Report of the 21st Session of the IOTC Working Party on Billfish

La Saline-les-Bains, Reunion, 6–9 September 2023

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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 21st Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Billfish (WPB) was in La Saline-les-Bains, Reunion, using a hybrid format from the 6 to 9 September 2023. A total of 97 participants (51 in 2022, 55 in 2021 and 55 in 2020) attended the Session (of which 31 attended in person). The list of participants is provided at Appendix I. The meeting was opened by the Vice Chairperson, Dr Jie Cao (China), who welcomed participants.

The following are the complete recommendations from the WPB21 to the Scientific Committee, which are also provided at Appendix X:

Review of new information on other billfishes biology, stock structure, fisheries and associated environmental data

WPB21.01 (para 132): Based on this presentation the WPB **AGREED** that there is evidence that the species is being caught in IOTC fisheries and that the species population size may be declining. As such the WPB reiterated its previous **RECOMMENDATION** that shortbill spearfish be included as an IOTC species.

Revision of the WPB Program of work (2024–2028)

WPB21.02 (para 142): The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2024–2028), as provided in Appendix IX.

Date and place of the 22nd and 23rd Sessions of the Working Party on Billfish

WPB21.03 (para 149): The WPB **NOTED** that in 2022, a two-day workshop to discuss the standard of billfish maturity staging inter-sessionally prior to the WPB was requested. As the funding for this workshop was approved by the Commission in 2023, the WPB **RECOMMENDED** that this workshop should take place immediately place prior to the next session of the WPB in 2024.

WPB21.04 (para 151): The WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB22 in 2024. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB. As the WPB are planning to hold a workshop immediately prior to the next WPB meeting, it was **REQUESTED** that the WPB once again take place before the WPEB in 2024.

Review of the draft, and adoption of the Report of the 21st Session of the Working Party on Billfish

WPB21.05 (para 152): The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB21, provided at Appendix X, 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 2023 (Fig. 3):

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

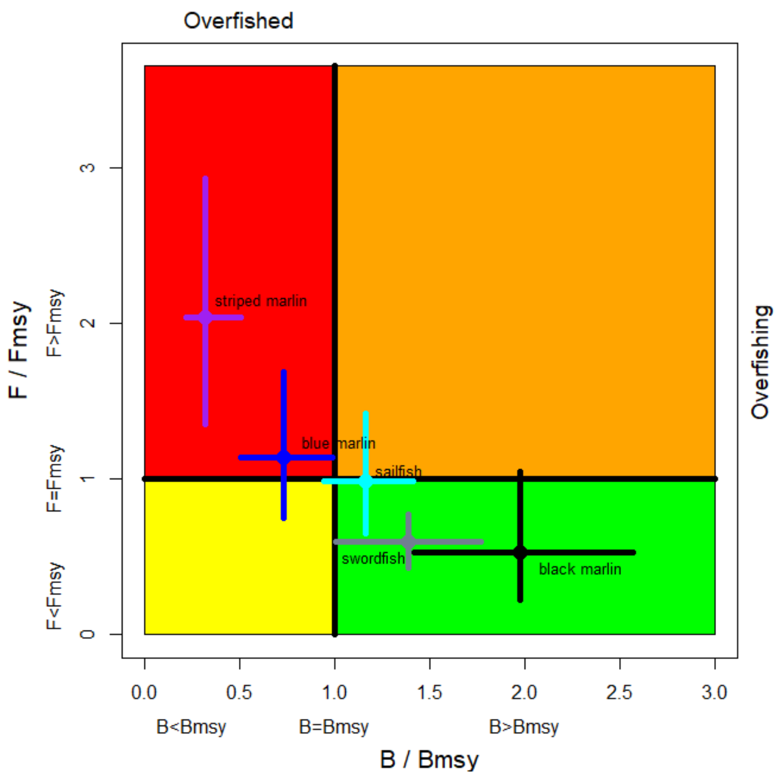

Fig. 3. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2018, 2019, 2021, 2022, and 2023 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in 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	2019	2020	2021	2022	2023	Advice to the Scientific Committee
Swordfish *Xiphias gladius*	Catch 2021 (t): 24,527 Average catch 2017-2021 (t): 31,226 MSY (1,000 t) (80% CI): 30 (26–33) F_{MSY} (80% CI): 0.16 (0.12–0.20) SB_{MSY} (1,000 t) (80% CI): 55(40–70) F_{2021}/F_{MSY} (80% CI): 0.60 (0.43–0.77) SB_{2021}/SB_{MSY} (80% CI): 1.39 (1.01–1.77) SB_{2021}/SB_{1950} (80% CI): 0.35 (0.32–0.37)					*97%*	***Stock status.*** In 2023 a new stock assessment was carried out for Swordfish in the IOTC area of competence to update the stock assessment undertaken in 2020. Two models were applied to the swordfish stock (ASPIC and Stock Synthesis (SS3)), with the SS3 stock assessment selected to provide scientific advice (as done previously). An update of the JABBA model was also conducted during the WPB meeting. The reported SS3 stock status is based on a grid of 48 model configurations designed to capture the uncertainty relating to steepness of the stock recruitment relationship (0.7, 0.8, and 0.9), recruitment variability (two levels), CPUE series (2 options), growth (2 options) and weighting of length composition data (two options). A number of the options included in the final grid were selected from a range of additional sensitivity runs that were conducted to explore uncertainties. Median spawning biomass in 2021 was estimated to be 35% (80% CI: 32-37%) of the unfished levels in 2021 and 1.39 (80% CI: 1.01-1.77) times higher than the level required to support MSY. Median fishing mortality in 2021 was estimated to be 60% (80% CI 43%-77%) of the FMSY level, and catch in 2021 (24,527 t) was well below the estimated MSY level of 29,856 t (80% CI: 26,319-33,393t). Taking into account the characterized uncertainty, and on the weight-of-evidence available in 2023, the swordfish stock is determined to be **not overfished** and **not subject to overfishing**. ***Management advice*.** The 2021 catches (23,237t at the time of the assessment) were significantly lower than the estimated MSY level (29,856 t). Under those levels of catches, the spawning biomass was projected to likely increase, with a high probability of maintaining at or above the SBMSY for the longer term. There is a very low risk of exceeding MSY-based reference points by 2031 if catches are maintained at 2021 levels (<1% risk that SB2031< SBMSY, and <1% risk that F2031> FMSY). Although the projections indicate that an increase of 40% or more from 2021 catch levels will not likely result in the biomass dropping below the SBMSY level for the longer term (with a 15% probability). Nevertheless, the Commission should consider monitoring the catches to ensure that the probability of exceeding the SBMSY target reference points in the long term remains minimal. Taking into account the differential CPUE and biomass trends between regions, the WPB noted that there is recurring evidence for localised depletion in the south western region (which appears to be more depleted than other regions) and suggests this should be further monitored. Click here for full stock status summary: Appendix IV
Black marlin *Makaira indica*	Catch 2021: 12,301 t Average catch 2017–2021: 16,000t MSY (1000 t) (95% CI): 17,301 (10,979 – 35,024) F_{MSY} (95% CI): 0.20 (0.12 - 0.34)						***Stock status.*** No new stock assessment was carried out for black marlin in 2023, thus the stock status is determined on basis of the 2021 assessment based on JABBA, a Bayesian state-space production model (using data up to 2019). 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 sharp increases in total catches (e.g., from 13,000 t in 2012 to over 22,000 t by 2016),

	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)						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 V
Blue marlin *Makaira nigricans*	Catch 2021: 6,138 t Average catch 2017–2021: 8,011 t MSY (1000 t) (80% CI): 8.74 (7.14 –10.72 F_{MSY} (80% CI): 0.24 (0.14 – 0.39) F_{2020}/F_{MSY} (80% CI): 1.14 (0.75 – 1.69) B_{2020}/B_{MSY} (80% CI): 0.73 (0.51 – 0.99) B_{2020}/B_{1950} (80% CI): 0.36 (0.26 – 0.50)					*72%*	***Stock status.*** No new stock assessment was carried out for blue marlin in 2023, thus the stock status is determined on basis of the 2022 assessment which was based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). Uncertainty in the biological parameters was still noted and as such the JABBA model (B_{2020}/B_{MSY} = 0.73, F_{2020}/F_{MSY} = 1/14) was selected as the base case as both models were consistent with regards to stock status. On the weight-of-evidence available in 2022, the stock is determined to be overfished and subject to overfishing. ***Management advice.*** The current catches of blue marlin (average of 7,964 t in the last 5 years, 2017-2021) are lower than MSY (8,740 t). The assessment conducted in 2022 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 20% compared to 2020 catch (7,126 t), to a maximum value of approximately 5,700 t. Click here for full stock status summary: Appendix VI
Striped marlin *Tetrapturus audax*	Catch 2021: 2,645 t Average catch 2017–2021: 2,936 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:*** No new stock assessment was carried out for striped marlin in 2023, thus the stock status is determined on basis of the 2021 assessment 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 VII
Indo-Pacific Sailfish *Istiophorus platypterus*	Catch 2021: 37,578 t Average catch 2017–2021: 32,491 t MSY (1,000 t) (80% CI): 25.9 (20.8 – 34.2) F_{MSY} (80% CI): 0.19 (0.15 - 0.24) B_{MSY} (1,000 t) (80% CI): 138 (108–186) F_{2019}/F_{MSY} (80% CI): 0.98 (0.65 – 1.42) B_{2019}/B_{MSY} (80% CI): 1.17 (0.94 – 1.42) B_{2019}/B_0 (80% CI): 0.58 (0.47 – 0.71)					**54%**	***Stock status:*** No new stock assessment was carried out for Indo-Pacific Sailfish in 2023, thus the stock status is determined on basis of the 2022 stock assessment based on JABBA, a Bayesian state-space production model. Data poor methods (C-MSY and SFA) applied to SFA in 2019 rely on catch data only, which is highly uncertain for this species, and resulted in the stock status determined to be uncertain. To overcome the lack of abundance indices for this species, this assessment incorporated length-frequency data to estimate annual Spawning Potential Ratio (SPR). Normalised annual estimates of SPR were assumed to be proportional to biomass and incorporated as an index of relative abundance in the JABBA model (assuming no trends in annual recruitment in the long term). This is a novel technique applied to overcome the paucity of abundance data for SFA. The results indicate that there has been a 41% decline in SPR since 1970. B/B_{MSY} declined consistently from the early-1980s, while F/F_{MSY} gradually increased from 1980, peaking in 2018 at 1.1. The latest (2019) estimate of B/B_{MSY} was 1.17, while the F/F_{MSY} estimate was 0.98. On the weight-of-evidence available in 2022, the stock status of Indo-Pacific Sailfish is determined to be **not overfished nor subject to overfishing.** ***Management advice*:** The catch limits as stipulated in Resolution 18/05 have been exceeded for two consecutive years since 2020. Thus, it is recommended that the Commission review the implementation and effectiveness of the measures contained in this Resolution and consider the adoption of additional conservation and management measures. 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 coastal gillnet and longline fisheries, and further exploration of stock assessment approaches for data poor fisheries are warranted. Given the limited data being reported for coastal 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. Click here for full stock status summary: Appendix VIII

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)		
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)		
Not assessed/Uncertain		

1. OPENING OF THE SESSION

1. The 21st Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Billfish (WPB) was in La Saline-les-Bains, Reunion, using a hybrid format from the 6 to 9 September 2023. A total of 97 participants (51 in 2022, 55 in 2021 and 55 in 2020) attended the Session (of which 31 attended in person). The list of participants is provided at Appendix I. The meeting was opened by the Vice Chairperson, Dr Jie Cao (China), 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 WPB21 are listed in Appendix III.

3. THE IOTC PROCESS: OUTCOMES, UPDATES AND PROGRESS

3.1 Outcomes of the 25th Session of the Scientific Committee

3. The WPB **NOTED** paper IOTC–2023–WPB21–03 which describes the main outcomes of the 25th Session of the Scientific Committee (SC25), specifically related to the work of the WPB:

"Report of the 20th Session of the Working Party on Billfish

*43. The SC **NOTED** the report of the 20th Session of the Working Party on Billfish (IOTC–2022–WPB20–R), including the consolidated list of recommendations provided as an appendix to the report. The meeting was attended by 51 participants (cf. 55 in 2021). No MPF funding was provided as the meeting was held online.*

*44. The SC **REMINDED** that its previous recommendation on the inclusion of shortbill spearfish (Tetrapturus angustirostris) as an IOTC species has not yet been addressed by the Commission and **REQUESTED** the WPB to collate more data on the species to support this recommendation which would require a revision of the IOTC Agreement.*

*45. The SC **NOTED** that a study was carried out to look at the inclusion of marine subsurface variables on swordfish habit modeling in the Indian Ocean. The study makes use of the Species Distribution Model (SDM), which employs three-dimensional environmental data to estimate species distribution and derive sub-surface parameters.*

*46. The SC **NOTED** that the next WPB meeting will be preceded by a two-day workshop on billfish reproductive biology studies. If time permits, the SC suggested that the workshop's scope be broadened to incorporate additional biological components (such as the age and growth research as specified in the program of work). The SC also acknowledged the advantages of compiling available biological studies and requested that a summary table of the CPCs' recent and/or ongoing research on billfish biology be provided at the next WPB meeting.*

7.2.1 Blue Marlin stock assessment

*47. The SC **NOTED** that a new stock assessment was conducted in 2022 based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). The SC further **NOTED** that uncertainty in the biological parameters was still apparent and as such the JABBA model (B_{2020}/B_{MSY} = 0.73, F_{2020}/F_{MSY} = 1.13) was selected as the base case as both models were consistent with regards to stock status.*

7.2.2 Indo-Pacific Sailfish stock assessment

*48. The SC **NOTED** that in 2022 a new stock assessment was conducted based on JABBA, a Bayesian state-space production model. Data poor methods applied to Indo-Pacific Sailfish in 2019 relied on catch data only, which is highly uncertain for this species, and resulted in the stock status determined to be uncertain. To overcome the lack of abundance indices for this species, this assessment incorporated length-frequency data to estimate annual Spawning Potential Ratio (SPR). Normalised annual estimates of SPR were assumed to be proportional to biomass and incorporated as an index of relative abundance in the JABBA model (assuming no trends in annual recruitment in the long term). This is a novel technique applied to overcome the paucity of abundance data for this species.*

49. *The SC **NOTED** that the new modelling approach has facilitated the use of additional information available for the species and provided additional insight into the Indo-Pacific sailfish stock status. As such, the SC **NOTED** that the stock status for Indo-Pacific sailfish has been revised from Unknown, to not overfished and not subject to overfishing.*

50. *The SC **NOTED** that the new assessment used the Just Another Red-List Assessment (JARA) model to link the LB-SPR and the JABBA model. It was NOTED that the JARA model was incorporated as an additional modelling step that acts as a smoother over the time series obtained from the LB-SPR and normalizes the time series with respect to the initial state, in order to calculate an estimate of depletion. However, the inclusion of the "JARA" model has a negligible influence on the outcomes of the JABBA assessment. The SC also **AGREED** that the methodology of converting the length data into an index of relative abundance, requires further review.*

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

51. *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".*

52. *The SC **NOTED** that reported catches of black marlin and Indo-Pacific sailfish have exceeded the limits set out in Resolution 18/05 for both 2020 and 2021. The SC further noted that catches of both species are predominantly taken by gillnet and as such, **RECOMMENDED** that any revision of Resolution 18/05 should focus mainly on gillnet fisheries, to be effective.*

53. *The SC **NOTED** that striped marlin and blue marlin assessments indicate these species to be overfished and subject to overfishing, with 100% and 72% probability, respectively. The SC advised that projections and associated Kobe 2 Strategy Matrices (K2SMs) are available for both species and **RECOMMENDED** that any revision of Resolution 18/05 catch limits with respect to these species should be based on projections as opposed to MSY estimates, given the need to rebuild these stocks.*

54. *The SC **NOTED** that the current minimum size limit in Res 18/05 (60 cm LJFL) is unlikely to be effective for these species, with the possible exception of blue marlin, due to the high at-haul mortality and low post release survival of these species particularly when taken by gillnet. For blue marlin, it is **RECOMMENDED** that further management options relating to limiting retention, including the option of increasing the current minimum size limit, be considered."*

3.2 Outcomes of the 27th Session of the Commission

4. The WPB **NOTED** paper IOTC–2023–WPB21–04 which provided the main outcomes of the 27th Session of the Commission specifically related to the work of the WPB.

5. Participants to WPB21 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.

6. The WPB **NOTED** that there was very little discussion related to the WPB and that the main items were the endorsement by the Commission of the SC information on stock status and Work Plan.

7. 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

8. The WPB **NOTED** paper IOTC–2023–WPB21–05 which aimed to encourage participants at the WPB21 to review some of the existing Conservation and Management Measures (CMMs) relevant to billfish, noting the CMMs referred to in document IOTC–2023–WPB21–05, 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 WPB20

9. The WPB **NOTED** paper IOTC–2023–WPB21–06 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.

10. 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 2023.

11. The WPB participants were **ENCOURAGED** to review IOTC-2023-WPB21-06 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 (WPB22).

12. 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 at the Secretariat

13. The WPB **NOTED** paper IOTC–2023–WPB21–07_Rev1 on a review of the statistical data available for Indian Ocean billfish (1951-2021), with the following abstract provided by the authors:

> *"The document provides an overview of the consolidated knowledge about fisheries catching billfish in the Indian Ocean since the early 1950s based on a range of data sets collected by the Contracting Parties and Cooperating Non-Contracting Parties (CPCs) of the IOTC and curated by the IOTC Secretariat. The reporting quality of fisheries statistics available for the five IOTC billfish species has strongly varied between 1950 and 2021, and improved substantially over the last decade. The catches from coastal gillnet and longline fisheries have steadily increased over time and now contribute to more than 60% of the total billfish catch of the Indian Ocean. Catches from industrial longline fisheries provide the bulk of the geo-referenced effort, catch, and size data available at the Secretariat. Additional details on the five billfish species under IOTC management mandate are provided in separate documents prepared for this meeting."*

14. The WPB **NOTED** how fisheries data are collated from CPCs and curated by the Secretariat, and include a breakdown by gear and species used for estimating the best scientific estimates of total retained catches for the five billfish species under IOTC mandate.

15. The WPB **NOTED** the scoring system used by the Secretariat to quantify the reporting quality of the three main data sets of total retained catch, geo-referenced catch and effort, and geo-referenced size-frequencies based on compliance with IOTC data reporting standards and sampling coverage.

16. The WPB **NOTED** how data available from all tuna Regional Fisheries Management Organizations indicate that the global catch of billfish underwent a major decline in recent years, to less than 200,000 t in 2020-2021 following high catch levels of about 233,000 t reported between 2013 and 2016, further **NOTING** that the Indian Ocean is the main fishing ground for billfish, representing about 45% of the global catch in recent years.

17. The WPB **NOTED** the upward trend in total catches of retained billfish in the IOTC area over the last decades, including a major decline in catch reported for 2020-2021, further **NOTING** the increasing contribution over time of artisanal fisheries to total billfish catches, mostly accounted for by gillnets and coastal longlines.

18. The WPB **NOTED** that the recent decline in billfish catch was mainly due to the continuous decrease in catch for most high-sea longline fisheries, which are dominated by Taiwan,China, combined with the major reduction in catch from coastal longline fisheries of Sri Lanka in 2021.

19. The WPB **NOTED** that there have been significant variations in the reporting quality of retained catch over time which affected the quality of the stock assessments.

20. Furthermore, the WPB **NOTED** that a substantial portion of IOTC species' catches comes from artisanal fisheries which are traditionally affected by several data collection issues hindering the quality of the reported information.

21. The WPB **ACKNOWLEDGED** that this is a persistent problem and **NOTED** how the IOTC assessments do not effectively address bias and uncertainty in catch reporting due to the challenges in developing robust and viable alternative scenarios.

22. The WPB also **NOTED** that although the IOTC Secretariat has been delivering frequent on-site missions to address catch reporting and estimation issues with certain CPCs and fisheries, the potential bias in historical catch reporting remains an issue.

23. The WPB **NOTED** that 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.

24. The WPB further **NOTED** that a fair amount of information from the IOTC Regional Observer Scheme (ROS) is available on discards for purse seine fisheries, indicating that levels are small overall, and that most billfish discarded at sea are dead.

25. Conversely, the WPB **NOTED** that discarding information is limited for a few industrial longline fisheries, showing much variability between fleets, and **RECALLED** that as of today no data are available in the ROS database for high-sea gillnet fisheries.

26. The WPB **NOTED** that the completeness and continuity of the time series of fishing effort reported to the Secretariat greatly varies between fisheries and fleets, and that different, incompatible units of effort have been used for some fisheries over time.

27. The WPB **NOTED** that the general reporting quality of catch and effort data decreased from the late 1950s to the mid-2000s, but that the situation has improved over the last decade with the increasing reporting of catch and effort for some artisanal fisheries (e.g., Indonesia, Sri Lanka).

28. Nevertheless, the WPB **NOTED** that logbook coverage used to derive the spatial distribution of the catch for these fisheries is generally reported to be low (<30% of total catches reported for the fleet / fishery).

29. The WPB **NOTED** that the number of billfish sampled for size is largely dominated by industrial longline fisheries and that it is very imbalanced, with about 80% of all samples available for swordfish.

30. The WPB further **NOTED** that the overall reporting quality of geo-referenced size data remains poor for all five IOTC billfish species and **ENCOURAGED** CPCs to increase sampling effort and comply with the target of a minimum of 1 fish per metric tonne set in IOTC Res. 15/02.

31. Finally, 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 and **REQUESTED** that concerned CPCs 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 New information on sports fisheries

32. The WPB **NOTED** that little to no information on billfish is officially reported by the various recreational fisheries operating in the Indian Ocean, notwithstanding the fact that IOTC made an attempt at establishing a region-wide data collection protocol for these fisheries in recent years.

5. SWORDFISH

5.1 Review of new information on swordfish biology, stock structure, fisheries and associated environmental data.

33. The WPB **NOTED** paper IOTC-2023-WPB21-09 which provided information on the population structure of swordfish across the ICCAT/IOTC management boundary, including the following abstract provided by the authors:

"South Africa is a member of the Indian Ocean Tuna Commission (IOTC) and International Commission for the Conservation of Atlantic Tuna (ICCAT), the two regional fisheries management organisations that are

responsible for the management of large pelagic fishes in the Indian and the Atlantic oceans, respectively. The 20°E longitudinal line represents the artificial reporting and management boundary between these two organisations, but it remains uncertain if the artificial indeed reflects a biological meaningful separation of populations of large pelagic fishes. The broadbill swordfish Xiphias gladius is a circumglobally distributed apex predator in temperate pelagic waters and an important target of longline fisheries in all major oceans. Previous studies confirmed genetic differentiation between the Atlantic and Indian Ocean stocks but there is no agreement on the direction of gene flow and where, or indeed if, a population boundary exists" – see paper for full abstract.

34. The WPB **NOTED** the challenge for South Africa in terms of boundary concerns with stocks straddling the IOTC/ ICCAT region of competence. The WPB **NOTED** that inter-oceanic boundaries are questionable for some species. The WPB further **NOTED** that geneflow does occur across this boundary for yellowfin, albacore and swordfish. WPB **ACKNOWLEGED** that admixture does occur between 17 to 30 degrees East and that this may need to be considered in future stock assessments if indices from South Africa are used.

35. The WPB **ACKNOWLEGED** the implications of this study on the management of the stock. The WPB **DISCUSSED** swordfish targeting in South Africa and **NOTED** that generally, tuna targeting is increasing in the South African fleet, but a small Swordfish/shark directed component exists. The WPB **QUERIED** the possibility of monitoring this genetic variation between the IOTC/ ICCAT boundary and **NOTED** that given capacity issues it would not be a priority.

36. The WPB **NOTED** paper IOTC-2023-WPB21-10 which described industrial longlining catch rates, temporal variation and length-frequency of swordfish (*Xiphias gladius*) fishery in the Kenyan Marine waters, including the following abstract provided by the authors:

"Swordfishes (Xiphias gladius) are important pelagic fish species found in tropical waters. The species are majorly caught by industrial longlines, the nominal catches of Swordfishes in the years 2019, 2020, 2021 and 2022 were 214MT, 16MT, 252MT and 261MT respectively. The species was encountered throughout the year with clear evidence of temporal variation in catch rates. Pooled data indicate industrial longline has an average catch rate of 1.2MT/1000hooks/Trip. The pooled data also indicates that average catch rates for swordfish were high between the months of May and November 2022 while the Low catches were recorded on the average between the months of February, April, and December 2022. The minimum and maximum fork length of the swordfish encountered in the sample were 59cm and 245 JFL cm respectively, whilst the average length was 124.5cm. Most of the species captured were within the size range of 77.5 cm-162.5 cm and Five length classes are evident from this analysis between 107.5cm to 132.5cm. The analysis indicates seasonality partly influenced the catch rates of swordfish in the Kenyan coastal waters. This temporal distribution of the swordfish catches and abundance could be partly attributed to the seasonal changes in the temperature of the sea water and availability of food in the environment. While length classes could be attributed to the different size and depth of hooks as well as length of set lines, and the specific size of individual fish targeted".

37. The WPB **NOTED** that the information used in the research were data collected as port sampling and not on-board vessels, although they are swordfish samples caught from industrial longline fisheries. **NOTING** that data collected as port sampling does not contain information on discarded swordfish.

38. The WPB **NOTED** paper IOTC-2023-WPB21-11 which provided information on the population structural dynamics of the swordfish, *Xiphias gladius*, across the Indian Ocean using Next Generation Sequencing, including the following abstract provided by the authors:

"The swordfish (Xiphias gladius) is of special economic importance in the Indian Ocean. At present, the Indian Ocean Tuna Commission (IOTC) considers the swordfish to be a single panmictic population in the Indian Ocean. Over the last few years, however, several population studies have contested this tenet, and through the implementation of different approaches, have provided conflicting results, including emerging evidence that population structuring exists within this species. Namely, Muths et al (2013) based their examination on the ND2 region of the mitochondrial locus and failed to identify multiple distinct populations within the Indian Ocean, while Grewe et al (2020) applied Single Nucleotide Polymorphic loci (SNPs) to highlight two subpopulations on either side of the equator. These past studies provided ambiguous results regarding the structure of this species and consequently, called into question the guidelines for management to be adopted for the IOTC.". – see paper for full abstract.

39. The WPB **THANKED** the authors for a comprehensive study on the population structure of swordfish across the Indian Ocean.

40. The WPB **ACKNOWLEDGED** the low genetic differentiation among swordfish in the Indian Ocean and that this further supports using a single stock for future stock assessments. The WPB **NOTED** the effect of different spawning grounds, spawning output, and fecundity on close-kin recapture as these would cause potential bias in the close kin model.

41. The WPB **NOTED** paper IOTC-2023-WPB21-23 which described the habitat and movements of the swordfish *Xiphias gladius* in the southern Indian Ocean oligotrophic gyre and beyond: preliminary results of swordfish tagging experiments in Reunion Island, including the following abstract provided by the authors:

> *"Habitat and migratory movements of swordfish in the Indian Ocean are still poorly known despite decades of research. Past tagging efforts were limited in time and space both due to a low survival rate of tagged swordfish and high cost of electronic tags. The limited number of swordfish tagged with conventional tags has provided a broad idea on the scale of horizontal displacements and tagging experiments using Pop-Up Satellite Archival Tags (PSATs) off South Africa have shown apparent site fidelity of swordfish in that area. Yet, the overall knowledge of the vertical habitat, dispersion rates and migratory patterns at the scale of the western Indian Ocean are still poorly known. Here we present results of swordfish tagging experiments using PSATs in the southwestern Indian Ocean that were carried out in the framework of EU-funded project PESCARUN where a total of 7 PSATs were deployed on swordfish between September 2021 and December 2022. We also used data from two swordfish tagged with PSATs in November 2012 and in December 2015 in the framework of the SWIOFP and PELICAN projects, respectively. All tagging operations took place within southwestern Indian Ocean oligotrophic gyre (in proximity with Reunion Island)."*. – see paper for full abstract.

42. The WPB **THANKED** the authors for this study and **NOTED** similarities from other studies on the horizontal and vertical movement of swordfish.

43. The WPB **NOTED** the residential behaviour shown in this study, albeit from a small sample size.

44. The WPB **NOTED** that further electronic tagging in combination with environmental sampling would be useful to fully understand the vertical and horizontal movements of swordfish in this region.

5.2 Review of new information on the status of swordfish

- **Nominal and standardised CPUE indices**

45. The WPB **NOTED** paper IOTC-2023-WPB21-12 on an update of the Swordfish Catch, Effort and Standardized CPUEs by the Portuguese Pelagic Longline Fleet Operating in the Indian Ocean, between 1998 and 2022, including the following abstract provided by the authors:

> *"The Portuguese pelagic longline fishery in the Indian Ocean started in the late 1990's, targeting mainly swordfish in the southwest. This document updates that analysis with regards to catch, effort and standardized CPUE trends for the Portuguese fleet operating in the Indian Ocean. Nominal annual CPUEs were calculated as kg/1000 hooks and were standardized with Generalized Linear Mixed Models (GLMMs) using year, quarter, area and targeting ratios. The vessel effects were used as random variables. Model goodness-of-fit and comparison was carried out with AIC and the coefficient of determination (R2), and model validation with a residual analysis. The final standardized CPUE trends show a general decreasing trend in the series, with an intermediate peak in the 2008 period. The results present an updated annual index of abundance for the swordfish captured by the Portuguese pelagic longline fleet in the Indian Ocean that can be integrated in stock assessment models for that species in the region."*

46. The WPB **NOTED** that swordfish is the main target of the Portuguese fleet though switching to targeting sharks has occurred in the recent years (60% of fishing operations). The WPB further **NOTED** that the fishing grounds and gear used to target sharks are fairly similar to that of swordfish except for the use of wire leaders and different bait types.

47. The WPB **NOTED** that the Portuguese fleet set shallow hooks to target swordfish and blue shark and that hooks per basket would therefore not be a useful addition to the standardisation model.

48. **ACKNOWLEDGING** that swordfish undertakes seasonal migrations (related to reproduction) the WPB **ADVISED** the authors to consider this and the subsequent seasonal targeting changes in their standardisation approach.

The authors argued that there is not much variation in the Portuguese fleet fishing grounds and that it might therefore not be relevant to produce CPUEs by area.

49. The WPB **NOTED** paper IOTC-2023-WPB21-13 on the Standardized CPUE of swordfish (*Xiphias gladius*) from Indonesian tuna longline fleets in the north-eastern Indian Ocean, including the following abstract provided by the authors:

"The main objective of this study was to assess the abundance index of swordfish (Xiphias gladius) in the northeastern Indian Ocean, using fishery-independent data collected by scientific observers. The study aimed to address the existing information gap associated with low coverage in this region. A total of 3,302 observer data points were obtained from the Indonesian scientific observer program, spanning the years 2006 to 2022. These data were spatially disaggregated into one-degree blocks and were collected alongside commercial longline fleets. To analyze the dataset, Poisson and negative binomial models were considered, with number of fish serving as the response variable. Six covariates were included in the models, and a backward procedure based on AIC was employed to identify the best-fitting model. The results revealed that, overall, the trend in swordfish CPUE remained relatively stable over time, although there were inter-annual fluctuations. These fluctuations were attributed to natural population variations rather than operational changes or inter-annual environmental factors. Despite the lower spatial coverage compared to logbook data, the scientific observer data proved to be reliable and generated a robust abundance index for swordfish in the northeastern Indian Ocean. This highlights the effectiveness of utilizing scientific observer data to enhance our understanding of the population dynamics of swordfish in the region".

50. The WPB **NOTED** that 5x5 squares were considered as the spatial component, however treating latitude (lat) and longitude (lon) of 5x5 squares as continuous variables. In that case, the WPB **ADVISED** the authors to rather use the lat and lon of the exact fishing locations since they should be available. The authors also clarified that they tested 5x5 squares as a categorical variable at first but obtained better results with lat and lon as continuous variables.

51. The WPB **NOTED** that the proposed index of abundance is based on observer data (2006-2022) with a low coverage of the total fishing effort (< 5%). However, the authors clarified that they are quite confident in the representativeness of the observer data, notably the spatial aspect.

52. The WPB **NOTED** that the authors used a delta-lognormal distribution for the standardized CPUE submitted for the previous swordfish stock assessment and are now proposing an abundance index based on a model using a Poisson and Negative Binomial distribution, showing fairly similar results.

53. The WPB **NOTED** paper IOTC-2023-WPB21-14 which included the CPUE standardization for swordfish (*Xiphias gladius*) by Japanese longline fishery in the Indian Ocean using zero-inflated Bayesian hierarchical spatial model, including the following abstract provided by the authors:

"Standardization of swordfish CPUEs (1979-1993, 1994-2022) in the Indian Ocean by Japanese longliners was conducted for the datasets in four areas (NW, NE, SW, SE). We applied Bayesian hierarchical spatial models. Since the catch data include many zeros, we evaluated zero-inflated Poisson GLMM (ZIP-GLMM). Best candidate model was selected based on Widely Applicable Bayesian Information Criterion (WAIC). From the lowest value of WAIC, spatial Poisson GLMM with autoregressive (AR1) modelled for the year trend (i.e. m_zip_spde2 model) was selected as the best candidate for each area except for SE area. The trends of CPUEs were generally similar among areas with slight differences."

54. The WPB **NOTED** that the Japanese index is based on a new methodology (ZIP Poisson with INLA), and its results align with those obtained using the previous methodology. Additionally, the WPB **NOTED** that the abundance indices displayed increasing trends in the NW, NE and SW areas, while indicating a decreasing trend in the SE area.

55. **NOTING** that the SE index diverges from the nominal catch, unlike the other 3 areas, the WPB **ADVISED** that Japan explore the utilisation of Tweedie and Negative Binomial distributions. These distributions are better suited for handling zero values and overdispersion compared to the Poisson distribution that was used.

56. The WPB **NOTED** that the SE index is representative of the fleet targeting SBT in this region.

57. The WPB expressed **CONCERN** with using the Japanese CPUE series as main abundance indices for stock assessment analysis as the fishing effort of the Japanese fleet has substantially decreased in recent years and catchability may also have changed over time.

58. The WPB **NOTED** paper IOTC-2023-WPB21-15 which provided information on updated Standardized Catch Rates of Swordfish (*Xiphias gladius*) Caught by the Spanish Surface Longline Fleet in the Indian Ocean During the 2001-2021 period, including the following abstract provided by the authors:

"This paper provides an updated of the standardized catch rates per unit of effort (CPUE) in number and in biomass for the swordfish Indian Ocean stock using Generalized Linear Models. A total of 2,832 trips, representing 90% of coverage of the Spanish surface longline fleet targeting swordfish, are analyzed for the period 2001-2021. The main factors considered in the analysis were year, quarter, area, targeting criteria of skippers, gear and the interaction quarter-area. The results indicate that the target criteria of the skippers was the most important factor which explained the CPUE variability followed by year and in less extent the other factors considered. The model explained 54% and 57% of CPUE variability in number and weight, respectively. The standardized CPUE show a slight decrease until 2005 followed by a stable trend until 2021."

59. The WPB **THANKED** the authors for this update to the CPUE series but **NOTED** that the Spanish index was not used for the stock assessment due to a misunderstanding in the submission of the CPUE series. The WPB further **NOTED** that the assessment would not include the Spanish index in the reference case but that it would be included as a sensitivity case.

60. The WPB **NOTED** paper IOTC-2023-WPB21-16 which provided the CPUE standardization of swordfish (*Xiphias gladius*) caught by Taiwan, Province of China large-scale longline fishery in the Indian Ocean, including the following abstract provided by the authors:

"This paper briefly describes historical patterns of swordfish catches caught by Taiwanese large-scale longline fishery in the Indian Ocean. The cluster analysis was adopted to explore the targeting of fishing operations. In addition, the delta-inverse Gaussian generalized linear models were selected to conduct the CPUE standardizations of swordfish caught by Taiwanese large-scale longline fishery. The results indicate that the catch rates of the positive catches and the opportunity of catching swordfish might be determined by the position of fishing operations in areas other than Area SW and might be influenced by the targeting of the fishing operation in Area SW. The standardized CPUE series revealed different trends by areas, they slightly decreased in northern areas (NW and NE) and increased in southern area (SW and SE) in recent years."

61. The WPB **NOTED** conflicting trends between the northern and southern areas. The WPB further **NOTED** that the Taiwan,China fleet catches swordfish as a bycatch but seasonally targets swordfish in the southwestern area, which may influence the CPUE standardization. However, targeting may be a complicated issue because the Taiwan,China fleet seasonally changes targeting between albacore, swordfish and oilfish in this area.

62. The WPB **NOTED** that the trend of the Taiwan,China index in the SW is not consistent with that of other fleets (PRT, SPA).

63. The authors were **REQUESTED** to compare their current index with the one presented in the previous assessment, which used a different methodology. The WPB **NOTED** that the model using the Inverse Gaussian distribution provided better results in all four areas (NW, NE, SW, SE).

64. **NOTING** the very narrow confidence intervals, the authors clarified that these intervals were estimated using standard methods and attributed their narrowness to the large number of observations in the Taiwanese dataset.

65. The WPB **AGREED** that the CPUE series in the southwestern area could be used for stock assessment as the data after 2005 are used in the CPUE standardization while the data related to substantial changes in catchability during the early 1990s have been excluded.

- **Stock assessments**

Close-Kin Mark Recapture (CKMR)

66. The WPB **NOTED** paper IOTC-2023-WPB21-17 which provided a population size estimation of swordfish through Close-Kin Mark Recapture, including the following abstract provided by the authors:

"Swordfish (Xiphias gladius) is managed in the Indian Ocean by the Indian Ocean Tuna Commission (IOTC) and is of special economic importance. Currently IOTC estimates the swordfish stock size using SS3 models based on CPUE which can have many biases. In this study, we present our Close-Kin Mark Recapture (CKMR) approach on Indian ocean swordfish. For CKMR, related individuals are identified from their genotypes and their number and pattern is used for abundance estimation. In our study, over 2 030 individuals were genotyped from around the Indian Ocean using Single Nucleotide Polymorphism (SNP) markers. With these

analyses, we were able to find one parent-offspring pair (POP) and one half-sibling pair (HSP). With this information, we estimate the number of adult swordfish was around 1 434 880 individuals in 2009 in the Indian Ocean. However, as a very low number of POPs was obtained from the analysis, we are not able to calculate a robust confidence interval or a strong CV. For improved statistical confidence, we estimate that we will need to obtain around 50 POPs/HSPs, which will require sampling about 15 000 individuals."

67. The WPB **NOTED** that CKMR determines population size based on the likelihood of kinship, which functions similarly to the Peterson estimator in a conventional tag-recapture experiment. The WPB queried and discussed how the method operates when there are multiple stocks living in various locations and there is a lack of stock mixing because of directional movement. It was noted that in order to avoid bias, the sampling coverage in this situation must include all stock components.

68. The WPB **NOTED** that the spawning output used in the estimation of kinship probability is determined by maturity and fecundity. The WPB **NOTED** that in the study the maturity-at-age and fecundity-at-age are based on estimates of Poisson & Fauvel (2009)[1]

Stock-Production Model Incorporating Covariates (ASPIC)

69. The WPB **NOTED** paper IOTC-2023-WPB21-18 which described a Stock assessment of swordfish (*Xiphias gladius*) in the Indian Ocean using A Stock-Production Model Incorporating Covariates (ASPIC), including the following abstract provided by the authors:

"A Stock-Production Model Incorporating Covariates (ASPIC) was used to conduct the stock assessment for swordfish in the Indian Ocean. The results indicated that the stock status became to be optimistic, and this may result from the obvious decline in catches in recent years, while the CPUE series revealed fluctuation with increasing or relatively flat trends. All scenarios of Fox models indicated that the current status of swordfish in the Indian Ocean may be not overfished and not subject to overfishing."

70. The WPB **NOTED** the key assessment results for the ASPIC model for swordfish as shown below (Table 2; Figure 1).

71. The WPB **THANKED** the author for providing an updated assessment for swordfish using the ASPIC model and **ACKNOWLEDGED** the various sensitivity analysis on combinations of relative abundance (CPUE) indices.

72. The WPB **NOTED** that despite different CPUE series combinations, biomass estimates remained consistent. The WPB further **NOTED** the Japanese CPUE contained in all models are crucial in driving the stock trend because the significant depletion in these indices is associated with a period when significant catches were made. The WPB suggested that looking at various CPUE indices independently can help reveal the impact that these indices have on estimates of stock status.

Table 2. Stock status summary table for the swordfish assessment (ASPIC) (CI = confidence interval).

MSY (1,000 t)	32.101 (30.875, 33.755)
F_{MSY}	0.3 (0.23, 0.39)
B_0(1,000 t)	292.077 (224.64, 386.638)
B_{2021} (1,000 t)	136.249 (96.725, 197.66)
B_{MSY}	107.449 (82.641, 142.24)
B_{2021}/B_0	0.47 (0.42, 0.52)
B_{2021} / B_{MSY}	1.34 (1.19, 1.47)
F_{2021} / F_{MSY}	0.58 (0.5, 0.68)

[1] Poisson, F., Fauvel, C. 2009., J., Reproductive dynamics of swordfish (*Xiphias gladius*) in the southwestern Indian Ocean (Reunion Island). Part 2: fecundity and spawning pattern. Aquatic Living Resources, 22(1), 59-68. doi:10.1051/alr/2009012.

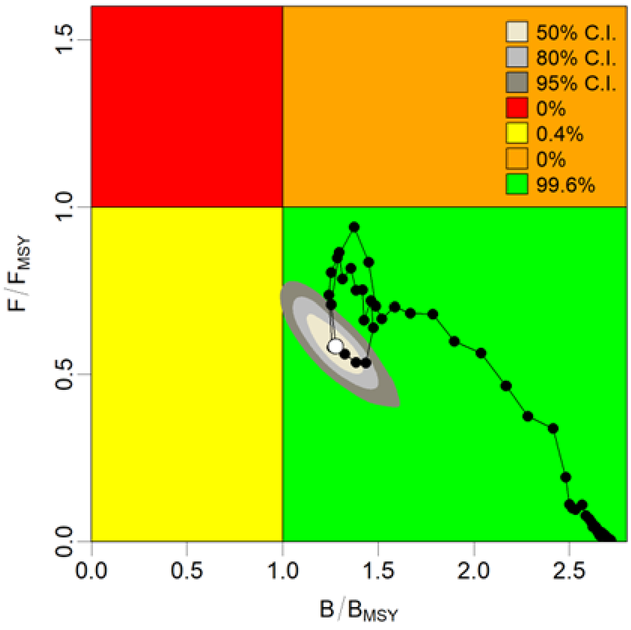

Figure 1. **ASPIC** model: Kobe stock status plot for the Indian Ocean for swordfish

Bayesian Surplus Production Model (JABBA)

73. The WPB **NOTED** the Bayesian Surplus Production Model (JABBA) which was provided in the previous assessment iteration was not available this year. However, the author of the ASPIC model has kindly provided a tentative update of this model during the meeting following the previous model configuration. The WPB **THANKED** the author for completing the analysis so quickly and noted modelling results in document IOTC–2023–WPB23–30.

74. The WPB **NOTED** that the JABBA is a very powerful and flexible platform that enables interactions with modellers to quickly explore a variety of model configurations in a limited amount of time, including different distributional assumptions of parameters. The WPB **ENCOURAGED** the CPC scientists to keep using the JABBA as an alternative method for assessing swordfish.

Stock Synthesis (SS3)

75. The WPB **NOTED** document IOTC-2023-WPB21-19 which described the stock assessment of swordfish in the Indian Ocean using Stock Synthesis, including the following abstract as provided by the author:

> *"This report presents a stock assessment for Indian Ocean swordfish (Xiphias gladius) using Stock Synthesis 3 (SS3). The assessment uses a spatially disaggregated, sex explicit, and age structured model that includes several sources of fisheries and biological data. The assessment model covers the period 1950–2021 and represents an update and revision of the 2018 assessment model with the inclusion of updated longline CPUE indices and length composition data. A range of sensitivity models are also presented to explore the impact of key data sets and model assumptions."* – see paper for full abstract.

76. The WPB **NOTED** the key assessment results for Stock Synthesis (SS3) as shown below (Table **3**; Figure 2) for which estimates from a model grid are reported.

77. The WPB **NOTED** that the assessment model is age / sex structured, spatially partitioned into 4 areas (NW, NE, SW, SE) to account for differential abundance and depletion levels among regions. The standardised indices included are the Japanese (for 4 regions), Portuguese (SW), and South African (SW) CPUE indices. The WPB further **NOTED** that the model defined 15 fisheries, based on gear, fleet and region.

78. The WPB **NOTED** that a continuity model run had been completed, updating the previous assessment model with new data but keeping the same configuration. The WPB **NOTED** that the continuity model's results were consistent with those of the previous assessment.

79. The WPB **NOTED** the model was subsequently revised to allow the estimation of separate selectivity in each region for the Japanese fleet (and substitutes the logistic selectivity in the NW region with a double normal selectivity) rather than using a common selectivity across model regions. This is done to account for the spatial variation in size structure in the Japanese length composition data. The WPB further **NOTED** that a logistic selectivity rather than a double normal selectivity was used for the EULL fleet.

80. The WPB **NOTED** that changes to the selectivity configurations (primarily for JPLL fisheries) improved the fits to the length composition of Japanese catches, especially in the NW and SW regions. The WPB also **NOTED** that the revision resulted in an estimate of initial biomass being about 20% lower than the previous model configuration.

81. The WPB **NOTED** that the assessment examined the effect of other CPUE settings by substituting the recent Japanese indices (or the Portuguese and South African indices in SW) with the Taiwanese (and Indonesia in NE) indices. The model resulted different regional abundance trend in NE and SE regions in recent years. The WPB further **NOTED** this alternative CPUE configuration was also included in the final model options.

82. The WPB **NOTED** that the South African index has not been updated this year so the same index from the last assessment was used. The WPB also **NOTED** that the index from the Spanish fleet, although submitted on time before the deadline for submission of papers, was made available later than other indices therefore it was not included in the assessment. The WPB requested a sensitivity analysis including the Spanish index during the meeting. The model estimated a slightly higher depletion in the SW region but the effect on the overall stock estimates was small.

83. The WPB **NOTED** that because the errors are typically very small and dependent on the number of observations, the assessment model did not use the errors calculated from the standardisation process for the CPUE indices. The assessment model made the assumption that regional CPUE indices would be given an equal weight to get adequate estimates of the regional abundance. However, the WPB **NOTED** that in a single region model setting, the weighting of CPUE indicators, partially for those with opposing trend, would be more important to consider.

84. The WPB **NOTED** spatial configuration of the assessment model which assumed no movement among the four regions. It was suggested that the spatial segmentation of Swordfish size structure and life stage (bigger females in higher latitude, for example) may be best explained by a migration mechanism. However, there aren't informative, direct observations to allow the model to predict movement. The WPB suggested that further assessment could evaluate the effects of migration by setting movement rates at various levels.

85. The WPB **NOTED** that the model ensemble included 48 MPD runs covering two CPUE configuration options, three steepness values (0.7, 0.8, and 0.9), two growth/maturity options (otoliths-based estimates from the SW Pacific by Farley et al. (2016)[2], spine-based estimates form Indian Ocean by Wang et al. (2010))[3], two recruitment variability (sigma=0.2 or 0.4), and two assumed effective sample size for length composition data (capped at 20 or 5). The WPB **NOTED** that these options remain the same as the previous assessment.

86. The WPB **NOTED** the various diagnostics, such as the Jittering analysis, R0 profile, retrospective analysis, and age-structured production model, to assess the performance of the assessment model. The R0 profile demonstrated that there is overall consistency between CPUE and length composition data and that this latter is not very influential on model estimations if its sample size was kept reasonably small.

87. The WPB **SUGGESTED** that one way of determining whether the model ensemble comprises clearly distinguishable modes representing multiple regimes of estimates is to plot the univariate distribution of key reference point estimates. The WPB also **SUGGESTED** to assess each model's convergency in the grid, which is important given that they are all incorporated to generate final estimates.

[2] Farley, J., Clear, Naomi., Kolody, D., Krusic-Golub, K,. Eveson, Paige., Young, Jock. 2016. Determination of swordfish growth and maturity relevant to the southwest Pacific stock. R 2014/0821.

[3] Wang, S.P., Chi-Hong, L., Chiang, W.C. 2010. Age and growth analysis of swordfish (Xiphias gladius) in the Indian Ocean based on the specimens collected by Taiwanese observer program. Working paper IOTC-2010-WPB-08 (revision 1).

88. The WPB **NOTED** that the Swordfish MSE operational model had selected a larger range (0.6-0.9) of steepness values, and requested a sensitivity run on the steepness value of 0.6. The WPB **NOTED** that although estimations of biomass are higher for low steepness values (since the stock is less productive), levels of stock depletion are very similar. The WPB further **NOTED** that the extreme insensitivity of depletion estimates to steepness values was probably caused by the fact that the depletion estimates are heavily influenced by CPUE trends, which the assessment model well fits.

89. The WPB **NOTED** the possibility of localised depletion for this species, which has been observed in other ocean basins, as well as evidence of latitudinal seasonal migrations in other ocean basins while also returning to the same subregions (i.e., evidence for some subregional fidelity), both of which would increase its susceptibility to localised depletion. The WPB **SUGGESTED** that this warrants additional thought in future assessments if the data permit it.

90. The WPB **NOTED** that the extremely abrupt growth in Japanese CPUE in the NE subregion between 2013 and 2016 comes from a fleet that accounts for relatively little catch in that region. Given that area is the highest catch area and was experiencing peak catch levels around that time, it appears improbable that this trend could be interpreted as a sudden rise in abundance. The same area experienced very considerable depletion at far lower catch levels previously in the time series. The model seems to be unable to explain the relationship between catch and CPUE other than by unexpectedly introducing huge numbers of recruits into the area, which seems improbable. As such, the WPB **SUGGESTED** that further examination of this is needed in the future assessments and for the potential to remove the Japanese series from the NE either partly or completely.

Table 3. Stock status summary table for the assessment final model grid (CI = confidence interval).

Catch in 2021 (t)	23,237
Average catch (t) 2017–2021	30,809
MSY (t)	29,856 (26 319–33 393)
F_{MSY}	0.16 (0.12–0.20)
SB_0 (t)	224,673 (200 328–249 019)
SB_{2021} (t)	75,891 (58 019–93 764)
SB_{MSY} (t)	55,055 (40 243 –69 866)
SB_{2021}/SB_0	0.35 (0.32–0.37)
SB_{2021} / SSB_{MSY}	1.39 (1.01–1.77)
F_{2021} / F_{MSY}	0.60 (0.43–0.77)

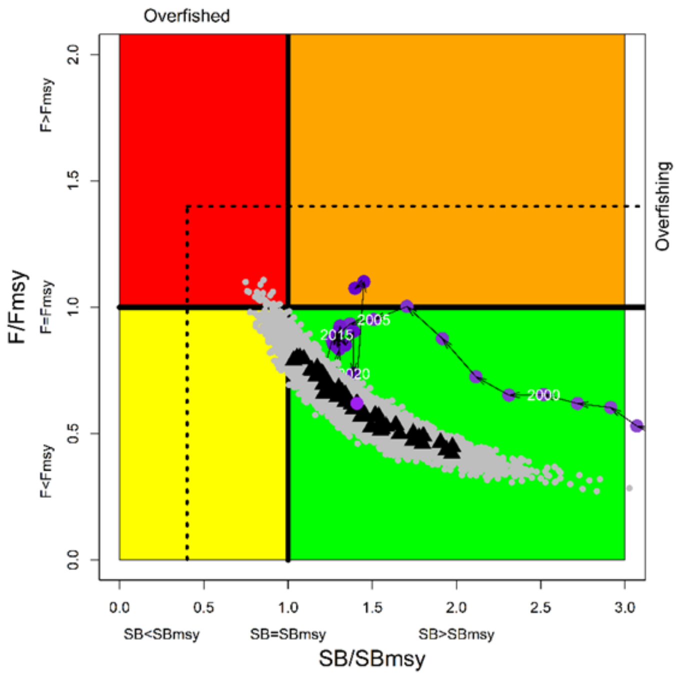

Figure 2. Stock synthesis grid-IO. Kobe stock status plot for the Indian Ocean for swordfish. Triangles represent Maximum Posterior Distribution estimates from individual models (The purple dot represents the estimate from the reference model). Grey dots represent uncertainty from individual models. The dashed lines represent limit reference points for Indian Ocean swordfish (SB_{lim} = 0.4 SB_{MSY} and F_{lim} = 1.4 F_{MSY}).

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

91. The WPB **AGREED** that the final advice for the executive summary should be based on the Stock Synthesis (SS3) model, based on the availability of length data and biological data specific for the Indian Ocean as well as the availability of CPUE series for several fisheries and better description of population dynamic for Swordfish. Therefore, the WPB **SUPPORTED** the use of Stock Synthesis (SS3) for swordfish as data and information are available to run this type of complex model. Other models provide useful complementary information to support SS3 results and were in general in agreement in terms of stock status.

92. The WPB **NOTED** the selection of SS3 model assemble as the base case as that it captures most of the uncertainty identified in the assessment. This model grid estimated MSY at 30,000 t which is above the current catch level (23,237 t).

93. The WPB **NOTED** the projection stock status matrix showing that the spawning biomass was projected to likely increase and there is a very low risk of exceeding MSY-based reference points by 2031 if catches are maintained at 2021 levels (<1% risk that SB_{2031}< SB_{MSY}, and <1% risk that F_{2031}> F_{MSY}). The projections also indicate that an increase of 40% or more from 2021 catch levels will not likely result in the biomass dropping below the SB_{MSY} level for the longer term (with a maximum 15% probability).

94. The WPB **ADOPTED** the management advice developed for swordfish, as provided in the draft status summary, and **REQUESTED** that the IOTC Secretariat update the draft stock status summary with the latest 2020 interaction data to be provided to the SC as part of the draft Executive Summary, for its consideration:

- Swordfish (*Xiphias gladius*) – Appendix IV

6. PROGRESS ON THE SWORDFISH MANAGEMENT STRATEGY EVALUATION

95. The WPB **NOTED** document IOTC-2023-WPB21-26 which provided an IOTC Swordfish Management Strategy Evaluation Update, including the following abstract as provided by the author:

"The reference operating model for the Indian Ocean swordfish stock was developed over the last three years and has been endorsed by the IOTC scientific committee. The OM was developed based on the 2020 WPB SS3 assessment, and covered the dynamics of the swordfish until the year 2018. This OM was updated to the

current year, 2023, by projecting the stock forward based on the reported catches for 2019, 2020 and 2021 and assuming a 2022 catch at the 2021 level. The choices made in 2020 for the construction of the OM by the previous researcher have been revisited. following the feedback received during the 2022 working party on billfish (WBP20). The structural uncertainty grid (different options for the stock assessment model parameters) was simplified by removing those parameters that were found to have little impact on the assessment (e.g. choice of the scaling method for the CPUE indices). This change in the grid resulted in a reduced number of combinations to consider, but in the end in a higher number of valid stock assessment models that can serve as the basis for the OM." – see document for full abstract.

96. The WPB **NOTED** that the OM was developed based on the 2020 swordfish assessment, and **REQUESTED** a verification be carried out that the OM is still appropriate considering the outcome of the assessment performed in 2023.

97. Noting that the robustness of the data-based MP to a recruitment failure was tested by the authors on the current data-based MP, the WPB **REQUESTED** that the same robustness test was conducted on the model-based MP as well.

98. The WPB also **REQUESTED** that a test of the robustness of the MPs to an overshoot of the TAC by 20% was conducted, to account for possible discarding practices that may start to occur in the future if the implementation of a MP leads to reductions in the TAC.

99. The WPB **ASKED** how the MSE was conditioned with regard to the uncertainty associated with the CPUE index used as input to the MPs, and whether it would be possible to use actual estimates of these values rather than an assumption. The author clarified that indeed a CV of 0.2 was assumed as uncertainty for the CPUE index, and explained that any other value could be used, provided that it was considered more accurate by the WPB. The actual CV of the CPUE residuals in the model is not completely limited by the input value.

7. OTHER BILLFISHES

7.1 Review of new information on other billfishes biology, stock structure, fisheries and associated environmental data

100. The WPB **NOTED** a presentation by the Secretariat on the status and perspectives on morphometric data for IOTC billfish species and **AGREED** on the importance of improving the IOTC reference conversion relationships and factors used to harmonize size-frequency data into standard lengths and estimate round weights.

101. The WPB **NOTED** the inconsistencies on the recommended standard lengths to be used for reporting of billfish size data to the Secretariat between the IOTC reporting guidelines and the documents produced by the Secretariat on reference relationships.

102. The WPB further **NOTED** that the reference relationships and conversion factors available for billfish are generally based either on a small number of samples, or on samples collected from specific fisheries of limited spatial extent, or are borrowed from other oceans, further **NOTING** that multiple relationships might be available from the literature for the same species in some cases.

103. Similarly, the WPB **NOTED** that the conversion factors for billfish available at the Secretariat were derived from historical sampling operations conducted in some landing ports of Indonesia through an OFCF project, but that fish dressing may vary with fleets, fisheries, and markets, and that the type of dressing and conversion factors used are generally poorly documented by CPCs for catch data reported to the Secretariat despite the requirements included in IOTC Res. 15/02.

104. Therefore, the WPB **URGED** CPCs to share with the Secretariat the relationships and conversion factors used for the processing the data of their national billfish fisheries.

105. The WPB **CONGRATULATED** IFREMER for releasing a set of morphometric data through an open repository (https://www.seanoe.org/data/00516/62757/) and **THANKED** the International Game Fish Association (IGFA) for kindly sharing some length and weight measurements of billfish with the Secretariat, including for very large billfish, **NOTING** however that the data need to be further curated as the variability observed in the length-weight relationships suggests some issues which might be linked to the units used for reporting.

106. The WPB **NOTED** that some length-weight relationships were made available in the past for marlins and swordfish based on data collected throughout the Soviet Indian Ocean Tuna Longline Research Programme in 1961-1989 (paper IOTC–2012–WPB10–18) and that these data could be made available to the Secretariat.

107. From a general point of view, the WPB **ACKNOWLEDGED** the necessity of sharing raw morphometric data to increase sample size and identify the main factors explaining the variability in relationships and conversion factors and **REQUESTED** the Secretariat to present the progress made on developing an electronic exchange format, a biological database, and a summary of the status of all biological data available at the Secretariat at the next session of the Working Party on Data Collection and Statistics (WPDCS).

108. The WPB **NOTED** that sex has been shown to significantly affect morphometric relationships in some billfish species and that several relationships available in the literature are published for males and females.

109. However, the WPB **NOTED** that the effect of sex on total weight is generally small (considering the large size of the fish) and that sex composition of the catch is generally non reported for the vast majority of the fisheries.

110. Nevertheless, the WPB **ACKNOWLEDGED** that the effect and influence of sex as well as fishing gear on estimates of catches in weight could be further explored for Indian Ocean billfish.

111. The WPB **AGREED** on the need to improve the sampling protocols for some specific measurements (e.g., pectoral fork length, cleithrum keel length) as the reference measuring locations require accurate description for consistency and repeatability and **REQUESTED** the Secretariat to include such protocols in the new IOTC reporting guidelines.

112. The WPB **NOTED** document IOTC-2023-WPB21-20 on billfish from Purse Seiners fisheries in the Andaman Sea of Thailand, including the following abstract as provided by the author:

    "Catch per unit effort (CPUE), species composition and size of billfish from purse seine fisheries in the Andaman Sea of Thailand were studied by collecting the data from purse seiners landing along the Andaman Sea Coast from January to December in 2020 - 2022. The results showed that the CPUE of purse seiners operated in the Andaman Sea of Thailand in 2020 - 2022 was 2,406 kilogram/day divided into Indo-Pacific sailfish (Istiophorus platypterus and Black marlin (Istiompax indica) equal 0.794 and 0.142 kilogram/day respectively. Species composition of billfish was 0.04% of the total catch divided into Indo-Pacific sailfish 0.03% and Black marlin 0.01%. The length (lower jaw to fork length; LJFL) of Indo-Pacific ranged from 40.0 - 190.0 cm and the average length was 129.0 ± 28.1 cm."

113. The WPB **NOTED** that Thailand is working closely with the Secretariat to review the species composition of their coastal purse seine fisheries. However, the WPB **NOTED** that the information on anchored FADs from Thailand are not provided to the Secretariat, **NOTING** that the vessels operated within the EEZ and are between 15 and 24m.

114. The WPB **NOTED** that the billfish caught in these fisheries are usually discarded and not retained.

115. The WPB **NOTED** document IOTC-2023-WPB21-21 which described evaluating the Status of Large Pelagic Fisheries in Iran: A Focus on Sustainable Management of Billfish fisheries, including the following abstract as provided by the author:

    "The fishery for tuna and tuna-like species is a major component in large pelagic fisheries in Iran and is one of the most important activities in the Persian Gulf, Oman Sea, and the high seas. In 2021, the country produced nearly 1.2 million tonnes of aquatic products, with marine capture fisheries accounting for approximately 702 thousand tonnes. Additionally, aquaculture activities contributed an additional 556 thousand tonnes to the national output. The production of large pelagic fishes amounted to around 334 thousand tonnes, representing approximately 48% of the country's total catch in 2021. The estimated total quantity of tuna and tuna-like species is approximately 274 thousand tonnes. The catch of billfish accounts for about 25 thousand tonnes, representing 7.6% of the total large pelagic catch. The dominant species within this category are as follows: Sailfish (16,566 t), followed by black marlin (4,637 t). Additionally, swordfish accounted for 1,152 t, striped marlin for 823 t, and other billfish species amounted to 2,237 t. While billfish are not typically targeted species, they are considered as by-catch species. However, in accordance with Iran's domestic regulations for tuna and tuna-like species, all data regarding the billfish catch will be collected and reported." – see paper for full abstract.

116. The WPB **THANKED** the authors for this document but **NOTED** that it was not presented.

117. The WPB **NOTED** document IOTC-2023-WPB21-22 which provided an analysis of the at-haulback mortality of striped marlin (*Tetrapturus audax*) in the western Indian Ocean by Chinese longline fishing using a GLM, including the following abstract as provided by the author:

"Striped marlin (Tetrapturus audax) is an oceanic pelagic migratory fish. The stock status of striped marlin in the Indian Ocean is now considered to be overfished and subject to overfishing. Quantifying the level of at-haulback mortality caused by tuna longline fishing is critical to reducing fishing pressure and protecting the fate of billfish stocks. This study was based on data from 2,482 longline fishing operations carried out by Chinese observers in the western Indian Ocean from 2012 to 2019. The dataset includes information on the survival status of 774 striped marlin and their corresponding details. We used a generalized linear model (GLM) to analyze the level of at-haulback mortality and its potential influencing factors. The results indicate that the distribution of 774 striped marlin had a lower jaw-fork length range from 130 to 220 cm, and 51.5% of the samples died at the time of haul-back. The observed at-haulback mortality rates showed significant differences among quarters, hook type, bait type, longitude, and environmental variables; the GLM model revealed that quarter, sea-surface temperature (SST), hook type, lower jaw-fork length (LJFL), chlorophyll (CHL), and longitude had significant effects on at-haulback condition when the fish were retrieved on board, with the quarter and sea surface temperature having the most significant effects." – see paper for full abstract.

118. The WPB **ASKED** if tagging operations were possible during these fishing activities. The authors confirmed that it was possible to do so and could be useful to investigate the post-release mortality.

119. The WPB **NOTED** document IOTC-2023-WPB21-24 which provided information on the effect of bait types on the catchability of billfish in tuna long line fishery in Sri Lanka, including the following abstract as provided by the author:

"Billfish represent three groups of species of marlins, sailfish and swordfish which can be considered as the third largest group of fish reported in large pelagic fish production in Sri Lanka. Being a by-catch in tuna longline fisheries, a deterministic role in the catchability of bill fish could be resulted from different bait types. This information would also be useful in exploring the potential to alter the catch in compliance with international obligations. The present study was based on logbook records of the Sri Lankan longline fishery from 2016 to 2019, with an aim of assessing the catch efficiency of bill fish species with respect to the bait types. During the period of study, it was noted that there were seven popular bait types; squid (Loligo spp.), bigeye scad (Selar crumenophthalmus), flying fish (family Exocoetidae), milkfish (Chanos chanos), Indian scad (Decapterus spp.), Sardine (Sardinella spp.) and artificial baits which represented 94.39 % in the fishery. Among those, squid was the most common bait while Sardinella spp. showed the least frequency in usage." – see paper for full abstract.

120. The WPB **NOTED** that the hook type could have an impact on the catch rate as the gear was not standardised throughout the study. The authors replied that this effect had not been investigated.

121. The WPB **QUERIED** whether bait was sourced locally and if bait type influenced the life stage (adult or juvenile) found in the catch. The authors noted that a mixture of imported and local bait is used and that it had been difficult to assess maturity of the catch and so the effect of bait type was unknown.

122. The WPB **NOTED** document IOTC-2023-WPB21-25 which addressed Larval billfish in the WIO and future research endeavor, including the following abstract as provided by the author:

"Stock assessment of highly migratory species such as tunas and billfishes from fisheries data alone is challenging. Using fisheries-independent larval data may be useful as a supplement to those models. As of date, billfish spawning is only reported in the Pacific and eastern Indian Ocean and no scientific record of billfish spawning in the western Indian Ocean has been reported. Opportunistic larval fish surveys were conducted on January 2022 in Tromelin and Reunion EEZ and on April 2023 in the Mozambique Channel within the French EEZ. Larval billfishes were collected from surface and subsurface tows. Maximum density was 19.77 istiophorids / 1000 m2 from the Mozambique Channel. Mean sea surface temperature was 28.79°C (± 0.69 SE). Istiophorids collected in 2022 were genetically identified to be blue marlin (Makaira nigricans, n = 25) and 2023 collection identified morphologically by pigment pattern and morphometrics relationships were blue marlin (n = 6) and Indo-Pacific sailfish (Istiophorus platypterus, n = 15). Monthly or bimonthly systematical sampling is recommended to reveal spatio-temporal spawning of the billfish species in the WIO and to better understand the role of the Mozambique Channel and adjacent water as spawning ground and nursery site for the billfish species."

123. The WPB **NOTED** that Sri Lanka has also conducted ichthyoplankton surveys and found around 80 different species of larval fish, but no billfish or tuna. The WPB further **NOTED** that a comparison between the eastern and western basin would be important and useful as data and sample sharing can lead to the identification of different spawning grounds, and different spawning areas can have an impact on the survival and growth of larvae. The WPB **ACKNOWLEDGED** that other international efforts have been conducted to carry out larval surveys in the Eastern basin (Indonesia/Australia area) and it would be interesting to gather these different data.

124. The WPB **NOTED** document IOTC-2023-WPB21-27 which provided the findings from 101 satellite tags deployed on Indian Ocean billfish during the FLOPPED project, including the following abstract as provided by the author:

"The FLOPPED project (2019-2023) aimed 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, 102 satellite tags were deployed around the Indian Ocean on blue marlin (Makaira nigricans; n=43), black marlin (Makaira indica; n=16), striped marlin (Tetrapturus audaxI; n=5), swordfish (Xiphias gladius; n=7), sailfish (Istiophorus platypterus; n=30) and a shortbill spearfish (Tetrapturus angustirostris; n=1). 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 searched for participants from a broader range of sites among our WPB colleagues to maximise the coverage and representativeness of this dataset."

125. The WPB **INQUIRED** whether the depth profiles displayed included mortalities, and if so, that these be removed from future analyses. The authors agreed that an artifact of mortality was displayed, noting that data analyses are just starting and agreed on their removal.

126. The WPB were **INFORMED** that the Secretariat had received confirmation from Stanford, IGFA, and Marine Megafauna that they were willing to share their tagging data, with the understanding that they be associated in any publications that arise using these data.

127. The WPB **REQUESTED** that the R Shiny application developed by IFREMER and exploiting the authors' tagging data be shared with the Secretariat for further discussions and development.

128. The WPB **NOTED** document IOTC-2023-WPB21-28 which described the Status of Billfish Populations in Somalia, the Challenges and Opportunities for Conservation and Management, including the following abstract as provided by the author:

"The study found that billfish are not a target species in Somali waters, but that their populations have declined globally by an estimated 20% in the past 20 years due to overfishing, habitat loss, and climate change. Somalia has the longest coastline in Africa and an Exclusive Economic Zone of 1,165,500 km2, with the potential to sustainably increase employment, food security, nutrition, and revenues from its fisheries. However, Somalia's fisheries management is currently precarious." – see paper for full abstract.

129. The WPB **THANKED** the authors for this document but **NOTED** that it was not presented.

130. The WPB **NOTED** paper IOTC-2023-WPB21-29 on shortbill spearfish (*Tetrapturus angustirostris*), which provided a note on the distribution and occurrence of this species in the Indian Ocean fisheries, including the following abstract provided by the authors:

"This note reports the distribution and occurrence of shortbill spearfish in the IOTC-managed fisheries. It highlights the relatively common occurrence of the species in the catch, and the urgent need to evaluate the population status, and establish a management regime for this species."

131. The WPB **NOTED** that several recommendations had been made in the past for the Commission to consider including the shortbill spearfish as an IOTC species. The WPB **RECALLED** that in 2022 it was agreed that it would be more productive to provide some additional justification for this request before making it again, including feedback on catches and the necessity for this inclusion.

132. Based on this presentation the WPB **AGREED** that there is evidence that the species is being caught in IOTC fisheries and that the species population size may be declining. As such the WPB reiterated its previous **RECOMMENDATION** that shortbill spearfish be included as an IOTC species.

7.2 Resolution 18/05 Catch Limits

133. The WPB **NOTED** paper IOTC-2023-WPB21-INF06 on recent catches of billfish in relation to catch limits set out in Resolution 18/05.

134. The WPB **NOTED** that Resolution 18/05 applies to striped marlin, black marlin, blue marlin and Indo-Pacific sailfish and states that if the average annual catch of any of these species exceeds the limit for two consecutive years from 2020 onwards, the Commission shall review the implementation and effectiveness of the measures contained in the Resolution.

135. The WPB **NOTED** that among the four species, catches of black marlin and Indo-Pacific sailfish continue to exceed the limits set out in Resolution 18/05 from 2020, with preliminary data reported for 2022 indicating catches of the two species exceeding their respective limits.

136. The WPB **NOTED** that 90% of the black marlin and Indo-Pacific sailfish are taken by the small-scale fisheries, where 70% are from gillnet fisheries and 20% from line fisheries. **NOTING** a substantial increase in the catches of the two species from the Iranian fisheries in recent years.

137. The WPB further **NOTED** that there have been efforts made in some CPCs to transition from gillnets to other gears such as handlines further **NOTING** that catches of billfish are likely to increase as a result of this transition.

138. WPB Program of work

7.3 Revision of the WPB Program of work (2024–2028)

139. The WPB **NOTED** paper IOTC–2023–WPB21–08 which provided an opportunity to consider and revise the WPB Program of Work (2024–2028), by taking into account the specific requests of the Commission, Scientific Committee, and the resources available to the IOTC Secretariat and CPCs.

140. 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).

141. The WPB **NOTED** that several Working Parties had identified CPUE standardisation as a priority and therefore **REQUESTED** that the WPM consider facilitating a cross-cutting CPUE standardisation workshop.

142. The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2024–2028), as provided in Appendix IX.

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

143. 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 WPB22 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.

144. 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 2024 by an Invited Expert:

- **Expertise**: Reproductive biology of billfish. Age and growth experience also beneficial.
- **Priority areas for contribution**: Providing expert input to the reproductivity workshop highlighted as a priority for the WPB.

8. OTHER BUSINESS

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

Chairperson

145. The WPB **NOTED** that the second term of the current Chairperson, Dr Denham Parker (RSA) expired at the close of the WPB21 meeting and, as per the IOTC Rules of Procedure (2014), participants are required to elect a new Chairperson of the WPB for the next biennium.

146. **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 Jie Cao (CHN) was nominated, seconded and elected as Chairperson of the WPB for the next biennium.

Vice-Chairperson

147. The WPB **NOTED** that the second term of the current Vice-Chairperson, Dr Jie Cao (CHN) expired at the close of the WPB21 meeting. As per the IOTC Rules of Procedure (2014), participants are required to elect a new Vice-Chairperson of the WPB for the next biennium.

148. **NOTING** the Rules of Procedure (2014), the WPB **CALLED** for nominations for the positions of Vice-Chairperson of the IOTC WPB for the next biennium. Mr Sylvain Bonhommeau was nominated, seconded and elected as Vice-Chairperson of the WPB for the next biennium.

8.2 Date and place of the 22nd and 23rd Sessions of the Working Party on Billfish

149. The WPB **NOTED** that in 2022, a two-day workshop to discuss the standard of billfish maturity staging inter-sessionally prior to the WPB was requested. As the funding for this workshop was approved by the Commission in 2023, the WPB **RECOMMENDED** that this workshop should take place immediately place prior to the next session of the WPB in 2024.

150. The WPB **REQUESTED** that CPCs that may be interested in hosting the 22nd and 23rd Working Party on Billfish meetings contact the Secretariat.

151. The WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB22 in 2024. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB. As the WPB are planning to hold a workshop immediately prior to the next WPB meeting, it was **REQUESTED** that the WPB once again take place before the WPEB in 2024.

8.3 Review of the draft, and adoption of the Report of the 21st Session of the Working Party on Billfish

152. The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB21, provided at Appendix X, 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 2023 (Fig. 3):

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

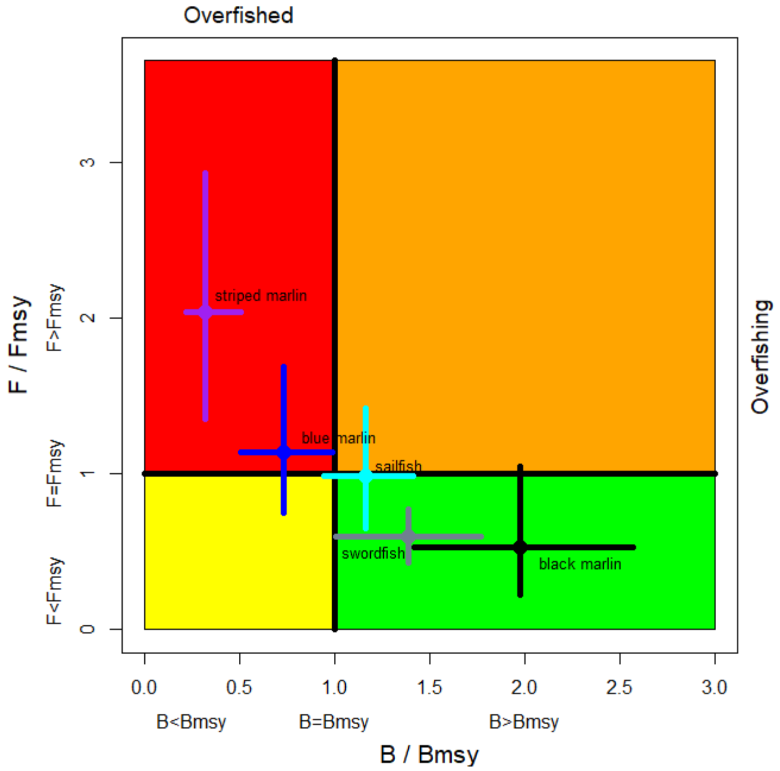

Fig. 3. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2018, 2019, 2021, 2022, and 2023 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs.

153. The report of the 21st Session of the Working Party on Billfish (IOTC–2023–WPB21–R) was **ADOPTED** by correspondence.

APPENDIX I - LIST OF PARTICIPANTS

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APPENDIX II - AGENDA FOR THE 21ST WORKING PARTY ON BILLFISH

Date: 6–9 September 2023
Location: Hotel le Récif, La Salins-les-Bains, Reunion, France
Time: 09:00 – 17:00 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. **IOTC PROCESS: OUTCOMES, UPDATES AND PROGRESS**
    - 3.1. Outcomes of the 25th Session of the Scientific Committee (IOTC Secretariat)
    - 3.2. Outcomes of the 27th Session of the Commission (IOTC Secretariat)
    - 3.3. Review of Conservation and Management Measures relevant to billfish (IOTC Secretariat)
    - 3.4. Progress on the recommendations of WPB20 (IOTC Secretariat)
4. **NEW INFORMATION ON FISHERIES AND ASSOCIATED ENVIRONMENTAL DATA FOR BILLFISH**
    - 4.1. Review of the statistical data available for billfish at the Secretariat (IOTC Secretariat)
    - 4.2. New information on sport fisheries (all)
5. **SWORDFISH**
    - 5.1. Review new information on swordfish biology, stock structure, fisheries and associated environmental data (all)
    - 5.2. Review of new information on the status of swordfish (all)
        - Nominal and standardised CPUE indices
        - Stock assessments
        - Selection of Stock Status indicators
    - 5.3. Development of management advice for swordfish 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. **PROGRESS ON THE SWORDFISH MANAGEMENT STRATEGY EVALUATION**
7. **OTHER BILLFISHES (new information for informing future assessments)**
    - 7.1. Review of new information on other billfishes biology, stock structure, fisheries and associated environmental data (all)
    - 7.2. Resolution 18/05 Catch Limits
8. **WPB PROGRAM OF WORK**
    - 8.1. Revision of the WPB Program of Work (2024–2028) (Chairperson and IOTC Secretariat)
    - 8.2. Development of priorities for an Invited Expert at the next WPB meeting (Chairperson)
9. **OTHER BUSINESS**
    - 9.1. Election of the Chairperson and Vice-Chairperson of the WPB for the next biennium (Secretariat)
    - 9.2. Date and place of the 22nd and 23rd Sessions of the Working Party on Billfish (Chairperson and IOTC Secretariat)
    - 9.3. Review of the draft, and adoption of the Report of the 21st Session of the Working Party on Billfish (Chairperson)

APPENDIX III - LIST OF DOCUMENTS FOR THE 21ST WORKING PARTY ON BILLFISH

Document	Title
IOTC-2023-WPB21-01a	Agenda of the 21st Working Party on Billfish
IOTC-2023-WPB21-01b	Annotated agenda of the 21st Working Party on Billfish
IOTC-2023-WPB21-02	List of documents of the 21st Working Party on Billfish
IOTC-2023-WPB21-03	Outcomes of the 25th Session of the Scientific Committee (IOTC Secretariat)
IOTC-2023-WPB21-04	Outcomes of the 27th Session of the Commission (IOTC Secretariat)
IOTC-2023-WPB21-05	Review of Conservation and Management Measures relevant to billfish (IOTC Secretariat)
IOTC-2023-WPB21-06	Progress made on the recommendations and requests of WPB20 and SC25 (IOTC Secretariat)
IOTC-2023-WPB21-07	Review of the statistical data and fishery trends for billfish species (IOTC Secretariat)
IOTC-2023-WPB21-08	Revision of the WPB Program of Work (2024-2028) (IOTC Secretariat)
IOTC-2023-WPB21-09	Population structure of swordfish across the ICCAT/IOTC management boundary (West W, da Silva C and Kerwath S)
IOTC-2023-WPB21-10	Industrial longlining catch rates, temporal variation and length-frequency of swordfish (*Xiphias gladius*) fishery in the Kenyan Marine waters (Lukhwenda P)
IOTC-2023-WPB21-11	Population structural dynamics of the swordfish, *Xiphias gladius*, across the Indian Ocean using Next Generation Sequencing (Chevrier T, Cowart D, Nieblas A-E, Charrier G, Bernard S, Evano H, Brisset B, Chanut J, Bourjea J, Bonhommeau S)
IOTC-2023-WPB21-12	Update of the Swordfish Catch, Effort and Standardized CPUEs by the Portuguese Pelagic Longline Fleet Operating in the Indian Ocean, Between 1998 and 2022 (Coelho R, Rosa D and Lino P)
IOTC-2023-WPB21-13	Standardized CPUE of swordfish (*Xiphias gladius*) from Indonesian tuna longline fleets in the north-eastern Indian Ocean (Setyadji B, Spencer M, Kell L, Wright S, Ferson S, Budiarto A, Hernuyadin Y)
IOTC-2023-WPB21-14	CPUE standardization for swordfish (*Xiphias gladius*) by Japanese longline fishery in the Indian Ocean using zero-inflated Bayesian hierarchical spatial model (Matsumoto T, Taki K, Ijima H, and Kai M)
IOTC-2023-WPB21-15	Updated Standardized Catch Rates of Swordfish (Xiphias gladius) Caught by the Spanish Surface Longline Fleet in the Indian Ocean During the 2001-2021 Period (Fernández-Costa J, Ramos-Cartelle A, García-Cortés B and Mejuto J)
IOTC-2023-WPB21-16	CPUE standardization of swordfish (*Xiphias gladius*) caught by Taiwanese large-scale longline fishery in the Indian Ocean (Lin C-Y, Wang S-P, Xu W-Q)
IOTC-2023-WPB21-17	Population size estimation of swordfish through Close-Kin Mark Recapture (Chevrier T, Cowart D, Nieblas A-E, Baylis S, Bravington M, Bernard S, Evano H, Brisset B, Chanut J, Bonhommeau S)
IOTC-2023-WPB21-18	Stock assessment of swordfish (*Xiphias gladius*) in the Indian Ocean using A Stock-Production Model Incorporating Covariates (ASPIC) (Xu W-Q, Wang S-P, Lin C-Y)
IOTC-2023-WPB21-19	Indian Ocean Swordfish Stock Assessment 1950-2021 (Stock Synthesis) (Fu D)
IOTC-2023-WPB21-20	Billfish from Purse Seiners fisheries in the Andaman Sea of Thailand (Hoimuk S and Piabpabrattana S)
IOTC-2023-WPB21-21	Evaluating the Status of Large Pelagic Fisheries in Iran: A Focus on Sustainable Management of Billfish fisheries (Dafrazi RN)
IOTC-2023-WPB21-22	Analysis of the at-haulback mortality of striped marlin (*Tetrapturus audax*) in the western Indian Ocean by Chinese longline fishing using a GLM (Li X, Wang X, Guo Y, Wu F and Zhu J)
IOTC-2023-WPB21-23	Habitat and movements of the swordfish *Xiphias gladius* in the southern Indian Ocean oligotrophic gyre and beyond: preliminary results of swordfish tagging experiments in Reunion Island (Romanov E, Sabarros P, Guillon N, Le Foulgoc L, Dardalhon C, Bach P, Marsac F)

Document	**Title**
IOTC-2023-WPB21-24	Effect of bait types on the catchability of billfish in tuna long line fishery in Sri Lanka (Jayasinghe P)
IOTC-2023-WPB21-25	Larval billfish in the WIO and future research endeavor (Shiroza A)
IOTC-2023-WPB21-26	IOTC Swordfish Management Strategy Evaluation Update (Brunel T, Mosqueira I)
IOTC-2023-WPB21-27	Findings from 101 satellite tags deployed on Indian Ocean billfish during the FLOPPED project (Nieblas AE, Bernard S, Big Game Fishing Réunion, Brisset B, Bury M, Chanut J, Chevrier T, Coelho R, Colas Y, Evano H, Faure C, Hervé G, Kerzerho V, Nithard A, Newton R, Newton T, Rouyer T, Tracey S, Worthington J, Bonhommeau S)
IOTC-2023-WPB21-28	The Status of Billfish Populations in Somalia: Challenges and Opportunities for Conservation and Management (Nor SA)
IOTC-2023-WPB21-29	Shortbill spearfish *Tetrapturus angustirostris*: a note on the distribution and occurrence in the Indian Ocean fisheries (Romanov E, Ramos ML, Baez JC, Coelho R, Ruiz J, Sabarros P, and Merino G)
IOTC-2023-WPB21-30	Updated stock assessment of swordfish (Xiphias gladius) in the Indian Ocean using the Bayesian state-space surplus production model (JABBA) (Wang S-P)
IOTC-2023-WPB21-INF01	Review of the statistical data available for Indian Ocean black marlin (1950-2021)
IOTC-2023-WPB21-INF02	Review of the statistical data available for Indian Ocean blue marlin (1950-2021)
IOTC-2023-WPB21-INF03	Review of the statistical data available for Indian Ocean striped marlin (1950-2021)
IOTC-2023-WPB21-INF04	Review of the statistical data available for Indian Ocean Indo-pacific sailfish (1950-2021)
IOTC-2023-WPB21-INF05	Review of the statistical data available for Indian Ocean swordfish (1950-2021)
IOTC-2023-WPB21-INF06	Status of marlins and sailfish catches - Resolution 18/05

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

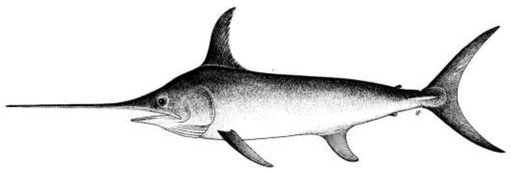

TABLE 1. Status of swordfish (*Xiphias gladius*) in the Indian Ocean.

Area[1]	Indicators		2023 stock status determination
Indian Ocean	Catch 2021[2] (t) Average catch 2017-2021 (t)	24,527 31,226	**97%**
	MSY (1,000 t) (80% CI) F_{MSY} (80% CI) SB_{MSY} (1,000 t) (80% CI) F_{2021}/F_{MSY} (80% CI) SB_{2021}/SB_{MSY} (80% CI) SB_{2021}/SB_{1950} (80% CI)	30 (26–33) 0.16 (0.12–0.20) 55 (40–70) 0.60 (0.43–0.77) 1.39 (1.01–1.77) 0.35 (0.32–0.37)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence
[2] Proportion of 2021 catch estimated or partially estimated by IOTC Secretariat: 22.7%

Colour key	Stock overfished ($SB_{year}/SB_{MSY} < 1$)	Stock not overfished ($SB_{year}/SB_{MSY} \geq 1$)
Stock subject to overfishing ($F_{year}/F_{MSY} > 1$)	0.002	0.000
Stock not subject to overfishing ($F_{year}/F_{MSY} \leq 1$)	0.03	0.97
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. In 2023 a new stock assessment was carried out for Swordfish in the IOTC area of competence to update the stock assessment undertaken in 2020. Two models were applied to the swordfish stock (ASPIC and Stock Synthesis (SS3)), with the SS3 stock assessment selected to provide scientific advice (as done previously). An update of the JABBA model was also conducted during the WPB meeting. The reported SS3 stock status is based on a grid of 48 model configurations designed to capture the uncertainty relating to steepness of the stock recruitment relationship (0.7, 0.8, and 0.9), recruitment variability (two levels), CPUE series (2 options), growth (2 options) and weighting of length composition data (two options). A number of the options included in the final grid were selected from a range of additional sensitivity runs that were conducted to explore uncertainties. Median spawning biomass in 2021 was estimated to be 35% (80% CI: 32-37%) of the unfished levels in 2021 (**Table 1**) and 1.39 times (80% CI: 1.01-1.77) times higher than the level required to support MSY. Median fishing mortality in 2021 was estimated to be 60% (80% CI 43%-77%) of the FMSY level, and catch in 2021 (23,237 t) was well below the estimated MSY level of 29,856 t (80% CI: 26,319-33,393t). Taking into account the characterized uncertainty, and on the weight-of-evidence available in 2023, the swordfish stock is determined to be not overfished and not subject to overfishing (**Table 1**, **Fig. 3**).

Outlook. The significant decrease in recent longline catch and effort from 2019 to 2021 (a 33% reduction from 34,718t to 23,237t) substantially lowered the pressure on the Indian Ocean stock as a whole, and current fishing mortality is not expected to reduce the population to an overfished state over the next decade. (**Table 1**). The estimated recent recruitment (2010-2020) was above the long-term average although this appears to be mainly driven by the sharp increase in the Japanese longline CPUE in the northern region. The WPB expressed concern over whether that CPUE index represents the change of abundance in that region which may require further investigation. Further, the Southwestern regions exhibit a declining biomass trend which indicate higher depletion in this region, compared to other regions.

Management advice. The 2021 catches (23,237t at the time of the assessment) were significantly lower than the estimated MSY level (29,856 t). Under those levels of catches, the spawning biomass was projected to likely increase, with a high probability of maintaining at or above the SB_{MSY} for the longer term. There is a very low risk of exceeding MSY-based reference points by 2031 if catches are maintained at 2021 levels (<1% risk that $SB_{2031} < SB_{MSY}$, and <1% risk that $F_{2021} > F_{MSY}$). Although the projections indicate that an increase of 40% or more from 2021 catch levels will not likely result in the biomass dropping below the SB_{MSY} level for the longer term (with a 15% probability). Nevertheless, the Commission should consider monitoring the catches to ensure that the probability of exceeding the SB_{MSY} target reference points in the long term remains minimal. Taking into account the differential CPUE and biomass trends between regions, the WPB noted that there is recurring evidence for localised depletion in the south western region (which appears to be more depleted than other regions) 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 29,856 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 fisheries (mean annual catch 2017-2021)**: swordfish are caught using longline (53.8%), followed by line (30.2%) and gillnet (15%). The remaining catches taken with other gears contributed to 0.9% of the total catches in recent years (**Fig. 1**).
- **Main fleets (mean annual catch 2017-2021)**: the majority of swordfish catches are attributed to vessels flagged to Sri Lanka (29.1%) followed by Taiwan,China (17.9%) and EU (Spain) (6.4%). The 25 other fleets catching swordfish contributed to 46.6% of the total catch in recent years (**Fig. 2**).

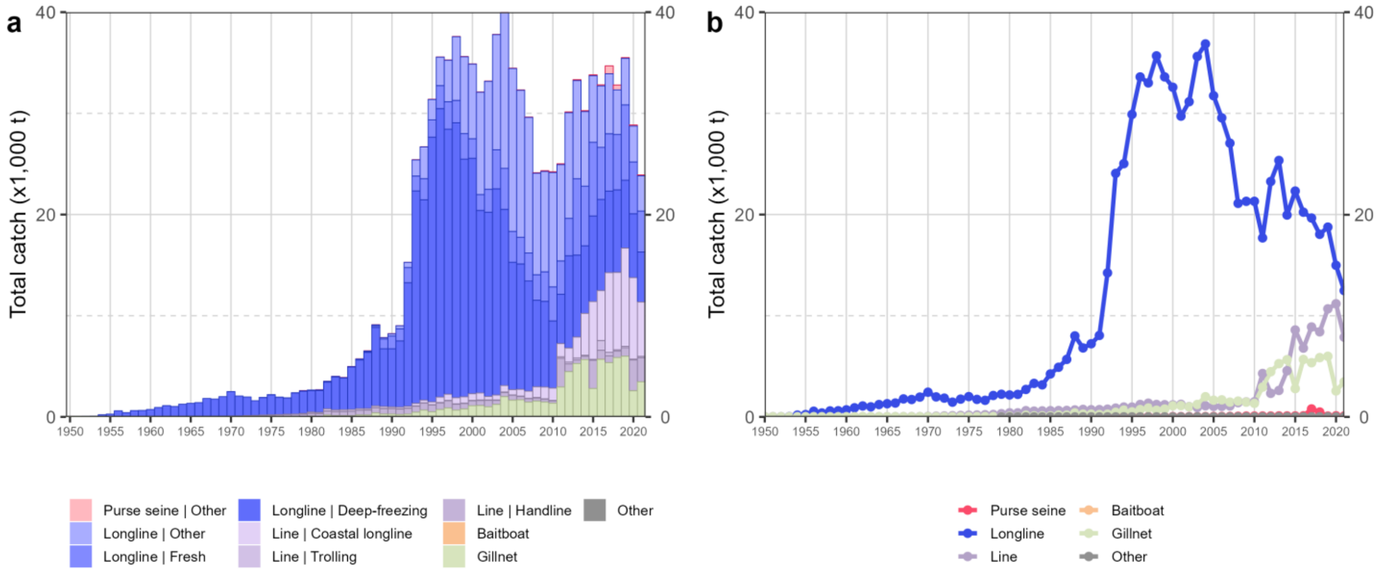

Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for swordfish during 1950–2021. Longline|Other: swordfish and sharks-targeting longlines; Other: all remaining fishing gears

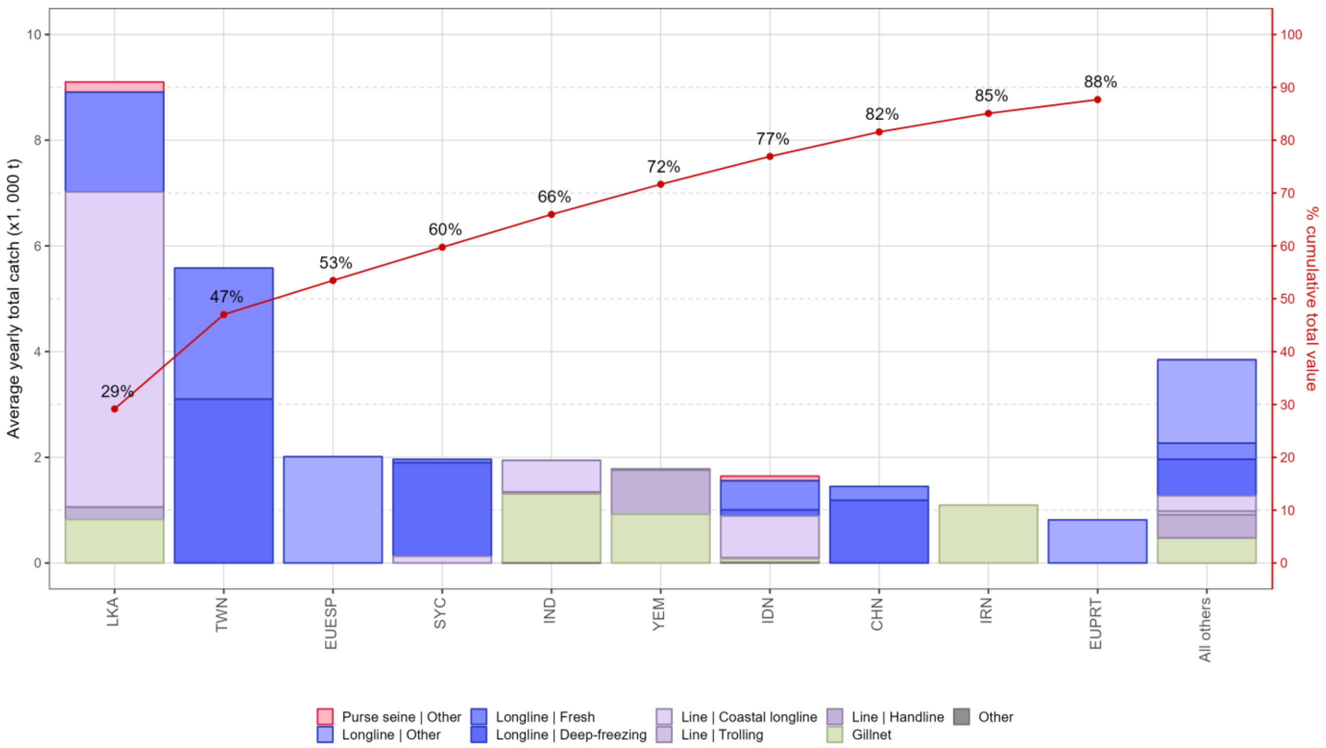

Fig. 2. Mean annual catches (metric tons; t) of swordfish by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

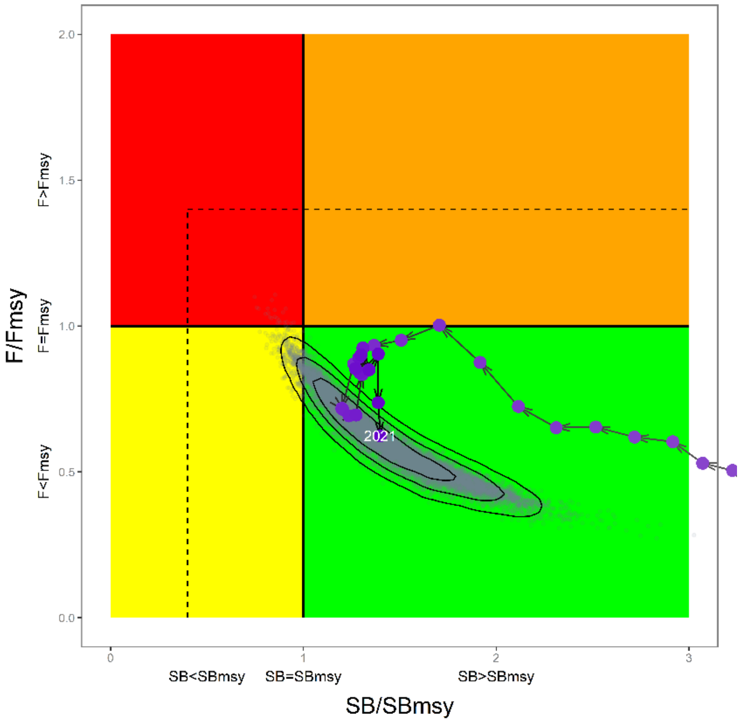

Fig. 3. Swordfish: 2021 stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the final model grid. Grey dots represent uncertainty from individual models with 50%, 80% and 95% contours lines. The arrowed line represents the time series of stock trajectory from the reference model. 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 2021* catch level (23 237t), 0%, ± 20%, ± 40%) projected for 10 years.

Pr ($SB<SB_{MSY}$)

Catch	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
60%	0.02	0.01	0	0	0	0	0	0	0	0
80%	0.02	0.01	0	0	0	0	0	0	0	0
100%	0.02	0.01	0.01	0.01	0	0	0	0	0	0
120%	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03
140%	0.02	0.02	0.02	0.03	0.04	0.06	0.09	0.11	0.14	0.15

Pr ($F>F_{MSY}$)

Catch	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120%	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.08
140%	0.18	0.20	0.24	0.28	0.33	0.36	0.40	0.42	0.35	0.30

** 2021 catches, at the time of the last swordfish assessment conducted in 2023.*

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

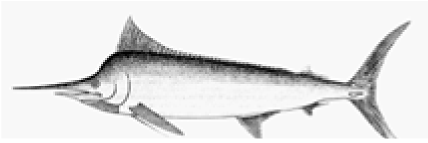

TABLE 1. Status of black marlin (*Istiompax indica*) in the Indian Ocean.

Area[1]	**Indicators**		**2022 stock status determination**
Indian Ocean	Catch 2021 (t)[2] Average catch 2017–2021 (t)	12,301 16,000	
	MSY (1,000 t) (95% CI) F_{MSY} (95% CI) B_{MSY} (1,000 t) (95% CI) F_{2019}/F_{MSY} (95% CI) B_{2019}/B_{MSY} (95% CI) B_{2019}/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 2021 catch fully or partially estimated by the IOTC Secretariat: 39.5%

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. No new stock assessment was carried out for black marlin in 2023, thus the stock status is determined on the basis of the 2021 assessment based on JABBA, a Bayesian state-space production model (using data up to 2019). (). The relative point estimates for this assessment are F/FMSY=0.53 (0.22-1.05) and B/BMSY=1.98 (1.42-2.57). The Kobe plot (Fig. 3) indicated that the stock is not subject to overfishing and is currently not overfished (Table 1; Fig. 3), 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 catch limits as stipulated in Resolution 18/05 have been exceeded for two consecutive years since 2020. Thus, it is recommended that the Commission review the implementation and effectiveness of the measures contained in this Resolution and consider the adoption of additional conservation and management measures. The Commission should provide mechanisms to ensure that catch limits are not exceeded by all concerned fisheries.

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 fisheries** (mean annual catch 2017-2021): black marlin are caught using gillnet (56.9%), followed by line (30.4%) and longline (8.4%). The remaining catches taken with other gears contributed to 4.4% of the total catches in recent years (**Fig. 1**).
- **Main fleets** (mean annual catch 2017-2021): the majority of black marlin catches are attributed to flagged to I. R. Iran (35.8%) followed by India (20.5%) and Sri Lanka (17.5%). The 25 other fleets catching black marlin contributed to 26% of the total catch in recent years (**Fig. 2**).

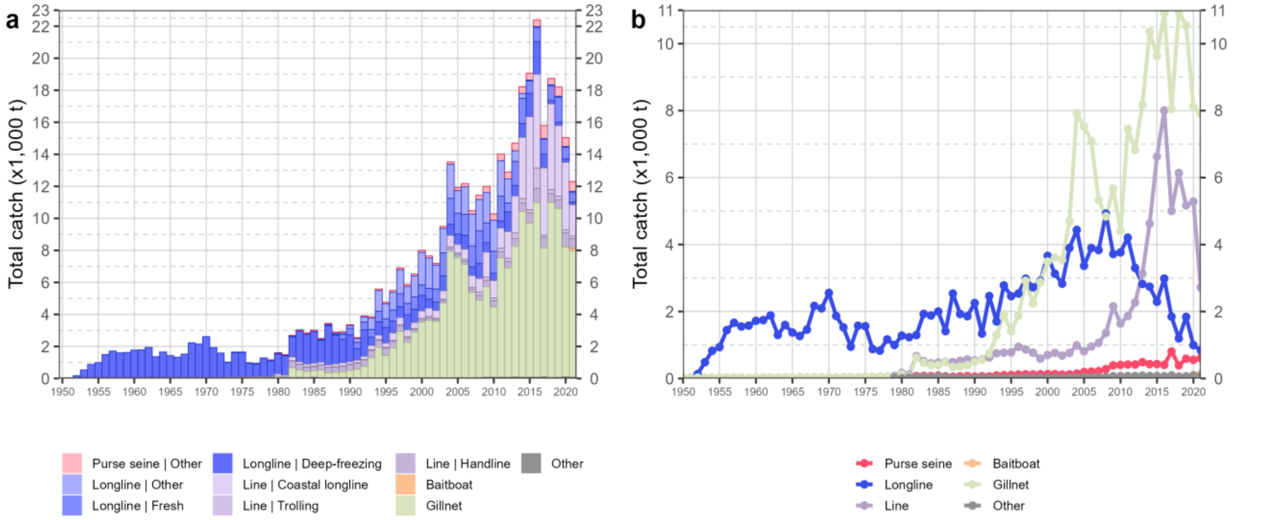

Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for black marlin during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

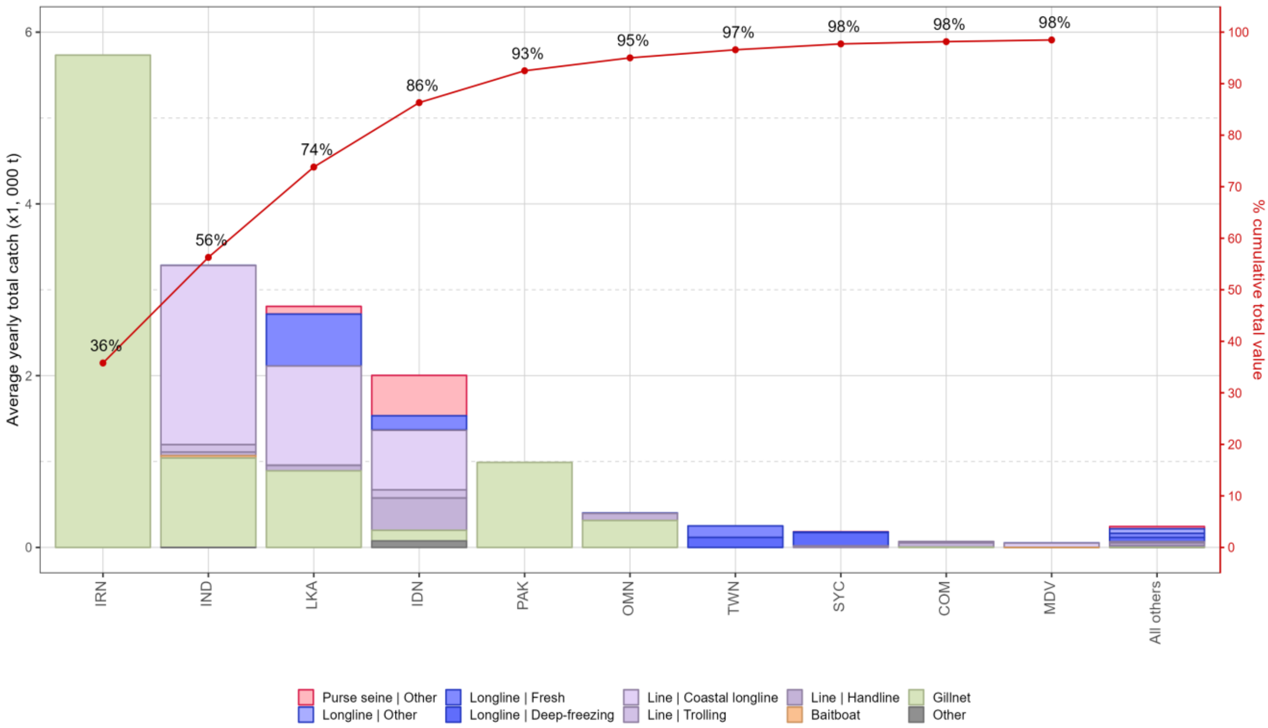

Fig. 2. Mean annual catches (metric tons; t) of black marlin by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

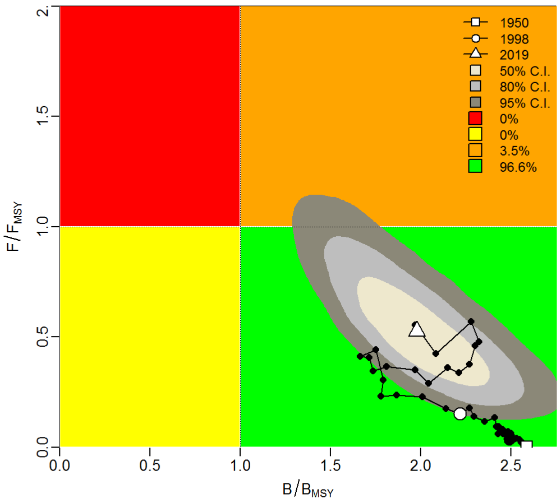

Fig. 2. JABBA Indian Ocean assessment Kobe plots for black marlin (contours are the 50, 80 and 95 percentiles of the 2019 estimate). Black line indicates the trajectory of the point estimates for the total biomass ratio (B/B_{MSY}) and fishing mortality ratio (F/F_{MSY}) for each year 1950–2019.

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

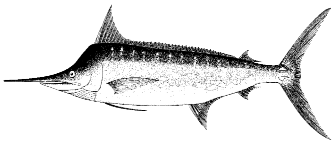

Table 1. Status of blue marlin (*Makaira nigricans*) in the Indian Ocean

Area[1]	Indicators		2022 stock status determination
Indian Ocean	Catch 2021[2] (t)	6,138	72%*
	Average catch 2017-2021 (t)	8,011	
	MSY (1,000 t) (80% CI)	8.74 (7.14 –10.72)	
	F_{MSY} (80% CI)	0.24 (0.14 – 0.39)	
	B_{MSY} (1,000 t) (80% CI)	35.8 (22.9 – 60.3)	
	F_{2020}/F_{MSY} (80% CI)	1.13 (0.75 – 1.69)	
	B_{2020}/B_{MSY} (80% CI)	0.73 (0.51 – 0.99)	
	B_{2020}/B_0 (80% CI)	0.36 (0.26 – 0.50)	

[1] Boundaries for the Indian Ocean are defined as the IOTC area of competence
[2] Proportion of 2021 catch estimated or partially estimated by IOTC Secretariat: 34.8%
* 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)	**72%**	**0%**
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	**26%**	**2%**
Not assessed/Uncertain		

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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. No new stock assessment was carried out for blue marlin in 2023, thus the stock status is determined on basis of the 2022 assessment which was based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured) (using data up to 2020). Uncertainty in the biological parameters is still evident and as such the JABBA model (B2020/BMSY = 0.73, F2020/FMSY =1.13) was selected as the base case. Both models were consistent with regards to stock status. On the weight-of-evidence available in 2022, the stock is determined to be ***overfished*** and ***subject to overfishing*** (**Table 1** and **Fig. 3**).

Outlook. The B/B_{MSY} trajectory declined from the mid-1980s to 2007. A short-term increase in B/B_{MSY} occurred from 2007 to 2012, which is thought to be linked to the NW Indian Ocean Piracy period. Thereafter, the B/B_{MSY} trajectory again declines to the current estimate **of 0.73**. F/F_{MSY} increased since the mid-1980s and despite a recent decline, F/F_{MSY} remains above 1. The majority of CPUE indices have shown a declining trend since 2015.

Management advice. The current catches of blue marlin (average of 7,964 t in the last 5 years, 2017-2021) are lower than MSY (8,740 t). 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 20% compared to 2020 catch (7,126 t), to a maximum value of approximately 5,700 t.

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the Indian Ocean blue marlin stock is 8,740 t (estimated range 7,140–10,720 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 fisheries (mean annual catch 2017-2021)**: blue marlin are caught using longline (53.1%), followed by line (22.9%) and gillnet (21%). The remaining catches taken with other gears contributed to 3.1% of the total catches in recent years (**Fig. 1**).
- **Main fleets (mean annual catch 2017-2021)**: the majority of blue marlin catches are attributed to vessels flagged to Taiwan,China (28.9%) followed by Sri Lanka (26.3%) and India (14.1%). The 22 other fleets catching blue marlin contributed to 30.7% of the total catch in recent years (Fig. 2).

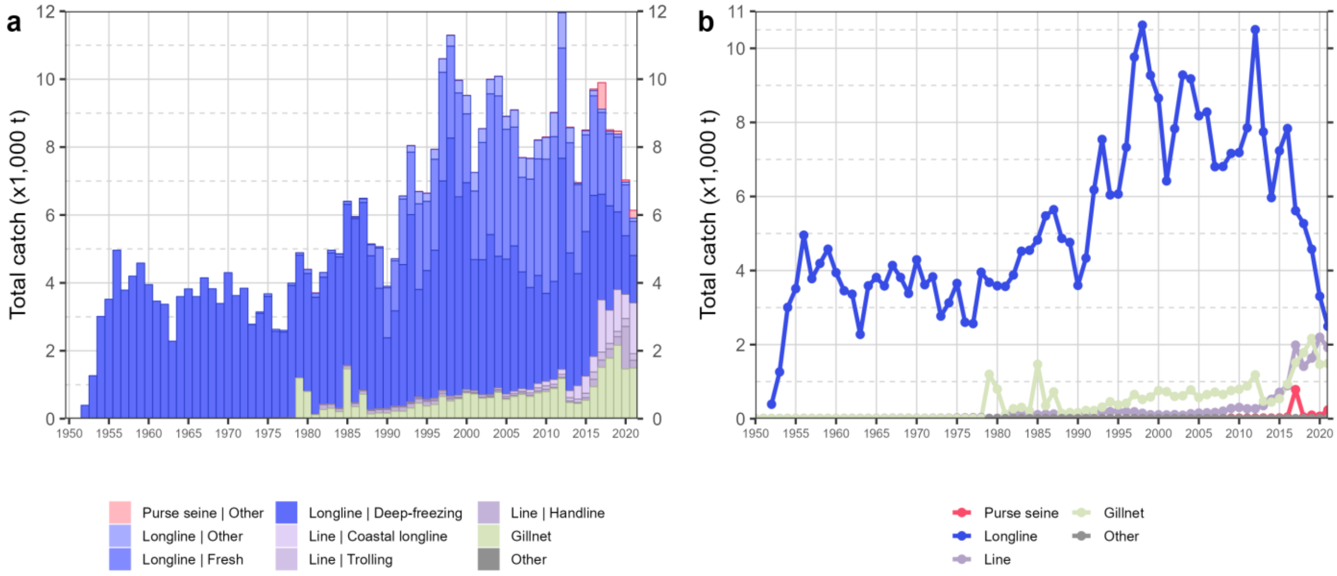

Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for blue marlin during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

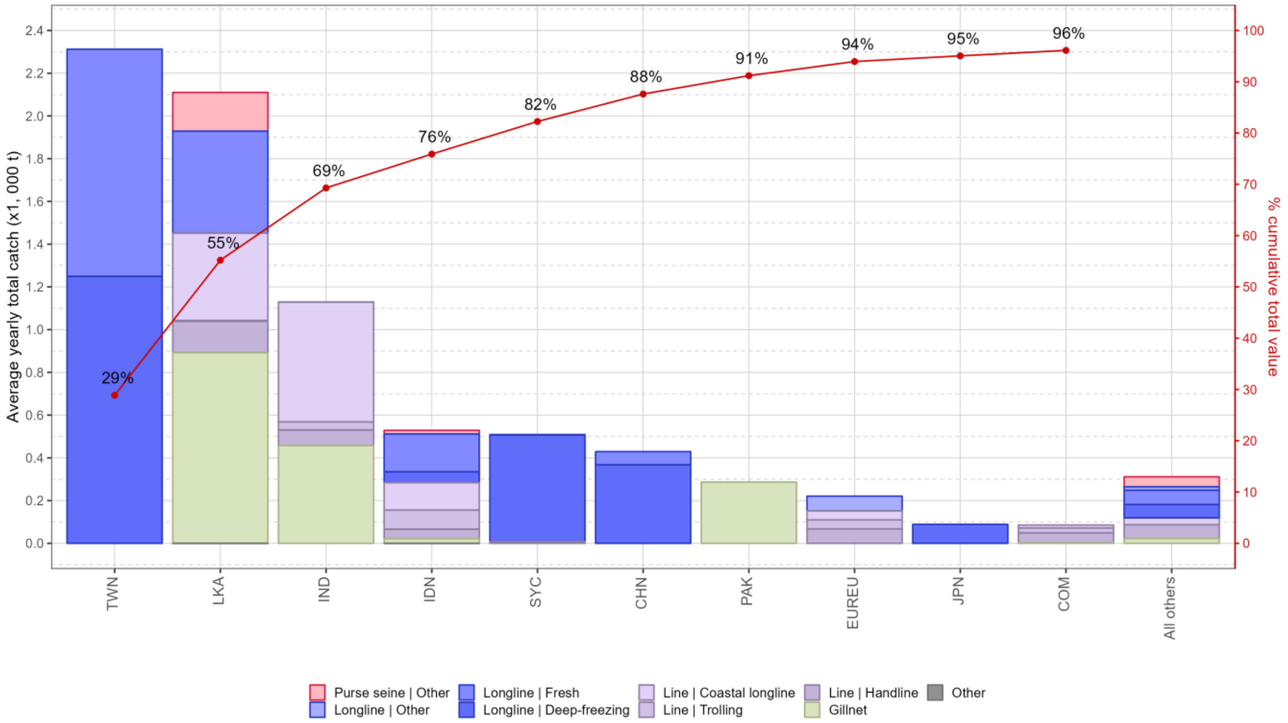

Fig. 2. Mean annual catches (metric tons; t) of blue marlin by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

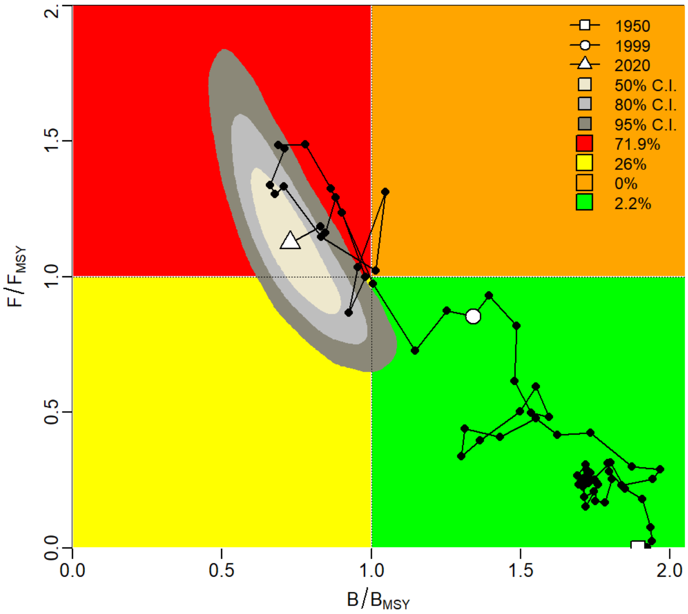

Fig. 3. Kobe stock status plot for the Indian Ocean stock of blue marlin, from the final JABBA base case (the black line traces the trajectory of the stock over time). Contours represent the smoothed probability distribution for 2020 (isopleths are probability relative to the maximum).

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 2020 catch level (7,126 t)

Probability $F<=F_{MSY}$ and $B>=B_{MSY}$

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030
2137 (30%)	65%	81%	90%	94%	96%	98%	99%	99%
2850 (40%)	59%	76%	85%	91%	94%	96%	97%	98%
3563 (50%)	54%	70%	80%	87%	90%	93%	95%	96%
4275 (60%)	48%	63%	73%	80%	86%	89%	91%	93%
4998 (70%)	42%	55%	65%	72%	78%	82%	85%	88%
5700 (80%)	36%	47%	56%	63%	69%	73%	77%	79%
6413 (90%)	30%	40%	46%	53%	57%	61%	65%	67%
7126 (100%)	25%	32%	37%	41%	45%	48%	51%	53%
7838 (110%)	21%	24%	28%	31%	33%	35%	37%	38%

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

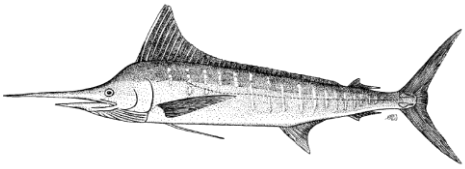

Table 1. Status of striped marlin (*Kajikia audax*) in the Indian Ocean

Area[1]	Indicators		2022 stock status determination
Indian Ocean	Catch 2021[2] (t) Average catch 2017-2021 (t)	2,645 2,936	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_{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)[4]	0.47 (0.35 - 0.63)	
	B_{2019}/B_0(JABBA)	0.12 (0.10 – 0.19)	
	SB_{2019}/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 2021 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. No new stock assessment was carried out for striped marlin in 2023, thus the stock status is determined on the basis of the 2021 assessment based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). (using data up to 2019). 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. 3**).

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 2019 catches (3,001 t) available at the time of the stock assessment 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 4,120 - 5,160 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 fisheries (mean annual catch 2017-2021)**: striped marlin are caught using gillnet (58.8%), followed by longline (27.1%) and line (12.2%). The remaining catches taken with other gears contributed to 1.9% of the total catches in recent years (**Fig. 1**).
- **Main fleets (mean annual catch 2017-2021)**: the majority of striped marlin catches are attributed to vessels flagged to I. R. Iran (29.5%) followed by Pakistan (25.4%) and Indonesia (17.9%). The 23 other fleets catching striped marlin contributed to 27.2% of the total catch in recent years (**Fig. 2**).

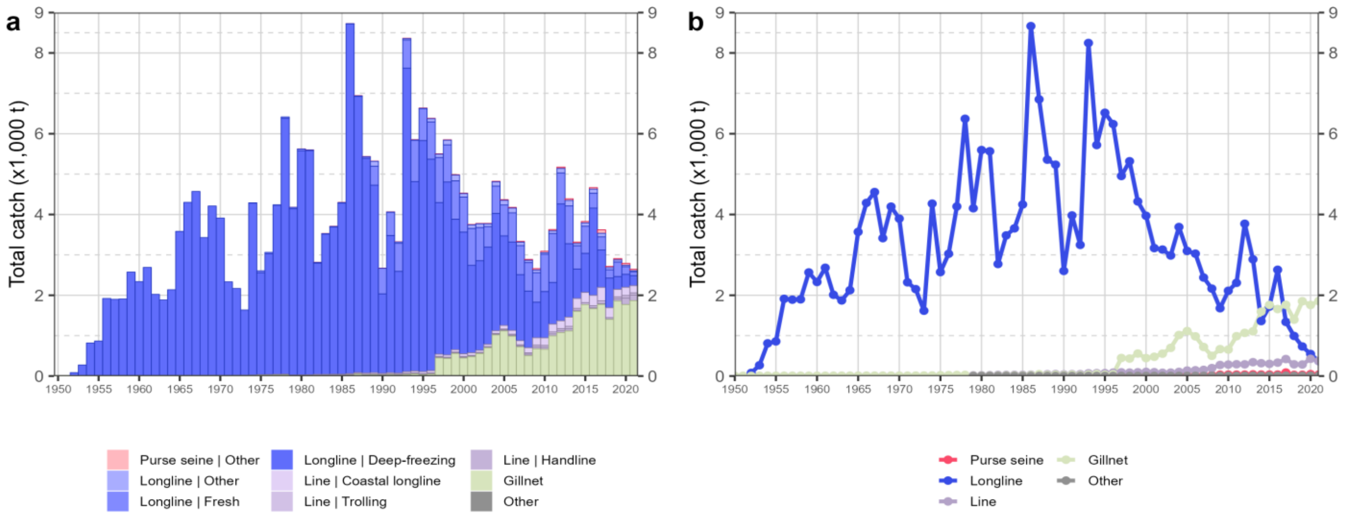

Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for striped marlin during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

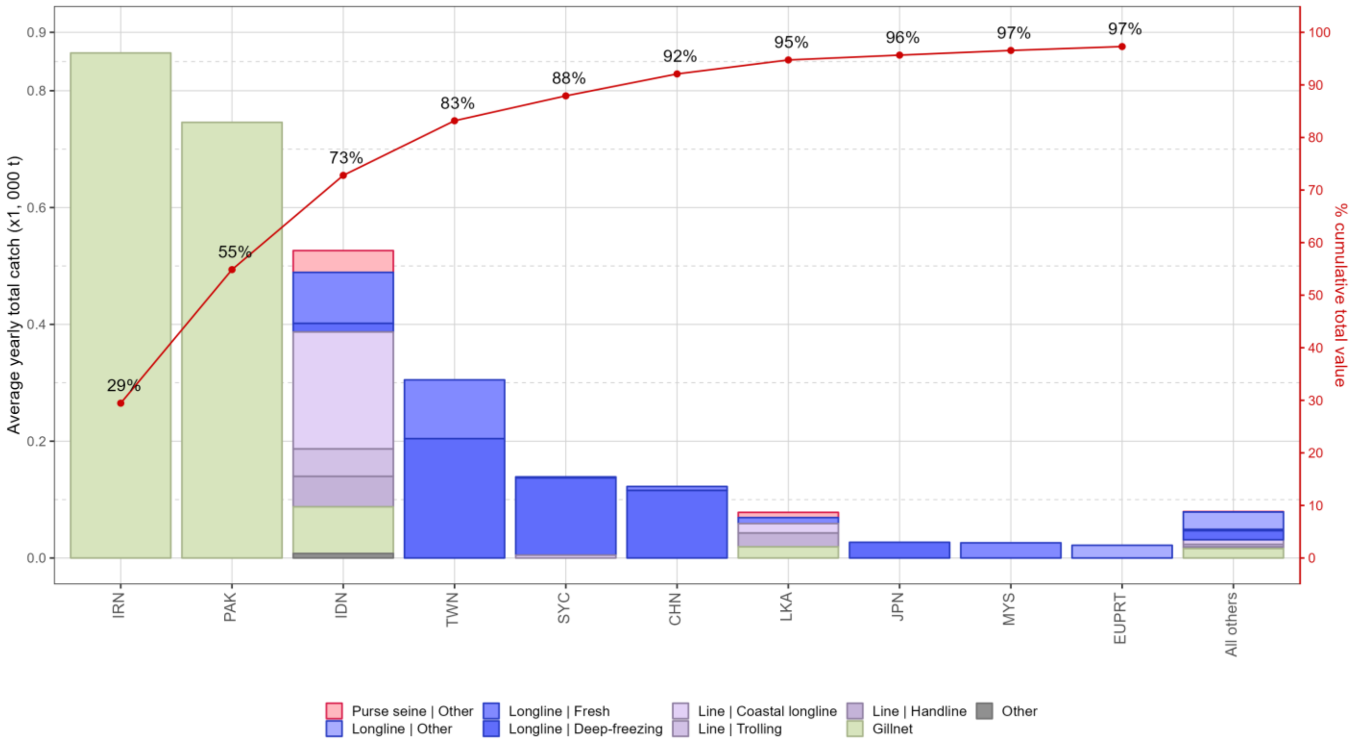

Fig. 2. Mean annual catches (metric tons; t) of striped marlin by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

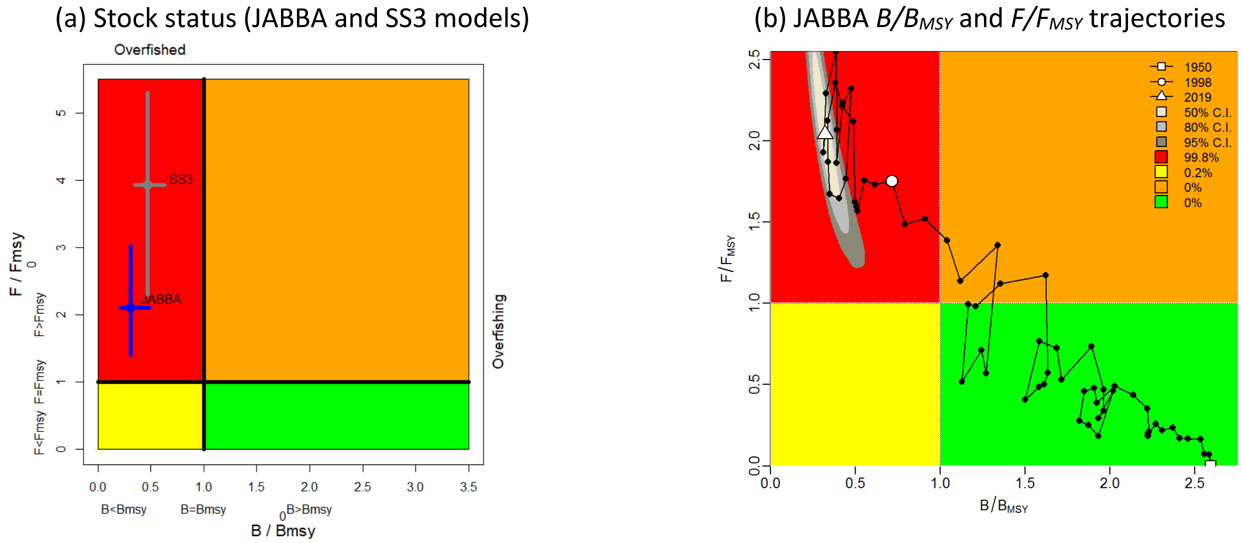

Fig. 3. (a) Striped marlin: Stock status from the Indian Ocean assessment JABBA (Bayesian State Space Surplus Production Model) and SS3 models with the confidence intervals (left); (b) Trajectories (1950-2019) of *B/B_{MSY} and F/F_{MSY}* from the JABBA model. NB: SS3 refers to SB/SB_{MSY} while the 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 VIII - [DRAFT] RESOURCE STOCK STATUS SUMMARY – INDO-PACIFIC SAILFISH

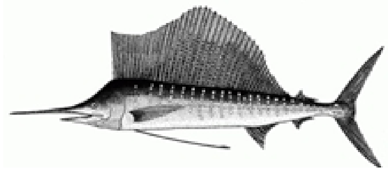

Table 1. Status of Indo-Pacific sailfish (*Istiophorus platypterus*) in the Indian Ocean

Area[1]	Indicators		2022 stock status determination
Indian Ocean	Catch 2021[2] (t) Average catch 2017-2021 (t)	37,587 32,491	**54%**
	MSY (1,000 t) (80% CI) F_{MSY} (80% CI) B_{MSY} (1,000 t) (80% CI) F_{2019}/F_{MSY} (80% CI) B_{2019}/B_{MSY} (80% CI) B_{2019}/B_0 (80% CI)	25.9 (20.8 – 34.2) 0.19 (0.15 - 0.24) 138 (108–186) 0.98 (0.65 – 1.42) 1.17 (0.94 – 1.42) 0.58 (0.47 – 0.71)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence
[2] Proportion of 2021 catch estimated or partially estimated by IOTC Secretariat: 39.5%

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)	7%	39%
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	0%	54%
Not assessed/Uncertain		

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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. No new stock assessment was carried out for Indo-Pacific Sailfish in 2023, thus the stock status is determined on basis of the 2022 stock assessment based on JABBA (using data up to 2019). Data poor methods (C-MSY and SFA) applied to SFA in 2019 rely on catch data only, which is highly uncertain for this species, and resulted in the stock status determined to be uncertain. To overcome the lack of abundance indices for this species, this assessment incorporated length-frequency data to estimate annual Spawning Potential Ratio (SPR). Normalised annual estimates of SPR were assumed to be proportional to biomass and incorporated as an index of relative abundance in the JABBA model (assuming no trends in annual recruitment in the long term). This is a novel technique applied to overcome the paucity of abundance data for SFA. The results indicate that there has been a 41% decline in SPR since 1970. B/B_{MSY} declined consistently from the early-1980s, while F/F_{MSY} gradually increased from 1980, peaking in 2018 at 1.1. The latest (2019) estimate of B/B_{MSY} was 1.17, while the F/F_{MSY} estimate was 0.98.
On the weight-of-evidence available in 2022, the stock status of Indo-Pacific sailfish is determined to be ***not overfished nor subject to overfishing*** (**Table 1**; **Fig. 3**).

Outlook. Catches have exceeded the estimated MSY since 2013 and the current catches (average of 31,593 t in the last 3 years, 2019-2021) are substantially higher than the current MSY estimate of 25,905 t. This increase in coastal gillnet longline 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 both the 2020 and 2021 catches 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 for two consecutive years since 2020. In spite of the Kobe green status of the stock, it is recommended that the Commission review the implementation and effectiveness of the measures contained in this Resolution and consider the adoption of additional conservation and management measures. 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 coastal gillnet and longline fisheries, and further exploration of stock assessment approaches for data poor fisheries are warranted. Given the limited data being reported for coastal 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 25,905 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 fisheries (mean annual catch 2017-2021):** Indo-Pacific sailfish are using gillnet (72.3%), followed by line (23.5%) and longline (3.3%). The remaining catches taken with other gears contributed to 1% of the total catches in recent years (**Fig. 1**)**.**
- **Main fleets (mean annual catch 2017-2021)**: the majority of Indo-Pacific sailfish catches are attributed to vessels flagged to I. R. Iran (39.3%) followed by India (22.8%) and United republic of Tanzania (8.3%). The 31 other fleets catching Indo-Pacific sailfish contributed to 29.3% of the total catch in recent years (**Fig. 2**).

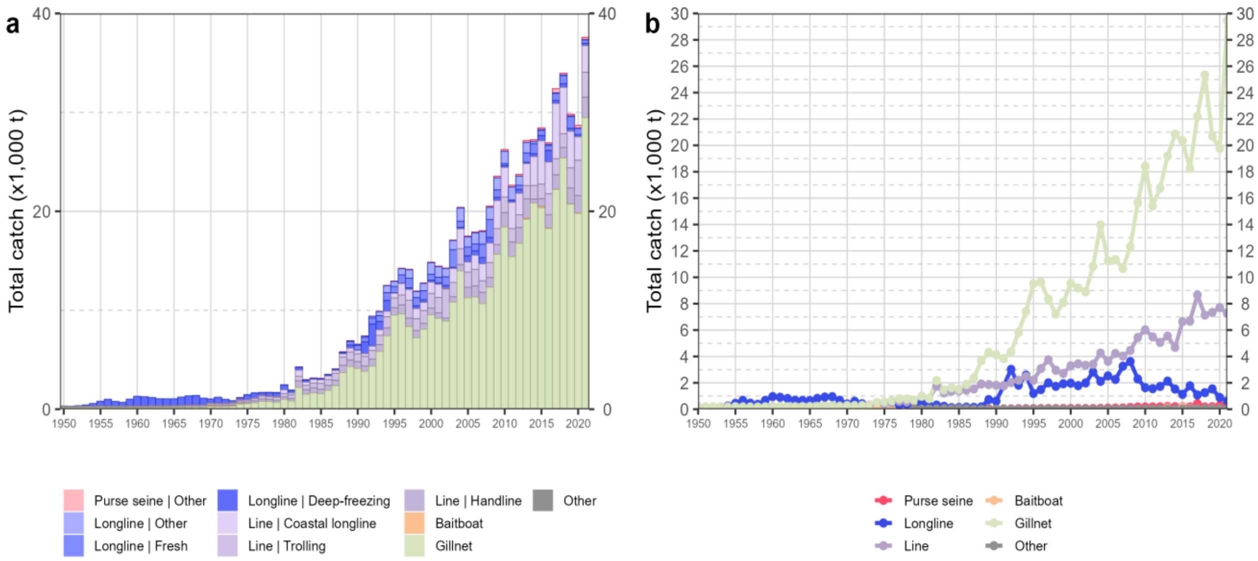

Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for Indo-Pacific sailfish during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

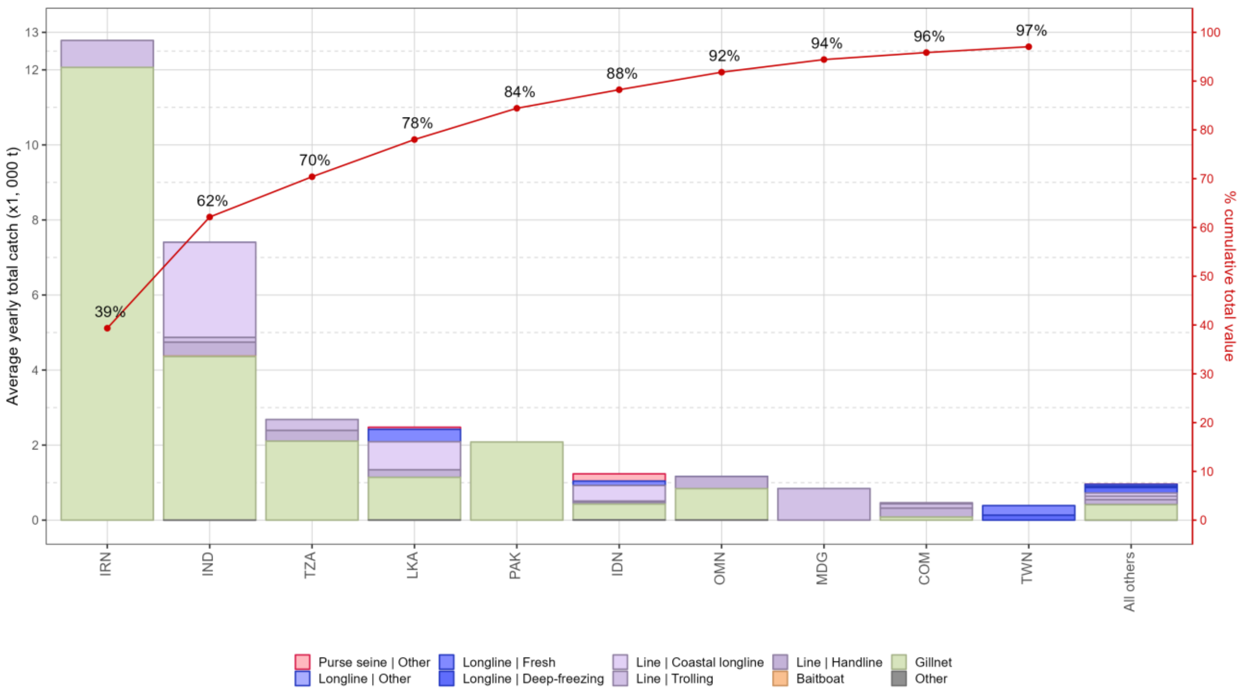

Fig. 2. Mean annual catches (metric tons; t) of Indo-Pacific sailfish by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

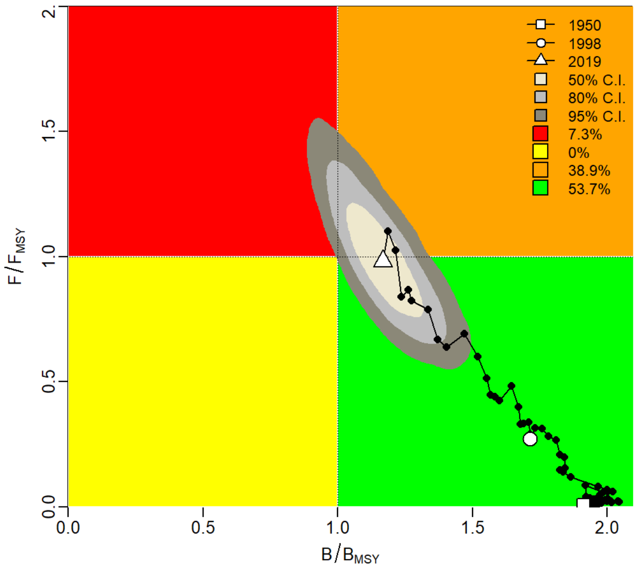

Fig. 3. Indo-Pacific sailfish: Kobe plot showing estimated trajectories (1950-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

Table 2. Summary of posterior quantiles presented in the form of marginal posterior medians and associated the 95% credibility intervals of parameters for the JABBA assessment of Indian Ocean Indo-Pacific sailfish.

Estimates	***Median***	***2.5%***	***97.5%***
K	276,803	215,921	371,953
r	0.375	0.293	0.476
ψ (*psi*)	0.964	0.827	0.999
σ_{proc}	0.052	0.034	0.088
F_{MSY}	0.188	0.146	0.238
B_{MSY}	138,402	107,961	185,977
MSY	25,906	20,789	34,168
B_{1959}/K	0.956	0.801	1.084
B_{2019}/K	0.584	0.472	0.709
B_{2019}/B_{MSY}	1.167	0.944	1.417
F_{2019}/F_{MSY}	0.982	0.65	1.421

APPENDIX IX
WORKING PARTY ON BILLFISH PROGRAM OF WORK (2024–2028)

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				
		2024	2025	2026	2027	2028
1. 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).					
2. Biological and ecological information	2.1 Age and growth research 2.1.1 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)					
	2.2 Spawning time and locations 2.2.1 Collect gonad samples from billfish or utilise any other scientific means to confirm the spawning time and location of the spawning areas 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.					

	2.3 Stock structure (connectivity and diversity) 2.3.1 Continue work on determining stock structure of Billfish species, using complimentary data sources, including genetic and microchemistry information as well as other relevant sources/studies.					
3. Billfish bycatch mitigation	WPB and CPCs scientists to firstly, review and summarise existing information on billfish bycatch mitigation, including also factors influencing at-haul and post-release mortality of billfish, and secondly to undertake further research to inform gaps in understanding on potential effective mitigation approaches, to provide options for the Commission to reduce fishing mortality for species where that is required (e.g. Black Marlin, Striped Marlin and Sailfish) focusing on gillnet and longline fisheries but also including recreational and sport fishing activities .					
Other Future Research Requirements (not in order of priority)						
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. 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.					
10. Billfish as bycatch	How to provide scientific advice to management on billfish caught as bycatch					

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

Species	2024	2025	2026	2027	2028
Black marlin	**Full assessment**			**Full assessment**	
Blue marlin		**Full assessment**			**Full assessment**
Striped marlin	**Full assessment**			**Full assessment**	
Swordfish		**Indicators****	**Full assessment**		**Indicators****
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 X
CONSOLIDATED RECOMMENDATIONS OF THE 21ST SESSION OF THE WORKING PARTY ON BILLFISH

Note: Appendix references refer to the Report of the 21st Session of the Working Party on Billfish (IOTC–2023–WPB21–R)

The following are the complete recommendations from the WPB21 to the Scientific Committee:

Review of new information on other billfishes biology, stock structure, fisheries and associated environmental data

WPB21.01 (para 132): Based on this presentation the WPB **AGREED** that there is evidence that the species is being caught in IOTC fisheries and that the species population size may be declining. As such the WPB reiterated its previous **RECOMMENDATION** that shortbill spearfish be included as an IOTC species.

Revision of the WPB Program of work (2024–2028)

WPB21.02 (para 142): The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2024–2028), as provided in Appendix IX.

Date and place of the 22nd and 23rd Sessions of the Working Party on Billfish

WPB21.03 (para 149): The WPB **NOTED** that in 2022, a two-day workshop to discuss the standard of billfish maturity staging inter-sessionally prior to the WPB was requested. As the funding for this workshop was approved by the Commission in 2023, the WPB **RECOMMENDED** that this workshop should take place immediately place prior to the next session of the WPB in 2024.

WPB21.04 (para 151): The WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB22 in 2024. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB. As the WPB are planning to hold a workshop immediately prior to the next WPB meeting, it was **REQUESTED** that the WPB once again take place before the WPEB in 2024.

Review of the draft, and adoption of the Report of the 21st Session of the Working Party on Billfish

WPB21.05 (para 152): The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB21, provided at Appendix X, 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 2023 (Fig. 3):

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

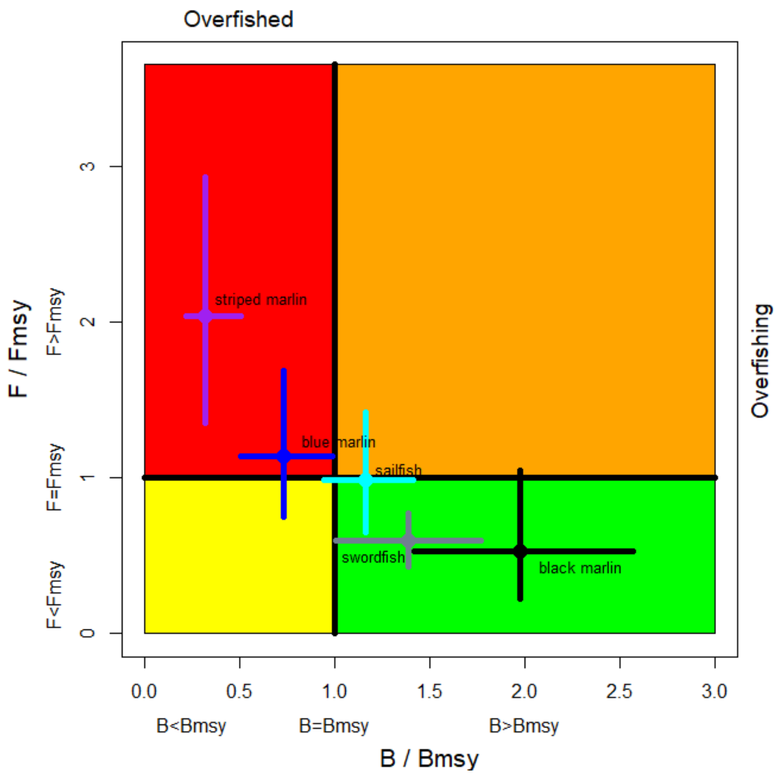

Fig. 3. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2018, 2019, 2021, 2022, and 2023 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs.