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

Online, 12–15 September 2022

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Contact details:

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

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**).

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 20th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Billfish (WPB) was held online using the Zoom platform from the 12 to 15 September 2022. A total of 51 participants (55 in 2021, 55 in 2020 and 25 in 2019) attended the Session. The list of participants is provided at Appendix I. The meeting was opened by the Chairperson, Dr Denham Parker (South Africa), who welcomed participants.

The following are the complete recommendations from the WPB20 to the Scientific Committee, which are also provided at Appendix XII:

Resolution 18/05 Catch Limits

WPB20.01 (para 142): The WPB **NOTED** that reported catches of two species, black marlin and Indo-Pacific sailfish, have exceeded the limits set out in Resolution 18/05 for both 2020 and 2021 and so the WPB **RECOMMENDED** that the SC report this to the Commission as management action is required.

Revision of the WPB Program of work (2023–2027)

WPB20.02 (para 148): The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2023–2027), as provided at Appendix XI.

Date and place of the 21st and 22nd Sessions of the Working Party on Billfish

WPB20.03 (para 152): The WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB21 in 2023. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB, with the WPEB taking place after the WPB in 2023.

Review of the draft, and adoption of the Report of the 20th Session of the Working Party on Billfish

WPB20.04 (para 153): The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB20, provided at Appendix XII, as well as the management advice provided in the draft resource stock status summary for each of the five billfish species under the IOTC mandate, and the combined Kobe plot for the five species assigned a stock status in 2022 (Fig. 4):

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

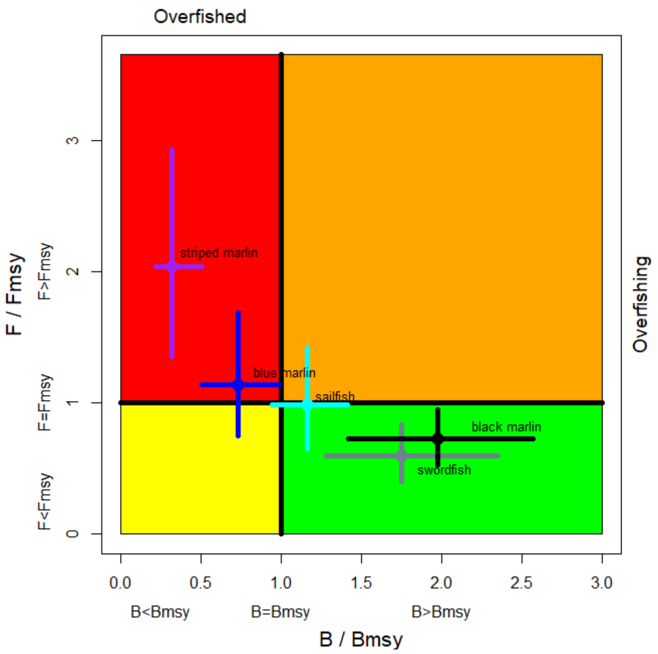


Fig. 4. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2018, 2019, 2020, 2021 and 2022 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in 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	2018	2019	2020	2021	2022	Advice to the Scientific Committee
Swordfish *Xiphias gladius*	Catch 2021 (t): 23,917 Average catch 2017-2021 (t): 31,157 MSY (1,000 t) (80% CI): 33 (27–40) F_{MSY} (80% CI): 0.23 (0.15–0.31) SB_{MSY} (1,000 t) (80% CI): 59 (41–77) F_{2018}/F_{MSY} (80% CI): 0.60 (0.40–0.83) SB_{2018}/SB_{MSY} (80% CI): 1.75 (1.28–2.35) SB_{2018}/SB_{1950} (80% CI): 0.42 (0.36–0.47)					*98%*	***Stock status.*** No new stock assessment was carried out for swordfish in 2022, thus the stock status is determined on the basis of the 2020 assessment. The assessment uses a spatially disaggregated, sex explicit and age structured model. The SS3 model, used for stock status advice, indicated that MSY-based reference points were not exceeded for the Indian Ocean population as a whole (F_{2018}/F_{MSY}< 1; SB_{2018}/SB_{MSY}> 1). The two alternative models (ASPIC and JABBA) applied to swordfish also indicated that the stock was above a biomass level that would produce MSY. Spawning stock biomass in 2018 was estimated to be 40-83% of the unfished levels. Most recent catches of 30,847 t in 2018 are below the MSY level (33,000 t). On the weight-of-evidence available in 2020, the stock is determined to be ***not overfished*** and ***not subject to overfishing***. ***Management advice.*** The most recent catches (33,590t in 2019 – at the time of the asssessment) are below the MSY level (33,000 t). Under the current levels of catches, the stock biomass is projected to remain relatively stable, with a high probability of maintaining at or above the SB_{MSY} for the longer term. An increase of 40% or more from current catch levels will likely result in the biomass dropping below the SB_{MSY} level for the longer term (with approximately 50% probability). Taking into account the updated information regarding swordfish stock structure (IOTC-2020-WPB18-09), as well as the differential CPUE and biomass trends between regions, the WPB should continue to discuss the swordfish stock assessment model specifications and consider the feasibility of including a multi-stock assessment in 2023. Recognising that there is recurring evidence for localised depletion in the southern regions the WPB expresses concern and suggests this should be further monitored. Click here for full stock status summary: Appendix VI
Black marlin *Makaira indica*	Catch 2021: 14,115 t Average catch 2017–2021: 16,864 t MSY (1000 t) (95% CI): 17,301 (10,979 – 35,024) F_{MSY} (95% CI): 0.20 (0.12 - 0.34) F_{2019}/F_{MSY} (95% CI): 0.53 (0.22 – 1.05) $B_{2019}B_{MSY}$ (95% CI): 1.98 (1.42 – 2.57) B_{2019}/B_{1950} (95% CI): 0.73 (0.53-0.95)						***Stock status.*** No new stock assessment was carried out for swordfish in 2022, thus the stock status is determined on the basis of the 2021 assessment based on JABBA, a Bayesian state-space production model (age-aggregated). The relative point estimates for this assessment are F/F_{MSY}=0.53 (0.22-1.05) and B/B_{MSY}=1.98 (1.42-2.57). The Kobe plot indicated that the stock is not **subject to overfishing** and is currently not **overfished**, however these status estimates are subject to a high degree of uncertainty. The recent sharp increases in total catches (e.g., from 13,000 t in 2012 to over 22,000 t by 2016), and conflicts in information between CPUE and catch data lead to large uncertainties in the assessment outputs. Similar uncertainties were observed in the 2018 assessment of black marlin, which caused the point estimate of the stock status to change from the red (2016) to the green (2018) zone of the Kobe plot without any evidence of a rebuilding trend. **Since 2018, there has been no discernable improvement in the data available for black marlin and the subsequent assessment outputs remain uncertain and should be interpreted with caution**. **As such, there is no reasonable justification to change the stock status from "Not assessed/Uncertain".**

							Management advice. The 2019 catches (18,068 t) are substantially higher than the MSY limit stipulated in Res (18/05), which is 9,932 t. The Commission should provide mechanisms to ensure that catch limits are not exceeded by all concerned fisheries. Projections were not carried out due to the poor predictive capabilities identified in the assessment diagnostics. Click here for full stock status summary: Appendix VII
Blue marlin *Makaira nigricans*	Catch 2021: 5,772 t Average catch 2017–2021: 7.964 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)					*87%*	***Stock status.*** In 2022 a stock assessment was conducted based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). Uncertainty in the biological parameters was still noted and as such the JABBA model (B2020/BMSY = 0.73, F2020/FMSY = 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 (F2027 < FMSY and B2027 > BMSY) 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 VIII
Striped marlin *Tetrapturus audax*	Catch 2021: 2,696 t Average catch 2017–2021: 2,946 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 2022, 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). Both models were generally consistent with regards to stock status and confirmed the results from 2012, 2013, 2015, 2017 and 2018 assessments, indicating that the stock is subject to overfishing ($F>F_{MSY}$) and is overfished, with the biomass being below the level which would produce MSY ($B<B_{MSY}$) for over a decade. On the weight-of-evidence available in 2021, the stock status of striped marlin is determined to be ***overfished*** and ***subject to overfishing*** ***Management advice.*** Current or increasing catches have a very high risk of further decline in the stock status. The current 2019 catches (3,001 t) are lower than MSY (4,601 t) but the stock has been overfished for more than two decades and is now in a highly depleted state. If the Commission wishes to recover the stock to the green quadrant of the Kobe plot with a probability ranging from 60% to 90% by 2026 as per Resolution 18/05, it needs to provide mechanisms to ensure the maximum annual catches remain between 900 t – 1,500 t. Click here for full stock status summary: Appendix IX
Indo-Pacific Sailfish	Catch 2021: 37,310 t Average catch 2017–2021: 32,178 t					54%	***Stock status:*** In 2022 a new stock assessment was conducted 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,

Istiophorus platypterus	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)					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/BMSY declined consistently from the early-1980s, while F/FMSY gradually increased from 1980, peaking in 2018 at 1.1. The latest (2019) estimate of B/BMSY was 1.17, while the F/FMSY 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 X

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

1. Opening of the session

1. The 20th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Billfish (WPB) was held online using the Zoom platform from the 12 to 15 September 2022. A total of 51 participants (55 in 2021, 55 in 2020 and 25 in 2019) attended the Session. The list of participants is provided at Appendix I. The meeting was opened by the Chairperson, Dr Denham Parker (South Africa), who welcomed participants.

2. Adoption of the Agenda and arrangements for the Session

2. The WPB **ADOPTED** the Agenda provided in Appendix II. The documents presented to the WPB20 are listed in Appendix III.

3. The IOTC process: Outcomes, updates and progress

3.1 Outcomes of the 24th Session of the Scientific Committee

3. The WPB **NOTED** paper IOTC–2022–WPB20–03 which describes the main outcomes of the 24th Session of the Scientific Committee (SC24), specifically related to the work of the WPB:

> ***"7.2 Report of the 19th Session of the Working Party on Billfish***
>
> *41. The SC **NOTED** the report of the 19th Session of the Working Party on Billfish (IOTC–2021–WPB19–R), including the consolidated list of recommendations provided as an appendix to the report. The meeting was attended by 55 participants (cf. 55 in 2020). No MPF funding was provided as the meeting was held online.*
>
> *42. **RECALLING** that one of the Indian Ocean billfish species (shortbill spearfish,* Tetrapturus angustirostris*) is currently not listed among the species managed by IOTC, and considering the ocean-wide distribution of this species, its highly-migratory nature, and that it is a common bycatch in IOTC managed fisheries, the SC reiterated its previous **RECOMMENDATION** that shortbill spearfish be included as an IOTC species.*
>
> *43. The SC further **NOTED** that this would require the revision of the IOTC Agreement and the Commission to include some flexible mechanism to allow for changes in the list of species under the IOTC mandate in the future.*
>
> *44. The SC **ACKNOWLEDGED** the potential interest of considering size limits (e.g., approximated by size at maturity) as a complementary management measure for billfish species but NOTED that this was not discussed at the WPB. As such, the SC **REQUESTED** the WPB to review the available information on size at its next session to be held in 2022, further NOTING that information on post-release mortality would be required for assessing the efficacy of such measures.*
>
> ***7.2.1 Black Marlin stock assessment***
>
> *45. The SC **NOTED** that a single assessment model was applied to the Indian Ocean stock of black marlin (BLM) in 2021; the Bayesian State-Space Surplus Production Model (JABBA). Catch data were available up to 2019 and four time series of standardised CPUE derived from longline fisheries of Japan, Taiwan,China (NW and NE) and Indonesia ending in 2019.*
>
> *46. The SC **NOTED** that the increasing trends in CPUE time series observed consistently over the four series throughout the 2000s and 2010s are inconsistent with the major increase in total catches of BLM reported during the same period, with the model showing some strong, systematic retrospective pattern, compensating for simultaneous increases in catch and relative abundance by inflating the pristine biomass estimate (parameter K of the model).*
>
> *47. Consequently, the SC **ACKNOWLEDGED** the large uncertainties in the model and the little confidence in the model's predictive capabilities, **AGREEING** that the stock status should remain "Not assessed/Uncertain" and **NOTING** that CPUE indices from coastal gillnet fleets would be required to provide more accurate information on the temporal trends in BLM abundance.*
>
> *48. The SC **NOTED** that the causes of conflicting information in the data could be due to (i) increased and/or improved reporting of catches by coastal CPCs over time and/or (ii) to the fact that catches mostly come from coastal gillnet fisheries while CPUE time series were derived from longline fisheries operating predominantly in the high seas.*

7.2.2 Striped Marlin stock assessment

*49. The SC **NOTED** that two assessment models were applied to the Indian Ocean stock of striped marlin (MLS) in 2021 using Stock Synthesis (SS3) and Bayesian State-Space Surplus Production Model (JABBA), with the catch data and the four time series of standardised CPUE derived from longline fisheries of Japan and Taiwan,China available up to 2019.*

*50. The SC **NOTED** that the two models (JABBA and SS3) applied to MLS both indicated that there is 100% probability that the stock was overfished and subject to overfishing in 2019 and **ENDORSED** the stock status determined by the WPB.*

*51. The SC **NOTED** that both surplus production models and age-structure models showed very similar results with low uncertainty, indicating that the estimate of stock status is robust.*

*52. The SC **NOTED** with concern the status of the stock of MLS which has been estimated to be in the red quadrant of the Kobe plot (i.e., overfished and subject to overfishing) for over 10 years, calling for management measures to be taken urgently.*

*53. The SC **QUERIED** whether there are any hotspots of catch that could be used to propose time-area closures and **NOTED** that most catches come from the coastal areas between Somalia and Indonesia, although a closer review of the catch data would be useful to provide more information on the matter.*

*54. The SC **NOTED** the mismatch in Catch and CPUE trends as well as the clarification that those trends are from different fleets (catch is mainly from gillnet) and CPUE from longline. The mismatch may result from improved catch reporting.*

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

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

*56. The SC **NOTED** that catches in recent years for black marlin and Indo-Pacific sailfish have exceeded all recent MSY estimates and catch limits set by Resolution 18/05 (para 3), and that the current catch trends for the two species show no signs of decline - these catch limits will likely be exceeded again in 2021. Furthermore, results from the 2021 assessment of striped marlin provided certainty that the stock is overfished and subject to overfishing (100% probability) and that biomass has been below that which would produce MSY for over a decade. The biomass of striped marlin is considered severely depleted. As such, the SC **NOTED** the inadequacy of Resolution 18/05 in limiting the catches of billfishes and **RECOMMENDED** the Commission to review the Resolution to update catch limits and provide mechanisms to ensure these limits are adhered to.*

*57. The SC further **NOTED** the major uncertainties associated with the catches of gillnet fisheries, which catch in particular black marlin, striped marlin and Indo-Pacific sailfish, and **RECALLED** the need for all concerned CPCs to ensure that the catch, effort and size data for these fisheries are systematically reported to the Secretariat in accordance with Resolution 15/02."*

4. The WPB **NOTED** that a recommendation to include shortbill spearfish in the IOTC list of species had been made for several consecutive years with no progress to date. As such the WPB **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. The WPB also **NOTED** that there may be a need to revise the IOTC agreement to accommodate this request.

5. The WPB **NOTED** that this year, data were available for 2020 and 2021 and therefore the WPB could finally evaluate the catch provisions under Res 18/05. The results of this analysis are provided in Section 8.2.

3.2 Outcomes of the 26th Session of the Commission

6. The WPB **NOTED** paper IOTC–2022–WPB20–04 which provided the main outcomes of the 26th Session of the Commission specifically related to the work of the WPB.

7. Participants to WPB20 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.

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

9. 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

10. The WPB **NOTED** paper IOTC–2022–WPB20–05 which aimed to encourage participants at the WPB20 to review some of the existing Conservation and Management Measures (CMM) relevant to billfish, noting the CMMs referred to in document IOTC–2022–WPB20–05, 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.

11. The WPB **NOTED** that although no new CMMs had been agreed that specifically address billfish species, provisions in other CMMs aimed at other species may have beneficial impacts on billfish species (such as the requirement to set gillnets at 2m depth from the surface by 2023 stated in Res 21/01 - which may reduce billfish catches).

3.4 Progress on the recommendations of WPB19

12. The WPB **NOTED** paper IOTC–2022–WPB20–06 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.

13. 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 2022.

14. The WPB participants were **ENCOURAGED** to review IOTC-2022-WPB20-06 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 (WPB21).

15. 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

16. The WPB **NOTED** paper IOTC–2022–WPB20–07 which summarises the standing of a range of data and statistics received by the IOTC Secretariat for billfish for the period 1950–2020, in accordance with IOTC Resolution 15/02 *Mandatory statistical requirements for IOTC Members and Cooperating non-Contracting Parties (CPC's)*. The paper also provided a summary of important reviews to the series of historical catches for billfish species, a range of fishery indicators (including catch-and-effort and average weight trends) for fisheries catching billfish in the IOTC area of competence and the range of equations used by the IOTC Secretariat to convert billfish measurements between non-standard and standard measurement types used for each species. A summary of the supporting information for the WPB is provided in Appendix IV.

17. The WPB **ACKNOWLEDGED** that, as of September 2022, new fishery statistics for the year 2021 have been submitted to the Secretariat by most CPCs, although due to their preliminary status these have not yet been incorporated in the IOTC databases for presentation to the current Working Party.

18. The WPB **NOTED** the recent proposed revision of billfish phylogeny that includes five *genera* in the *Istiophoridae* family (*Istiophorus*, *Makaira*, *Istiompax*, *Kajikia*, and *Tetrapturus*).

19. In light of this, the WPB **REQUESTED** the IOTC scientific community to consistently refer to the officially accepted scientific names of all billfish species of interest to the IOTC in line with the international standards set up by reference institutions such as ITIS, GBIF, ASFIS, and FISHBASE.

20. The WPB **NOTED** the time series of global captures of billfish collated from the FAO-FIRMS Global Tuna Atlas, which include information sourced by the five tuna RFMOs (t-RFMOs), and **ACKNOWLEDGED** that swordfish is the leading billfish species in terms of reported annual captures overall.

21. The WPB also **NOTED** that in recent years IOTC fisheries are the major contributors of billfish catches among all fisheries under management mandate of the five t-RFMOs, having exceeded 80,000 t out of an annual total of ~200,000 t.

22. **ACKNOWLEDGING** that revisions of annual total catches of billfish species have occurred since the 19th session of this working party (2021), the WPB **NOTED** how these revisions have introduced annual increases of around 2,000 - 4,000 t overall in the period 2010-2019 (for all billfish species combined).

23. The WPB also **NOTED** the different extent of catch revisions, in the period 1995-2019, affecting blue marlin and Indo-Pacific sailfish, with the former reporting a generalised, minor increase in annual catches as opposed to catches of the latter species, that instead have been generally decreased (although minimally) in consequence of these revisions.

24. The WPB **ACKNOWLEDGED** the various distinct sources of revisions affecting all billfish species, and in particular:

    a) the significant updates to annual catches of fisheries from Yemen, and minor updates to annual catches of fisheries from Jordan (2016-2019) and United Arab Emirates (2018-2019) as available in the FAO global capture production database;

    b) the minor updates directly provided by IOTC CPCs, and specifically:

        i) Seychelles line and longline fisheries (1998-2019)

        ii) Pakistan gillnet fishery (2016-2017)

        iii) Mozambique line fishery (2019)

        iv) India artisanal fisheries (2018-2019)

    c) the updates to the spatial distribution of geo-referenced catch data (i.e., east / west indian Ocean) for some fisheries (e.g., Sri Lanka);

    d) the re-assignment of historical catches from EU,United Kingdom (EUGBR) to United Kingdom (GBR) following the withdrawal of the United Kingdom from the EU (2020).

25. Additionally, the WPB **NOTED** that around 6,800 t of catches of billfish species (8.1% of the total) had to be estimated by the IOTC Secretariat for the statistical year 2020, due to information not being officially reported by CPCs, and to the inclusion of data from non-IOTC members.

26. The WPB **RECALLED** that billfish are generally not directly targeted by Indian Ocean fisheries, except for some industrial longline fisheries targeting swordfish.

27. The WPB **ACKNOWLEDGED** that historical information on catches of billfish is mainly available from large-scale, tuna-targeting longline fisheries, although large gaps in data occur throughout the 1990s and 2000s due to known issues with non-reporting by some major longline fleets during the period.

28. In terms of overall trends by fisheries, the WPB **ACKNOWLEDGED** that catch data for billfish show a steady expansion of gillnet and line fisheries since the 1980s complemented by a decline in catches from longline fisheries since 2004, and **RECALLED** that in recent years over 60% of billfish catches were reported by gillnets and coastal longlines (40% and 20%, respectively).

29. The WPB also **NOTED** how the re-estimation of artisanal catches from Indonesia, as performed by the Secretariat under advice from the IOTC Scientific Committee, has affected the best scientific estimates of all billfish species, introducing major reductions in estimated catches of black marlin, blue marlin, and Indo-Pacific sailfish and a moderate increase in estimated catches of swordfish for the year 2020.

30. **NOTING** the increase in the proportion of billfish catches reported by artisanal fisheries in recent years (contributing to over 60% of the total in 2020) and particularly from fisheries using gillnets and lines, the WPB **ACKNOWLEDGED** that in the case of blue marlin a large proportion of the catches is still accounted for by industrial longlines, although these are now subject to a decreasing trend in terms of reported catches for the species.

31. In this regard, the WPB **ACKNOWLEDGED** that the overall quality of the data sets available to the IOTC for the two species under consideration (blue marlin and Indo-Pacific sailfish) is directly affected by the type of fisheries contributing to their exploitation, and **NOTED** that for this reason, geo-referenced catch-and-effort as well as size-frequency data of Indo-Pacific sailfish are of particularly low quality due to the artisanal nature of the fisheries involved.

32. Nevertheless, the WPB **NOTED** improvements in the quality of the reported nominal catch and catch-and-effort data for both species in the last decade, **ACKNOWLEDGING** that these are mainly due to the efforts made by some CPCs (e.g., I.R. Iran and Indonesia) to improve the accuracy, completeness and timeliness of the information collected and reported to the Secretariat in agreement with IOTC Resolutions 15/01 and 15/02.

33. In addition, the WPB **RECALLED** how information on discards of billfish species is still lacking, with the exception of some data reported under the IOTC Regional Observer Scheme (ROS) by industrial purse seine and longline fisheries implementing scientific data collection programmes through onboard observers.

34. The WPB **ACKNOWLEDGED** that while discard levels are generally thought to be low, these might have been affected by the entry in force of Res. 18/05, that called CPCs to not retain on board, tranship or land any specimen of Indo-Pacific sailfish or marlins smaller than 60 cm in lower-jaw fork length.

35. The WPB also **RECALLED** that only limited geo-referenced effort data are available for several artisanal fleets, and furthermore that their coverage and usefulness are severely impacted by the lack of a standardised effort unit when reporting the information to the Secretariat.

36. **NOTING** how in some fisheries billfish are beheaded and eviscerated when landed (e.g., Pakistan) the WPB **ACKNOWLEDGED** that issues might exist with the correct interpretation of the actual reported values of landed catches, which might refer to *dressed weight* rather than *live-weight* equivalent (as requested by IOTC).

37. Therefore, the WPB **SUGGESTED** that future assessments take this additional source of uncertainty in due consideration, and **INVITED** all concerned CPCs to complement the data provided to the Secretariat with a clear description of the processing applied to the catches (e.g., the exact type of weight reported as *nominal catch*).

38. The WPB **ACKNOWLEDGED** that updates are also expected regarding morphometric data of billfish species (among others), and that these will include revised conversion factors as well as new length-weight and length-length relationships, with data also available from other oceans.

39. Furthermore, and specifically regarding size-frequency data of billfish species, the WPB **RECALLED** how the limited availability of this information is also negatively impacted by other issues such as the provision of original length data through very large size-bins (well beyond the minimum deemed acceptable for the species), or the submission of size samples using non-standard length measurement types, for which no conversion equation is readily available to the Secretariat.

40. 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 (provided in Appendix V) and **REQUESTED** that the CPCs listed in the Appendix make efforts to remedy the identified data issues – with support from the IOTC Secretariat, when required – and report back to the WPB at its next meeting.

4.2 New information on sports fisheries

41. 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.

42. The WPB **RECALLED** how one of the reasons known to prevent sport fishing clubs from participating in this data collection and reporting exercise was the perception that the information collected could have been used by local governments to establish catch limits or impose additional taxations on the fisheries.

43. The WPB **NOTED** that the Seychelles Fishing Authority (SFA) is currently engaging with local sport fishing clubs to re-establish a data collection exercise for billfish species, and that in 2023 a report on all aspects of recreational fisheries in Seychelles will follow this baseline study.

44. The WPB **NOTED** that SFA is still developing the practical aspects of this sampling programme, which will either be carried out through direct collaboration with fishermen or by employing technicians at the landing sites, and **REQUESTED** SFA to report back to this same Working Party about any future development in this regard.

5. MARLINS (PRIORITY SPECIES FOR 2021: BLUE MARLIN)

5.1 Review of new information on the status of blue marlins

- **Nominal and standardised CPUE indices**

45. The WPB **NOTED** paper IOTC-2022-WPB20-09 on CPUE standardization of blue marlin (*Makaira nigricans*) caught by Taiwan,China large-scale longline fishery in the Indian Ocean, including the following abstract provided by the authors:

> *"This paper briefly described the historical patterns of blue marlin 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 CPUE standardizations were conducted using delta-general linear models with different assumptions of the error distributions. Based on the diagnostic statistics and trend of model fits, the standardized CPUE series obtained based on the delta GLM with inverse gaussian error distribution for positive catches would be recommended by this study. The results indicate that the effect of latitude provided the most significant contributions to the explanation of the variance of CPUE for positive catches and delta models for both northern areas (NW and NE), except for the year effects. The standardized CPUE series in both northern areas revealed decreasing trends in recent years."*

46. The WPB **THANKED** the authors for the update to the Taiwan,China CPUE series, which is an integral input into the stock assessment models.

47. The WPB **NOTED** that the analysis did not include data before to 2005 on the recommendation of the IOTC longline CPUE workshops, which had found problems with the accuracy of the logbook data for the Taiwan,China longline fishery prior to 2005. The historical time- series (prior to 2005) was developed separately as a continuity or sensitivity run for the blue marlin assessment. As in the previous assessment, the CPUE indices were calculated only for the North-West (NW) and North-East (NE) regions.

48. The WPB **NOTED** the species composition cluster analysis conducted to determine the targeting strategy. The WPB suggested that in order to confirm the accuracy of the analysis, the clustering could be compared to observer data where the target species has been recorded. The WPB also **NOTED** that because billfish encounter rates are so low, these species have been combined. The author also confirmed that the "Other" cluster was made up primarily of oilfish.

49. The WPB **NOTED** that there was a significant increase (4-fold) in CPUE from 2008 to 2011 in the NW area. The magnitude of this increase is biologically implausible, and further investigation into the possible reasons for this increase should be carried out. Furthermore, the confidence intervals for the NW area are substantially narrower than those in the NE which is likely a result of the number of observations.

50. The WPB **NOTED** that the choice of the delta inverse Gaussian model was based on AIC values and residual plots. Despite having a relatively high probability of catching a blue marlin (approx. 40%), using non-zero inflated models produced residual plots that exhibited structuring/patterns, and were therefore considered to be less appropriate.

51. The WPB **NOTED** paper IOTC-2022-WPB20-10 on the Standardized CPUE of blue marlin (*Makaira mazara*) caught by Japanese longline fishery in the Indian Ocean: Analysis between 1979 and 2021, including the following abstract provided by the authors:

> *"We addressed to standardize CPUE of blue marlin (Makaira mazara) caught by Japanese longline fishery in the Indian Ocean. Start year is 1979 as with the indices in the last stock assessment. Three core areas (Northwest, Southwest and Central east) were used as with the previous studies. We applied the zero-inflated Poisson GLMM for the CPUE standardization (catch number). Terminal year for the Northwest CPUE was 2010 due to paucity of operations in recent years. The standardized CPUE usually showed decreasing trend. There was some difference of standardized CPUEs among quarters and between two gear depths. In the model diagnostics, we checked Pearson residuals corresponding to the explanatory variables. There are little clear trends against the explanatory variables, but Pearson residual showed some time-spatial patterns for all core areas"*

52. The WPB **THANKED** the authors for the update to the Japanese CPUE series and **NOTED** the CPUE standardisation from Japan has used a zero-inflated model. The CPUE was conducted for NW, CE, and SW. The WPB **NOTED** the index for SW was developed as continuity/reference run and was not included in the assessment.

53. The WPB **NOTED** the significant conflict between the nominal index and the standardised index for the SW. Although the cause of the discrepancy is unclear, it might be related to changes in the important covariates over time (e.g., HBF). The WPB **NOTED** that this is the primary justification for excluding the SW CPUE from the assessment (there is also almost no catches from quarter 2 and 3). The WPB **NOTED** the authors' suggestion to potentially split the indices, and standardise prior and after 1994 separately. This suggestion is based on changes in fishing behaviour that is evident in HBF. The WPB **AGREED** that the SW may provide abundance statistics for the most recent time because the index in the NW was terminated after 2010 due to a lack of data. The WPB therefore **SUGGESTED** the utility of the SW index to be further explored in future analysis.

54. The WPB **NOTED** the core areas approach (NW, CE, and SW) would allow the analysis to focus on areas with high blue marlin density, and reduce the proportion of zero sets in the dataset and define a fishery that is more consistent with the spatial extent of these areas based on the current effort distribution. On the other hand, fish may move in and out of the area, which presents a problem because the index might not accurately reflect the larger population (for example, estimated quarterly effects may have indicated possible seasonal migration of fish population).

55. The WPB **NOTED** paper IOTC-2022-WPB20-11 which provided an update on CPUE Standardization of Blue Marlin (*Makaira nigricans*) from Indonesian Tuna Longline Fleets 2006-2021, including the following abstract provided by the authors:

> *"Black marlin (Makaira indica) is commonly caught as frozen by-catch from Indonesian tuna longline fleets targeting albacore, yellowfin and bigeye tuna and its contributed around 7% (~600 tons/year). Relative abundance indices as calculated based on commercial catches are the input data for several to run stock assessment analyses that provide models to gather information useful information for decision making and fishery management. In this paper a Delta-Lognormal Model (GLM) was used to standardize the catch per unit effort (CPUE) and to calculate estimate relative abundance indices based on the Indonesian longline dataset."* – see document for full abstract

56. The WPB **THANKED** the authors for work and **ACKNOWLEDGED** the delta-lognormal model used to derive standardized CPUE for blue marlin, based on the data gathered by the Indonesian scientific observers on commercial tuna longline.

57. The WPB **NOTED** that the catch rate and the percentage of positive sets for blue marlin peaked around 2011–2012, which is somewhat related to the shift in trip length (after that, trips tend to be shorter) and how the species is recorded by the observer (blue marlin was recorded as part of a species group at the time rather than as a separate species).

58. The WPB **NOTED** that further investigations for the data and methodology for CPUE analysis are suggested due to the high zero catch proportion of blue marlin for the entire time series.

59. The WPB **NOTED** that the trend of Indonesian standardized CPUE is similar to Japanese standardized CPUE in the central eastern Indian Ocean.

60. The WPB **NOTED** the different trends seen in the longline CPUE series and discussed which might be considered more reliable. The WPB **NOTED** the majority of these CPUE indices were reasonably consistent, which exhibited a high peak around 2011–12 and a subsequent declining trend. The WPB **AGREED** to consider the updated Japanese longline for NW (up to 2010) and CE regions, and Taiwan,China indices for the NW and NE, and Indonesian indices for the blue marlin stock assessment model (Figure 1).

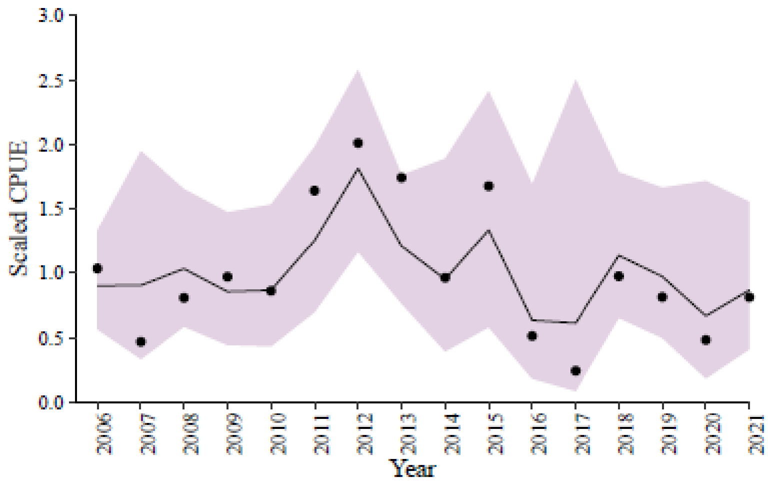


Figure 1. Standardized CPUE series of blue marlin in the Indian Ocean These series have been scaled to the mean for comparison**.**

- **Stock assessments**

Bayesian Surplus Production Model (JABBA)

61. The WPB **NOTED** paper IOTC-2022-WPB20-12 which described the updated stock assessment of blue marlin (*Makaira nigricans*) in the Indian Ocean using JABBA, including the following abstract provided by the authors:

"Three Bayesian State-Space Surplus Production Model scenarios were run to assess blue marlin (Makaira nigricans) in the Indian Ocean using the JABBA framework, based on catch and effort data up to and including 2020. A 'drop one' sensitivity analysis indicated that omitting any of the CPUE time-series would not significantly alter the stock status. Similarly, a retrospective analysis produced highly consistent results for stock status estimates back to 2015 and therefore provided no evidence for an undesirable retrospective pattern. The B/BMSY trajectory declined from the mid-1980s to 2007. A short-term increase in B/BMSY occurred from 2007 to 2012, which is thought to be linked to the NW Indian Ocean Piracy period. Thereafter, the B/BMSY trajectory again declines to the current estimate. F/FMSY increased since the mid-1980s and despite a recent decline, F/FMSY remains above 1. Terminal points of the time series fall within the red quadrant of the Kobe plot in all scenarios (61.4% - 74% probability). As such, the blue marlin stock in the Indian Ocean is currently "overfished" and "subject to overfishing". However, the current catches of blue marlin are marginally lower than the estimated MSY for all scenarios."

62. The WPB **THANKED** the authors for providing the continuity run. This approach was to ensure comparability of models used in-between assessments, thus increasing the confidence of model results to be used for management advice.

63. The WPB **RECALLED** that the last stock assessment used for management advice, conducted in 2019 using the JABBA Model, estimated that the stock of blue marlin in 2017 was overfished and subject to overfishing.

64. The WPB **NOTED** the assessment is primarily an update from the 2019 assessment and the models presented are of similar structure to the 2019 reference model. The WPB **NOTED** the following model runs:

    - S1 (Cont_hist): Parker et al. (2019) prior formulation; all CPUE
    - S2 (Cont_new): Parker et al. (2019) prior formulation; remove historical TWN CPUE
    - S3 (Update): updated K, initial depletion, and observation error prior formulation; remove historical Taiwan,China CPUE.

65. The WPB **NOTED** the model that included historical (1979-2004) TWN CPUE information S1: Cont_hist was for continuity only, and was not considered further as this CPUE information was not deemed to be reliable. The difference between the remaining two models is limited to changes in the priors. For example, the use of the "beta" distribution in the *S3: Update* model is an additional option within the JABBA framework that better captures the plausible distribution of the initial depletion prior.

66. The WPB **NOTED** that the r prior calculated during the previous assessment has been retained to maintain continuity. The WPB further **NOTED** that the Indian Ocean lacks biological information on blue marlin. Therefore, biological parameters must be obtained from other oceans in order to develop the r prior.

67. The WPB **NOTED** that process errors estimated in the biomass dynamics may help account for some of the trend in the CPUE and also improve MCMC performance. The WPB **NOTED** the suggestion that it would be an useful addition to the future JABBA development to allow the process error to be "turned off" (currently process errors are always to be estimated at least for the period when the abundance is available), which aids in assessing the model's predictive ability.

68. The WPB **NOTED** that only Schaefer models were considered in this assessment. The WPB **RECALLED** that in the 2019 assessment a sensitivity run of JABBA using a fox-type model produced very similar results to the SS3 model.

69. In view of the continuity runs, the WPB **AGREED** to use S3 model (updated prior and remove historical Taiwan,China CPUE) as the basis for the 2022 JABBA assessment. This model also facilitates the comparison with the SS3 assessment.

70. The WPB **NOTED** the key assessment results for JABBA assessment for blue marlin as shown below (Table 1; Figure 2).

Table 1. Stock status summary table for the blue marlin assessment base case model (JABBA)

Management Quantity	JABBA (base)
Current catch (2021)	5 772 (t)
Mean catch over last 5 years (2017-2021)	7 964 (t)
MSY (1000 t)	8.74 (7.14 –10.72)
F_{MSY}	0.24 (0.14 – 0.39)
Current Data Period	1950 – 2020
F_{2020}/F_{MSY}	1.14 (0.75 – 1.69)
B_{2020}/B_{MSY}	0.73 (0.51 – 0.99)
SB_{2020}/SB_{MSY}	n.a.
B_{2020}/B_0	0.36 (0.26 – 0.50)
SB_{2020}/SB_0	n.a.

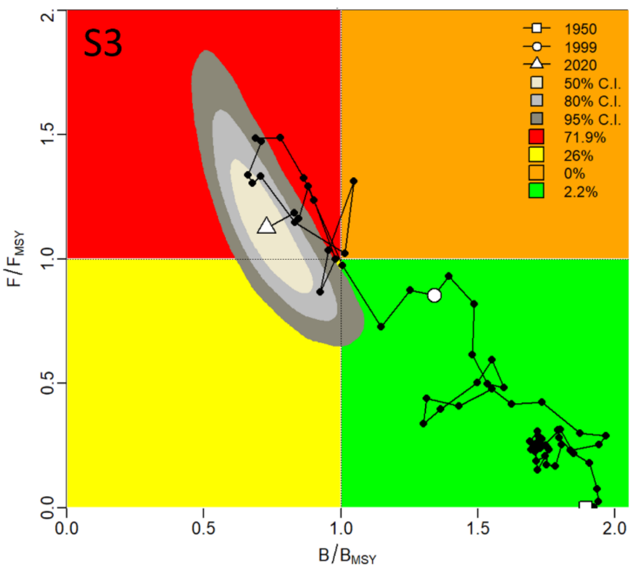


Figure 2. JABBA: Kobe stock status plot for the Indian Ocean for blue marlin, from the final JABBA base case (S3). The black line traces the trajectory of the stock over time. Contours represent the smoothed probability distribution for 2020 (isopleths are probability relative to the maximum).

Stock Synthesis (SS3)

71. The WPB **NOTED** document IOTC-2022-WPB20-13_Rev1 which described the stock assessment of blue marlin (*Makaira nigricans*) in the Indian Ocean using Stock Synthesis, including the following abstract as provided by the author:

> *"In this study, Stock Synthesis (SS) was applied to conduct the stock assessment for blue marlin in the Indian Ocean. The analyses were performed by incorporating historical catch, standardized CPUE series and length-frequency data. The results of most scenarios indicated that the current stock status of blue marlin in the Indian Ocean was not overfished and not overfishing, but it may be subject to overfishing and overfished when fixed natural mortality and two-area assumptions were used. It should be noted that most of the life-history parameters used in this study were based on the values of blue marlin in the Pacific Ocean and this may lead to uncertainties in the evaluation of the stock status of blue marlin in the Indian Ocean."*

72. The WPB **NOTED** that the reference SS3 model for blue marlin was configured as a single area, sex specific model (due to sexual dimorphic growth), and that the fisheries were grouped as longline fisheries from Taiwan,China, Japan, Indonesia, and other, whereas the longline fisheries from Taiwan,China and Japan were further split into an East and West component. The observational data included the standardised CPUE indices for the fleet from Taiwan,China (2005-2020, NW and NE series), fleet from Japan (1979-2010 for NW and 1979–2020 for CE), and fleet from Indonesia (2006-2020), and size frequency data. The WPB further **NOTED** that the life history parameters were fixed at known estimates from the Pacific Ocean.

73. The WPB **NOTED** that the model assumed a dome-shaped, time-invariant selectivity for the Taiwan,China and Japanese longline. The selectivity for the Indonesian and "other" fleets was assumed to be the same as the Taiwan,China fleet. The WPB **NOTED** that eight model scenarios were conducted as follows:

74. S1: All data updated (Taiwan,China CPUE data of 1979-2004 were obtained and used from the previous assessment);
    - S2: as S1 but Japanese and Taiwan,China fleets and their catch and length-frequency data were separated by areas;
    - S3: as S1 but age-specific natural mortalities were used;
    - S4: as S2 but age-specific natural mortalities were used;
    - S5 – S8: repeat S1~S4 but Taiwan,China CPUE data of 1979-2004 were excluded.

75. The WPB **NOTED** that the difference in length compositions between east and west regions (for both the Japanese and Taiwan,China longline fleets) indicate that it makes sense to divide the fisheries by region to better account for the variation in selectivity. This is also consistent with CPUE standardization's regional stratification.

76. The WPB **NOTED** that the age-specific mortality scenarios (based on a Lorenzen curve) and the constant natural mortality scenarios were significantly different that have resulted in very divergent stock estimates. It was stated that one typical method is to scale the mean natural mortality (for either the full or a specified age range) to match a target mortality while using the Lorenzen function to calculate the shape of the mortality ogive at age.

77. The WPB that **NOTED** the selectivity of the IDN (i.e., Indonesia) and "Other" fisheries has been fixed to that of the Taiwan,China fleet. It was **NOTED** that the "Other" fishery consists of a variety of gears that capture a substantial volume of catch with a very wide range in length. As a result, the model may be sensitive to the selectivity setup of this fleet. However, the fleet's selectivity could not be determined due to a lack of length data.

78. The WPB **NOTED** that the potential effect of effort creep (from the longline fishery) is not considered in the current assessment and **SUGGESTED** this could be explored in the future.

79. On the basis of the discussions, the WPB **AGREED** to conduct two sensitivity analyses concerning the natural mortality and the selectivity set-up as below:
    - S9:S6, but fix the selectivity of the IND and "Other" fleets to that of the Japanese East fleet
    - S10:S8, but rescale the age-specific M to match the constant M assumption (both males and females).

80. The WPB **NOTED** that the results of model S9 were very similar to model S6, indicating the model is not sensitive to the proxy selectivity assumed for the IDN and "Other" fishery.

81. The WPB **NOTED** that Model S10 produced stock estimates were very different than S8, with an estimated abundance that was much lower. The results of model S10, however, were very similar to model 5 (constant M). This indicates that in this case the scale of natural mortality has a greater influence on the outcome than the shape of natural mortality. The WPB **AGREED** that the age-specific M based on the Lorenzen function is more biologically plausible, but urged that future assessments should explore more on the feasible range of the mean natural morality. The WPB **AGREED** that Model S10 will be used as a reference case.

82. The WPB **NOTED** the key assessment results for SS3 for blue marlin as shown below (Table 2; Figure 3).

Table 2. Stock status summary table for the blue marlin SS3 assessment (model S10).

Management Quantity	**Aggregate Indian Ocean**
2021 catch estimate	5 772 (t)
Mean catch from 2017–2021	7 964 (t)
MSY (1000 t) (80% CI)	7.572 (6.496–8.648)
Data period (catch)	1950–2020
F_{MSY} (80% CI)*	5.118 (4.545–5.691)
SB_{MSY} (1,000 t) (80% CI)	10.641 (9.116–12.167)
F_{2020}/F_{MSY} (80% CI)	1.119 (0.959–1.279)
SB_{2020}/SB_{MSY} (80% CI)	0.974 (0.774–1.173)
SB_{2020}/SB_{1950} (80% CI)	0.158 (0.134–0.180)

** Fishing mortality was estimated based on the approach of hybrid methods of SS3.*

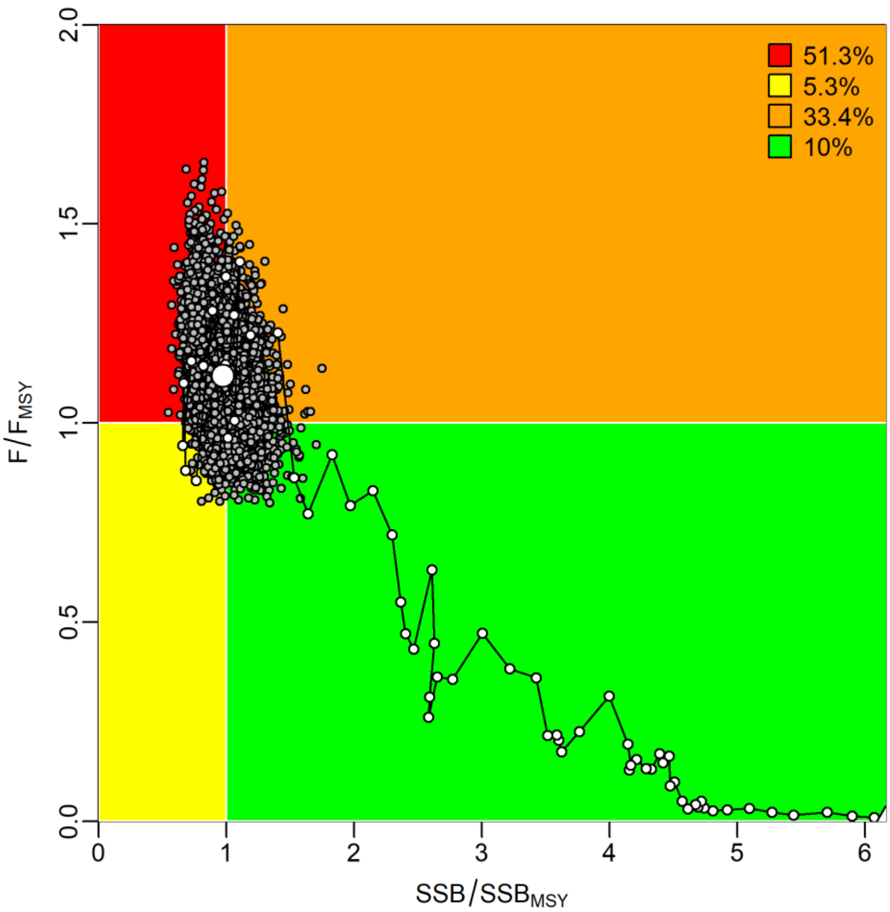


Figure 3. Stock synthesis: Kobe stock status plot for the Indian Ocean for blue marlin (model S5). The black line traces the trajectory of the stock over time.

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

83. The WPB **NOTED** the overall consistent biomass trend estimated by the JABBA and SS3 models, and that the differences in estimated management quantities are likely to be attributed to different production functions inherent in these models. The WPB further **NOTED** that there is still considerable uncertainty in the biological parameters of blue marlin used in the SS3 model. As such, the WPB **AGREED** that the JABBA model be used for management advice for blue marlin.

84. The WPB **NOTED** there appeared to be no progress in gathering biological data for blue marlin in the Indian Ocean and all of the biological parameters for the SS3 model still needed to be sourced from other oceans. The WPB **STRESSED** the importance for CPCs to gather biological data on marlin species in order to reduce the possible uncertainty of future stock assessments

85. The WPB **NOTED** the JABBA assessment model estimated the current stock biomass is below BMSY, and the current fishing mortality is higher than FMSY.

86. The WPB also **NOTED** that there were no systematic deviations in the retrospective analysis from the JABBA model, which provides some confidence in the predictive capabilities of the model.

87. The WPB **NOTED** that one issue of the aggregated biomass dynamic model (like JABBA) is that it typically is unable to account for the time lag of some of the key dynamics (e.g., when there is a significant difference between age-at-vulnerability and age-at maturity). The WPB **NOTED** that for marlin species where mostly adult fish are caught, this problem may not be as pronounced. The WPB also **NOTED** that there has been some progress in addressing the assumption of how process error is handled in the projection of the JABBA model.

88. The WPB **ADOPTED** the management advice developed for blue marlin, 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:

- Blue marlin (*Makaira nigricans*) – Appendix VII

6. Indo-Pacific Sailfish

6.1 Review new information on I.P sailfish biology, stock structure, fisheries and associated environmental data

89. The WPB **NOTED** document IOTC-2022-WPB20-14 which provided information on the determination of Size Discrepancies for Sailfish, *Istiophorous platypterus*, in Varying Ocean Basins, including the following abstract as provided by the author:

> *"This paper describes an internship project to fulfill the requirements for a Master of Professional Science from the University of Miami. The internship sought out to determine if sailfish grow to larger asymptotic sizes in different areas of the worlds oceans and hypothesize what factors, both environmental and oceanographic, could lead to differences in the length of sailfish. This internship project, in cooperation with the International Game Fish Association (IGFA), focused on using the available size (length and weight) data held by the host organization as well as databases held by regional fishery management councils to compare size frequencies and asymptotic length of sailfish around the globe."* – see document for full abstract

90. The WPB **ACKNOWLEDGED** the quality of the analyses and the novelcomparisons between oceans. Clarification regarding the origin of the data was requested, especially for the density maps of occurrences, and the data was confirmed to be derived from RFMOs databases and IGFA fishing records. Further clarification on the statistical analyses performed to account for some effects such as season, area, fishing gear was requested. It was **NOTED** that due to time constraints to achieve these analyses, statistical analyses have been limited.

91. The WPB also **NOTED** that this work led to the question of the population structure of Indo-Pacific sailfish. The WPB **NOTED** that mark-recapture experiments conducted for Indo-Pacific sailfish showed that individuals are generally resident and do not conduct large-scale migrations. Genetic studies from the 1990s have also shown no genetic differentiation between Atlantic and Indo-Pacific sailfish. It would, however, be interesting and important for future stock assessments to have this information about population structure.

92. The WPB **NOTED** that the differences observed in size between the eastern and western parts of Sri Lanka could be due to difference in fishing gear accessibility and selectivity (depth, etc.), spawning aggregations or segregated habitats between females and males, as well as method of dressing between fleets and conversion into standard length. The author mentioned the sex information was not available or used in this analysis.

93. The WPB **ENCOURAGED** the author to continue the work and develop statistical models to analyse the effects of the different factors on the size distribution of Indo-Pacific sailfish.

94. The WPB **NOTED** that it might be interesting to collect some metrics describing the morphometrics characteristics (e.g., surface, height, etc.) of the sail of Indo-Pacific sailfish for identifying the origin of the fish. To the group and author's knowledge, there is no information about this potential differentiation. For some other species such as yellowfin tuna, it has been observed that the length of the dorsal fin is larger in the Atlantic than in the Indian Ocean. These anatomical traits could be useful for identification.

6.2 Review of new information on the status of I.P. Sailfish

- **Stock assessments**

95. The WPB **NOTED** document IOTC-2022-WPB20-15 which provided information on alternative methods to assess the data poor Indo-Pacific sailfish (*Istiophorus platypterus*) stock, including the following abstract as provided by the author:

"Assessing the status of the Indo-Pacific Sailfish in the Indian Ocean is challenging due to the paucity of data. We explore alternative methods to assess the stock status of IP Sailfish by using length-frequency data to estimate annual Spawning Potential Ratio (SPR). Normalised annual estimates of SPR for two fleets are combined into a single SPR time series, which is assumed to be proportional to biomass, and used as an index of relative abundance. This index is incorporated in the Bayesian State-Space Surplus Production model, JABBA. The results indicate that there has been a 41% decline in SPR since 1970. B/BMSY declined consistently from the early-1980s to the latest estimate in 2019, while F/FMSY gradually increased from 1980, peaking in 2018 at 1.1. The 2019 estimate of B/BMSY was 1.17, while the F/FMSY estimate was 0.98. There is a 53,7% probability that the IP sailfish stock falls within the green quadrant - not overfished nor subject to overfishing. However, the current catches (average of 30,420 t in the last 3 years, 2018-2020) are substantially higher than the 2019 MSY estimate of 25,905 tons. This suggest overfishing is occurring. Catches should be decreased to below 25,000 tons to avoid further declines."

96. The WPB **NOTED** it is difficult to assess the status of the stock of Indo-Pacific sailfish and **CONGRATULATED** the authors for the use of new methods that assemble different fragmented pieces of information together and integrate the size data, which is generally not done with catch-only methods, **ACKNOWLEDGING** that some good information is generally available from size data sets.

97. **NOTING** that the length based spawning potential ratio (LBSPR) method needs a selectivity ogive reaching a maximum value on the right hand side of the length range and cannot be based on data collected from fisheries with a dome-shaped selectivity, the WPB **NOTED** that size data from gillnet fisheries could not be used in the assessment model. The WPB further **NOTED** that some trials were conducted with size frequency data available from gillnet fisheries and that they resulted in high interannual variations in the outputs.

98. The WPB **NOTED** that there are some caveats associated with the method that need to be well documented: (1) the recruitment is assumed stable over time to use the spawner potential ratio (SPR) trend as an index of biomass and (2) the size distribution is assumed at equilibrium. The author agreed and also explained that SPR is a proxy relative abundance for spawner biomass as opposed to exploitable biomass which is the information required for surplus production models. Notably, estimates for MSY were found to be consistent between the 2015, 2019 and 2022 stock assessments (i.e., approx. 25 000 t).

99. The WPB **QUERIED** why some size frequency data with strange patterns were included in the analysis and **SUGGESTED** the use of trend analysis to combine the data and avoid implementing a cut off (smoother).

100. The WPB **QUERIED** on the representativeness of the size-frequency data (from the longline fisheries of Japan and Taiwan,China) for the whole Indian Ocean stock and **ACKNOWLEDGED** the need to convey the message of uncertainty on the results on stock status with the method which cannot be considered on par the other assessments.

101. The WPB further **NOTED** the need to assess the confidence in the assessment based on this method and **AGREED** to further discuss with the WPM on the possible biases associated with deriving "relative abundance" trends from SPR-based methods.

102. The WPB **NOTED** that there has been some issue of misidentification on billfish reported by Pakistan in the past and that this could affect the time series of nominal catches used in the model, **NOTING** that the Secretariat will liaise with WWF Pakistan to follow-up on the species composition of the billfish catch in the Pakistani gillnet fishery.

6.3 Development of management advice for I.P. Sailfish and update of species Executive Summary for the consideration of the Scientific Committee, including discussion on current catch limits as per standing IOTC Resolutions

103. The WPB **ADOPTED** the management advice developed for I.P Sailfish, 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:

- I.P. Sailfish (*Istiophorus platypterus*) – Appendix VII

7. SWORDFISH

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

104. The WPB **NOTED** document IOTC-2022-WPB20-16 which provided an assessment of the impact of the inclusion of marine subsurface variables on habitat modelling of swordfish in the Indian Ocean, including the following abstract as provided by the author:

> *"Species distribution models (SDM) have emerged as an important technique for defining and forecasting species habitats. In the maritime domain, species distribution models have historically been constructed primarily as two-dimensional species occurrence and environmental data, with a lack of understanding of the real ecological environments of species. Our capacity to examine subsurface marine characteristics has grown thanks to developments in models and technology, but their integration into SDM is still somewhat restricted. We explored the impact of adding subsurface environmental factors in SDM on species habitat suitability to define habitat variation of adult swordfish (Xiphias gladius) in the Indian Ocean using environmental data from various depth layers in the research region."* – see document for full abstract

105. The WPB **THANKED** the authors for this interesting presentation that highlighted the usefulness of including subsurface variables in swordfish distribution models. The WPB **NOTED** that model-based subsurface variable datasets are as easily obtainable as remote sensing data on the EU Copernicus platform.

106. The WPB **NOTED** that only presence/abundance data of swordfish in the Chinese longline observer data were used in this study. The WPB further **NOTED** that the SDM used here does not work with absence data.

107. The WPB **NOTED** document IOTC-2022-WPB20-17 which provided an analysis of at-haulback mortality and influencing factors of Indian Ocean Swordfish (*Xiphias gladius*), including the following abstract as provided by the author:

> *"The at-haulback mortality of swordfish (Xiphias gladius), a highly migratory fish, in the Indian Ocean during tuna longline fishery is a concern of the Indian Ocean Tuna Commission Fisheries Management. We obtained the data of 1,144 swordfish recorded in 1925 operations in the Indian Ocean by Chinese tuna longline observers from 2012–2018. A generalized linear model was used to analyze the at-haulback mortality of swordfish and the potential influencing factors. The overall mortality rate of swordfish was 64.0%, and the average female size was 166.3 cm (SD = 32.5 cm), with an observed at-haulback mortality rate of 64.3%. The average male size was 155.1 cm (SD = 25.6 cm), which was smaller than females."* – see document for full abstract

108. The WPB **NOTED** unexpected effects and interactions (e.g. longitude with individual size) on swordfish at-haulback mortality. The WPB **SUGGESTED** that these effects may result from collinearity with other variables and **REQUESTED** that the authors further investigate the collinearity between variables.

109. The WPB **NOTED** that lunar illumination may have an effect on swordfish mortality and that this should be investigated in the future. The WPB further **SUGGESTED** that the authors test the potential influencing variables that were listed in their presentation but have not been used in this study (e.g. bait type).

110. The WPEB **NOTED** IOTC-2022-WPB20-INF02 which presented the Preliminary results of swordfish in Reunion Island including experimental fishing, electronic tagging and trophic ecology in the Indian Ocean (Romanov et al.) and included the following abstract provided by the authors:

"Swordfish (Xiphias gladius) behaviour, movements, biology and trophic ecology was studied off Reunion Island (southwestern Indian Ocean) within framework of EU-funded project PESCARUN. The project includes experimental fishing with buoy fishing gear, stomach content analysis and tagging with a pop-up satellite electronic tags (PSATs). Here we present preliminary results of the project including tagging of 5 individuals, results of night fishing trials and stomach content analysis performed to date."

111. The WPB **THANKED** the author for this interesting presentation and **NOTED** that 5 tags from the PESCARUN project remain to be deployed.

112. The WPB **NOTED** that the proportion of non-reporting tags is generally under 10% for WildLife Computers PSATs, further **NOTING** that technical failures (i.e., battery issues) are rare considering the technological improvements of the tags in recent years. The WPB **NOTED** that the absence of transmission may occur in cases where the tag was damaged or ingested by a predator, or when the tag would have come up to the surface but was blocked under a pile of marine debris, preventing the tag from transmitting data.

113. The WPEB **NOTED** that the premature release of a tag may occur when (i) the tag has been poorly placed or anchored on the animal, (ii) the tether breaks, or (iii) when the animal dies which triggers the automatic release of the tag. The WPB further **NOTED** that Domeier anchors are preferred for fish while Titanium anchors are preferred for sharks. Tag design has now greatly improved so the "broken pin" or "broken nose" issues are no longer occurring. The WPB also **NOTED** that the information on whether the pin broke or not is transmitted by the tag.

114. **NOTING** the limited number of tags (10) used for this project, the WPB **ACKNOWLEDGED** the authors opinion that studies have shown that such sample sizes can still be considered as representative for the species habitat use and vertical behaviour (at least locally), further **NOTING** that the intent of this project is to provide information to the fishermen from Reunion Island on the species movements in their operating fishing grounds and is not solely for academic analysis.

115. The WPEB **NOTED** the tagging efforts on swordfish presented in this paper and those of Ifremer (presented in IOTC-2022-WPB20-20) and **ASKED** the authors to pool the data together. An agreement to realise this possibility remains to be defined.

116. The WPB further **NOTED** that the Secretariat has contacted various scientists requesting them to share tagging data with the Secretariat, and the WPB **ENCOURAGED** CPCs to provide tagging data (or at least metadata) with the Secretariat. The WPB **ACKNOWLEDGED** that the exchange format needs to be discussed and agreed upon but **REQUESTED** that the Secretariat develop a regional database for tagging data.

117. **ACKNOWLEDGING** the suggestion by the Secretariat for developing good practises for tagging (billfishes, sharks, etc.) based on the CPCs experience, the WPB **ENCOURAGED** CPCs to participate and share their experience with the Secretariat to create these guidelines.

7.2 Updates on the Management Strategy Evaluation for Swordfish

118. The WPB **NOTED** document IOTC-2022-WPB20-18 which provided updated information on the Indian Ocean swordfish MSE including suggestions for modification on the Operating model. No abstract was provided by the authors.

119. **NOTING** the limited range for the steepness (below 0.8) tested by the authors, the WPB **REQUESTED** that steepness values between 0.6 and 0.9 be investigated as has been done for swordfish in other oceans. The WPB further **ACKNOWLEDGED** that values between 0.7 and 0.9 are usually applied for tuna species but **NOTED** that as billfishes are considered to be less productive than tuna species, a lower value of 0.6 would be appropriate to capture this aspect of their biology. The WPB **REQUESTED** that the WPM further investigate and provide advice on this issue.

120. The WPB **NOTED** that there is currently assumed to be no population structure for the swordfish in the Indian Ocean. The WPB further **NOTED** that there are conflicting CPUE trends from different regions of the Indian Ocean (such as the decreasing trend in the South West which contrasts with CPUE trends from the other regions). As such the WPB **ASKED** whether this could be accounted for in the operating model (OM). The WPB **NOTED** that the authors clarified that it would be difficult because (i) the stock assessment models do not include a spatial structure, and (ii) the issue of including conflicting CPUE trends in surplus production models is problematic for

model fitting and as such a representative (or "best") CPUE for the entire region is usually included. The WPB **AGREED** that using the CPUE from the South West region would not be representative of the entire population and therefore using this CPUE as a proxy in an MP was not recommended, however, no clear solution for addressing the apparent decrease in abundance in this specific region was identified.

121. The WPB **NOTED** that WCPFC is developing a new method for uncertainty characterisation in a model ensemble based on the joint prior of biological parameters. The method allows values in the uncertainty axis to be sampled from a continuous distribution, which may help address the issue of bimodally distributed model estimates which typically resulted from the use of discrete values in the uncertain axis.

122. The WPB **NOTED** that in the current study, a sigmaR of 0.2 was applied in addition to a value of 0.6. The WPB **AGREED** that as this parameter did not appear to be particularly influential, the value of 0.2 should be dropped (retaining 0.6) as this would reduce the dimensions of the model grid.

8. Other Billfishes

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

123. The WPB **NOTED** document IOTC-2022-WPB20-19 on the status of fisheries of billfish of Pakistan: Status and Trends, including the following abstract as provided by the author:

> *"Billfish form important part of the landings of tuna and tuna like fishes from Pakistan contributing about 8 to 10 % in total landings of tuna gillnet operations. Its landings during 2021 was reported to be about 4,025 m. tons which is about 5.61 % less than 2020. The decrease is attributed to a much longer closed season observed by the tuna gillnet fisheries in 2021. Fishing in 2021 was stopped in the late April or beginning of May and initiated only in last week of August i.e. almost no fishing for four months as against normal 2 month ban of June and July. Out of six species of billfishes Indo-Pacific sailfish (Istiophorus platypterus) contributed about 1,892 m. tons, black marlin (Istiompax indica) 983 m. tons, striped marlin (Kajikia audax) 845 m. tons whereas Indo-Pacific blue marlin (Makaira mazara) contributed 305 m. tons. Contribution of shortbill spearfish (Tetrapturus angustirostris) and swordfish (Xiphias gladius) was insignificant.. Billfishes are not locally consumed but transported to neighboring country through land or sea route."*

124. The WPB **NOTED** that the major source of data presented by the author is based on the interactions with fishermen that are engaged in gillnet fishing for tuna and tuna-like species in the coastal and offshore waters of Pakistan through the WWF-Pakistan Crew Based Programme.

125. The WPB **NOTED** that official data from Pakistan published in the Handbook of Fisheries Statistics of Pakistan include aggregated billfish landing data and so do not provide information about species composition.

126. The WPB **NOTED** that for the last cycle, mandatory statistical data has not yet been provided by Pakistan and **REQUESTED** Pakistan to submit the data as earliest possible.

127. The WPB **NOTED** that the majority of catches of billfish recorded in Pakistan are of juveniles and further **NOTED** that all billfish caught in Pakistan are exported to I.R. Iran.

128. The WPB **NOTED** that the sub-surface setting of gillnets which has been implemented on the majority of vessels operating in Pakistan (as well as in I.R. Iran and parts of India) which has reportedly led to a major decrease in catches of billfish.

129. The WPB **NOTED** document IOTC-2022-WPB20-20 which outlined an improved protocol for satellite tagging of billfish, including the following abstract as provided by the author:

> *"Satellite tags have been widely used to investigate the biology and ecology of marine species (e.g., migration, vertical movements, reproductive behavior, post-release mortality). The techniques used to tag the animals are substantially different depending on species and the experience of taggers. Tuna have been tagged onboard with manual sticks, spearguns, or harpoons. For billfish, the most common technique is to use a harpoon as these species can be dangerous to handle onboard, are difficult to bring onboard, and are very sensitive with high mortality rates once onboard. Here we present the key elements that can help to maximize the success of tagging from our experience on 84 tags on billfish in the Indian Ocean. We investigate the potential effect of different factors (tagger, handling time, fight time, position of the tag on the animal, …). We show that the position of the tag on the animal is critical for the subsequent retention time of the tag while other factors are less significant. The best position is determined to be below the first dorsal spine and*

above the lateral line. Retention time was XX times longer when targeting this area compared to other locations.”.

130. The WPB **NOTED** a series of criteria to improve the tagging protocol, including the assessment of fish fitness for tagging as well the optimal tagging zone, which are strongly related with the deployment time.

131. The WPB **NOTED** that all five billfish species (swordfish, blue marlin, black marlin, striped marlin and sailfish) are being targeted by this tagging project. The WPB further **NOTED** that the main species for which tags were deployed were blue marlin and Indo-Pacific Sailfish, and Australia and Reunion were the major areas of deployment.

132. The WPB **NOTED** that the trajectories of tagged individuals by species show long distance movements but do not show mixing between east and west areas. The WPB further **NOTED** that tags have been deployed in Western Australia and it is possible that these tags will show some movement between east and west regions of the Indian Ocean.

133. The WPB **NOTED** that 18 tags are still at sea and there is a plan to deploy another 16 tags by June 2023.

134. The WPB **NOTED** that around 40% of the tags deployed and programmed to pop after 3 to 12 months floated prematurely **NOTING** that the tags are programmed to pop from individuals if they reach a depth threshold of 1200m, beyond the depth preference of swordfish. The WPB therefore **NOTED** that these pops are thought to mostly be related to mortality but there may also have been some issues with anchoring.

135. The WPB **NOTED** that previous papers have found a large effect due to the tagger and **NOTED** that while this effect was considered, individual taggers did not significantly affect the tag retention time. However, the WPB **NOTED** that at an aggregated level, there was some effect between experienced and less-experienced taggers. The WPB further **NOTED** that the effect of the placement zone of the tag on the fish was by far the most significant factor evaluated in terms of tag retention time.

136. The WPB **NOTED** that the tags deployed were Wildlife Computers tags and that 25% of the tags did not report any data, but the authors hope that the remaining tags will transmit data as they were still within the range of the programmed deployment time. The WPB **NOTED** that the tags deployed more recently were deployed for 360 days in an attempt to capture a full reproductive cycle and that while there are some risks due to limitations in data transmission and battery life, the benefits outweigh the risks.

137. The WPB **CONGRATULATED** the authors on their work, **ACKNOWLEDGING** the effort required to coordinate the deployment of tags on the five different billfish species from numerous different sites. The WPB **NOTED** the collaboration that was required to develop a pan-oceanic network of taggers and the logistical complications that were overcome, especially considering the context of the global COVID-19 pandemic.

138. The WPB **REQUESTED** that training videos be developed as an output of the work, and **NOTED** the importance of these materials for future tagging activities.

139. The WPB **ACKNOWLEDGED** the preliminary results presented and the important information that can be derived from this data source.

8.2 Resolution 18/05 Catch Limits

140. The WPB **NOTED** paper IOTC-2022-WPB20-INF04 on recent catches of billfish in relation to catch limits set out in Resolution 18/05.

141. 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.

142. The WPB **NOTED** that reported catches of two species, black marlin and Indo-Pacific sailfish, have exceeded the limits set out in Resolution 18/05 for both 2020 and 2021 and so the WPB **RECOMMENDED** that the SC report this to the Commission as management action is required.

143. The WPB **NOTED** that while the data in recent years can be assumed to be of fairly good quality, the data from 2021 are preliminary.

144. The WPB **NOTED** that the catch limits set in the Resolution may be outdated and will likely need to be updated.

145. The WPB **NOTED** that around 60% of billfish catches are taken in gillnets and that much of the remaining catches are accounted for by other coastal fisheries mostly using lines. 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.

9. WPB PROGRAM OF WORK

9.1 Revision of the WPB Program of work (2023–2027)

146. The WPB **NOTED** paper IOTC–2022–WPB20–08 which provided an opportunity to consider and revise the WPB Program of Work (2023–2027), by taking into account the specific requests of the Commission, Scientific Committee, and the resources available to the IOTC Secretariat and CPCs.

147. 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).

148. The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2023–2027), as provided at Appendix XI.

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

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

150. 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 2023 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.

10. OTHER BUSINESS

10.1 Date and place of the 21st and 22nd Sessions of the Working Party on Billfish

151. The WPB **NOTED** that with the global Covid-19 pandemic easing, there was a desire to return to physical meetings in 2023. The Secretariat will continue to liaise with CPCs to determine their interest in hosting meetings in the future. A tentative offer was made by Ifremer (EU) to host the WPB and WPEB in Reunion in 2023.

152. The WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB21 in 2023. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB, with the WPEB taking place after the WPB in 2023.

10.2 Review of the draft, and adoption of the Report of the 20th Session of the Working Party on Billfish

153. The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB20, provided at Appendix XII, as well as the management advice provided in the draft resource stock status summary for each of the five billfish species under the IOTC mandate, and the combined Kobe plot for the five species assigned a stock status in 2022 (Fig. 4):

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

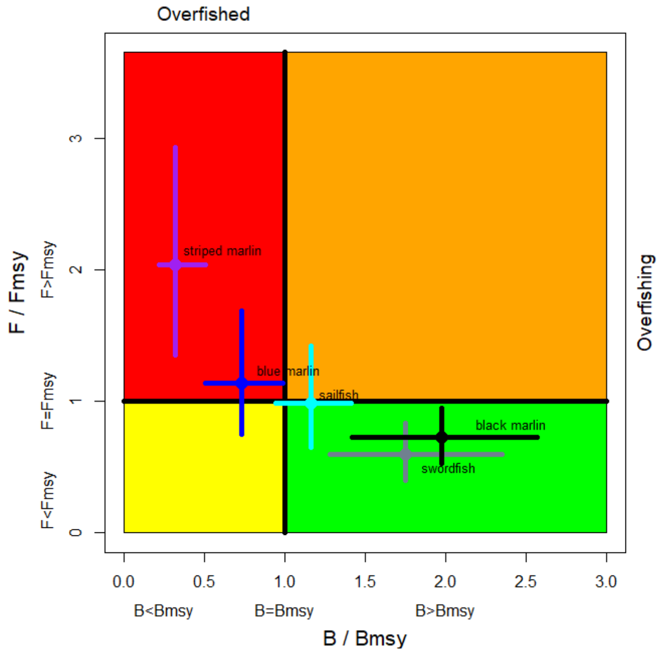


Fig. 4. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2018, 2019, 2020, 2021, 2022 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs.

154. The report of the 20th Session of the Working Party on Billfish (IOTC–2022–WPB20–R) was **ADOPTED** by correspondence.

APPENDIX I - LIST OF PARTICIPANTS

CHAIRPERSON
Dr. Denham **Parker**
DFFE
DParker@dffe.gov.za

VICE-CHAIRPERSON
Dr. Jie **Cao**
North Carolina State University
jcao22@ncsu.edu

PARTICIPANTS
Mrs. Thejani **Balawardhana**
National Aquatic Resources Research and development Agency
thejani.fmst2008@gmail.com

Mrs. Kishara **Bandaranayake**
NARA
kisharabandaranayake@gmail.com

Mr. Carlos **Barciela Segura**
ORPAGU
cbarciela@orpagu.com

Dr. Sylvain **Bonhommeau**
IFREMER
sylvain.bonhommeau@ifremer.fr

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

Dr. Thomas **Brunel**
Wageningen Marine Research
thomas.brunel@wur.nl

Dr. Florencia **Cerutti**
IFREMER
florencia.cerutti@ifremer.fr

Mrs. Umi **Chodriyah**
National Research and Innovation Agency
umi_chodriyah@yahoo.co.id

Dr. Rui **Coelho**
IPMA - Portuguese Institute for the Ocean and Atmosphere
rpcoelho@ipma.pt

Dr. Ansuman **Das**
Fishery Survey of India
1006ansu@gmail.com

Mr. Logamany **Dilukshani Gayathry**
NARA
gayathrydilu93@gmail.com

Mr. Jacob **Espittia**
University of Miami
jacob.espittia@rsmas.miami.edu

Mr. Jose **Fernández Costa**
Spanish Institute of Oceanography, Spanish National Research Council (IEO-CSIC)
jose.costa@ieo.csic.es

Dr. Tadanori **Fujino**
OFCF
ofcf.fujino@gmail.com

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

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

Mrs. Hety **Hartaty**
National Research and Innovation Agency
hety001@brin.go.id

Mrs. Sandamali **Herath**
Department of Fisheries & Aquatic Resources
hlsherath@gmail.com

Mr. Sichon **Hoimuk**
Department of Fisheries, Thailand
s.hoimuk@gmail.com

Dr. Krystle **Keller**
Australian Department of Agriculture, Forestry and Fisheries
krystle.keller@agriculture.gov.au

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

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

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

Dr. Mohammed **Koya**
CMFRI-India
koya313@gmail.com

Mrs. Xiuzhen **Li**
Shanghai Ocean University
jlxz981018@163.com

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

Ms. Juliette **Lucas**
SFA
jlucas@sfa.sc

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

Mrs. Esther **Mollier**
IRD
esther.mollier@ird.fr

Dr. Iago **Mosqueira**
Wageningen Marine Research
iago.mosqueira@wur.nl

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

Dr. Anne-Elise **Nieblas**
COOOL
anne.elise.nieblas@company-coool.io

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

Ms. Amelie **Nithard**
IFREMER
amelie.nithard@ifremer.fr

Mr. Dian **Novianto**
Center for Fisheries Research, National Research and Innovation Agency of the Republic of Indonesia
dianovianto78@gmail.com

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

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

Ms. Surya **S**
CMFRI
revandasurya@gmail.com

Dr. Philippe **Sabarros**
IRD
philippe.sabarros@ird.fr

Dr. Lilis **Sadiyah**
National Research and Innovation Agency
sadiyah.lilis2@gmail.com

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

Mr. Bram **Setyadji**
National Research and Innovation Agency
bram.setyadji@gmail.com

Mr. Kuruppuge **Suraj Chandrakumara**
Department of Fisheries and Aquatic Resources
ksckdumidi@gmail.com

Mr. Wei **Tang**
Shanghai Ocean University
m200210753@st.shou.edu.cn

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

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

Dr. Xuefang **Wang**
Shanghai Ocean University
xfwang@shou.edu.cn

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

Mr. Agustinus Anung **Widodo**
National Research and Innovation Agency
agus184@brin.go.id

Mr. Ashley **Wilson**
Pew
awilson@pewtrusts.org

IOTC SECRETARIAT

Dr Paul **de Bruyn**
Paul.Debruyn@fao.org

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

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

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

Ms Lauren **Nelson**
Lauren.Nelson@fao.org

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

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

APPENDIX II - AGENDA FOR THE 20TH WORKING PARTY ON BILLFISH

Date: 12–15 September 2022
Location: Online
Time: 12:00 – 16:00 daily (Seychelles time)
Chair: Dr Denham Parker (South Africa); **Vice-Chair:** Dr Jie Cao (China)

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

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

3. **THE IOTC PROCESS: OUTCOMES, UPDATES AND PROGRESS**
   - Outcomes of the 24th Session of the Scientific Committee (IOTC Secretariat)
   - Outcomes of the 26th Session of the Commission (IOTC Secretariat)
   - Review of Conservation and Management Measures relevant to billfish (IOTC Secretariat)
   - Progress on the recommendations of WPB19 (IOTC Secretariat)

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

5. **MARLINS (Priority species for 2022: Blue marlin)**
   - Review new information on marlin biology, stock structure, fisheries and associated environmental data (all)
   - Review of new information on the status of blue marlins (all)
     - Nominal and standardised CPUE indices
     - Stock assessments
     - Selection of Stock Status indicators
   - Development of management advice for blue marlins and update of species Executive Summaries for the consideration of the Scientific Committee, including discussion on current catch limits as per standing IOTC Resolutions (all)

6. **INDO-PACIFIC SAILFISH**
   - Review new information on I.P sailfish biology, stock structure, fisheries and associated environmental data (all)
   - Review of new information on the status of I.P. Sailfish (all)
     - Available abundance indices
     - Stock assessments
     - Selection of Stock Status indicators
   - Development of management advice for I.P. Sailfish and update of species Executive Summary for the consideration of the Scientific Committee, including discussion on current catch limits as per standing IOTC Resolutions (all)

7. **SWORDFISH**
   - Review of new information on swordfish biology, stock structure, fisheries and associated environmental data (all)
   - Review of new information and indicators on the status of swordfish (all)
     - Nominal and standardised CPUE indices
     - Other indicators
   - Updates on the Management Strategy Evaluation for Swordfish

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

9. WPB PROGRAM OF WORK

- Revision of the WPB Program of Work (2023–2027) (Chairperson and IOTC Secretariat)
- Development of priorities for an Invited Expert at the next WPB meeting (Chairperson)

10. OTHER BUSINESS

- Date and place of the 21st and 22nd Sessions of the Working Party on Billfish (Chairperson and IOTC Secretariat)
- Review of the draft, and adoption of the Report of the 20th Session of the Working Party on Billfish (Chairperson)

APPENDIX III - LIST OF DOCUMENTS FOR THE 20TH WORKING PARTY ON BILLFISH

Document	Title
IOTC-2022-WPB20-01a	Agenda of the 20th Working Party on Billfish
IOTC-2022-WPB20-01b	Annotated agenda of the 20th Working Party on Billfish
IOTC-2022-WPB20-02	List of documents of the 20th Working Party on Billfish
IOTC-2022-WPB20-03	Outcomes of the 24th Session of the Scientific Committee (IOTC Secretariat)
IOTC-2022-WPB20-04	Outcomes of the 26th Session of the Commission (IOTC Secretariat)
IOTC-2022-WPB20-05	Review of Conservation and Management Measures relevant to billfish (IOTC Secretariat)
IOTC-2022-WPB20-06	Progress made on the recommendations and requests of WPB19 and SC24 (IOTC Secretariat)
IOTC-2022-WPB20-07	Review of the statistical data and fishery trends for billfish species (IOTC Secretariat)
IOTC-2022-WPB20-08	Revision of the WPB Program of Work (2023-2027) (IOTC Secretariat)
IOTC-2022-WPB20-09	CPUE standardization of blue marlin (Makaira nigricans) caught by Taiwanese large scale longline fishery in the Indian Ocean (Wang S-P)
IOTC-2022-WPB20-10	Standardized CPUE of blue marlin (*Makaira mazara*) caught by Japanese longline fishery in the Indian Ocean: Analysis between 1979 and 2021 (Matsumoto, Taki, and Ijima)
IOTC-2022-WPB20-11	Update on CPUE Standardization of Blue Marlin (*Makaira nigricans*) from Indonesian Tuna Longline Fleets 2006-2021 (Setyadji B, Parker D, Wang S-P)
IOTC-2022-WPB20-12	Updated stock assessment of blue marlin (*Makaira nigricans*) in the Indian Ocean using JABBA (Parker D)
IOTC-2022-WPB20-13	Stock assessment of blue marlin (*Makaira nigricans*) in the Indian Ocean using Stock Synthesis (Wang S-P)
IOTC-2022-WPB20-14	Determination of Size Discrepancies for Sailfish, *Istiophorous platypterus*, in Varying Ocean Basins (Espittia J)
IOTC-2022-WPB20-15	Alternative methods to assess the data poor Indo-Pacific sailfish (*Istiophorus platypterus*) stock (Parker D and Espittia J)
IOTC-2022-WPB20-16	Assessment of the impact of the inclusion of marine subsurface variables on habitat modelling of swordfish in the Indian Ocean (Tang W)
IOTC-2022-WPB20-17	Analysis of At-haulback Mortality and Influencing Factors of Indian Ocean Swordfish (*Xiphias gladius*) (Li X)
IOTC-2022-WPB20-18	Indian Ocean swordfish MSE: suggestions for modification on the Operating model (Brunel T and Mosqueira I)
IOTC-2022-WPB20-19	Status of fisheries of billfish of Pakistan: Status and Trends (Moazzam M)
IOTC-2022-WPB20-20	Improved protocol for satellite tagging of billfish (Nieblas A.E., Chanut J, Tracey S, Nithard A, Brisset B, Evano H, Bernard S, Rouyer T, Kerzerho V, Bonhommeau S)
IOTC-2022-WPB20-INF01	High-resolution post-release behaviour and recovery periods of two highly prized recreational sportfish: the blue marlin and sailfish (Logan R, Vaudo J, Lowe C, Wetherbee B, Shivji M)
IOTC-2022-WPB20-INF02	Project PESCARUN – preliminary results of swordfish studies in Reunion Island including experimental fishing, electronic tagging and trophic ecology (Romanov E, Guillon N, Sabarros P, Polard Y, Geffory O, Brighigna L, Stéphan K, Demouge M, Jaquemet S, Marsac F, Bach P)
IOTC-2022-WPB20-INF03	Habitat suitability of Indo-Pacific sailfish Istiophorus platypterus (Shaw, 1792) in the Arabian Sea (Surya S, Prathibha R, Abdussamad EM, Asha T, Santhosh B, Nayak B, Karankumar R, Mini K, Kingsly J, Anil M)

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

(*Extract from IOTC–2022–WPB20–07*)

Nominal catches

Historical trends (1950-2020)

Billfish are mainly caught by industrial fisheries in offshore areas using longlines and gillnets, but they are also taken with purse seines and some artisanal gears such as troll and hand lines in more coastal fishing grounds. The total nominal catches of the IOTC billfish species showed a major increase over the last seven decades, from an average of 5,500 t per year in the 1950s to an average of 88,200 t per year in the 2010s. The marked increase in annual catches of billfish species caught by industrial fisheries recorded between the 1990s and the 2000s was mainly driven by the longline fisheries from Taiwan,China (**Fig. A1a**). Since then, industrial catches showed large variations between a maximum of 58,700 t in 2004 and a minimum of 32,500 t in 2010. Catches from artisanal fisheries have steadily increased over time, with their contribution to the total catch of billfish increasing from less than 10% prior to the 1970s to more than 50% in recent years (**Fig. A1b**).

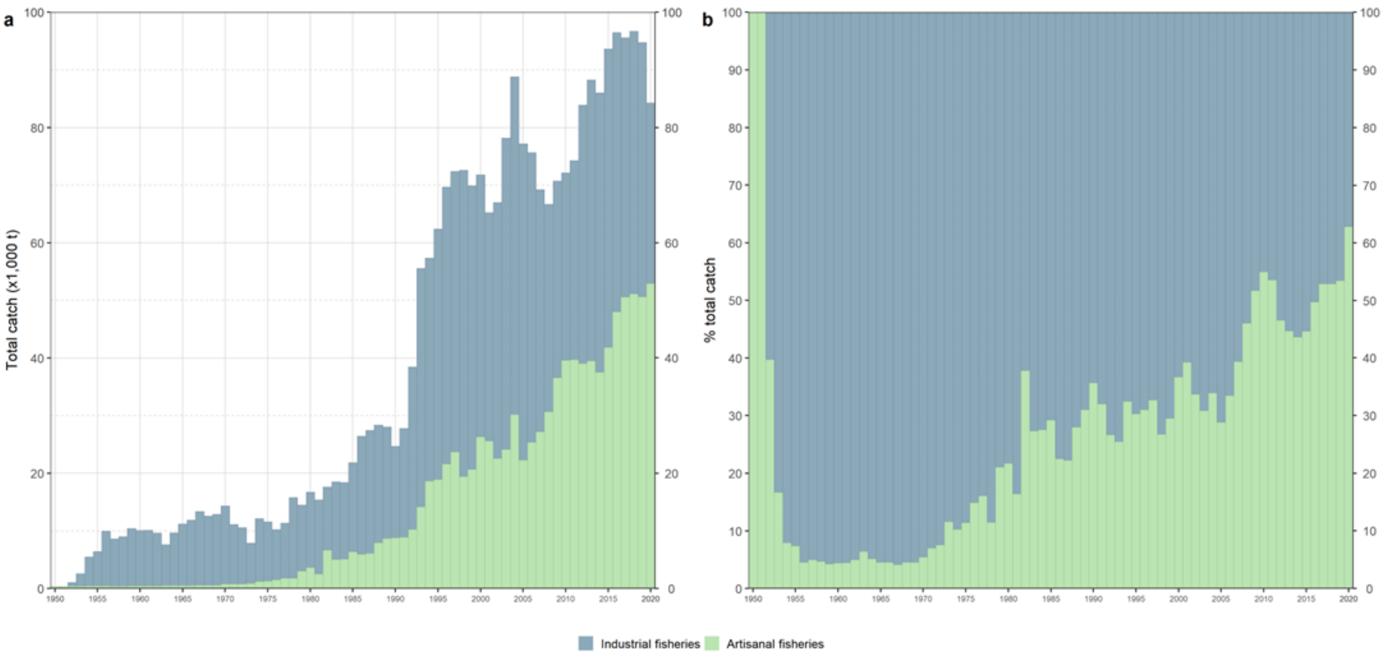


Figure A1: Annual time series of cumulative nominal absolute (a) and relative (b) catches (metric tons; t) of IOTC billfish by fishery type for the period 1950-2020

The composition of the fisheries catching billfish varies over time and between species. While billfish have mainly been reported to be caught by longliners until the early 1990s, the contribution of gillnet and coastal line fisheries has substantially increased over the last two decades (**Fig. A2**). In particular, gillnet catches of billfish have steadily increased since the early 1980s to reach about 36,000 t in 2020, representing 43% of the total catches of billfish in that year. Total catches of billfish reported for line fisheries showed a marked increase from the early 2010s (**Fig. A2**) reflecting in particular the increased reporting of billfish species caught by the coastal longline fishery of Sri Lanka, that went from 37 t in 2013 to 4,426 t in 2014. This sharp increase is thought to be mainly due to an improvement in the fisheries statistics of Sri Lanka starting with the early 2010s, when a closer monitoring of the catches in multi-gear fisheries (e.g., gillnet and longline operated during the same trip) was combined with a better break-down of longline fisheries data (i.e., separation between coastal and offshore components). In parallel, the catches of billfish taken by coastal longliners operating in the Indian areas of national jurisdiction have doubled over the last decade, increasing from 3,309 t in 2013 to 5,190 t in 2020.

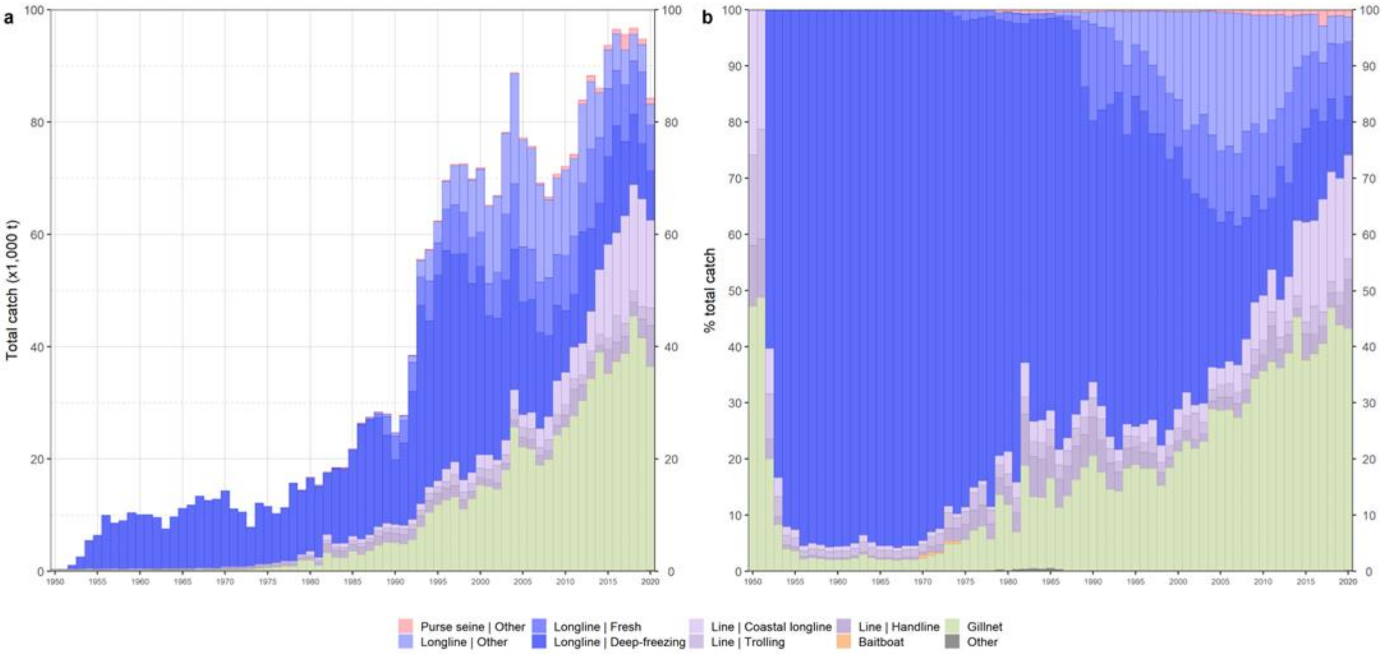


Figure A2: Annual time series of cumulative nominal absolute (a) and relative (b) catches (metric tons; t) of IOTC billfish by fishery for the period 1950-2020

The five IOTC billfish species show different catch levels and trends over time, with a total of 2.7 million metric tons of billfish reported to have been caught in the Indian Ocean since the 1950s. In terms of total catches, swordfish (SWO) represents the main billfish species, contributing to 37% of the cumulative catches of billfish available in the IOTC database, followed by Indo-Pacific sailfish (SFA) with a contribution of 24% (**Fig. A3**). Blue marlin (BUM) and black marlin (BLM) contributed about equally with cumulative catches of about 408,000 t, roughly corresponding to 15% of total billfish catches taken during that period. Striped marlin (MLS) appears to be less abundant in the catches of IOTC billfish with a maximum annual catch of 8,730 t observed between 1950 and 2020 and a total cumulative catch of about 260,000 t reported as caught over that period.

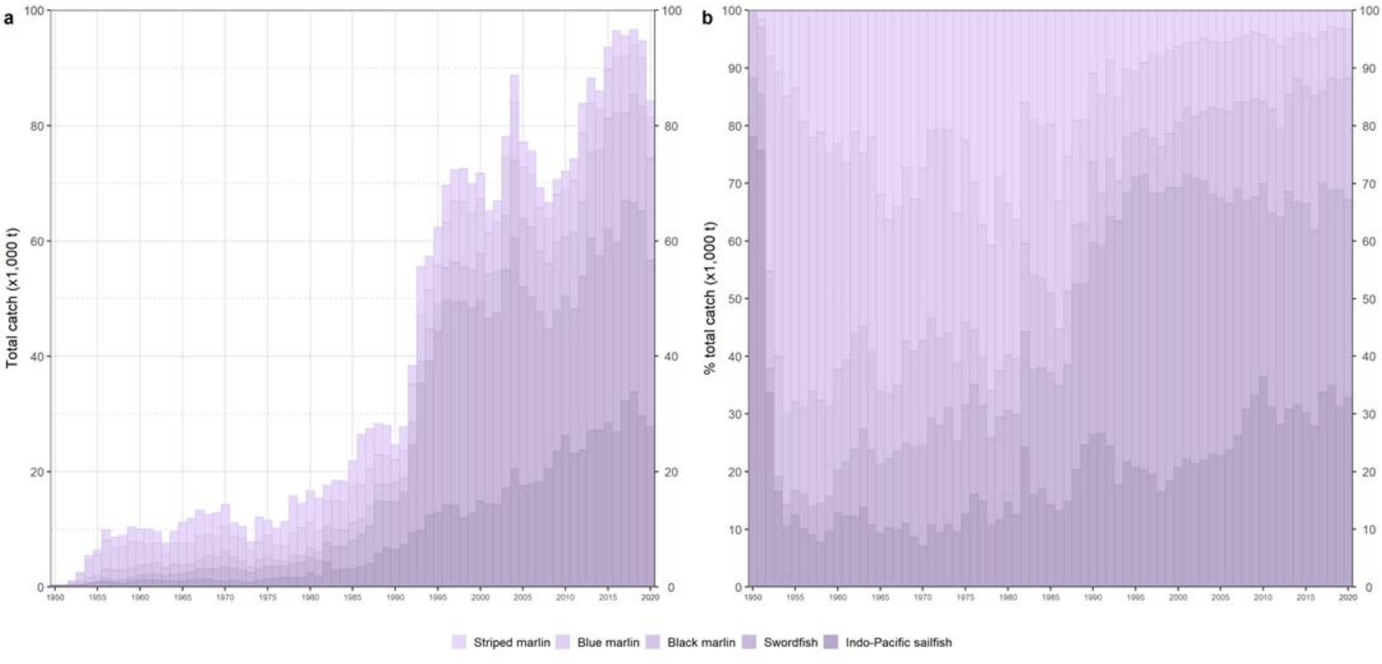


Figure A3: Annual time series of cumulative nominal absolute (a) and relative (b) catches (metric tons; t) of IOTC billfish by species for the period 1950-2020

Recent fishery features (2016-2020)

In recent years (2016-2020), total nominal catches of all IOTC billfish species combined were about 93,600 t per year, with gillnet, longline, and line fisheries contributing to 42.6%, 29.9%, and 25.9% of all catches, respectively. Between 2016 and 2020, the mean annual catches of IOTC billfish have been dominated by a few CPCs, to the point that about two thirds of all catches were accounted for by four distinct fleets: I.R. Iran (mostly composed of gillnet fisheries), Sri Lanka and India (described by a large diversity of fisheries and gears), and Taiwan,China (composed of an equal mix of fresh and deep-freezing longliners) (**Fig. A4**).

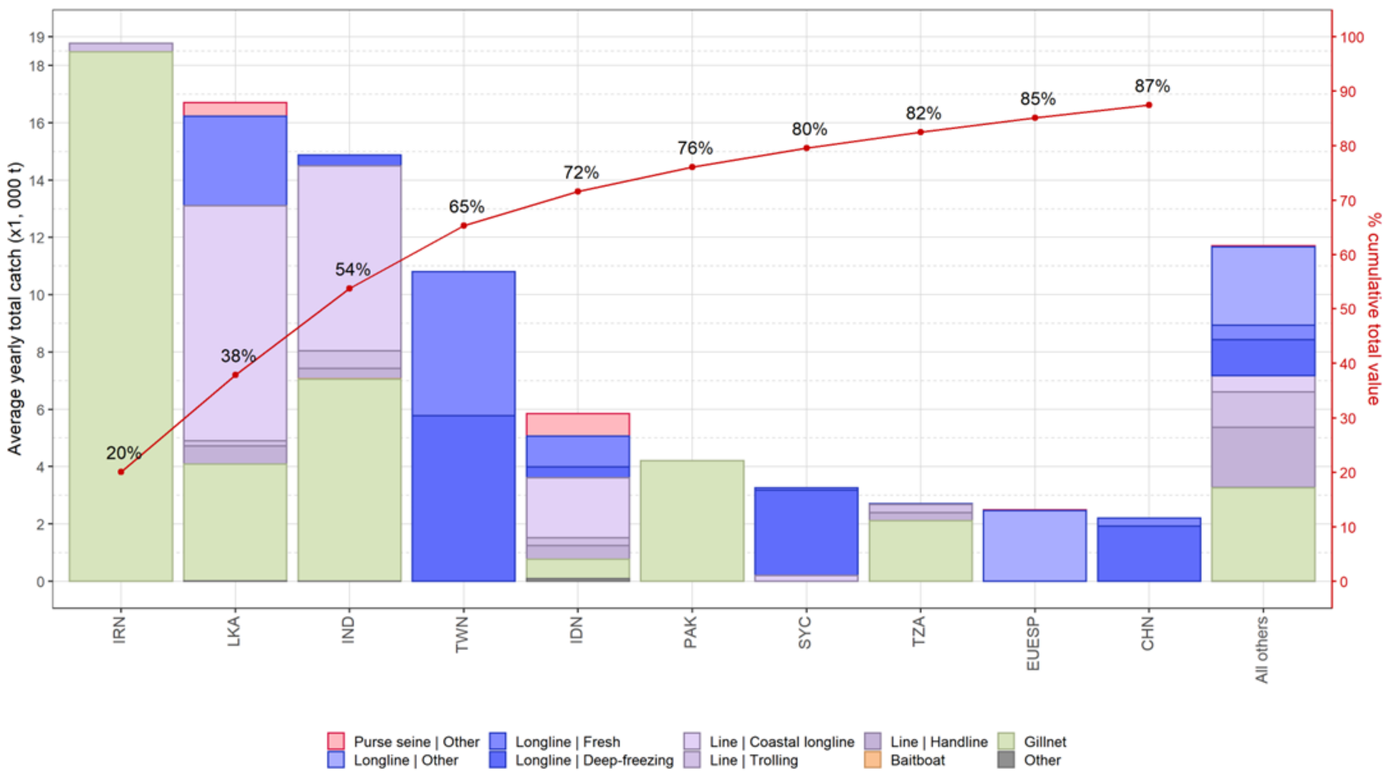


Figure A4: Mean annual catches (metric tons; t) of IOTC billfish species by fleet and fishery between 2016 and 2020, with indication of cumulative catches by fleet

Over the last five years of the time series (2016-2020), gillnet catches of billfish species showed an increase followed by a decrease when catches reported by longline fisheries substantially decreased and line catches showed a regular increasing trend (**Fig. A5**). Meanwhile, catches from the other fishery groups (i.e., purse seine, baitboat, and other fisheries) were small or negligible. Between 2016 and 2020, the catches of billfish taken by line fisheries increased from 22,800 t to 26,000 t, while catches of billfish taken by longline fisheries decreased from 35,500 t to 20,700 t (**Fig. A5**).

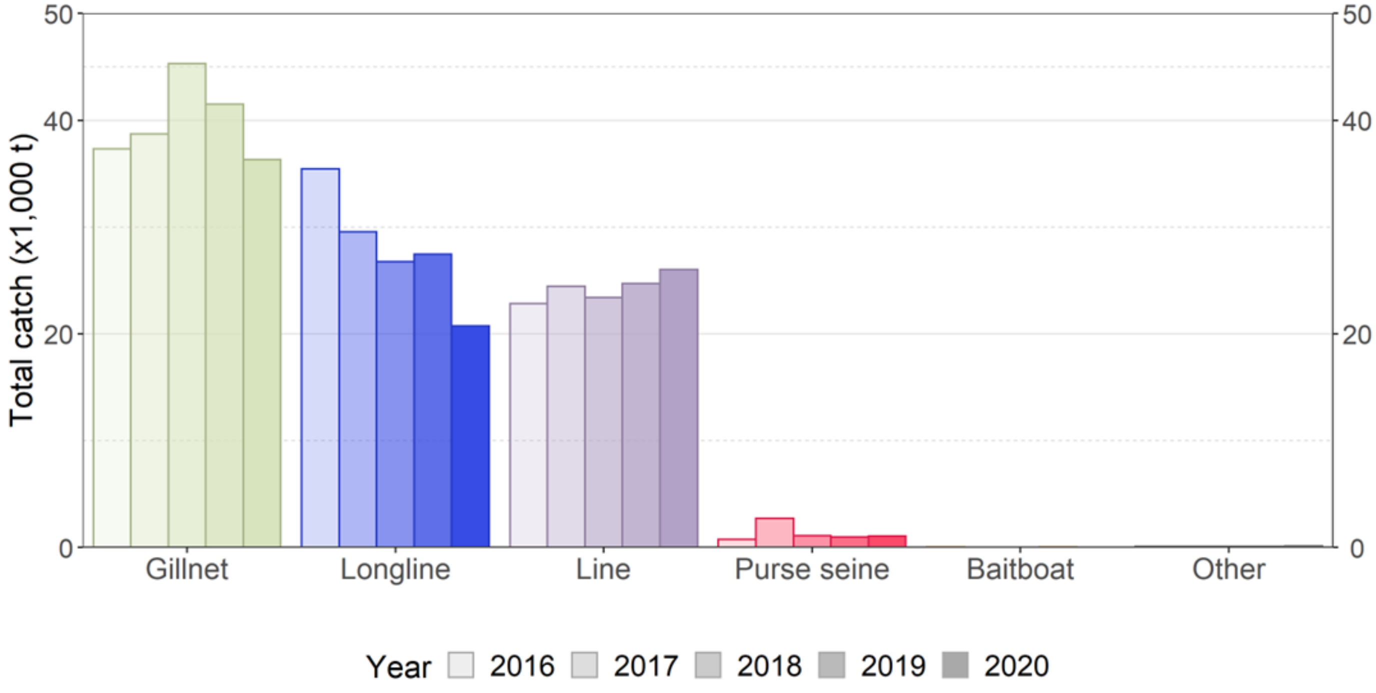


Figure A5: Annual catch (metric tons; t) trends of IOTC billfish species by fishery group between 2016 and 2020

Uncertainties in nominal catch data

The overall quality of nominal catches for the five IOTC billfish species with regards to IOTC reporting standards has strongly varied between 1950 and 2020, and improved substantially over the last decade. The percentage of nominal catches fully or partially reported to the Secretariat i.e., scores between 0 and 2) showed large variations over time, decreasing from more than 90% prior to the 1970s, when the catches were dominated by industrial longline fisheries, to less than 40% in the late 2000s (**Fig. A6**). Since then, the reporting quality improved for both industrial and artisanal fisheries with the overall percentage of data fully or partially reported to the Secretariat reaching 87% in 2020. The reporting quality of nominal catch data varies between species and over time and information on quality is available on a species-specific basis from the data review papers on black marlin (IOTC-2022-WPB20-07a), blue marlin (IOTC-2022-WPB20-07b), striped marlin (IOTC-2022-WPB20-07c), Indo-Pacific sailfish (IOTC-2022-WPB20-07d), and swordfish (IOTC-2022-WPB20-07e).

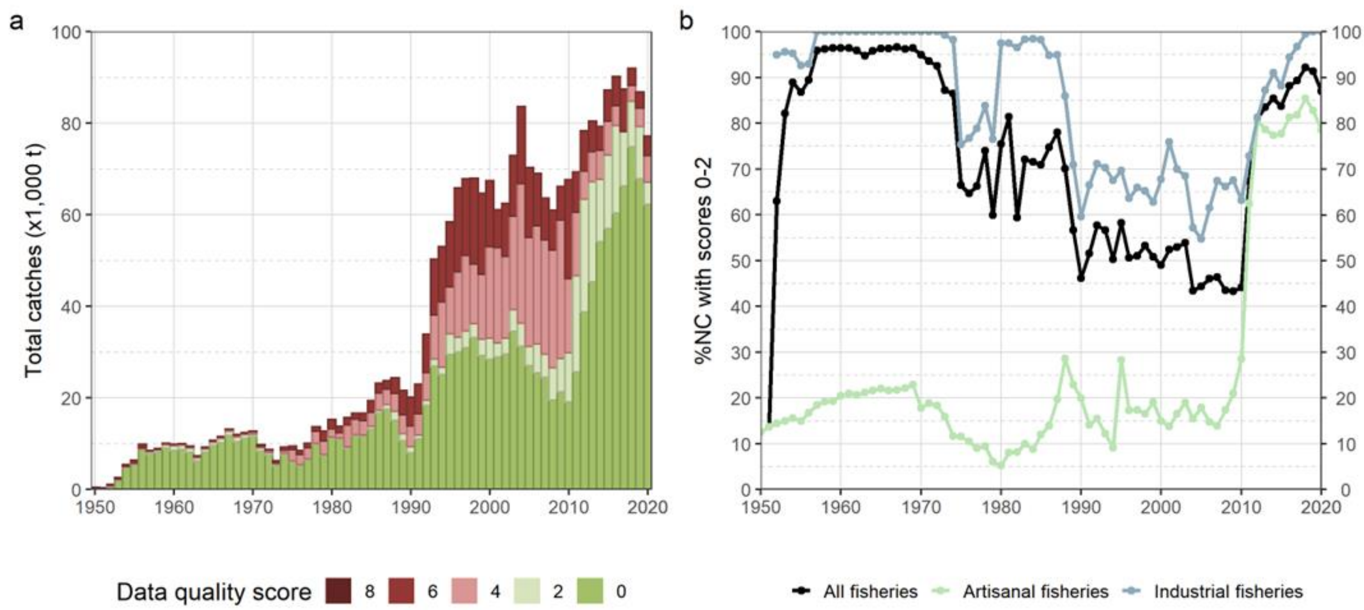


Figure A6: (a) Annual nominal catches (metric tons; t) of IOTC billfish species estimated by quality score and (b) percentage of nominal catches by type of fishery fully and partially reported to the IOTC Secretariat according to IOTC standards

Discard levels

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

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

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

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

Geo-referenced catch and effort data

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

Hence, no geo-referenced catches were available for a large part of the nominal catches of billfish species between the 1990s and 2010s (**Fig. A7**), with the percentage of good-quality catch and effort data (scores of 0-2) decreasing from more than 80% in the late 1950s to a minimum of about 30% in the mid-2000s (**Fig. A7**). The situation has however improved over the last decade with the increasing reporting of catch and effort for some artisanal fisheries (e.g., Indonesia, Sri Lanka), although the logbook coverage used to derive the spatial distribution of the catch for these fisheries is generally reported to be low (<30%). The reporting quality of geo-referenced catch and effort data varies between species and over time and information on quality on a species-specific basis is available from the data review papers on black marlin (IOTC-2022-WPB20-07a), blue marlin (IOTC-2022-WPB20-07b), striped marlin (IOTC-2022-WPB20-07c), Indo-Pacific sailfish (IOTC-2022-WPB20-07d), and swordfish (IOTC-2022-WPB20-07e).

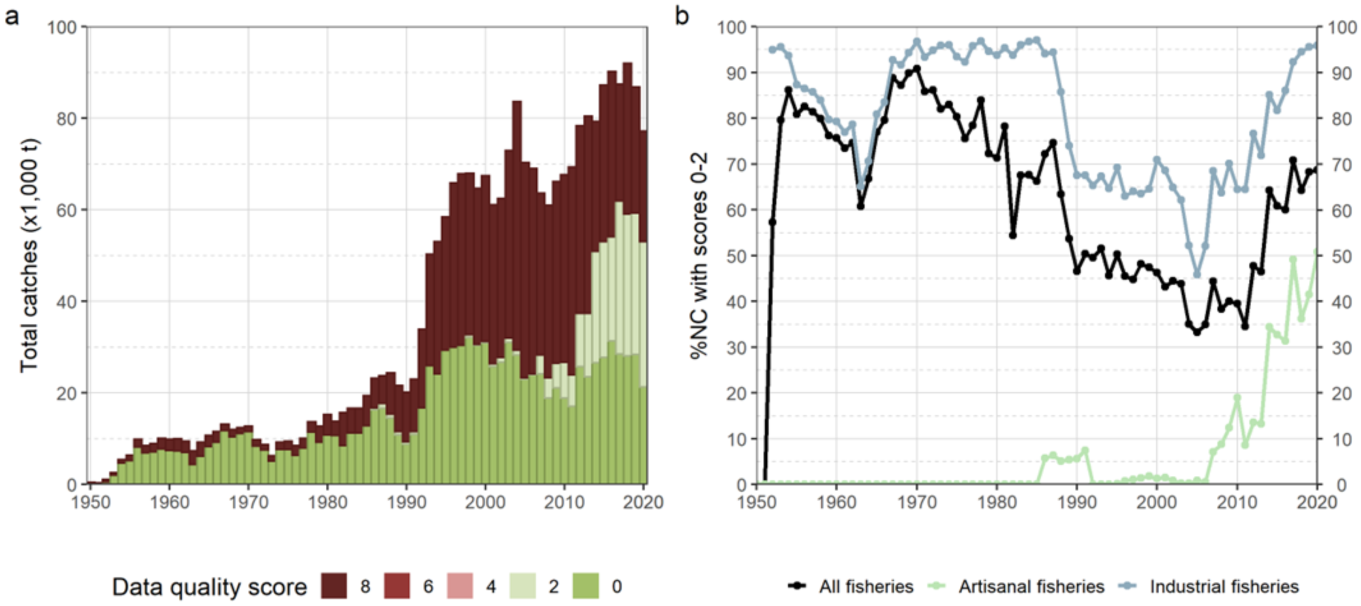


Figure A7: (a) Annual nominal catches (metric tons; t) of IOTC billfish species estimated by quality score and (b) percentage of nominal catches by type of fishery with good quality information (i.e., logbook coverage>30% and compliant with IOTC standards) for the corresponding geo-referenced catch and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

Size data

The overall reporting quality for geo-referenced size data is poor for all five IOTC billfish species. In fact, almost no size data is available prior to the 1980s and the few data available during the 1970s for industrial longliners from Japan are characterized by low sampling coverage (<1 fish per metric ton) and are not compliant with IOTC reporting standards (**Fig. A9**). Some size data of good reporting quality became available from longliners from Taiwan,China and gillnetters from Sri Lanka during the 1980s and later on from the swordfish-targeting fresh longline fisheries of EU,Spain, EU,France (La Réunion) and Seychelles, which developed and expanded throughout the 1990s. The availability of good quality size data sharply declined from the mid-2000s, mostly due to the major decrease in catches of swordfish reported by the deep-sea longline fisheries of Taiwan,China (**Fig. A9**). It increased in very recent years with the reporting of size data by Sri Lanka for its coastal longline fishery. The reporting quality of geo-referenced size frequency data varies between species and over time and information on quality on a species-specific basis is available from the data review papers on black marlin (IOTC-2022-WPB20-07a), blue marlin (IOTC-2022-WPB20-07b), striped marlin (IOTC-2022-WPB20-07c), Indo-Pacific sailfish (IOTC-2022-WPB20-07d), and swordfish (IOTC-2022-WPB20-07e).

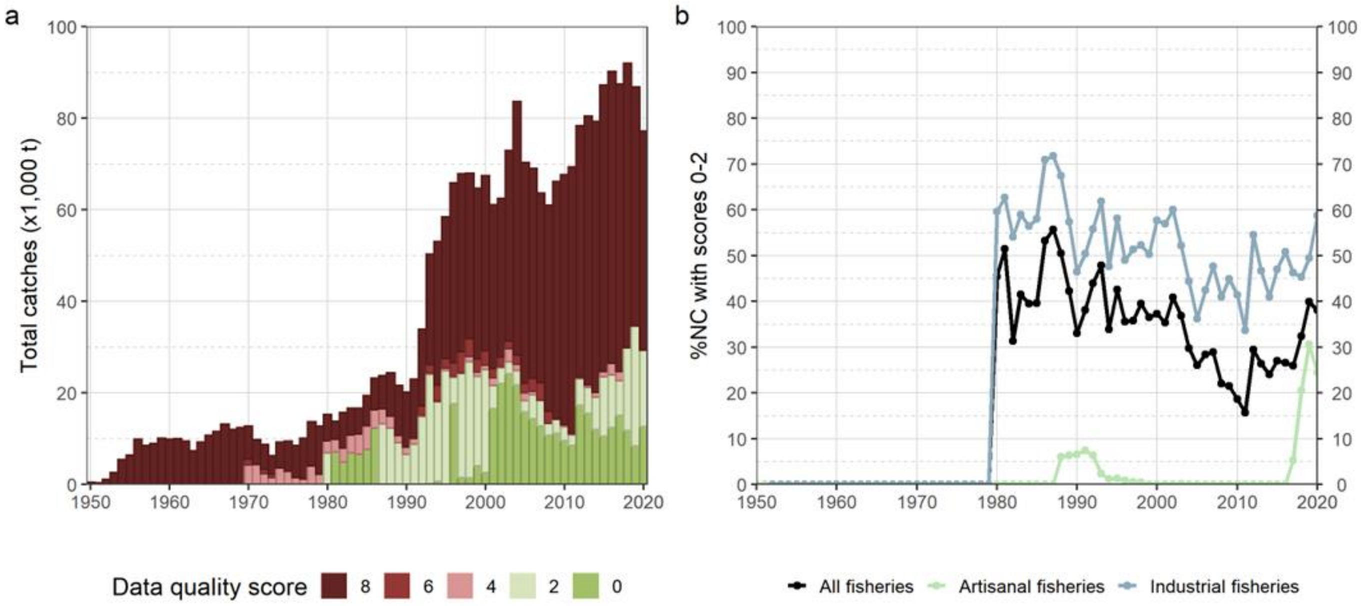


Figure A9: (a) Annual nominal catches (metric tons; t) of IOTC billfish species estimated by quality score and (b) percentage of nominal catches by type of fishery with good quality information (i.e., >1 fish per metric ton caught and compliant with IOTC standards) for the corresponding geo-referenced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

APPENDIX V

Main issues identified concerning data on IOTC billfish species

Extract from IOTC–2022–WPB20)–07

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

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

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

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

• Industrial purse seine fisheries

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

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

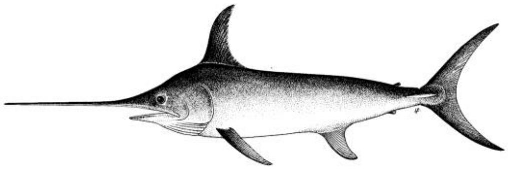


TABLE 1. Swordfish: Status of swordfish (*Xiphias gladius*) in the Indian Ocean.

Area[1]	Indicators		2021 stock status determination
Indian Ocean	Catch 2021[2] (t) Average catch 2017-2021 (t)	23,917 31,157	**98%**
	MSY (1,000 t) (80% CI) F_{MSY} (80% CI) SB_{MSY} (1,000 t) (80% CI) F_{2018}/F_{MSY} (80% CI) SB_{2018}/SB_{MSY} (80% CI) SB_{2018}/SB_{1950} (80% CI)	33 (27–40) 0.23 (0.15–0.31) 59 (41–77) 0.60 (0.40–0.83) 1.75 (1.28–2.35) 0.42 (0.36–0.47)	

[1] Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence
[2] Proportion of 2020 catch estimated or partially estimated by IOTC Secretariat: 12.42%

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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. An assessment was undertaken in 2020 using stock synthesis with fisheries data up to 2018. The assessment uses a spatially disaggregated, sex explicit and age structured model. The SS3 model, used for stock status advice, indicated that MSY-based reference points were not exceeded for the Indian Ocean population as a whole (F_{2018}/F_{MSY}< 1; SB_{2018}/SB_{MSY}> 1). The two alternative models (ASPIC and JABBA) applied to swordfish also indicated that the stock was above a biomass level that would produce MSY. Spawning biomass in 2018 was estimated to be 40-83% of the unfished levels. Most recent catches of 33,590 t in 2019 are approximately at the *MSY* level (33,000 t). On the weight-of-evidence available in 2020, the stock is determined to be ***not overfished*** and ***not subject to overfishing*** (**Table 1**, **Fig. 3**).

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

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

The following key points should also be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the Indian Ocean is 33,000 t.
- **Provisional reference points**: noting that the Commission in 2015 agreed to Resolution 15/10 *on target and limit reference points and a decision framework*, the following should be noted:
    a. **Fishing mortality**: current fishing mortality is considered to be below the provisional target reference point of F_{MSY} and below the provisional limit reference point of 1.4*F_{MSY} (**Fig. 2**).
    b. **Biomass**: current spawning biomass is considered to be above the target reference point of SB_{MSY}, and therefore above the limit reference point of 0.4*SB_{MSY} (**Fig. 2**).
- **Main fisheries (mean annual catch 2017-2021)**: swordfish are caught using longline (53.9%), followed by line (30.2%) and gillnet (14.9%). 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 swordfish catches are attributed to vessels flagged to Sri Lanka (29.2%) followed by Taiwan,China (17.9%) and EU (Spain) (6.5%). The 25 other fleets catching swordfish contributed to 46.4% of the total catch in recent years (**Fig. 2**).

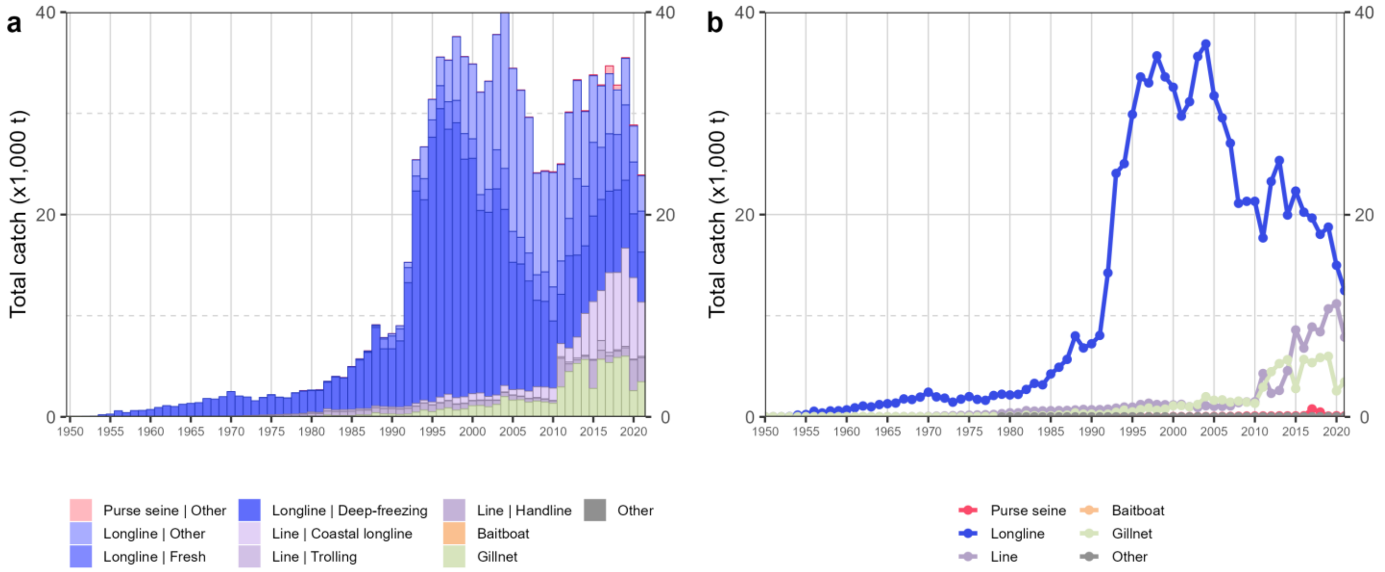


Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for swordfish during 1950–2021. Longline|Other: swordfish and sharks-targeting longlines; Other: all remaining fishing gears

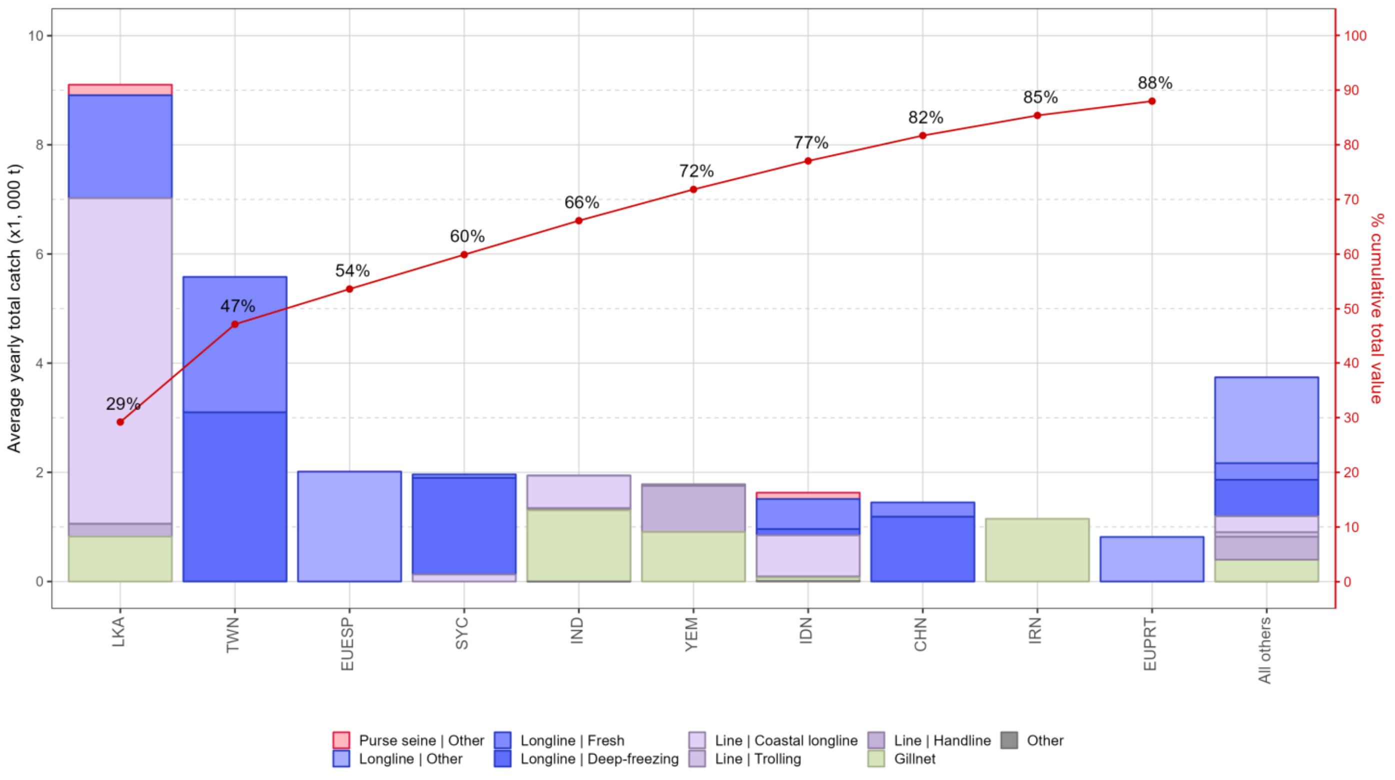


Fig. 2. Mean annual catches (metric tons; t) of swordfish by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

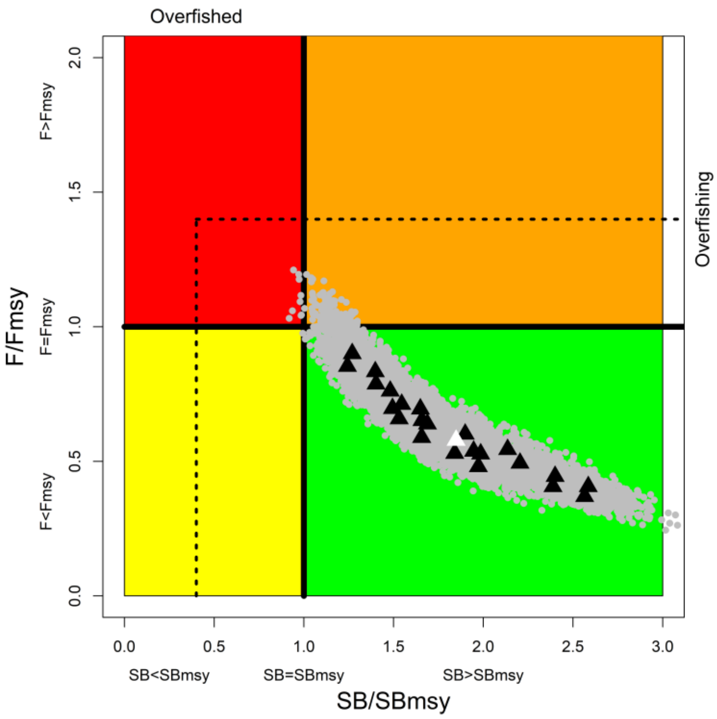


Fig. 3. Swordfish: current stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the final model grid. Triangles represent MPD estimates from individual models (white triangle represent the estimate from the basic model). Grey dots represent uncertainty from individual models. The dashed lines represent limit reference points for Indian Ocean swordfish (SB_{lim} = 0.4 SB_{MSY} and F_{lim} = 1.4*FMSY)

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

Pr ($SB<SB_{MSY}$)

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

Pr ($F>F_{MSY}$)

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

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

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

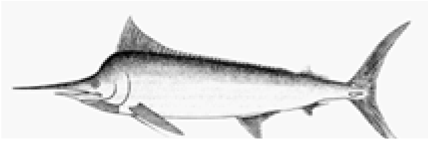


TABLE A8. Black marlin: Status of black marlin (*Makaira indica*) in the Indian Ocean.

Area[1]	Indicators		2021 stock status determination
Indian Ocean	Catch 2021 (t)[2]	14,115	
	Average catch 2017–2021 (t)	16,864	
	MSY (1,000 t) (95% CI)	17.30 (11.00 – 35.02)	
	F_{MSY} (95% CI)	0.20 (0.12 - 0.34)	
	B_{MSY} (1,000 t) (95% CI)	87.39 (53.82-167.70)	
	$F_{current}/F_{MSY}$ (95% CI)	0.53 (0.22 – 1.05)	
	$B_{current}/B_{MSY}$ (95% CI)	1.98 (1.42 – 2.57)	
	$B_{current}/B_0$ (95% CI)	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 2020 catch fully or partially estimated by the IOTC Secretariat: 42.5%

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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. A stock assessment based on JABBA, a Bayesian state-space production model (age-aggregated), was conducted in 2021 for black marlin. The relative point estimates for this assessment are F/F_{MSY}=0.53 (0.22-1.05) and B/B_{MSY}=1.98 (1.42-2.57). The Kobe plot (Fig. 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 (59.7%), followed by line (28.3%) and longline (8%). The remaining catches taken with other gears contributed to 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 vessels flagged to I. R. Iran (39.4%) followed by India (19.7%) and Sri Lanka (16.6%). The 24 other fleets catching black marlin contributed to 24% of the total catch in recent years (**Fig. 2**).

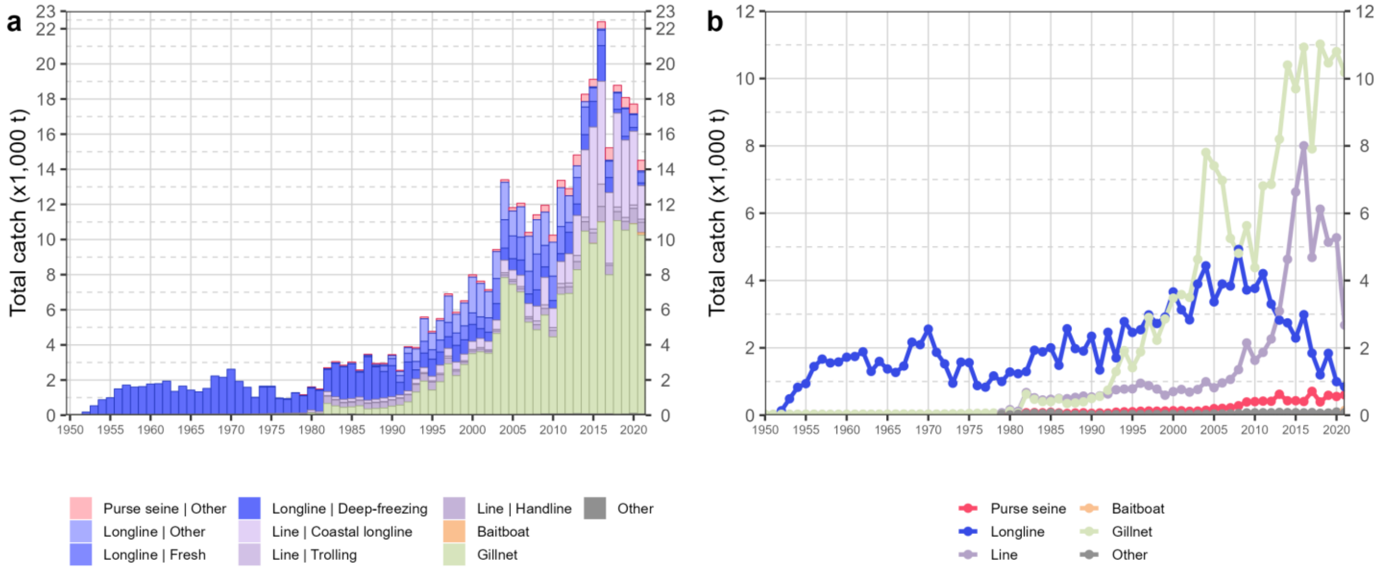


Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for black marlin during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

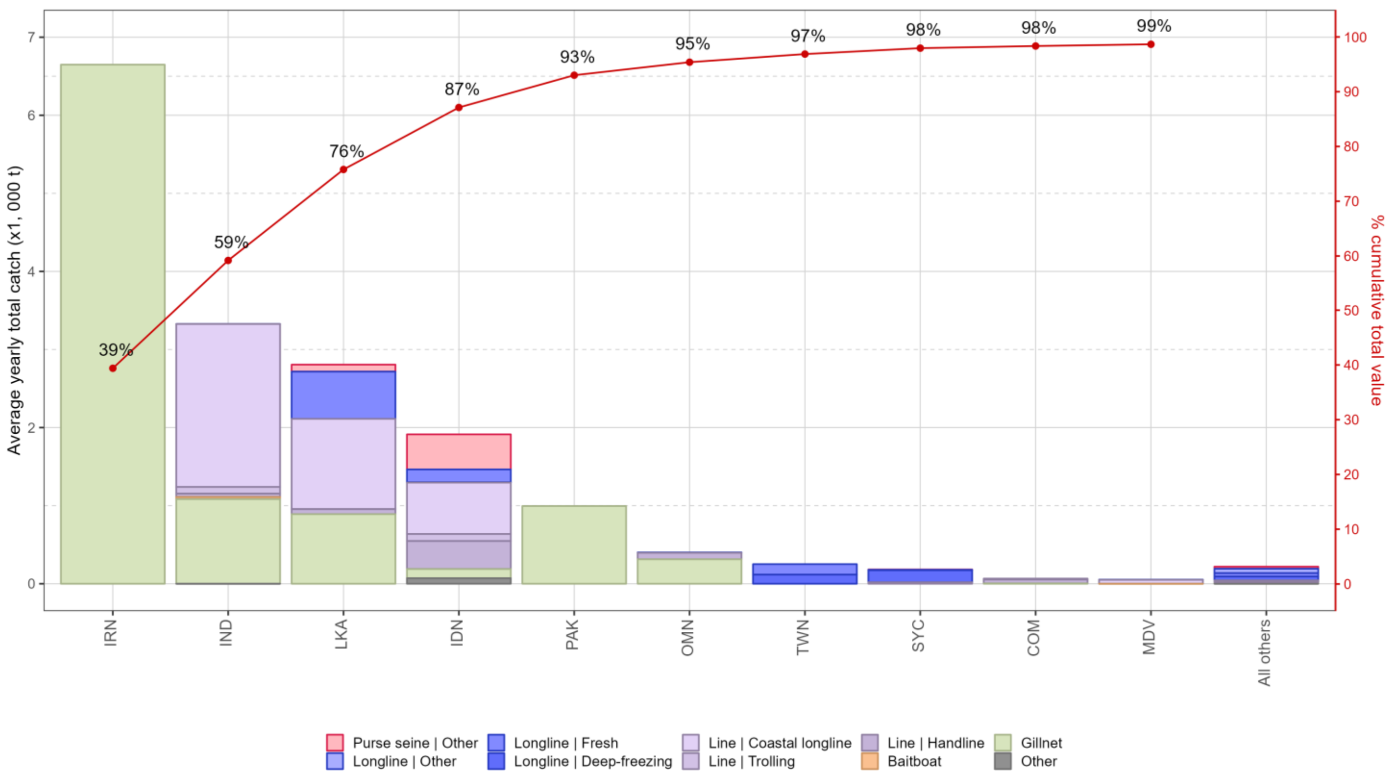


Fig. 2. Mean annual catches (metric tons; t) of black marlin by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

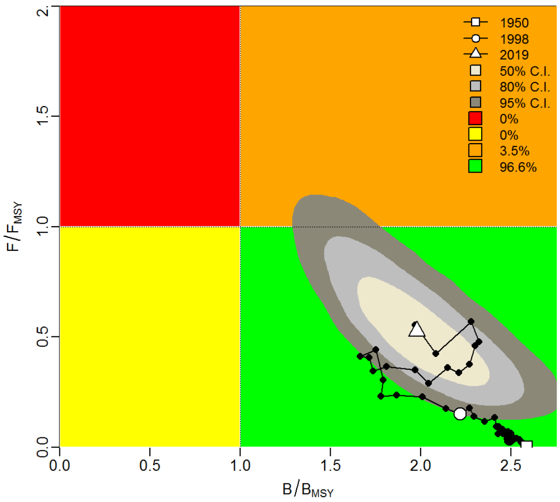


Fig. 2. JABBA Indian Ocean assessment Kobe plots for black marlin (contours are the 50, 80 and 95 percentiles of the 2019 estimate). Black line indicates the trajectory of the point estimates for the total biomass ratio (B/B_{MSY}) and fishing mortality ratio (F/F_{MSY}) for each year 1950–2019.

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

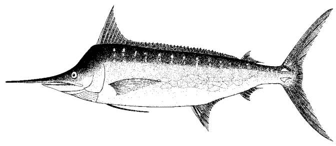


Table 1. Status of blue marlin (*Makaira nigricans*) in the Indian Ocean

Area[1]	Indicators		2022 stock status determination
Indian Ocean	Catch 2021[2] (t)	5,772	**72%***
	Average catch 2017-2021 (t)	7,964	
	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 2020 catch estimated or partially estimated by IOTC Secretariat: 38.6.7%
* Estimated probability that the stock is in the respective quadrant of the Kobe plot (shown below), derived from the confidence intervals associated with the current stock status

Colour Table	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. In 2022 a stock assessment was conducted based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). 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 (53.4%), followed by line (22.9%) and gillnet (20.7%). 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 (29%) followed by Sri Lanka (26.5%) and India (13.6%). The 21 other fleets catching blue marlin contributed to 30.9% of the total catch in recent years (**Fig. 2**).

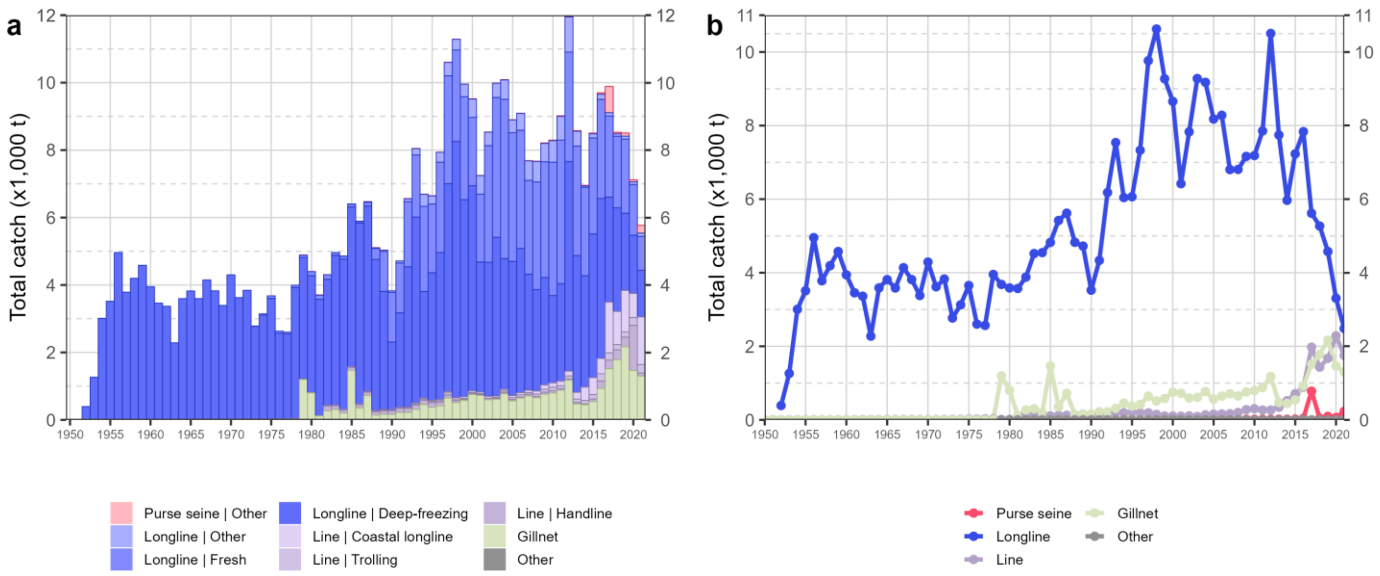


Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for blue marlin during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

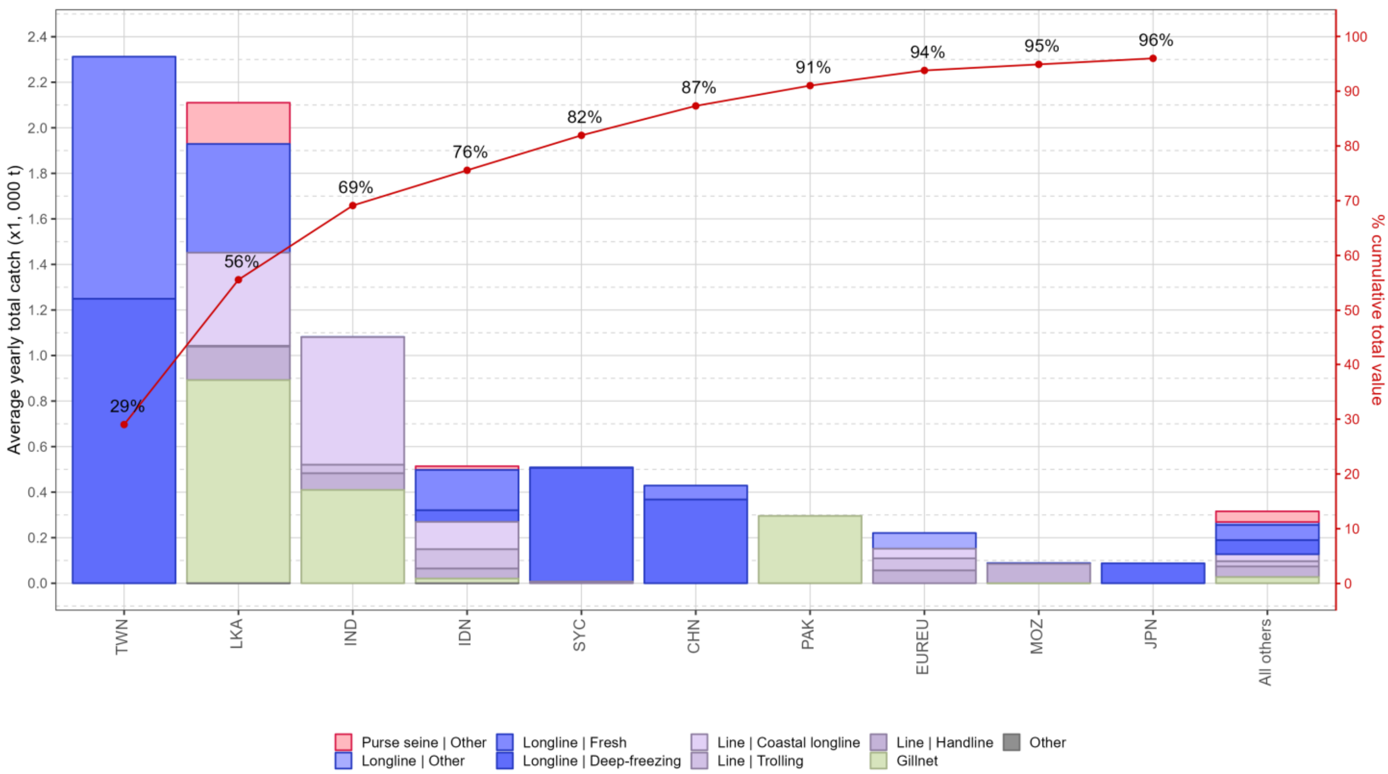


Fig. 2. Mean annual catches (metric tons; t) of blue marlin by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

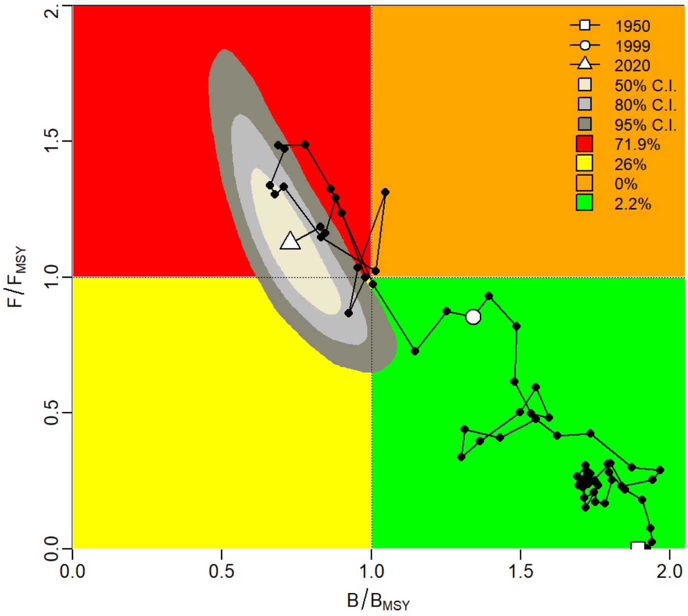


Fig. 2. Kobe stock status plot for the Indian Ocean stock of blue marlin, from the final JABBA base case (the black line traces the trajectory of the stock over time. Contours represent the smoothed probability distribution for 2020 (isopleths are probability relative to the maximum)

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 $F \le F_{MSY}$ and $B \ge B_{MSY}$								
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 IX - [DRAFT] RESOURCE STOCK STATUS SUMMARIES – STRIPED MARLIN

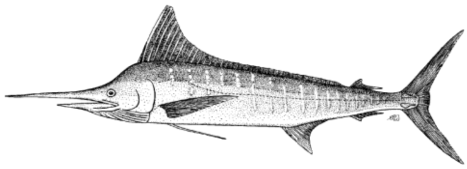


Table 1. Status of striped marlin (*Tetrapturus audax*) in the Indian Ocean

Area[1]	**Indicators**		**2021 stock status determination**
Indian Ocean	Catch 2021[2] (t)	2,696	**100%***
	Average catch 2017-2021 (t)	2,946	
	MSY (1,000 t) (JABBA)	4.60 (4.12 - 5.08)[3]	
	MSY (1,000 t) (SS3)	4.82 (4.48 - 5.16)	
	F_{MSY} (JABBA)	0.26 (0.20–0.33)	
	F_{MSY} (SS3)	0.23 (0.23 - 0.23)	
	$F_{current}/F_{MSY}$ (JABBA)	2.04 (1.35 - 2.93)	
	$F_{current}/F_{MSY}$ (SS3)	3.93 (2.30 - 5.31)	
	$B_{current}/B_{MSY}$ (JABBA)	0.32 (0.22 - 0.51)	
	$SB_{current}/SB_{MSY}$ (SS3)[4]	0.47 (0.35 - 0.63)	
	$B_{current}/B_0$(JABBA)	0.12 (0.10 – 0.19)	
	$SB_{current}/SB_0$ (SS3)	0.06 (0.05 - 0.08)	

[1] Boundaries for the Indian Ocean are defined as IOTC area of competence
[2] Proportion of 2020 catch estimated or partially estimated by IOTC Secretariat: 52%
[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 Table	Stock overfished (B_{year}/B_{MSY}< 1)	Stock not overfished (B_{year}/B_{MSY}≥ 1)
Stock subject to overfishing (F_{year}/F_{MSY}> 1)	**100%**	**0.0%**
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)	**0.0%**	**0.0%**
Not assessed/Uncertain		

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

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. In 2021 a stock assessment was conducted based on two different models: JABBA, a Bayesian state-space production model (age-aggregated); and SS3, an integrated model (age-structured). Both models were generally consistent with regards to stock status and confirmed the results from 2012, 2013, 2015, 2017 and 2018 assessments, indicating that the stock is subject to overfishing ($F>F_{MSY}$) and is overfished, with the biomass being below the level which would produce MSY ($B<B_{MSY}$) for over a decade. On the weight-of-evidence available in 2021, the stock status of striped marlin is determined to be ***overfished*** and ***subject to overfishing*** (**Table 1**; **Fig. 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 4,270 t – 5,180 t. However, the current biomass is well below the B_{MSY} reference point and fishing mortality is in excess of F_{MSY} at recent catch levels.
- **Provisional reference points**: although the Commission adopted reference points for swordfish in Resolution 15/10 *on target and limit reference points and a decision framework*, no such interim reference points have been established for striped marlin.
- **Main fisheries (mean annual catch 2017-2021)**: striped marlin are caught using gillnet (59.5%), followed by longline (27%) and line (11.7%). The remaining catches taken with other gears contributed to 1.7% 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 (30.1%) followed by Pakistan (25.5%) and Indonesia (17.1%). The 22 other fleets catching striped marlin contributed to 27.1% of the total catch in recent years (**Fig. 2**).

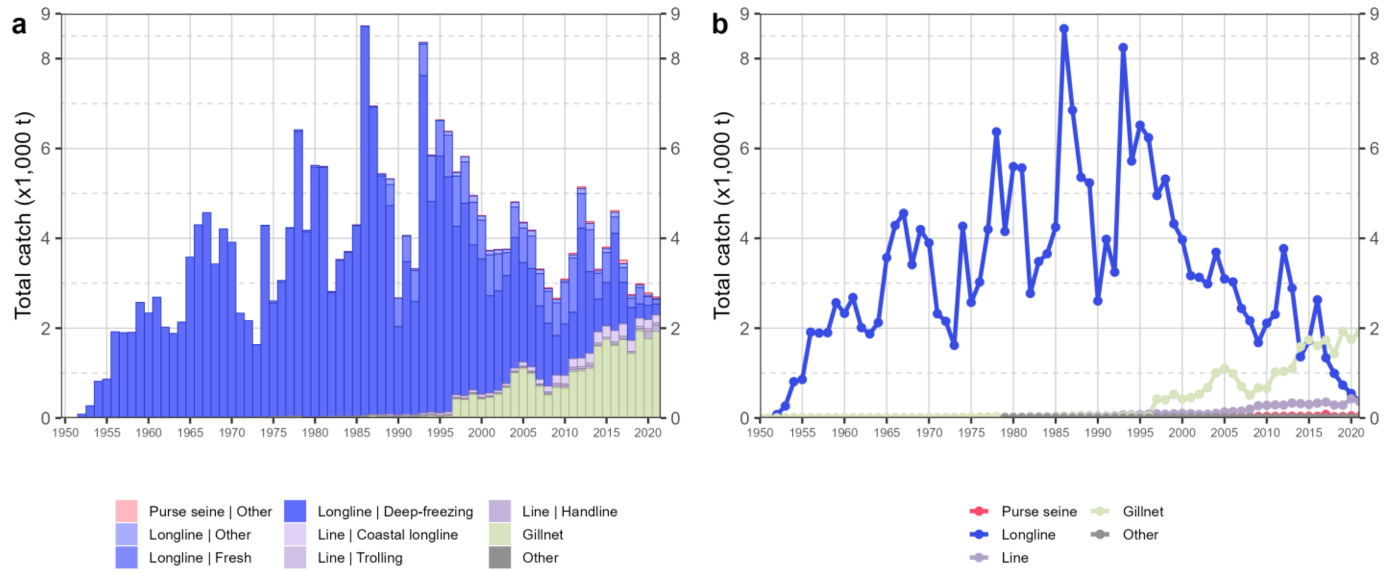


Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for striped marlin during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

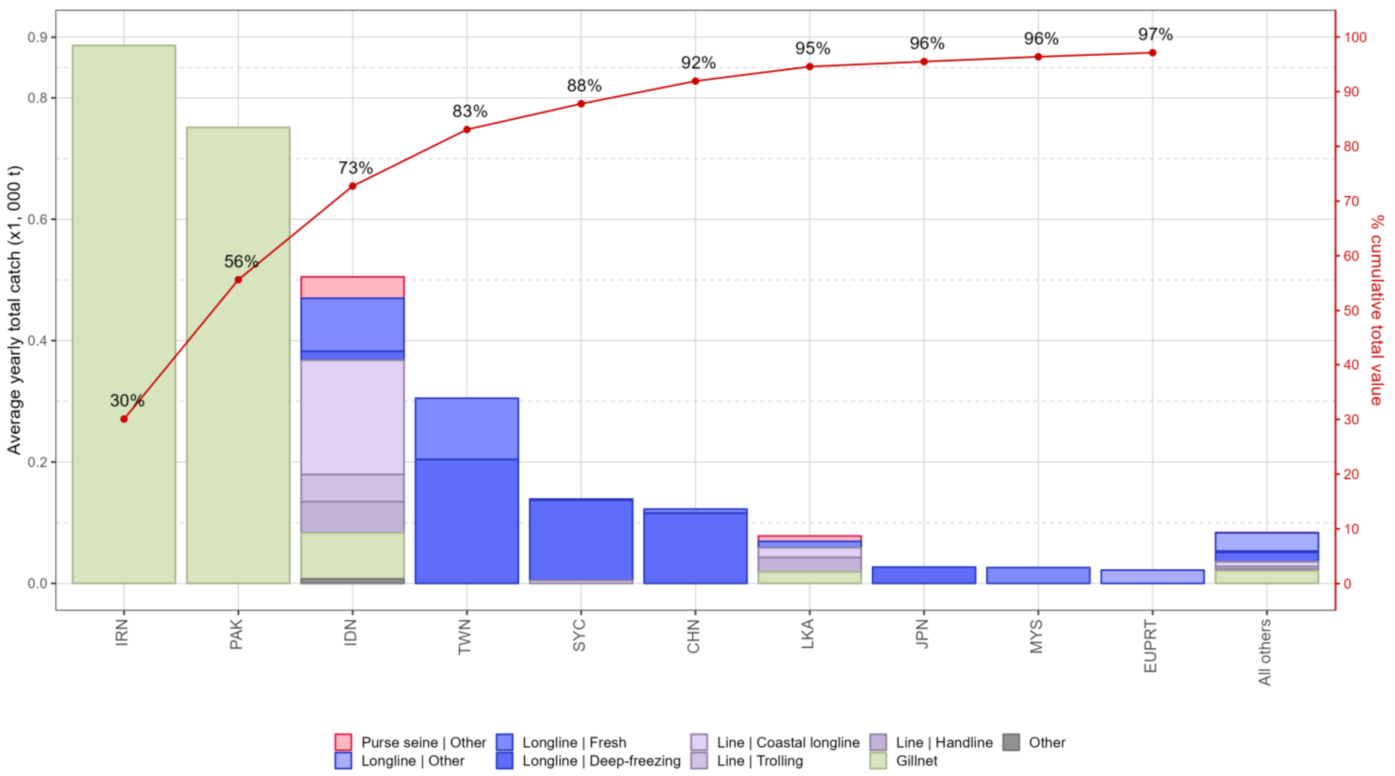
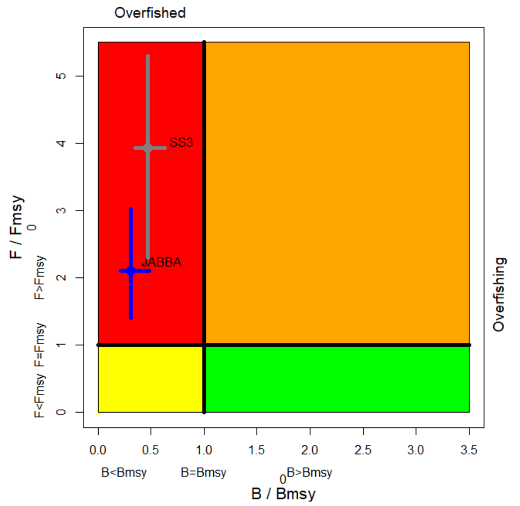


Fig. 2. Mean annual catches (metric tons; t) of striped marlin by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

(a) Stock status (JABBA and SS3 models)



(b) JABBA B/B_{MSY} and F/F_{MSY} trajectories

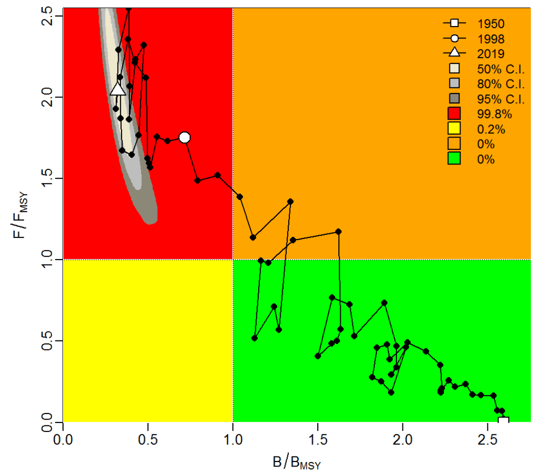


Fig. 3. (a) Striped marlin: Stock status from the Indian Ocean assessment JABBA (Bayesian State Space Surplus Production Model) and SS3 models with the confidence intervals (left); (b) Trajectories (1950-2019) of *B/B_{MSY} and F/F_{MSY}* from the JABBA model. NB: SS3 refers to SB/SB_{MSY} while the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

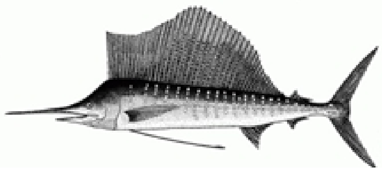


Table 1. Status of Indo-Pacific sailfish (*Istiophorus platypterus*) in the Indian Ocean

Area[1]	Indicators		2022 stock status determination
Indian Ocean	Catch 2021[2] (t)	37,310	**54%**
	Average catch 2017-2021 (t)	32,178	
	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)	

[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: 45.3%

Colour Table	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. In 2022 a new stock assessment was conducted 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*** (**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. 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

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 caught using gillnet (73.1%), followed by line (22.6%) and longline (3.4%). 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 (38.6%) followed by India (23%) and United republic of Tanzania (8.3%). The 31 other fleets catching Indo-Pacific sailfish contributed to 29.8% of the total catch in recent years (**Fig. 2**).

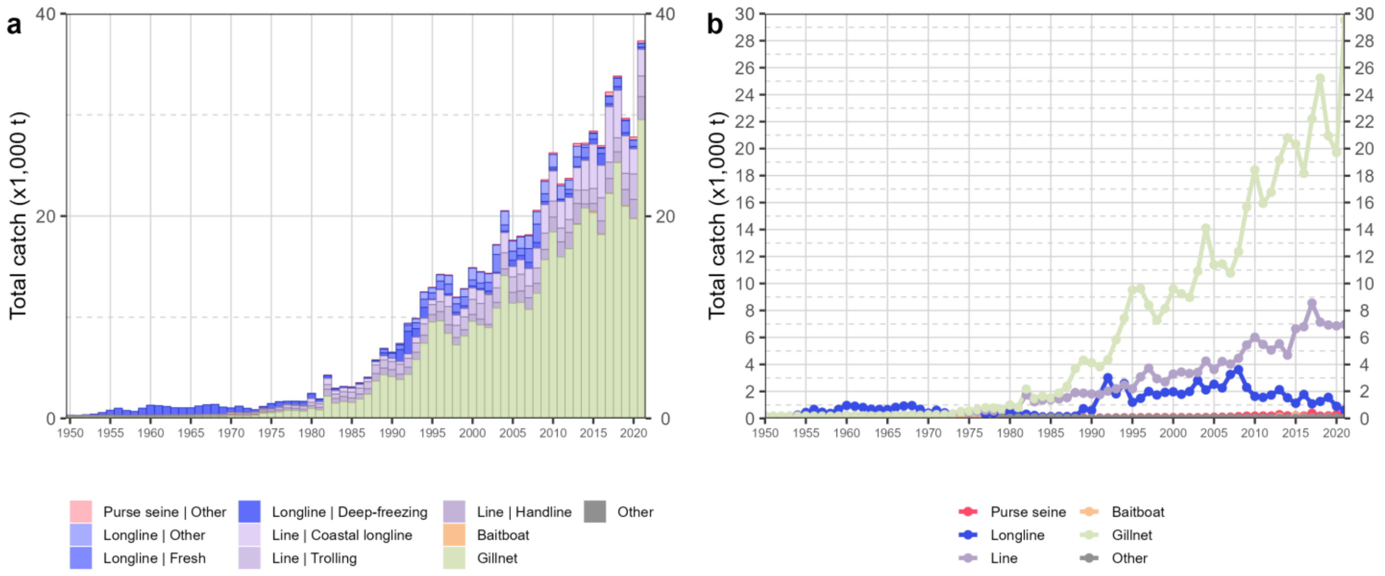


Fig. 1. Annual time series of (a) cumulative nominal catches (metric tons; t) by fishery and (b) individual nominal catches (metric tons; t) by fishery group for Indo-Pacific sailfish during 1950-2021. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

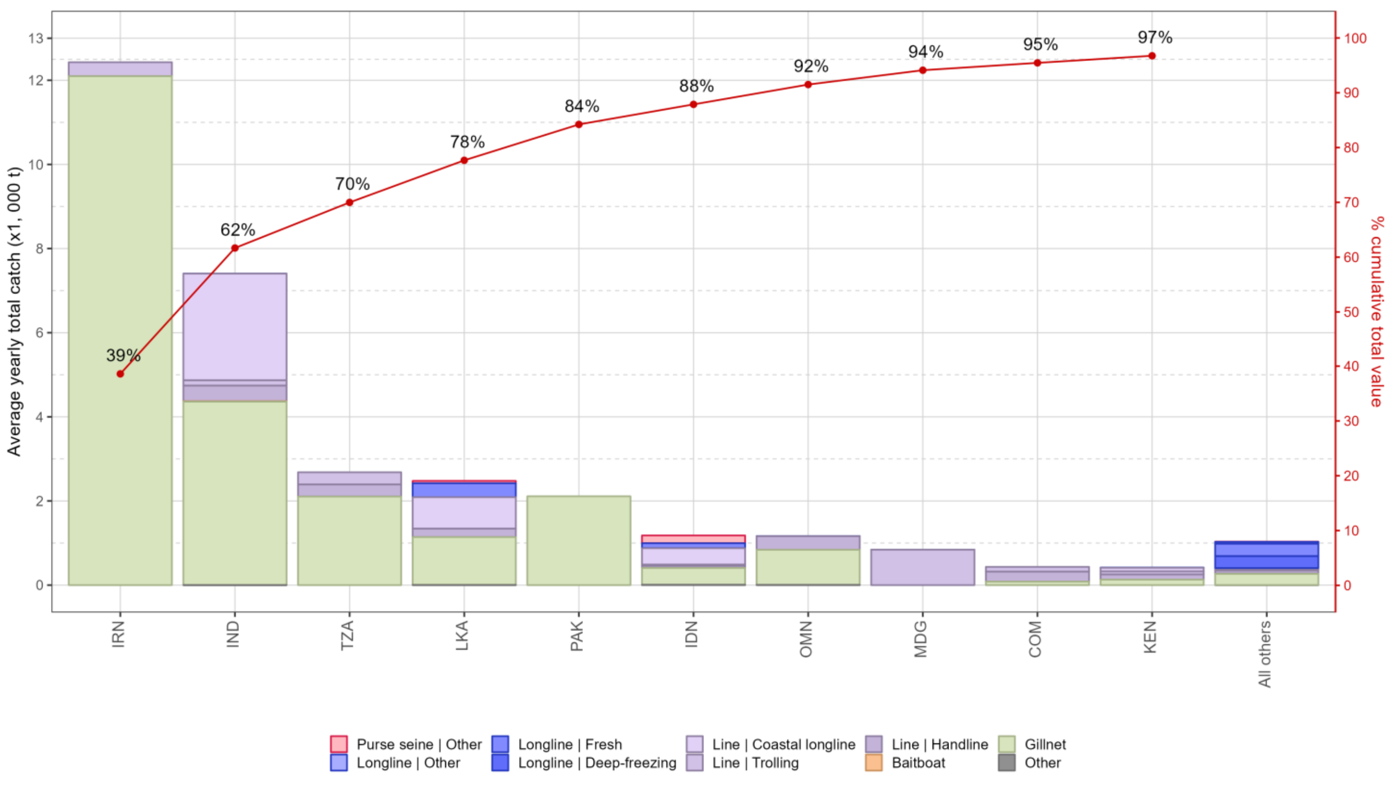


Fig. 2. Mean annual catches (metric tons; t) of Indo-Pacific sailfish by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Longline | Other: swordfish and sharks-targeted longlines; Other: all remaining fishing gears

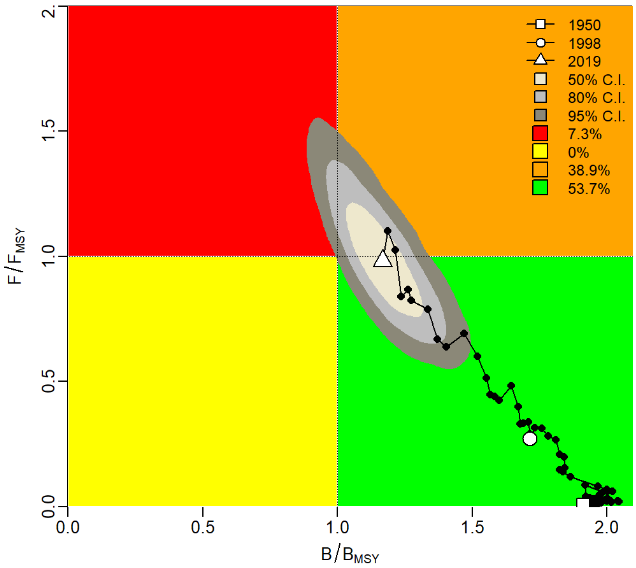


Fig. 3. Indo-Pacific sailfish: Kobe plot showing estimated trajectories (1950-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated 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 XI
WORKING PARTY ON BILLFISH PROGRAM OF WORK (2023–2027)

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				
		2023	**2024**	**2025**	**2026**	**2027**
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.					

3. Stock structure (connectivity and diversity)	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.					
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	**2023**	**2024**	**2025**	**2026**	**2027**
Black marlin		**Full assessment**			**Full assessment**
Blue marlin			**Full assessment**		
Striped marlin		**Full assessment**			**Full assessment**
Swordfish	**Full assessment**		**Indicators****	**Full assessment**	
Indo-Pacific sailfish			**Full assessment***		

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

APPENDIX XII
CONSOLIDATED RECOMMENDATIONS OF THE 20TH SESSION OF THE WORKING PARTY ON BILLFISH

Note: Appendix references refer to the Report of the 20th Session of the Working Party on Billfish (IOTC–2022–WPB20–R)

The following are the complete recommendations from the WPB20 to the Scientific Committee:

Resolution 18/05 Catch Limits

WPB20.01 (para 142): The WPB **NOTED** that reported catches of two species, black marlin and Indo-Pacific sailfish, have exceeded the limits set out in Resolution 18/05 for both 2020 and 2021 and so the WPB **RECOMMENDED** that the SC report this to the Commission as management action is required.

Revision of the WPB Program of work (2023–2027)

WPB20.02 (para 148): The WPB **RECOMMENDED** that the SC consider and endorse the WPB Program of Work (2023–2027), as provided at Appendix XI.

Date and place of the 21st and 22nd Sessions of the Working Party on Billfish

WPB20.03 (para 152): The WPB **RECOMMENDED** the SC consider early September as a preferred time period to hold the WPB21 in 2023. As usual it was also **AGREED** that this meeting should continue to be held back-to-back with the WPEB, with the WPEB taking place after the WPB in 2023.

Review of the draft, and adoption of the Report of the 20th Session of the Working Party on Billfish

WPB20.04 (para 153): The WPB **RECOMMENDED** that the Scientific Committee consider the consolidated set of recommendations arising from WPB20, provided at Appendix XII, as well as the management advice provided in the draft resource stock status summary for each of the five billfish species under the IOTC mandate, and the combined Kobe plot for the five species assigned a stock status in 2022 (Fig. 4):

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

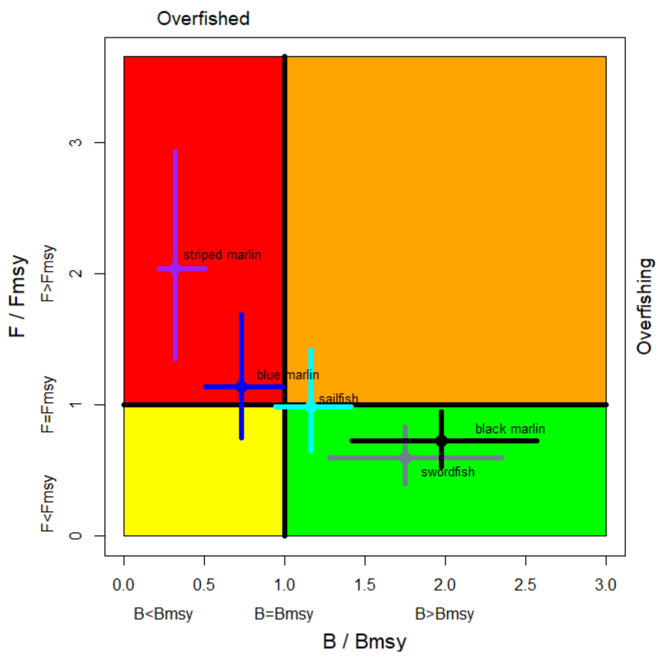


Fig. 4. Combined Kobe plot for swordfish (grey), indo-pacific sailfish (cyan), black marlin (black), blue marlin (blue) and striped marlin (purple) showing the 2018, 2019, 2020, 2021 and 2022 estimates of current stock size (SB or B, species assessment dependent) and current fishing mortality (F) in relation to optimal spawning stock size and optimal fishing mortality. Cross bars illustrate the range of uncertainty from the model runs.