracts from IOTC–2020–WPTT22(AS)–03_Rev3)

The following section provides a summary of the main issues, by type of dataset, that the IOTC Secretariat considers to negatively affect the quality of tropical tuna statistics available at the IOTC for the consideration of the WPTT.

Nominal (retained) catches

- EU (purse seiners): changes introduced in the statistical methodologies used by one component of the EU purse-seine fleet to estimate species composition for 2018, resulted in figures largely contrasting with other segments of the same fleet: this specific issue was discussed during the 21st Session of the WPTT and – while no revision to the catch figures has been officially provided by EU – the WPTT21 agreed on using revised catch levels for stock assessment and management purposes. To date, no official revision for the species composition of catches reported by the EU purse-seine fishery in 2018 was received by the IOTC Secretariat and the species composition for 2019 seems to have returned to levels comparable with what was available prior to 2018.
- 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 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 3,000 – 6,000 MT per year. 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 mislabeling 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). Until then the IOTC Secretariat estimated I.R. Iran catches of bigeye tuna 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 eventually provided by I.R. Iran for the period 2005 – 2011 at around 700 MT per year, however these estimates remain uncertain.
- Pakistan (drifting gillnet): revised catch series for the gillnet fishery of Pakistan (from 1987 to 2018) have been officially endorsed in December 2019 following the WPDCS15 and eventually the 22nd session of the Scientific Committee, and are now included in the IOTC database. These revised catch series introduce sensible changes to the total yearly captures of both skipjack tuna and yellowfin tuna: catch volumes of the former are now around 2,165 MT less (on a yearly average), while for the latter an average yearly increase of 6,224 MT is recorded. Still, the revised catch series continue reporting zero catches of bigeye tuna, which is partially contrasting with information from comparable gillnet fisheries operating in similar areas: for this reason, the IOTC Secretariat is still liaising with the Ministry of Fisheries and WWF Pakistan to understand, and resolve, this potential inconsistency.
- Coastal fisheries of Indonesia, Madagascar, Sri Lanka[5] (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 2012 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

[5] 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

sampling to monitor the catches unloaded by the fisheries in selected location along the coast. The IOTC Secretariat and the *Centre National de ressources Halieutiques* of Comoros derived estimates of catch using the data collected and the new catches estimated are at around half the values reported in the past by Comoros (around 5,000 MT per year instead of 9,000 MT). 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 IOTC Resolution 13/11, superseded by IOTC Resolutions 15/06 and 17/04[6]) despite the obligation to report these data as per IOTC Resolution 15/02. Discards of tropical 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.

The practice of *high grading* in longline fisheries (with a particular focus on yellowfin tuna following the implementation of catch limits in 2017[7]) has been raised and discussed at the sixth *IOTC CPUE Workshop on Longline Fisheries*[8]. Such practice might only concern a component of the Taiwanese longline fishery operating in the South of the Indian Ocean while discarding of tropical tunas is generally considered negligible by experts from other longline fisheries (e.g. Japan, Korea, Seychelles) as there is a market for small-sized tunas. Further analysis of the datasets collected through the Regional Observer Scheme (ROS), which have been growing in number over the years[9], might be helpful to provide information on discards of tropical tunas in order to better estimate the effects they may have on (i) fisheries selectivity, (ii) magnitude of the catch, and (iii) CPUE time series.

Catch-and-effort and CPUE series

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

- EU (purse seine): as in the case of nominal catches, the changes in statistical methodologies used to estimate species composition from one component of the EU purse seine fleet introduced a range of statistical artifacts in the catch-and-effort data submitted for 2018. A proposal for re-estimating the species composition of time-area catches for the fleet using proxy data (from the same and comparable fleets) was discussed at the WPDCS15 in 2019, although no official revision was received or produced by the IOTC Secretariat to date. The artifact identified in 2018 is not found in the C-E data reported by the EU in 2019 and the overall species composition of reported C-E data for the fleet seems to be more closely in line with 2017 and previous years.

- I.R. Iran (coastal and offshore fisheries): I.R. Iran ranks fifth highest in terms of total catches of tropical tunas in 2019 (mostly accounted for by drifting gillnets), however - until recently - catch-and-effort data 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 began to submit catch-and-effort data in accordance with the reporting requirements of IOTC Resolution 15/02, and this led 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 did not report 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.

[6] IOTC Resolution 17/04 *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*
[7] IOTC Resolution. 16/01 *On an interim plan for rebuilding the Indian Ocean yellowfin tuna stock*, superseded by IOTC Resolutions. 17/01, 18/01 and 19/01
[8] https://iotc.org/fr/documents/WPTT/21/INF01
[9] https://www.iotc.org/documents/WPEB/16/08-ROS

- 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 fleets 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 levels.

- 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 implementing a crew-based data collection programme for over four 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 data collected and see whether these could be used for other purposes besides cross-verifying the revised catch series provided in recent years.

- India (commercial 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)

- EU (purse seine)**:** potential discrepancies identified in the size-frequency data provided by EU,ESP and EU,FRA in 2018 and 2019. In particular, the average weight of sampled yellowfin tuna caught in free schools by EU,ESP in 2019 is the lowest recorded in the last 5 years (29.34 Kg/fish vs. an average of 40.43 Kg/fish for 2015-2018). EU,ESP also provided *unraised* size-frequency data in 2018, which show a possible bias towards larger specimens of sampled yellowfin tuna, yielding an average weight of 9.34 Kg/fish vs. an average of 5.89 Kg/fish for 2019 and 2015-2017). A similar tendency by EU,ESP to sample larger fish in 2018 has also been detected for bigeye and skipjack tuna.

  In the case of EU,FRA the situation is somehow complementary, as EU,FRA reported *unraised* size frequency data in 2019 which yield the highest average weight for all three sampled tropical tuna species in recent years (18.48 Kg/fish for yellowfin tuna, 9.92 Kg/fish for bigeye tuna and 3.97 Kg/fish for skipjack tuna). This situation raises important questions about the representativeness of the raw samples reported by the two components of the EU purse seine fleet in 2018 and 2019, which are particularly important in light of the usage of these size-frequency samples in the assessments of the stocks of all species concerned.

- Japan and Taiwan,China (longline): in 2010, the IOTC Scientific Committee identified several issues concerning the size frequency statistics available for longline fisheries of Japan and Taiwan,China, which remain unresolved.

  Until 2016 the number of specimens sampled for length on-board Japan-flagged longliners remained below the minimum of one-fish-per-metric-ton of catch recommended by the IOTC – although since 2010 size data are being recorded by scientific observers and also provided by Japan as part of the IOTC 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[10].

[10] https://www.iotc.org/documents/review-length-frequency-data-taiwanchina-distant-water-longline-fleet

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 now finalized and its report will be presented at the IOTC Working Parties and Scientific Committee in late 2020.

- I.R. Iran and Pakistan (gillnet): although both countries have reported size frequency data for their gillnet fisheries in the past (Pakistan) and in recent years (I.R. Iran), these have not been fully reported according to requirements, and the number of samples is often 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 (but no data for gillnet and coastal longliners and ringnetters in 2018), the very strong similarity between the annual size histograms of skipjack tuna caught with gillnet and ringnet suggests the data have been duplicated from one year to the other and raises questions regarding the data collection system in place in Sri-Lanka.

- 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 down by fishing area (i.e., 5°x5° grid) and they refer exclusively to longliners based in ports in this country. In 2019 and 2020. size-frequency data in agreement with the requirements of IOTC Resolution 15/02 were received by the IOTC Secretariat for the first time for both the coastal and fresh-tuna longline fleets of Indonesia.

- To date, these countries **have not reported size frequency data for their fisheries**:
    - Longline (commercial): India, Oman and the Philippines;
    - Coastal fisheries: India and Yemen (Indonesia has recently reported data for some of their coastal fisheries in 2018 and 2019).

Biological data (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 would be the Regional Observer Scheme (ROS) database, which collates data – including size and weight measurements – 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 future, once the extent of the information within the ROS database is deemed adequate for the purpose.

  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.

APPENDIX VI
DRAFT RESOURCE STOCK STATUS SUMMARY
BIGEYE TUNA (BET : THUNNUS OBESUS)

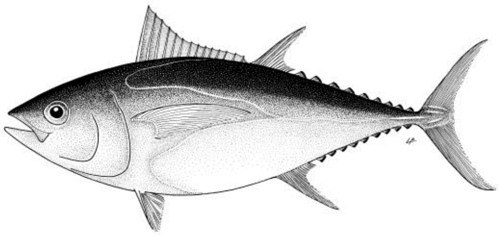


Table 1. Status of bigeye tuna (*Thunnus obesus*) in the Indian Ocean

Area[1]	Indicator	Value	Status[3]
Indian Ocean[5]	Catch in 2019 (MT)[2]	73,165[4]	38.2%*
	Average catch 2015-2019 (MT)	88,303	
	MSY (1,000 MT) (80% CI)	87 (75-108)	
	F_{MSY} (80% CI)	0.24 (0.18-0.36)	
	SSB_{MSY} (1,000 MT) (80% CI)	503 (370-748)	
	F_{2018} / F_{MSY} (80% CI)	1.20 (0.70-2.05)	
	SSB_{2018} / SSB_{MSY} (80% CI)	1.22 (0.82-1.81)	
	SSB_{2018} / SSB_0 (80% CI)	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 2019: 18%
[3]The stock status refers to the most recent years' data used in the 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 SSB_{2018} / SSB_0 were not estimated for the models used

Colour key	Stock overfished (SSB_{2018} / SSB_{MSY}<1)	Stock not overfished (SSB_{2018} / SSB_{MSY}≥ 1)
Stock subject to overfishing (F_{2018} / F_{MSY}≥ 1)	34.6%	38.2%
Stock not subject to overfishing (F_{2018} / F_{MSY}≤ 1)	0%	27.2%
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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. In 2019 a new stock assessment was carried out for bigeye tuna in the IOTC area of competence to update the stock status undertaken in 2016. Two models were applied to the bigeye stock (JABBA and Stock Synthesis (SS3)). The stock assessment selected to provide scientific advice was carried out using SS3, a fully integrated model used to provide scientific advice for the three tropical tunas stocks in the Indian Ocean. The reported stock status is based on the SS3 model formulation using a grid of 18 model configurations designed to capture the uncertainty on stock recruitment relationship, the influence of tagging information and selectivity of longline fleets. Due to concerns on the reported catch data for 2018, the stock status is based on SS3 model formulations using the best catch estimate by the Scientific Committee (for details see WPTT report). Spawning stock biomass in 2018 was estimated to be 31% of the unfished levels in 2018 (**Table 1**) and 122% (82–181%) of the level that can support MSY. The assessment outcome is qualitatively different to the stock assessment conducted in 2016 due to the increase of catch of small size, changes in modelling assumptions about longline selectivity, and the abundance index developed in 2019. Considering the characterized uncertainty, the assessment indicates that SSB_{2018} is above SSB_{MSY} with high probability (65.4%) and that fishing mortality is above F_{MSY} also with high probability (72.8%). The median value of MSY from the model runs presented with SS3 was 87,000 MT with a range between 75,000 and 108,000 MT (a median level 16% lower than the estimate in 2016). Catches in 2018 (~81,413 MT) remain lower than the estimated median MSY values from the stock assessment conducted in 2019 but within the range of estimated MSY. The average catch over the previous five years (2014–18; ~89,717 MT) is just above the estimated median MSY and within the range of estimated values. Thus, on the weight-of-evidence available in 2019, the bigeye tuna stock is determined to be **not overfished** but **subject to overfishing** (**Table 1**).

Outlook. Declines in longline effort since 2007, particularly from the Japanese, Taiwanese and Rep. of Korea longline fleets lowered the pressure on the Indian Ocean bigeye tuna stock since 2007. However, recent increase in catch from purse seine fleets have increased this pressure and the stock is estimated to be subject to overfishing. The estimated MSY has declined significantly (16%) from the previous estimate (from 2016) due to the increase of purse seine catch in the overall change in catch composition, changes in modelling assumptions about longline selectivity, and the inclusion of a more pessimistic abundance index in the western tropical region. The Kobe strategy matrix (K2SM) based on the plausible model runs from SS3 in 2019 illustrates the levels of quantified risk associated with varying catch levels over time that could be used to inform future management actions (**Table 2**). The projections produced to estimate the K2SM (**Table 2**) are, in the short term, driven by the below average recruitment estimated for the recent years. The SS3 projections from the 2019 assessment show that there is a risk of breaching MSY-based reference points by 2021, and 2028 if catches are maintained at 2018 levels at the current selectivity and therefore size distribution of catch (**Table 2**). Should the management objective of maintaining biomass at levels higher than SBMSY with more than 50% probability in 2028 be pursued, the overall catch should be reduced 10% from current levels (73,272 MT).

Management advice. The stock status determination changed qualitatively in 2019 to not overfished but subject to overfishing. If catches remain at current levels there is a risk of breaching MSY reference points with 58.9% and 60.8% probability in 2021 and 2028. Reduced catches of at least 10% from current levels will likely reduce the probabilities of breaching reference levels to 49.1% in 2028. Continued monitoring and improvement in data collection, reporting and analyses is required to reduce the uncertainty in assessments (**Table 2**).

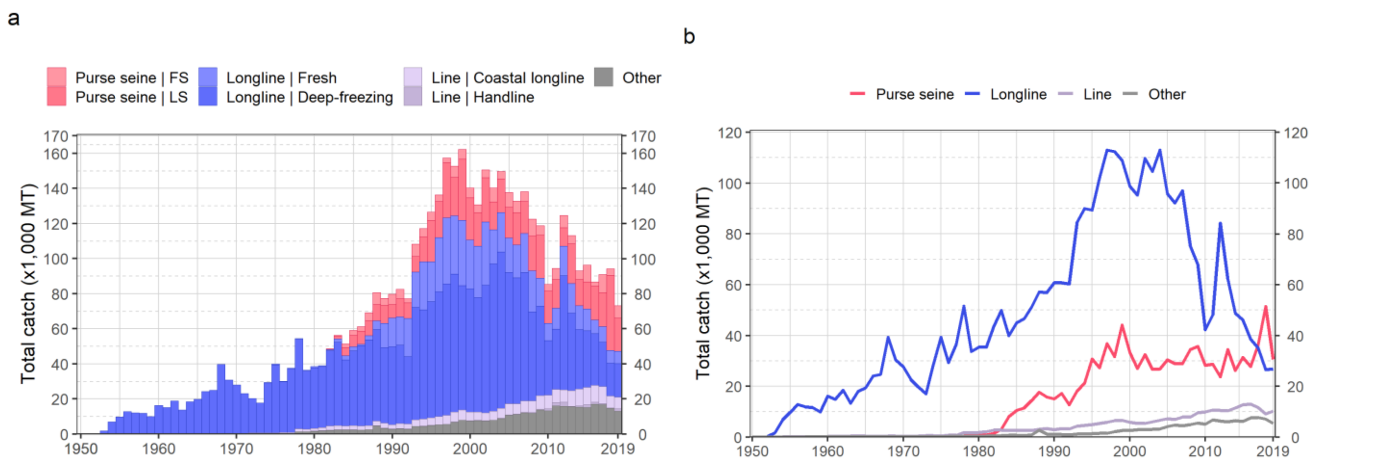


Fig. 1. Annual time series of (a) cumulative and (b) individual nominal catches (MT) by gear group for bigeye tuna during 1950–2019. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

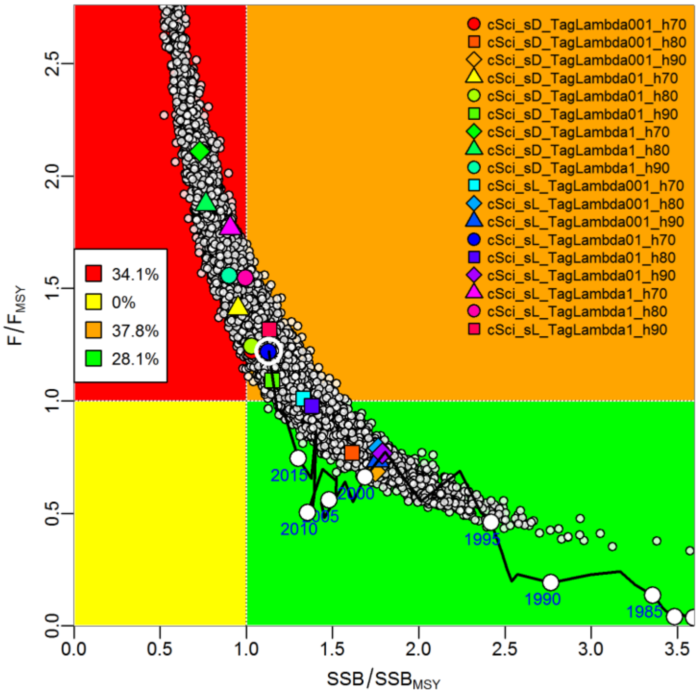


Fig. 2. Bigeye tuna: SS3 Aggregated Indian Ocean assessment Kobe plot. The coloured points represent stock status estimates from the 18 model options. The grey dots represent 5,000 estimates of 2018 stock status from the multivariate normal approximation from the mean and variance-covariance of the 18 model options. The legend indicates the estimated probability of the stock status being in each of the Kobe quadrant. The white circle (around the purple dot) represents the median stock status in 2018

Table 2. Bigeye tuna: Stock Synthesis base case Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (relative to average catch level from 2018 (81,413 MT); -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% (48,848 MT)	**70%** (56,990 MT)	**80%** (65,130 MT)	**90%** (73,272 MT)	**100%** (81,413 MT)
$B_{2021} < B_{MSY}$	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% (48,848 MT)	**70%** (56,990 MT)	**80%** (65,130 MT)	**90%** (73,272 MT)	**100%** (81,413 MT)
$B_{2021} < B_{LIM}$	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

APPENDIX VII
DRAFT RESOURCE STOCK STATUS SUMMARY
SKIPJACK TUNA (SKJ: KATSUWONUS PELAMIS)

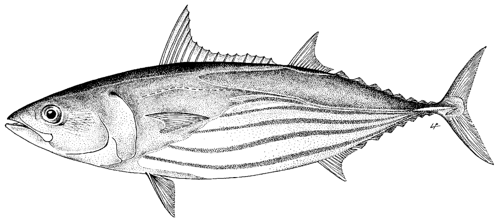


Table 1. Status of skipjack tuna (*Katsuwonus pelamis*) in the Indian Ocean

Area[1]	Indicator	Value	Status[2]
Indian Ocean	Catch in 2019 (MT)	547,248	60.4%*
	Average catch 2015-2019 (MT)	506,555	
	$C_{40\%SSB0}$ (MT)	535,964 (461,995–674,536)	
	C_{2019} / $C_{40\%SSB0}$ (MT)	1.02 (0.81–1.18)	
	$E_{40\%SSB0}$[3]	0.59 (0.53–0.66)	
	E_{2019} / $E_{40\%SSB0}$	0.92 (0.67-1.21)	
	SSB_0 (MT)	1,992,089 (1,691,710–2,547,087)	
	SSB_{2019} (MT)	870,461 (660,411–1,253,181)	
	$SSB_{40\%SSB0}$ (MT)	794,310 (672,825–1,019,056)	
	$SSB_{20\%SSB0}$ (MT)	397,155 (336,412–509,528)	
	SSB_{2019} / SSB_0	0.45 (0.38-0.5)	
	SSB_{2019} / $SSB_{40\%SSB0}$	1.11 (0.95-1.29)	
	SSB_{2019} / SSB_{MSY}	1.99 (1.47-2.63)	
	MSY (MT)	601,088 (500,131–767,012)	
	E_{2019} / E_{MSY}	0.48 (0.35-0.81)	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence
[2]The stock status refers to the most recent years' data used in the assessment conducted in 2020
[3]E is the annual harvest rate
*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 (SSB_{2019} / $SSB_{40\%SSB0}$<1)	Stock not overfished (SSB_{2019} / $SSB_{40\%SSB0}$≥ 1)
Stock subject to overfishing (E_{2019} / $E_{40\%SSB0}$≥ 1)	19.5%	19.5%
Stock not subject to overfishing (E_{2019} / $E_{40\%SSB0}$≤ 1)	0.6%	60.4%
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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. A new stock assessment was carried out for skipjack tuna in 2020 using Stock Synthesis with data up to 2019. The outcome of the 2020 stock assessment model does not differ substantially from the previous assessment (2017) despite the large catches recorded in the period 2018-2019, which exceeded the catch limits established in 2017 for this period.

The final overall estimate of stock status indicates that the stock is above the adopted target for this stock and that the current exploitation rate is just below the target. Also, the models estimate that the spawning biomass remains above its SSB_{MSY} and the fishing mortality remains below E_{MSY} with very high probability. Over the history of the fishery, biomass has been well above the adopted limit reference point ($0.2*SSB_0$). The recent catches have been within the range of estimated target yield (see $C_{40\%SSB0}$). Current spawning stock biomass relative to unexploited levels is estimated at 45% (**Table 1**). Thus, on the weight-of-evidence available in 2020, the skipjack tuna stock is determined to be: (i) above the adopted biomass target reference point; (ii) **not overfished** (SSB_{2019}>$SSB_{40\%SSB0}$); (iii) with fishing mortality below the adopted target fishing mortality, and; (iv) **not subject to overfishing** (E_{2019}<$E_{40\%SSB0}$).

Outlook. Total catches in 2018 were 30% larger than the resulting catch limit from the skipjack HCR for the period 2018-2020, which raises concern in the WPTT. It is important to note that reaching the management objectives defined in Resolution 16/02 requires that the catch limits adopted by the skipjack HCR are implemented effectively. It should be noted that skipjack catches for most gears have increased from 2017 to 2018 (+44% for purse seine (log/FAD-associated), +12% for gillnet and +13% for pole-and-line). In 2019, catch was reduced considerably compared to 2018. Due to its specific life history attributes, skipjack can respond quickly to ambient foraging conditions driven by ocean productivity, which seem to have been favourable in recent years. Environmental indicators should be closely monitored to inform on the potential increase/decrease of stock productivity. There remains considerable uncertainty in the assessment: The assumption of two hypotheses for the effort creep since 1995 for the standardized European purse seine CPUE was included in the model grid. The range of runs analysed illustrate a range of stock status to be between 36% and 51% of SSB_{2019} / SSB_0 based on all runs examined. It is important to note the differences between the runs that apply an additional effort creep parameter to the standardized series of CPUE (median SSB_{2019}/SSB_0=0.44) and those that do not (median SSB_{2019} / SSB_0=0.45). Also, there was contrast between runs that fully weighted tagging information (median SSB_{2019} / SSB_0=0.42) and those that reduced their influence (median SSB_{2019}/SSB_0=0.48).

Management advice. The catch limit will be calculated applying the HCR specified in Resolution 16/02. The Commission needs to ensure that catches of skipjack tuna in the 2021–2023 period do not exceed the agreed limit.

The following key points should also be noted:

- **Reference points**: Commission in 2016 agreed to Resolution 16/02 on *harvest control rules for skipjack tuna in the IOTC area of competence*;
- **Exploitation rate**: Current exploitation rate 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 above the target reference point of 40% of SSB_0, and above the limit reference point of $0.2*SSB_0$ (**Fig. 2**) as per Resolution 15/10;
- **Main fishing gears** (average catches 2016-19): Purse seine ~47% (FAD/log associated school ~44% and free-swimming school ~3%); Pole-and-line ~19%; Gillnet ~18%; Other gears ~16% (**Fig. 1**);
- **Main fleets** (average catches 2016-19): European Union ~27% (EU-Spain: ~19.3%; EU-France: ~7.1%; EU-Italy: 0.4%); Maldives ~16%; Indonesia ~15%; Seychelles ~13%; I.R. Iran ~9%; Sri Lanka ~8%.

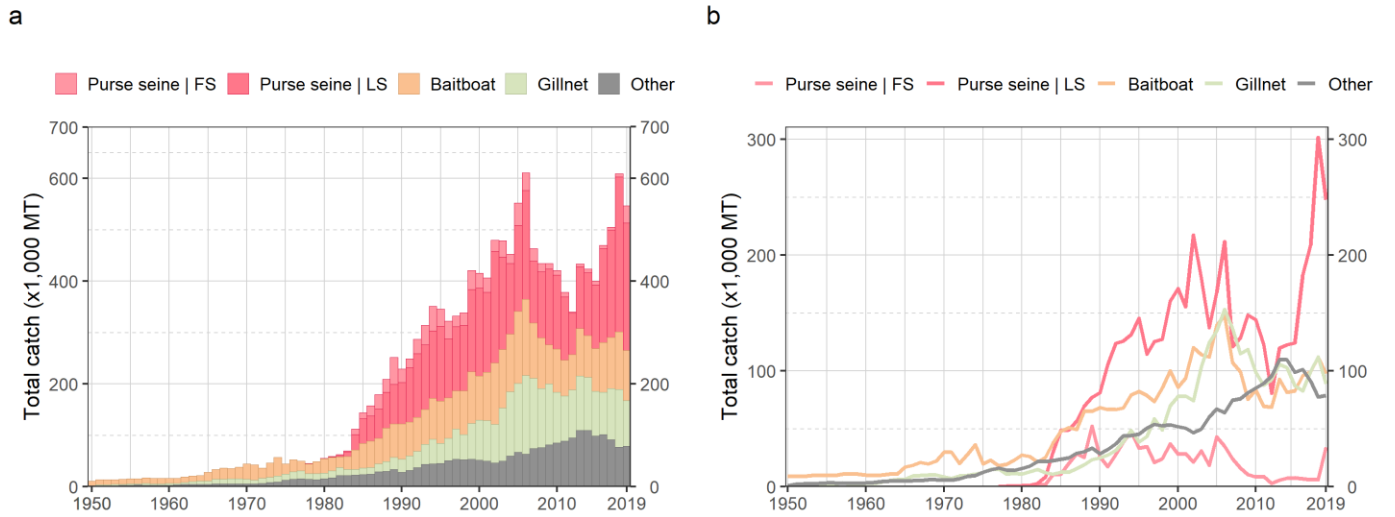


Fig. 1. Annual time series of (a) cumulative and (b) individual nominal catches (MT) by fishery for skipjack tuna during 1950–2019. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

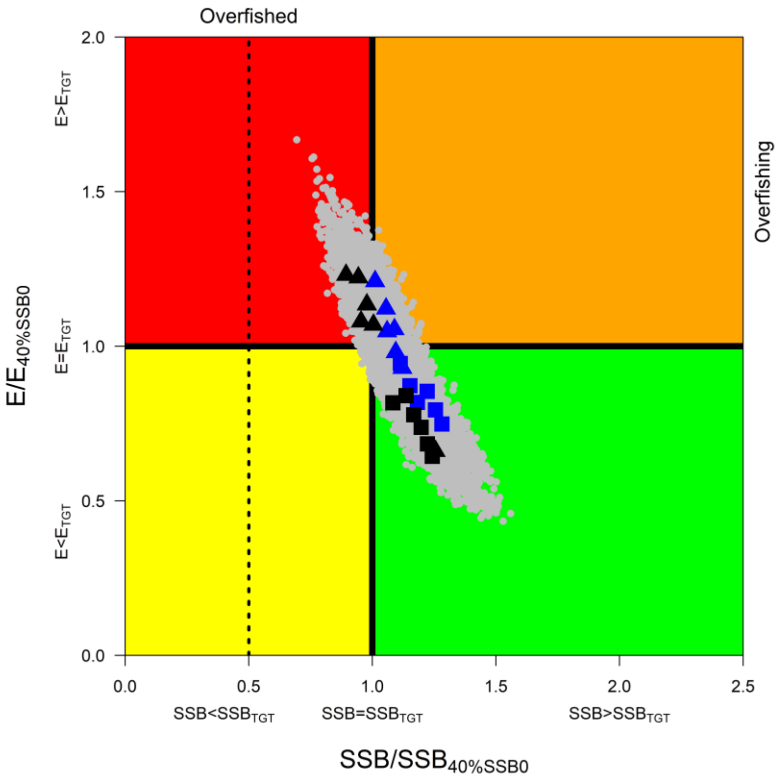


Fig. 2. Skipjack tuna: SS3 Aggregated Indian Ocean assessment Kobe plot of the 2020 uncertainty grid. Symbols represent MPD estimates of current stock status relative to $SSB_{40\%SSB0}$ (x-axis) and $E_{40\%SSB0}$ (y-axis) for the individual models (blue, no effort creep; black, additional effort creep; triangle, full weighting of tagging data; square, tagging data downweighted). Grey dots represent uncertainty from individual models. The vertical dashed line represents the limit reference point for Indian Ocean skipjack tuna (SSB_{lim} = 20%SSB_0)

APPENDIX VIII
DRAFT RESOURCE STOCK STATUS SUMMARY
YELLOWFIN TUNA (YFT: *THUNNUS ALBACARES*)

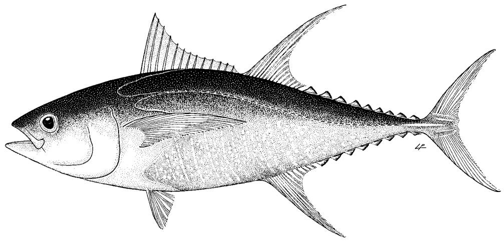


Table 1. Status of yellowfin tuna (*Thunnus albacares*) in the Indian Ocean

Area[1]	Indicator	Value	Status[3]
Indian Ocean	Catch in 2019 (MT)[2]	427,240[4]	94%*
	Average catch 2015-2019 (MT)	424,104[4]	
	MSY (1,000 MT) (80% CI)	403 (339-436)	
	F_{MSY} (80% CI)	0.15 (0.13-0.17)	
	SSB_{MSY} (1,000 MT) (80% CI)	1,069 (789-1,387)	
	F_{2017} / F_{MSY} (80% CI)	1.20 (1.00-1.71)	
	SSB_{2017} / SSB_{MSY} (80% CI)	0.83 (0.74-0.97)	
	SSB_{2017} / SSB_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 2019: 11%
[3]The stock status refers to the most recent years' data used in the assessment conducted in 2017
[4]Considering the alternative purse seine log-associated catch 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). Median and quantiles calculated from the uncertainty grid taking into account of weighting on models

Colour key	Stock overfished (SSB_{2017} / SSB_{MSY}<1)	Stock not overfished (SSB_{2017} / SSB_{MSY}≥ 1)
Stock subject to overfishing (F_{2017} / F_{MSY}≥ 1)	94%	4%
Stock not subject to overfishing (F_{2017} / F_{MSY}≤ 1)	2%	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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. No new stock assessment was carried out for yellowfin tuna in 2019, thus, stock status is determined on the basis of the 2018 assessment and other indicators presented in 2019. The 2018 stock assessment was carried out using Stock Synthesis III (SS3), a fully integrated model that is currently used to provide scientific advice for the three tropical tunas stocks in the Indian Ocean. The model used in 2018 is based on the model developed in 2016 with a series of revisions that were noted during the WPTT. The model uses four types of data: catch, size frequency, tagging and joint longline CPUE indices. The 2018 assessment results were based on a grid of 24 SS3 model runs which are recognized as insufficient to explore the spectrum of uncertainties and scenarios, noting the large uncertainty associated with data quality (e.g., spatial representativeness of CPUE coverage, estimation of catch and inconsistency in length-composition) and lack of considering model statistical uncertainty. Some of these uncertainties have were explored in 2019 following the Workplan the Scientific Committee adopted in 2018. However, due to the complexity of the work, lack of agreement on key model aspects and time constraints, no new management advice is provided in 2019. According to the 2018 stock assessment, spawning stock biomass in 2017 was estimated to be 30.0% of the unfished levels (**Table 1**). According to the information available in 2019, the total catch has remained relatively stable at levels around the estimated MSY since 2012 (i.e., between 390,000 MT and 436,000 MT), with the 2018 catch being the largest since 2010 (437,422 MT), and exceeding the MSY range considering the best catch estimate by the Scientific Committee (for details see WPTT report). The 2018 stock assessment estimates SSB_{2017} / SSB_{MSY} at 0.83 (0.74-0.97) and F_{2017} / F_{MSY} at 1.20 (1.00-1.71). However, it is noted that the quantified uncertainty in stock status is likely underestimating the underlying uncertainty of the assessment. On the weight-of-evidence available in 2018 and 2019, the yellowfin tuna stock is determined to remain overfished and subject to overfishing (**Table 1** and **Fig. 1**).

Outlook. The increase in catches in recent years has substantially increased the pressure on the Indian Ocean stock, resulting in fishing mortality exceeding the MSY-related levels. The results of projections of the Stock Synthesis are provided in the form of K2SM (**Table 2**). There is a high risk of continuing to violate the MSY-based reference points if catches remain at 2017 levels (~409,000 MT in 2017) (**Table 2**). However, the projections shown in K2SM results do not adequately reflect known sources of uncertainty due to a series of issues with data and model performance, and should be taken with caution given the issues identified by the Committee.

Management advice. The decline in stock to below MSY reference level is not well understood due to various uncertainties. 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.

In the 2018 Scientific Committee a Workplan was developed to address the issues identified in the assessment review, aimed at increasing the Committee's ability to provide more concrete and robust advice by the 2019 meeting of the Scientific Committee. The workplan started in January 2019 which aimed at addressing the issues identified by the WPTT and the external reviewer in 2018. The draft workplan is attached as Appendix 38 of the 2018 Scientific Committee Report (IOTC-2018-SC21-R). The Commission should ensure that this workplan is budgeted appropriately. Despite the progress made to reduce the uncertainties inherent to this fishery, the WPTT agreed that no new advice could be provided in 2019.

The Commission has an interim plan for the rebuilding the yellowfin stock, with catch limitations based on 2014/2015 levels (Resolution 19/01, which superseded 17/01 and 18/01). Some of the fisheries subject to catch reductions had fully achieved a decrease in catches in 2018 in accordance with the levels of reductions specified in the Resolution; however, these reductions were offset by increases in the catches from CPCs exempt and some CPCs subject to limitations on their catches of yellowfin tuna (see table 9 in IOTC-2019-WPTT21-R). Thus, the total catches of yellowfin in 2018 increased by around 9% 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.

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the Indian Ocean stock is 403,000 MT with a range between 339,000-436,000 MT (**Table 1**). The 2014-2018 average catches (404,655 MT) were just above the estimated MSY level. The last year (2018), catch has been substantially higher than the median MSY.
- **Interim reference points**: Noting that the Commission in 2015 agreed to Resolution 15/10 on target and limit reference points and a decision framework, the following should be noted:

– **Fishing mortality**: Current fishing mortality is considered to be 20% above the interim target reference point of F_{MSY}, and below the interim limit reference point of 1.4*F_{MSY} (**Fig. 2**).

– **Biomass**: Current spawning biomass is considered to be 17 % below the interim target reference point of SSB_{MSY} and above the interim limit reference point of 0.4*SSB_{MSY} (**Fig. 2**).

- **Main fishing gears** (average catches 2015-19): Purse seine ~33% (FAD associated school ~23%; free swimming school ~10%); Longline ~9%; Gillnet ~20%; All other gears ~37% (**Fig. 1**).
- **Main fleets** (average catches 2015-19): European Union ~19% (EU-Spain ~12%; EU-France ~7%); Maldives ~12%; I.R. Iran ~12%; Seychelles ~10%; Sri Lanka ~9%; All other fleets ~38%.

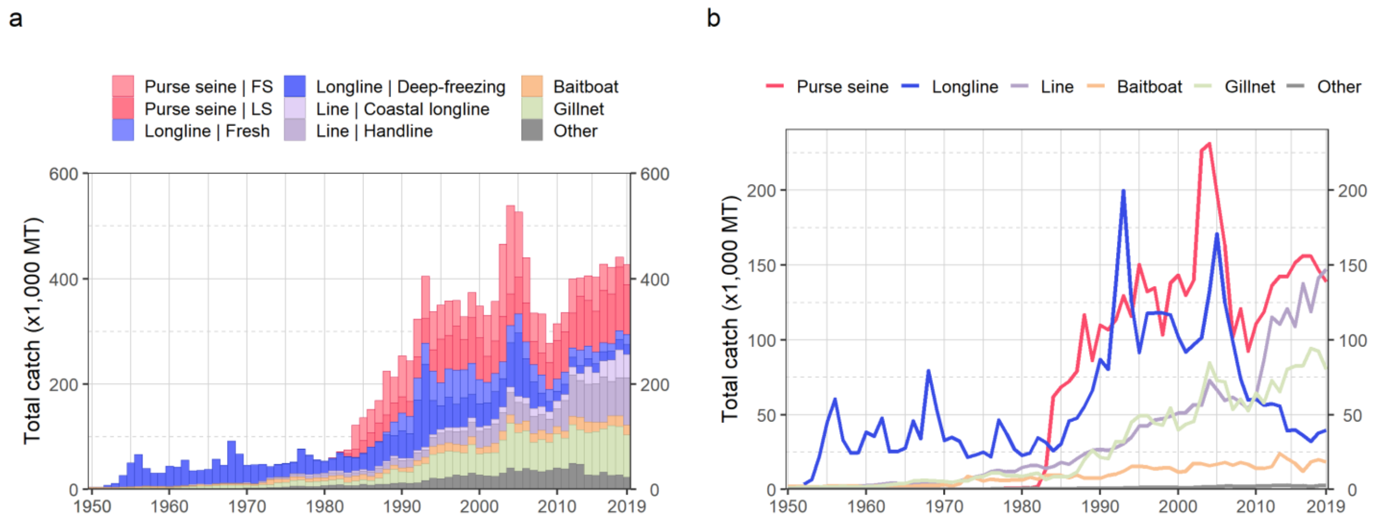


Fig. 1. Annual time series of (a) cumulative nominal catches (MT) by fishery and (b) individual nominal catches (MT) by fishery group for yellowfin tuna during 1950–2019. Purse seine includes industrial purse seiners and 'Other' includes all remaining fishing gears. LS = drifting log or FAD-associated school and FS = free-swimming school

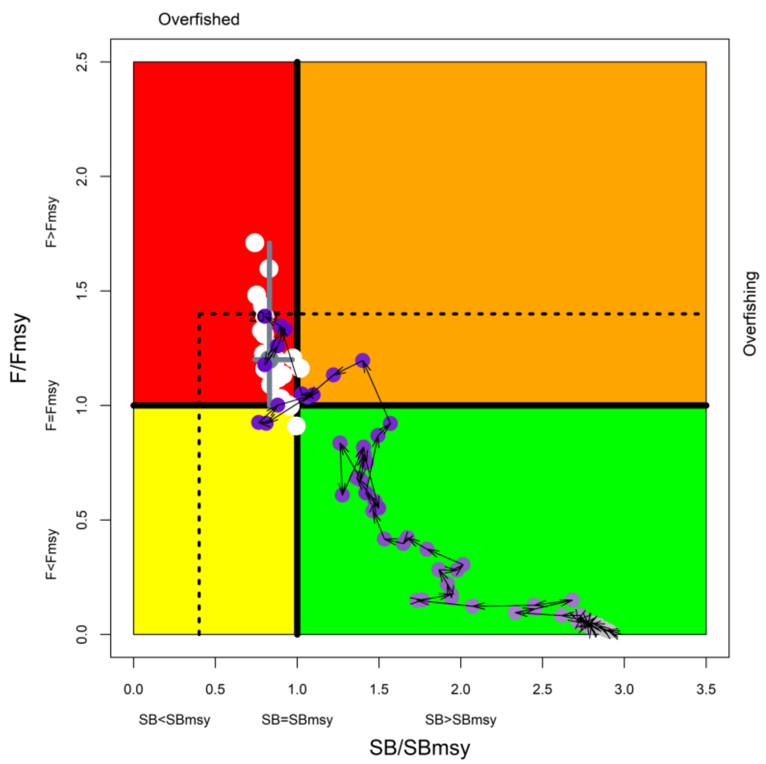


Fig. 2. Yellowfin tuna: Stock synthesis Kobe plot. Blue dots indicate the trajectory of the point estimates for the SSB/SSB_{MSY} ratio and F/F_{MSY} ratio for each year 1950–2017. The grey line represents the 80% confidence interval associated with the 2017 stock status. Dotted black lines are the interim limit reference points adopted by the Commission via Resolution 15/10. The white circles represent 2017 stock status for each grid run

Table 2. Yellowfin tuna: Stock synthesis assessment Kobe II Strategy Matrix. Probability of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (relative to the catch level from 2017 (409,567 MT), -35%, - 30%, -25%, -20%, -15%, - 10%, -5%, +10%) projected for 3 (2020) and 10 years (2027). Catch levels are given between brackets

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2017) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**								
	65% (266,218)	70% (286,697)	75% (307,175)	80% (327,654)	85% (348,132)	90% (368,610)	95% (389,089)	100% (409,567)	110% (450,523)
$B_{2020} < B_{MSY}$	0.48	0.48	0.73	0.85	0.85	0.96	0.98	0.98	1.00
$F_{2020} > F_{MSY}$	0.08	0.23	0.25	0.48	0.56	0.79	0.96	0.98	1.00
$B_{2027} < B_{MSY}$	0.08	0.08	0.25	0.42	0.56	0.79	0.98	1.00	1.00*
$F_{2027} > F_{MSY}$	0.06	0.08	0.23	0.42	0.63	0.85	1.00	1.00	1.00*

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2017) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.4\ B_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	65% (266,218)	70% (286,697)	75% (307,175)	80% (327,654)	85% (348,132)	90% (368,610)	95% (389,089)	100% (409,567)	110% (450,523)
$B_{2020} < B_{Lim}$	0.00	0.00	0.00	0.00	0.00	0.06	0.15	0.23	0.42
$F_{2020} > F_{Lim}$	0.00	0.06	0.08	0.21	0.23	0.42	0.56	0.63	0.92
$B_{2027} < B_{Lim}$	0.00	0.06	0.08	0.27	0.42	0.50	0.83	0.90	1.00*
$F_{2027} > F_{Lim}$	0.00	0.08	0.23	0.42	0.50	0.65	0.94	0.94	1.00*

** stock crashed or at least one fishery not able to take the catch due to absence of vulnerable fish in the projection period for all models. The probability levels are not well determined, but likely progressively high as the catch level increases beyond 100%.*

APPENDIX IX
WORKING PARTY ON TROPICAL TUNAS PROGRAM OF WORK (2021–2025)

The following is the Draft WPTT Program of Work (2021–2025) and is based on the specific requests of the Commission and Scientific Committee. 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 in order of priority	**Sub-topic and project**	**TIMING**				
		2021	**2022**	**2023**	**2024**	**2025**
Stock assessment priorities	Detailed review of the existing data sources, including*:* i. Size frequency data: Evaluation of the reliability of length composition from the longline fisheries (including recent and historical data), ii. Tagging data: Further analysis of the tag release/recovery data set. iii. Organisation of expert group to investigate tagging mortality iv. Re-estimation of M using updated tagging data.					
Fisheries Independent Monitoring	i. 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). It would be valuable to conduct a scoping exercise to evaluate the applicability to the tropical tuna species					
CPUE standardisation	Develop standardised CPUE series for each tropical tuna fleet/fishery for the Indian Ocean					

Other Future Research Requirements (not in order of priority)							
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.						
	1.1.1 Population genetic analyses to decipher intraspecific connectivity, levels of gene flow, genetic divergence and effective population sizes based on genome-wide distributed Single Nucleotide Polymorphisms (SNPs).						
	1.2 Connectivity, movements and habitat use						
	1.2.1 Connectivity, movements, and habitat use, including identification of hotspots and investigate associated environmental conditions affecting the tropical tuna species distribution, making use of conventional and electronic tagging (P-SAT). 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.						
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.						
	2.1.2 Collect gonad samples from tropical tunas to confirm the spawning periods and location of the spawning area that are presently hypothesized for each tropical tuna species.						

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.					
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					
		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.					
		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.					
		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 and to permit cluster analysis using vessel level data.					
		Bigeye tuna: High priority fleets					
		Skipjack tuna: High priority fleets					
		Yellowfin tuna: High priority fleets					
		4.1.5 Gillnet CPUE standardization including further investigate and use of gillnet CPUE series from Sri Lankan gillnet fishery					
		4.1.6 Workshops to assist in standardising CPUEs for tropical tuna fleets					

		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).					
		4.3 Investigate the potential to use the Indian longline survey as a fishery-independent index of abundance for tropical tunas.					
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).					
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: ii. Acoustic FAD monitoring, with the objective of deriving abundance indices based on the biomass estimates provided by echo-sounder buoys attached to FADs iii. Longline-based surveys (expanding on the Indian model) or “sentinel surveys” in which a small number of commercial sets follow a standardised scientific protocol iv. Aerial surveys, potentially using remotely operated or autonomous drones					

	v. Studies (research) on flux of tuna around anchored FAD arrays to understand standing stock and independent estimates of the stock abundance. vi. 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 vii. Investigate the possibility of conducting ongoing ad hoc, low level tagging in the region					
7 Target and Limit reference points	7.1 To advise the Commission, on Target Reference Points (TRPs) and Limit Reference Points (LRPs). 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	2021	2022	2023	2024	2025
Bigeye tuna	Indicators	**Data preparatory meeting** **Full assessment**	Indicators	Indicators	**Data preparatory meeting** **Full assessment**
Skipjack tuna	Indicators	Indicators	**Data preparatory meeting** **Full assessment**	Indicators	Indicators
Yellowfin tuna	**Data preparatory meeting** **Full assessment**	Indicators	Indicators	**Data preparatory meeting** **Full assessment**	Indicators

APPENDIX X

CONSOLIDATED RECOMMENDATIONS OF THE 22ND SESSION OF THE WORKING PARTY ON TROPICAL TUNAS

Note: Appendix references refer to the Report of the 22nd Session of the Working Party on Tropical Tunas (IOTC–2020–WPTT22–R)

Stock Assessment Result

WPTT22.01 (para. 37): The WPTT **RECOMMENDED** additional analyses and a workshop, to further progress CPUE standardization efforts, evaluate evidence related to CPUE catchability trends, and make specific recommendations for time series and assumptions to use in future assessments and Operating Model (OM) conditioning.

Revision of the WPTT Program of Work (2021–2025)

WPTT22.02 (paras. 159): The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2021–2025), as provided in Appendix IX.

Date and place of the 23rd and 24th Sessions of the WPTT (Chair and IOTC Secretariat)

WPTT22.03 (paras. 162): The WPTT **NOTED** that the global Covid-19 pandemic has resulted in international travel being almost impossible and with no clear end to the pandemic in sight, it was impossible to finalise arrangements for the meeting in 2021. The Secretariat will continue to liaise with CPCs to determine their interest in hosting these meetings in the future when this once again becomes feasible. The WPTT **RECOMMENDED** the SC consider late October 2021 as a preferred time period to hold the WPTT22 Assessment meeting in 2021 with a Data Preparatory meeting to be held in the first half of 2021 to prepare for the YFT assessment.

Review of the draft, and adoption of the report of the 22nd session of the WPTT

WPTT22.04 (para. 164): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT22, 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 2020 (Figure 2):

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