Report of the 19th Session of the IOTC Working Party on Billfish

Microsoft Teams Online, 13–16 September 2021

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Acronyms

ABF	African Billfish Foundation
ASPIC	A Stock-Production Model Incorporating Covariates
B	Biomass (total)
B_{MSY}	Biomass which produces MSY
BLM	Black marlin (FAO code)
BSP-SS	Bayesian Surplus Production Model – State-Space
BUM	Blue marlin (FAO code)
CE	Catch and effort
CI	Confidence Interval
CMM	Conservation and Management Measure (of the IOTC; Resolutions and Recommendations)
CPCs	Contracting parties and cooperating non-contracting parties
CPUE	Catch per unit of effort
current	Current period/time, i.e. $F_{current}$ means fishing mortality for the current assessment year.
EU	European Union
EEZ	Exclusive Economic Zone
F	Fishing mortality; F_{2010} is the fishing mortality estimated in the year 2010
FAO	Food and Agriculture Organization of the United Nations
F_{MSY}	Fishing mortality at MSY
GLM	Generalized linear model
HBF	Hooks between floats
IO	Indian Ocean
IOTC	Indian Ocean Tuna Commission
JABBA	Just Another Bayesian Biomass Assessment (a generalized Bayesian State-Space Surplus Production Model)
LL	Longline
M	Natural Mortality
MLS	Striped marlin (FAO code)
MSY	Maximum sustainable yield
n.a.	Not applicable
NGO	Non-governmental organization
PS	Purse-seine
q	Catchability
r	Intrinsic rate of population increase
ROS	Regional Observer Scheme
SC	Scientific Committee of the IOTC
SB	Spawning biomass (sometimes expressed as SSB)
SB_{MSY}	Spawning stock biomass which produces MSY
SFA	Indo-Pacific sailfish (FAO code)
SS3	Stock Synthesis III
SWO	Swordfish (FAO code)
Taiwan,China	Taiwan, Province of China
WPB	Working Party on Billfish of the IOTC
WPEB	Working Party on Ecosystems and Bycatch of the IOTC

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 formalize 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 19th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Billfish (WPB) was held online using the Microsoft Teams platform from the 13th to 16th September 2021. A total of 55 participants (55 in 2020 and 25 in 2019) attended the Session. The list of participants is provided at Appendix I. The meeting was opened by the Chairperson, Dr Denham Parker (South Africa), who welcomed participants.

The following are the complete recommendations from the WPB19 to the Scientific Committee, which are also provided at Appendix XII:

WPB19.01 (para 4): **RECALLING** that one of the Indian Ocean billfish species (shortbill spearfish, *Tetrapturus angustirostris*) is currently not listed among the species managed by IOTC, and considering the ocean-wide distribution of this species, its highly-migratory nature, and that it is a common bycatch in IOTC managed fisheries, the WPB reiterated its previous **RECOMMENDATION** that the Scientific Committee consider requesting the Commission to include it in the list of species to be managed by the IOTC. The WPB further **NOTED** that as this species has no management in place, any fleet catching this species as bycatch could be considered to be engaging in IUU fishing. As such the WPB **STRONGLY URGES** the SC to endorse this recommendation and encourage CPCs to address this issue at the next meeting of the Commission.

Revision of the WPB Program of work (2022–2026)

WPB19.02 (para 118): The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2022–2026), as provided at Appendix XI.

Date and place of the 20th and 21st Sessions of the Working Party on Billfish

WPB19.03 (para 125) The WPB **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 WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB20 in 2022. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB, with the WPEB taking place after the WPB in 2022.

Review of the draft, and adoption of the Report of the 19th Session of the Working Party on Billfish

WPB19.04 (para. 126): The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB19, provided at Appendix XII, as well as the management advice provided in the draft resource stock status summary for each of the five billfish species under the IOTC mandate, and the combined Kobe plot for the five species assigned a stock status in 2021 (Fig. 4):

- Swordfish (*Xiphias gladius*)– Appendix VI
- Black marlin (*Makaira indica*) – Appendix VII
- Blue marlin (*Makaira nigricans*) – Appendix VIII
- Striped marlin (*Tetrapturus audax*) – Appendix IX
- Indo-Pacific sailfish (*Istiophorus platypterus*) – Appendix X

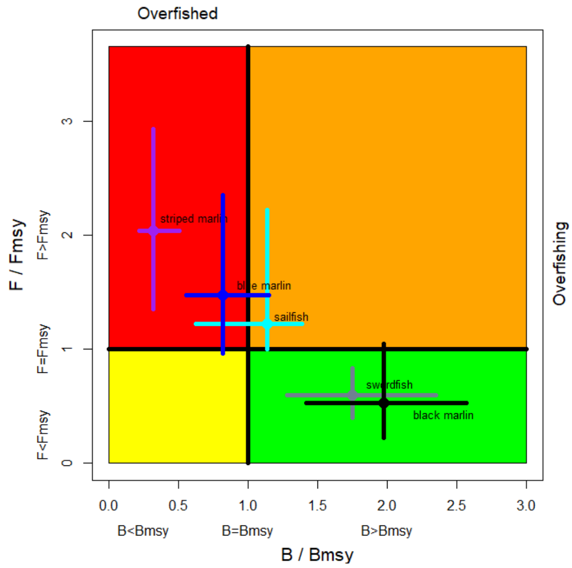

Fig. 4. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2017, 2018, 2019, 2020 and 2021 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs.

Table 1. Status summary for billfish species under the IOTC mandate.

Stock	Indicators	2017	2018	2019	2020	2021	Advice to the Scientific Committee
Swordfish *Xiphias gladius*	Catch 2019 (t): 33,590 Average catch 2015-2019 (t): 31,930 MSY (1,000 t) (80% CI): 33 (27–40) F_{MSY} (80% CI): 0.23 (0.15–0.31) SB_{MSY} (1,000 t) (80% CI): 59 (41–77) F_{2018}/F_{MSY} (80% CI): 0.60 (0.40–0.83) SB_{2018}/SB_{MSY} (80% CI): 1.75 (1.28–2.35) SB_{2018}/SB_{1950} (80% CI): 0.42 (0.36–0.47)					*98%*	***Stock status.*** No new stock assessment was carried out for swordfish in 2021, thus the stock status is determined on the basis of the 2020 assessment. The assessment uses a spatially disaggregated, sex explicit and age structured model. The SS3 model, used for stock status advice, indicated that MSY-based reference points were not exceeded for the Indian Ocean population as a whole (F_{2018}/F_{MSY}< 1; SB_{2018}/SB_{MSY}> 1). The two alternative models (ASPIC and JABBA) applied to swordfish also indicated that the stock was above a biomass level that would produce MSY. Spawning stock biomass in 2018 was estimated to be 40-83% of the unfished levels. Most recent catches of 30,847 t in 2018 are below the MSY level (33,000 t). On the weight-of-evidence available in 2020, the stock is determined to be ***not overfished*** and ***not subject to overfishing***. ***Management advice*****.** The most recent catches (32,671t in 2019) are below the MSY level (33,000 t). Under the current levels of catches, the stock biomass is projected to remain relatively stable, with a high probability of maintaining at or above the SB_{MSY} for the longer term. An increase of 40% or more from current catch levels will likely result in the biomass dropping below the SB_{MSY} level for the longer term (with approximately 50% probability). Taking into account the updated information regarding swordfish stock structure (IOTC-2020-WPB18-09), as well as the differential CPUE and biomass trends between regions, the WPB should continue to discuss the swordfish stock assessment model specifications and consider the feasibility of including a multi-stock assessment in 2023. Recognising that there is recurring evidence for localised depletion in the southern regions the WPB expresses concern and suggests this should be further monitored. Click here for full stock status summary: Appendix VI
Black marlin *Makaira indica*	Catch 2019: 18,068 t Average catch 2015–2019: 18,721 t MSY (1000 t) (95% CI): 17,301 (10,979 – 35,024) F_{MSY} (95% CI): 0.20 (0.12 - 0.34) F_{2019}/F_{MSY} (95% CI): 0.53 (0.22 – 1.05) B_{2019}/B_{MSY} (95% CI): 1.98 (1.42 – 2.57) B_{2019}/B_{1950} (95% CI): 0.73 (0.53-0.95)						***Stock status.*** A stock assessment based on JABBA, a Bayesian state-space production model (age-aggregated) was conducted in 2021 for black marlin. The relative point estimates for this assessment are F/F_{MSY}=0.53 (0.22-1.05) and B/B_{MSY}=1.98 (1.42-2.57). The Kobe plot indicated that the stock is not **subject to overfishing** and is currently not **overfished**, however these status estimates are subject to a high degree of uncertainty. The recent sharp increases in total catches (e.g., from 13,000 t in 2012 to over 22,000 t by 2016), and conflicts in information between CPUE and catch data lead to large uncertainties in the assessment outputs. Similar uncertainties were observed in the 2018 assessment of black marlin, which caused the point estimate of the stock status to change from the red (2016) to the green (2018) zone of the Kobe plot without any evidence of a rebuilding trend. **Since 2018, there has been no discernable improvement in the data available for black marlin and the subsequent assessment outputs remain uncertain and should be interpreted with caution**. **As such, there is no reasonable justification to change the stock status from "Not assessed/Uncertain".**

							Management advice. The 2019 catches (18,068 t) are substantially higher than the MSY limit stipulated in Res (18/05), which is 9,932 t. The Commission should provide mechanisms to ensure that catch limits are not exceeded by all concerned fisheries. Projections were not carried out due to the poor predictive capabilities identified in the assessment diagnostics. Click here for full stock status summary: Appendix VII
Blue marlin *Makaira nigricans*	Catch 2019: 8,486 t Average catch 2015–2019: 8.988 t MSY (1000 t) (80% CI): 9.98 (8.18 –11.86) F_{MSY} (80% CI): 0.21 (0.13 – 0.35) B_{MSY} (1,000 t) (80% CI): 47 (29.9 – 75.3) F_{2015}/F_{MSY} (80% CI): 1.47 (0.96 – 2.35) B_{2015}/B_{MSY} (80% CI): 0.82 (0.56 – 1.15) B_{2015}/B_{1950} (80% CI): 0.41 (0.28 – 0.57)					***87%***	***Stock status.*** No new stock assessment was carried out for blue marlin in 2021, thus the stock status is determined on the basis of the 2019 assessment. The stock status is based on the Bayesian State-Space Surplus Production model JABBA that suggests that there is an 87% probability that the Indian Ocean blue marlin stock in 2017 is in the red zone of the Kobe plot, indicating the stock is ***overfished*** and ***subject to overfishing*** (B_{2017}/B_{MSY}=0.82 and F_{2017}/F_{MSY}=1.47). The most recent catch exceeds the estimate of MSY ($Catch_{2017}$ = 12,029 t; MSY = 9,984 t). The previous assessment of blue marlin (Andrade 2016[1]) concluded that in 2015 the stock was subject to overfishing but not overfished. The change in stock status can be attributed to increased catches for the period 2015-2017 as well as improved standardisation of CPUE indices, which includes the area disaggregation of JPN and TWN indices to account for fleet dynamics. ***Management advice.*** The current catches of blue marlin (average of 9,898 t in the last 5 years, 2014-2018) are higher than MSY (9,984 t) and the stock is currently overfished and subject to overfishing. In order to achieve the Commission objectives of being in the green zone of the Kobe Plot by 2027 (F_{2027} < F_{MSY} and B_{2027} > B_{MSY}) with at least a 60% chance, the catches of blue marlin would have to be reduced by 35% compared to the average of the last 3 years, to a maximum value of approximately 7,800 t. Click here for full stock status summary: Appendix VIII
Striped marlin *Tetrapturus audax*	Catch 2019: 3,001 t Average catch 2015–2019: 3,477 t MSY (1,000 t) (JABBA): 4.60 (4.12–5.08) MSY (1,000 t) (SS3): 4.82 (4.48–5.16) F_{MSY} (JABBA): 0.26 (0.20–0.33) F_{MSY} (SS3): 0.23 (0.23–0.23) F_{2019}/F_{MSY} (JABBA): 2.04 (1.35–2.93) F_{2019}/F_{MSY} (SS3): 3.93 (2.30 - 5.31) B_{2019}/B_{MSY} (JABBA): 0.32 (0.22 – 0.51) SB_{2019}/SB_{MSY} (SS3): 0.47 (0.35 - 0.63) SB_{2019}/SB_{0} (SS3): 0.06 (0.05 - 0.08)					***100%***	***Stock status:*** In 2021 a stock assessment was conducted based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). Both models were generally consistent with regards to stock status and confirmed the results from 2012, 2013, 2015, 2017 and 2018 assessments, indicating that the stock is subject to overfishing (F>F_{MSY}) and is overfished, with the biomass being below the level which would produce MSY (B<B_{MSY}) for over a decade. On the weight-of-evidence available in 2021, the stock status of striped marlin is determined to be ***overfished*** and ***subject to overfishing*** ***Management advice.*** Current or increasing catches have a very high risk of further decline in the stock status. The current 2019 catches (3,001 t) are lower than MSY (4,601 t) but the stock has been overfished for more than two decades and is now in a highly depleted state. If the Commission wishes to recover the stock to the green quadrant of the Kobe plot with a probability ranging from 60% to 90% by 2026 as per Resolution 18/05, it needs to provide mechanisms to ensure the maximum annual catches remain between 900 t – 1,500 t. Click here for full stock status summary: Appendix IX

[1] Andrade, HA (2016). Preliminary stock assessment of blue marlin (*Makaira nigricans*) caught in the Indian Ocean using a Bayesian state-space production model. IOTC-2016-WPB14-27.

Indo-Pacific Sailfish *Istiophorus platypterus*	Catch 2019: 29,635 t Average catch 2015–2019: 30,263 t MSY (1,000 t) (80% CI): 23.9 (16.1 – 35.4) F_{MSY} (80% CI): 0.19 (0.14 - 0.24) B_{MSY} (1,000 t) (80% CI): 129 (81–206) F_{2017}/F_{MSY} (80% CI): 1.22 (1 – 2.22) B_{2017}/B_{MSY} (80% CI): 1.14 (0.63 – 1.39) B_{2017}/B_0 (80% CI): 0.57 (0.31 – 0.70)	[orange]	[orange]	[grey]	[grey]	[grey]	***Stock status:*** No new stock assessment was carried out for Indo-Pacific Sailfish in 2021, thus the stock status is determined on the basis of the 2019 assessment using the C-MSY model. The data poor stock assessment techniques indicated that F was above F_{MSY} (F/F_{MSY}=1.22) and B above B_{MSY} (B/B_{MSY}=1.14). Another alternative model using the Stock Reduction Analysis (SRA) techniques produced similar results. The stock appears to show a continued increase catches which is a cause of concern, indicating that fishing mortality levels may be becoming too high. However both assessment models rely on catch data, which is considered to be highly uncertain. In addition, aspects of the biology, productivity and fisheries for this species combined with the data poor status on which to base a more formal assessment are also a cause for concern. On the weight-of-evidence available in 2019, the stock status cannot be assessed and is determined to be uncertain. ***Management advice*:** Given the uncertainty in the catch estimates, the management advice is unchanged from 2018 (i.e., that catches should be below the current MSY level of 23,900 t). Click here for full stock status summary: Appendix X

Colour key	Stock overfished(SB_{year}/SB_{MSY}< 1)	Stock not overfished (SB_{year}/SB_{MSY}≥ 1)
Stock subject to overfishing(F_{year}/F_{MSY}> 1)	[red]	[orange]
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	[yellow]	[green]
Not assessed/Uncertain	[grey]	

1. Opening of the session

1. The 19th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Billfish (WPB) was held online using the Microsoft Teams platform from the 13th to 16th September 2021. A total of 55 participants (55 in 2020 and 25 in 2019) attended the Session. The list of participants is provided at Appendix I. The meeting was opened by the Chairperson, Dr Denham Parker (South Africa), who welcomed participants.

2. Adoption of the agenda and arrangements for the session

2. The WPB **ADOPTED** the Agenda provided in Appendix II. The documents presented to the WPB19 are listed in Appendix III.

3. The IOTC process: Outcomes, updates and progress

3.1 Outcomes of the 23rd Session of the Scientific Committee

3. The WPB **NOTED** paper IOTC–2021–WPB19–03 which describes the main outcomes of the 23rd Session of the Scientific Committee (SC23), specifically related to the work of the WPB:

"7.2.1 Swordfish stock assessment

- *The SC **NOTED** the need to better evaluate the influence of low-quality catch data on billfish stock assessments and to develop CPUE time series for billfish species caught in large gillnet fisheries, as recently initiated for some neritic species in collaboration with I.R. Iran.*

- *The SC **NOTED** that the assessment of stock status performed for swordfish in 2020, with fisheries data up to 2018, indicates that the stock is not overfished (SB2018/SBMSY=1.75) and not subject to overfishing (F2018/FMSY=0.6).*

- *The SC **NOTED** that the good status of the stock may be surprising taking into account the fact that swordfish is targeted by many longline fisheries and that the status of the other billfish species under IOTC mandate are bad or uncertain in the case of black marlin.*

- *The SC **NOTED** that the Taiwanese CPUE index was excluded from the assessment due to uncertainty in the data and for consistency reasons with previous assessments.*

- *The SC **NOTED** the conflicting signal trends in swordfish CPUE between areas, with an apparent major depletion in the South West and increasing trend in the North East Indian Ocean.*

- *The SC **ACKNOWLEDGED** the need for more accurate information on swordfish population structure to better define the stock units (e.g. two distinct stocks vs. metapopulation with seasonal mixing) to be assessed in 2023.*

- *The SC **NOTED** that the preliminary results of genomic-based approaches applied to swordfish suggest a certain level of differentiation between the Northern and Southern parts of the Indian Ocean, and ENCOURAGED the continuation of the work with complementary approaches such as microchemistry and tagging experiments.*

- *The SC **ACKNOWLEDGED** the interest of reducing the catch level intervals included in the Kobe II Strategy Matrix (K2SM) (2019-2028) around the MSY (i.e. close to the current catch levels) from 20% to 10% in order to better describe and assess the changes in spawning stock biomass (SB) and fishing mortality (F) expected under different catch scenarios.*

7.2.2 Revision of catch levels of Marlins under Resolution 18/05

- *The SC **RECALLED** that Resolution 18/05 On management measures for the conservation of billfish, striped marlin, black marlin, blue marlin and Indo-Pacific sailfish encourages CPCs to "…ensure that the overall catches, of the Indian Ocean Striped Marlin, Black Marlin, Blue Marlin and Indo Pacific Sailfish in any given year do not exceed either the MSY level or, in its absence, the lower limit of the MSY range of central values as estimated by the Scientific Committee…". Moreover, Resolution 18/05 also requires the SC to "…annually review the information provided and assess the effectiveness of the fisheries management measures reported by CPCs on striped marlin, black marlin, blue marlin and Indo-Pacific sailfish and, as appropriate, provide advice to the Commission". The SC further **NOTED** that the MSY for* *several of these species was updated after the Resolution came into force based on the updated stock assessments for these species.*

- *The SC **NOTED** that current catches for Black Marlin and Indo-Pacific Sailfish have exceeded the MSY as well as the catch limits set by Resolution 18/05, and that current catch trends for the two species show no signs of decline in line with meeting the catch limits by 2020. As such, the SC urgently reiterates its **RECOMMENDATION** that measures are agreed to reduce current catches to the limits set for the two species covered by Resolution 18/05 as per the management advice given in the Executive Summaries.*
- *The SC further **NOTED** the major uncertainties associated with the catches of gillnet fisheries, which target in particular black marlin and Indo-Pacific sailfish, and **RECALLED** the need for all concerned CPCs to ensure that the catch, effort and size data for these fisheries are systematically reported to the Secretariat in accordance with Resolution 15/02."*

4. **RECALLING** that one of the Indian Ocean billfish species (shortbill spearfish, *Tetrapturus angustirostris*) is currently not listed among the species managed by IOTC, and considering the ocean-wide distribution of this species, its highly-migratory nature, and that it is a common bycatch in IOTC managed fisheries, the WPB reiterated its previous **RECOMMENDATION** that the Scientific Committee consider requesting the Commission to include it in the list of species to be managed by the IOTC. The WPB further NOTED that as this species has no management in place, any fleet catching this species as bycatch could be considered to be engaging in IUU fishing. As such the WPB **STRONGLY URGES** the SC to endorse this recommendation and encourage CPCs to address this issue at the next meeting of the Commission.

3.2 *Outcomes of the 24th and 25th Sessions of the Commission*

5. The WPB **NOTED** paper IOTC–2021–WPB19–04 which provided the main outcomes of the 24th and 25th Sessions of the Commission specifically related to the work of the WPB.
6. Participants to WPB19 were **ENCOURAGED** to familiarise themselves with the previously adopted Resolutions, especially those most relevant to the WPB and **AGREED** to consider how best to provide the Scientific Committee with the information it needs, in order to satisfy the Commission's requests, throughout the course of the current WPB meeting.
7. The WPB **NOTED** that there was very little discussion related to the WPB, due to the shortened format of the Commission meetings and that the main items were the endorsement by the Commission of the SC information on stock status and Work Plan. The WPB also **NOTED** that the report form S25 has yet to be adopted and so no official guidance is available from that meeting at this stage.
8. The WPB **AGREED** that any advice to the Commission would be provided in the Management Advice section of each stock status summary.

3.3 *Review of Conservation and Management Measures relevant to billfish*

9. The WPB **NOTED** paper IOTC–2021–WPB19–05 which aimed to encourage participants at the WPB19 to review some of the existing Conservation and Management Measures (CMM) relevant to billfish, noting the CMMs referred to in document IOTC–2021–WPB19–05, and - as necessary - to 1) provide recommendations to the Scientific Committee on whether modifications may be required and 2) recommend whether other CMMs may be required.

3.4 *Progress on the recommendations of WPB18*

10. The WPB **NOTED** paper IOTC–2021–WPB19–06 which provided an update on the progress made in implementing the recommendations from the previous WPB meeting which were endorsed by the Scientific Committee, and **AGREED** to provide alternative recommendations for the consideration and potential endorsement by participants as appropriate given any progress.
11. The WPB **NOTED** that good progress had been made on these Recommendations, and that several of these, would be directly addressed by the assessment scientists when presenting the updated results for 2021.
12. The WPB participants were **ENCOURAGED** to review IOTC-2021-WPB19-06 during the meeting and report back on any progress in relation to requests or actions by CPCs that have not been captured by the report, and to note any pending actions for attention before the next meeting (WPB20).

13. The WPB **REQUESTED** that the IOTC Secretariat continue to annually prepare a paper on the progress of the recommendations arising from the previous WPB, incorporating the final recommendations adopted by the Scientific Committee and endorsed by the Commission.

4. New information on fisheries and associated environmental data for billfish

4.1 Review of the statistical data available for billfish

14. The WPB **NOTED** paper IOTC–2021–WPB19–07 which summarises the standing of a range of data and statistics received by the IOTC Secretariat for billfish for the period 1950–2018, in accordance with IOTC Resolution 15/02 *Mandatory statistical requirements for IOTC Members and Cooperating non-Contracting Parties (CPC's)*. The paper also provided a summary of important reviews to the series of historical catches for billfish species, a range of fishery indicators (including catch-and-effort and average weight trends) for fisheries catching billfish in the IOTC area of competence and the range of equations used by the IOTC Secretariat to convert billfish measurements between non-standard and standard measurement types used for each species. A summary of the supporting information for the WPB is provided in Appendix IV.

15. The WPB **NOTED** that the total nominal catches of the IOTC billfish species showed a major increase over the last seven decades, from an average of 5,451 t per year in the 1950s to an average of 85,800 t per year in the 2010s, and that total nominal catches of all IOTC billfish species combined were more than 93,000 t per year in recent years (2015-2019), with gillnet, longline, and line fisheries contributing to 41.2%, 33.1%, and 24.2% of all catches, respectively.

16. The WPB **NOTED** the steady increase in the contribution of artisanal fisheries to the total catches of the five IOTC billfish species over the last four decades, from less than 10% in the mid-1970s to more than 50% in recent years, **RECALLING** that this reduced the overall reporting quality of the fisheries data sets (nominal catches, catch-and-effort and size frequency) available at the Secretariat due to the generally poorer data quality of artisanal compared with industrial fisheries.

17. The WPB **NOTED** that the total amount of billfish species discarded at sea is thought to be small but that it remains unknown for most fisheries and time periods despite the obligation to report these data as per IOTC Res. 15/02.

18. The WPB further **ACKNOWLEDGED** that data collected as part of the Regional Observer Scheme do provide useful information on the magnitude and fate of the catch (i.e., retained or discarded) as well as the status of the fish discarded at sea, **NOTING** with concern that the IOTC Regional Observer database is currently limited to a few longline (Japan, Sri Lanka) and purse seine (EU,Spain, EU,France, Seychelles) fleets and **URGED** all CPCs to comply with IOTC Res. 11/04 and submit observer data according to IOTC standard formats.

19. The WPB **NOTED** that the overall reporting quality of the nominal catch data available at the Secretariat for all five IOTC billfish species combined has strongly varied between 1950 and 2019, and has improved over the last decade thanks to the reporting of data for a few artisanal and industrial fisheries even though these are characterized by a low sampling coverage.

20. However, the WPB **NOTED** that the reporting quality varies strongly between species and over time, with swordfish being characterized by the best quality nominal catches while the data for black marlin and Indo-Pacific sailfish were considered to be of very bad quality during the 1990s and 2000s; while blue and striped marlins show an intermediate quality status.

21. The WPB **NOTED** that few geo-referenced data on catch and effort have been reported for billfish species until recent years and most of the available spatial information comes from industrial longline fisheries, thus providing an incomplete historical perspective on the spatio-temporal dynamics of billfish species in the Indian Ocean.

22. The WPB **NOTED** that the overall reporting quality for geo-referenced size data is poor for all five IOTC billfish species, with almost no size data available for black marlin and Indo-Pacific sailfish.

23. The WPB **NOTED** the main billfish data issues, by type of dataset and fishery, that are considered to negatively affect the quality of the statistics available at the IOTC Secretariat (provided in Appendix V) and **REQUESTED** that the CPCs listed in the Appendix make efforts to remedy the identified data issues – with support from the IOTC Secretariat, when required – and report back to the WPB at its next meeting.

4.2 Review new information on fisheries and associated environmental data

24. The WPB **NOTED** paper IOTC–2021–WPB19–09 which provided information on the status of billfish fisheries in Pakistan with special reference to use of subsurface gillnetting, was withdrawn.

25. The WPB **NOTED** paper IOTC-2021-WPB19-10 on the fishery and stock status of billfishes exploited from the eastern Arabian sea, including the following abstract provided by the authors:

> "*Billfishes are a group of highly predatory fishes distributed extensively along the world oceans. In India, the billfish fishery is supported by four genera and following five species: Istiophorus platypterus, Istiompax indica, Makaira nigricans, Xiphias gladius, Tetrapturus audax and T. angustirostis. Mechanised gillnetters contributed major share of their landings. I. platypteurs was the dominant species in the fishery and T.angustirostis was sporadically landed. Billfishes along the Indian coast were mainly exploited by mechanised gillnetters followed by other mechanised crafts operating pelagic longlines. The west coast of India recorded 60% of annual billfish landings. The maturity and length range of I. platypterus, I. indica, M. nigricans and X. gladius, the major species in the fishery, were monitored during 2019 and the length at which 50% of the population matured (Lm_{50}) and stock parameters of these four species of billfishes were estimated based on samples collected from major landing centres along the eastern Arabian Sea. Fishery biological observations of billfish species indicated that the stocks in general are healthy, with fairly high spawning stock biomass and are being fished at sustainable levels.*"

26. The WPB **NOTED** that the extension and continued collection of data into the Bay of Bengal is promising. The group further **NOTED** that the average length of swordfish sampled was lower than the length at maturity, indicating that it is mostly juveniles that are being caught in this region, and also indicating a potential nursery or breeding area for swordfish. This supposition was further supported by the group, by noting that the size composition of swordfish caught by Pakistan in the Arabian Sea also appears to be made up of juveniles (66-130 cm), with adults rarely caught in that region. The WPB **NOTED** that it was interesting that different sets of data appear to corroborate the idea that the study area may be a potential nursery area for swordfish.

27. A question was posed as to how the stock status was derived from the Elefan method used, and how it was determined that fishing was sustainable as the fishing mortality *F* was the only indicator of fishing pressure, and it was far higher than natural mortality. It was clarified that the measure of sustainability was not based on *F*, but rather on the mean size at catch relative to the length at maturity. The WPB **NOTED** that the length frequency data appear to be positive relative to this indicator, but that it was presumptuous to declare the stock sustainable using these methods.

28. The authors **NOTED** that data collection is ongoing and they hope to collect data on the full range of lengths in the stock.

29. The Secretariat **NOTED** that this paper collected important size data that are critical for improved estimates and stock assessment and **ENCOURAGED** CPCs to report size data when possible.

30. The WPB **NOTED** paper IOTC-2021-WPB19-11 which presented an analysis on fishing strategy for target species for Taiwanese large-scale longline fishery in the Indian Ocean, including the following abstract provided by the authors:

> *"The cluster analysis approach was utilized to account for the patterns of the fishing strategy for target species for Taiwanese large-scale longline fishery in the Indian Ocean. The analyses were separately conducted for 4 sub-areas defined for the stock assessment for billfishes. For each sub-area, data from two different time periods of 1979-2020 and 2005-2020 were used. In general, the clustering approach was able to explicitly and clearly identify the targeting of each set. The cluster analysis suggested that main target species would be yellowfin tuna and bigeye tuna in the two northern sub-areas, while albacore and other species were the major target species in the two southern sub-areas, with some bigeye tuna also included."*

31. The WPB **THANKED** the authors for their efforts in including all the data and latest time series and **NOTED** that there appeared to be changes in the fleet dynamics with oilfish and southern bluefin tuna, but that the results did not appear to identify a particular fishing strategy targeting billfish species over time.

32. The WPB **NOTED** that clustering in CPUE standardisation is generally used as a proxy for targeting, but the results of the paper indicate that targeting was not found using this method. The authors **AGREED** that clustering should be used to identify which vessels target striped marlin and black marlin, but as Taiwanese vessels do not target these species, it is difficult to identify fishing operations targeting these species with the current analysis. However, the WPB **AGREED** that the use of clusters in CPUE standardisation helps to represent the different

fishing strategies used by different vessels for different species and the effect may still inform the catch rates of these two species.

33. The WPB **NOTED** that recommendations derived from past practices suggest that cluster analysis should be used for temperate regions and that targeting strategy is not well defined in tropical regions. Instead, the recommendation for tropical zones is to use the number of hooks between floats for tropical regions, as the utility of clustering in these regions is unsure. The authors replied that data on hooks between floats is available from 1995, but that the clustering analysis allowed them to include the whole time range, including the period prior to 1995.

34. The WPB **NOTED** that in the absence of other targeting information, clustering was a good approach.

35. The WPB **NOTED** that while overlapping, the NW and NE region still appear to be well defined with mixed species. The authors highlighted the SW area where most operations target ALB, but some vessels target SBT, and **NOTED** that this may be a reason why the overlap in this area is much more obvious than in other areas.

36. The WPB **NOTED** paper IOTC-2021-WPB19-12 which provided an update on satellite tagging of billfish around the Indian Ocean, including the following abstract provided by the authors:

> *"The FLOPPED project aims to investigate the reproduction zones of five billfish species in the Indian Ocean through a comprehensive data collection initiative, including satellite tagging data and biological sampling. Within the framework of this project, 100 satellite tags are to be deployed around the Indian Ocean, on blue marlin (Makaira nigricans), black marlin (Makaira indica), striped marlin (Tetrapturus audax), swordfish (Xiphias gladius), and sailfish (Istiophorus platypterus). Tagging and biological sampling were originally focused on six study sites, including Reunion, Mayotte, Mauritius (Rodrigues), Seychelles, Sri Lanka and Indonesia. However, due to logistical complications resulting from the global COVID-19 pandemic, we search for participants from a broader range of sites among our WPDCS colleagues to maximise the coverage and representativeness of this dataset. Here, we present on the first results of the 48 tags that have been deployed since the start of the project."* – see document for full abstract

37. The WPB **QUESTIONED** whether the anchoring issue experienced early in the project could have been related to the size of the tagged individuals. The authors responded that there was a clear effect of the anchor, and they felt it was really a technical issue with the anchoring system, rather than size of the individual. The previous anchoring system had been too weak and led to numerous premature tag releases, while the switch to the new anchoring system related to much longer tag durations. The authors noted that the lessons learned from these experiences were being incorporated into a detailed protocol that could be shared with future tagging teams.

38. The WPB **NOTED** that the authors had reported that 21% of the satellite tags did not report, in part due to battery failure, but that there could be many additional reasons that a tag may not report.

39. The WPB **ENCOURAGED** continued efforts into tagging billfish in the Indian Ocean.

40. The WPB **QUESTIONED** whether the long migrations observed for blue marlin could be size-related. The authors acknowledged this suggestion, but noted that the analyses were not sufficiently progressed to respond.

41. The WPB **QUESTIONED** whether recreational fishers had been contacted in Kenya, to which authors replied that they had been. The Kenyan group had been very positive in its response, and the authors had sent tags; however due to logistical and administrative issues, the tags were eventually sent back without being deployed. Further details on the problems encountered will be followed up with the Kenyan country representatives to identify where they could facilitate.

42. The WPB **NOTED** that the authors acknowledged in their report that there were no tagging activities currently planned in the northern basin, and were actively searching for partners there. They indicated that it is preferable if potential partners have some previous experience either with satellite or conventional tagging, and **NOTED** that common reasons for short tag duration is often due either to poor placement of the tag, or misidentifying the state of the fish (i.e., tagging and releasing fish with low probability of survival). The authors **NOTED** that prior to travel restrictions related to Covid, their group would participate in initial fishing trips to train the partners, but that options for virtual training could be developed.

5. MARLINS (PRIORITY SPECIES FOR 2021: BLACK MARLIN AND STRIPED MARLIN)

5.1 Review of new information on the status of black and striped marlins

Striped Marlin

- **Nominal and standardised CPUE indices**

43. The WPB **NOTED** paper IOTC-2021-WPB19-13 on the CPUE standardization of striped marlin (*Tetrapturus audax*) caught by Taiwanese large scale longline fishery in the Indian Ocean, including the following abstract provided by the authors:

    "This study aggregated and analyzed catch, effort and length data of striped marlin caught by Taiwanese large longline fisheries in the Indian Ocean and conducted CPUE standardization for striped marlin for 1979-2020 and 2005-2020. This paper briefly describes historical patterns of fishing operations and striped marlin catches caught by Taiwanese large scale longline in the Indian Ocean. The groups of data sets derived from cluster analysis based on species compositions were incorporated in the CPUE standardization models as a covariate for explaining the target to obtain the relative abundance indices for further stock assessments. Except for the delta-lognormal models, the standardized CPUE series obtained from different model assumptions revealed similar trends."

44. The WPB **THANKED** and **CONGRATULATED** the authors for the comprehensive study conducted with a good range of statistical models that aimed to account for the proportion of null catch records through the splitting of the data into two probability components: (i) zero occurrence and (ii) positive CPUE.

45. The WPB **RECALLED** that the WPTT identified some major issues in the Taiwanese catch and effort data for tropical tunas prior to the mid-2000s and **NOTED** that a similar approach was taken by the authors for the CPUE analysis of billfish species, **NOTING** that the different issues are extensively described in the reports available from the tropical tuna CPUE workshops.

46. The WPB **NOTED** that previous assessments used two alternative time series: (i) a long time series starting from 1979 and (ii) a short time series starting from 2005, and further **NOTED** that discussions could be held following the results of the assessment models to make decisions on the best time series to consider.

47. The WPB **NOTED** that in the case of striped marlin, the results of the assessment models and diagnostics on stock status were not really affected by the length of the time series considered.

48. The WPB **NOTED** that the data set includes a large quantity of null catch records as striped marlin is not a target of the deep-freezing longline fishery of Taiwan,China, and **QUERIED** whether the initial decline observed in the standardised index was explained by the changes in proportions of zeros in the data or from the signal extracted from the positive catches.

49. The WPB **NOTED** that the increased proportion of zeros observed in the second part of the time series suggested that the decline observed could be driven by the proportion of zeros and **ENCOURAGED** the authors to revisit the data set and possibly filter the vessels that never report any catch of striped marlin to improve the model.

50. The WPB **NOTED** that there was some apparent spatial transfer of fishing effort between the distinct areas considered in the standardisation process which could affect the estimated trends in CPUE and **ENCOURAGED** the authors to develop a model combining data across all areas in the future in order to better account for spatio-temporal changes in effort.

51. The WPB **NOTED** paper IOTC-2021-WPB19-25 on the Japanese Longline CPUE Standardization (1979-2019) for striped marlin (*Tetrapturus audax*) in the Indian Ocean using Bayesian hierarchical spatial model, including the following abstract provided by the authors:

    "To estimate a historical trajectory of striped marlin stock abundance in the Indian Ocean, we standardized the CPUE of striped marlin caught by Japanese longliners for 1979-2019. We separated the logbook data into four areas (NW, NE, SW, SE) based on the IOTC area definition, and divided the time-period into two periods, 1979-1993 and 1994-2019. In this analysis, we applied Bayesian hierarchical spatial models. Since the catch data is countable and characterized by many zeros, we used zero-inflated Poisson generalized linear mixed model (ZIP-GLMM)." – see document for full abstract

52. The WPB **THANKED** the authors for the study and **CONGRATULATED** them for the progress made in including the spatial effects in the model.

53. The WPB **NOTED** that the computation of the abundance index was solely derived from the year effect and did not include the sum of the spatial effects for each year.

54. The WPB **NOTED** that the trends in abundance may be driven by the importance of the zero catch records, as observed for the CPUE derived for the longline fishery of Taiwan,China, and **ENCOURAGED** the authors to explore the influence of the zeroes on the results.

55. The WPB **NOTED** that the Half-Cauchy distribution is not appropriate to be used for random effects as it only takes positive values and **ENCOURAGED** the authors to address this issue and continue the work

- **Stock assessments**

Stock Synthesis

56. The WPB **NOTED** paper IOTC-2021-WPB19-14 which described the Stock assessment of striped marlin (*Tetrapturus audax*) in the Indian Ocean using the Stock Synthesis, including the following abstract provided by the authors:

"In this study, Stock Synthesis (SS) was applied to conduct the stock assessment for striped marlin in the Indian Ocean. The analyses were performed by updating the historical catch, standardized CPUE series and length-frequency data, while life-history parameters and model assumptions remained the same with the scenario for the previous stock assessment adopted in 2018. The results indicated that the current spawning biomass was lower than the MSY level and the fishing mortality was higher than the MSY level. In addition, the current stock status might be more pessimistic than that obtained from the previous stock assessment in 2018."

57. The WPB **NOTED** the SS3 model for striped marlin was configured as a single area, one sex model. The fisheries were grouped into three fleets: Taiwanese longline, Japanese longline, and others. The observational data included the standardised CPUE indices for the Taiwanese fleet (1979-2019, NW and NE series combined) and Japanese fleet (1994-2019), and size frequency data. The WPB further **NOTED** that the life history parameters were fixed at known estimates from the Pacific Ocean.

The WPB **NOTED** the three scenarios as follows:
- Ref: Taiwanese CPUE of 1979-2019 and Japanese CPUE of 1994-2019 were used.
- TWN_CPUE2005: CPUE of 2005-2019 and Japanese CPUE of 1994-2019 were used
- Data_2018: The catches, CPUE and length-frequency adopted in the previous assessment were used to rerun the model using the new version of SS.

58. The WPB **NOTED** the recommendation from the WPTT to omit the Taiwanese CPUE before 2005 given the concern about the quality of the logbook data. Therefore, the WPB **AGREED** the use scenario TWN_CPUE2005 as a reference case.

59. The WPB **NOTED** that the model assumed dome-shaped selectivity for the Taiwanese and Japanese longline. Due to the lack of size data, the selectivity for the "others" fleet was assumed to be the same as the Taiwanese fleet. The WPB **SUGGESTED** an additional analysis in the future to examine whether the fishery structure can be further refined with the available length composition data. The WPB also **SUGGESTED** an additional analysis to examine the use of asymptotic selectivity for at least one of the fisheries to ensure that there is no encrypted biomass estimated in the model.

60. The WPB **NOTED** that the assessment model is relying on longline fleets with diminishing catches, and there is a need to develop CPUE from other fisheries to reduce bias.

61. The WPB **NOTED** that the model assumed a steepness value of 0.5, which was suggested by the previous WPB meeting (a value of 0.68 was used in the previous assessment, based on the ISC assessment). The WPB **SUGGESTED** future assessments could examine a wider range of steepness values which are expected to impact the estimation of MSY. However, the WPB further **NOTED** that the JABBA assessment has explored a range of steepness/productivity scenarios and found that the terminal stock depletion is not sensitive to alternative steepness values.

62. The WPB **NOTED** the key assessment results for SS3 for striped marlin as shown below (**Table 2; Figure 1**).

Table 2. Stock status summary table for the striped marlin assessment (reference case). CI = Confidence interval

Management quantity	**Aggregate Indian Ocean**
2019 catch estimate (t)	3,001
Mean catch 2015–2019 (t)	3,477
MSY (1,000 t) (80% CI)	4.819 (4.477 - 5.162)
Data period (catch)	1950–2019

F_{MSY} (80% CI)	0.231 (0.229 - 0.232)
SB_{MSY} (1,000 t) (80% CI)	N/A
F_{2019}/F_{MSY} (80% CI)	3.925 (2.297 - 5.306)
SB_{2019}/SB_{MSY} (80% CI)	0.470 (0.349 - 0.630)
SB_{2019}/SB_{1950} (80% CI)	0.063 (0.048 - 0.079)

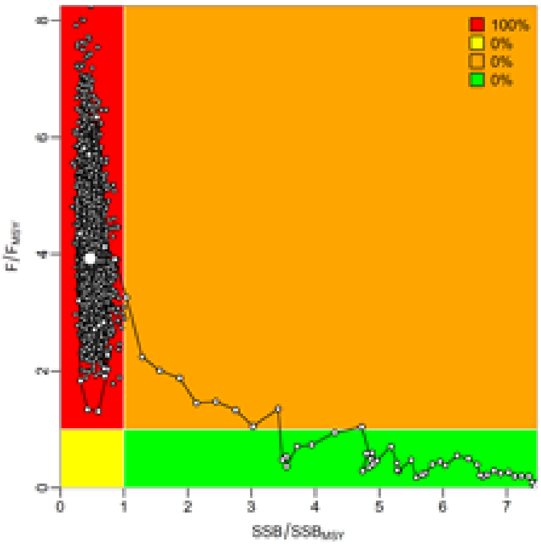

Figure 1. Stock synthesis: Kobe stock status plot for the Indian Ocean for striped marlin (reference case). The black line traces the trajectory of the stock over time.

Bayesian Surplus Production Model (JABBA)

63. The WPB **NOTED** document IOTC-2021-WPB19-15 which described the assessment of the Indian Ocean striped marlin (*Tetrapturus audax*) stock using JABBA, including the following abstract as provided by the author:

"Six scenarios were run using the Bayesian State-Space Surplus Production Model JABBA to assess the Indian Ocean striped marlin (Tetrapturus audax). A 'drop one' sensitivity analysis indicated that omitting any of the "new" CPUE time-series would not significantly alter the stock status. Similarly, a retrospective analysis produced highly consistent results for stock status estimates back to 2009 and therefore provided no evidence for an undesirable retrospective pattern. The omission of historical CPUE time-series was considered on the advice of CPC scientists providing the CPUE standardization analyses, and so data from 1970 was only included in two scenarios: S1 and S3. The results for the six alternative scenarios estimated MSY between 4,430 and 4,826 tons, median estimates of B/BMSY ranged between 0.26 - 0.32 and estimates of B/K were between 0.06 - 0.13. All scenarios produce B/BMSY trajectories that steadily declined from the late 1970s to 2010 before leveling at the approximate current B/BMSY estimates. There has been a steady increase of F/FMSY since the 1970s, which has only recently showed signs of slowing. Individual Kobe biplots were similar among all scenarios and each indicated a >96% probability that the Indian Ocean striped marlin stock is overfished and subject to overfishing – which is a result comparable with the 2018 assessment for this species."

64. The WPB **RECALLED** that in the last assessment conducted in 2018, Both models (JABBA, SS3) of the Indian Ocean striped marlin estimated that the stock was overfished, and was subject to overfishing.

65. The WPB **NOTED** that the six scenarios selected for the 2021 JABBA assessment incorporated three differing CPUE time-series combinations, three differing *r* priors and associated input values of B_{MSY}/K, and a single scenario with inflated process error. The continuity model (S1) follows that of the 2018 assessment reference base case.
    - S1 (Cont.): for $B_{MSY}/K = 0.37$ (h = 0.5), r prior LN ~ (log (0.25), 0.15)), CPUE = TWN_NW_hist, TWN_NE_hist, JPN_NW, JPN_NE

- S2 (New): for B_{MSY}/K = 0.37 (h = 0.5), r prior LN ~ (log (0.25), 0.15)), CPUE = TWN_NW, TWN_NE, JPN_NW, JPN_NE
- S3 (Hist): for B_{MSY}/K = 0.37 (h = 0.5), r prior LN ~ (log (0.25), 0.15)), CPUE = TWN_NW_hist, TWN_NE_hist, JPN_NW_hist, JPN_NE_hist, JPN_NW, JPN_NE
- S4 (Low): for B_{MSY}/K = 0.4 (h = 0.4), r prior LN ~ (log (0.21), 0.14)), CPUE = TWN_NW, TWN_NE, JPN_NW, JPN_NE
- S5: (High): for B_{MSY}/K = 0.23 (h = 0.86), r prior LN ~ (log (0.31), 0.16)), CPUE = TWN_NW, TWN_NE, JPN_NW, JPN_NE
- S6: (Proc) for B_{MSY}/K = 0.37 (h = 0.5), r prior LN ~ (log (0.25), 0.15)), CPUE = TWN_NW, TWN_NE, JPN_NW, JPN_NE, process error = 0.2.

66. The WPB **NOTED** that the six scenarios have estimated different absolute abundance with low productivity scenarios producing high biomass estimates. However, ratio-based estimates (B/B_{MSY} and F/F_{MSY}) are very consistent amongst the scenarios, producing similar estimates of terminal stock status.

67. The WPB **NOTED the** recommendation from the WPTT to omit the Taiwanese CPUE before 2005 given the concern to the quality of the logbook data. Therefore, the WPB **AGREED** to use scenario S2 as a reference case.

68. The WPB **NOTED** that the model fits to the CPUE data are relatively poor mainly due to the fact that several CPUE indices included in the model are relatively short and have somewhat conflicting trends that have caused pronounced patterns in the residuals.

69. The WPB **NOTED** that the CPUE indices for the NW and NE region are fitted as separated series, both being assumed to have represented the whole Indian Ocean. The WPB **DISCUSSED** whether the regional indices should be combined into a single index as is often done for mainly surplus production models. However, the WPB **NOTED** that combining indices may hide contrasting trends amongst individual indices, and a more appropriate approach is to classify CPUE into groups based on similarity in trends. The WPB **AGREED** that the "drop one" sensitivity analysis is a good way to assess whether the assessment is robust to potential conflicts of CPUE indices that have been included in the model.

70. The WPB **NOTED** that the models with and without the historical Taiwanese CPUE estimated similar stock depletion. This is because the recent CPUE is quite stable, therefore the model is less dependent on the historic CPUE to estimate a very depleted stock status. As a result, the estimated confidence bound for the depletion is tight.

71. The WPB **NOTED** the key assessment results for Bayesian State Space Surplus-Production Model (JABBA) for striped marlin from the base case (S2) as shown below (**Table 3; Figure 2**).

72. The WPB **NOTED** that the estimates of posterior distribution of *K* were precise and that the retrospective analysis produced highly consistent stock status estimates back to 2007, thus providing a degree of confidence in the predictive capabilities of the assessment (**Figure 3**).

Table 3. Stock status summary table for the striped marlin assessment (JABBA). CI = Confidence interval

Management quantity	JABBA (S2)
Current catch	3,001
Mean catch 2015–2019 (t)	3,477
MSY (1,000 t) (95% CI)	4.57 (4.11 –5.03)
F_{MSY} (95% CI)	0.25 (0.19 – 0.33)
Data period (catch)	1950 – 2019
F_{2019}/F_{MSY}	2.10 (1.41 – 3.02)
B_{2019}/B_{MSY} (95% CI)	0.31 (0.21 – 0.48)
SB_{2019}/SB_{MSY}	N/A
B_{2019}/B_0 (95% CI)	0.12 (0.08 – 0.18)

SB_{2019}/SB_0	N/A

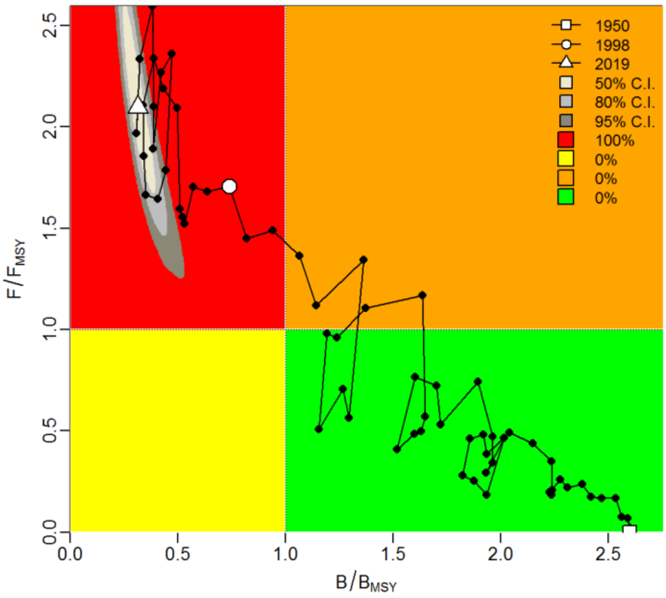

Figure 2. JABBA: Kobe stock status plot for the Indian Ocean for striped marlin for the JABBA reference case model (S2). The black line traces the trajectory of the stock over time. Contours represent the smoothed probability distribution for 2019 (isopleths represent the probabilities relative to the maximum)

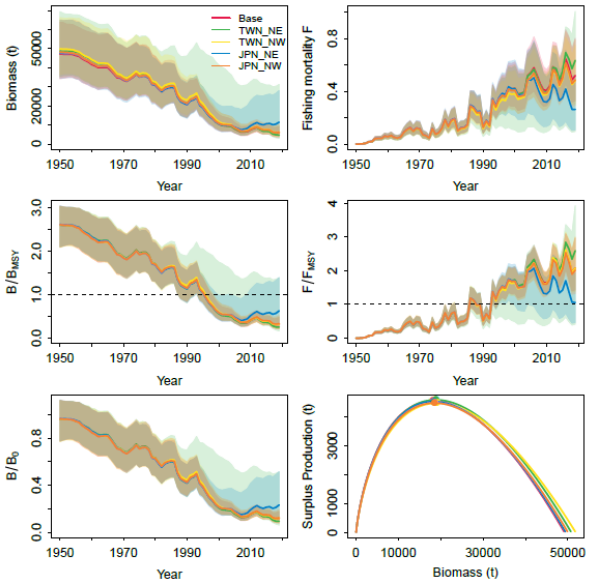

Figure 3: Retrospective analysis for stock biomass (t), surplus production function (maximum = MSY), B/B_{MSY} and F/F_{MSY} for the Indian Ocean striped marlin JABBA model (reference case (S2))

Black Marlin

- **Nominal and standardised CPUE indices**

73. The WPB **NOTED** paper IOTC-2021-WPB19-16 on CPUE standardization of black marlin (*Makaira indica*) caught by Taiwanese large scale longline fishery in the Indian Ocean, including the following abstract provided by the authors:

"In this study, the delta-linear models with different assumptions of error distribution were adopted to conduct the CPUE standardization of black marlin caught by the Taiwanese large-scale longline fishery in the Indian Ocean for 1979-2020 and 2005-2020. The groups of data sets derived from cluster analysis based on species compositions were incorporated in the models as a covariate for explaining the target. The results indicate that the targeting effects (clusters) provided most significant contributions to the explanation of the variance of CPUE for the models with positive catches, while the catch probability might be mainly influenced by the position of fishing operations. The standardized CPUE series obtained from different model

assumptions revealed quite similar trends for all model except for delta-lognormal model. For 1979-2020, CPUE trends were similar for the northern areas (NW and NE) and they fluctuated before early 1990s, gradually declined until late 2000s, increased until mid-2010s, then substantially decreased again, and reveals an increasing trend in recent years. For 2005-2020, the trends of CPUE for the northern areas (NW and NE) also revealed similar patterns, CPUE increased from 2013 to 2016, decreased until 2018, and increased in recent years."

74. The WPB **THANKED** the authors for the work and **NOTED** that the comments made for paper IOTC-2021-WPB19-13 and relative to data quality prior to the mid-2000s (i.e., time series length), analysis conducted independently in each area (i.e., potential issue of fishing effort displacements across areas), and impact of the zero catch records on the results, also applied to the CPUE analysis of black marlin.

75. The WPB **NOTED** that the time series of proportions of zero showed some patterns over time, suggesting that the trends in abundance indices may be driven by the first component of the delta model and **ENCOURAGED** the authors to check the definition of zero catch and possibly filter some of the data in future analyses.

76. The WPB further **NOTED** that this issue would be addressed when only the short time series (2005-2019) is considered in the model.

77. The WPB **NOTED** paper IOTC-2021-WPB19-17 on an update on CPUE Standardization of Black Marlin (*Makaira indica*) from Indonesian Tuna Longline Fleets 2006-2020, including the following abstract provided by the authors:

"Black marlin (Makaira indica) is commonly caught as frozen by-catch from Indonesian tuna longline fleets. Its contribution estimated 18% (~2,500 tons) from total catch in Indian Ocean. Relative abundance indices as calculated based on commercial catches are the input data for several to run stock assessment analyses that provide models to gather information useful information for decision making and fishery management. In this paper a Delta-Lognormal Model (GLM) was used to standardize the catch per unit effort (CPUE) and to calculate estimate relative abundance indices based on the Indonesian longline dataset. Data was collected from August 2005 to December 2020 through scientific observer program." – see document for full abstract

78. The WPB **THANKED** and **CONGRATULATED** the authors for the study which provides additional information on the population dynamics of black marlin for some fisheries other than Japan and Taiwan,China and **NOTED** that this study relies on observer data.

79. The WPB **NOTED** that the data for 2005 were removed from the analysis as there were some issues of misidentification by some observers for that year.

80. The WPB **NOTED** that the average observer coverage for the Indonesian longline fishery was below 5% for each year of the time series. Moreover, the WPB **NOTED** that trips with no black marlin reported by observers were removed in an attempt to reduce zero catches data and due to the potential misidentification of billfishes on these trips. As a result, about 10% of the observed effort was removed from the data to calculate the standardized CPUE for the black marlin.

81. The WPB **NOTED** paper IOTC-2021-WPB19-26 regarding Japanese Longline CPUE Standardization (1979-2019) for black marlin (*Makaira indica*) in the Indian Ocean using Bayesian hierarchical spatial model, including the following abstract provided by the authors:

"To estimate a historical trajectory of black marlin stock abundance in the Indian Ocean, we standardized the CPUE of black marlin caught by Japanese longliners for 1979-2019. We defined the same area of analysis based on the spatial distribution of the mean body weight as Ijima (2018), and divided the time-period into two periods, 1979-1993 and 1994-2019. In this analysis, we applied Bayesian hierarchical spatial models. Since the catch data is countable and characterize by many zeros, we used zero-inflated Poisson generalized linear mixed model (ZIP-GLMM)." – see document for full abstract

82. The WPB **THANKED** the authors for the study and **NOTED** that the technical comments were the same as for the application of the method to striped marlin as described in paper IOTC-2021-WPB19-25.

- **Stock assessments**

Bayesian Surplus Production Model (JABBA)

83. The WPB **NOTED** document IOTC-2021-WPB19-18: Assessment of the Indian Ocean black marlin (*Makaira indica*) stock using JABBA, including the following abstract as provided by the author:

"Six scenarios were run using the Bayesian State-Space Surplus Production Model JABBA to assess the Indian Ocean black marlin (Makaira indica) based on alternative specifications of the Pella-Tomlinson model type that incorporated three differing CPUE input data series, three differing r priors and associated input values of BMSY/K and two different values for process error. A general increase in black marlin catches is evident from 1990 onward with steep increases from 2010. Relative abundance (CPUE) trajectories show a steady decline from 1979 until 2005, after which signals of an increasing trend become apparent." – see document for full abstract

84. The WPB **RECALLED** that in the last stock assessment conducted in 2018, the assessment was characterized by model uncertainty and consequently, the black marlin stock was classified as "Not assessed/Uncertain" in 2018.

85. The WPB **NOTED** that the six scenarios selected for the 2021 JABBA assessment incorporated three differing CPUE time-series combinations, three differing *r* priors and associated input values of B_{MSY}/K, and a single scenario with inflated process error. The continuity model (S1) follows that of the 2018 assessment reference base case:
    - S1 (Cont.): for B_{MSY}/K = 0.37 (h = 0.5), r prior LN ~ (log (0.19), 0.30)), CPUE = TWN_NW_hist, TWN_NE_hist, JPN, IND.
    - S2 (Ref.): for B_{MSY}/K = 0.37 (h = 0.5), r prior LN ~ (log (0.19), 0.30)), CPUE = TWN_NW, TWN_NE, JPN, IND.
    - S3 (Hist): for B_{MSY}/K = 0.37 (h = 0.5), r prior LN ~ (log (0.19), 0.30)), CPUE = TWN_NW_hist, TWN_NE_hist, JPN_hist, JPN, IND.
    - S4 (Low): for B_{MSY}/K = 0.41 (h = 0.4), r prior LN ~ (log (0.16), 0.30)), CPUE = TWN_NW, TWN_NE, JPN, IND.
    - S4 (High): for B_{MSY}/K = 0.34 (h = 0.6), r prior LN ~ (log (0.21), 0.30)), CPUE = TWN_NW, TWN_NE, JPN, IND.
    - S6 (Proc.): for B_{MSY}/K = 0.37 (h = 0.5), r prior LN ~ (log (0.19), 0.30)), CPUE = TWN_NW, TWN_NE, JPN, IND, process error = 0.2.

86. The WPB **NOTED** the key assessment results for the reference case (S2) of the Bayesian State Space Surplus-Production Model (JABBA) for black marlin as shown below (**Table 4; Figure 4**).

87. The WPB **NOTED** that similarly to the last assessment, the estimated posterior distribution of *K* is very wide, indicating very high model uncertainty. Furthermore, the retrospective analysis produced an undesirable pattern, as evident by systematic departures from the reference case predictions (**Figure 5**). The WPB **NOTED** that the retrospective pattern is caused by the inconsistent trend between the CPUE and catch series (e.g., the observed increasing CPUE and catch since 2010).

88. The WPB **AGREED** that the systematic deviations in the retrospective analysis provide little confidence in the predictive capabilities of the model, and as such the resultant fishery reference points for black marlin should be treated with caution.

89. The WPB **NOTED** that the assessment is primarily based on CPUE indices from deep freezing longline fleets operating on the high seas whereas a much greater part of the total catches is actually taken by coastal fisheries. Hence the WPB requested alternative CPUE indices be developed from coastal fisheries (e.g., gillnet) to complement the longline CPUE. The WPB also **SUGGESTED** that other assessment methods based on alternative data sources (e.g., length-based spawning potential) be developed to verify or corroborate the CPUE-based assessment.

Table 4. Stock status summary table for the black marlin assessment (JABBA). CI = Confidence interval

Management quantity	JABBA (S2)
Current catch in assessment	18,005
Mean catch 2015–2019 (t)	18,721
MSY (1,000 t) (95% CI)	17.30 (10.98–35.02)
F_{MSY} (95% CI)	0.20 (0.12 – 0.34)
Data period (catch)	1950 – 2019

F_{2019}/F_{MSY}	0.53 (0.22 – 1.05)
B_{2019}/B_{MSY} (95% CI)	1.98 (1.42 – 2.57)
SB_{2019}/SB_{MSY}	N/A
B_{2019}/B_0 (95% CI)	0.73 (0.53 – 0.95)
SB_{2019}/SB_0	N/A

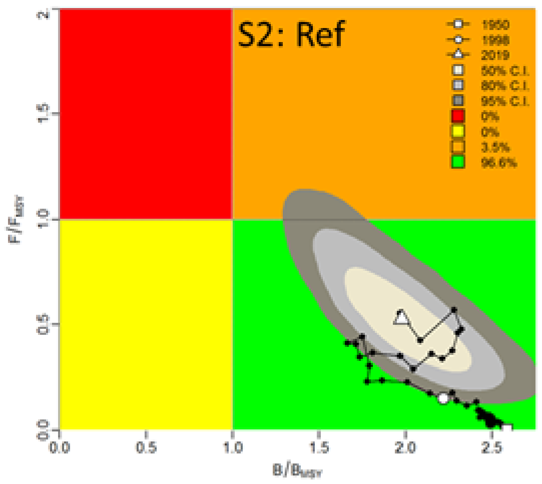

Figure 4: JABBA: Kobe stock status plot for the Indian Ocean for black marlin, from the final JABBA base case (Reference Scenario - S2). The black line traces the trajectory of the stock over time. Contours represent the smoothed probability distribution for 2019 (isopleths are probability relative to the maximum)

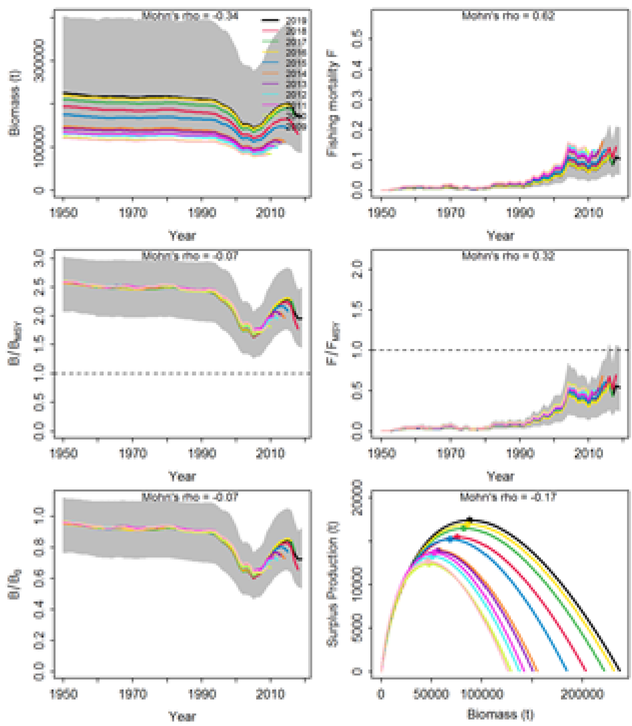

Figure 5: Retrospective analysis for stock biomass (t), surplus production function (maximum = MSY), *B/B_{MSY}* and *F/F_{MSY}* for the Indian Ocean black marlin JABBA Reference Scenario (S2)

5.2 Development of management advice for black and striped marlins and update of species Executive Summaries for the consideration of the Scientific Committee, including discussion on current catch limits as per standing IOTC Resolutions

Black marlin

90. The WPB **NOTED** that the JABBA assessment model estimated that the current stock biomass is above B_{MSY}, and the current fishing mortality is below F_{MSY}.

91. The WPB **NOTED** that the recent catch levels appear to be inconsistent with the observed increase in CPUE, and that the historic catch estimates are highly uncertain. The WPB further **NOTED** the 2021 JABBA model diagnostics highlighted the poor performance with regard to the robustness of management reference point estimates and these should be treated with extreme caution.

92. The WPB **NOTED** that the systematic deviations in the retrospective analysis provide little confidence in the predictive capabilities of the model, and as such model projections should not be used to provide management advice.

93. The WPB **ADOPTED** the management advice developed for black marlin, as provided in the draft status summary and **REQUESTED** that the IOTC Secretariat update the draft stock status summary with the latest 2019 interaction data to be provided to the SC as part of the draft Executive Summary, for its consideration:

    - Black marlin (*Makaira indica*) – Appendix VII

Striped marlin

94. The WPB **NOTED** that all examined models were consistent, indicating that the stock has been subject to overfishing in the last two decades and that, as a result, the stock biomass is well below the B_{MSY} level. The WPB also **NOTED** the stock status estimates are consistent between the SS3 and the JABBA models.

95. On the weight-of-evidence available in 2021, the WPB **AGREED** that the stock status of striped marlin is determined to be *overfished* and *subject to overfishing*.

96. The WPB **AGREED** that projections are to be conducted using the base case (S2) of the JABBA model to provide management advice. However, the WPB **NOTED** that the age-structured model can better account for the lagging effect in stock recovery and requested the projections to also be conducted using the SS3 model in the next iteration of striped marlin assessment.

97. The WPB **ADOPTED** the management advice developed for striped marlin, as provided in the draft status summary and **REQUESTED** that the IOTC Secretariat update the draft stock status summary with the latest 2019 interaction data and the JABBA to be provided to the SC as part of the draft Executive Summary, for its consideration.

    - Striped marlin (*Tetrapturus audax*) – Appendix IX

6. OTHER BILLFISHES

6.1 Review of new information on other billfishes (swordfish, other marlins, I.P. sailfish) biology, stock structure, fisheries and associated environmental data

98. The WPB **NOTED** document IOTC-2021-WPB19-19 on Sex identification of swordfish using a low cost genetic method, including the following abstract as provided by the author:

    "Sex identification of animal species is a critical piece of information to derive parameters for population dynamic models. In the context of stock assessment (SA) for marine population, sex identification provides information about the sex-ratio of the population which is subsequently used to calculate the stock spawning biomass. In these SA models, sex-ratio can be set to an constant value throughout the lives of individuals (e.g. 0.5) or age-structured to account for changes linked to the physiology of individuals (e.g. females may live longer and represent a larger proportion of the population) or the selectivity of the fishery (e.g. a gender may be more accessible to the fishery at specific stages)." – see document for full abstract

99. The WPB **NOTED** the document, but unfortunately the authors were not able to present it and so no discussions took place.

100. The WPB **NOTED** document IOTC-2021-WPB19-20 which provided a review of the Reproductive biology of the Swordfish (*Xiphias gladius*) in the Indian Ocean, including the following abstract as provided by the author:

"This paper review the reproductive biology of swordfish (Xiphias gladius) in the Pacific, Atlantic and Indian Oceans as well as the Mediterranean Sea, with particular focus in the Indian Ocean to inform the next swordfish stock assessment scheduled for 2023, as part of the 'GERUNDIO' project. The review focuses on the reproductive strategy, seasonal and geographical spawning activity, maturity patterns and fecundity of swordfish. In general, available literature on swordfish reproductive biology is scarce, with most of the studies located in the Atlantic and Pacific Oceans. Swordfish is characterised as a multiple spawner species showing an asynchronous oocyte development and indeterminate fecundity. Swordfish size at maturity and fecundity studies have revealed significant variation both between and within oceans depending on sex, geographical area and environmental conditions. However, the differences could also stem from the different techniques used to determine the maturity status of individual fish among studies and estimate fecundity and/or the limited samples used." – see document for full abstract.

101. The WPB **NOTED** that the paper did not present new information on reproductive biology for swordfish but reviewed previous curves, recommending that the sex specific maturity curves from Poisson and Fauvel (2009), collected in the South-West Indian Ocean, are explored as a possibility in the stock assessment instead of Farley et al. (2016) from the Pacific Ocean, referring that the estimates for females are similar for both studies.

102. The WPB **NOTED** that the recommendation in the document regarding the use of sex disaggregated maturity ogives for use in the next SWO assessment. The WPB, however further **NOTED** that in the assessment, spawning biomass is based on the female portion of the population and the maturity of males is not taken into account. As such a sex-disaggregated maturity ogive may not be appropriate in the current model formulation.

103. The WPB **NOTED** document IOTC-2021-WPB19-21 which described the preliminary age and growth of Swordfish (*Xiphias gladius*) in the western Indian Ocean, including the following abstract as provided by the author:

"This paper describes preliminary work to estimate the age and growth of swordfish in the Indian Ocean as part of the 'GERUNDIO' project . The most recent stock assessment for Indian Ocean swordfish was undertaken in 2020 using Stock Synthesis. The base case model used otolith-based growth estimates for swordfish from the southwest Pacific Ocean from Farley et al. (2016), and the sensitivity models used fin spine-based growth estimates for swordfish in the northern Indian Ocean from Wang et al. (2010). Farley et al. (2016) found that age estimates from fin spines from Pacific Ocean swordfish are likely to underestimate age of older swordfish, so the current project was undertaken to assess the suitability of otoliths to estimate age and growth for swordfish in the Indian Ocean." – see document for full abstract

104. The WPB **NOTED** that the study represented a new estimation of growth for swordfish in the Indian Ocean using otoliths. The WPB **NOTED** that the sampling distribution was unfortunately fairly limited and only samples from the western Indian Ocean were available for the estimation.

105. The WPB **ENCOURAGED** any scientists/CPCs collecting swordfish samples in other regions of the Indian Ocean, to share them with the authors to increase the coverage and facilitate the estimation of a growth curve that could be more representative of the entire Indian Ocean. The WPB especially **NOTED** that research cruises had taken place in the Arabian sea and preliminary studies had indicated that swordfish in this region are of a smaller size. As such, data from these cruises would be valuable for including in the current study.

106. The WPB were also informed that additional swordfish otolith samples are being stored by the CSIRO but that there is no associated sex information for these samples. The authors informed the WPB that there was a possibility that future genetic analysis could be carried out to determine the sex of each sample and this would also provide more information for the study.

107. The WPB **AGREED** that the SWO base case assessment model should continue to use the current growth curve which is from the Pacific, until such time as the sampling coverage of this study in the Indian Ocean is increased.

108. The WPB **NOTED** document IOTC-2021-WPB19-22 which provided standardized CPUE of swordfish (*Xiphias gladius*) caught by French Reunion-based longline fishery (2006-2020).

109. The WPB **NOTED** that the document wasn't provided to the meeting and so was considered withdrawn.

110. The WPB **NOTED** document IOTC-2021-WPB19-23 on comparing four nominal CPUEs indices of swordfish (*Xiphias gladius*) with longline observer data in the Indian Ocean, including the following abstract as provided by the author:

"The catch per unit effort (CPUE) is an essential statistical indicator of the status of stocks. In the longline fishery, because of the different statistical methods of catch and fishing effort, there are many forms for

calculating nominal CPUE. Using the swordfish (Xiphias gladius) of Chinese tuna longline fishery in the Indian Ocean as an example, we evaluate the performance of four nominal CPUEs of two effort forms (1000 hooks and 10000 hours) and two catch forms (number and weight) combinations in CPUE standardization.” – see document for full abstract

111. The WPM **ACKNOWLEDGED** the presentation and **THANKED** the authors for this contribution to the group.

112. The WPB **NOTED** document IOTC-2021-WPB19-24 which provided an update on Indian Ocean swordfish management strategy evaluation: Operating model. No abstract was provided by the author.

113. The WPB **SUPPORTED** the use of the model diagnostics in the development of the operating model and **SUGGESTED** MASE scores for length and age data could also be investigated.

114. The WPB **AGREED** with the current grid of uncertanintes and **ENCOURAGED** the work to be presented to WPM for more technical aspects of the development.

115. The WPB **NOTED** that the declining biomass trends in the southwest region should be taken into account in projections, at least through a robustness test.

7. WPB PROGRAM OF WORK

7.1 Revision of the WPB Program of work (2022–2026)

116. The WPB **NOTED** paper IOTC–2021–WPB19–08 which provided an opportunity to consider and revise the WPB 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.

117. The WPB **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).

118. The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2022–2026), as provided at Appendix XI.

7.2 Development of priorities for an Invited Expert at the next WPB meeting

119. The WPB **NOTED** that an Invited Expert may be required to support the next WPB meeting and **AGREED** that the decision for the selection of the candidate for the WPB20 be considered inter-sessionally. Once decided, the selection will be performed by advertising the position through the IOTC science list (as a priority channel) and finalized after receipt and assessment of résumés and supporting information for potential candidates, according to the deadlines set forth by the rules and procedures of the Commission.

120. The WPB **AGREED** to the following core areas of expertise and priority areas for contribution that need to be enhanced for the next meeting of the WPB in 2022 by an Invited Expert:

- **Expertise**: Stock assessment, including from regions other than the Indian Ocean; SS3 assessment approaches.
- **Priority areas for contribution**: Refining the information base, historical data series and indicators for billfish species for stock assessment purposes (species focus: Swordfish).

8. OTHER BUSINESS

8.1 Election of a Chairperson and a Vice-Chairperson of the WPB for the next biennium

Chairperson

121. The WPB **NOTED** that the first term of the current Chairperson, Dr Denham Parker (South Africa) expired at the close of the WPBT19 meeting and, as per the IOTC Rules of Procedure (2014), participants are required to elected a new Chairperson of the WPB for the next biennium.

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

Vice-Chairperson

123. The WPB **NOTED** that the first term of the current Vice-Chairperson, Jie Cao (China) expired at the close of the WPB19 meeting and, as per the IOTC Rules of Procedure (2014), participants are required to elected a new Vice-Chairperson of the WPB for the next biennium.

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

8.2 Date and place of the 20th and 21st Sessions of the Working Party on Billfish

125. The WPB **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 WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB20 in 2022.. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB, with the WPEB taking place after the WPB in 2022.

8.3 Review of the draft, and adoption of the Report of the 19thSession of the Working Party on Billfish

126. The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB19, provided at Appendix XII, as well as the management advice provided in the draft resource stock status summary for each of the five billfish species under the IOTC mandate, and the combined Kobe plot for the five species assigned a stock status in 2021 (Fig. 4):

- Swordfish (*Xiphias gladius*)– Appendix VI
- Black marlin (*Makaira indica*) – Appendix VII
- Blue marlin (*Makaira nigricans*) – Appendix VIII
- Striped marlin (*Tetrapturus audax*) – Appendix IX
- Indo-Pacific sailfish (*Istiophorus platypterus*) – Appendix X

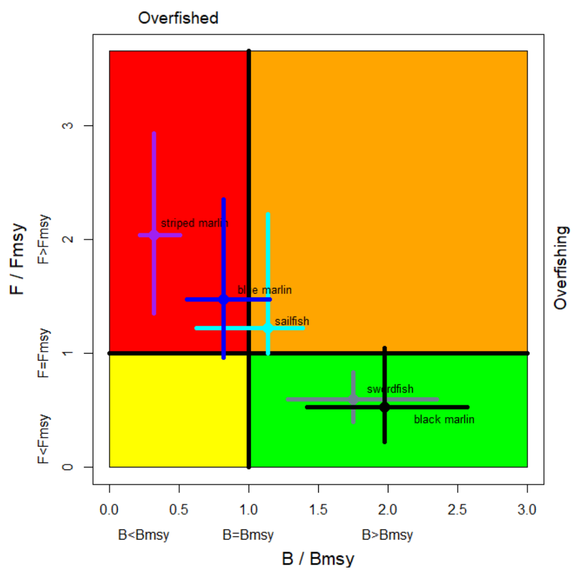

Fig. 4. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2017, 2018, 2019, 2020 and 2021 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs.

127. The report of the 19th Session of the Working Party on Billfish (IOTC–2021–WPB19–R) was **ADOPTED** by correspondence.

APPENDIX I - LIST OF PARTICIPANTS

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APPENDIX II - AGENDA FOR THE 19TH WORKING PARTY ON BILLFISH

Date: 13–16 September 2021
Location: Online
Time: 12:00 – 16:00 daily (Seychelles time)
Chair: Dr Denham Parker (South Africa); **Vice-Chair:** Dr Jie Cao (China)

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

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

3. **THE IOTC PROCESS: OUTCOMES, UPDATES AND PROGRESS**
   - Outcomes of the 23rd Session of the Scientific Committee (IOTC Secretariat)
   - Outcomes of the 24th and 25th Sessions of the Commission (IOTC Secretariat)
   - Review of Conservation and Management Measures relevant to billfish (IOTC Secretariat)
   - Progress on the recommendations of WPB18 (IOTC Secretariat)

4. **NEW INFORMATION ON FISHERIES AND ASSOCIATED ENVIRONMENTAL DATA FOR BILLFISH**
   - Review of the statistical data available for billfish (IOTC Secretariat)
   - Review new information on fisheries and associated environmental data (general CPC papers)
   - New information on sport fisheries (all)

5. **MARLINS (Priority species for 2021: Black marlin and Striped marlin)**
   - Review new information on marlin biology, stock structure, fisheries and associated environmental data (all)
   - Review of new information on the status of black and striped marlins (all)
     - Nominal and standardised CPUE indices
     - Stock assessments
     - Selection of Stock Status indicators
   - Development of management advice for black and striped marlins and update of species Executive Summaries for the consideration of the Scientific Committee, including discussion on current catch limits as per standing IOTC Resolutions (all)

6. **OTHER BILLFISHES (new information for informing future assessments)**
   - Review of new information on other billfishes (swordfish, other marlins, I.P. sailfish) biology, stock structure, fisheries and associated environmental data (all)

7. **WPB PROGRAM OF WORK**
   - Revision of the WPB Program of Work (2022–2026) (Chairperson and IOTC Secretariat)
   - Development of priorities for an Invited Expert at the next WPB meeting (Chairperson)

8. **OTHER BUSINESS**
   - Election of a Chairperson and a Vice-Chairperson of the WPB for the next biennium (Secretariat)
   - Date and place of the 20th and 21st Sessions of the Working Party on Billfish (Chairperson and IOTC Secretariat)
   - Review of the draft, and adoption of the Report of the 19th Session of the Working Party on Billfish (Chairperson)

APPENDIX III - LIST OF DOCUMENTS FOR THE 19TH WORKING PARTY ON BILLFISH

Document	Title
IOTC-2021-WPB19-01a	Agenda of the 19th Working Party on Billfish
IOTC-2021-WPB19-01b	Annotated agenda of the 19th Working Party on Billfish
IOTC-2021-WPB19-02	List of documents of the 19th Working Party on Billfish
IOTC-2021-WPB19-03	Outcomes of the 23rd Session of the Scientific Committee (IOTC Secretariat)
IOTC-2021-WPB19-04	Outcomes of the 24th and 25th Sessions of the Commission (IOTC Secretariat)
IOTC-2021-WPB19-05	Review of Conservation and Management Measures relevant to billfish (IOTC Secretariat)
IOTC-2021-WPB19-06	Progress made on the recommendations and requests of WPB18 and SC23 (IOTC Secretariat)
IOTC-2021-WPB19-07	Review of the statistical data and fishery trends for billfish species (IOTC Secretariat)
IOTC-2021-WPB19-08	Revision of the WPB Program of Work (2022-2026) (IOTC Secretariat)
IOTC-2021-WPB19-09	Status of billfish fisheries in Pakistan with special reference to use of subsurface gillnetting (Moazzam M)
IOTC-2021-WPB19-10	Fishery and stock status of billfishes exploited from the eastern Arabian sea (Surya S, Prathibha R, Abdussamad EM, Mini KG, Koya KM, Ghosh S, Jayasankar J, Anulekshmi C, Azeez PA)
IOTC-2021-WPB19-11	Analysis on fishing strategy for target species for Taiwanese large-scale longline fishery in the Indian Ocean. (Wang S-P, Xu W-Q, Lin C-Y, Kitakado T)
IOTC-2021-WPB19-12	An update on satellite tagging of billfish around the Indian Ocean (Nieblas AE , Bernard S, Big Game Fishing Réunion, Brisset B, Bury M, Chanut J, Chevrier T, Coelho R, Colas Y, Jayanti AD, Evano H, Faure C, Hervé G, Kerzerho V, Rouyer T, Tracey S, Bonhommeau S)
IOTC-2021-WPB19-13	CPUE standardization of striped marlin (*Tetrapturus audax*) caught by Taiwanese large scale longline fishery in the Indian Ocean (Xu W-Q, Wang S-P, Lin C-Y)
IOTC-2021-WPB19-14	Stock assessment of striped marlin (*Tetrapturus audax*) in the Indian Ocean using the Stock Synthesis (Wang S-P, Xu W-Q, Lin C-Y)
IOTC-2021-WPB19-15	Assessment of the Indian Ocean striped marlin (*Tetrapturus audax*) stock using JABBA (Parker D)
IOTC-2021-WPB19-16	CPUE standardization of black marlin (*Makaira indica*) caught by Taiwanese large scale longline fishery in the Indian Ocean (Lin C-Y, Wang S-P, Xu W-Q)
IOTC-2021-WPB19-17	Update on CPUE Standardization of Black Marlin (*Makaira indica*) from Indonesian Tuna Longline Fleets 2006-2020 (Setyadji B, Parker D, Wang S-P, Sulistyaningsih RK)
IOTC-2021-WPB19-18	Assessment of the Indian Ocean black marlin (*Makaira indica*) stock using JABBA (Parker D)
IOTC-2021-WPB19-19	Sex identification of swordfish using a low cost genetic method (Helary L, Chevrier T, Roumagnac M, Chanut J, Nieblas A-E, Padron M, Brisset B, Evano H, Bonhommeau S)
IOTC-2021-WPB19-20	A review of the Reproductive biology of the Swordfish (*Xiphias gladius*) in the Indian Ocean (Murua H, Zudaire I, Luque PL, Artetxe-Arrate I, Farley J, Romanov E, Marsac F, Fraile I, Merino G)
IOTC-2021-WPB19-21	Preliminary age and growth of Swordfish (*Xiphias gladius*) in the western Indian Ocean (Farley J, Robertson S, Norman S, Parker D, Eveson P, Luque P, Krusic-Golub K, Fraile I, Zudaire I, Artetxe I, Murua H, Marsac F, Merino G)
IOTC-2021-WPB19-22	Standardized CPUE of swordfish (*Xiphias gladius*) caught by French Reunion-based longline fishery (2006-2020) (Juhel J-P, Bonhommeau S, Evano H, Brisset B)
IOTC-2021-WPB19-23	Comparing four nominal CPUEs indices of swordfish (*Xiphias gladius*) with longline observer data in the Indian Ocean (Peng S, Wang X, Xu L, Wu F, and Zhu J)
IOTC-2021-WPB19-24	Indian Ocean swordfish management strategy evaluation: Operating model (Rosa D, Fu D, Coelho R, Mosqueira I)

Document	**Title**
IOTC-2021-WPB19-25	Japanese Longline CPUE Standardization (1979-2019) for striped marlin (*Tetrapturus audax*) in the Indian Ocean using Bayesian hierarchical spatial model (Taki K, Ijima H, and Kai M)
IOTC-2021-WPB19-26	Japanese Longline CPUE Standardization (1979-2019) for black marlin (*Makaira indica*) in the Indian Ocean using Bayesian hierarchical spatial model (Taki K, Ijima H, and Kai M)
Information papers	
IOTC-2021-WPB19-INF01	Stock structure of billfishes observed during the exploratory surveys in the Indian Exclusive Economic Zone- A Decadal study (Siva A, Mali K, Pawar R, Shirke S, Joshi H, Singh T, Kadam A, Das A, Ramachandran S, Ramanamurthy N, Bhaskar C, Raut B, Kumar A, Gangurde Y and Mudumala V)
IOTC-2021-WPB19-INF02	Movement ecology of black marlin *Istiompax indica* in the Western Indian Ocean (Rohner C, Bealey R, Fulanda B, Everett J, Richardson A and Pierce S)
IOTC-2021-WPB19-INF03	Movement and habitat use of striped marlin Kajikia audax in the Western Indian Ocean (Rohner C, Bealey R, Fulanda B and Pierce S)

APPENDIX IV
The standing of a range of information received by the IOTC Secretariat for the five IOTC billfish species

(*Extract from IOTC–2021–WPB19–07_Rev1*)

Nominal catches

Historical trends (1950-2019)

Billfish are mainly caught by industrial fisheries using longline and gillnet, but they are also taken by purse seiners and more artisanal gears such as troll line and hand line. The total nominal catches of the IOTC billfish species showed a major increase over the last seven decades, from an average of 5,451 t per year in the 1950s to an average of 85,800 t per year in the 2010s. The annual catches of billfish species by industrial fisheries showed a marked increase between the 1990s and the 2000s, which was mainly driven by the longline fisheries from Taiwan,China (**Fig. A1a**). Since then, they showed large variations between a maximum of 58,734 t in 2004 and a minimum of 32,658 t in 2010. Catches from artisanal fisheries have steadily increased over time, with their contribution to the total catch of billfish increasing from less than 10% prior to the 1970s to more than 50% in recent years (**Fig. A1b**).

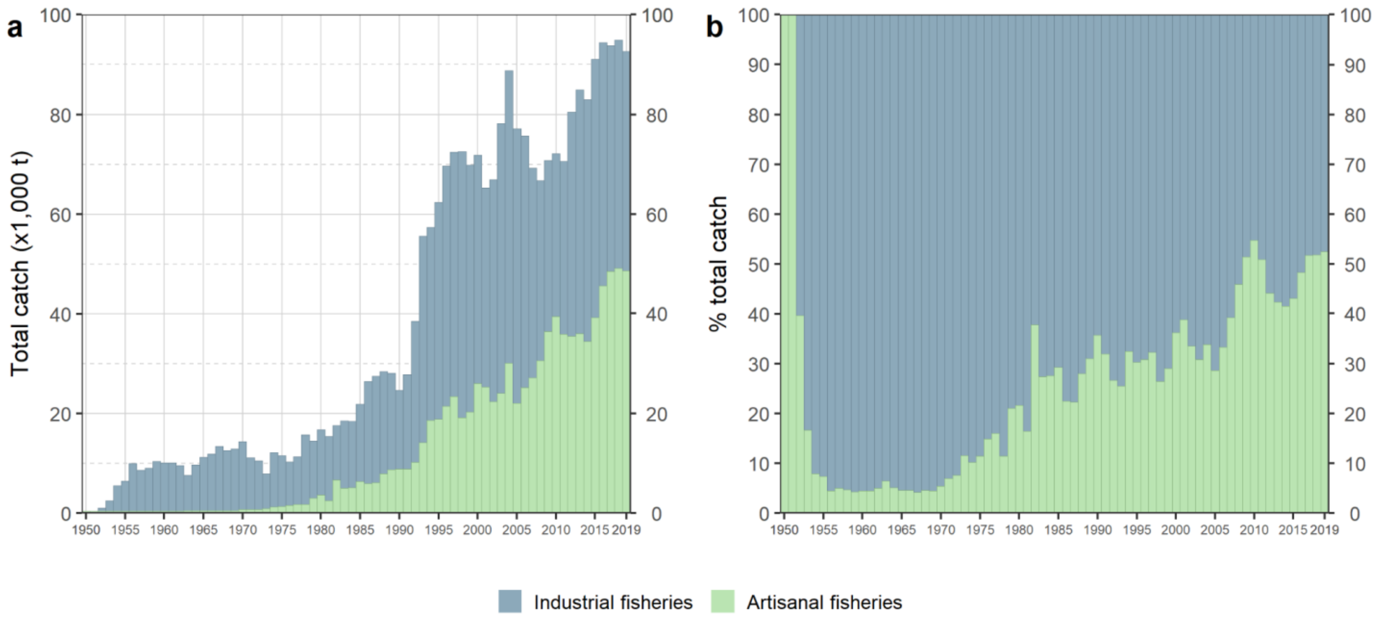

Figure A1: Annual time series of cumulative nominal absolute (a) and relative (b) catches of IOTC billfish in metric tons (t) by fishery type for the period 1950-2019

The composition of the fisheries catching billfish varies over time and between species. While billfish have mainly been reported to be caught by longliners until the early 1990s, the contribution of gillnet and coastal line fisheries has substantially increased over the last two decades (**Fig. A2**). In particular, gillnet catches of billfish have steadily increased since the early 1980s to reach 40,200 t in 2019, representing 43% of the total catches of billfish in that year. Total catches of billfish reported for line fisheries showed a marked increase from the early 2010s (Fig. 3) reflecting in particular the increased reporting of billfish species caught by the coastal longline fishery of Sri Lanka, that went from 37 t in 2013 to 4,426 t in 2014. This sharp increase is thought to be mainly due to an improvement in the fisheries statistics of Sri Lanka starting with the early 2010s, when a closer monitoring of the catches in multi-gear fisheries (e.g., gillnet and longline operated during the same trip) was combined with a better break-down of longline fisheries data (i.e., separation between coastal and offshore components). In parallel, the catches of billfish taken by coastal longliners operating in the Indian EEZ have doubled over the last decade, increasing from 3,607 t in 2013 to 6,929 t in 2019.

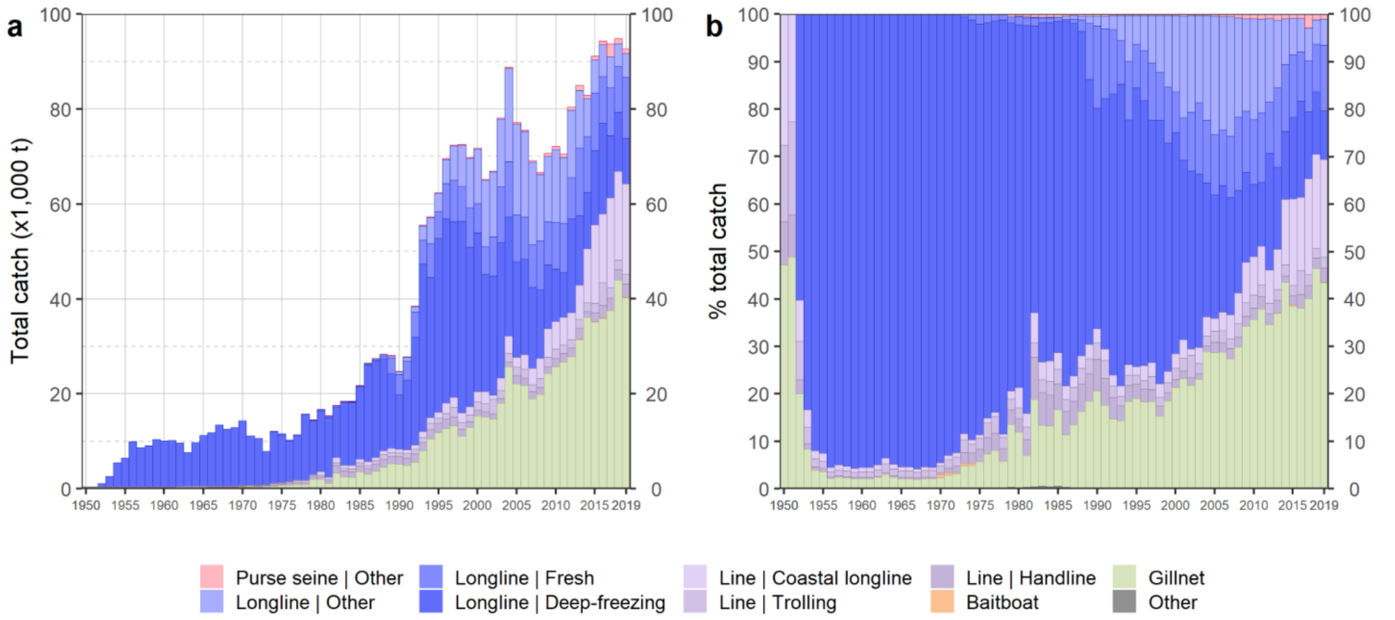

Figure A2: Annual time series of cumulative nominal absolute (a) and relative (b) catches of IOTC billfish in metric tons (t) by fishery for the period 1950-2019

A total of 2.6 million metric tons of billfish have been reported to have been caught in the Indian Ocean since the 1950s. In terms of total catches, swordfish (SWO) represents the main billfish species, contributing to 36% of the cumulative catches of billfish available in the IOTC database, followed by Indo-Pacific sailfish (SFA) with a contribution of 24% (**Fig. A3**). Blue marlin (BUM) and black marlin (BLM) contributed about equally with cumulative catches of about 400,000 t, roughly corresponding to 15% of total billfish catches taken during that period. Striped marlin (MLS) appears to be less abundant in the catches of IOTC billfish with a maximum annual catch of 8,730 t observed between 1950 and 2019 and a total cumulative catch of about 256,000 t reported as caught over that period.

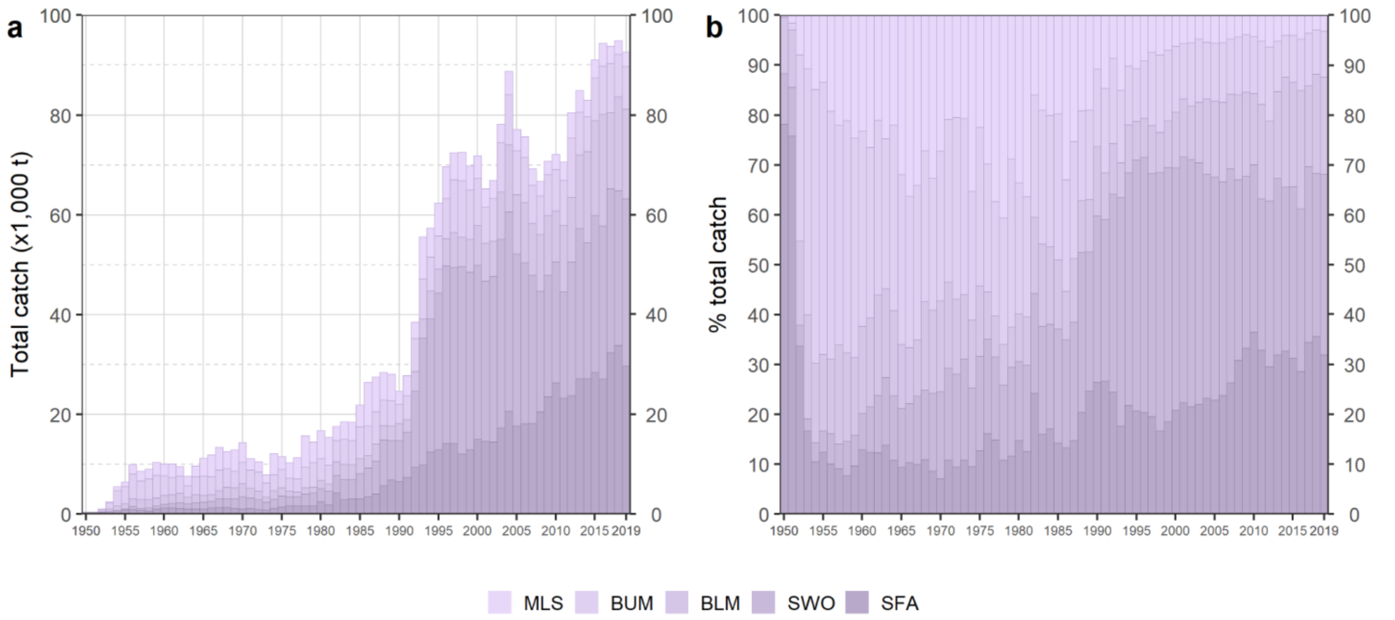

Figure A3: Annual time series of cumulative nominal absolute (a) and relative (b) catches of IOTC billfish in metric tons (t) by species for the period 1950-2019

Recent fishery features (2015-2019)

In recent years (2015-2019), total nominal catches of all IOTC billfish species combined were about 93,376 t per year, with gillnet, longline, and line fisheries contributing to 41.2%, 33.1%, and 24.2% of all catches, respectively. Between 2015 and 2019, the mean annual catches of IOTC billfish have been dominated by a few CPCs, to the point that about two thirds of all catches were accounted for by four distinct fleets: I.R. Iran (mostly composed of gillnet fisheries), Sri Lanka and India (described by a large diversity of fisheries and gears), and Taiwan,China (composed of an equal mix of fresh and deep-freezing longliners) (**Fig. A4**).

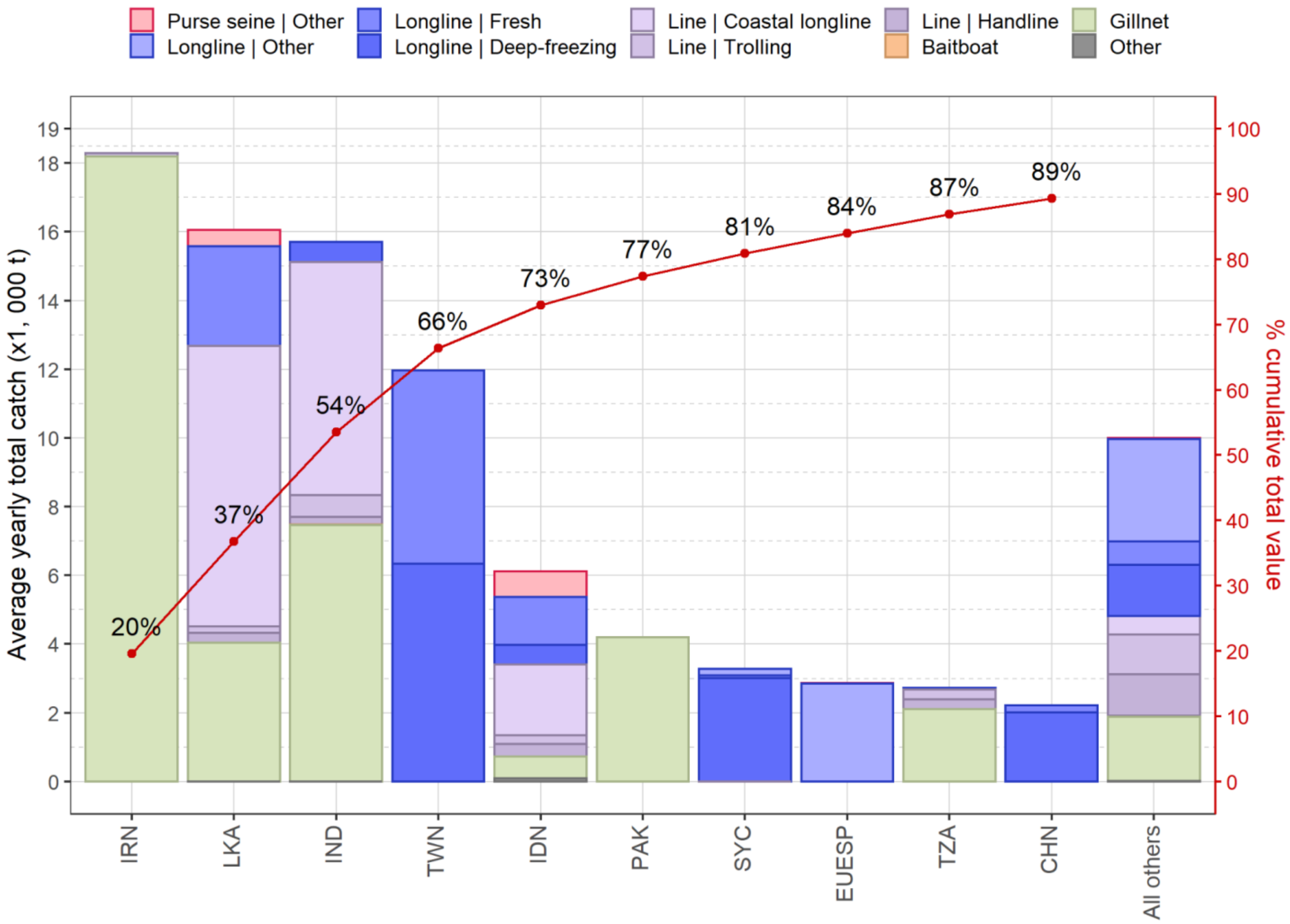

Figure A4: Mean annual catches of IOTC billfish species by fleet and fishery in metric tons (t) between 2015 and 2019, with indication of cumulative catches by fleet

Over the last five years of the time series (2015-2019), the gillnet and line catches of billfish species showed increasing trends, while catches reported by longline fisheries decreased and catches from other fishery groups (i.e., purse seine, baitboat, and other fisheries) were small or negligible (**Fig. A5**). Between 2015 and 2019, the catches of billfish taken by gillnet and line fisheries increased from 35,045 t to 40,200 t and from 20,367 t to 23,947 t respectively, while catches of billfish taken by longline fisheries decreased from 34,729 t to 27,435 t (**Fig. A5**).

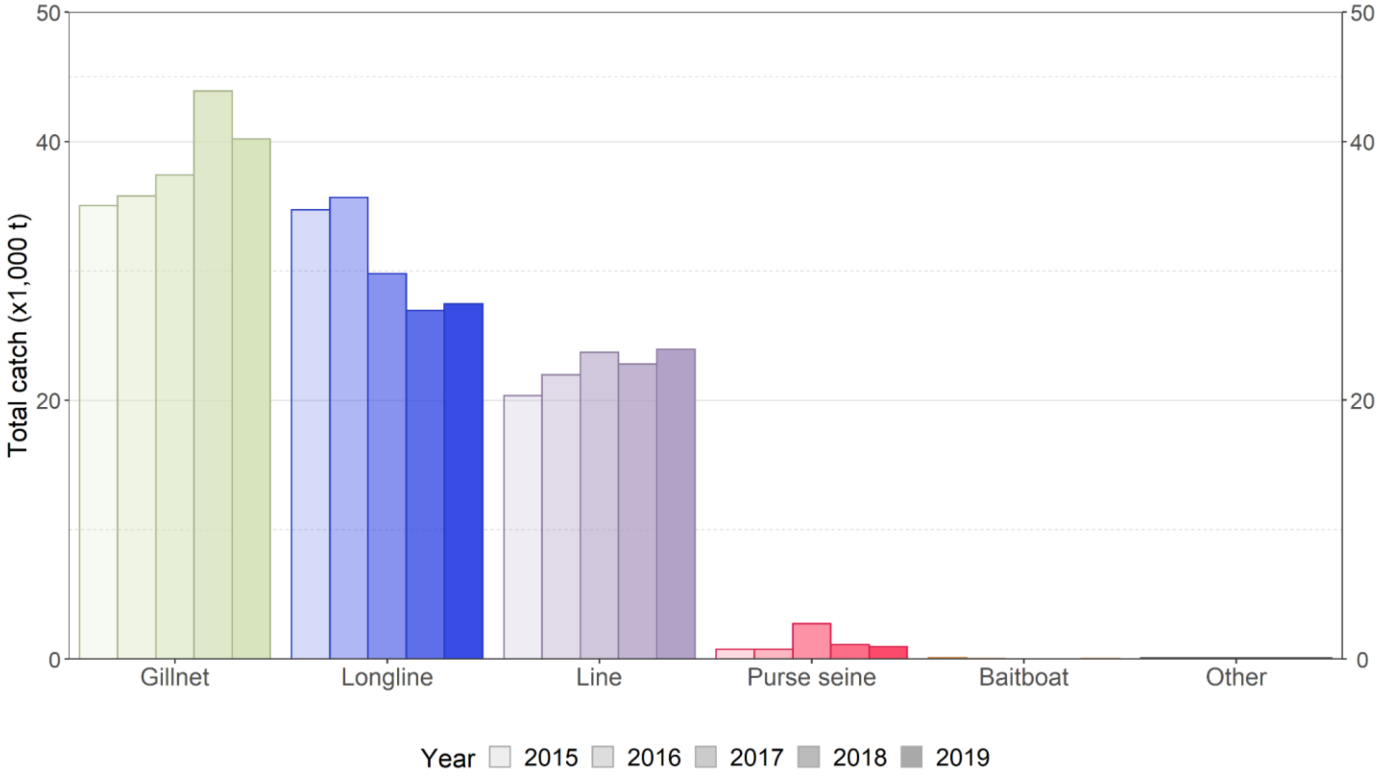

Figure A5: Annual catch trends of IOTC billfish species by fishery group in metric tons (t) between 2015 and 2019

Uncertainties in nominal catch data

The overall quality of nominal catches for the five IOTC billfish species with regards to IOTC reporting standards has strongly varied between 1950 and 2019, and improved substantially over the last decade. The percentage of nominal catches fully or partially reported to the Secretariat i.e., scores between 0 and 2; Table 3) showed large variations over time, decreasing from more than 90% prior to the 1970s, when the catches were dominated by industrial longline fisheries, to less than 40% in the late 2000s (**Fig. A6**). Since then, the reporting quality improved for both industrial and artisanal fisheries with the overall percentage of data fully or partially reported to the Secretariat reaching 80% in 2019 (**Fig. A6**).

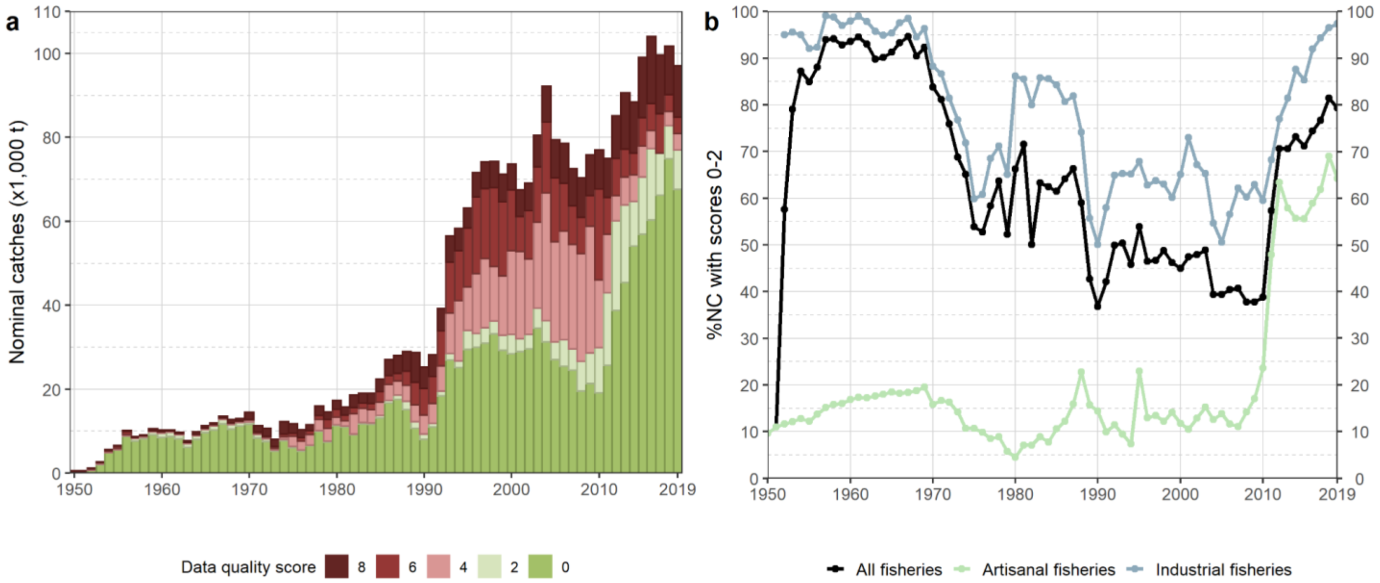

Figure A6: (a) Annual nominal catches of IOTC billfish species in metric tons (t) estimated by quality score and (b) percentage of nominal catches by type of fishery fully and partially reported to the IOTC Secretariat according to IOTC standards

Discard levels

The total amount of billfish species discarded at sea remains unknown for most fisheries and time periods despite the obligation to report these data as per IOTC Res. 15/02. Furthermore, the implementation of IOTC Res. 18/05 that bans the release of specimens of billfish smaller than 60 cm FL may have modified discarding practices in recent years. Despite the lack of information available, discarding of billfish species is overall considered to be limited in most coastal and industrial fisheries targeting tuna and tuna-like species in the IOTC area of competence.

In large-scale purse seine fisheries, part of the billfish has been shown to be discarded at sea despite the entry in force of IOTC Res. 19/05 that bans the discard of non-targeted species caught with purse seine. The levels of bycatch of billfish in Indian Ocean purse seine fisheries have been shown to be low and dominated by marlins, although sailfish may occasionally be caught (Romanov 2002; Ruiz et al. 2018). Based on a large data set of observations at sea collected during the period 2008-2017, the annual catch levels of billfish in the main component of the Indian Ocean purse seine fishery were estimated to vary between 100 and 400 t per year (Ruiz et al. 2018), providing an upper limit for the discard levels.

Information from the literature indicates that levels of discards of billfish are low in Indian Ocean longline fisheries (Huang and Liu 2010; Gao and Dai 2016). Discarding is mainly due to under size, damaged condition, and depredation by whales and sharks that has been shown to be substantial in some longline fisheries of the western Indian Ocean (Munoz-Lechuga et al. 2016; Rabearisoa et al. 2018).

In absence of market value, marlins and swordfish have been assumed to be discarded in some gillnet fisheries such as in I.R. Iran although information available for this fishery suggests that billfish are retained and landed (Rajaei 2013; Shahifar et al. 2013).

Geo-referenced catch and effort data

Overall, few geo-referenced data on catch and effort have been reported for billfish species until recent years and most of the available spatial information comes from industrial longline fisheries. Consequently, the general trend in quality is driven by the changes in fishing patterns that occurred in the Indian Ocean over the last decades, and reflects the increased contribution of artisanal fisheries to the total catches of billfish species over time (**Fig. A1**).

Hence, no geo-referenced catches were available for a large part of the nominal catches of billfish species between the 1990s and 2010s (**Fig. A7**), with the percentage of good-quality catch and effort data (scores of 0-2) decreasing from more than 80% in the late 1950s to a minimum of about 30% in the mid-2000s (**Fig. A7**). The situation has however improved over the last decade with the increasing reporting of catch and effort for some artisanal fisheries (e.g., Indonesia, Sri Lanka), although the logbook coverage used to derive the spatial distribution of the catch for these fisheries is generally reported to be low (<30%).

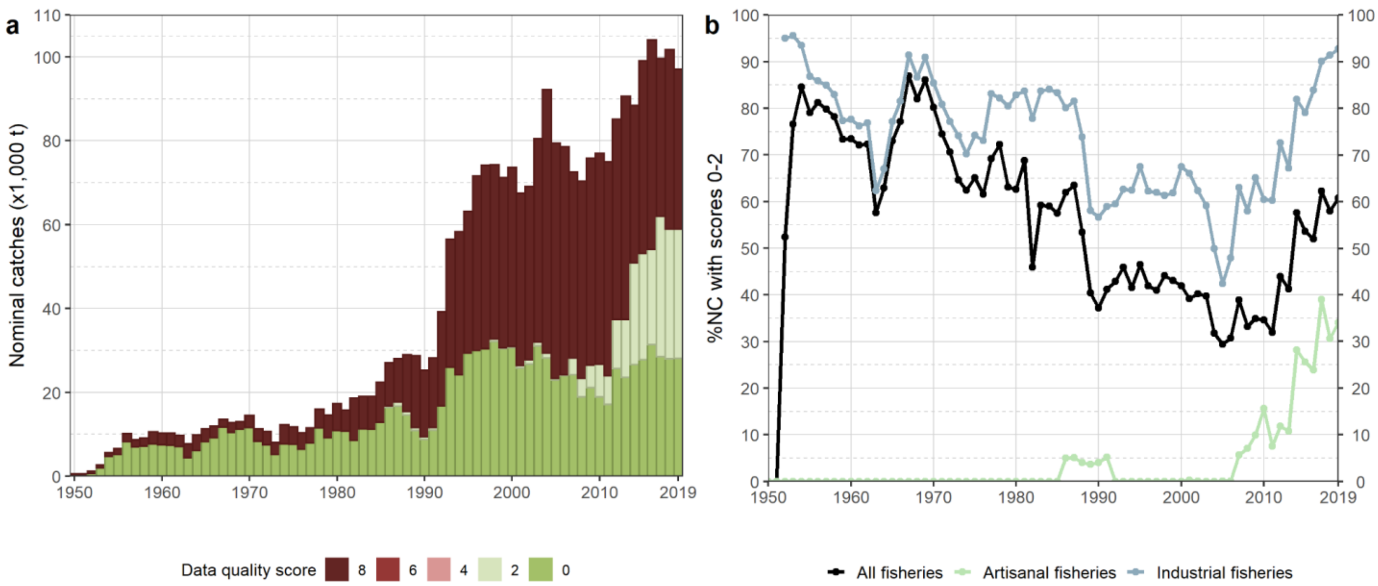

Figure A7: (a) Annual nominal catches of IOTC billfish species in metric tons (t) estimated by quality score and (b) percentage of nominal catches by type of fishery with good quality information (i.e., logbook coverage>30% and compliant with IOTC standards) for the corresponding geo-referenced catch and effort data reported to the IOTC Secretariat

The reporting quality for the geo-referenced catch-effort data greatly varies between species and over time. Indo-Pacific sailfish (SFA) and black marlin (BLM) show the worst quality, with their geo-referenced information missing for a very large proportion of the corresponding nominal catches between the 1990s and 2010s (**Fig. A8**). The situation is the worst for Indo-Pacific sailfish which is mostly caught by artisanal fisheries and for which spatial information is lacking for most of years between 1950 and 2010. For BLM and SFA, minor improvements have been observed over the last decade, with some information reported to the Secretariat even though characterized by a low logbook coverage (<30%). In 2019, the percentage of nominal catches for which some geo-referenced catch data for black marlin and Indo-Pacific sailfish were available was 58.3% and 38.8%, respectively.

The overall reporting quality is better for blue marlin (BUM) and striped marlin (MLS) but it shows a major decrease during the 1990s and 2000s, again in consequence of the increasing contribution of artisanal fisheries to the total catches of marlin species over time. The quality has improved for blue marlin over the last decade, with the percentage of nominal catches with scores of 0-2 reaching 68.4% in 2019. By contrast, the reporting quality for the catch and effort data for striped marlin has steadily decreased since the 1980s because of the concomitant decrease in catches of MLS by longline fisheries, and the increasing catches by gillnet fisheries. In 2019, the fraction of nominal catches described by good quality information for the corresponding geo-referenced catches was 24.2%.

Finally, as was the case with nominal catch data, the quality of swordfish catch and effort data appears to be the best among the IOTC billfish species although showing a decreasing trend between the 1970s and mid-2010s, in relation with the expansion of gillnet and line fisheries from India, Sri Lanka, and Indonesia (**Fig. A8**). The quality of the spatial data has increased in recent years due to the increasing catch by longliners from Taiwan,China and the recent reporting of geo-referenced catch and effort data by Sri Lanka for its coastal longline fishery.

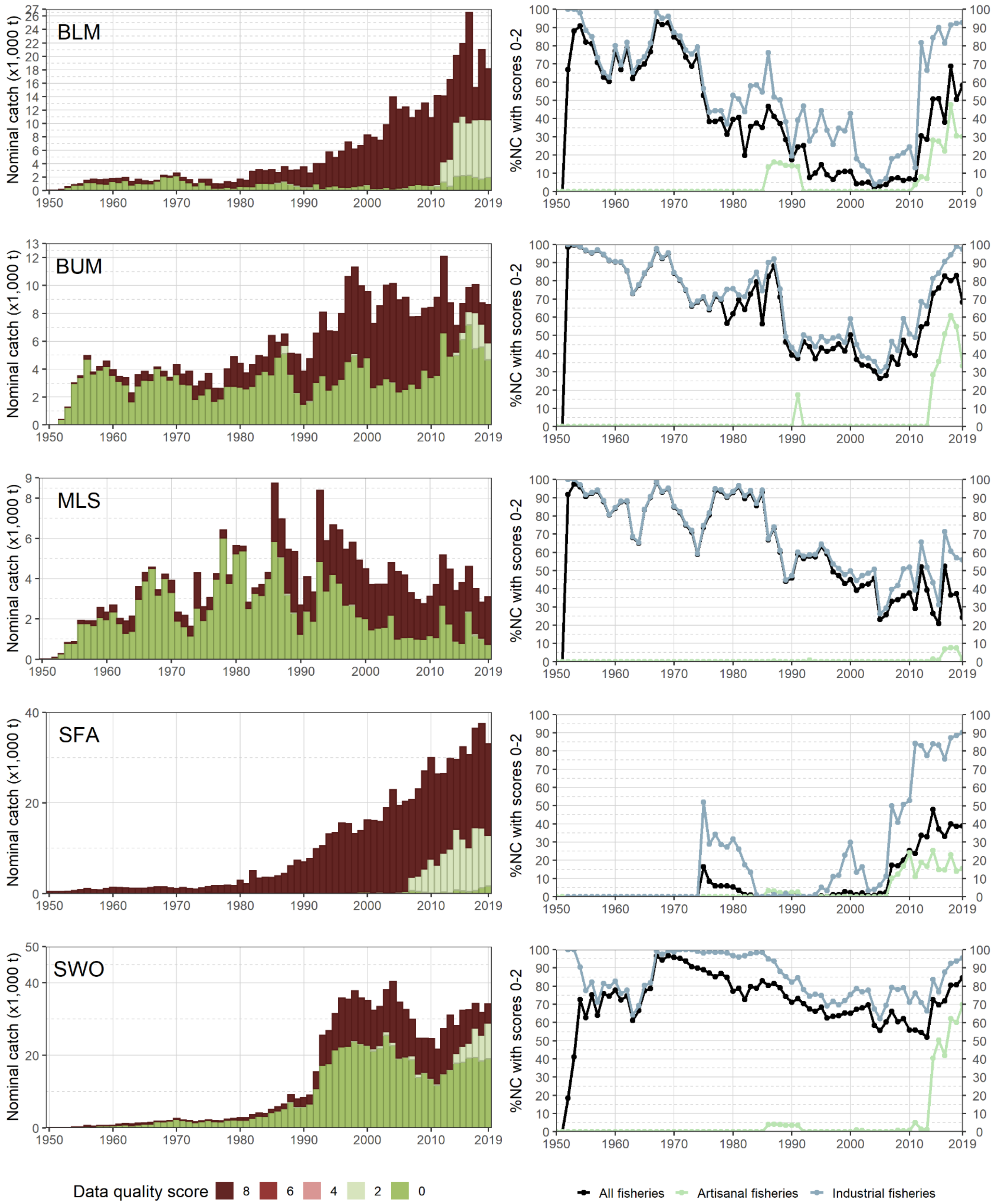

Fig. A8: (left panel) Annual nominal catches in metric tons (t) estimated by quality score and (right panel) percentage of nominal catches by type of fishery with good-quality information (quality score of 0-2) for the geo-referenced catches reported to the IOTC Secretariat for each IOTC billfish species

Size data

The overall reporting quality for geo-referenced size data is poor for all five IOTC billfish species. In fact, almost no size data is available prior to the 1980s and the few data available during the 1970s for industrial longliners from Japan are characterized by low sampling coverage (<1 fish per metric ton) and are not compliant with IOTC reporting standards (**Fig. A9**). Some size data of good reporting quality became available from longliners from Taiwan,China and gillnetters from Sri Lanka during the 1980s and later on from the swordfish-targeting fresh longline fisheries of EU,Spain, EU,France (La Réunion) and Seychelles, which developed and expanded throughout the 1990s. The availability of good quality size data sharply declined from the mid-2000s, mostly due to the major decrease in catches of swordfish reported by the deep-sea longline fisheries of Taiwan,China (**Fig. A9**). It increased in very recent years with the reporting of size data by Sri Lanka for its coastal longline fishery.

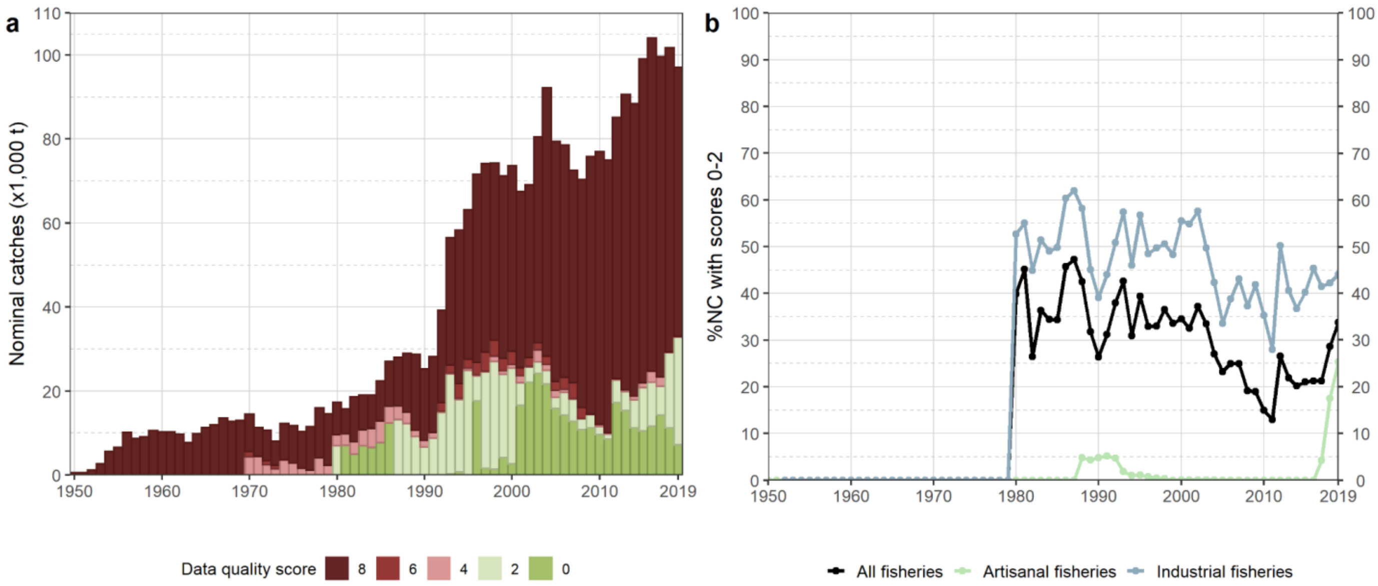

Figure A9: (a) Annual nominal catches of IOTC billfish species in metric tons (t) estimated by quality score and (b) percentage of nominal catches by type of fishery with good quality information (i.e., >1 fish per metric ton caught and compliant with IOTC standards) for the corresponding geo-referenced size frequency data reported to the IOTC Secretariat

The availability and reporting quality of size data varies according to species and over time. There are almost no size data available for black marlin (BLM) and Indo-Pacific sailfish (SFA) (**Fig. A10**). The amount of size data available at the IOTC Secretariat decreased substantially for blue marlin (BUM) and striped marlin (MLS) from the 1980s to the early 2010s with the decline of the deep-sea longline fishery from Taiwan,China, but increased thereafter to the point that the percentage of nominal catches for which good reporting size data have been reported (scores 0-2) reached 48.2% and 11.5% in 2019 for BUM and MLS, respectively (**Fig. A10**). For swordfish (SWO), the percentage of nominal catches with scores 0-2 remained stable at about 50% since the 1980s. Some size data have been reported by Sri Lanka for its gillnet fishery since 2018, increasing the percentage of good quality to 64% of the total nominal catches of swordfish in 2019 (**Fig. A10**).

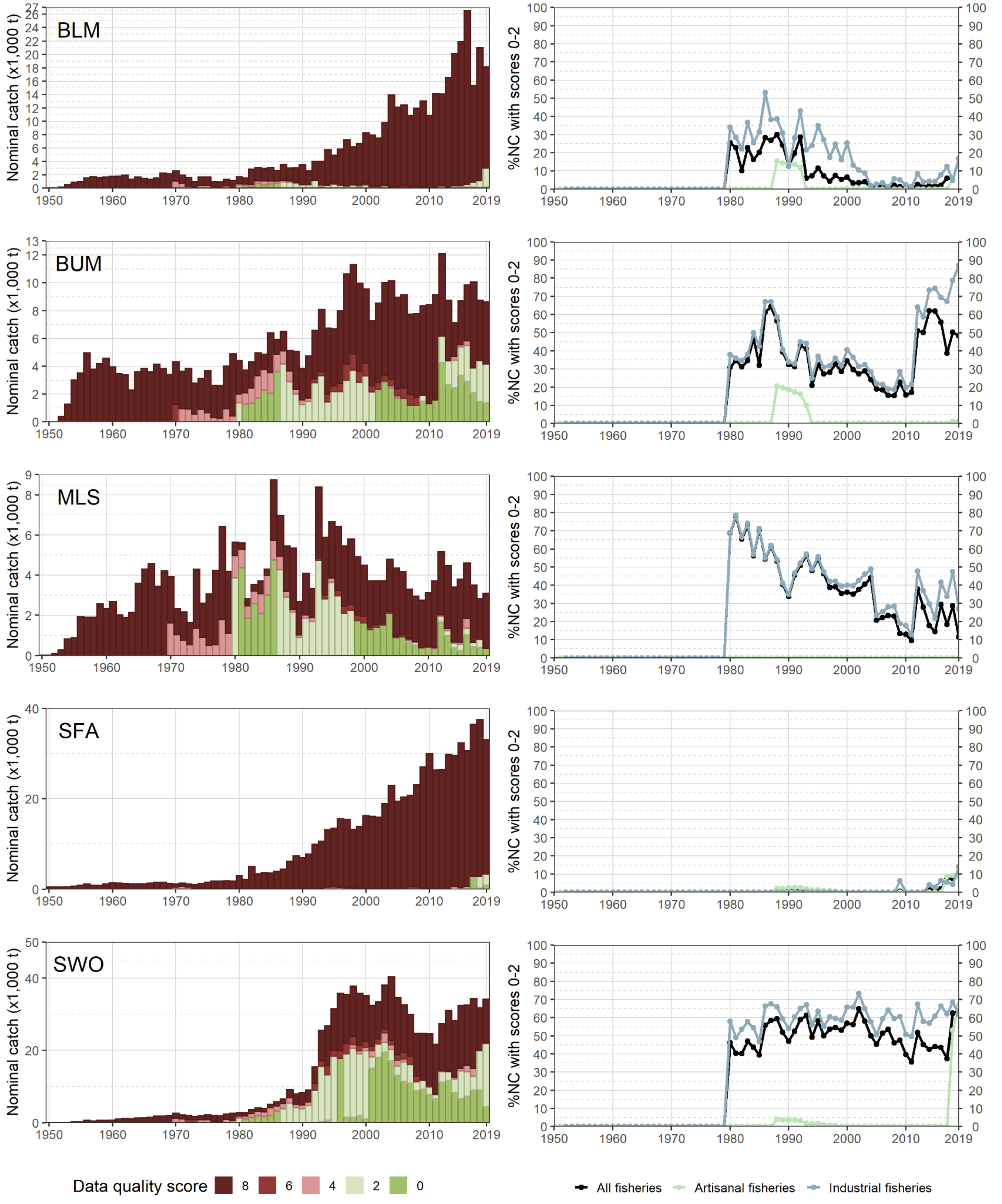

Figure A10: (left panel) Annual nominal catches in metric tons (t) estimated by quality score and (right panel) percentage of nominal catches by type of fishery with good-quality information (quality score of 0-2) for the geo-referenced size frequency data reported to the IOTC Secretariat for each IOTC billfish species

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APPENDIX V
Main issues identified concerning data on IOTC billfish species

Extract from IOTC–2021–WPB19)–07_Rev1

In addition to the issues in reporting, several other key issues emerge from the available nominal catches of some CPCs, that need to be noted and addressed to improve the fisheries statistics of the five IOTC billfish species:

- Artisanal fisheries (including sport fisheries)
  - Catches of billfish reported by Indonesia for its artisanal fisheries in the last decade have been very high, at around 15-19% of the total catches of billfish in the Indian Ocean. In 2012 the Secretariat revised the nominal catch dataset for Indonesia, using information from various sources, including official reports. While Indonesia is implementing a number of improvements to the collection and validation of data for artisanal fisheries, such as electronic logbooks and complete enumeration of catches at key landing sites, catches are still considered to be uncertain for Indonesian small-scale fisheries;
  - Sport fisheries of Australia, France (La Réunion), India, Indonesia, Madagascar, Mauritius, Oman, Seychelles, Sri Lanka, Tanzania, Thailand and United Arab Emirates: data have either never been submitted, or are available for only a limited number of years for sport fisheries in each of the referred CPCs. Sport fisheries are known to catch billfish species, and are particularly important for catches of blue marlin, black marlin and Indo-Pacific sailfish. Although some data are available from sport fisheries in the region (e.g., Kenya, Mauritius, Mozambique, South Africa), the information cannot be used to estimate levels of catch for other fisheries. In 2017 the IOTC Secretariat commissioned a pilot project to develop tools and training materials for CPCs to improve the collection and reporting of catch-and-effort and size frequency from sport fisheries in the Western Indian Ocean (Pepperell et al. 2017). The project focused on trialling specifically-developed data collection tools on a small number of CPCs, including La Réunion, Kenya, Mauritius and Seychelles – however data reporting continues to be an on-going issue for sports and recreational fisheries.
- The drifting gillnet fisheries of I.R. Iran and Pakistan are estimated to account for around 22,000 t of catches of billfish (equivalent to about 24% of the total billfish catches in the Indian Ocean). However, catches for these components remain uncertain:
  - In recent years I.R. Iran has reported catches of marlins and swordfish for their gillnet fishery (from 2012 onwards) which significantly revises the catch-by-species previously estimated by the IOTC Secretariat. While the IOTC Secretariat has used the new catch reports to re-build the historical series for its offshore gillnet fishery (pre-2012), the resulting estimates are thought to be highly uncertain;
  - In 2019, the IOTC WPDCS and SC endorsed the revised catch series (from 1987 onwards) provided by the Pakistan government for its gillnet fleet, and based on the results of the work from the data collection programme supported by WWF-Pakistan. These revised catch series introduced large differences in the reported catches of billfish species, in particular for what concerns swordfish, striped marlin and Indo-Pacific sailfish that are now far lower than what originally reported. As a consequence, current catch estimates for Pakistan account for around 6% of the total catches of billfish in the Indian Ocean, and still suffer from the lack of detailed per-species information until 2017 (catches are reported as “generic” billfish species until that year, with some explicit records of Indo-Pacific sailfish appearing throughout the revised time series).
- Industrial longline fisheries
  - Following issues with the reliability of catch estimates of Indonesia’s fresh longline fleet in recent years, in 2018 the IOTC Secretariat developed in collaboration with Indonesia a new methodology of

catch estimation that mostly affects Indonesia's catches of swordfish, striped marlin, and blue marlin (Geehan 2018). The revised catches are significantly lower for Indonesia's fresh longline fleet in recent years, compared to previous IOTC estimates, while total catches across all fleets have also been revised downwards by as much as 30% for each species as a consequence of the new estimation methodology. The methodology was not applied to the catches for 2019;

– Despite a decrease in the number of Taiwanese fresh-longline vessels of around 30% between 2013-2016, catches have remained at similar levels, or even marginally increased as average catches per vessel have risen from 100 t per vessel in 2013 to around 175 t per vessel in 2016. Over the same period, the proportion of swordfish reported by the Taiwanese fresh longline fleet has risen from around 8% to over 30% - due to improvements in the estimation of catches by species, according to official sources. Both these issues (i.e., the sharp increase in average catches per vessel and changes to the species composition) require further clarification to ensure that the recent increase in average catches is valid.

- Industrial purse seine fisheries

Catches of billfish recorded by all industrial purse seiners are thought to be a fraction of those retained on board. Due to the species being a bycatch, catches are seldom recorded in the logbooks although information collected through the ROS shows that some purse seine fleets do retain billfish for marketing.

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Pepperell, J.G., Griffiths, S., and Kadagi, N. 2017. Acquisition of catch-and-effort and size data from sport fisheries in the Western Indian Ocean. IOTC, San Sebastian, Spain, 10-14 September 2017. p. 59. Available from https://www.iotc.org/documents/acquisition-catch-and-effort-and-size-data-sport-fisheries-western-indian-ocean.

APPENDIX VI - [DRAFT] RESOURCE STOCK STATUS SUMMARY – SWORDFISH

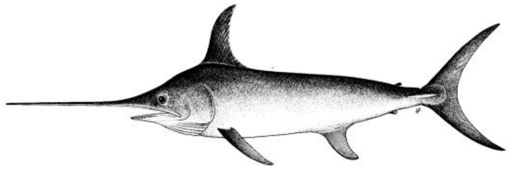

TABLE 1. Swordfish: Status of swordfish (*Xiphias gladius*) in the Indian Ocean.

Area[1]	Indicators		2021 stock status determination
Indian Ocean	Catch 2019[2] (t) Average catch 2015-2019 (t)	33,590 31,930	**98%**
	MSY (1,000 t) (80% CI) F_{MSY} (80% CI) SB_{MSY} (1,000 t) (80% CI) F_{2018}/F_{MSY} (80% CI) SB_{2018}/SB_{MSY} (80% CI) SB_{2018}/SB_{1950} (80% CI)	33 (27–40) 0.23 (0.15–0.31) 59 (41–77) 0.60 (0.40–0.83) 1.75 (1.28–2.35) 0.42 (0.36–0.47)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence
[2] Proportion of 2019 catch estimated or partially estimated by IOTC Secretariat: 9.6%

Colour key	Stock overfished (SB_{year}/SB_{MSY}< 1)	Stock not overfished (SB_{year}/SB_{MSY}≥ 1)
Stock subject to overfishing (F_{year}/F_{MSY}> 1)	0.005	0.005
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	0.01	0.98
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. A new assessment was undertaken in 2020 using stock synthesis with fisheries data up to 2018. The assessment uses a spatially disaggregated, sex explicit and age structured model. The SS3 model, used for stock status advice, indicated that MSY-based reference points were not exceeded for the Indian Ocean population as a whole (F_{2018}/F_{MSY}< 1; SB_{2018}/SB_{MSY}> 1). The two alternative models (ASPIC and JABBA) applied to swordfish also indicated that the stock was above a biomass level that would produce MSY. Spawning biomass in 2018 was estimated to be 40-83% of the unfished levels. Most recent catches of 33,590 t in 2019 are approximately at the *MSY* level (33,000 t). On the weight-of-evidence available in 2020, the stock is determined to be ***not overfished*** and ***not subject to overfishing*** (**Table 1**, **Fig. 2**).

Outlook. The decrease in longline catch and effort from 2005 to 2011 lowered the pressure on the Indian Ocean stock as a whole, and despite the recent increase in total recorded catches, current fishing mortality is not expected to reduce the population to an overfished state over the next decade. There is a very low risk of exceeding MSY-based reference points by 2028 if catches are maintained at 2018 levels (<5% risk that SB_{2028}< SB_{MSY}, and <10% risk that F_{2028}> F_{MSY}) (**Table 1**). However, the Southern regions exhibit declining biomass trends which indicate higher depletion in these regions, compared to northern regions.

***Management advice*.** The most recent catches (33,590 t in 2019) are at approximately the MSY level (33,000 t). Under the current levels of catches, the spawning biomass is projected to remain relatively stable, with a high probability of maintaining at or above the SB_{MSY} for the longer term. Nevertheless, the Commission should consider limiting the catches so as not to exceed the 2018 catch level (30,847 t at the time of the assessment) to ensure that the probability of exceeding the SB_{MSY} target reference points in the long term remains minimal (2%). Projections indicate that an increase of 40% or more from 2018 catch levels will likely result in the biomass dropping below the SB_{MSY} level for the longer term (>75% probability). Taking into account the updated information regarding swordfish stock structure (IOTC-2020-WPB18-09), as well as the differential CPUE and biomass trends between regions, the WPB should continue to discuss the swordfish stock assessment model specifications and consider the feasibility of including a multi-stock assessment in 2023. Recognising that there is recurring evidence for localised depletion in the southern regions (particularly the South West) the WPB expresses concern and suggests this should be further monitored.

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the Indian Ocean is 33,000 t.
- **Provisional 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:
    a. **Fishing mortality**: current fishing mortality is considered to be below the provisional target reference point of F_{MSY} and below the provisional limit reference point of $1.4*F_{MSY}$ (**Fig. 2**).
    b. **Biomass**: current spawning biomass is considered to be above the target reference point of SB_{MSY}, and therefore above the limit reference point of $0.4*SB_{MSY}$ (**Fig. 2**).
- **Main fishing gears (average catches 2015-19)**: offshore longline catches, including sharks and swordfish-targeted longlines, comprised more than 60% of total swordfish catches in the Indian Ocean in recent years. The remaining catches mainly came from coastal longline (~22%) and gillnets (~13%) (**Fig. 2**).
- **Main fleets (average catches 2015-19): o**ver 63% of swordfish catches are accounted for by four fleets: Sri Lanka (longline-gillnet): ~25%; Taiwan,China (longline): ~21%; India (coastal longline):~9%; EU,Spain (swordfish-targeted longline): ~9%.

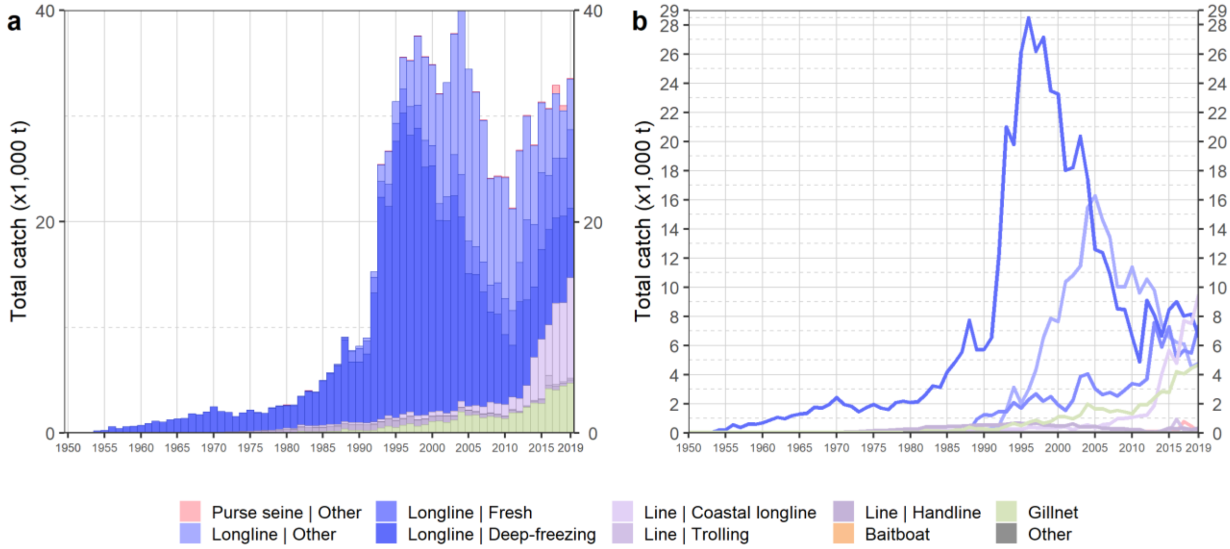

Fig. 1. Annual time series of (a) cumulative and (b) individual nominal catches (t) by fishery for swordfish during 1950–2019. <u>Longline|Other</u>: Swordfish and sharks-targeting longlines; <u>Longline|Fresh</u>: fresh longline; <u>Longline|Deep-freezing</u>: deep-freezing longline; Line|Coastal longline: coastal longline; <u>Gillnet</u>: coastal and offshore gillnets, driftnet; <u>Other</u>: all remaining gears

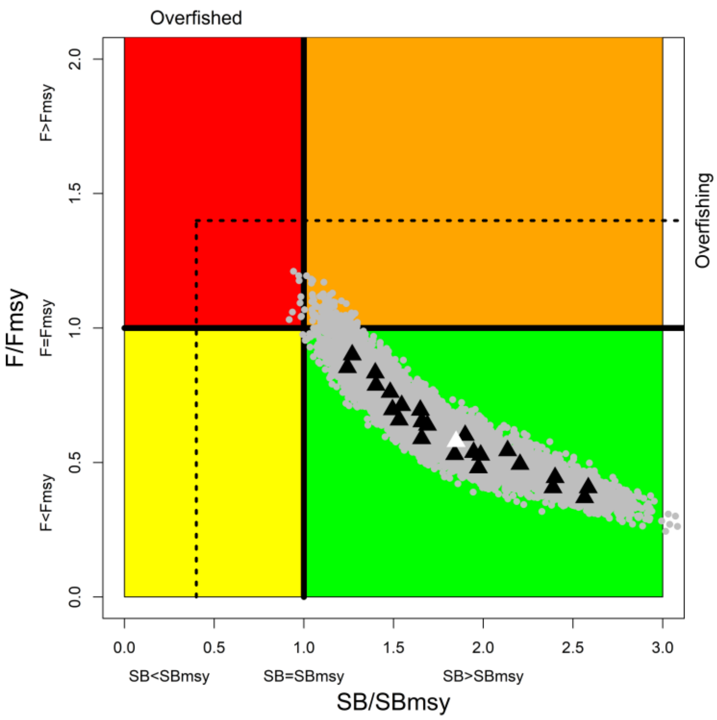

Fig. 2. Swordfish: current stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the final model grid. Triangles represent MPD estimates from individual models (white triangle represent the estimate from the basic model). Grey dots represent uncertainty from individual models. The dashed lines represent limit reference points for Indian Ocean swordfish (SB_{lim} = 0.4 SB_{MSY} and F_{lim} = 1.4*FMSY)

Table 2. Swordfish: SS3 aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of exceeding the MSY-based target reference points for five constant catch projections relative to 2018* catch level (30,847 t), 0%, ± 20%, ± 40%) projected for 10 years

Pr ($SB<SB_{MSY}$)

Catch	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
60%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100%	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02
120%	0.00	0.00	0.01	0.02	0.03	0.06	0.08	0.11	0.13	0.18
140%	0.00	0.01	0.01	0.04	0.10	0.17	0.25	0.32	0.40	0.47

Pr ($F>F_{MSY}$)

Catch	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
60%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100%	0.02	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.06	0.07
120%	0.10	0.13	0.18	0.21	0.26	0.30	0.32	0.35	0.38	0.42
140%	0.25	0.34	0.44	0.51	0.57	0.62	0.66	0.70	0.73	0.78

** 2018 catches, at the time of the last swordfish assessment conducted in 2020.*

APPENDIX VII - [DRAFT] RESOURCE STOCK STATUS SUMMARIES – BLACK MARLIN

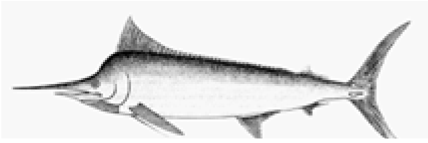

TABLE A8. Black marlin: Status of black marlin (*Makaira indica*) in the Indian Ocean.

Area[1]	Indicators		2021 stock status determination
Indian Ocean	Catch 2019 (t)[2] Average catch 2015–2019 (t)	18,068 18,721	
	MSY (1,000 t) (95% CI) F_{MSY} (95% CI) B_{MSY} (1,000 t) (95% CI) $F_{current}/F_{MSY}$ (95% CI) $B_{current}/B_{MSY}$ (95% CI) $B_{current}/B_0$ (95% CI)	17.30 (11.00 – 35.02) 0.20 (0.12 - 0.34) 87.39 (53.82-167.70) 0.53 (0.22 – 1.05) 1.98 (1.42 – 2.57) 0.73 (0.53 – 0.95)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence
[2] Proportion of 2019 catch fully or partially estimated by the IOTC Secretariat: 37%

Colour key	Stock overfished (B_{year}/B_{MSY}< 1)	Stock not overfished (B_{year}/B_{MSY}≥ 1)
Stock subject to overfishing (F_{year}/F_{MSY}> 1)		
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)		
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. A stock assessment based on JABBA, a Bayesian state-space production model (age-aggregated), was conducted in 2021 for black marlin. The relative point estimates for this assessment are F/F_{MSY}=0.53 (0.22-1.05) and B/B_{MSY}=1.98 (1.42-2.57). The Kobe plot (Fig. 2) indicated that the stock is not **subject to overfishing** and is currently not **overfished** (Table A8; Fig. 2), however these status estimates are subject to a high degree of uncertainty. The recent sharp increases in total catches (e.g., from 13,000 t in 2012 to over 22,000 t by 2016), and conflicts in information between CPUE and catch data lead to large uncertainties in the assessment outputs. Similar uncertainties were observed in the 2018 assessment of black marlin, which caused the point estimate of the stock status to change from the red (2016) to the green (2018) zone of the Kobe plot without any evidence of a rebuilding trend. **Since 2018, there has been no discernable improvement in the data available for black marlin and the subsequent assessment outputs remain uncertain and should be interpreted with caution**. **As such, there is no reasonable justification to change the stock status from "Not assessed/Uncertain".**

Outlook. While the recent high catches seem to be mainly due to developing coastal fisheries operating in the core habitat of the species (mainly IR.Iran, India and Sri Lanka), the CPUE indicators are from industrial fleets operating mostly offshore on the edges of the species' distribution. The outlook is likely to remain uncertain in the absence of CPUE indices from gillnet and coastal longline fleets to inform stock assessment models. Moreover, catches remain substantially higher than the limits stipulated in Res 18/05 and are a cause for concern as this will likely continue to drive the population towards overfished status.

Management advice. The 2019 catches (18,068 t) (Fig. 1) are substantially higher than the MSY limits stipulated in Res (18/05) which is 9,932 t. The Commission should provide mechanisms to ensure that catch limits are not exceeded by all concerned fisheries. Projections were not carried out due to the poor predictive capabilities identified in the assessment diagnostics.

The following key points should be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the whole Indian Ocean is 17,300 t.
- **Provisional reference points**: Although the Commission adopted reference points for swordfish in Resolution 15/10 *on target and limit reference points and a decision framework*, no such interim reference points nor harvest control rules have been established for black marlin.
- **Main fishing gears (average catches 2015-19)**: black marlin are largely considered to be a non-target species of industrial and artisanal fisheries. Gillnets account for more than 53% of total catches in the Indian Ocean, followed by coastal longline, troll and handlines (32%), with remaining catches mostly recorded under longlines (11%) (**Fig. 1**).
- **Main fleets (average catches 2015-19): m**ore than 75% of the total catches of black marlin are accounted for by three fleets: I.R. Iran (gillnet): 32%; India (gillnet and coastal longline): 24%; Sri Lanka (gillnet and fresh longline): 20%.

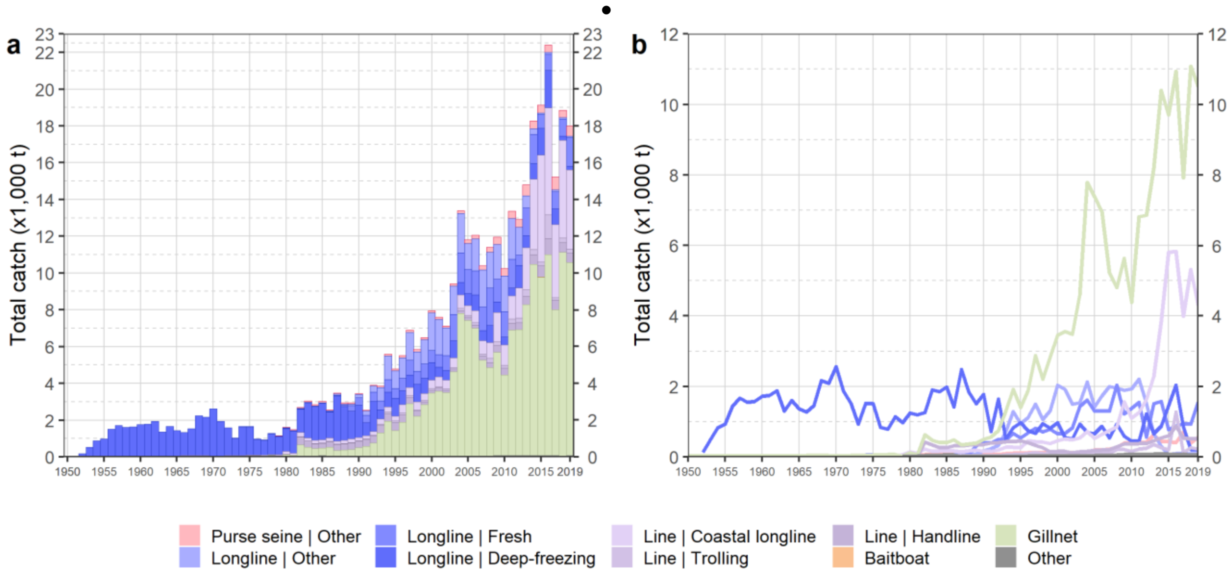

Fig. 1. Annual time series of (a) cumulative and (b) individual nominal catches (t) by fishery for black marlin during 1950–2019. Longline: deep-freezing and fresh longlines, swordfish and sharks-targeted longlines; Line: coastal longline, hand line, troll line; Gillnet: coastal and offshore gillnets, driftnet; Other: all remaining gears

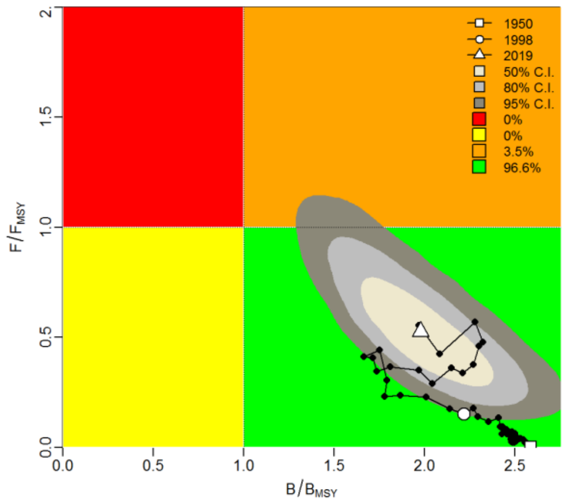

Fig. 2. Black marlin: JABBA Indian Ocean assessment Kobe plots for black marlin (contours are the 50, 80 and 95 percentiles of the 2019 estimate). Black line indicates the trajectory of the point estimates for the total biomass ratio (B/B_{MSY}) and fishing mortality ratio (F/F_{MSY}) for each year 1950–2019.

APPENDIX VIII - [DRAFT] RESOURCE STOCK STATUS SUMMARIES – BLUE MARLIN

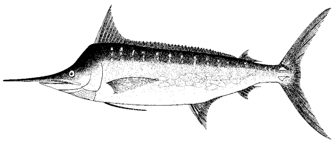

Table 1. Status of blue marlin (*Makaira nigricans*) in the Indian Ocean

Area[1]	Indicators		2021 stock status determination
Indian Ocean	Catch 2019[2] (t)	8,486	87%*
	Average catch 2015-2019 (t)	8,988	
	MSY (1,000 t) (80% CI)	9.98 (8.18 –11.86)	
	F_{MSY} (80% CI)	0.21 (0.13 – 0.35)	
	B_{MSY} (1,000 t) (80% CI)	47 (29.9 – 75.3)	
	F_{2017}/F_{MSY} (80% CI)	1.47 (0.96 – 2.35)	
	B_{2017}/B_{MSY} (80% CI)	0.82 (0.56 – 1.15)	
	B_{2017}/B_0 (80% CI)	0.41 (0.28 – 0.57)	

[1] Boundaries for the Indian Ocean are defined as the IOTC area of competence
[2] Proportion of 2019 catch estimated or partially estimated by IOTC Secretariat: 24.7%
* 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 (B_{year}/B_{MSY}< 1)	Stock not overfished (B_{year}/B_{MSY}≥ 1)
Stock subject to overfishing (F_{year}/F_{MSY}> 1)	**87%**	**10%**
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	**0%**	**3%**
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. Stock status based on the Bayesian State-Space Surplus Production model JABBA suggests that there is an 87% probability that the Indian Ocean blue marlin stock in 2017 is in the red zone of the Kobe plot, indicating the stock is **overfished** and **subject to overfishing (**B_{2017}/B_{MSY}=0.82 and F_{2017}/F_{MSY}=1.47) as shown in **Table 1** and **Fig. 2**. The most recent catch is lower than the estimate of MSY ($Catch_{2019}$ = 8,486 t; MSY = 9,984 t). The previous assessment of blue marlin concluded that in 2015 the stock was subject to overfishing but not overfished. The change in stock status can be attributed to increased catches for the period 2015-2017 as well as improved standardisation of CPUE indices, which includes the area disaggregation of JPN and TWN indices to account for fleet dynamics.

Outlook. The B_{2017}/B_{MSY} trajectory declined from the mid-1980s to 2008 and a steady increase of F/F_{MSY} since the mid-1980s has continued unabated. Periodic data conflict between the CPUE indices included in the assessment, particularly JPN and TWN, inflate uncertainty in B_{2017}/B_{MSY} and F_{2017}/F_{MSY} point estimates. However, a 'drop one' sensitivity analysis indicated that omitting any of the CPUE time-series would not alter the stock status.

Management advice. The current catches of blue marlin (average of 8,988 t in the last 5 years, 2015-2019) are lower than MSY (9,984 t). The assessment conducted in 2017 indicated that the stock was overfished and subject to overfishing. In order to achieve the Commission objectives of being in the green zone of the Kobe Plot by 2027 (F_{2027} < F_{MSY} and B_{2027} > B_{MSY}) with at least a 60% chance, the catches of blue marlin would have to be reduced by 35% compared to the average of the last 3 years, to a maximum value of approximately 7,800 t.

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the Indian Ocean blue marlin stock is 9,984 t (estimated range 8,180–11,860 t).
- **Provisional reference points**: although the Commission adopted reference points for swordfish in Resolution 15/10 *on target and limit reference points and a decision framework*, no such interim reference points, nor harvest control rules have been established for blue marlin.
- **Main fishing gear (average catches 2015-19)**: blue marlin are largely considered to be a non-target species of industrial and artisanal fisheries. Longline catches account for around 68% of total catches in the Indian Ocean, followed by gillnets (15%), with remaining catches recorded under coastal longline, troll and handlines (**Fig. 1**).
- **Main fleets (average catches 2015-19):** around 70% of the total catches of blue marlin are accounted for by three fleets: Taiwan,China (longline): 43%; Sri Lanka (gillnet, hook and line and longline): 21% and Indonesia (longline and hook-and-line): 7%.

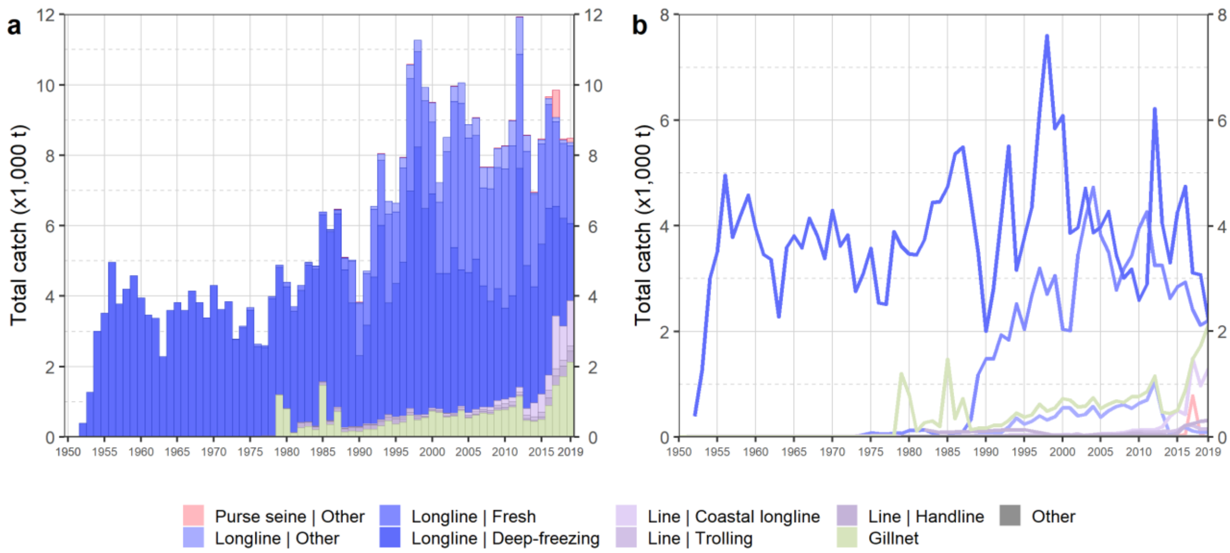

Fig. 1. Annual time series of (a) cumulative and (b) individual nominal catches (t) by fishery for blue marlin during 1950–2019. Longline: deep-freezing and fresh longlines, swordfish and sharks-targeted longlines; Line: coastal longline, handline, troll line; Gillnet: coastal and offshore gillnets, driftnet; Other: all remaining gears

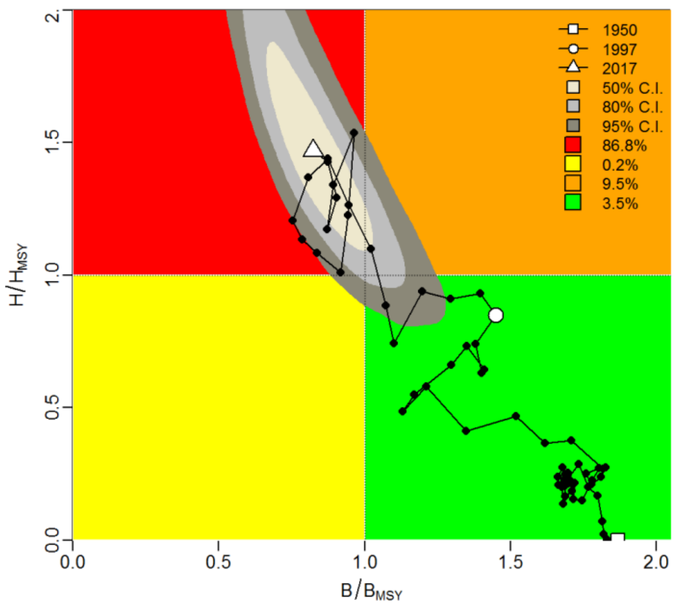

Fig. 2. Kobe stock status plot for the Indian Ocean stock of blue marlin, from the final JABBA base case (the black line traces the trajectory of the stock over time. Contours represent the smoothed probability distribution for 2018 (isopleths are probability relative to the maximum)

Table 2. Blue Marlin: Indian Ocean JABBA Kobe II Strategy Matrix. Probability (percentage) of achieving the green quadrant of the KOBE plot nine constant catch projections, with future catch assuming to be 30–110% (in increments of 10%) of the 2017 catch level (12,029 MT)

TAC | Year	2019	2020	2021	2022	2023	2024	2025	2026	2027
30% (3609)	20	39	58	71	81	87	91	93	95
40% (4812)	20	36	51	63	72	79	83	87	90
50% (6014)	21	33	44	54	62	68	73	77	81
60% (7217)	20	29	38	45	51	56	60	64	67
70% (8420)	20	26	32	37	41	45	47	50	52
80% (9623)	20	23	26	28	30	31	33	34	35
90% (10826)	17	18	19	19	20	20	20	20	20
100% (12029)	11	11	11	10	10	10	10	9	9
110% (13232)	7	6	6	6	5	5	4	4	4

APPENDIX IX - [DRAFT] RESOURCE STOCK STATUS SUMMARIES – STRIPED MARLIN

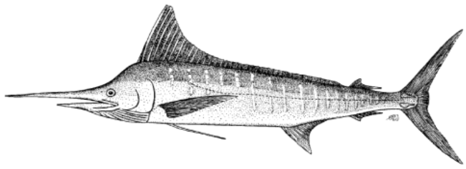

Table 1. Status of striped marlin (*Tetrapturus audax*) in the Indian Ocean

Area[1]	Indicators		2021 stock status determination
Indian Ocean	Catch 2019[2] (t) Average catch 2015-2019 (t)	3,001 3,477	**100%***
	MSY (1,000 t) (JABBA)	4.60 (4.12 - 5.08)[3]	
	MSY (1,000 t) (SS3)	4.82 (4.48 - 5.16)	
	F_{MSY} (JABBA)	0.26 (0.20–0.33)	
	F_{MSY} (SS3)	0.23 (0.23 - 0.23)	
	$F_{current}/F_{MSY}$ (JABBA)	2.04 (1.35 - 2.93)	
	$F_{current}/F_{MSY}$ (SS3)	3.93 (2.30 - 5.31)	
	$B_{current}/B_{MSY}$ (JABBA)	0.32 (0.22 - 0.51)	
	$SB_{current}/SB_{MSY}$ (SS3)[4]	0.47 (0.35 - 0.63)	
	$B_{current}/B_0$(JABBA)	0.12 (0.10 – 0.19)	
	$SB_{current}/SB_0$ (SS3)	0.06 (0.05 - 0.08)	

[1] Boundaries for the Indian Ocean are defined as IOTC area of competence
[2] Proportion of 2019 catch estimated or partially estimated by IOTC Secretariat: 19%
[3] JABBA estimates are the range of central values shown in Fig. 2
[4] SS3 is the only model that used SB/SB_{MSY}, all others used B/B_{MSY}
* 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 (B_{year}/B_{MSY}< 1)	Stock not overfished (B_{year}/B_{MSY}≥ 1)
Stock subject to overfishing (F_{year}/F_{MSY}> 1)	**100%**	**0.0%**
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	**0.0%**	**0.0%**
Not assessed/Uncertain		

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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. In 2021 a stock assessment was conducted based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). Both models were generally consistent with regards to stock status and confirmed the results from 2012, 2013, 2015, 2017 and 2018 assessments, indicating that the stock is subject to overfishing ($F>F_{MSY}$) and is overfished, with the biomass being below the level which would produce MSY ($B<B_{MSY}$) for over a decade. On the weight-of-evidence available in 2021, the stock status of striped marlin is determined to be ***overfished*** and ***subject to overfishing*** (**Table 1**; **Fig. 1**).

Outlook. Biomass estimates of the Indian Ocean striped marlin stock have likely been below BMSY since the late 90's – the stock has been severely depleted (B/B_0 = 0.12; JABBA model). The outlook is pessimistic, and a substantial decrease in fishing mortality is required to ensure a reasonable chance of stock recovery in the foreseeable future (**Table 2**). It should be noted that point estimates from SS3 indicate that F_{curr}/F_{MSY} are higher than those estimated by JABBA.

Management advice. Current or increasing catches have a very high risk of further decline in the stock status. The current 2019 catches (3,001 t; **Fig. 1**) are lower than MSY (4,601 t) but the stock has been overfished for more than a decade and is now in a highly depleted state. If the Commission wishes to recover the stock to the green quadrant of the Kobe plot with a probability ranging from 60% to 90% by 2026 as per Resolution 18/05, it needs to provide mechanisms to ensure the maximum annual catches remain between 900 t – 1,500 t (**Table 3**).

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY)**: estimates for the Indian Ocean stock are highly uncertain and estimates range between 4,270 t – 5,180 t. However, the current biomass is well below the B_{MSY} reference point and fishing mortality is in excess of F_{MSY} at recent catch levels.
- **Provisional reference points**: although the Commission adopted reference points for swordfish in Resolution 15/10 *on target and limit reference points and a decision framework*, no such interim reference points have been established for striped marlin.
- **Main fishing gears (average catches 2015-19)**: striped marlin is largely considered to be a non-target species of industrial fisheries. Gillnets account for ~47% of total catches in the Indian Ocean, followed by longlines (~43%). The remaining catches are mostly recorded under coastal longline (**Fig. 1**).
- **Main fleets (average catches 2015-19):** around 75% of the total catches of striped marlin are accounted for by four fleets: I.R. Iran (gillnet): 26%; Pakistan (gillnet): 18%; Taiwan,China (longline): 17% and Indonesia (coastal and offshore longline): 16%.

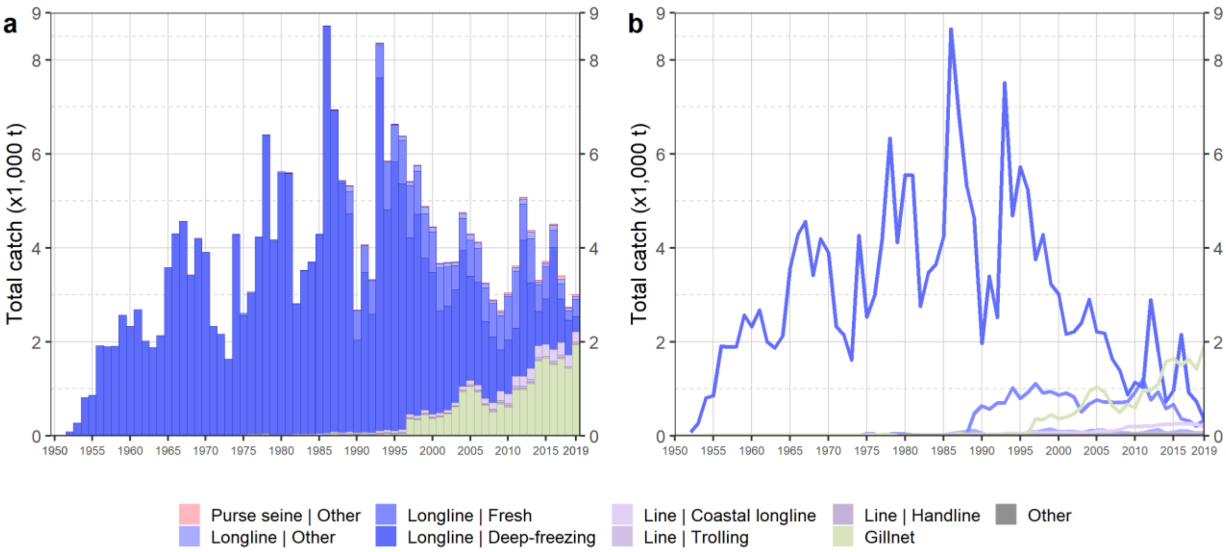

Fig. 1. Annual time series of (a) cumulative and (b) individual nominal catches (MT) by fishery for striped marlin during 1950–2019. Longline: deep-freezing and fresh longlines, swordfish and sharks-targeted longlines; Line: coastal longline, handline, troll line; Gillnet: coastal and offshore gillnets, driftnet; Other: all remaining gears

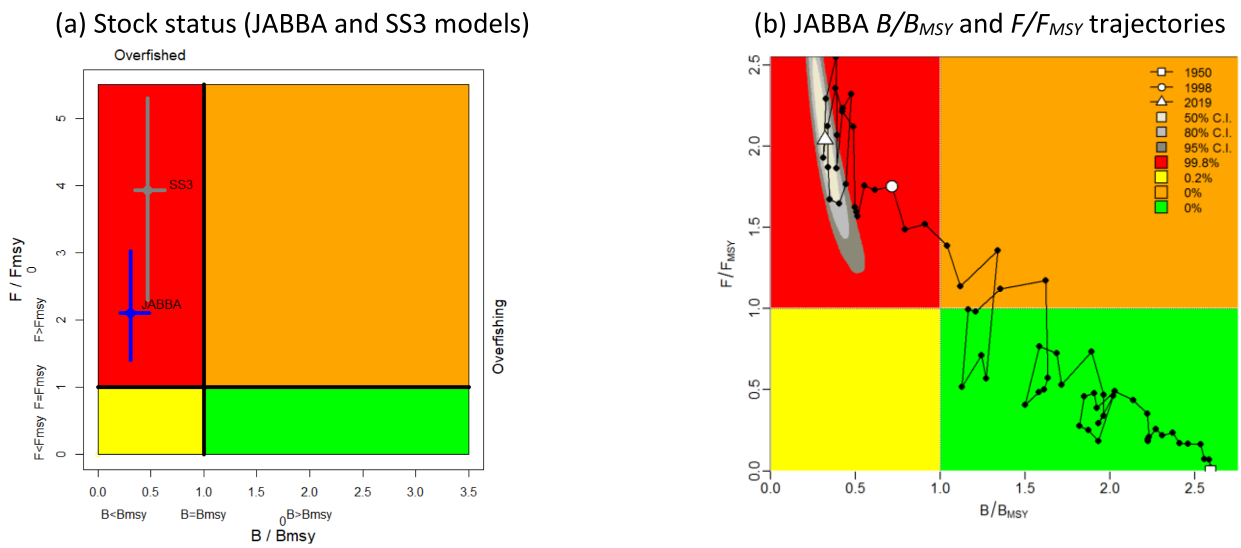

Fig. 2. (a) Striped marlin: Stock status from the Indian Ocean assessment JABBA (Bayesian State Space Surplus Production Model) and SS3 models with the confidence intervals (left); (b) Trajectories (1950-2019) of B/B_{MSY} *and* F/F_{MSY} from the JABBA model. NB: SS3 refers to SB/SB_{MSY} while the JABBA model's output refers to B/B_{MSY}

Table 2. Striped marlin: JABBA Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target reference points for nine constant catch projections relative to the 2019 catch level (3,001 t)*, ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the 2019 catch of 3,001 t) and probability (%) of violating MSY-based target reference points (Btarg = B_{MSY}; Ftarg = F_{MSY})**								
	60% (1,801 t)	**70%** (2,101 t)	**80%** (2,401 t)	**90%** (2,701 t)	**100%** (3,001 t)	**110%** (3,301 t)	**120%** (3,602 t)	**130%** (3,902 t)	**140%** (4,202 t)
$B_{2022} < B_{MSY}$	100	100	100	100	100	100	100	100	100
$F_{2022} > F_{MSY}$	21	49	75	90	97	99	100	100	100
$B_{2029} < B_{MSY}$	6	18	39	62	82	93	98	100	100
$F_{2029} > F_{MSY}$	0	2	9	29	57	81	94	99	100

Table 3. Striped marlin: Probability (percentage) of achieving the KOBE green quadrat from 2022-2029 for a range of constant catch projections (JABBA).

TAC | Year	2022	2023	2024	2025	2026	2027	2028	2029
300	4	31	75	95	99	100	100	100
600	2	22	62	89	98	100	100	100
900	1	15	48	79	94	98	100	100
1201	1	9	33	65	87	96	99	100
1501	1	6	22	49	73	89	96	98
1801	0	3	13	32	55	75	87	94
2101	0	2	7	19	37	55	71	82
2401	0	1	3	10	21	35	49	61
2701	0	0	2	5	10	18	28	38
3001	0	0	1	2	4	8	13	18

APPENDIX X - [DRAFT] RESOURCE STOCK STATUS SUMMARY – INDO-PACIFIC SAILFISH

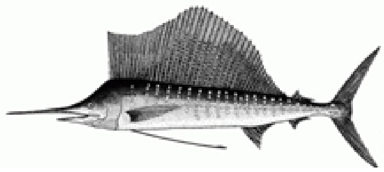

Table 1. Status of Indo-Pacific sailfish (*Istiophorus platypterus*) in the Indian Ocean

Area[1]	**Indicators**		**2021 stock status determination**
Indian Ocean	Catch 2019[2] (t) Average catch 2015-2019 (t)	29,635 30,263	
	MSY (1,000 t) (80% CI) F_{MSY} (80% CI) B_{MSY} (1,000 t) (80% CI) F_{2017}/F_{MSY} (80% CI) B_{2017}/B_{MSY} (80% CI) B_{2017}/B_0 (80% CI)	23.9 (16.1 – 35.4) 0.19 (0.14 - 0.24) 129 (81–206) 1.22 (1 – 2.22) 1.14 (0.63 – 1.39) 0.57 (0.31 – 0.70)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence
[2] Proportion of 2019 catch estimated or partially estimated by IOTC Secretariat: 42.4%

Colour key	Stock overfished (B_{year}/B_{MSY}< 1)	Stock not overfished (B_{year}/B_{MSY}≥ 1)
Stock subject to overfishing (F_{year}/F_{MSY}> 1)	17%	60%
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	5%	16%
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

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Stock status. No new stock assessment for Indo-Pacific sailfish was carried out in 2021, thus, the stock status is determined on the basis of the 2019 assessment using the C-MSY model. The data poor stock assessment techniques indicated that F was above F_{MSY} (F/F_{MSY}=1.22) and B is above B_{MSY} (B/B_{MSY}=1.14). Another alternative model using the Stock Reduction Analysis (SRA) techniques produced similar results. The stock appears to show a continued increase in catches which is a cause of concern (**Fig. 1**), indicating that fishing mortality levels may be becoming too high (**Fig. 2**). However, both assessment models rely on catch data only, and the catch series is highly uncertain. In addition, aspects of the biology, productivity and fisheries for this species, combined with the data poor status on which to base a more formal assessment, are also a cause for concern. On the weight-of-evidence available in 2019, the stock status cannot be assessed and is determined to be uncertain.

Outlook. Catches in 2010 and since 2013 have exceeded the estimated MSY, and have also increased by 62% between 2007 and 2019. This increase in coastal gillnet catches and fishing effort in recent years is a substantial cause for concern for the Indian Ocean stock, however there is not sufficient information to evaluate the effect this will have on the resource. It is also noted that 2019 catches (29,635 t) exceed the catch limit prescribed in Resolution 18/05 (25,000 t).

Management advice. The catch limits as stipulated in Resolution 18/05 have been exceeded. The Commission should provide mechanisms to ensure that catch limits are not exceeded by all concerned fisheries. Research emphasis on further developing possible CPUE indicators from gillnet fisheries, and further exploration of stock assessment approaches for data poor fisheries are warranted. Given the limited data being reported for coastal gillnet fisheries, and the importance of sports fisheries for this species, efforts must be made to rectify these information gaps. The lack of catch records in the Persian Gulf should also be examined to evaluate the degree of localised depletion in Indian Ocean coastal areas.

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY):** estimate for the Indian Ocean stock is 23,900 t.
- **Provisional reference points:** although the Commission adopted reference points for swordfish in Resolution 15/10 on target and limit reference points and a decision framework, no such interim reference points have been established for Indo-Pacific sailfish.
- **Main fishing gear (average catches 2015-19)**: gillnets account for around 70% of total catches in the Indian Ocean, followed by lines (coastal longline, troll and hand lines) (24%), with remaining catches recorded under longlines and other gears (**Fig. 1**).
- **Main fleets (average catches 2015-19):** if we exclude the Republic of Tanzania (whose catch data have been repeated in recent years by the Secretariat, due to the lack of explicit reporting from the country), then three quarters of the total catches of Indo-Pacific sailfish are accounted for by four countries situated in the Arabian Sea: I.R. Iran (gillnets): 34%; India (gillnets and coastal longline): 26%; Pakistan (gillnets): 8%; and Sri Lanka (gillnets and longlines): 8%.

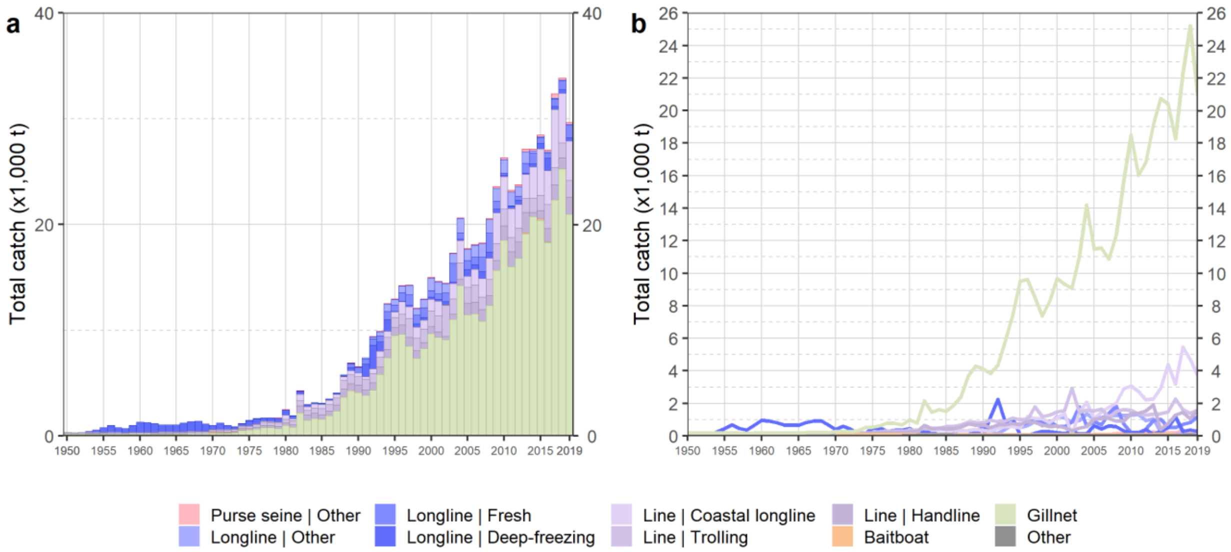

Fig. 1. Annual time series of (a) cumulative and (b) individual nominal catches (t) by fishery for Indo-Pacific sailfish during 1950–2019. <u>Longline</u>: deep-freezing and fresh longlines, swordfish and sharks-targeted longlines; <u>Line</u>: coastal longline, handline, troll line; <u>Gillnet</u>: coastal and offshore gillnets, driftnet; <u>Other</u>: all remaining gears

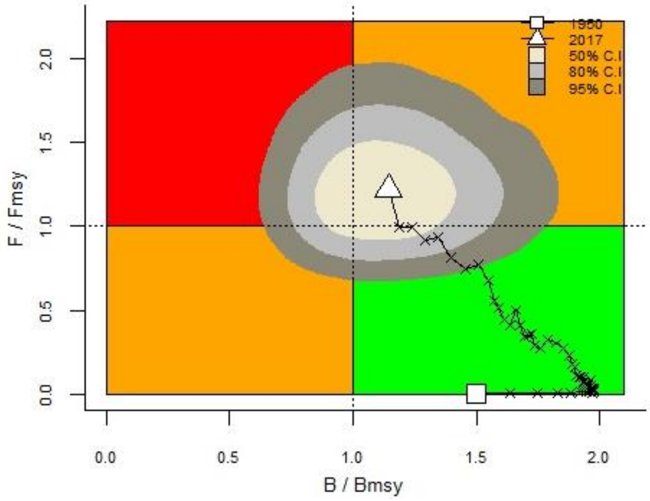

Fig. 2. Indo-Pacific sailfish: Kobe plot derived from the stock reduction analysis (C-MSY Method) (contours are the 50, 65 and 90 percentiles of the 2017 estimate). Black lines indicate the trajectory of the point estimates (black crosses) for the biomass ratio (B/B_{msy}) and fishing mortality ratio (F/F_{msy}) for each year 1950–2017

APPENDIX XI
WORKING PARTY ON BILLFISH PROGRAM OF WORK (2022–2026)

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**: High priority topics for obtaining the information necessary to develop stock status indicators for billfish in the Indian Ocean; and
- **Table 2**: Stock assessment schedule.

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

Topic in order of priority	Sub-topic and project	Timing				
		2022	**2023**	**2024**	**2025**	**2026**
1. Data mining and processing – (Development of subsequent CPUE indices)	Data on gillnet fisheries are available in Pakistan (and potentially other CPCs) and the recovery of this information and the development of gillnet CPUE indices would improve species assessments, particularly for: • Black marlin • Sailfish					
2. Biological and ecological information (incl. parameters for stock assessment and provide answers to the Commission)	Reproductive biology study CPCs to conduct reproductive biology studies, which are necessary for billfish throughout its range to determine key biological parameters including length-at-maturity, age-at-maturity and fecundity-at-age, which will be fed into future stock assessments, as well as provide advice to the Commission on the established Minimum Retention Sizes (Res 18-05, paragraphs 5 and 14c). (Priority: marlins and sailfish). Propose to have a two-day workshop to discuss the standard of billfish maturity staging inter-sessionally prior to the next WPB. Funding are needed to support the workshop participation of CPCs and expert(s) on billfish reproduction (expecting to have confirmation from the host organization).					
3. Stock structure (connectivity and diversity)	Continue work on determining stock structure of Swordfish, using complimentary data sources, including genetic and microchemistry information as well as other relevant sources/studies.					
Other Future Research Requirements (not in order of priority)						

1. Biological and ecological information (incl. parameters for stock assessment and provide answers to the Commission)	1.1 Age and growth research					
	1.1.1 CPCs to provide further research on billfish biology, namely age and growth studies including through the use of fish otolith or other hard parts, either from data collected through observer programs, port sampling or other research programs. (Priority: all billfishes: swordfish, marlins and sailfish)					
	1.2 Spawning time and locations					
	1.2.1 Collect gonad samples from billfish to confirm the spawning time and location of the spawning area that are presently hypothesized for each billfish species. This will also provide advice to the Commission on the request for alternative management measures (Res. 18-05, paragraph 6). Partially supported by EU, on-going support and collaboration from CPCs are required.					
2. Historical data review	2.1 Changes in fleet dynamics					
	2.1.1 Continue the work with coastal countries to address recent changes and/or increases of marlins catches especially in some coastal fleets. The historical review should include as much explanatory information as possible regarding changes in fishing areas, species targeting, gear changes and other fleet characteristics to assist the WPB understand the current fluctuations observed in the data and very high increases in some species (e.g., black marlin mainly due to very high catches reported by India in recent years). The possibility of producing alternative catch histories should also be explored. Priority countries: India, Pakistan, Iran, I.R., Indonesia.					
	2.2 Species identification					
	2.2.1 The quality of the data available at the IOTC Secretariat on marlins (by species) is likely to be compromised by species miss-identification. Thus, CPCs should review their historical data in order to identify, report and correct (if possible) potential identification problems that are detrimental to any analysis of the status of the stocks. Consider the application of DNA-Barcoding technology for billfish species identification.					

	2.3 Tagging data recovery from alternate sources (e.g. Billfish foundation) to supplement IOTC tagging database information.	▒	▒			
3. Observer Training to improve data collection for billfish (and other) species	3.1 Training for observers with respect to billfish species identification, various length measurements and biological sampling (gonads, spines and otoliths).	▒	▒	▒		
4. CPUE standardization	4.1 Develop and/or revise standardized CPUE series for each billfish species and major fisheries/fleets for the Indian Ocean.					
	4.1.1 Swordfish: Priority LL fleets: Taiwan,China, EU(Spain, Portugal, France), Japan, Indonesia, South African	▒	▒			
	4.1.2 Striped marlin: Priority fleets: Japan, Taiwan,China	▒	▒			
	4.1.3 Black marlin: Priority fleets: Longline: Taiwan,China; Gillnet: I.R. Iran, Sri Lanka, Indonesia	▒	▒			
	4.1.4 Blue marlin: Priority fleets: Japan, Taiwan,China, Indonesia	▒	▒			
	4.1.5 I.P. Sailfish: Priority fleets: Priority gillnet fleets: I.R. Iran and Sri Lanka; Priority longline fleets: EU(Spain, Portugal, France), Japan, Indonesia;	▒	▒			
	4.1.6 Joint analysis of operational catch and effort data from Indian Ocean longline fleets as recommended by WPM	▒	▒			
5. Stock assessment / Stock indicators	5.1 Workshops on techniques for assessment including CPUE estimations for billfish species in 2021 and 2022. Priority fleets: Gillnet fisheries	▒	▒			
6. Target and Limit reference points	6.1 Assessment of the interim reference points as well as alternatives: Used when assessing the Swordfish stock status and when establishing the Kobe plot and Kobe matrices.	▒	▒	▒		
7. Management measure options	7.1 To advise the Commission, on potential management measures having been examined through the Management Strategy Evaluation (MSE) process.					
	7.1.1 These management measures will therefore have to ensure the achievement of the conservation and optimal utilization of stocks as laid down in article V of the Agreement for the establishment of the IOTC and more particularly to ensure that, in as short a period as possible and no later than 2020, (i) the fishing mortality rate does not exceed the fishing mortality rate allowing the	▒	▒			

	stock to deliver MSY and (ii) the spawning biomass is maintained at or above its MSY level.					
8. Close-Kin Mark-Recapture studies	Review of CKMR applicability for Billfish species and potential feasibility study					
9. Stock structure (connectivity and diversity)	Tagging research (PSAT tags) to determine connectivity, movement rates and mortality estimates of billfish (Priority species: swordfish). Similar projects have been partially funded by EU, with a focus on epipelagic species. More tags are needed for swordfish.					

Table 2. Assessment schedule for the IOTC Working Party on Billfish (WPB)

Species	2022	2023	2024	2025	2026
Black marlin			**Full assessment**		
Blue marlin	**Full assessment**			**Full assessment**	
Striped marlin			**Full assessment**		
Swordfish	**Indicators****	**Full assessment**		**Indicators****	**Full assessment**
Indo-Pacific sailfish	**Full assessment***			**Full assessment***	

* Including data poor stock assessment methods; Note: the assessment schedule may be changed depending on the annual review of fishery indicators, or SC and Commission requests.
** Including biological parameters, standardized CPUE, and other fishery trend.

APPENDIX XII
CONSOLIDATED RECOMMENDATIONS OF THE 19TH SESSION OF THE WORKING PARTY ON BILLFISH

Note: Appendix references refer to the Report of the 19th Session of the Working Party on Billfish (IOTC–2021–WPB19–R)

The following are the complete recommendations from the WPB19 to the Scientific Committee,:

WPB19.01 (para 4): **RECALLING** that one of the Indian Ocean billfish species (shortbill spearfish, *Tetrapturus angustirostris*) is currently not listed among the species managed by IOTC, and considering the ocean-wide distribution of this species, its highly-migratory nature, and that it is a common bycatch in IOTC managed fisheries, the WPB reiterated its previous **RECOMMENDATION** that the Scientific Committee consider requesting the Commission to include it in the list of species to be managed by the IOTC. The WPB further **NOTED** that as this species has no management in place, any fleet catching this species as bycatch could be considered to be engaging in IUU fishing. As such the WPB **STRONGLY URGES** the SC to endorse this recommendation and encourage CPCs to address this issue at the next meeting of the Commission.

Revision of the WPB Program of work (2022–2026)

WPB19.02 (para 118): The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2022–2026), as provided at Appendix XI.

Date and place of the 20th and 21st Sessions of the Working Party on Billfish

WPB19.03 (para 125) The WPB **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 WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB20 in 2022.. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB, with the WPEB taking place after the WPB in 2022.

Review of the draft, and adoption of the Report of the 19th Session of the Working Party on Billfish

WPB19.04 (para. 126): The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB19, provided at Appendix XII, as well as the management advice provided in the draft resource stock status summary for each of the five billfish species under the IOTC mandate, and the combined Kobe plot for the five species assigned a stock status in 2021 (Fig. 4):

- Swordfish (*Xiphias gladius*)– Appendix VI
- Black marlin (*Makaira indica*) – Appendix VII
- Blue marlin (*Makaira nigricans*) – Appendix VIII
- Striped marlin (*Tetrapturus audax*) – Appendix IX
- Indo-Pacific sailfish (*Istiophorus platypterus*) – Appendix X

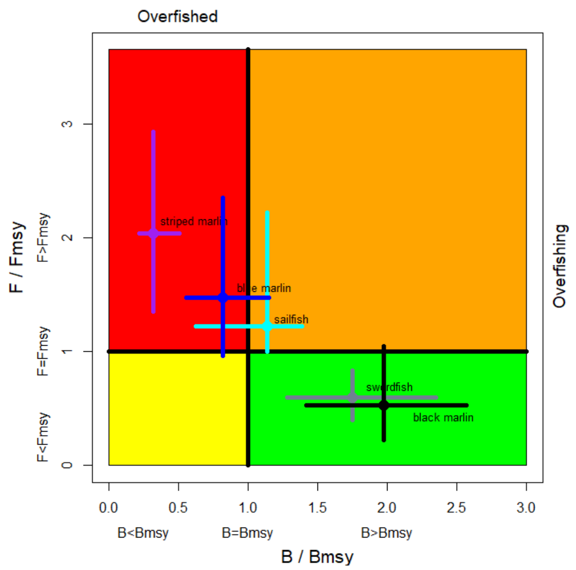

Fig. 4. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2017, 2018, 2019, 2020 and 2021 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs.