Report of the 23rd Session of the IOTC Working Party on Tropical Tunas

Virtual Meeting, 25 - 30 October 2021

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IOTC–WPTT23 2021. Report of the 23rd Session of the IOTC Working Party on Tropical Tunas. Online, 25 - 30 October 2021. *IOTC–2021–WPTT23–R[E]: 59 pp.*

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Contact details:

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

ACRONYMS

aFAD	anchored Fish aggregating device
ASAP	Age-Structured Assessment Program
ASPIC	A Stock-Production Model Incorporating Covariates
ASPM	Age-Structured Production Model
B	Biomass (total)
BDM	Biomass Dynamic Model
BET	Bigeye tuna
B_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 23rd Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT), was held online using Zoom from 25 - 30 October 2021. 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 108 participants attended the Session (cf. 111 in 2020, 68 in 2019 and 57 in 2018). The list of participants is provided at Appendix I.

The following are the recommendations from the WPTT23 to the Scientific Committee, which are provided at Appendix VIII.

Revision of the WPTT Program of Work (2022–2026)

WPTT23.01 (para. 184): The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2022–2026), as provided in Appendix VII.

Date and place of the 24th and 25th Sessions of the WPTT (Chair and IOTC Secretariat)

WPTT23.02 (para. 191) 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 2022. 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 2022 as a preferred time period to hold the WPTT24 Assessment meeting in 2022 with a Data Preparatory meeting to be held in the first half of 2022 to prepare for the BET assessment.

Review of the draft, and adoption of the report of the 23rd session of the WPTT

WPTT23.03 (para. 193): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT23, provided at Appendix VIII, 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 2021 (Figure 2):

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

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

Stock	Indicators		2013	2014	2015	2016	2017	2018	2019	2020	2021	Advice to the Commission
Bigeye tuna *Thunnus obesus*	Catch in 2020 (MT) Average catch 2016–2020 (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)	83,498 86,880 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 2021 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 2020 (MT): Average catch 2016-2020 (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}	555,211 546,095 535,964 (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%** *	🟩	No new stock assessment was conducted in 2021 and so the advice is based on the 2020 assessment 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 2020 (MT) Average catch 2016–2020 (MT) MSY (1000 MT)(80% CI)) F_{MSY} (80% CI) SB_{MSY} (1,000 MT) (80% CI)) F_{2020} / F_{MSY} (80% CI) SB_{2020}/ SB_{MSY} (80% CI) SB_{2020} / SB_0 (80% CI)	432,624 434,569 394 (325–463) 0.18 (0.14–0.21) 1,515 (1,146–1,885) 1.27 (0.64–1.91) 0.78 (0.57–0.98) 0.28 (0.21.–0.34)	🟩	🟩	🟥 **94%** *****	🟥 **68%** *****	🟥	🟥 **94%** *****	🟥	🟥	🟥 **67%** *****	A new stock assessment was carried out for yellowfin tuna in 2021. The 2021 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 2021 is based on the model developed in 2018 with a series of revisions that were noted during the WPTT in 2018, 2019 and 2020. The model ensemble (a total of 96 models) encompasses a range of stock dynamics. A number of sensitivity runs were conducted to address additional uncertainty. On the weight-of-evidence available in 2021, the yellowfin tuna stock is determined to remain **overfished** and **subject to overfishing.** 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 projections were not available during the WPTT23 and will be developed intersessionally prior to the SC in 2021. The critical errors in the projections and estimations for computing probabilities in the K2SM developed in 2018 have been addressed and the updated projections should no longer suffer from the issues previously experienced. As such a new K2SM will be developed that will be suitable for use to provide management advice. Resolution 21/01 *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>

*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 23rd Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT), was held online using Zoom from 25 - 30 October 2021. 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 108 participants attended the Session (cf. 111 in 2020, 68 in 2019 and 57 in 2018). 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 WPTT23 are listed in Appendix III.

3. UPDATE OF ANY NEW DATA AVAILABLE AT THE SECRETARIAT FOR TROPICAL TUNA SPECIES SINCE THE DATA PREPARATORY MEETING

3. The WPTT **NOTED** paper IOTC–2021–WPTT23–03 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 1950–2020. 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.
4. The WPTT **ACKNOWLEDGED** that the information presented in this is based on official data up to the year 2020 (submitted by most CPCs by the deadline of June 30th 2021) that were not originally available during the data preparatory meeting held in May 2021.
5. The WPTT **NOTED** that compared to the nominal catch time series available in May 2021, there are very minor differences (200 t less in total catches of yellowfin tuna for 2019) which are mostly caused by updates to historical data received from CPCs in the intersessional period, and negligible re-adjustment in gear / species disaggregation in the early period of the time series.
6. The WPTT **NOTED** how to date the information available on total annual discards by fleet and species is basically unavailable for all IOTC CPCs, and **RECALLED** how increasing the level of compliance to the IOTC ROS (Res. 11/04) in terms of minimum coverage reached by scientific observers onboard could be particularly useful to CPCs in order to gain insights on this important type of information.
7. At the same time the WPTT **RECALLED** how data for non-reporting CPCs and fisheries is usually taken from the FAO capture database (e.g., Yemen) or repeated from previous years (e.g., Yemen, Madagascar, Tanzania for selected fisheries), while data for some CPCs (e.g., Eritrea, Somalia) is completely unavailable.
8. The WPTT **ACKNOWLEDGED** that the approach of repeating annual catch levels for Yemen (as currently done in the FAO capture database, and therefore in the IOTC) might cause an overestimation of recent catches, due to the socio-political situation in the country that has potentially and negatively impacted the fishing sector.
9. The WPTT **NOTED** the recent efforts made by the IOTC Secretariat to engage with representatives from Somalia and Yemen, with the goal of increasing their compliance level (also for matters related to statistical data collection and reporting) and **ACKNOWLEDGED** that the IOTC Secretariat will report to its Working Parties on future developments of this strengthened dialogue.
10. **NOTING** the steady increase in catches from the "line" fishery group recorded in the years between 2016 and 2020, to the point that starting with 2019 these gears provide the highest contribution

to total catches reported for yellowfin tuna, the WPTT **ACKNOWLEDGED** that this might be explained by several factors, including some CPCs progressively transitioning from gillnets to coastal longlines, which are currently categorized under the “line” fishery group in the IOTC.

11. Furthermore, the WPTT **ACKNOWLEDGED** that the current classification of coastal longlines within the “line” fishery group might not accurately reflect the characteristic of the gear, that might be more properly categorized under the “longline” fishery group, and **REQUESTED** that this issue is brought to the attention of the WPDCS for further discussion.

12. The WPTT **NOTED** that information on operational aspects of several line fisheries are limited or missing, and **ENCOURAGED** CPCs to formally report such information at least through their National Reports.

13. The WPTT **RECALLED** that one of the other aspects that might explain the recent increase in catches from gears within the “line” category could also be the development of fishing capacity and increase in exerted effort for some of the major handline fisheries.

14. In particular, the WPTT **NOTED** that catches of yellowfin tuna from the handline fishery of Oman have more than doubled between 2019 and 2020 (increasing from ~25,000 t to almost ~60,000 t) while at the same time little to no information has been reported by the fleet in terms of georeferenced catch-and-effort data, which are known to be collected at national level.

15. Therefore the WPTT **REQUESTED** that Oman further liaises with the IOTC Secretariat to ensure that all currently missing statistical information be provided according to the existing reporting requirements.

16. The WPTT **NOTED** again that information on operational aspects and the fleet composition of several line fisheries are limited or missing, and **ENCOURAGED** CPCs to report such information through their National Reports or (preferably) through the fishing craft data submissions (IOTC form 2FC).

17. The WPTT **ACKNOWLEDGED** that the voluntary nature of the fishing crafts’ data submissions limits the possibility of using this information for analytical purposes, and **RECALLED** that the data available to the IOTC Secretariat in this regard is thought to be inaccurate and incomplete for some fleets and years.

18. The WPTT **NOTED** with concern that georeferenced monthly catch-and-effort data for many important artisanal fisheries are not consistently reported to the Secretariat by several CPCs (e.g., Oman, Yemen, India, Indonesia) and **URGED** all concerned CPCs to take the necessary steps to collect and report this important information in agreement with the requirements of Resolution 15/02.

19. Also, the WPTT **ACKNOWLEDGED** that the EU is currently liaising with National Institutions to ensure that the missing mandatory statistical information for the Italian component of its fleet operating in the Indian Ocean is recovered and submitted to the IOTC Secretariat in 2022.

20. The WPTT **NOTED** that no official updates have yet been provided by the EU to explain the exceptional composition of part of their purse seine catches following a change in estimation methodology reported by EU,Spain in 2018, and **RECALLED** that in lack of upcoming updates, the original catch data submitted by the EU continued to be used in the assessments of the stock performed in 2021.

21. **NOTING** how the Italian component of the European Union fleet currently consists of a single vessel and **CONSIDERING** the constraints on data confidentiality currently expressed by Res. 12/02 (para. 2a in particular), the WPTT **SUGGESTED** that the WPDCS further discuss these confidentiality issues in collaboration with all CPCs in a comparable situation.

22. The WPTT **ACKNOWLEDGED** that yellowfin tuna catches recorded by Pakistan for its gillnet fleet continue to be at a recent-years low, due to various circumstances that include reduced local market demand, poor environmental conditions and change in targeting from tuna to other non-IOTC species.

23. The WPTT also **DISCUSSED** about the possibility that a fraction of the overall Pakistani catches is actually accounted for by I.R. Iran, where some vessels offload their catches due to better market conditions, and **NOTED** the statement by Iran that for double- counting to be verified Pakistan should provide the available documents and evidence of this for investigation by Iranian authorities. .

24. The WPTT **CONSIDERED** the possibility that a similar behaviour might also be one of the factors explaining the recent increase in catches reported by the handline fishery of Oman, that could potentially include catches originally taken by Yemeni vessels offloading in the country, and for this reason **REQUESTED** the IOTC Secretariat to investigate this matter further with support of national scientists from the countries involved.

25. The WPTT **ACKNOWLEDGED** that due to the insurgence of the CoViD-19 pandemic in Q1 2020, it has been particularly challenging for several fleets to implement regular sampling programmes during the year, and therefore **NOTED** that size data for 2020 are available in very limited numbers, particularly when considering the free-swimming school component of purse seine catches.

26. The WPTT **RECALLED** that the Scientific Committee recommendation that both unraised (raw) and raised (catch-at-size) size frequency data be reported to the IOTC, and **REQUESTED** all concerned CPCs to liaise with the Secretariat to ensure that historical and new submissions of size data including both types of information are provided for incorporation into the IOTC databases.

27. The WPTT **NOTED** the limited number of samples available from some industrial purse-seine fleets (particularly from 2018 onwards), which does not reach the minimum recommended level of 1 fish sampled per ton of catch retained.

28. Also, the WPTT **RECALLED** how the provisions from Res. 15/02 (para. 5) that size-frequency data collected by observers onboard be used as a replacement for regular data recorded through logbooks or by enumerators at landing site only applies to longline fleets for which there’s at least a level of observers’ coverage of 5% of all fishing operations.

29. For this reason, the WPTT **REITERATED** how data provided under the IOTC ROS cannot (in general) be used as a substitute of mandatory statistical data, but rather as their complement and as a cross-verification mechanism.

30. The WPTT **RECALLED** how the comparison of average weights of yellowfin tuna derived from the size-frequency and catch-and-effort data (in both weight and numbers) reported by the deep-freezing longline fisheries of Taiwan,China appear to be biased for all years from 2002 onwards, and for this reason **ACKNOWLEDGED** that length-frequency data for the strata concerned are not used to produce the basic inputs for the stock assessment of the species.

31. The WPTT **ACKNOWLEDGED** that the estimated average weight of yellowfin tuna caught by all fisheries in the Indian Ocean has reached an all-time low of 6.85 kg in 2020, and **NOTED** how this is mostly driven by the average weight of fish caught by purse seiners fishing on FAD-associated schools (estimated to be at around 4.08 kg in 2020).

4. YELLOWFIN STOCK ASSESSMENT

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

32.WPTT **NOTED** paper IOTC–2021–WPTT23–05 on a preliminary estimation of growth parameters for yellowfin tuna (*Thunnus albacares*) in the Indian Ocean from otolith-based age estimates (Farley et al), including the following abstract:

> *"This paper describes work to estimate the age and growth of yellowfin tuna (Thunnus albacares) in the Indian Ocean from otoliths as part of the 'GERUNDIO' project1. The 2018 stock assessment for yellowfin tuna in the Indian Ocean (IOTC) indicated that the stock is. overfished and subject to overfishing (Fu et al. 2018; IOTC 2020). The stock assessment model used a fixed growth function from Fonteneau (2008) in the base model and additional growth curves from Eveson et al. (2015) and Dortel et al. (2015) in sensitivity models."* – see document for full abstract

33.The WPTT **CONGRATULATED** the authors for the study which relies on a new method recently developed for bigeye tuna from the Western-Central Pacific Ocean that combines counts of micro-increments (assumed to represent days) and opaque zones (assumed to represent full years) observed in the sagittal otoliths of yellowfin tuna to derive a decimal age.

34. The WPTT **NOTED** that the new length-at-age data and growth curve are consistent with (i) the growth estimated within the Multifan-CL model used for the yellowfin tuna stock assessment of 2008, (ii) the length-at-otolith weight data, (iii) the age vs. otolith size of IOTTP tag-recapture otoliths, and the length-at-age of IOTTP tag-recapture fish.

35.The WPTT **NOTED** that some age verification work based on bomb radiocarbon dating and analysis of the OTC marked otoliths by a reader with no prior knowledge of the time at liberty or fish length is currently underway.

36.The WPTT **NOTED** that only males were observed in the data set for fork length larger than 150 cm, consistently with a process of sexual dimorphism that has been described in yellowfin tuna and other tuna species, although the mechanisms involved in this process and effects on growth and mortality are poorly known.

37.The WPTT **NOTED** the recommendation made by the authors to collect and read additional otoliths, particularly from the eastern and northern Indian Ocean in order to assess sex-specific and regional-specific growth and inter-annual variation in length at age.

38.The WPTT **NOTED** that the residual variance of the models is small, likely due to the limited sample size (n = 250), **ACKNOWLEDGING** the need for more otolith data to be included in the model in order to get a good representativeness of the population.

39.Regarding the major difference between the new growth curve and previous growth estimates of yellowfin tuna, the WPTT **REQUESTED** using the new results on growth as a sensitivity analysis run in the 2021 assessment.

40.The WPTT **NOTED** that the estimates of asymptotic length (L_∞) derived for the four different growth models fitted to the decimal age data are all larger than 160 cm and consistent with the biology of yellowfin tuna, **RECALLING** that L_∞ represents the average size of the older fish and not the maximum length observed in the population.

41.The WPTT **QUERIED** whether a year effect was included in the model component predicting the daily age from otolith size so as to account for interannual variability in environmental conditions and **NOTED** that this effect was not included in the model due to the limited size of the data set.

42. The WPTT **NOTED** the strong relationship between otolith weight and (decimal) age for yellowfin tuna, **NOTING** however that otolith weight alone cannot be used for predicting age due to the variability around the mean.

43. The WPTT **NOTED** the interest of updating the growth models integrating the new age data with the mark-recapture data and modal progressions in length frequency data from the purse seine fishery, as well as estimating the growth curve within the assessment model by including the ageing data inside SS3 in future assessments.

44. WPTT **NOTED** paper IOTC–2021–WPTT23–06 which provided a comparative study of Indian Ocean Dipole impacts on yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) catch rates in the Indian Ocean, including the following abstract:

> *"Anomalous sea temperature changes could have direct impacts on fish spatial distribution and stock dynamics. Large-scale climate fluctuations as one of the major reasons causing temperature changes has attracted extensive attention. However Indian Ocean Dipole (IOD), an ocean-atmosphere interaction causing interannual climate variability, has not been largely explored. And few of studies tested whether IOD have different effects between different tuna species and whether IOD have spatially distinct influences on one single tuna species. This study adopted public longline fishery data and spatial structure carried by IOTC comparing the differences of IOD impacts between bigeye tuna and yellowfin tuna. Results found that IOD event have significant influence on bigeye tuna only in the tropical western Indian Ocean. For yellowfin tuna, IOD showed significant effects on catch per unit effort (CPUE) both in tropical western and eastern Indian Ocean. And indicators showed that IOD have more significant influence on yellowfin tuna than bigeye tuna. In the south Indian Ocean, both for bigeye tuna and yellowfin tuna, IOD didn't show obvious relationship with CPUE."*

45. The WPTT **THANKED** the authors for this contribution to the understanding of climate impacts on tropical tuna catch rates.

46. The WPTT were **INFORMED** that this study is still preliminary and work is ongoing to improve the outputs of the analysis, such as the use of standardised CPUEs in the models.

47. The WPTT **NOTED** a potential conflict in the outputs of the model with what would be commonly expected and has been shown in other studies. Particularly, the lower catch rates predicted in both the East and the West despite the former experiencing a negative dipole and the latter a positive dipole. One would expect the catch rates to be lower in the case of a positive dipole, but higher in a negative dipole situation. The authors noted that most of the catch is located in the West and this may have caused some errors in the estimations. They again stressed that more work is required to improve the model.

48. WPTT **NOTED** paper IOTC–2021–WPTT23–07 on a review of size data from Indian Ocean longline fleets, and its utility for stock assessment, including the following abstract:

> *"This report reviews the procedures used to collect and process longline size data for use in IOTC stock assessments. It describes the types of data collected, with a particular focus on data provided by the Japanese, Taiwanese, Korean and Seychelles fleets. It investigates the reliability of size data by comparing spatial and temporal patterns in median size among fleets and time periods. It explores reasons behind sudden changes in the shape of length frequency distributions for the Taiwanese fleet and recommends that stock assessments should in future omit Taiwanese length data but include weight data and observer data. It provides recommendations for analysts preparing size data to include in stock assessments, and proposes future directions for research."*

49. The WPTT **NOTED** that the model residuals for the size data for the 2021 assessment conducted for yellowfin tuna have improved compared to the 2018 assessment but they still show some issues that need to be understood and properly addressed.

50. The WPTT **NOTED** that removing outliers from the Seychelles dataset improved the behaviour of trends through time, but that inconsistencies remain in spatial patterns, cautioning the use of Seychelles longline size data for the stock assessment.

51. The WPTT **NOTED** that the assessment model cannot fit the Japanese size data available in the early period (i.e., pre-1962) and the other size data sets with the same selectivity and that this affects the fit to the size data sets and conflicts with some trends in CPUE, further **NOTING** that there is little information available on the sampling protocol and accuracy of the Japanese size data in the early years of the fishery development.

52. The WPTT **NOTED** that a specific analysis of the temporal trends in length of yellowfin tuna between 1952 and 1970 in each 10° x 20° spatial cell supported the hypothesis that the decrease in average length would be an effect of selectivity rather than sampling quality as the decline was observed at the start of the data set in most spatial cells and the timing of decline was linked to the timing of the onset of longline fishing.

53. The WPTT **NOTED** that there has been several hypotheses put forward to explain the fast decline in average weights and CPUE in the early period of tuna longline fisheries, including the quick capture of the "naive" fish which would be related to fish behavior. The WPTT further **NOTED** that the decline is not considered to be due to the vertical expansion of fishing grounds enabled by technological improvements since the targeting of bigeye tuna in deeper waters developed during the 1970s and there is no evidence available that yellowfin tuna caught in deeper waters are larger.

54. The WPTT **NOTED** the main recommendations on size data made by the consultant to improve the assessment model by avoiding misfit to the size data: (i) remove the pre-1962 Japanese size data from the model, (ii) for the period post-2000, keep only the Japanese size data, given the major differences in average length between the different data sets in each area (e.g., larger lengths reported for Indonesian longliners in region R4), and (iii) use distinct dome-shaped selectivity in each region except the region with the largest fish, while preventing 'cryptic biomass' by constraining selectivity at maximum age/size to be non-zero in all regions.

55. The WPTT **NOTED** that knowledge of the sampling protocols and availability of operational data are essential to assess the quality of the sampling design, including the strata to sample (e.g., accounting for sets within a trip since fish caught in a same set may be of similar size) and randomness of the sampling across the domain.

56. WPTT **NOTED** paper IOTC–2021–WPTT23–08 on approaches for estimating natural mortality in tuna stock assessments: application to Indian Ocean yellowfin tuna., including the following abstract:

> *"The values used for natural mortality (M) are very influential in stock assessment models, affecting model outcomes and management advice. There is often limited information about the true levels. This paper summarises the evidence used to estimate natural mortality at age for the four main stocks of yellowfin tuna, identifying some problems and information gaps. It also describes the history of parameter values used in stock assessments by each tuna RFMO. Through time, Indian Ocean yellowfin tuna (IO-YFT) stock assessments have assumed a variety of values for M. The values used in the most recent assessment were intermediate between the higher levels assumed in assessments for the Eastern Pacific and the Western and Central Pacific, and the lower levels assumed in the Atlantic. In June 2021 an online meeting was held by the Center for the Advancement of Population Assessment Methodology (CAPAM), to provide advice and guidance on practices for modeling natural mortality in fishery assessments. Based on presentations and discussions at the meeting, this*

> *paper provides IO-YFT natural mortality options for prior distributions derived from maximum observed age and suggests approaches for using these priors in stock assessments. It also recommends future research needed to develop improved estimates of natural mortality."*

57. The WPTT **THANKED** the author for the work which provides a review of the methods available to derive estimates of natural mortality (M) and useful insight into how to improve the M inputs for the assessment model of yellowfin tuna.

58. The WPTT **NOTED** that the M value of 0.8 used in several assessments of yellowfin tuna in the Pacific Ocean and in the Indian Ocean up to 2008 was derived from a catch curve analysis limited to a baitboat fishery in coastal areas of the eastern Pacific Ocean and considered to be flawed due to the selectivity bias affecting the estimate of total mortality.

59. The WPTT **NOTED** the interest of methods based on empirical estimators of M from meta-analyses to predict M from life history traits such as the maximum age (Amax) observed from unfished or lightly fished stocks.

60. The WPTT **NOTED** that natural mortality is an influential parameter in stock assessments, with higher values of Amax resulting in lower values of M and consequently higher values of fishing mortality. The WPTT further **NOTED** that more samples and more widespread sampling increase the probability of finding older individuals, and that the Indian Ocean age sampling has been limited to date, with most samples obtained from the western Indian Ocean. The WPTT also **NOTED** that the maximum age method assumes that the stock is unfished or lightly fished, such that the higher fishing mortality in the Indian Ocean would tend to reduce Amax and may positively bias the estimate of M. Some participants expressed concern that the sampling of maximum age can be difficult in tuna populations and may result in overestimation of Amax if the maximum age observed within the individuals sampled is used as it may not represent the average life expectancy. The author responded by stating that he did not think this was an issue using the proposed method as it explicitly requires the use of the oldest observed fish and the method is in fact not trying to investigate the average life expectancy.

61. The WPTT **QUERIED** whether considering a maximum age of 18 years for Indian Ocean yellowfin tuna, as estimated in the Atlantic Ocean with the use of bomb radiocarbon dating (Andrews et al. 2020), would be consistent with the maximum time at liberty of about 6.4 years observed throughout the RTTP-IO. The WPTT **NOTED** that the maximum time at liberty derived from purse seine recoveries might be biased toward smaller values due to under-reporting of tags from large yellowfin tunas caught in longline fisheries, while the high fishing mortality adds to the natural mortality and truncates the age-structure of the stock, removing most fish before they can reach old age.

62. The WPTT **ACKNOWLEDGED** that bomb radiocarbon dating is a useful method to validate age in tropical tuna and **NOTED** that the yellowfin tuna from the Atlantic Ocean aged at 18 years had an otolith weight and clear patterns consistent with a fish of that age.

63. WPTT **NOTED** paper IOTC–2021–WPTT23–09 which contained a preliminary report on estimate of fecundity, age at maturity, sex ratios, spawning season, and spawning fraction for yellowfin tuna, including the following abstract:

> *"This document shows preliminary data to assess the sex-ratio, spawning season, length at 50% maturity and fecundity estimation of yellowfin tuna (Thunnus albacares) in the Indian Ocean as part of the 'GERUNDIO' project. A total of 936 samples were collected (571 males, 351 females and 14 indeterminates) among different Indian Ocean regions. These preliminary results are based on 826 individuals (284 females) from northwest Indian Ocean. Individuals' maturity staging was reported as part of the project for 284 females. Size ranged*

> *from 70 to 149 cm fork length (FL) for females and between 72 and 158 cm FL for males. According to available data, male individuals were much more numerous, especially in large individuals but also in small size individuals, being significant this difference between 75 and 110 cm FL. The preliminary results about spawning season does not differ from previous studies. Estimates on size at 50% maturity and fecundity estimates are in progress."*

64.The WPTT **NOTED** that the study mainly utilised samples collected from the purse seine fishery. The authors explained that to reduce bias, samples from different fleets should be analysed separately but acknowledged that not many samples from other fleets had been obtained due to logistical challenges associated with the pandemic. The WPTT further **NOTED** that the authors had reached out to partners to obtain samples from other fleets, but that more data is still needed.

65.The WPTT **AGREED** that it would be very useful if national institutes could fully catalogue their data and make them available for re-estimation if or when required. The authors clarified that one of aims of the project was to collect information and create a database of all samples and data which will be made available for future studies.

66.WPTT **NOTED** paper IOTC-2021-WPTT23-21 which provided information on investigating growth information for yellowfin and bigeye tuna from the IOTTP tag-recapture data, including the following abstract:

> *"Previous growth models that were estimated for yellowfin (Thunnus albacares) and bigeye (T. obesus) tuna using tag-recapture data from the Indian Ocean Tuna Tagging Programme (IOTTP) suggested both species have a phase of slow growth as juveniles, followed by a phase of faster growth (Eveson et al. 2015; Dortel et al. 2015). One of the drawbacks of using tag-recapture data to model growth is that the age of a fish at release is unknown. These models deal with the problem by modelling the age at release as a random effect. In 2020, the European Union and the Indian Ocean Tuna Commission (IOTC) supported a project to develop new estimates of age and growth for yellowfin and bigeye tuna in the Indian Ocean. The aim was to follow methods recently developed by Farley et al. (2017; 2020) for bigeye tuna in the Western Central Pacific Ocean (WCPO) to estimate the age and growth of yellowfin and bigeye tuna from counts of daily and annual growth zones in otoliths. Using the relationship between the daily age estimates obtained from this project and fish length, the age at release for fish in the tag-recapture data could be estimated from their release lengths. The resulting age estimates are very different than those obtained from the random effects models. Here we present these new findings and discuss potential reasons for the differences."*

67.The WPTT **THANKED** the authors for the interesting study which contributes to the improved knowledge on yellowfin and bigeye tuna growth.

68.The WPTT **NOTED** that almost all the samples in the study came from months 6 – 8 and so it is unlikely that the results are confounded by seasonal growth variations.

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

69.WPTT **NOTED** paper IOTC–2021–WPTT23–10 which provided a standardized purse seine CPUE of Yellowfin tuna in the Indian Ocean for the European fleet, including the following abstract:

> *"The time series of EU purse seine fleet catches per unit effort (CPUE) of small (<10kg) and large (>=10kg) yellowfin tuna (YFT) from the Indian Ocean were standardized using an extension of the Delta-lognormal GLMM to three components. These components are: (i) the detection rate of schools per unit of searching time, (ii) the proportion of sets for which the targeted size category is present and (iii) the biomass of the targeted size category in the fish school. The aim was to use the commercial size categories as a proxy to depict the trend in*

> *abundance for adult and juvenile YFT observed in free schools (FSC), as well as for juveniles caught under floating objects (FOB)."*

70.The WPTT **THANKED** the authors for the work has improved over the last few years and aims to complement the abundance indices derived from longline fisheries for purse seine.

71. The WPTT **NOTED** that the trend in the standardised CPUE index for purse seine on free schools between 1991 and 2019 was not inconsistent with the trends derived from the joint longline CPUE and purse seine on floating objects for adult yellowfin tuna, although this latter includes fish generally smaller than observed on free schools.

72. The WPTT **NOTED** that the implementation of IOTC resolutions . 17/01, 18/01 and 19/01 has acutely modified the strategy of the purse seine fleets in the Indian Ocean since 2017 (e.g.., avoiding setting on free swimming schools), cautioning the interpretation of the index on free schools during the period 2017-2019.

73. The WPTT **NOTED** that changes in accessibility to some fishing areas (e.g., changes in the fishing agreements to access the national waters of Tanzania or closure of the Chagos archipelago fishing grounds from April 2010) may also have an affect the CPUE time series although the authors indicated that the results were found to be robust to these changes.

74.WPTT **NOTED** paper IOTC–2021–WPTT23–11 which provided the outcomes of joint CPUE analysis, including the following abstract:

> *"Three distant-water tuna longline fishing fleets, Japan, Korea and Taiwan,China have started a collaborative study since December 2019 for producing the joint abundance indices using integrated fishery data of these fleets to contribute to the upcoming stock assessments of yellowfin tuna in the Indian Ocean. The intention is to produce reliable indices by increasing the spatial and temporal coverage of fishery data. In this paper, results using data up to 2020 fisheries were provided to update the WPTT on the progress of this activity. As an underlying analysis, a clustering approach was utilized to account for the inter-annual changes of the target in each fishery in each region. For this purpose, a hierarchical clustering method with "fastcluster" was used, and the outputs of the finalized cluster were then used to assign the cluster label on fishery target to each catch-effort data. For standardizing the catch-per-unit-effort data, the conventional linear models and delta-lognormal linear models were employed for data of monthly and 1° grid resolution in each region. In addition to the implicit target species through the clustering, geographical and temporal covariates were used in the regression structures. The models were diagnosed by the standard residual plots and influence analysis"*

75.The WPTT **THANKED** the collaborators on this work for the update to the joint CPUE LL index, which is an important input to the stock assessment models.

76.The WPTT **NOTED** that effort creep in the Longline fishery was not explicitly addressed in the current analysis due to time constraints. The analysts had intended to investigate this issue having reviewed literature from the Pacific and Atlantic on how this could be done, but ultimately it was not possible prior to the current meeting.

77.The WPTT **NOTED** that two methods were considered for addressing switches in targeting between YFT and BET by the LL fleets, namely a cluster analysis or incorporating hooks between floats into the standardisation model. The current preference by the authors is to utilise clustering to address the issue. In the future environmental conditions will also be considered and potentially incorporated to further address this issue.

78.The WPTT **NOTED** that several improvements had been made to the model based on the comments from the previous meeting, however there remain some confounding effects between the vessels and the clusters. The authors agreed that access to and analysis of the operational data may help resolve this issue.

79.The WPTT **NOTED** that when YFT and BET are in in separate clusters, there can be confounding between the abundance trend and the trend explained by the cluster as there are less targets and fewer fishing strategies in the clusters. The authors noted that they conducted the K=4 test on the individual fleets, and in each case the analysis satisfied the conditions of this test.

80.The WPTT **NOTED** the importance of determining whether the difference in results of this analysis from the previous one are due to improvements in the model or effects in the clustering. The WPTT were **INFORMED** that the data resolution between fleets are quite different so direct comparisons cannot be obtained, however the authors noted that there are similar patterns in aggregated and operational data results using a very simple analysis but further investigation is required.

81.The WPTT **NOTED** the importance of analysing the operational data, and the possibility of having this information shared for additional analysis, such as regional scaling.

82.The WPTT **NOTED** an update on the work provided in paper IOTC–2021–WPTT23(DP)–15, which was presented to the WPTT23(DP) meeting. The paper discussed an associative Behavior-Based abundance Index (ABBI) for yellowfin tuna (*Thunnus albacares*) in the Western Indian Ocean. No new paper was submitted.

83.The WPTT **NOTED** the updated presentation of the paper presented at the WPTT23(DP) meeting and **THANKED** the authors for the information.

84. The WPTT **NOTED** that the index was designed to provide absolute values of abundance as and was not intended to be purely a relative index.

85.The WPTT **NOTED** an update on the work provided in paper IOTC–2021–WPTT23(DP)–13, which was presented to the WPTT23(DP) meeting. The paper discussed a Bayesian Skipjack and Yellowfin Tuna CPUE Standardisation Model for Maldives Pole and Line 1970-2019. No new paper was submitted.

86.The WPTT **NOTED** the updated work carried out on this index and **THANKED** the authors for the information.

4.3 Stock Assessment Result

- **Stock Synthesis**

87.The WPTT **NOTED** paper IOTC–2021–WPTT23–12 describing the preliminary Indian Ocean yellowfin tuna stock assessment 1950-2020 (Stock Synthesis), including the abstract:

> *"This report presents a preliminary stock assessment for Indian Ocean yellowfin tuna (Thunnus albacares) using Stock Synthesis 3 (SS3). The assessment uses an age-structured and spatially-explicit population model and is fitted to catch rate indices, length-composition data, and tagging data. The assessment covers 1950 – 2020 and represents an update of the previous assessment model, taking into account progress and improvements made since the previous assessment. The assessment assumes that the Indian Ocean yellowfin tuna constitute a single spawning stock, modelled as spatially disaggregated four regions, with 21 fisheries."* - See paper for full abstract)

88.The WPTT **CONGRATULATED** the assessment team for their hard work and significant progress in improving the assessment.

89.The WPTT **NOTED** the suggestion to investigate including the waters of the Maldives as a separate spatial region in the stock assessment model to account for a potential localized population. The WPTT **NOTED** that while this would be possible given the availability of a long catch dataset, the individual CPUE series from the area and the extensive tagging data from the region, it would add complexity to the model as additional information on spatial linkages may be required.

90. The WPTT **NOTED** that the Maldivian CPUE series is provided through a R Markdown script that has been made publicly available and **ENCOURAGED** scientists to make use of this script and to provide CPUE datasets in a similar manner so that it is transparent and reproducible.

91. The WPTT **NOTED** that for the diagnostic model, the only CPUE series included was the longline CPUE, for consistency with the model for the previous assessment conducted in 2018. Some modifications to fleet and spatial structure were then made in order to include the purse seine CPUE series in an exploratory model. The WPTT **NOTED** that of the purse seine CPUE series, the series including only adults is thought to be the most reliable and most consistent with the longline series, so this is prioritized. Other CPUE series are included for sensitivity and exploratory model runs but are not included in the final model grid.

92. The WPTT **NOTED** that weightings of observational datasets in the assessment model are based on recommended practice but they have not been analysed thoroughly. The WPTT **SUGGESTED** that different weightings could be applied to different indices in the model based on their perceived reliability and a finer weighting scheme could be applied to individual years. The WPTT **NOTED** that these types of approaches have been explored with tagging data in the past in an attempt to account for uncertainties in the model caused by these data. The WPTT further **NOTED** the assertion that it is more important to assess how conflicts between different datasets can be accounted for in the model.

93. The WPTT **NOTED** that the modelling effort maintained the same data weighting scheme used in the previous IOTC yellowfin tuna stock assessment. Each year of each CPUE time series was assigned a CV of 0.20 with no year-to-year variability. The WPTT commented that this may be oversimplifying the uncertainty of the CPUE and **SUGGESTED** that some exploration be conducted to perhaps better capture the year-to-year variation that likely exists, especially in the longer term CPUE time series. The WPTT **NOTED** that a variance reweighting approach that objectively estimates an added variance parameter could be a helpful exploration to demonstrate the agreement (or otherwise) between abundance indices.

94. Similarly, the assessment used a length composition data effective sample size of five (5) for each year and fishery. Given the wide degree of variation in the observed sample size, one constant value for all fisheries and years may not sufficiently capture the between-fishery or between-year uncertainty. In fact, examination of the Francis data weighting method results suggested that further adjustment of the sample sizes of the length data (via variance reweighting) was warranted. However, the WPTT **NOTED** that the author believes that this approach is unlikely to significantly impact the key conclusion of the assessment.

95. The WPTT **NOTED** that the assessment presentation outlined substantial disagreement between the various observational data categories (CPUE, length and tagging data) used to condition the model. For example, the profile analysis demonstrated substantial disagreement between the CPUE and the tagging data with regards to natural mortality. Nonetheless, there was limited exploration of different weightings between the major data categories. However, the uncertainty of the tagging data was captured within the overall uncertainty grid by using lambdas of both 1.0 and 0.10. This would have contributed to capturing the effects of disagreement between data categories.

96. The WPTT **NOTED** that the growth curves used to assign an age to each tagged fish in the model were the Fonteneau and Dortel growth curves which had been used in the previous assessment, further **NOTING** that the new growth curve presented in paper IOTC–2021–WPTT23–05 has not yet been incorporated into the model as it was not finalized in time for the final model runs, and applying the new growth curve requires additional changes to the assessment model. The WPTT

NOTED that the new estimates of natural mortality presented in paper IOTC-2021-WPTT23-08 have also not been included in the final model runs. Instead, the impact of both of these new parameters (new growth and new natural mortality) on the assessment outcomes were explored in a number of the sensitivity runs. The WPTT **NOTED** that the potential inclusion of these new parameters in future stock assessments will be discussed during the next YFT WPTT data preparatory meeting.

97. The WPTT **NOTED** conflicts between the purse seine commercial size data and tagging data where the estimated catch from log school sets appeared to be missing a lot of large fish that exist in the tagging data. As such, the estimation of purse seine selectivity may be biased. The WPTT **NOTED** that the different weightings of the tagging data in the final grid have captured some of the uncertainty in the estimation of selectivity due to the influence of these data. The WPTT further **NOTED** the assertion from Spanish scientists that the fishery catches more large sized fish than the sampling has indicated.

98. The WPTT **NOTED** that IOTTP tagging data have a large influence on the models for all tropical tuna species, **NOTING** that inferences from tagging data are known to be affected by a range of issues including incomplete mixing, uncertainty on tag reporting and tag losses, which can create scaling problems. The WPTT further **NOTED** that tagging data help to provide information on natural mortality.

99. The WPTT **NOTED** that longline selectivity has been changed from the previous assessment to allow selectivity to vary by region. Given the spatial size variation of longline-caught fish, this change improved the fits to the size data. The WPTT also **NOTED** that allowing non-asymptotic longline selectivity in some regions would further improve the fit. The WPTT **NOTED** that assuming asymptotic selectivity in longline fisheries tends to favour higher natural mortality estimates, as seen in the size data component of the likelihood profile on natural mortality.

100. The WPTT **NOTED** that it has not yet been possible to fix the problem of the systematic underfitting of tagging data (which may indicate overestimation of biomass) and understanding the influence of these data on the model, further **NOTING** that this issue has been seen in previous assessments as well, in particular for younger fish. The WPTT **NOTED** that using different estimates of natural mortality affects the fit of the tagging data to a certain extent but that further work is still required.

101. The WPTT **NOTED** that in the diagnostic model the tagging data were treated in the same way as in the previous assessment, in that all tagging data were included. The WPTT **NOTED** that the influence on the model of the poor fit of tag recoveries is reduced by assuming a very high level of overdispersion. However, the underfitting does not show characteristics of overdispersion, but appears likely to be due to a scaling problem. The WPTT **NOTED** that this may be due to a spatial issue as the tagging data fit well in a one-area model that fits only to the Region 1 data.

102. The WPTT **NOTED** that recoveries from the purse seine fisheries accounted for over 90% of tag observations, which is informative for the estimation of regional abundance and fishing mortality. On the other hand, a constant reporting rate must be estimated for each of the other fisheries when the reporting rate is more likely to have changed over time, which could be a source of bias. As such, the option of including only tag recoveries from the purse seine fleet is considered in the revised model with the alternative spatial and fleet structure.

103. The WPTT **NOTED** that Region 1 is a very large area and there may be spatial structure within it that affects movement and mixing and is not currently modelled. For example, new genetic studies have suggested that there may be separate populations within that area which currently are not accounted for in the spatial structure of the model.

104. The WPTT **NOTED** that Spawning Stock Biomass (SSB) appears to be increasing in the latest years suggesting that there are potential issues in some aspect of the assessment, since the CPUE series does not decrease as much as expected given the recent high catches of yellowfin.

105. The WPTT **NOTED** that the very low recruitment deviates in the period 2004-2006 correspond with the so called 'golden years' when there were record catches of yellowfin which were thought to be a result of oceanographic factors which increased productivity in the Indian Ocean. The WPTT **NOTED** that this initial period was followed by a period of low productivity and deep thermoclines from 2007-2009 which may have led to low catchability during this period which is seen in the decline in the CPUE series. The WPTT **NOTED** that this period of low productivity was then followed by the years when the fishery was impacted by piracy so there are possible compounding effects on the CPUE. The WPTT **NOTED** that oceanographic conditions are not accounted for in the model.

106. The WPTT **NOTED** that the recruitment pattern has remained consistent throughout exploratory analyses that were conducted to attempt to find the factors influencing the series, including the elimination of tagging data and CPUE during the piracy years from the model. The analysis indicated that the low recruitment from 2004-2006 could relate both to the tagging data and CPUE during the piracy period. The WPTT further **NOTED** that the catch trend is also likely to be driving the drop in recruitment in this period.

107. The WPTT **NOTED** that the alternative spatial structure (revised model) further extends the boundaries of Region 1 to better accommodate the distribution of the EU purse seine fishery. This model also divides the purse seine fishery into the small (≤80 cm) and large (>80cm) fish components so that it can fit to the purse seine free-school CPUE indices standardized separately for the juvenile and adult fish. The WPTT further **NOTED** that the variable composition of juvenile and adult fish in the length frequency time series of the purse seine fishery is better accounted for through the division of the fishery by length modes.

108. The WPTT **NOTED** that there is a somewhat unrealistic distribution of fishing mortality between regions, with fishing mortality very high in the north and very low in the south. The WPTT **NOTED** that the recruitment trend also appears quite unrealistic with a steady increase in the proportion allocated to the west compared to the east. This pattern is thought to be related to spatial distribution due to the known catches being incompatible with the CPUE trend in each region. Both issues suggest possible spatial misspecification in the model.

109. The WPTT **NOTED** that assumptions were made to redistribute catches from several fisheries between regions. For example, the fresh longline fishery occurs in both Region 3 and Region 4 but for convenience the catches were allocated to Region 4 due to the lack of size data for this fishery until very recently. The WPTT **NOTED** that the high fishing mortality by fresh tuna longliners in Region 4 and the low fishing mortality in Region 2 and Region 3 suggests that the regional distribution of biomass may be biased, which suggests the need to investigate the regional scaling factors.

110. The WPTT **NOTED** the high peaks in the joint CPUE series in the period 1976-78, further **NOTING** that these are likely to relate to issues with data reporting and management. The WPTT **NOTED** that excluding these data points helped to remove some irregularities seen in the biomass trajectory but further **NOTED** that this had no effect on the results of the model.

111. The WPTT **NOTED** that hindcasting has been used as a diagnostic tool for the assessment to evaluate the entire grid but further **NOTED** that this is a work in progress and that consensus has not yet been reached on a process for using diagnostic results to choose between models. The WPTT **NOTED** that as the hindcasting diagnostic requires repeated refitting of the model, it is not practical to run this for the entire grid within a reasonable time frame. The WPTT **NOTED** that hindcasting conducted on a selected number of models did not provide sufficient contrast in performance between these models.

112. The WPTT **NOTED** that the new growth curve (presented in paper IOTC-2021-WPTT23-05) was used in a sensitivity run. However, adjusting ages at release of tagged fish in this model to the new growth curve led to model failure. The WPTT **SUGGESTED** that this should be investigated in more

detail. The WPTT **NOTED** that the CV estimated from the growth study was unrealistically small (<5%) due to the relatively small number of samples used to produce the curve. The WPTT further **NOTED** that a 10% CV is assumed in the assessment model.

113. The WPTT **NOTED** that the 3% annual increase in catchability applied to the purse seine CPUE was derived from the trends in the residuals in the model which placed zero weight on the purse seine CPUE, and further **NOTED** that this catchability change put the trend in the purse seine CPUE in line with the trend in the longline CPUE, **NOTING** that this method has been used in other RFMOs. The WPTT also **SUGGESTED** exploring changes in catchability of the longline CPUE in a sensitivity model.

114. The WPTT **NOTED** that the CPUE series are the main sources of abundance indices and **SUGGESTED** that alternative CPUEs indices from a wider range of fleets be examined. However, the WPTT further **NOTED** that while this has been attempted for other IOTC species in assessments, for tropical tuna species this is limited by how the CPUE indices were developed, especially as more focus is being put on the joint CPUE series.

115. The WPTT discussed how recruitment distribution and deviations are assumed in projections, **NOTING** that the latest version of SS3 can only project a constant level of recruitment, further **NOTING** that, ideally, future recruitment would be dealt with in a fully stochastic way.

116. The WPTT **NOTED** that a minimum of three or four quarters are considered necessary for proper tag mixing for this stock, further **NOTING** that much of the data would be excluded if this period was increased further.

117. The WPTT **NOTED** that the model that splits the longline CPUE in R1 before and after the piracy period suggested a reduction in catchability of 40%, further **NOTING** that there is little evidence to support this change and that the degree of change was considered to be somewhat unrealistic. The catchability change is largely driven by the model trying to fit large fish in the LL1 fishery at the end of the time series that were caught by non-Japanese fleets, which paper IOTC-2021-WPTT23-07 recommended should be removed. The WPTT **NOTED** that the issue of catchability change has been discussed in the past and that for the previous assessment in 2018, it was decided to adjust the catchability in this way to try to reflect the movement of vessels to other areas and the overall spatial contraction of the longline fleet, although the WPTT also **NOTED** that fishing location and vessel identity are included in the joint CPUE standardization model. The WPTT decided not to change this option due to lack of time to consider changes to the grid. The WPTT **REQUESTED** that further investigation should be carried out on the potential for catchability to have changed during this period.

118. Based on the above discussions, the WPTT **SUGGESTED** several sensitivity runs to the diagnostic model to complement the final model grid:

- Growth: replace base model with the new growth curve from IOTC-2021-WPTT23-05.
- Natural mortality: replace base model with alternatives based on A_{max} of 10.9 or 18.
- Selectivity: down-weight the fresh longline size data to ESS of 0.5; remove non-Japanese size data from longline fisheries.
- Effort creep in joint longline CPUE series: increase by 1% per year over the whole period.
- Regional scaling: divide scaling factors for Region 2 and Region 3 by 2.

119. The WPTT **NOTED** that the model would require reconfiguration in order to work well with the new parameters for growth and natural mortality and that this will be done during the next round of assessments.

120. The WPTT **NOTED** that applying the revised natural mortality ogives from paper IOTC-2021-WPTT23-08_Rev1, based on maximum age of either 10.9 or 18, assuming the same natural mortality for both sexes, and assuming that natural mortality at size followed the Lorenzen curve, had large impacts on estimates of biomass and fishing mortality.

121. The WPTT **NOTED** that the model using the new growth curve could not be run while including the tagging data (with age at release re-estimated) without the model immediately crashing which requires further investigation. The WPTT **NOTED** that using this new growth curve without tagging data resulted in an extremely pessimistic level of biomass, which was found to be related to the misspecification of maturity ogive as a result of the change of growth curve. The WPTT **NOTED** that using the new growth curve improved the fit to the size data, particularly when dome shaped selectivity was used for northern longline fisheries.

122. The WPTT **NOTED** that applying the 1% annual increase over time since the inception of the time series, to the longline CPUE series had the effect of decreasing the CPUE by 40-50% on average by the end of the time series, as well as increasing the biomass depletion level.

123. The WPTT **NOTED** that removing the non-Japanese size data from the longline fisheries in order to address the poor fit of large fish seen at the end of the time series had a large impact on the biomass estimates, suggesting that the modelling approach for this part of the data series requires further scrutiny in the future.

124. The WPTT **NOTED** that adjusting the regional scaling factors affected the biomass distribution in each region in such a way that the biomass was almost halved in Region 2 and Region 3 (as intended), with corresponding increases in fishing mortality in these regions.

125. The WPTT **NOTED** that all the sensitivity runs provided a more pessimistic output in the Kobe matrix than the diagnostic model.

126. The WPTT **NOTED** that with the current model configuration, the projections are likely to be overly optimistic. The WPTT **NOTED** that this issue is occurring because no explicit bias adjustment controls were incorporated into the model so the default approach for bias adjustment was used. This resulted in too much bias adjustment for all periods without estimated recruitments, including the projection period. The WPTT **SUGGESTED** examining a single run from the reference model with and without bias correction to see how different the output projections are. WPTT **NOTED** that the bias adjustment will be made intersessionally before running the final projections to develop the K2SM and management advice.

4.4 Selection of Stock Status Indicators for yellowfin

127. The WPTT **AGREED** that the final grid of 96 model runs from the SS3 stock assessment would be used for the development of management advice for the Scientific Committee's consideration. These 96 model runs encompass a range of stock dynamics and correspond to a combination of model configurations, including: alternative assumptions about the spatial structure (2 options); longline CPUE catchability (2 options on the effect of piracy); weighting of the tagging dataset (lambda = 0.1 or 1); steepness values (0.7, 0.8, and 0.9); natural mortality values (2 options); and growth parameters (2 options).

128. The WPTT **ADOPTED** the stock status advice developed for yellowfin tuna as provided in the draft resource stock status summary and **REQUESTED** that the IOTC Secretariat update the draft stock status summary for yellowfin tuna with the latest 2020 catch data (if necessary), and for the summary to be provided to the SC as part of the draft Executive Summary, for its consideration:

- Yellowfin tuna (*Thunnus albacares*) – Appendix VI

4.5 Update on Yellowfin Management Strategy Evaluation Progress

129. The WPTT **NOTED** paper IOTC–2021–WPM12–13 Ocean yellowfin tuna management procedure evaluation update, including the following abstract excerpt:

> *"• No updates to the IOTC yellowfin Management Procedure (MP) evaluation project have been undertaken since the last WPM given problems in the current Operating Model (OM) which are closely associated with the problems encountered in the yellowfin stock assessment model.*
>
> *• The TCMP (June 2021) agreed to defer discussions on the yellowfin MP evaluation given the updated yellowfin stock assessment due in 2021 which should provide the basis for the updated OM for yellowfin.*
>
> *• Phase 3 of the current yellowfin tuna MP evaluation project ended in June 2021, and funding has been secured from the Australian Department of Foreign Affairs and Trade for the next phase of the yellowfin MP evaluation to June 2023.*
>
> *• To enable progress during the next phase of this project, options to progress the development of the yellowfin tuna OM, given the possible outcomes from the 2021 yellowfin stock assessment are defined."*

130. The WPTT **NOTED** that no new results were presented because the problems with the stock assessment that have been encountered in recent years had not been resolved prior to this meeting, including catch removal issues with the projections which caused similar problems in the OM and diminished the plausibility of the OMs.

131. The WPTT **NOTED** that there are two options suggested: 1) If the 2021 stock assessment is endorsed by the Scientific Committee, and there are no obvious issues in the projections that appear likely to manifest in the OMs, then the OMs will be reconditioned and the candidate MP testing will resume; or 2) if the new assessment is not endorsed by the SC, or the projections are not sufficiently robust, alternative OMs may be developed to enable resumption of the evaluation of candidate MPs

4.6 Development of management advice for yellowfin tuna

132. The WPTT **NOTED** that the analytic estimates of forecasts are not yet available and projections will be conducted intersessionally when the bias adjustment is made to develop the K2SM from the final SS3 model grid to provide management advice. The Kobe stock status derived from the 96 models in the grid is provided in Figure 1. These results indicate that the stock is currently overfished and subject to overfishing.

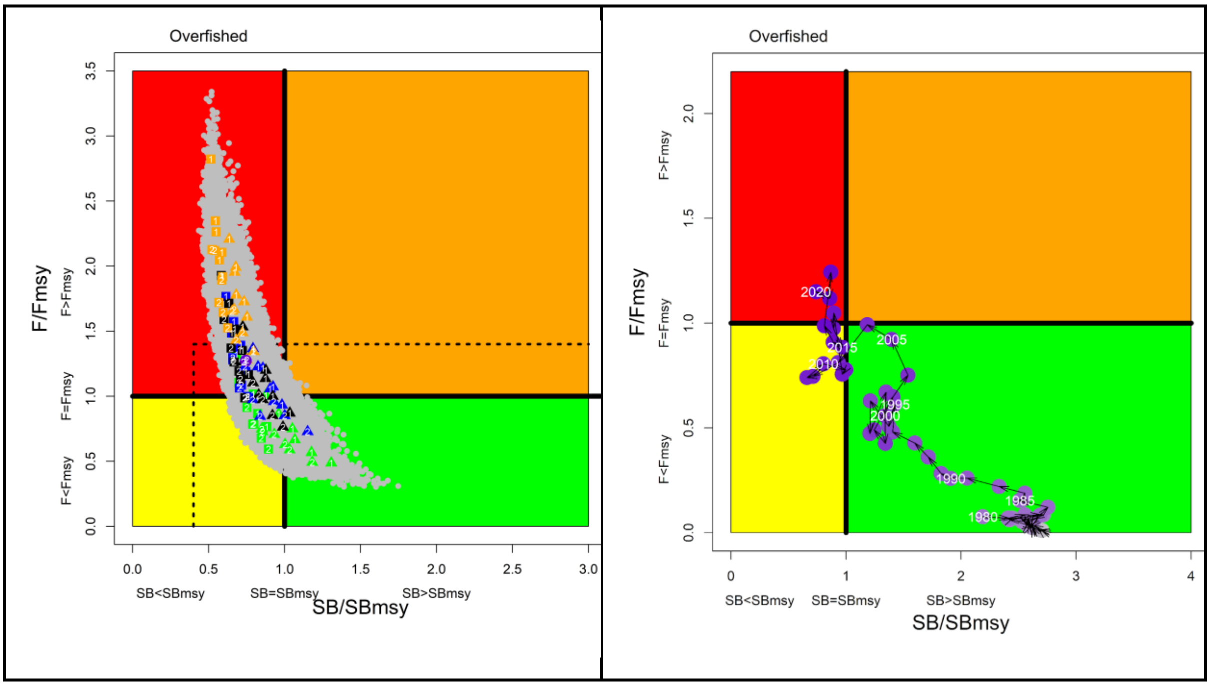


Figure 1. Yellowfin tuna: SS3 Indian Ocean assessment Kobe plot: (Left): current stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the final model options. Coloured symbols represent Maximum posterior density (MPD) estimates from individual models: square and Triangles and represents LL CPUE catchability options q1 and q2 respectively; green, blue, black, and orange represents growth and natural mortality option combination Gbase_Mbase, GDortel_Mbase, Gbase_Mlow, and GDortel_Mlow respectively; 1,2, represents spatial structure option io and sp respectively. The purple dot represents the basic model. Grey dots represent uncertainty from individual models. The dashed lines represent limit reference points for IO yellowfin tuna (SB_{lim} = 0.5 SB_{MSY} and F_{lim} = 1.4 F_{MSY}); (right) stock trajectory from the basic model.

4.7 Update of yellowfin tuna Executive Summary for the consideration of the Scientific Committee

133. The WPTT **NOTED** that as the projections for the SS3 model had not been reviewed during the meeting, management advice would not be included in the Executive summary appended to this report. The WPTT **REQUESTED** that the Secretariat facilitate an intersessional meeting prior to the SC to discuss and agree on the Executive Summary to be presented.

4.8 External Peer Review

134. The WPTT **AGREED** on the need for an external peer review process to review and provide feedback on the IOTC stock assessment. The WPTT **NOTED** that most tuna RFMOs have a review process in pace and that the IOTC could use these examples to develop a process suitable for the IOTC needs.

135. The WPTT **NOTED** an external document WCPFC-SC17-2021/SA-WP-06 which was provided by one of the participants. The document contained draft terms of reference for an independent peer review of the 2020 WCPO yellowfin tuna assessment. The WPTT were informed that in WCPFC the review is effectively a three year process. In the first year, the assessment modellers work on the list of issues raised about the assessment during the assessment session and make as much progress as possible to address these issues. In the second year, a meeting of an external review panel is convened and the external experts provide comments and recommendations to the existing assessment. In the third year, these comments are incorporated into the assessment by the modellers for presentation to the next assessment meeting.

136. The WPTT **DISCUSSED** the relative benefits of having a panel of experts in a face-to-face meeting review the assessment, or of having a single reviewer scrutinise and provide comment on the assessment over an extended period of time via ongoing correspondence. The WPTT **AGREED** that the feedback received from a panel of experts (each able to focus on different aspects of the assessment) along with a multi-year timeframe to deal with the feedback and revisions will be extremely beneficial and that IOTC should adapt the WCPFC approach for its own needs.

137. The WPTT **NOTED** that a three year timeframe also fits conveniently with the current assessment schedule for most key IOTC stocks, which are generally assessed every third year.

138. The WPTT **REQUESTED** that the chairs and vice chairs of the WPTT, WPM and SC, along with the secretariat, develop Terms of Reference for the external peer review panel and present these, along with the suggested review framework, to the SC in 2021.

139. The WPTT **NOTED** that although the review panel would only be required to meet in the second year of the timeframe, external experts should be contacted as soon as possible to determine their willingness to participate as well as their availability.

5. OTHER TROPICAL TUNAS

- **General**

Climate and Oceanic conditions

140. The WPTT **NOTED** paper IOTC–2021–WPTT23–14 provided an outline of climate and oceanic conditions in the Indian Ocean: an update to mid-2021, including the following abstract:

> *"We examine several descriptors of the ocean status to depict the inter-annual variability and to track trends in the large pelagic ecosystem. The most recent El Niño event occurred from January to July 2019. This was a weak event followed by a positive Indian Ocean dipole from July 2019 to January 2020. The ocean response was a 50-80 m deepening of the thermocline in the West Indian Ocean (WIO) and a shoaling of the thermocline of 20 to 60 m above normal in the East Indian Ocean (EIO). From October 2019 to February 2020, the surface chlorophyll concentration decreased from 30 to 60% below normal in the West Indian Ocean and increased from 40 to 200% above normal in the EIO. On the opposite, a La Niña event developed from August 2020 to March 2021, followed by a short negative Indian Ocean dipole in June-July 2021."* – see paper for full abstract

141. The WPTT **CONGRATULATED** the author for the work which provides insight into the major oceanographic features of the Indian Ocean with a focus on the period 2019-2021, including monthly maps of anomalies of sea surface temperature, 20° isotherm depths, and sea surface chlorophyll.

142. The WPTT **NOTED** the major influence that large-scale environmental features may have on marine productivity and vertical structure of the ocean, and the need to disentangle the effects of abundance and catchability in the CPUE standardisation process.

143. The WPTT **NOTED** how the occurrence of a strong positive dipole in the eastern Indian Ocean at the end of 2019 and early 2020 resulted in the dominance of cold waters over the purse seine fishing grounds during several months, reducing the availability of skipjack tuna and forcing the Japanese purse seiners to move to the Pacific Ocean. The WPTT further **NOTED** that a positive dipole index that occurred in 2006 in the south of Sumatra similarly affected the availability of skipjack tuna during a tagging cruise which was eventually unsuccessful.

144. The WPTT **ACKNOWLEDGED** the interest of the dipole mode index (DMI) which captures some important oceanographic features affecting the three tropical tuna species and **ENCOURAGED**

further work to account for this in the CPUE standardisation, **NOTING** that the DMI may need to be associated with other factors as it might not play a consistent role across the whole Indian Ocean.

Aggregation times on FADs

145. The WPTT **NOTED** paper IOTC–2021–WPTT23–15 on aggregation times of tuna schools to FADs estimated by echosounder data, including the following abstract:

> *"We perform a systematic study of aggregation and disaggregation times of tuna schools to drifting Fish Aggregating Devices (dFADs), using the signal provided by the echo-sounder buoys attached to dFADs deployed across all major oceans in the period 2018-2020. The tuna biomass estimation for each day in the time series has been obtained by applying the TUN-AI Machine Learning model (Precioso et al., 2021), which incorporates oceanographic information and hourly echo-sounder data in 10 depth layers on a time window of 72 hours prior to the prediction. We preprocess the data collected from the buoys to select around 10 000 series with daily estimations where no human intervention has occurred. A statistical analysis of these time series with different smoothing techniques shows that tuna schools remain aggregated to dFADs for a median time of 3-9 days, and that the aggregation and disaggregation processes are symmetrical.."*

146. The WPTT **ACKNOWLEDGED** the merit of this work that complements small-scale studies on tuna aggregations, using dFAD buoys echosounder data collected across the three tropical oceans.

147. The WPTT **NOTED** the further work plan to be rolled out by the authors. It was suggested 1) to incorporate an indicator of the FAD density to explore the dynamics of "meta-aggregations" between neighbour FADs, in line with the "ecological trap" hypothesis, which applies to FAD networks rather than individual FADS; and 2) to discriminate the data analysis by ocean due to different abiotic and biotic conditions that may affect the aggregation/disaggregation process.

148. The WPTT **NOTED** that the biomass estimated through the data is a noisy signal, suggesting that substantial changes can occur from one day to another.

149. The WPTT **NOTED** that the AI-based model developed in this study is being improved as more data are incorporated (learning process).

Drifting FAD beachings

150. The WPTT **NOTED** paper IOTC–2021–WPTT23–16 which provided a fine-scale analysis of drifting Fish Aggregating Device (dFAD) beachings in the Seychelles Archipelago: Hotspots offer hope for clean-up, including the following abstract:

> *"Tropical tuna purse seiners extensively use drifting Fish Aggregating Devices (dFADs), human-made floating objects deployed by fishers to facilitate the capture of tunas. The majority of drifting Fish Aggregating Devices (dFADs) in use today are constructed primarily of highly durable non-biodegradable synthetic materials. There is currently no legal obligation to recover dFADs after deployment, which leads to beaching events. To ascertain the extent of beachings within a local context, we analysed all identified beaching events (n=3,775) in the Seychelles Archipelago found among trajectories of dFADs deployed by French purse seiners during 2010-2020 as a function of intra- and inter-annual trends, water depth and distance from land, seasonality and benthic habitat. Beachings occurred most frequently during the (boreal) winter monsoon (December-March). Due the extended shallow Mahé Plateau, beaching occurred in both nearshore (≤5 km from land, 0-40m water depth) and offshore regions (>5 km, 0-60m depth). Despite representing <20% of the overall mapped habitat, the majority of beachings occurred within the benthic habitat 'Coral/Algae' (38.1%), and therefore, pose a significant concern for conservation. Our results provide a detailed view*

> *of the spatiotemporal pattern of beachings and suggest recovery efforts be directed to reduce marine debris and perturbations of coastal habitats."*

151. The WPTT **NOTED** that FADs that had stranded on a site could break free and beach a second time on another site, making the deleterious effects of stranding impact larger than what can be assessed from the recorded number of FADs beached.

152. The WPTT **NOTED** that groups of islands are more affected than others. This outcome is useful to fine tune the activities of the FAD Watch project being rolled out in Seychelles.

153. The WPTT **NOTED** than the FAD Watch project has produced figures on stranding events that are significantly less than those derived from the GPS data presented in the paper. The authors indicated that FAD Watch figures may be underestimated as the project's team are not able to survey all islands and reefs of the Seychelles archipelago.

Nominal catches of tropical tunas by artisanal and industrial fisheries

154. The WPTT **NOTED** paper IOTC–2021–WPTT23–17 which provided information on the nominal catch of tropical tunas by artisanal and industrial fishery in the IOTC area of competence, including the following abstract excerpt:

> *"Nominal catch data publicly available in the IOTC website was analysed to study the tropical tuna (yellowfin, skipjack and bigeye tuna) catch by artisanal and industrial tuna fishery of the Indian Ocean. The nominal catch during 1950-2019 indicates that, of the three species of tropical tunas, skipjack (44.14%) is caught in higher proportions, followed by yellowfin (41.75%) and bigeye (14.14%). In 2019, 66.21% of the total tropical tuna catch was by industrial fishery, whereas the contribution of artisanal fishery to the total nominal catch of Indian Ocean tropical tuna fishery was only 33.79%. The yellowfin caught by industrial fishery in 2019 was 255,356 t, against 199,533 t caught during 2014, whereas yellowfin catch (2019) by artisanal fishery was 190,271 t, against 204,022 t caught during 2014, indicating that in the year 2019, the industrial tuna fishery increased their yellowfin catch by 28% than 2014, whereas the catch by artisanal fishery had decreased by 6.74%. More than 72% of the total Indian Ocean skipjack are caught by industrial fleet, while the remaining 28% by artisanal fleet. From the year 2014 onwards, there was a phenomenal growth in the skipjack catch by industrial fleet. This fishery increased the skipjack catch by 138.68% with reference to skipjack catch by the industrial fishery in 2014, whereas at the same period the artisanal fishery registered negative growth by 33.41%."*

155. While **NOTING** the upward trend of tropical tuna catches attributed to industrial gears compared to artisanal catch and ones, the WPTT **ACKNOWLEDGED** that preliminary data for 2020 show a counter-tendency in this regard when compared to previous years, and **RECALLED** that the industrial gears responsible for this increase include the 'offshore' component of some gillnet fisheries, together with longline and purse seine fisheries from coastal as well as distant water fishing nations..

156. Considering yellowfin, the WPTT **NOTED** that two of the industrial gears increased their catches from the 2014 baseline, by 7.5% for purse seine and by 35.7% for gillnet (offshore), with longline gears decreasing catch by 4.4% during the same timeframe.

157. The WPTT **RECALLED** that the current distinction between artisanal and industrial fisheries depends on the size and area of operations of the vessels involved, and that its attribution might be questionable for several fisheries. For instance, coastal purse seiners fishery of Indonesia that is currently categorised as artisanal should more pertinently be classified as industrial based on he

size of several vessels within the fleet (exceeding the length of 24m LoA which is the threshold between the two categorizations). Therefore, the WPTT **NOTED** that the apportioning of catches between artisanal and industrial fisheries within the IOTC might require further revision.

158. The WPTT **ACKNOWLEDGED** the challenges faced by developing CPCs to produce accurate estimates of catches from their artisanal fisheries, due to the numerous landing sites and the lack of capacity for a more comprehensive sampling, and **RECALLED** that these fisheries suffer from a generalized lack of accurate geospatial data (e.g. monthly catch-and-effort data derived from logbooks or similar) that could complement the annual nominal catches and increase their accuracy, and that for this reason it is difficult for the Secretariat to properly evaluate the quality and completeness of the original data submissions.

- **Bigeye Tuna**

Management Strategy Evaluation

159. The WPTT **NOTED** paper IOTC–2021–WPM12–11 on an update to the Indian Ocean Bigeye Tuna Management Procedure Evaluation, including the following abstract:

> *"• The most recent bigeye OMs and candidate MPs were presented at the MSE taskforce meeting (March 2021) and TCMP (June 2021).*
>
> *• The bigeye Operating Models (OMs) and the MP evaluation process are at a reasonably mature stage, with a suite of potentially viable candidate MPs that all achieve current tuning objectives*
>
> *• Given this relative state of maturity, we seek a discussion within the WPM on endorsement of the OMs and selection of a set of candidate MPs for adoption of a final MP within the IOTC structure*
>
> *• We do, however, note that a revision of the length-at-age relationship for this species is to be presented at the WPTT which could have potential implications for the robustness of the current suite of OMs. We discuss this in the context of having a data and OM "guillotine" requirement (as agreed at WPM MSE taskforce 2021) and a well-defined process for handling exceptional circumstances.."*

160. The WPTT **THANKED** the developer for the work and **NOTED** that this paper was also presented to WPM12.

Bigeye age and growth

161. The WPTT **NOTED** paper IOTC–2021–WPTT23–18 on estimating the age and growth of bigeye tuna (*Thunnus obesus*) in the Indian Ocean from counts of daily and annual increments in otoliths., including the following abstract:

> *"This paper describes work to estimate the age and growth of bigeye tuna (Thunnus obesus) in the Indian Ocean from otoliths as part of the 'GERUNDIO' project1. The most recent stock assessment for Indian Ocean bigeye tuna indicated that the stock is not overfished but overfishing is occurring (Fu 2019; IOTC 2020). The stock assessment model used a fixed growth function from Eveson et al. (2012), which was estimated using tag-recapture data and daily age estimates from otoliths."* – see paper for full abstract

162. The WPTT **THANKED** the authors for the presentation and **CONGRATULATED** them on the work, **ACKNOWLEDGING** that it provides a good improvement on previous growth estimates for bigeye tuna.

163. The WPTT **NOTED** that there was very little difference in the sex ratios across the length distributions of sampled individuals in this study as compared with the trend of fewer females than males in the larger size classes that was observed for yellowfin tuna. The WPTT **NOTED** that the authors had found there to be a slightly lower asymptotic length for females than male bigeye tuna but further **NOTED** that there was insufficient data to fully assess sex-specific differences in growth and so further samples are required. The WPTT **SUGGESTED** that plotting the residuals from the growth curves by sex would enable us to see more clearly the sex-specific differences in growth.

164. The WPTT **NOTED** that there were two clear length modes in the released bigeye tuna in the tagging data (at ~45 and ~60 cm FL, with a clear separation at 55 cm FL), and that the estimated age at recapture indicates a clear pattern of slower initial growth in the smaller of the two modes (see paper IOTC–2021–WPTT23–18_Rev1 for more detail), but further **NOTED** that the fish tagged at smaller sizes eventually grew to be larger than the fish tagged at larger sizes. The WPTT **NOTED** that these differences may be related to the selectivity of gears but is more likely to be a tagging effect, whereby smaller fish are more affected by the tagging process than larger fish.

165. The WPTT **NOTED** that the estimated size-at-age for fish in the larger release mode (>55 cm FL) were consistent with the estimates from this study which were based on otolith increment counts. However, the estimated size-at-age for fish in the smaller release mode (<55 cm FL) underestimated the size-at-age compared with the data from this study.

166. The WPTT **NOTED** that in the previous growth models estimated by Eveson et al. (2015) that used the tagging data, the release age was estimated as a random effect. For these models to fit the different growth rates of the two length modes, the models estimated the age of fish in the faster growing cohort (>55 cm FL) to be much older, which produced the characteristic two-stanza growth curve that has been used in the stock assessments.

167. The WPTT **NOTED** the strong edge effect in the estimated size-at-age of young (<2yo) recaptured bigeye tuna, and that this may be the result of using the relationship between daily age and length to predict the release age of each individual.

168. The WPTT **NOTED** that the method used in this study to estimate the age of bigeye tuna from daily and annual increments in otoliths provides a good improvement on previous growth curve estimates and **REQUESTED** that this method for estimating growth are considered for use in future stock assessments, further **NOTING** that the study can be further discussed and validated during the next scheduled data preparatory meeting. The WPTT **NOTED** that it is valuable to continue with this work, in particular with an increase in the size, sex ratios and spatial distribution of samples. The WPTT **NOTED** that further information that can be found on how growth varies between sexes and potentially spatially would also be valuable.

Size at sexual maturity

169. The WPTT **NOTED** paper IOTC–2021–WPTT23–19: Estimating the size at sexual maturity of bigeye tuna (*Thunnus obesus*) in the eastern Indian Ocean., including the following abstract:

> *"Accurate information of reproductive characteristics of bigeye tuna (Thunnus obesus) is an important factor in determining its regeneration capacity in a population. However, a robust analysis with proper samples representation in the eastern Indian Ocean was still limited. The study aimed to give a preliminary result on estimating size at maturity of bigeye tuna based on histological datasets from 2019-2020. A total of 78 female bigeye tuna (78-161 cm FL) were sampled from Indonesian longline fisheries and the ovaries were analyzed histologically. The estimated length at maturity (Lm50) was 101.25 cm FL at the advanced yolked stage as the threshold of maturity."*

170. The WPTT **NOTED** that the size at maturity estimates found in this study are in line with those from previous studies.

171. The WPTT **NOTED** that otoliths are also collected from large bigeye tuna captured by Indonesian longliners, and that these could be used to provide some additional data for the bigeye growth analyses.

172. The WPTT **NOTED** that there are opportunities for broader collaboration between Research Institute for Tuna Fisheries (RITF) and other agencies in the region to build on the existing biological knowledge of tropical tuna, as well as an opportunity to collaborate on an evaluation of the quality of the size data collected from Benoa.

173. The WPTT **NOTED** that collaboration with other organisations and CPCs was not possible for this study due to administrative issues. The WPTT **ENCOURAGED** collaboration in future studies, in particular in relation to collecting samples in and around Indonesia's waters which has historically been an area from which samples for studies such as the GERUNDIO project have been lacking.

174. The WPTT **NOTED** that the RITF in Indonesia have a range of otolith samples that would be valuable in any continuation of the growth studies presented in papers IOTC-2021-WPTT23-05_Rev1 and IOTC-2021-WPTT23-18_Rev1 (under the GERUNDIO project) as well as any future growth studies..

Spatial distribution of EU purse seine fishing

175. The WPTT **NOTED** paper IOTC–2021–WPTT23–20 on temporal trends and variability in the spatial distribution of European tropical tuna purse-seine fishing in the Atlantic and Indian Oceans, including the following abstract:

> *"It is useful to complement more sophisticated stock status estimations based on stock assessment models with simpler approaches based on analyses of raw catch-effort data to maximize the probability of detecting overexploitation and hyperstability as early as possible. Here we develop a series of annual indices for the spatial distribution of catch over 1991-2019 by European purse seine vessels of the three major tropical tuna species as a function of ocean and fishing mode (floating object or free swimming fish schools). Time series of these indices are examined to identify temporal patterns with a focus on any long term trends that might be indicative of declining stock status or hyperstability. Spatial indices are also calculated for important bycatch species over 2011-2019 from observer data for French vessels. In general, results indicate a relative stability in the spatial distribution of catch over the last 30 years, though major perturbations, such as Somali piracy and major El Niño events, are identifiable. Nevertheless, recent decreasing trends in the presence of bigeye tuna and certain bycatch species merit further investigation.."*

176. The WPTT **NOTED** that the results show no major signs of spatial concentration of fishing effort that would be indicative of hyperstability

177. The WPTT **NOTED** that some inter-annual variability in the spatial distribution of catch and bycatch in European tropical tuna purse-seine fisheries could be partially related with changes in fishing agreements although the main factor can be attributed to the long term shift of purse seine fishing from FSC to FOB sets.

- **Skipjack Management Strategy Evaluation**

178. The WPTT **NOTED** paper IOTC–2021–WPM12–10 on the evaluation of empirical control rules for Indian Ocean Skipjack, including the following abstract:

> *"The primary objective of this work is to develop a Management Procedure (MP) for Indian Ocean Skipjack tuna (SKJ), which includes specification of the data inputs, harvest control rule (HCR) and management outputs, and that has been fully tested using an appropriate simulation framework. Following the presentation of developmental work to the Working Party on Methods (Edwards, 2020a,b, IOTC, 2020a), the MSE Task Force (IOTC, 2021b) and the Technical Committee on Management Procedures (Edwards, 2021, IOTC, 2021c), in which a suitable simulation evaluation framework was proposed, the current work presents further development of an empirical MP with which to recommend a total catch for the fishery.."*

179. The WPTT **THANKED** the author for the good progress made in reviewing the skipjack Management Procedure.

180. The WPTT **NOTED** that further work on simulation testing, particularly concerning alternate future recruitment assumptions, construct diagnosis on robustness of each Management Procedure to positive implementation error, the inclusion of possible asymmetric limits to TAC change will be developed.

6. WPTT PROGRAM OF WORK

6.1 Revision of the WPTT Program of Work (2022–2026)

181. The WPTT **NOTED** paper IOTC–2021–WPTT23–04, which provided the WPTT23 with an opportunity to consider and revise the WPTT Program of Work (2022–2026), by taking into account the specific requests of the Commission, Scientific Committee, and the resources available to the IOTC Secretariat and CPCs.

182. 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)*

183. 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.

184. The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2022–2026), as provided in Appendix VII.

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

185. 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.

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

Chairperson

187. The WPTT **NOTED** that the first term of the current Chairperson, Dr Gorka Merino (EU) expired at the close of the WPTT23 meeting and, as per the IOTC Rules of Procedure (2014), participants are required to elected a new Chairperson of the WPTT for the next biennium.

188. **NOTING** the Rules of Procedure (2014), the WPTT **CALLED** for nominations for the position of Chairperson of the IOTC WPTT for the next biennium. Dr Merino was nominated, seconded and re-elected as Chairperson of the WPTT for the next biennium.

Vice-Chairperson

189. The WPTT **NOTED** that the first term of the current Vice-Chairperson, Dr Shiham Adam (IPNLF) expired at the close of the WPTT23 meeting and, as per the IOTC Rules of Procedure (2014), participants are required to elected a new Vice-Chairperson of the WPTT for the next biennium.

190. **NOTING** the Rules of Procedure (2014), the WPTT **CALLED** for nominations for the position of Vice-Chairperson of the IOTC WPTT for the next biennium. Dr Adam was nominated, seconded and re-elected as Vice-Chairperson of the WPTT for the next biennium.

7.2 Date and place of the 24th and 25th Sessions of the WPTT

191. 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 2022. 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 2022 as a preferred time period to hold the WPTT24 Assessment meeting in 2022 with a Data Preparatory meeting to be held in the first half of 2022 to prepare for the BET assessment.

192. 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 2022.

7.3 Review of the draft, and adoption of the Report of the 23rd Session of the WPTT

193. The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT23, provided at Appendix VIII, 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 2021 (Figure 2):

- Bigeye tuna (*Thunnus obesus*) – Appendix IV

- ○ Skipjack tuna (*Katsuwonus pelamis*) – Appendix V
- ○ Yellowfin tuna (*Thunnus albacares*) – Appendix VI

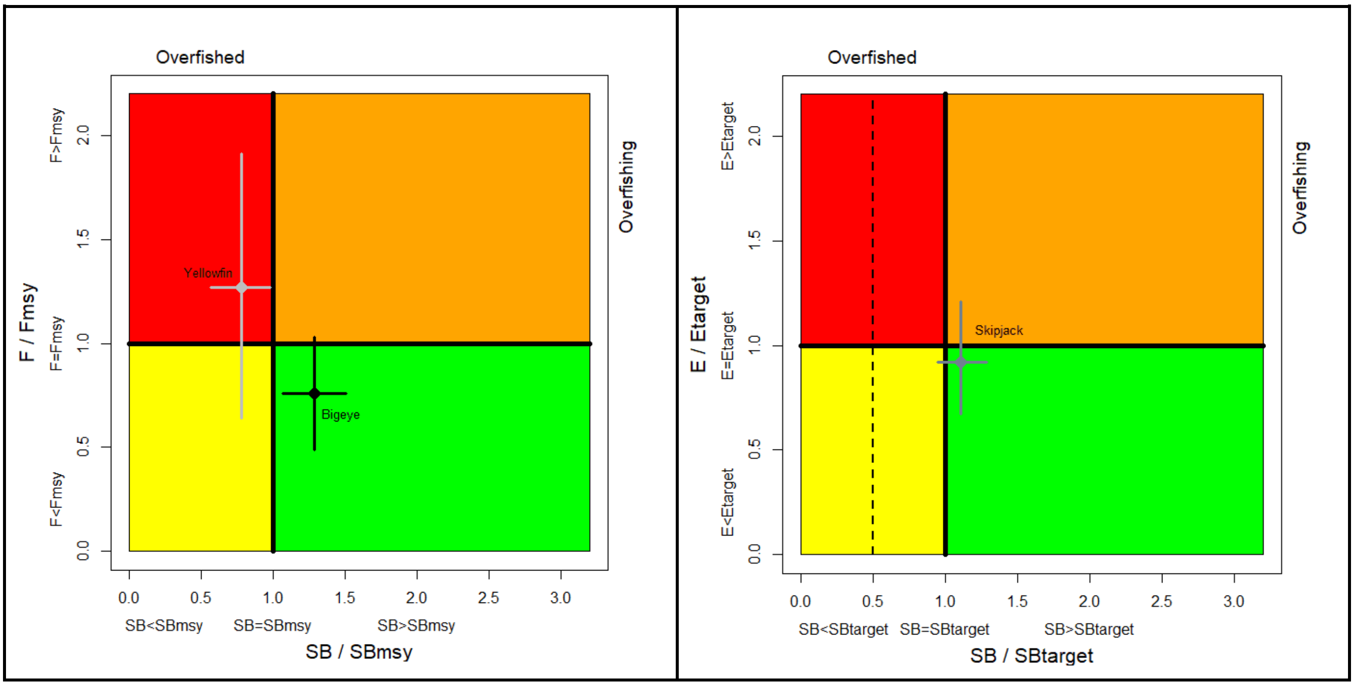


Figure 2. (Left) Combined Kobe plot for bigeye tuna (black: 2019), and yellowfin tuna (grey: 2021) showing the estimates of current stock size (SB) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. (Right) Kobe plot for skipjack tuna showing the 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.

194. The report of the 23rd Session of the Working Party on Tropical Tunas Meeting (IOTC–2021–WPTT23–R) was **ADOPTED** by correspondence.

APPENDIX I
LIST OF PARTICIPANTS

Chairperson
Dr Gorka **Merino**
AZTI
gmerino@azti.es

Vice-Chairperson
Dr M. Shiham **Adam**
International Pole and Line Foundation
shiham.adam@ipnlf.org

Invited Expert
Dr. Michael **Schirripa**
NOAA
michael.schirripa@noaa.gov

Other Participants

Ms. Nabeela **Abdulla**
Maldives Marine Research Institute
nabeela.abdulla@mmri.gov.mv

Mr. Mohamed **Ahusan**
Maldives Marine Research Institute
mohamed.ahusan@gmail.com

Dr. Alex **Aires-da-Silva**
IATTC
alexdasilva@iattc.org

Mr. Mokhtar **Akhondi**
IRNA Fisheries Org
akhondi2200@yahoo.com

Dr. Nekane **Alzorriz**
Asociación Nacional De Armadores De Buques Atuneros Congeladores-ANABAC
nekane@anabac.org

Mr. Siva **Anandhan**
Fishery Survey Of India
sivafsi2006@gmail.com

Dr. Iraide **Artetxe-Arrate**
AZTI
i.artetxe73@gmail.com

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

Dr. Jose Carlos **Baez**
IEO
josecarlos.baez@ieo.es

Dr. Yannick **Baidai**
IRD/MARBEC
yannick.baidai@ird.fr

Dr. Franco **Biagi**
European Commission -DG MARE
Franco.Biagi@ec.europa.eu

Dr. Don **Bromhead**
ABARES, Department of Agriculture, Water and Environment
Don.Bromhead@awe.gov.au

Mr. John **Burton**
Sustainable Fisheries and Communities Trust
John.burton@sustainablefisheriesandcommunitiestrust.org

Mrs. Manuela **Capello**
IRD
manuela.capello@ird.fr

Ms. Naomi **Clear**
CSIRO
naomi.clear@csiro.au

Dr. Ansuman **Das**
Fishery Survey of India
ansuman@fsi.gov.in

Dr. Antoine **Duparc**
IRD
antoine.duparc@ird.fr

Dr Charles **Edwards**
IOTC consultant
cescapecs@gmail.com

Ms. Paige **Eveson**
CSIRO
paige.eveson@csiro.au

Ms. Jessica **Farley**
CSIRO
jessica.farley@csiro.au

Mr. Theotime **Fily**
IRD
theotime.fily@ird.fr

Dr. Shunji **Fujiwara**
OFCF
roku.pacific@gmail.com

Dr. Daniel **Gaertner**
IRD UMR MARBEC
daniel.gaertner@ird.fr

Mrs. Veronique **Garrioch**
IBL Seafood
vgarrioch@iblseafood.com

Ms. Kathryn **Gavira**
Satlink
kgo@satlink.es

Dr. Shubhadeep **Ghosh**
ICAR-CMFRI
subhadeep_1977@yahoo.com

Pr. David **Gómez-Ullate**
University of Cádiz
david.gomezullate@uca.es

Dr. Andrew **Gordon**
Marine Stewardship Council
andrew.gordon@msc.org

Dr. Maitane **Grande**
AZTI
mgrande@azti.es

Dr. Loreleï **Guéry**
CIRAD
lorelei.guery@cirad.fr

Mrs. Riana **Handayani**
Ministry of Marine Affairs and Fisheries
daya139@yahoo.co.id

Dr. Sisira **Haputhantri**
National Aquatic Resources Research and Development Agency (NARA)
sisirahaputhantri@yahoo.com

Mrs. Hety **Hartaty**
Research Institute for Tuna Fisheries
hhartaty@gmail.com

Mr. Miguel **Herrera**
OPAGAC
miguel.herrera@opagac.org

Dr. Rich **Hillary**
CSIRO
rich.hillary@csiro.au

Dr. Glen **Holmes**
The Pew Charitable Trusts
gholmes@pewtrusts.org

Dr. Simon **Hoyle**
IOTC consultant
simon.hoyle@gmail.com

Mr. Jose Luis **Jauregui**
Echebastar Fleet SLU
jljauregui@echebastar.com

Dr. Prabath **Jayasinghe**
National Aquatic Resources Research and Development Agency (NARA)
prabath_jayasinghe@yahoo.com

Mrs. Hanista **Jhumun-Foolheea**
Ministry of Blue Economy, Marine Resources, Fisheries and Shipping
hfoolheea@govmu.org

Dr. David **Kaplan**
IRD
david.kaplan@ird.fr

Mr. Muhammad Moazzam **Khan**
WWF-Pakistan
mmoazzamkhan@gmail.com

Ms. Beatrice **Kinyua**
Sustainable Fisheries & Communities Trust
beatrice.kinyua@sfact.org

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

Dr. Mohammed **Koya**
Scientist
koya313@gmail.com

Dr. Patricia **Lastra**
Fundazion AZTI-AZTI Fundazioa
plastra@azti.es

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

Mr. Francisco **Leotte**
Thai Union
francisco.leotte@thaiunion.com

Ms. Yanan **Li**
Shanghai Ocean University
liyananxiada@yeah.net

Dr. Jung-hyun **Lim**
National Institute of Fisheries Science
jhlim1@korea.kr

Dr. Maria Teresa **Losada Ros**
Satlink
tlr@satlink.es

Mrs. Juliette **Lucas**
Seychelles Fishing Authority
jlucas@sfa.sc

Dr. Qiuyun **Ma**
Shanghai Ocean University
qyma@shou.edu.cn

Ms. Isla **MacMillan**
University of Plymouth, WWF and Institut de Recherche pour le Developpement (IRD)
isla.macmillan@postgrad.plymouth.ac.uk

Mr. Ariyaratne **Manage**
Department of Fisheries
mma_fi@yahoo.com

Dr. Francis **Marsac**
IRD
francis.marsac@ird.fr

Mr. Hakimu **Matola**
Tanzania Deep Sea Fishing Authority
hakim.matola@dsfa.go.tz

Dr. Takayuki **Matsumoto**
Fisheries Resources Institute
matumot@affrc.go.jp

Dr. Alexandra **Maufroy**
ORTHONGEL
amaufroy@orthongel.fr

Dr. Paul **Medley**
MMRI
paulahmedley@gmail.com

Dr. Alexia **Morgan**
Sustainable Fisheries Partnership
alexia.morgan@sustainablefish.org

Dr. Vinodkumar **Mudumala**
Fishery Survey of India
vmudumala@gmail.com

Dr. Hilario **Murua**
ISSF
hmurua@iss-foundation.org

Mr. Manuel **Navarro**
Universidad Carlos III de Madrid
manuel.navarro@komorebi.ai

Mr. Stephen **Ndegwa**
Kenya Fisheries Service
ndegwafish@yahoo.com

Dr. Tom **Nishida**
Fisheries Resources Institute (Japan)
aco20320@par.odn.ne.jp

Mrs. Praulai **Nootmorn**
Department of Fisheries, Thailand
nootmorn@yahoo.com

Mr. Pavarot **Noranarttragoon**
Department of Fisheries, Thailand
pavarotn@gmail.com

Mr. Alejandro **Pérez San Juan**
N/A
muestreos.tunidos.seychelles@gmail.com

Dr. Tom **Pickerell**
Global Tuna Alliance
tom@globaltunaalliance.com

Mr. Daniel **Precioso**
University of Cadiz
daniel.precioso@uca.es

Ms. Ann **Preece**
CSIRO
ann.preece@csiro.au

Mrs. Lourdes **Ramos**
IEO
mlourdes.ramos@ieo.es

Ms. Jessica **Rattle**
Blue Marine Foundation
jess@bluemarinefoundation.com

Mr. Stuart **Reeves**
Cefas
stuart.reeves@cefas.co.uk

Dr. Jan **Robinson**
SIOTI
janrobinson71@gmail.com

Dr. Prathibha **Rohit**
ICAR CMFRI
prathizoom2020@gmail.com

Dr. Evgeny **Romanov**
CITEB
evgeny.romanov@citeb.re

Mr. Andrew **Russell**
Thai Union
andy.russell.consultant@thaiunion.com

Mrs. Surya **S**
Central Marine Fisheries Research Institute
revandasurya@gmail.com

Mr. Patrick **Sachs**
Department of Agriculture, Water and the Environment
patrick.sachs@awe.gov.au

Mrs. Saraswati **Saraswati**
Ministry of Marine Affairs and Fisheries of the Republic Indonesia
cacasaras@gmail.com

Mr. Ian **Scott**
ECHEBASTAR
ianroyscott@yahoo.com

Mr. Umair **Shahid**
WWF
ushahid@wwf.org.pk

Mr. Chris **Shearlock**
Princes
chris.shearlock@princes.co.uk

Mr. Abdirahim **Sheik Heile**
Ministry of Fisheries and Marine Resources
sgunrahim@yahoo.com

Mr. Mohamed **Shimal**
Maldives Marine Research Institute
mohamed.shimal@mmri.gov.mv

Mrs. Clivy **Shung**
Ministry of Blue Economy, Marine Resources, Fisheries and Shipping
clivilim@yahoo.com

Pr. Liming **Song**
Shanghai Ocean University
lmsong@shou.edu.cn

Mr. Rahulkumar **Tailor**
Fishery Survey Of India
rt311280@gmail.com

Mr. Weerapol **Thitipongtrakul**
Department of Fisheries, Thailand
weerapol.t@gmail.com

Dr. Geoff **Tingley**
SFP
geoff.tingley@sustainablefish.org

Dr. Muneharu **Tokimura**
Overseas Fishery Cooperation Foundation of Japan
tokimura@ofcf.or.jp

Dr. Alberto **Torres-Barrán**
Komorebi AI Technologies
alberto.torres@komorebi.ai

Dr. Wen-Pei **Tsai**
National Kaohsiung University of Science and Technology
wptsai@nkust.edu.tw

Dr. Yuji **Uozumi**
Japan Tuna Fisheries Co-operative Association
uozumi@japantuna.or.jp

Dr. Agurtzane **Urtizberea**
AZTI
aurtizberea@azti.es

Ms. Neda **Vadiati**
IRNA Fisheries Org
shirinvad@gmail.com

Dr. Sijo **Varghese**
Fishery Survey of India
varghesefsi@hotmail.com

Ms. Yang **Wang**
Shanghai Ocean University
shouwyh@163.com

Dr Sheng-Ping **Wang**
National Taiwan Ocean University
wsp@mail.ntou.edu.tw

Dr. Ashley **Williams**
CSIRO
ashley.williams@csiro.au

Dr. Tianjiao **Zhang**
Shanghai Ocean University
tjzhang@shou.edu.cn

Pr. Jiangfeng Zhu
Shanghai Ocean University
jfzhu@shou.edu.cn

Dr. Iker Zudaire
AZTI
izudaire@azti.es

IOTC Secretariat

Dr Paul **De Bruyn**
Paul.DeBruyn@fao.org

Mr Fabio **Fiorellato**
Fabio.Fiorellato@fao.org

Mr Dan **Fu**
Dan.Fu@fao.org

Dr Emmanuel **Chassot**
Emmanuel.chassot@fao.org

Ms. Lauren Nelson
Lauren.nelson@fao.org

Ms Cynthia **Fernandez-Diaz**
Cynthia.FernandezDiaz@fao.org

Ms. Lucia **Pierre**
Lucia.pierre@fao.org

APPENDIX II

AGENDA FOR THE 23RD WORKING PARTY ON TROPICAL TUNAS, ASSESSMENT MEETING

Date: 25 - 30 October 2021
Location: Online
Time: 12:00 – 16:00 (Seychelles time)
Chair: Dr Gorka Merino (European Union); **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. YELLOWFIN STOCK ASSESSMENT (Chair)

4.1 Review any new information on yellowfin 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 yellowfin
4.5 Development of management advice for yellowfin tuna (all)
4.6 Update of yellowfin tuna Executive Summary for the consideration of the Scientific Committee (all)

5 OTHER TROPICAL TUNAS
- Bigeye
- Skipjack

6 WPTT PROGRAM OF WORK

6.1 Revision of the WPTT Program of Work (2022–2026)
6.2 Development of priorities for an Invited Expert at the next WPTT meeting

7 OTHER BUSINESS

7.1 Election of a Chairperson and a Vice-Chairperson of the WPTT for the next biennium (Secretariat)
7.2 Date and place of the 24th and 25th Sessions of the WPTT (Chair and IOTC Secretariat)
7.3 Review of the draft, and adoption of the Report of the 23rd Session of the WPTT(AS) (Chair)

APPENDIX III
LIST OF DOCUMENTS FOR THE 23RD WORKING PARTY ON TROPICAL TUNAS

Document	Title
IOTC–2021–WPTT23–01a	Draft: Agenda of the 23rd Working Party on Tropical Tunas
IOTC–2021–WPTT23–01b	Draft: Annotated agenda of the 23rd Working Party on Tropical Tunas
IOTC–2021–WPTT23–02	Draft: List of documents for the 23rd Working Party on Tropical Tunas
IOTC–2021–WPTT23–03	Review of the statistical data and fishery trends for tropical tunas (IOTC Secretariat)
IOTC–2021–WPTT23–04	Revision of the WPTT Program of Work (2022–2026) (IOTC Secretariat)
IOTC–2021–WPTT23–05	Preliminary estimation of growth parameters for yellowfin tuna (*Thunnus albacares*) in the Indian Ocean from otolith-based age estimates (Farley et al)
IOTC–2021–WPTT23–06	Comparative study of Indian Ocean Dipole impacts on yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) catch rates in the Indian Ocean (Wang Y, Zhu J, Zhang F)
IOTC–2021–WPTT23–07	Review of size data from Indian Ocean longline fleets, and its utility for stock assessment (Hoyle S, Chang S-T, Fu D, Itoh T, Lee SI, Lucas J, Matsumoto T, Yeh Y-M, Wu R-F, Lee MK)
IOTC–2021–WPTT23–08	Approaches for estimating natural mortality in tuna stock assessments: application to Indian Ocean yellowfin tuna. (Hoyle, S).
IOTC–2021–WPTT23–09	A preliminary report on estimate of fecundity, age at maturity, sex ratios, spawning season, and spawning fraction for yellowfin tuna (Zudaire et al).
IOTC–2021–WPTT23–10	Standardized purse seine CPUE of Yellowfin tuna in the Indian Ocean for the European fleet (Guéry L, Kaplan D, Grande M, Abascal F, Baez J-C. and Gaertner D.).
IOTC–2021–WPTT23–11	Outcomes of joint CPUE analysis (Kitakado et al).
IOTC–2021–WPTT23–12	Preliminary Indian Ocean yellowfin tuna stock assessment 1950-2020 (Stock Synthesis) (Fu et al.)
IOTC–2021–WPTT23–14	Outline of climate and oceanic conditions in the Indian Ocean: an update to mid-2021. (Marsac et al.).
IOTC–2021–WPTT23–15	Aggregation times of tuna schools to FADs estimated by echosounder data (Navarro-García M, Precioso D, Gavira-O'Neill K, Torres-Barrán A, Gordo D, Gallego-Alcalá V, and Gómez- Ullate D).
IOTC–2021–WPTT23–16	Fine-scale analysis of drifiting Fish Aggregating Device (dFAD) beachings in the Seychelles Archipelago: Hotspots offer hope for clean-up (McMillan et al).
IOTC–2021–WPTT23–17	Nominal catch of tropical tunas by artisanal and industrial fishery in the IOTC area of competence (Varghese S, Pandey S, Siva A, Jeyabaskaran R).
IOTC–2021–WPTT23–18	Estimating the age and growth of bigeye tuna (*Thunnus obesus*) in the Indian Ocean from counts of daily and annual increments in otoliths. (Farley J, Krusic-Golub K, Eveson P, Clear
IOTC–2021–WPTT23–19	Estimating the size at sexual maturity of bigeye tuna (*Thunnus obesus*) in the eastern Indian Ocean. (Hartaty H, Setyadji B, Arnenda G, and Sulistyaningsih R).
IOTC–2021–WPTT23–20	Temporal trends and variability in the spatial distribution of European tropical tuna purse-seine fishing in the Atlantic and Indian Oceans (Kaplan D, Báez JC, Pascual Alayon P, Vidal T).
IOTC–2021–WPTT23–21	Investigating growth information for yellowfin and bigeye tuna from the IOTTP tag-recapture data. (Farley et al.)
Papers from other Working Parties	
IOTC–2021–WPTT23(DP)–15	UPDATE: Associative Behavior-Based abundance Index (ABBI) for yellowfin tuna (*Thunnus albacares*) in the Western Indian Ocean. (Baidai Y, Dagorn L, Gaertner D, Denebourg J-L, Duparc A and Capello M)

Document	Title
IOTC–2020–WPM11–10	Evaluation of empirical control rules for Indian Ocean Skipjack (Edwards C)
IOTC–2020–WPM11–11	Indian Ocean Bigeye Tuna Management Procedure Evaluation Update (Hillary R, Williams A, Preece A and Jumppanen)
Information papers	
IOTC–2021–WPTT23–INF01	Outcomes of the 25th Session of the Commission
IOTC–2021–WPTT23–INF02	Preliminary stock assessment of Indian Ocean yellowfin tuna using Statistical-Catch-At-Size (SCAS) (1950-2020) (Nishida T and Kitakado T)
IOTC–2021–WPTT23–INF03	Development of Statistical-Catch-At-Size (SCAS) software (Nishida T, Kitakado T and Iwasaki)

APPENDIX IV

DRAFT RESOURCE STOCK STATUS SUMMARY

BIGEYE TUNA (BET : THUNNUS OBESUS)

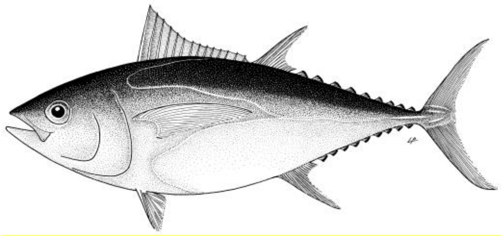


Table 1. Status of bigeye tuna (*Thunnus obesus*) in the Indian Ocean

Area[1]	Indicator	Value	Status[3]
Indian Ocean[1]	Catch in 2020 (t)[2]	83,498	38.2%*
	Average catch 2016-2020 (t)	86,880	
	MSY (1,000 t) (80% CI)	87 (75-108)	
	F_{MSY} (80% CI)	0.24 (0.18-0.36)	
	SB_{MSY} (1,000 t) (80% CI)	503 (370-748)	
	F_{2018} / F_{MSY} (80% CI)	1.20 (0.70-2.05)	
	SB_{2018} / SB_{MSY} (80% CI)	1.22 (0.82-1.81)	
	SB_{2018} / SB_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: 17%

[3] The stock status refers to the most recent years' data used in the assessment conducted in 2019, i.e. 2018

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

Colour key	Stock overfished (SB_{2018} / SB_{MSY}<1)	Stock not overfished (SB_{2018} / SB_{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 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 SB_{2018} is above SB_{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 t with a range between 75,000 and 108,000 t (a median level 16% lower than the estimate in 2016). Catches in 2018 (~81,413 t) 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 t) 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 the2018 selectivity and therefore size distribution of catch (**Table 2**). Should the management objective of maintaining biomass at levels higher than SB_{MSY} with more than 50% probability in 2028 be pursued, the overall catch should be reduced 10% from 2018 levels (73,272 t).

Management advice. The stock status determination changed qualitatively in 2019 to not overfished but subject to overfishing. If catches remain at 2018 levels there is a risk of breaching MSY reference points with 58.9% and 60.8% probability in 2021 and 2028. Maintaining catches of at least 10% below 2018 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**).

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY):** estimate for the Indian Ocean stock is 87,000 t with a range between 75,000–108,000 t for SS3 (**Table** 1). The average 2014-2018 catches of ≈89,717 t, and catches for each year since 2012 are within the range of the estimated MSY level.
- **Interim reference points**: Noting that the Commission in 2015 agreed to Resolution 15/10 *on target and limit reference points and a decision framework*, the following should be noted:
  - **Fishing mortality**: Current fishing mortality is considered to be at 120% of the interim target reference point of F_{MSY}, and 92% of the interim limit reference point of $1.3*F_{MSY}$ (**Fig. 2**).
  - **Biomass**: Current spawning biomass is considered to at 122% of the interim target reference point of SB_{MSY} and well above the interim limit reference point of $0.5*SB_{MSY}$ (**Fig. 2**).
- **Main fisheries** (average catches 2016-2020): purse seine (41.4%) (Log/FAD schools = 28.6%; free school = 6.4%), deep-freezing longline (27.5%), fresh longline (9.5%), coastal longline (9.3%) (**Fig. 1**);
- **Main fleets** (average catches 2016-2020): EU (45%) (Spain (16.9%), France (4.5%), Italy (0.5%), Indonesia (23.1%), Taiwan,China (15.7%), Seychelles (13.6%), Sri Lanka (5.7%).

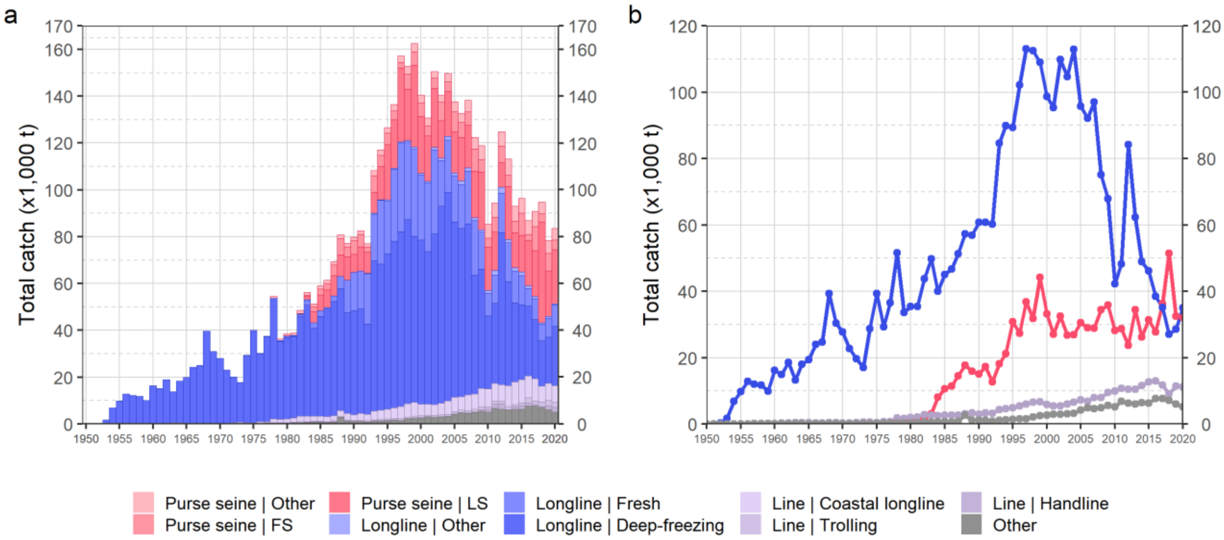


Fig. 1. Annual time series of (a) cumulative nominal catches (t) by fishery and (b) individual nominal catches (t) by fishery group for bigeye tuna during 1950–2020. LS = drifting log or FAD-associated school and FS = free-swimming school. Purse seine other: coastal purse seine, purse seine, ring net; Longline: deep-freezing and fresh longlines, swordfish and sharks-targeted longlines; Line: coastal longline, trolling and handline; Other: all remaining fishing gears

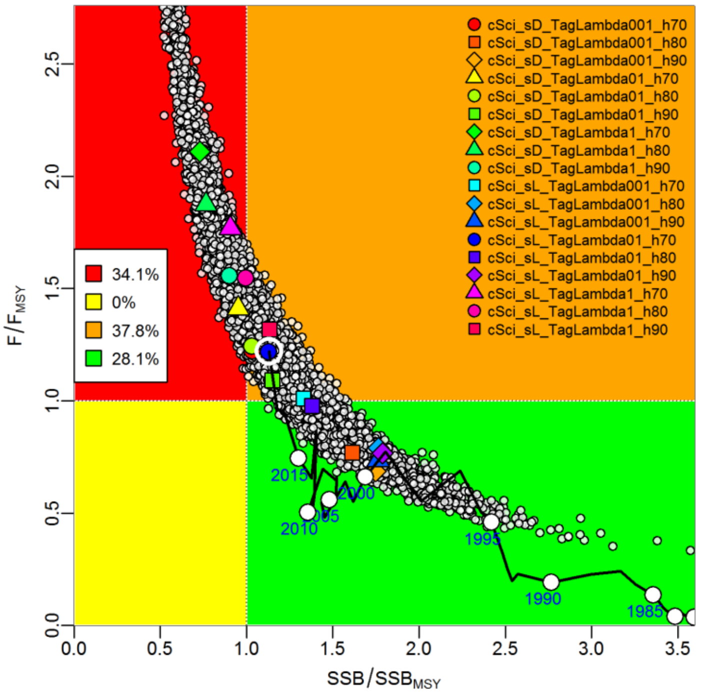


Fig. 2. Bigeye tuna: SS3 Aggregated Indian Ocean assessment Kobe plot. The coloured points represent stock status estimates from the 18 model options. The grey dots represent 5,000 estimates of 2018 stock status from the multivariate normal approximation from the mean and variance-covariance of the 18 model options. The legend indicates the estimated probability of the stock status being in each of the Kobe quadrant. The white circle (around the blue 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 t); -10%, -20%, -30%, -40%) projected for 3 and 10 years

Reference point and projection timeframe	**Alternative catch projections (relative to the catch level from 2018) and weighted probability (%) scenarios that exceed reference point**				
	60% (48,848 t)	**70%** (56,990 t)	**80%** (65,130 t)	**90%** (73,272 t)	**100%** (81,413 t)
$SB_{2021} < SB_{MSY}$	51.1	53.3	54.2	57.1	58.9
$F_{2021} > F_{MSY}$	7.3	17.8	32	47.9	62.8
$SB_{2028} < SB_{MSY}$	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 ($SB_{lim} = 0.5\ SB_{MSY}$; $F_{Lim} = 1.3\ F_{MSY}$)**				
	60% (48,848 t)	**70%** (56,990 t)	**80%** (65,130 t)	**90%** (73,272 t)	**100%** (81,413 t)
$SB_{2021} < SB_{LIM}$	0	0	0	0	0
$F_{2021} > F_{LIM}$	6.0	11.0	17.0	28.0	39.0
$SB_{2028} < SB_{LIM}$	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 V

DRAFT RESOURCE STOCK STATUS SUMMARY

SKIPJACK TUNA (SKJ: KATSUWONUS PELAMIS)

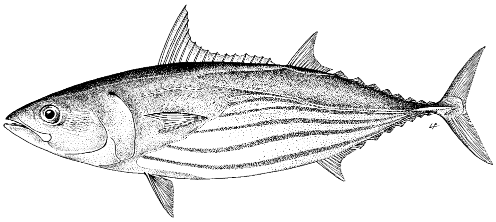


Table 1. Status of skipjack tuna (*Katsuwonus pelamis*) in the Indian Ocean

Area[1]	Indicator	Value	Status[2]
Indian Ocean	Catch in 2020 (t)	555,211	🟩 60.4%*
	Average catch 2016-2020 (t)	546,095	
	$C_{40\%SB0}$ (t) (80% CI)	535,964 (461,995–674,536)	
	C_{2019} / $C_{40\%SB0}$ (80% CI)	1.02 (0.81–1.18)	
	$E_{40\%SB0}$ [3] (80% CI)	0.59 (0.53–0.66)	
	E_{2019} / $E_{40\%SB0}$ (80% CI)	0.92 (0.67-1.21)	
	SB_0 (t) (80% CI)	1,992,089 (1,691,710–2,547,087)	
	SB_{2019} (t) (80% CI)	870,461 (660,411–1,253,181)	
	$SB_{40\%SB0}$ (t) (80% CI)	794,310 (672,825–1,019,056)	
	$SB_{20\%SB0}$ (t) (80% CI)	397,155 (336,412–509,528)	
	SB_{2019} / SB_0 (80% CI)	0.45 (0.38-0.5)	
	SB_{2019} / $SB_{40\%SB0}$ (80% CI)	1.11 (0.95-1.29)	
	SB_{2019} / SB_{MSY} (80% CI)	1.99 (1.47-2.63)	
	MSY (t) (80% CI)	601,088 (500,131–767,012)	
	E_{2019} / E_{MSY} (80% CI)	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, i.e. 2019

[3] $E_{40\%SB0}$ is the equilibrium annual exploitation rate (Etarg) associated with the stock at Btarg, and is a key control parameter in the skipjack harvest control rule as stipulated in Resolution 16/02. Note that Resolution 16/02 did not specify the exploitation rate associated with the stock at Blim.

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

Colour key	Stock overfished (SB_{2019} / $SB_{40\%SB0}<1$)	Stock not overfished (SB_{2019} / $SB_{40\%SB0}\geq 1$)
Stock subject to overfishing (E_{2019} / $E_{40\%SB0}\geq 1$)	🟥 19.5%	🟧 19.5%
Stock not subject to overfishing (E_{2019} / $E_{40\%SB0}\leq 1$)	🟨 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 SB_{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 ($0.2*SB_0$). The recent catches have been within the range of estimated target yield (see $C_{40\%SB0}$). Current spawning 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** ($SB_{2019}>SB_{40\%SB0}$); (iii) with fishing mortality below the adopted target fishing mortality, and; (iv) **not subject to overfishing** ($E_{2019}<E_{40\%SB0}$).

Outlook. Total catches in 2018 were 30% larger than the resulting catch limit from the skipjack HCR for the period 2018-2020 (470,029 t), 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 SB_{2019} / SB_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 $SB_{2019}/SB_0=0.44$) and those that do not (median SB_{2019} / $SB_0=0.45$). Also, there was contrast between runs that fully weighted tagging information (median SB_{2019} / $SB_0=0.42$) and those that reduced their influence (median $SB_{2019}/SB_0=0.48$).

Management advice. The catch limit calculated applying the HCR specified in Resolution 16/02 is 513,572 t for the period 2021-2023. The SC noted that this catch limit is higher than for the previous period. This is attributed to the new stock assessment which estimates a higher productivity of the stock and a higher stock level relative to the target reference point, possibly due to skipjack life history characteristics and favourable environmental conditions. Thus, it is likely that the recent catches that have exceeded the limits established for the period 2018-2020 have been sustained by favourable environmental conditions. Therefore, the Commission needs to ensure that catches of skipjack tuna during this 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*;
- **Biomass**: Current spawning biomass was considered to be above the target reference point of 40% of SB_0, and above the limit reference point of $0.2*SB_0$ as per Resolution 16/02 (**Fig. 2**);
- **Main fisheries** (average catches 2016-20): Purse seine ~55% (FAD/log associated school ~45%; free-swimming school ~2.3%; other ~7,5%); Pole-and-line ~19%; Gillnet ~17%; Other gears ~9% (**Fig. 1**);
- **Main fleets** (average catches 2016-20): European Union ~26% (EU-Spain: ~18.2%; EU-France: ~6.7%; EU-Italy: 0.5%); Indonesia ~18%; Maldives ~16.5%; Seychelles ~13%; I.R. Iran ~8%; Sri Lanka ~7.4%.

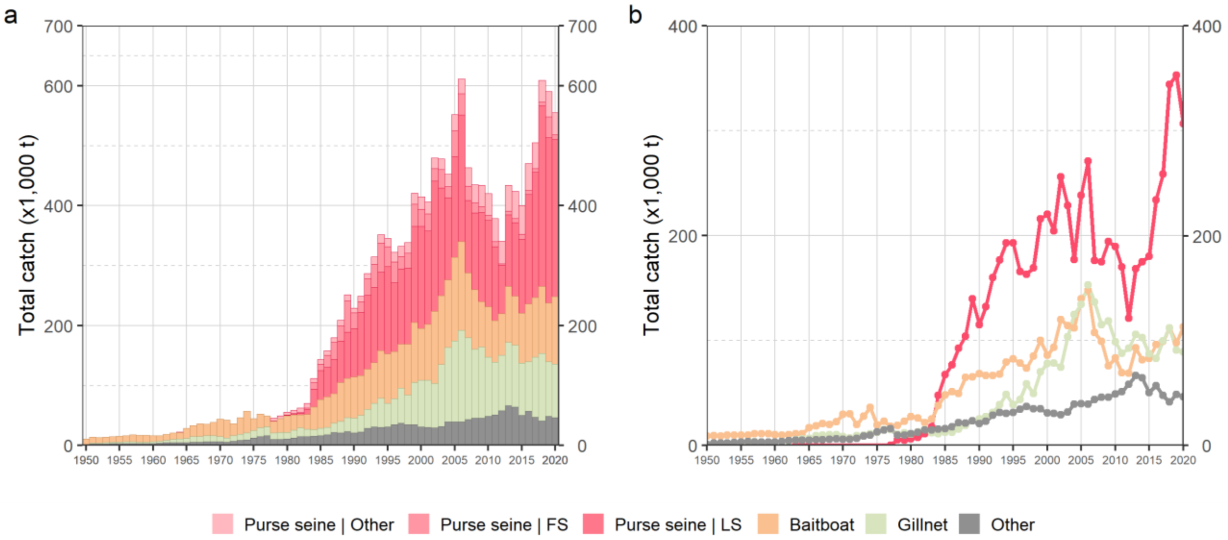


Fig. 1. Annual time series of (a) cumulative nominal catches (t) by fishery and (b) individual nominal catches (t) by fishery group for skipjack tuna during 1950–2020. FS = free-swimming schools; LS = drifting log or FAD-associated school . Purse seine other: coastal purse seine, purse seine, ring net; Baitboat: coastal and offshore baitboats; Gillnet: coastal and offshore gillnets, driftnet; Other: all remaining fishing gears

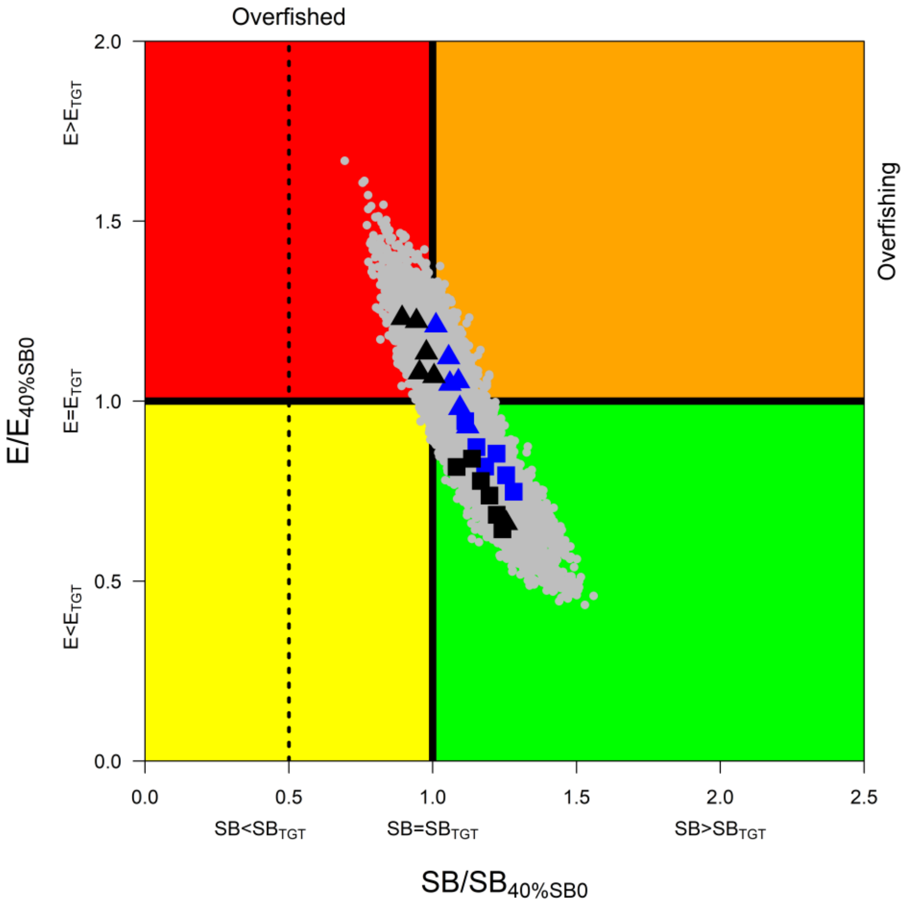


Fig. 2. Skipjack tuna: SS3 Aggregated Indian Ocean assessment Kobe plot of the 2020 uncertainty grid. Symbols represent MPD estimates of current stock status relative to $SB_{40\%SB0}$ (x-axis) and $E_{40\%SB0}$ (y-axis) for the individual models (blue, no effort creep; black, additional effort creep; 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 (SB_{lim} = $20\%SB_0$)

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

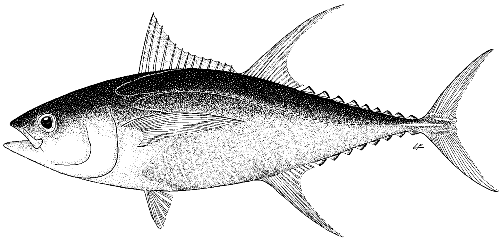


Table 1. Status of yellowfin tuna (*Thunnus albacares*) in the Indian Ocean

Area[1]	Indicator	Value	Status[3]
Indian Ocean	Catch in 2020 (t)[2]	432,624	67%*
	Average catch 2016-2020 (t)	434,569	
	MSY (1,000 t) (80% CI)	394 (325-463)	
	F_{MSY} (80% CI)	0.18 (0.14-0.21)	
	SB_{MSY} (1,000 t) (80% CI)	1,515 (1,146-1,885)	
	F_{2020} / F_{MSY} (80% CI)	1.27 (0.64-1.91)	
	SB_{2020} / SB_{MSY} (80% CI)	0.78 (0.57-0.98)	
	SB_{2020} / SB_0 (80% CI)	0.28 (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 2020: 13.6%

[3] The stock status refers to the most recent years' data used in the assessment conducted in 2021, i.e., 2020

*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 (SB_{2020} / SB_{MSY}<1)	Stock not overfished (SB_{2020} / SB_{MSY}≥ 1)
Stock subject to overfishing (F_{2020} / F_{MSY}≥ 1)	67%	<1%
Stock not subject to overfishing (F_{2020} / F_{MSY}≤ 1)	23%	10%
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 yellowfin tuna in 2021. The 2021 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 2021 is based on the model developed in 2018 with a series of revisions that were noted during the WPTT in 2018, 2019 and 2020. The model uses four types of data: catch, size frequency, tagging and CPUE indices. The proposed final assessment model options correspond to a combination of model configurations, including alternative assumptions about the spatial structure (2 options), longline CPUE catchability (2 options on the effect of piracy), weighting of the tagging dataset (lambda =0.1 or 1), steepness values (0.7, 0.8, and 0.9), natural mortality values (2 options), and growth parameters (2 options). The model ensemble (a total of 96 models) encompasses a range of stock dynamics. A number of sensitivity runs were conducted to address additional uncertainty , including two new natural mortalities (based on maximum age of 10.9 and 18, respectively), a new growth curve (based on the most recent aging study), an assumed Longline catchability increase (1% per annual), as well as a model that includes only the Japanese size data for the Longline fishery. The results of these models generally indicate a more pessimistic stock status but are well within the range of uncertainty estimated by the model grid. However, the sensitivity models requires further scrutinization. . The new model grid represents a marked improvement over the previous results available in 2018 and incorporates a far wider range of uncertainty. According to the information available in 2021, the total catch has remained relatively stable at levels around the estimated MSY since 2012 (i.e., between 399,000 MT and 448,642 MT), with the 2019 catch (448,642 MT) being the largest since 2010, and exceeding the MSY range considering the best catch estimate by the Scientific Committee (for details see WPTT23 report). Overall stock status estimates do not differ substantially from the previous assessment. Spawning biomass in 2020 was estimated to be 28% on average of the unfished levels (**Table 1**). Biomass is estimated to have been declining in recent years, and since the previous assessment. Spawning biomass in 2020 was estimated to be 78% of the level that supports the maximum sustainable yield (SB2020/ SBMSY = 0.78). Current fishing mortality is estimated to be 27% higher than FMSY (F2020/ FMSY = 1.27). The probability of the stock being currently in the red Kobe quadrant is estimated to be 67%. On the weight-of-evidence available since 2018, the yellowfin tuna stock is determined to remain **overfished** and **subject to overfishing** (**Table 1** and **Fig. 2**).

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 projections were not available during the WPTT23 and will be developed intersessionally prior to the SC in 2021. The critical errors in the projections and estimations for computing probabilities in the K2SM developed in 2018 have been addressed and the updated projections should no longer suffer from the issues previously experienced. As such a new K2SM will be developed that will be suitable for use to provide management advice.

Management advice. The decline in stock status has been thoroughly investigated since 2018, however, it is still not well understood due to various uncertainties. The Commission should ensure that CPCs take all necessary action to achieve the catch reductions in their fleets, as per Res 21/01 (and 19/01), to reduce overfishing.

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 next assessment. The workplan started in January 2019 which aimed at addressing the issues identified by the WPTT and the external reviewer in 2018. The current assessment is the culmination of the work conducted since 2018 to improve the assessment and provide scientific advice for management.

The Commission has an interim plan for the rebuilding the yellowfin stock, with catch limitations based on 2014/2015 levels (Resolution 21/01which superseded 19/01, 18/01 and 17/01). Some of the fisheries subject to catch reductions have achieved a decrease in catches in 2020 in accordance with the levels of reductions specified in the Resolution; however, these reductions were offset by increases in the catches from CPCs exempt from and some CPCs subject to limitations on their catches of yellowfin tuna. Thus, the total catches of yellowfin in 2020 represent an increase of around 6.33% from 2014 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 394,000 MT with a range between 325,000-463,000 MT (**Table 1**). The 2016-2020 average catches (434,569 MT) were above the estimated MSY level. The last year (2020), catch has been substantially higher than the mean 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**: 2020 fishing mortality is considered to be 27% above the interim target reference point of F_{MSY}, and below the interim limit reference point of 1.4*F_{MSY} (**Fig. 2**).
- **Biomass**: 2020 spawning biomass is considered to be 22 % below the interim target reference point of SB_{MSY} and above the interim limit reference point of 0.4*SB_{MSY} (**Fig. 2**).
- **Main fishing gears** (average catches 2016-20): Purse seine ~34.3% (FAD associated school ~24%; free swimming school ~8.6%; unclassified ~1.7%); Line: 33.5%; Gillnet ~19.1%; Longline ~8.5%; All other gears ~4.6% (**Fig. 1**).
- **Main fleets** (average catches 2016-20): European Union ~18.2% (EU-Spain ~11%; EU-France ~6.7%, EU-Italy ~5%); I.R. Iran ~12.3%; Maldives ~10.9%; Seychelles ~9.7%; Sri Lanka ~8.9%; All other fleets ~40%.

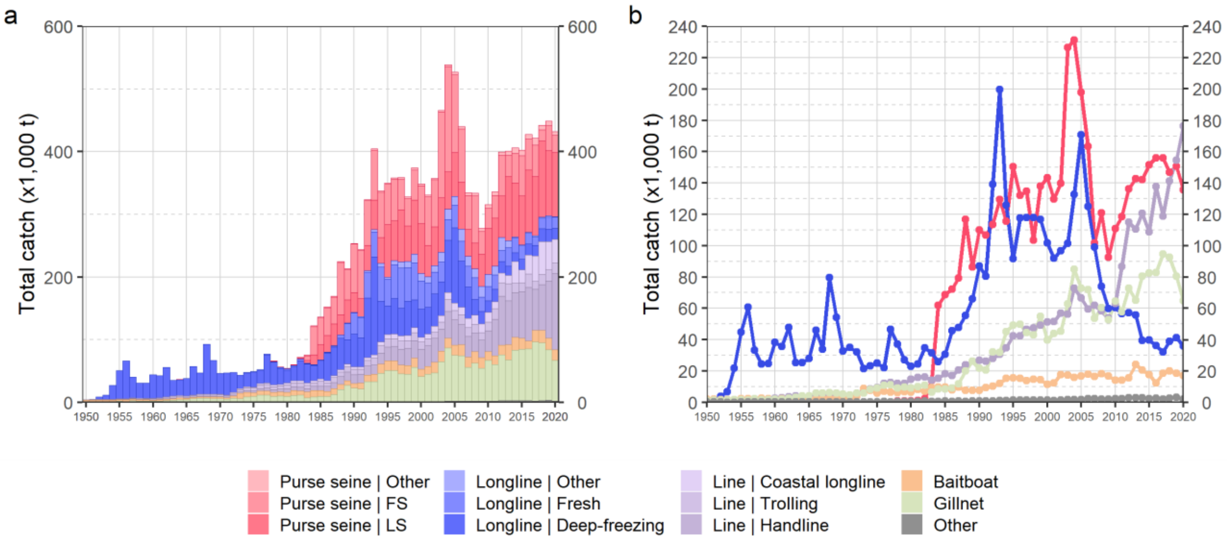


Fig. 1a-b. Annual time series of (a) cumulative nominal catches (MT) by fishery and (b) individual nominal catches (t) by fishery group for yellowfin tuna during 1950–2020. FS = free-swimming school; LS = drifting log or FAD-associated school . Purse seine other: coastal purse seine, purse seine, ring net; Longline: deep-freezing and fresh longlines, swordfish and sharks-targeted longlines; Line: coastal longline, trolling and handline; Baitboat: coastal and offshore baitboats; Gillnet: coastal and offshore gillnets, driftnet; Other: all remaining fishing gears

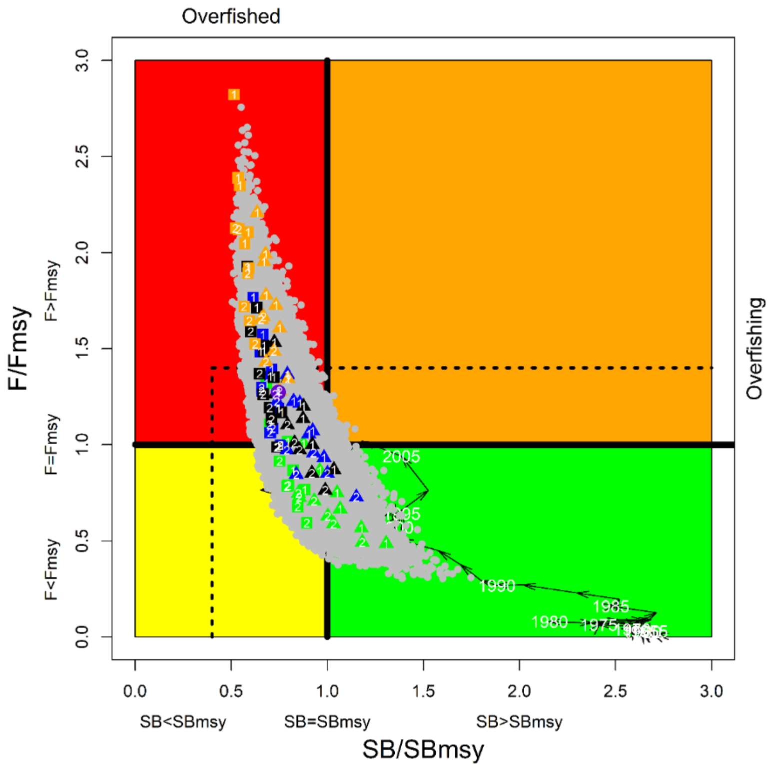
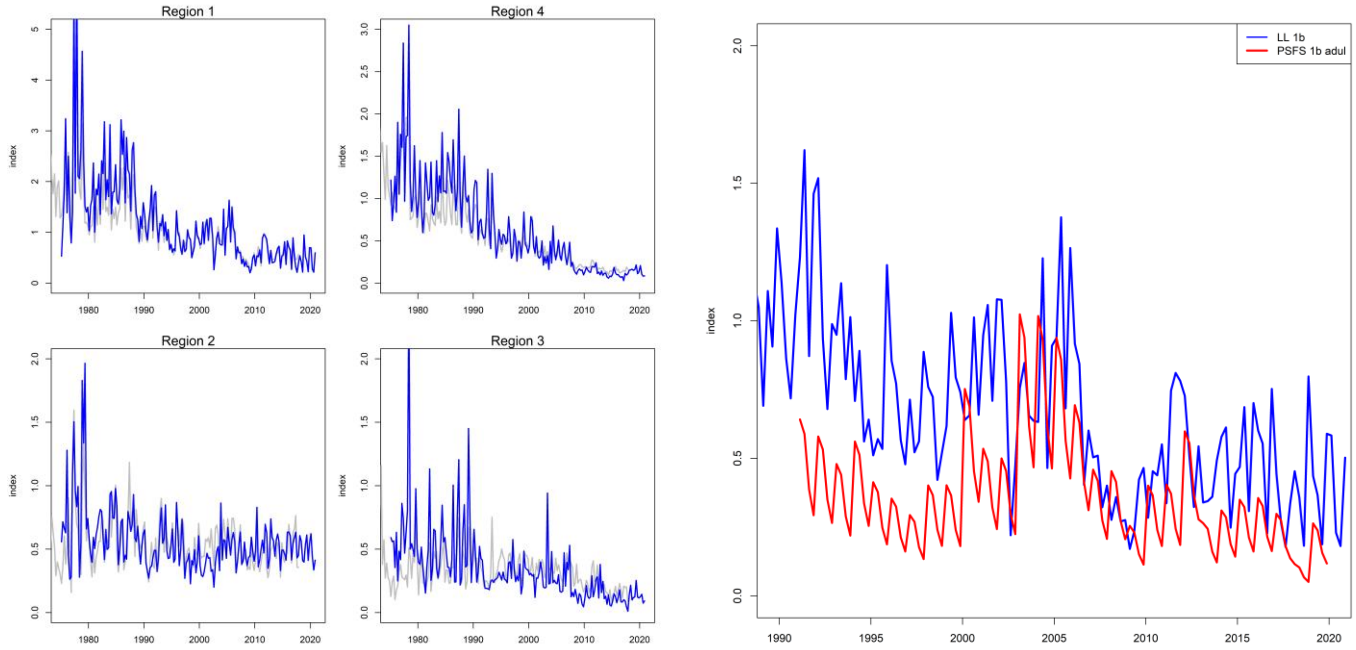


Fig. 2. Yellowfin tuna: Stock synthesis Kobe plot. Coloured symbols represent MPD estimates from individual models: square and Triangles and represents LL CPUE catchability options q1 and q2 respectively; green, blue, black, and orange represents growth and natural mortality option combination Gbase_Mbase, GDortel_Mbase, Gbase_Mlow, and GDortel_Mlow respectively; 1,2, represents spatial structure option io and sp respectively). The purple dot and arrowed line represent estimates of the basic model. Grey dots represent uncertainty from individual models. The dashed lines represent limit reference points for IO yellowfin tuna (SBlim = 0.4 SBMSY and Flim = 1.4 FMSY).



(a) (b)

Fig 3: Standardised CPUE indices used in the final assessment models: (a) Joint longline CPUE indices by region 1975-2020 (The grey lines are indices used in 2018 assessment 1972 – 2017), and (b) EU Purse seine free school CPUE on adults (≥10 kg) (overlaid with the longline CPUE in region 1).

APPENDIX VII
WORKING PARTY ON TROPICAL TUNAS PROGRAM OF WORK (2022–2026)

The following is the Draft WPTT Program of Work (2022–2026) 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**				
		2022	**2023**	**2024**	**2025**	**2026**
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. v. Additional growth and other biological studies for Tropical tunas.	▨	▨			
CPUE standardisation	Develop standardised CPUE series for each tropical tuna fleet/fishery for the Indian Ocean • Review period where stock was assessed as being overfished without experiencing overfishing. • Regional scaling parameters • Effect of piracy on CPUE after piracy period	▨	▨			
Fisheries impact analysis	Impact of individual fisheries on stock parameters	▨	▨			

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: i. Acoustic FAD monitoring, with the objective of deriving abundance indices based on the biomass estimates provided by echo-sounder buoys attached to FADs ii. Longline-based surveys (expanding on the Indian model) or “sentinel surveys” in which a small number of commercial sets follow a standardised scientific protocol iii. Aerial surveys, potentially using remotely operated or autonomous drones	▨	▨	▨	▨	▨

	iv. Studies (research) on flux of tuna around anchored FAD arrays to understand standing stock and independent estimates of the stock abundance. v. Scoping study to investigate genetics-based tagging techniques using recaptured individuals or identification of close-related pairs. Use of Close Kin Mark Recapture (CKMR) methods to study fishery independent methods of generating spawner abundance estimates based on genotyping individuals to a level that can identify close relatives (e.g. parent-offspring or half-siblings). The method avoids many of the problems of conventional tagging, e.g. live handling is not required (only catch needs to be sampled), tag shedding, tag-induced mortality and recovery reporting rates are irrelevant. It has been cost-effective in a successful application to southern bluefin tuna, but it remains unknown how the cost scales with population size. It would be valuable to conduct a scoping exercise to evaluate the applicability to the tropical tuna species vi. Investigate the possibility of conducting ongoing ad hoc, low level tagging in the region					
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					
8 Fisheries Independent Monitoring	8.1 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 8.2 Future work to be conducted on implementation					
9 Fisheries Indicators	9.1 Examination of additional fisheries indicators and their discussion at WP meetings. Perhaps a section in report to accommodate these. See how this is being addressed in other RFMOs.					
10 Peer review	10.1 Plan and ToRs for a peer review to be presented to the SC					

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

Species	2022	2023	2024	2025	2026
Bigeye tuna	**Data preparatory meeting** **Full assessment**	Indicators	Indicators	**Data preparatory meeting** **Full assessment**	Indicators
Skipjack tuna	Indicators	**Data preparatory meeting** **Full assessment**	Indicators	Indicators	**Data preparatory meeting** **Full assessment**
Yellowfin tuna	Indicators	External Review of 2021 Assessment	**Data preparatory meeting** **Full assessment**	Indicators	Indicators

APPENDIX VIII

CONSOLIDATED RECOMMENDATIONS OF THE 23RD SESSION OF THE WORKING PARTY ON TROPICAL TUNAS

Note: Appendix references refer to the Report of the 23rd Session of the Working Party on Tropical Tunas (IOTC–2021–WPTT23–R)

Revision of the WPTT Program of Work (2022–2026)

WPTT23.01 (para. 184): The WPTT **RECOMMENDED** that the SC consider and endorse the WPTT Program of Work (2022–2026), as provided in Appendix VII.

Date and place of the 24th and 25th Sessions of the WPTT (Chair and IOTC Secretariat)

WPTT23.02 (para. 191) 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 2022. 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 2022 as a preferred time period to hold the WPTT24 Assessment meeting in 2022 with a Data Preparatory meeting to be held in the first half of 2022 to prepare for the BET assessment.

Review of the draft, and adoption of the report of the 23rd session of the WPTT

WPTT23.03 (para. 193): The WPTT **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPTT23, provided at Appendix VIII, 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 2021 (Figure 2):

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