Report of the 20th Session of the IOTC Working Party on Ecosystems and Bycatch – Data Preparatory meeting

Online via Zoom, 22 – 26 April 2024

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ACRONYMS

ABNJ	Areas Beyond National Jurisdiction
ACAP	Agreement on the Conservation of Albatrosses and Petrels
BPUE	Bycatch Per Unit of Effort
BSH	Blue shark
CITES	Convention on International Trade in Endangered Species
CKMR	Close-Kin-Mark-Recapture
CMM	Conservation and Management Measure (of the IOTC; Resolutions and Recommendations)
CMS	Convention on Conservation of Migratory Species of Wild Animals
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.
EEZ	Exclusive Economic Zone
EMS	Electronic Monitoring System
ERA	Ecological Risk Assessment
ETP	Endangered, Threatened and Protected Species
EU	European Union
EU-DCF	European Union Data Collection Framework
F	Fishing mortality; F_{2015} is the fishing mortality estimated in the year 2015
FAD	Fish Aggregation Device
FAO	Food and Agriculture Organization of the United Nations
FOB	Floating Object
F_{MSY}	Fishing mortality at MSY
GAM	Generalised Additive Model
GLM	Generalised liner model
HBF	Hooks between floats
IO	Indian Ocean
IOTC	Indian Ocean Tuna Commission
IOSEA	Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia
IO-ShYP	Indian Ocean Shark multi-Year Plan
IPOA	International Plan of Action
IUU	Illegal, Unreported and Unregulated, fishing
IWC	International Whaling Commission
LL	Longline
LSTLV	Large-scale tuna longline vessel
MoU	Memorandum of Understanding
MPF	Meeting Participation Fund
MSY	Maximum sustainable yield
n.a.	Not applicable
NDF	Non Detriment Finding
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
NPOA	National Plan of Action
PSA	Productivity Susceptibility Analysis
RPOA	Regional Plan of Action
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
SMA	Shortfin mako shark
Taiwan,China	Taiwan, Province of China
UN	United Nations
WPDCS	Working Party on Data Collection and Statistics, of the IOTC
WPEB	Working Party on Ecosystems and Bycatch, of the IOTC
WWF	World Wildlife Fund

KEY DEFINITIONS

Bycatch	All species, other than the 16 species listed in Annex B of the IOTC Agreement, caught or interacted with by fisheries for tuna and tuna-like species in the IOTC area of competence.
Discards	Any species, whether an IOTC species or bycatch species, which is not retained onboard for sale or consumption.
Large-scale driftnets	Gillnets or other nets or a combination of nets that are more than 2.5 kilometres in length whose purpose is to enmesh, entrap, or entangle fish by drifting on the surface of, or in, the water column.

STANDARDISATION OF IOTC WORKING PARTY AND SCIENTIFIC COMMITTEE REPORT TERMINOLOGY

SC16.07 (para. 23) The SC **ADOPTED** the reporting terminology contained in Appendix IV and **RECOMMENDED** that the Commission considers adopting the standardised IOTC Report terminology, to further improve the clarity of information sharing from, and among its subsidiary bodies.

HOW TO INTERPRET TERMINOLOGY CONTAINED IN THIS REPORT

Level 1: From a subsidiary body of the Commission to the next level in the structure of the Commission:

RECOMMENDED, RECOMMENDATION: Any conclusion or request for an action to be undertaken, from a subsidiary body of the Commission (Committee or Working Party), which is to be formally provided to the next level in the structure of the Commission for its consideration/endorsement (e.g. from a Working Party to the Scientific Committee; from a Committee to the Commission). The intention is that the higher body will consider the recommended action for endorsement under its own mandate, if the subsidiary body does not already have the required mandate. Ideally this should be task specific and contain a timeframe for completion.

Level 2: From a subsidiary body of the Commission to a CPC, the IOTC Secretariat, or other body (not the Commission) to carry out a specified task:

REQUESTED: This term should only be used by a subsidiary body of the Commission if it does not wish to have the request formally adopted/endorsed by the next level in the structure of the Commission. For example, if a Committee wishes to seek additional input from a CPC on a particular topic, but does not wish to formalise the request beyond the mandate of the Committee, it may request that a set action be undertaken. Ideally this should be task specific and contain a timeframe for the completion.

Level 3: General terms to be used for consistency:

AGREED: Any point of discussion from a meeting which the IOTC body considers to be an agreed course of action covered by its mandate, which has not already been dealt with under Level 1 or level 2 above; a general point of agreement among delegations/participants of a meeting which does not need to be considered/adopted by the next level in the Commission's structure.

NOTED/NOTING: Any point of discussion from a meeting which the IOTC body considers to be important enough to record in a meeting report for future reference.

Any other term: Any other term may be used in addition to the Level 3 terms to highlight to the reader of and IOTC report, the importance of the relevant paragraph. However, other terms used are considered for explanatory/informational purposes only and shall have no higher rating within the reporting terminology hierarchy than Level 3, described above (e.g. **CONSIDERED**; **URGED**; **ACKNOWLEDGED**).

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Executive summary

The 20th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Ecosystems and Bycatch - WPEB Data Preparatory meeting was held online via Zoom from 22-26 April 2024. A total of 55 participants (100 in 2023, 103 in 2022, 93 in 2021, 108 in 2020, and 41 in 2019) attended the Session. The list of participants is provided in Appendix I. The meeting was opened by the Chairperson, Dr Mariana Tolotti from IRD, France, who welcomed participants and formally opened the meeting.

The following are the complete recommendations from the WPEB20(DP) to the Scientific Committee which are also provided in Appendix V:

Section 3. Longline bycatch mitigation workshop

Section 3.1.1 All taxa

WPEB20(DP).01 (para. 26) The WPEB **RECOMMENDED** that the SC request that CPCs carry out training with fishers to ensure that they are aware of the best practices for handling and release of sharks including the minimisation of trailing gears. The WPEB **REQUESTED** that CPCs provide information on how they are monitoring the implementation of these best practices in the form of training materials, number of training/handling workshops etc.

Section 3.2 Leader type/shark lines

WPEB20(DP).02 (para. 46) The WPEB **RECOMMENDED** that the collection of information on leader material type should be made mandatory under the Regional Observer Scheme Minimum Data Requirements and reported to the Secretariat. The WPEB also **RECOMMENDED** that these data collected under the ROS are strictly used for scientific purposes in research.

WPEB20(DP).03 (para. 47) The WPEB **RECOMMENDED** that mitigation surveys should be developed by CPCs in the IOTC areas and with different gear types and configurations to assess mitigation measures such as the type of leaders and other factors to be tested and implemented. The WPEB **NOTED** that the increase of bite offs by the prohibition of wire leaders could lead to the decrease in the basic information necessary for stock assessment or monitoring abundance of shark species. **ACKNOWLEDGING** the importance of these data, the WPEB **SUGGESTED** that bite offs are recorded by observers to further inform bycatch estimates.

Section 3.3 Hook type

WPEB20(DP).04 (para. 57) The WPEB **NOTED** that some studies using large circle hook have reduced injury to sharks by increasing rates of mouth hooking. The WPEB further **NOTED** that decreasing injury rates associated with large circle hooks results in a reduction in at-vessel mortality for some species. Circle hooks use also reduces observed retention of some vulnerable taxa, such as sea turtles and marlins. The WPEB also **NOTED** that some experimental sea-trials from other Oceans have reported increases in observed retention of some shark species when using large circle hooks, especially blue shark and crocodile shark, and that the results from a global meta-analysis and multiple experimental sea-trials have found that the use of large circle hooks reduces retention of target species like swordfish. The WPEB further **NOTED** that there are still many information gaps regarding their effectiveness for sharks, and the number of case studies on deep-setting operations and effect of hook size is still too few and there is also concern that circle hooks may increase shark catches, the WPEB **RECOMMENDED** continued accumulation of information on circle hook effectiveness including in deep-setting operations.

Section 3.5 Workshop summary

WPEB20(DP).05 (para. 74) The WPEB **NOTED** on the basis of its review of global research that a prohibition on the use of wire leaders and shark lines by longline and other fisheries operating in the IOTC would likely result in a reduction in both the observed catch and the fishing mortality of shark species. The WPEB **NOTED** supporting evidence from a range of research studies as seen in Table 2 (in

Appendix VI). The WPEB **NOTED** that these results are likely to be similar in the Indian Ocean. Based on these studies and on the basis of taking the precautionary approach, and consistent with existing SC advice on the need to reduce fishing mortality for shortfin mako, oceanic whitetip and silky shark, the WPEB **RECOMMENDED** that additional mitigation measures such as, but not limited to, the non-use of wire leaders and shark lines should be implemented. The WPEB **AGREED** to further discuss this issue at the WPEB Assessment meeting in September.

Section 8. Review of the draft, and adoption of the Report of the 20th Session of the WPEB (Data Preparatory)

WPEB20(DP).06 (para. 133) The WPEB **RECOMMENDED** that the WPEB20(AS) consider the consolidated set of recommendations arising from WPEB20(DP), provided at Appendix V.

A summary of the stock status for some of the most commonly caught shark species caught in association with IOTC fisheries for tuna and tuna-like species is provided in Table 1.

Table 1. Status summary for key shark species caught in association with IOTC fisheries for tuna and tuna-like species.

Stock	Indicators		2018	2019	2020	2021	2022	2023	Advice to the Commission
Sharks: Although sharks are not part of the 16 species directly under the IOTC mandate, sharks are frequently caught in association with fisheries targeting IOTC species. Some fleets are known to actively target both sharks and IOTC species simultaneously. As such, IOTC Contracting Parties and Cooperating Non-Contracting Parties are required to report information at the same level of detail as for the 16 IOTC species. The following are the main species caught in IOTC fisheries, although the list is not exhaustive									
Blue shark *Prionace glauca*	Reported catch 2022: Estimated catch 2019: Not elsewhere included (nei) sharks 2022: Average reported catch 2018–22: Average estimated catch 2015–19: Ave. (nei) sharks[2] 2018–22:	24,424t 43,240 t 32,558 t 25,275 t 48,781 t 31,303 t	**72.6%**	**72.6%**	**72.6%**	**99.9%**	**99.9%**	**99.9%**	Target and limit reference points have not yet been specified for pelagic sharks in the Indian Ocean. Even though the blue shark in 2021 was assessed to be not overfished nor subject to overfishing, current catches are likely to result in decreasing biomass and making the stock become overfished and subject to overfishing in the near future. If the catches are increased by over 20%, the probability of maintaining spawning biomass above MSY reference levels ($SB>SB_{MSY}$) over the next 10 years will be decreased. While mechanisms exist for encouraging CPCs to comply with their recording and reporting requirements (Resolution 16/06), these need to be further implemented by the Commission, so as to better inform scientific advice in the future. Click below for a full stock status summary: ● Blue sharks – Appendix VII
	MSY (1,000 t) (80% CI): F_{MSY} (80% CI): SSB_{MSY} (1,000 t) (80% CI): F_{2015}/F_{MSY} (80% CI): SSB_{2019}/SSB_{MSY} (80% CI): SSB_{2019}/SSB_0 (80% CI):	36.0 (33.5 - 38.6) 0.31 (0.306- 0.31) 42.0 (38.9 - 45.1) 0.64 (0.53 - 0.75) 1.39 (1.27 - 1.49) 0.46 (0.42 - 0.49)							
Oceanic whitetip shark *Carcharhinus longimanus*	Reported catch 2022: Not elsewhere included (nei) sharks 2022: Average reported catch 2018–2022: Not elsewhere included (nei) sharks 2018-2022:	41 t 32,558 t 35 t 31,303 t							
Scalloped hammerhead shark	Reported catch 2022: Not elsewhere included (nei) sharks 2022: Average reported catch 2018–2022: Not elsewhere included (nei) sharks 2018-2022:	607 t 33,949 t 198 t 33,612 t							

Sphyrna lewini								There is a paucity of information available for these species and this situation is not expected to improve in the short to medium term. There is no quantitative stock assessment and limited basic fishery indicators currently available. Therefore, the stock status is highly uncertain. The available evidence indicates considerable risk to the stock status at current effort levels. The primary source of data that drive the assessment (total catches) is highly uncertain and should be investigated further as a priority. Click below for a full stock status summary: • Oceanic whitetip sharks – Appendix VIII • Scalloped hammerhead sharks – Appendix IX • Shortfin mako sharks – Appendix X • Silky sharks – Appendix XI • Bigeye thresher sharks – Appendix XII • Pelagic thresher sharks – Appendix XIII
Shortfin mako *Isurus oxyrinchus*	Reported catch 2022 (t) 666 t Catches reported to MAK in 2022 (t) 1,947 t Average catches reported to MAK 2018-2022 (t) 2,057 t Catches in 2022 (MAK, SMA, LMA) (t) 2,627 t Average catches 2018-2022 (MAK, SMA, LMA) (t) 3,081 t Not elsewhere included (nei) sharks2 2022 (t) 34,248 t Average reported catch 2018-22 (t) 1,013 t Av. Not elsewhere included (nei) sharks2 2018-22 (t) 33,072 t							
Silky shark *Carcharhinus falciformis*	Reported catch 2022: 1,426 t Not elsewhere included (nei) sharks 2022: 32,558 t Average reported catch 2018–2022: 1,755 t Not elsewhere included (nei) sharks 2018-2022: 31,303 t							
Bigeye thresher shark *Alopias superciliosus*	Reported catch 2022: <1 t Not elsewhere included (nei) sharks 2022: 37,497 t Thresher sharks nei 2022: 5,209 t Average reported catch 2018–2022: <1 t Not elsewhere included (nei) sharks 2018-2022: 35,865 t Av. Thresher sharks nei 2018-2022: 4,859 t							
Pelagic thresher shark *Alopias pelagicus*	Reported catch 2022: 156 t Not elsewhere included (nei) sharks 2022: 37,497 t Thresher sharks nei 2022: 5,209 t Average reported catch 2018–2022: 217 t Not elsewhere included (nei) sharks 2018-2022: 35,865 t Av. Thresher sharks nei 2018-2022: 4,859 t							

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

1 Opening of the meeting

1. The 20th Session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Ecosystems and Bycatch - WPEB Data Preparatory meeting was held online via Zoom from 22-26 April 2024. A total of 55 participants (100 in 2023, 103 in 2022, 93 in 2021, 108 in 2020, and 41 in 2019) attended the Session. The list of participants is provided in Appendix I. The meeting was opened by the Chairperson, Dr Mariana Tolotti from IRD, France, who welcomed participants and formally opened the meeting.

2 Adoption of the Agenda and arrangements for the Session

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

3 Longline bycatch mitigation measures workshop

3.1 All/several measures combined

3.1.1 All taxa

3. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-04, A review of reported effects of pelagic longline fishing gear configurations on target, bycatch and vulnerable species, including the following abstract provided by the authors:

   "A meta-analysis of 40 publications totalling 59 experiments was undertaken to review and assess the effects of changing the hook (circle vs. J-hooks or tuna hooks), bait (fish vs. squid) and leader (wire vs. nylon) type on retention and at-haulback mortality rates of teleosts (tunas and billfishes), elasmobranchs and sea turtles caught on shallow-set and deep-set pelagic longline fisheries. Circle hooks are a promising approach to mitigate the impact of pelagic longline fisheries on sea turtles, as they reduced sea turtle retention rates. The adoption of circle hooks would, however, also lead to a decrease in swordfish retention, the main target species of shallow-set pelagic longlines. Using fish as bait resulted in lower retention rates of sea turtles, highlighting that option as an additional measure to further mitigate sea turtle bycatch. The bait type had non-significant effects on sharks, except for blue shark and shortfin mako, for which at-haulback mortality rates were significantly higher with fish bait. The use of nylon leaders instead of wire leaders could serve as a conservation measure for sharks, as they reduced the retention of blue shark without adversely impacting the catches of swordfish. The results on the effect of the leader material types should, however, be interpreted with caution owing to the limited information available reporting on leader material effects. When considering future research directions, priority should be given to experimental field work on the effects of leader material and on deep-set longlines. Evaluating the post-release survival of species should also be a priority."

4. The WPEB **NOTED** that the results of the meta-analysis indicated that circle hooks resulted in lower sea turtle interactions (especially when fish bait used) and lower at-haulback mortality including for blue shark, shortfin mako and scalloped hammerhead but also result in reduced retention of swordfish, a target species, on shallow longline sets, reducing catch value. The WPEB further **NOTED** that the study found reduced retention of blue shark on monofilament leaders, but the information included to assess other shark species was limited. The study had relatively high numbers of hook type trials to draw upon but very few trials for leader type. Most trials were for shallow set longline fisheries, few were for deep-set longline fisheries.

5. **NOTING** that the analysis showed less retention of hard-shelled sea turtle species (i.e., all sea turtle species encountered in IOTC fisheries with the exception of leatherback turtles) when using fish bait vs squid bait, the WPEB **NOTED** that there was not a significant difference between the two bait types for leatherback turtles and **NOTED** that these differences may relate to differences in feeding ecology between the two groups of species.

6. The WPEB **NOTED** that thresher sharks tend to get tail hooked which might explain the higher at-haulback mortality for those species.

7. The WPEB **NOTED** that the analysis did not attempt to look at the interaction effects between the hook type and the bait type as the study would require significantly more data to look at interaction effects, something that would benefit from more investigation in the future.

8. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-05, A cross-taxa assessment of pelagic longline bycatch mitigation measures: conflicts and mutual benefits to elasmobranchs, including the following abstract provided by the authors:

   "Elasmobranch mortality in pelagic longline fisheries poses a risk to some populations, alters the distribution of abundance between sympatric competitors, changing ecosystem structure, processes and stability. Individual and synergistic effects on elasmobranch catch and survival from pelagic longline gear factors, including methods prescribed to mitigate bycatch of other vulnerable taxa, were determined. Overall relative risk of higher circle vs. J-shaped hook shark catch rates conditioned on potentially informative moderators, from 30 studies, was estimated using an inverse-precision weighted mixed-effects meta-regression modelling approach. Sharks had a 1.20 times (95% CI: 1.03–1.39) significantly higher pooled relative risk of capture on circle hooks, with two significant moderators. The pooled relative risk estimate of ray circle hook catch from 15 studies was not significant (RR = 1.22, 95% CI: 0.89– 1.66) with no significant moderators. From a literature review, wire leaders had higher shark catch and haulback mortality than monofilament. Interacting effects of hook, bait and leader affect shark catch rates: hook shape and width and bait type determine hooking position and ability to sever monofilament leaders. Circle hooks increased elasmobranch catch, but reduced haulback mortality and deep hooking relative to J-shaped hooks of the same or narrower width. Using fish vs. squid for bait increased shark catch and deep hooking. Pelagic stingray (Pteroplatytrygon violacea) catch and mortality were lower on wider hooks. Using circle instead of J-shaped hooks and fish instead of squid for bait, while benefitting sea turtles, odontocetes and possibly seabirds, exacerbates elasmobranch catch and injury, therefore warranting fishery-specific assessments to determine relative risks."

9. The WPEB **NOTED** that the paper demonstrated how there can be conflicts and trade-offs between different mitigation approaches which would impact management effectiveness that depend on whether the fishery is deep or shallow or fishing night or day. A measure that can reduce risks in one species group can increase risk in another. The WPEB **NOTED** that cross-taxa considerations of mitigation effects are therefore critical when designing mitigation-based management responses to ensure unintended consequences to not occur.

10. The WPEB **NOTED** recent work done by the authors looking at the differences in shark catch rates in relation to the distance between the weight and the hook and further **NOTED** that these differences may be a result of different movement patterns of the various configurations.

11. The WPEB **NOTED** that while meta-analyses can be conducted on summary data from studies, it is far more effective to get the original research trial data from each study. The WPEB **NOTED** that management measures should not be based off single research trial results but should draw from

multiple studies to draw inferences relating to effects of different mitigation measures being considered. Meta-analyses aim to generalise from individual studies that are each context specific.

12. The WPEB **NOTED** that the most effective mitigation is avoidance in the first instance but where avoidance is not possible, reducing capture mortality is the next best option followed by reducing post release mortality. The WPEB **NOTED** that for species or taxa such as marine turtles where at-vessel mortality is very low, focus should be on improving survivorship post release while for species or taxa where at-vessel mortality is very high, the focus should be on minimising interactions between the species and the fishery.

13. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-07, titled What's the catch? Examining optimal longline fishing gear configurations to minimise negative impacts on non-target species, including the following abstract provided by the authors:

    "Changes to fishing gear configurations have great potential to decrease fishing interactions, minimize injury and reduce mortality for non-target species in commercial fisheries. In this two-part study, we investigate potential options to optimize fishing gear configurations for United States Pacific pelagic longline vessels to maintain target catch rates whilst reducing bycatch mortality, injury, and harm. In part one, a paired-gear trial was conducted on a deep-set tuna longline vessel to compare catch rates and catch condition of target and non-target species between wire and monofilament leader materials. Temperature-depth recorders were also deployed on hooks to determine sinking rates and fishing depth between the two leader materials. In part two, hooks of different configurations (size, diameter, shape, metal type, and leader material) were soaked in a seawater flume for 360 days to obtain quantitative estimates of breaking strength, as well as the time taken for gear to break apart. We found that switching from wire to monofilament leaders reduced the catch rate of sharks by approximately 41 %, whilst maintaining catch rates of target species (Bigeye tuna, Thunnus obesus). However, trailing gear composed of monofilament did not break apart even after 360 days. In contrast, branchlines with wire leaders began to break at the crimps after approximately 60 days. Additionally, the breaking strength of soaked fishing hooks was greater for larger, forged hooks composed of stainless steel typically used in United States Pacific longline fisheries. These results have direct implications for fisheries management and the operational effectiveness of bycatch mitigation strategies for longline fisheries worldwide."

14. The WPEB **NOTED** the 41% reduction in shark bycatch that was found during the study as a result of switching from wire to monofilament leaders and further **NOTED** that catch rates of the target species had also been maintained.

15. The WPEB **NOTED** that sharks which are unable to bite through the line, and which are not released by cutting the line close to the hook, may be burdened with increased trailing gear as a result of implementing this switch, and this is a potential trade-off as the monofilament has been found to not break apart in under 360 days.

16. **NOTING** that some bony fish can bite off at the line, the WPEB **NOTED** that this study assumed that 100% of the bite offs were made by sharks. The WPEB **NOTED** that it is probably not correct to assume 100% of bite-offs are sharks, and discussed whether a comparison of other species catch rates at vessel between wire and monofilament leaders might help to determine what proportion of bite offs might be sharks, although that too would require a number of assumptions.

17. The WPEB **NOTED** the authors suggestion that observers should be recording bite-offs so as to generate more accurate statistics relating to shark catch rates for the development of abundance indices, but also **NOTED** that such data would need to be used carefully as it may cause a discontinuity in the CPUE timeseries that could bias abundance trends upwards (due to bite offs not previously being recorded then suddenly being recorded). The WPEB **NOTED** that the species of

shark causing bite offs would be unknown, however. Regardless of the impact on the time series, the WPEB **NOTED** that it would still be useful to start recording this information now to improve future time series.

18. The WPEB **NOTED** that the study found similar sinking rates between the wire and monofilament leaders which was unexpected but further **NOTED** that this could be due to the sizes of weights used.
19. The WPEB **NOTED** that this particular study was conducted in the central Pacific Ocean region over a limited time period in four back-to-back trips.
20. The WPEB **NOTED** that while the study was conducted in a localised region, its results would be relevant to fisheries operating in a similar manner (target species, gear etc) in the Indian Ocean as they still use either wire or monofilament. However, detailed specifics in the results could differ between oceans due to factors such as differing longline configurations, fishing depths and spatial differences which could impact catch composition. The WPEB further **NOTED** that it would require very different behavioural responses to hooking to expect that a given species biting free in the Pacific would not also be able to bite free on monofilament leader material in the Indian Ocean.
21. The WPEB **NOTED** that the effect of the size of sharks on catch rates was not considered in this study.
22. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-08 on Technical mitigation techniques to reduce bycatch of sharks: there is no silver bullet, including the following abstract provided by the authors:

    "The synthesis of evidence above demonstrates that there is no single technique that can be applied to all species, fishing gears and regions, with the exception of improving handling practices. Responses to gear modifications vary between regions, depending on local environmental conditions, species composition and other confounding factors, so that techniques that are effective in one area cannot be assumed to work in another. To effectively mitigate bycatch of sharks, most fisheries will require a combination of techniques to be employed but may result in unintended impacts on other species. This will require that each fishery with unintended catches of sharks to assess what species they are catching, what they should not be catching, which of these are most at risk, and what the life history, behavioural and feeding characteristics they have that could be exploited to minimize their catch. There is also a need to address interactive factors of biological, environmental, and technical issues to find a solution for these particular circumstances Trials of techniques should be undertaken in relevant areas to ensure efficacy prior to mandating a particular approach to reducing bycatch...." [see paper for full conclusions]

23. The WPEB **NOTED** that the review grouped mitigation approaches into three types, those that prevent capture, those that enable escape and those that decrease at-vessel mortality and increase post release survival. The authors concluded that the most effective measures for WPEB species of interest in longlines were the use of monofilament leaders, circle hooks, reduced soak time, release before haulback, and good handling techniques.
24. The WPEB **NOTED** that larger species and those with retention bans in place are rarely brought onboard so it is necessary to ensure that best practice release techniques, including cutting the line as close to the hook as possible, are implemented.
25. With respect to best handling approaches, the WPEB **NOTED** that providing books and guidelines to fishers is good, but it is critical that countries then enforce the implementation of those guidelines in their fisheries. The WPEB also **NOTED** that in considering whether to implement mitigation measures it is important to take account of information on population status and consequences of mitigation where that information is available, to inform policy decisions.

26. Therefore, the WPEB **RECOMMENDED** that the SC request that CPCs carry out training with fishers to ensure that they are aware of the best practices for handling and release of sharks including the minimisation of trailing gears. The WPEB **REQUESTED** that CPCs provide information on how they are monitoring the implementation of these best practices in the form of training materials, number of training/handling workshops etc.

27. The WPEB **NOTED** discussions that for one longline fishery targeting blue shark in the Indian Ocean, the use of electrical repellents, which may be effective for blue shark, would not be appropriate for use as mitigation for that species due to it being a target species and in a healthy population state. The authors also noted the expense of deploying such measures.

28. The WPEB **NOTED** that it is important to look at the population consequences of the effects of mitigation measures and there is a need to look at the exposure to risk for various events.

3.1.2 Sharks

29. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-09 on Statistical and Monte Carlo Analysis of the Hawaii Deep-Set Longline Fishery with Emphasis on Take and Mortality of Oceanic Whitetip Shark, including the following abstract provided by the authors:

   "The study developed a process model from pelagic observer data to describe the take and mortality of oceanic whitetip shark (OCS) in the Hawaii deep-set longline fishery. The process model considered the: 1) probability of interaction (Catch model #1); 2) probability of branchline bite-off (Catch model #2); 3) probability of mortality at retrieval (Fate model #1); 4) probability of mortality due to handling between retrieval and release (Fate model #2); and 5) probability of post-release mortality and mortality of bite- off (Fate model #3). Three scenarios were considered for the OCS process models: 1) the current fishery use of using wire leaders and leaving ~10 m of trailing gear on a released shark (Scenario 1-Status quo); 2) intended use of monofilament, removing all trailing gear (0 m) on a released shark (Scenario 2- Monofilament leaders); and 3) intended use of monofilament, removing all trailing gear (0 m) on a released shark and gear modification by eliminating three hooks adjacent to longline floats (Scenario 3- Monofilament leaders and gear modification). Monte Carlo simulations were conducted for each of the three scenarios. The annual anticipated take level (ATL) for OCS has a mean of 1,708. Mortality at longline retrieval averaged 19.2% (95% CI, 13.1%–27.3%). There was a positive benefit of a reduced catchability for OCS estimated from the voluntary transition from branchlines that have 1 m of wire leader at the terminal end to branchlines being entirely composed of monofilament. Median estimates of annual OCS catch were 1,708 for the status quo, 1,153 for monofilament leaders, and 678 with monofilament leaders and no shallow hooks deployed. Median estimates of annual mortality were 362 for the status quo, 255 with monofilament leaders, and 150 with monofilament leaders and no shallow hooks deployed. The transition from wire to monofilament leaders was estimated to have a 32% and 30% reduction in catch and mortality, respectively. The lowest OCS catch and mortality occurred with monofilament leaders and no shallow hooks deployed; however, a large revenue decrease occurs when no shallow hooks are used due to reduced catch of target and incidental species."

30. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-10 on a Review of potential mitigation measures to reduce fishing-related mortality on silky and oceanic whitetip sharks, including the following abstract provided by the authors:

   "The paper develops and applies a model for how silky (Carcharhinus falciformis) and oceanic whitetip (C. longimanus) shark might interact with longline gear in the Western and Central Pacific Ocean (WCPO) and potential reductions in mortality with two different management measures: 1) the removal of shark lines and 2) the transition from branchlines with wire leaders to monofilament

leaders. Using Regional Observer Program (ROP) data, the study compared absolute values of total catch and total mortality across scenarios and the relative change in fishing-related mortality from the status-quo option given a conversion from wire to monofilament leaders, no shark lines used, and both a conversion to monofilament leaders and no shark lines. The analysis also explores reduction rates of both shark species under a variety of management scenarios, including banning both shark lines and wire leaders. The study provides an update to Harley et al. (2015) by using recently available observer information (2010–2018) on longline."

31. The above papers were discussed together.

32. **ACKNOWLEDGING** that data collection of leader type (mono vs stainless steel) is not mandatory in the ROS but it is mandatory in WCPFC and that this information used in the analysis includes data from the Japanese observer program and also possibly by other CPCs (e.g. EU,France), the WPEB **ENCOURAGED** CPCs to provide such data and **SUGGESTED** that a collaborative analysis is conducted to evaluate the effect of leader type on catch rates of sharks in the IOTC area. The WPEB **NOTED** that Japan will provide such data as a summary report for the next WPEB.

33. The WPEB **NOTED** the differences between the Pacific and Indian Oceans in terms of target species and available data (fewer data are available in the Indian Ocean) to select the species that should be prioritised for this analysis. As a result, the WPEB **SUGGESTED** adopting a step-by-step approach in the Indian Ocean by first collecting data on the use of the different leader types by fleets, then identifying the target shark species of concern and comparing the distribution of the species and the area where wire leaders are used. The WPEB **ENCOURAGED** CPCs to provide this summary by September.

34. The WPEB **NOTED** that it would be interesting to consider the overlap of the species distribution with the use of different gear configurations during these analyses to assess how effective the introduction of a mitigation measure might be.

35. The WPEB **NOTED** that the Monte-Carlo simulation applied in this study involves resampling (~10,000) catchability estimates from the GLM modelling in order to calculate the distribution of the reduction of catches for sharks species. This can better account for the uncertainty in the effects of the mitigation on the reduction of fishing mortality of shark species.

36. The WPEB **NOTED** that differences in tooth morphology of shortfin mako, oceanic whitetip and blue shark may affect the ability of each of these species to bite-off a monofilament leader. The WPEB further **NOTED** that priority species such as blue and silky shark have less active hunting behaviours than shortfin mako and so a sensitivity analysis was suggested, using information from other carcharhinid species such as blue shark for this process.

37. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-16 on a Review of research on future projections and potential mitigation measures to reduce fishing related mortality on oceanic whitetip sharks, including the following abstract provided by the authors:

    "Pelagic sharks, including oceanic whitetips and silky sharks, face significant threats due to fishing-related mortality. This paper provides a review of research aimed at identifying effective mitigation measures to reduce mortality rates among these vulnerable species. As a study species, oceanic whitetip sharks in the Western and Central Pacific Ocean are used to assess the efficacy of existing conservation and management measures and investigate potential strategies to enhance conservation efforts. The study reviews two previous papers Rice et al. (2021) and Bigelow et al (2022) which highlight the inadequacy of previous bans on shark lines or wire traces alone in mitigating fishing-related mortality. Despite initial attempts to address the issue, these measures have fallen short of achieving desired outcomes. Through an analysis of available data and insights,

we conclude that a combination of bans on both shark lines and wire traces holds the greatest promise for reducing mortality rates to sustainable levels."

38. The WPEB **NOTED** that this study showed a forecast from 2016 onwards showing the results of different catch reduction scenarios and **NOTED** that the study does not assume which specific methods have been used to reduce the catch levels examined under each scenario.

39. The WPEB **NOTED** that the prevalence of the use of wire leaders across the all longline fleets in the WCPO was unknown so a reduction in their use could not be modelled in this study but further **NOTED** that it would be useful to estimate the prevalence of wire leader use both in the Indian and Pacific Oceans, particularly across the tropical region which is the core habitat of silky and oceanic whitetip sharks in order to be able to assess the potential effect of reducing their use on catch rates in the core area.

40. The WPEB **NOTED** that the future projections were updated using mortality information up to 2022. The WPEB **NOTED** that the results suggest a total fishing mortality rate of 25% in the case of no retention for the shark species studied. Therefore, the WPEB **NOTED** that a non-retention of these species by all fleets, if implemented perfectly, would be effective in recovering the populations of these species without the prohibition of wire leaders and shark lines.

41. The WPEB **NOTED** the study's conclusion that the effect of no fleets using wire leaders or shark lines would also decrease interactions and so decrease mortality rates due to the lower probability of being caught or hooked.

3.2 Leader type/shark lines

42. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-11 which provided A review of the influence of wire leaders and shark lines on shark bycatch in pelagic longline fisheries, including the following abstract provided by the authors:

"This paper provides a detailed review of the global scientific research and evidence pertaining to the influence of wire leaders and shark lines, upon the catch rates and mortality of pelagic shark species caught by longline fisheries targeting tuna and swordfish. It discusses the implications of the review findings for future potential Indian Ocean Tuna Commission (IOTC) shark conservation measures. The review considered evidence from scientific fishing trials/surveys, commercial fishery data analyses, and predictive modelling approaches. The review highlights a number of consistent and relevant findings, specifically:

1. *Experimental fishing trials/surveys, designed to look at leader material effects, and focussed on pelagic longline fisheries targeting tuna or swordfish, have consistently determined that monofilament leaders result in significantly lower at-vessel catch rates of pelagic sharks (grouped) and of specific shark species (most commonly shortfin mako Isurus oxyrinchus and blue shark Prionace glauca, but also pelagic thresher Alopias pelagicus and oceanic whitetip shark Carcharhinus longimanus), with the precise outcomes differing depending on species, trial, and sampling numbers. Shark lines were not assessed in those trials.*
2. *A number of these trials inferred from bite-off data that the difference in at-vessel catch rate was due to bite-offs on monofilament lines, allowing sharks to escape after initial hooking, and that actual catch rates between leader types, at the point of bait being taken, were likely similar.*
3. *A number of the trials found that catch rates of at least one or more target tuna and billfish species were higher on monofilament than wire leaders. None of these studies found that target species at-vessel catch rates were significantly lower on monofilament leaders.*
4. *Analyses of observer catch rates data in the Pacific provides strong evidence that prohibiting the use of shark lines can significantly reduce the mortality of some shark species, in situations where the use of shark lines is common.*

5. *Predictive modelling research conducted in the Pacific determined that banning both shark lines and wire traces in the WCPFC Area had the potential to reduce fishing mortality by 30.8% and 40.5% for silky sharks and oceanic whitetip sharks respectively in that region (Harley et al. 2015, Bigelow & Carvahlo, 2021).*

While research clearly indicates the potential of measures prohibiting wire leaders and shark lines to reduce pelagic shark mortality, the degree to which a reduction would occur in the IOTC depends on the current level of use of these gears in IOTC, which is uncertain and requires further investigation. However, prohibition of these gears can strengthen current IOTC shark conservation measures by either reducing future mortality (where use of these gears is common) or preventing future increases in shark mortality due to increased use of these gears (if current use is low). Current IOTC shark conservation measures include provisions banning retention of thresher sharks (Family Alopiidae) and oceanic whitetip shark. While these measures will clearly help to reduce mortality of these species, their efficacy is dependent on the proportion of sharks alive and healthy at haul and their survivability post release. A prohibition on the use of shark lines and wire leader, if adopted by IOTC, would further strengthen IOTC measures by reducing initial capture rates (shark line prohibition) and increase escapement post capture (wire leader prohibition), resulting in reduced overall mortality. They would also reduce fishing mortality across a broader range of pelagic shark species. Such provisions would be consistent with IOTC Scientific Committee (SC) advice pertaining to the need to reduce mortality of shortfin mako, silky shark (Carcharhinus falciformis) and oceanic whitetip shark. This paper provides three recommendations pertaining to a) prohibiting the use of wire leaders and shark lines; b) making collection of branch line material data mandatory and c) acquiring additional information on wire leader and shark line use in IOTC fisheries for IOTC Working Party in Ecosystems and Bycatch (WPEB) consideration."

43. The WPEB **NOTED** that experimental trials, as examined in this study, face the same issues as meta-analyses in that they can be quite data limited. The WPEB further **NOTED** that there are a lot of uncontrolled variables in normal fisheries data and so it is useful to examine observer data as well.

44. The WPEB **NOTED** that the effort being applied in Indian Ocean fisheries with different gear types is still unknown, particularly in coastal fleets, so using experimental trials is an alternative way of determining the effect of reducing wire leader use and shark lines on CPUE. The WPEB further **NOTED** that there is also limited information on how shark populations in the Indian Ocean are interacting with these fisheries.

45. The WPEB **NOTED** that the level of Indian Ocean specific data required to give evidence-based information for policy decisions, including relating to population status, is not available (and lower than those data available in the WCPFC for example) and is unlikely to be available for some time but further **NOTED** that this should not be used as a reason for not providing scientific advice and taking management action based on relevant research and information from other oceans.

46. The WPEB **RECOMMENDED** that the collection of information on leader material type should be made mandatory under the Regional Observer Scheme Minimum Data Requirements and reported to the Secretariat. The WPEB also **RECOMMENDED** that these data collected under the ROS are strictly used for scientific purposes in research.

47. The WPEB **RECOMMENDED** that mitigation surveys should be developed by CPCs in the IOTC areas and with different gear types and configurations to assess mitigation measures such as the type of leaders and other factors to be tested and implemented. The WPEB **NOTED** that the increase of bite offs by the prohibition of wire leaders could lead to the decrease in the basic information necessary for stock assessment or monitoring abundance of shark species. **ACKNOWLEDGING** the importance of these data, the WPEB **SUGGESTED** that bite offs are recorded by observers to further inform bycatch estimates.

48. The WPEB further **NOTED** that while an increase in bite offs as a result of increased use of monofilament leaders would mean that observers have less of a chance to identify species which have interacted with gears (reducing the information available for estimating CPUEs that are key inputs to stock assessments), that alone would not be reason for not undertaking such measures to reduce shark mortality.

3.3 Hook type

49. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-12 which provided a review of the effect of circle hooks on retention and at-haulback mortality of sharks, including the following abstract provided by the authors:

   "Elasmobranchs (sharks, skates, and rays) are characterized by life histories that include slow growth, late maturity, and low fecundity. These traits collectively contribute to the high vulnerability of elasmobranchs to exploitation by fisheries. Modifications to both fishing gear and behavior have been effective in mitigating bycatch, reducing injury rates, and decreasing overall fishing mortality. One example includes the use of circle hooks. Here we compare the effects of circle hooks vs. J-hooks on the retention rates and at-vessel mortality of sharks (and rays). After reviewing two meta-analyses, we updated the analysis to remove the effect of confounding variables and present estimates of the relative risk of retention on circle vs. J-hooks for ten frequently encountered species in pelagic longline fisheries. Two of the ten species considered exhibited significant increases in retention rates due to circle hook use, one had a significant decrease in retention rates due to circle hook use, and there were no significant differences for the remaining seven. While some point estimates indicate higher retention rates on circle hooks vs. J-hooks, we suspect increased rates of gut-hooking and subsequent bite offs artificially deflate retention on J-hooks as hooked sharks are likely to evade capture and therefore not be counted. This behavior, and subsequent erroneous counting, has been demonstrated in the literature and is plausible as circle hook use results in significantly less gut-hooking and bite offs. In addition to the re-analysis, we also review the effects of circle hook use on at-vessel mortality of sharks. Collectively, this review discusses the utility of circle hooks in pelagic longline operations and the viability of the gear to increase the effectiveness of conservation measures."

50. **NOTING** that even though J-hooks exhibit lower retention on sharks, they may lead to higher rates of gut-hooking and bite-offs, and therefore cryptic mortality. As a result, the WPEB **NOTED** that bite-offs should be considered in catch and mortality analyses.

51. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-13 on Multifaceted effects of bycatch mitigation measures on target/non-target species for pelagic longline fisheries and consideration for bycatch management, including the following abstract provided by the authors:

   "The pelagic longline fishery, in an effort to reduce bycatch of sea turtles, have developed and deployed fisheries bycatch mitigation techniques such as replacing J/tuna hooks and squid bait with circle hooks and whole fish bait. However, little emphasis has been placed on the side effects of bycatch mitigation measures on endangered species other than target bycatch species. Several previous studies of the side effects have been marred by lack of control for the covariates. Here, based on long-term data obtained from research cruises by a pelagic longline vessel, we examined the effects of using circle hooks and whole fish bait to replace squid bait on the fishing mortality of target and non-target fishes, and also bycatch species. A quantitative evaluation analysis of our results, based on a Bayesian approach, showed the use of circle hooks to increase mouth hooking in target and bycatch species, and their size to be proportional to the magnitude of the effect. While deploying circle hooks did not increase fishing mortality per unit effort (MPUE) for shortfin mako sharks, combining to whole fish bait had a significant increase on

MPUE. Because the impact of the introduction of bycatch mitigation measures on species other than the focused bycatch species is non-negligible, a quantitative assessment of bycatch mitigation-related fishing mortality is critical before introducing such measures."

52. The WPEB **NOTED** that there were differences in the CPUE response by blue shark and shortfin mako shark in response to the use of circle hooks (blue shark showed a decrease in CPUE while shortfin mako showed an increase) and **NOTED** that this may be related to foraging methods.

53. The WPEB **NOTED** that the use of wire leaders in this study tended to keep sharks alive on the line. The WPEB **NOTED** the importance of good release practices, noting that poor practices may have a more significant negative impact on fishing mortality and post-release mortality than the use of wire leaders alone.

54. The WPEB **NOTED** that soak time does not significantly affect at-haulback mortality of sharks, but the study did not consider the actual hooking time for each line. The WPEB further **NOTED** that the absence of effect of soak time may be due to the limited range of sizes in sharks observed.

55. The WPEB **NOTED** the importance of investigating hook position in shortfin mako shark considering the influence of bait.

56. The WPEB **NOTED** the reduced hook swallowing and mortality seen in marine turtles with the use of circle hooks and further **NOTED** that this decreased injury rate appears to carry over for many shark species.

57. The WPEB **NOTED** that some studies using large circle hook have reduced injury to sharks by increasing rates of mouth hooking. The WPEB further **NOTED** that decreasing injury rates associated with large circle hooks results in a reduction in at-vessel mortality for some species. Circle hooks use also reduces observed retention of some vulnerable taxa, such as sea turtles and marlins. The WPEB also **NOTED** that some experimental sea-trials from other Oceans have reported increases in observed retention of some shark species when using large circle hooks, especially blue shark and crocodile shark, and that the results from a global meta-analysis and multiple experimental sea-trials have found that the use of large circle hooks reduces retention of target species like swordfish. The WPEB further **NOTED** that there are still many information gaps regarding their effectiveness for sharks, and the number of case studies on deep-setting operations and effect of hook size is still too few and there is also concern that circle hooks may increase shark catches, the WPEB **RECOMMENDED** continued accumulation of information on circle hook effectiveness including in deep-setting operations.

58. Considering the benefits of the use of circle hooks on sea turtles and marlins seen from these studies and based on the precautionary approach, the WPEB **SUGGESED** that large circle hooks used in shallow longline operations would likely lead to reduced mortality of these species. The WPEB **AGREED** to further discuss this issue during the WPEB Assessment Meeting.

59. **ACKNOWLEDGING** that the use of fish bait increases at-haulback mortality and mortality per unit of effort for shortfin mako shark while not affecting turtles, the WPEB **EMPHASISED** the importance and complexity of the interactions between hook type and bait and the need for multi-taxa approach to optimize the impact of future mitigation measures. Consequently, The WPEB **SUGGESTED** that a collaborative analysis could be conducted in the Indian Ocean including not only leader type but also hook type and bait based on available data.

60. The WPEB **NOTED** that size effects were examined during this study, but they didn't appear to impact the mortality rate much but further **NOTED** that limited size classes were studied so it would be useful to include size effect in the future with a broader size distribution. The WPEB **NOTED** that the diets of species such as shortfin mako shark change as they get older which may impact their hooking rates.

61. The WPEB **NOTED** that sea surface temperature was examined in relation to haulback mortality and did appear to impact several teleost species (including swordfish and several tuna species) but there was little impact on shark species.

3.4 Other measures

62. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-14 on Effect of pelagic longline bait type on species selectivity: a global synthesis of evidence, including the following abstract provided by the authors:

"Fisheries can profoundly affect bycatch species with 'slow' life history traits. Managing bait type offers one tool to control species selectivity. Different species and sizes of marine predators have different prey, and hence bait, preferences. This preference is a function of a bait's chemical, visual, acoustic and textural characteristics and size, and for seabirds the effect on hook sink rate is also important. We conducted a global meta-analysis of existing estimates of the relative risk of capture on different pelagic longline baits. We applied a Bayesian random effects meta-analytic regression modelling approach to estimate overall expected bait-specific catch rates. For blue shark and marine turtles, there were 34% (95% HDI: 4–59%) and 60% (95% HDI: 44–76%) significantly lower relative risks of capture on forage fish bait than squid bait, respectively. Overall estimates of bait-specific relative risk were not significantly different for seven other assessed taxa. The lack of a significant overall estimate of relative capture risk for pelagic shark species combined but significant effect for blue sharks suggests there is species-specific variability in bait-specific catch risk within this group. A qualitative literature review suggests that tunas and istiophorid billfishes may have higher catch rates on squid than fish bait, which conflicts with reducing marine turtle and blue shark catch rates. The findings from this synthesis of quantitative and qualitative evidence support identifying economically viable bycatch management measures with acceptable tradeoffs when multispecies conflicts are unavoidable, and highlight research priorities for global pelagic longline fisheries."

63. This paper was discussed in combination with paper IOTC-2024-WPEB20(DP)-05.

64. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-15 on Quantitative estimates of post-release survival rates of sharks captured in Pacific tuna longline fisheries reveal handling and discard practices that improve survivorship, including the following abstract provided by the authors:

"Shark catch rates are higher in pelagic longline fisheries than in any other fishery, and sharks are typically discarded (bycatch) at sea. The post-release fate of discarded sharks is largely unobserved and could pose a significant source of unquantified mortality that may change stock assessment outcomes and prevent sound conservation and management advice. This study assessed post-release mortality rates of blue (Prionace glauca), bigeye thresher (Alopias superciliosus), oceanic whitetip (Carcharhinus longimanus), silky (C. falciformis) and shortfin mako (Isurus oxyrhincus) sharks discarded in the Hawaii deep-set and American Samoa longline fisheries targeting tuna in the central Pacific Ocean. The impacts on survival rates were examined considering species, fishery, fishing gear configuration, handling method, animal condition at capture and at release, and the amount of trailing fishing gear remaining on discarded sharks. Bayesian survival analysis showed that the condition at release (good vs. injured), branchline leader material, and the amount of trailing fishing gear left on the animals were among the factors that had the largest effect on post-release fate—animals captured on monofilament branchline leaders and released in good condition without trailing fishing gear had the highest rates of survival. This study shows that fisher behavior can have a significant impact on pelagic shark post-release mortality. Ensuring that sharks are handled carefully and released with minimal amounts of trailing fishing gear may reduce fishing mortality on shark populations."

65. The WPEB **NOTED** that having good observer data would be useful to assess the effectiveness of mitigation measures but **NOTED** that currently observer data are limited for Indian Ocean tuna fisheries. The WPEB **NOTED** that useful data fields would include handling methods, amount of trailing gear and hooking locations and it would be advantageous to create a condition matrix to cover a range of different conditions at release for predicting survivorship and total mortality.

66. **RECOGNISING** the importance of best handling and release practices on post-release survival rates of sharks, the WPEB **ENCOURAGED** CPCs to provide any observer and tagging data to better understand the effect of size, catch conditions and handling methods on post-release survival rates of sharks across fleets. The WPEB also **ENCOURAGED** CPCs to update their longline best practices guidelines accordingly.

67. The WPEB **NOTED** that during this study, tags were predominantly deployed on individuals with a high probability of survival – those that were alive and in good health – and on species with major concerns – oceanic whitetip and blue shark – due to the high cost of the tags, which can introduce a bias into the results.

68. The WPEB **SUGGESTED** that the length of the trailing gear could be estimated by observers by subtracting the remaining branchline from its original length. However, these data are not routinely collected because the process takes a lot of time.

69. The WPEB **NOTED** that the paper examined that used pop-up tags suggested that monofilament leaders did not have a significantly lower post release mortality (compared to wire leaders) and so this should be considered while providing advice to the SC.

70. The WPEB **NOTED** that sinking depth varies between different leader types (wire vs monofilament), while sinking rate is comparable.

71. The WPEB **NOTED** that wire leaders tend to degrade after about a hundred days, while monofilament leaders appear to remain intact over a significantly longer time period. This has implications for animals being burdened by trailing gears after at vessel cut-offs by crew, if crew do not cut-off close to the hook.

72. **RECOGNISING** the detrimental effect of trailing gear, the WPEB **AGREED** that the best handling and release practices include cutting the line as close to the hook as possible.

73. The WPEB **NOTED** that condition of individual at-haulback (hook swallowed, bleeding in gills, inverted stomach, subject to depredation, wrapped in the line, etc.) is the best predictor of post-release survival rate.

3.5 Workshop summary

74. The WPEB **NOTED** on the basis of its review of global research that a prohibition on the use of wire leaders and shark lines by longline and other fisheries operating in the IOTC would likely result in a reduction in both the observed catch and the fishing mortality of shark species. The WPEB **NOTED** supporting evidence from a range of research studies as seen in **Table 2** (in Appendix VI). The WPEB **NOTED** that these results are likely to be similar in the Indian Ocean. Based on these studies and on the basis of taking the precautionary approach, and consistent with existing SC advice on the need to reduce fishing mortality for shortfin mako, oceanic whitetip and silky shark, the WPEB **RECOMMENDED** that additional mitigation measures such as, but not limited to, the non-use of wire leaders and shark lines should be implemented. The WPEB **AGREED** to further discuss this issue at the WPEB Assessment meeting in September.

75. A summary of the pros and cons of the mitigation measures discussed during the workshop can be found in Annex VI.

4 Review of data available at the Secretariat for bycatch species

4.1 Review of the statistical data available for bycatch species

76. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-03 which provided an overview of the data managed by the IOTC Secretariat for mako shark species for the period 1950–2022.

77. The WPEB **RECALLED** that with the term *bycatch* the IOTC refers to all those species other than the 16 managed by the IOTC, regardless of their being targeted, incidentally caught, or elsewhere affected by IOTC fisheries.

78. The WPEB **NOTED** that the catches of mako shark species were dominated by artisanal fisheries until the early 1990s, with an average of 1,300 t per year. With the expansion of the industrial fishery, there was a steady increase to a peak of around 5,168 t in 2016, after which the trend reversed, with total catches falling by around 50% last year.

79. The WPEB **NOTED** that shortfin mako dominates the catches of mako shark reported by industrial fisheries, although it varies from year to year, accounting for between 50% and 70% of catches of these species. Longfin makos are poorly recorded in the Indian Ocean and catches reported to the Secretariat in recent years represent less than 1% of mako species. For artisanal fisheries around 80% of catches reported for mako species are aggregated.

80. The WPEB **NOTED** that the main fleets accounting for 74% of total catches of mako shark species are Indonesia, Taiwan,province of China, Madagascar and EU,Spain. The WPEB also **NOTED** that most tuna and tuna-like fisheries of the Indian Ocean show a decline in reported catches of mako sharks in recent years with the exemption of Indonesia line fishery which has shown a smooth increasing trend.

81. The WPEB **NOTED** that the level of catches presented do not contain data on discards reported through form 1DI by some CPCs. **NOTING** that Resolution 15/02 currently requires CPCs to report estimates of total catch by species, separated whenever possible into retained catches and discards, the WPEB **NOTED** that discard data are very seldom reported to the Secretariat and are usually not raised to the total catch. Therefore, the WPEB **REQUESTED** CPCs to fully comply with Resolutions 15/01 and 15/02 to ensure reporting of scientific estimates of discards for IOTC species as well as the most commonly caught sharks (as listed in Resolution 15/01 for longline fisheries), and that details on the estimation methods should be provided to the Scientific Committee.

82. The WPEB **NOTED** that the information on discarding practices can only be inferred from observer data collected through the ROS programme, which shows that mako shark interactions are mostly recorded in the Western Indian Ocean and at an aggregated species level. The WPEB also **NOTED** that most of the interactions are recorded as retained catches indicating their commercial importance.

83. The WPEB **NOTED** that around 70% of the fish size samples collected come from logbooks and the size data collected for shortfin mako by observers onboard deep-freezing longliners show a distribution described by a median fork length of 177.5 cm, which is larger than the median of the sizes collected by other enumerators (162 cm).

84. The WPEB **REQUESTED** the IOTC Secretariat to develop a summary paper, based on available observer data, that documents the fleet, spatial and temporal patterns in catch, catch rates, fate and condition (life status) of pelagic shark taken by the different IOTC fisheries, as well as high level statistics on the use of wire trace and shark lines. Where the IOTC Secretariat does not hold sufficient CPC observer data, the IOTC Secretariat could request summaries of the relevant data fields from the CPCs. This will facilitate further discussion and development of scientific advice by the WPEB at its meeting in September 2024.

85. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-17 which provided a summary of key information pertaining to pelagic shark catches, status and management in the IOTC, including the following abstract provided by the authors:

> *"This paper provides a summary of information pertaining to the catches, status and management of pelagic shark species taken in Indian Ocean Tuna Commission (IOTC) fisheries to help facilitate discussions at the IOTC's 20th Working Party on Ecosystems and Bycatch Preparatory Meeting in April 2024. The information was compiled from existing IOTC meeting documents, resolutions and data provided by the IOTC Secretariat, and is compiled in a manner to facilitate quick comparisons across species. This paper focusses mainly on the 7 pelagic shark species for which the IOTC Scientific Committee meeting reports contain species status summaries, being blue shark (Prionace glauca), oceanic whitetip (Carcharhinus longimanus), scalloped hammerhead (Sphyrna lewini), shortfin mako (Isurus oxyrinchus), silky shark (Carcharhinus falciformis), bigeye thresher (Alopias superciliosus) and pelagic thresher (Alopias pelagicus). However, it is important to note that fisheries in the IOTC area of competence interact with a broader range of shark species whose conservation and management may be affected by both general and species-specific shark resolutions adopted by the Commission. For example, a summary of longline and purse-seine observer data (provided by the IOTC Secretariat) indicates that there are at least 22 species observed to interact with longline and 3 species observed to interact with purse seine (Table 1). Many of these species are known to interact with gillnet and other fishing gears used in IOTC fisheries, but less fishery-independent data are collected and reported in those fisheries."*

86. The WPEB **NOTED** that the summary provides estimates of catch levels for most species, noting that these are highly uncertain. Therefore, only the stock status of blue sharks has been satisfactorily assessed and assessments for the other key shark species have not been carried out or are preliminary due to lack of information or uncertainty in the information.

87. The WPEB **NOTED** that in the absence of quantitative stock assessments the SC has drawn upon a wide range of information related to the 6-7 key species to help develop its species summaries and management advice. That information includes IUCN global conservation status information for sharks taken in IOTC, which indicates that two are critically endangered (oceanic whitetip and scalloped hammerhead), two are endangered (shortfin mako and pelagic thresher) and two vulnerable (silky shark and bigeye thresher).

88. The WPEB **NOTED** that the SC also draws on information from the 2018 ecological risk assessment (ERA) of shark species in IOTC fisheries. That ERA ranked some species (e.g. silky shark, porbeagle and shortfin mako) as likely to have similar or higher vulnerability to longline fishing compared to thresher and oceanic whitetip shark which the IOTC has already has retention bans in place for.

89. The WPEB **NOTED** that the data used to produce this paper were aggregated (2005 to date).

90. The WPEB **NOTED** that the management advice for these species provided by the SC to the Commission emphasises the need for a cautious approach to management of a range of these species, including the need to reduce fishing mortality in particular on oceanic whitetip, silky shark and shortfin mako shark.

91. The WPEB also **EMPHASISED** the fact that the interpretation of the catch and observer data summaries in the paper requires caution as they are a summary of the available information provided by CPCs. With observer coverage in the Indian Ocean being low (coverage is meant to be 5% but this is not consistently met by certain CPCs), these data may not accurately reflect the overall IOTC fishery.

5 Review information on biology, ecology, fisheries and environmental data relating to shortfin mako shark

5.1 Presentation of new information available on sharks

92. The WPEB **NOTED** that paper IOTC-2024-WPEB20(DP)-18 was withdrawn.

93. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-19 on Information on the catch of shortfin mako (*Isurus oxyrinchus*) caught by Japanese longline fishery in the Indian Ocean after 2018, including the following abstract provided by the authors:

    "The fishing effort and catch of shortfin mako by Japanese longline fleet in the Indian Ocean after the previous stock assessment in 2020 were summarized, and the activity and the fate information of this species were also detailed based on the data from logbook and observer program for Japanese longline fishery in the Indian Ocean. Between 2018 and 2022, retained catch decreased rapidly from 2018 to 2020, and kept low level afterward. It was suggested that the decrease of catch was caused by the regulation on this species rather than the decrease of stock. The observer deployment was interrupted since 2020 due to the pandemic of COVID-19 and the chance of observation on this species decreased significantly after the pandemic. As a result, the amount of data available for the estimation of abundance index became quite few and Japan cannot provide the update of abundance index for the stock assessment of shortfin mako in the Indian Ocean. In addition, the decreased catch (i.e., reported catch) of this stock should be carefully interpreted, because the reported catch is affected by various factors such as a regulation. Continuation of data collection from observer program would provide information useful to monitor the trend of this population".

94. The WPEB **NOTED** that the retained number of shortfin mako sharks declined after 2018 due to a CITES regulation that caused all sharks to be released and, therefore, less information on shortfin mako is collected on both logbook and observer data (also due to COVID pandemic) as since 2018-2019 most of the SMA are released. As a result, the WPEB **NOTED** the amount of data available for the estimation of the Japanese abundance index from logbooks has been reduced since 2018 and, hence, Japanese shortfin mako CPUE cannot be updated including the period 2018-2022 for the stock assessment of shortfin mako in the Indian Ocean. The WPEB **NOTED** that the fishing effort of the Japanese fleet in the Indian Ocean has been stable in recent years, and the estimated CPUE of that fleet was stable or increasing until 2018.

95. The WPEB **NOTED** that the decrease of shortfin mako reported catch in Japanese logbook data should be carefully interpreted as the reported catch has been affected by the CITES regulation since 2018. The WPEB further **NOTED** that as of 2024, deployment of observers on the distant water longline fishery has recovered to similar levels to those seen in 2019. The WPEB **AGREED** that the decrease in catch (reported catch) in Japanese logbook data should be carefully interpretated as declines may be related to regulation and not stock abundance. Continuation of data collection from observer program would provide information useful to monitor the abundance trend of this population.

96. The WPEB **AGREED** that the previous Japanese CPUE from 1993 to 2018 can be used as an index of abundance in the stock assessment.

6 Review of new information on the status of shortfin mako shark

6.1 Nominal and standardised CPUE indices

97. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-20: Updated fishery indicators for shortfin mako shark (*Isurus oxyrinchus*) caught by the Portuguese pelagic longline fishery in the Indian Ocean, between 1999-2022: Catch, effort and standardised CPUEs, including the following abstract provided by the author:

> *"This working document provides updated fishery indicators for the shortfin mako shark captured by the Portuguese pelagic longline fishery in the Indian Ocean, in terms of catches, effort and standardized CPUEs. The analysis was based on data collected from fishery observers, skipper's logbooks (self-sampling) and official electronic logbooks collected between 1999 and 2022. The CPUEs were analyzed for the Indian Ocean and compared between years, and were modeled with tweedie GLM models for the CPUE standardization procedure. In general, there was a large variability in the CPUE trends, especially in the earlier years, with the standardized CPUEs relatively similar to the nominal trend. There was a general increasing trend until 2012, followed by a more stable period for the more recent years, between 2012-2022."*

98. The WPEB **NOTED** that the fishery typically records 500-700 sets per year, with approximately 1000-1200 hooks per set. Effort distribution over the years shows a trend towards contraction, particularly in recent years due to a decrease in vessel numbers.

99. The WPEB **NOTED** that a set-by-set calculation of the ratio of swordfish to blue sharks was used to reflect the targeting strategy in the standardisation procedure, considering that both species are pursued simultaneously and the techniques for catching blue sharks and mako sharks may differ.

100. The WPEB **NOTED** that the annual changes of proportions in catch composition, particularly the ratio of sharks to swordfish, exhibits considerable variability. Potential factors influencing these fluctuations include market dynamics, spatial variations in abundance, fuel prices, and targeting strategies. The WPEB **NOTED** that historical data from logbooks are reliable in terms of retention, but recent policy changes, such as CITES regulations and no-retention policies, have altered catch retention and discarding dynamics, especially for lower-value species like blue sharks, compared to the historically retained and highly valuable shortfin mako shark.

101. The WPEB **NOTED** that in the last 3 years the fishery has been contracted to the southwest Indian Ocean which might impact the CPUE results. The WPEB **SUGGESTED** performing an alternative CPUE standardization restricted to the southwest Indian Ocean, which can be considered the core area of the Portuguese fleet as its effort is consistently located in this region throughout the time series. The WPEB **NOTED** that restricting the analysis to the core area could allow comparisons of the trends in different fleet CPUEs in the Southwest Indian Ocean that may then inform the representativeness of the standardized CPUE for the whole area.

102. The WPEB **QUERIED** whether the vessel effect was incorporated in the CPUE because the changes in the number of vessels over time and, as a result, the distribution of the relative vessel effects, could affect the CPUE standardization. The WPEB **SUGGESTED** the authors investigate this issue and present any further analyses at the next WPEB meeting.

103. The WPEB **AGREED** that this index should be considered and explored for inclusion in the 2024 shortfin mako assessment.

104. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-21 on Updated standardized catch rates of shortfin mako (*Isurus oxyrinchus*) inferred from the Spanish surface longline fishery in the Indian Ocean during the period 2001-2022, including the following abstract provided by the author:

" This paper provides an updated of the standardized catch rates per unit of effort (CPUE) in number and in biomass for the shortfin mako in the Indian Ocean stock using Generalized Linear Models. A total of 2,828 trips (80.3 millions of hooks) which represents around 90% of the total effort deployed by the Spanish surface longline fleet targeting swordfish, were analyzed for the period 2001-2022. The main factors considered in the final models were year, quarter, area, and the targeting criteria of skippers. The results indicate that the year regularly was the most important factor explained the CPUE variability. However, the ranking and the relative importance of each main factor are depending on whether capture rates are considering in number or weight. The model explained 33% and 26% of CPUE variability in number and weight, respectively. Both standardized CPUE show stable trends until 2008 with an increasing trend until 2021 and a slightly decreasing in the last year of the series"

105. The WPEB **QUERIED** whether the level of discards are accounted for or whether there has been any change in the shortfin mako retention practices for this fleet due to the new CITES regulation that lead to fleets releasing shortfin mako sharks. The WPEB **NOTED** that there have not been differences in the retention practice over time because all shortfin mako are retained due to their high value and because the CITES shortfin mako quota for the Spanish fleet is not exceeded and, thus, the Spanish fleet can retain all shortfin mako catches. The WPEB **NOTED** that discards are not included in the analysis but that are very low due to the reasons explained.

106. The WPEB **NOTED** that there are two standardised series, one in number of individuals and the other in weight and requested the authors to suggest the one that should be included in the stock assessment. The WPEB **NOTED** that the authors prefer the standardised CPUE based on weight.

107. The WPEB **NOTED** that the Spanish fleet has operated in the whole Indian Ocean area although in the last few years has mostly operated in the southwest Indian Ocean.

108. The WPEB **NOTED** that due to the reduction and contraction of the Spanish and Portuguese fleets, these CPUEs might better represent the southwest Indian Ocean abundance than the abundance of the whole Indian Ocean. The WPEB **REITERATED** its **SUGGESTION** to performing an alternative CPUE standardization restricted to the southwest Indian Ocean, which can allow a comparison of the different fleet standardised CPUEs in this region.

109. The WPEB **NOTED** that the spatial effect is included in the CPUE standardization and, therefore, that contraction is taken into account in the standardization process for both Portuguese and Spanish CPUE and, therefore, they could be considered representative of the whole Indian Ocean area where the fleet operates. However, it was **NOTED** that the models can compensate for those spatial changes to some extent but not entirely, and as such the authors agreed to perform an alternative CPUE analysis on the Southwest Indian Ocean to check the trend of the index in this area and compare among indices (Japanese, Spain and Portugal) in this particular area.

110. The WPEB **AGREED** that this index should be considered and explored for inclusion in the 2024 shortfin mako assessment.

111. The WPEB **NOTED** paper IOTC-2024-WPEB20(DP)-22 on Historical standardised CPUEs for the Indian Ocean shortfin mako (*Isurus oxyrinchus*) for 1966 through 1989 with catch estimation, including the following abstract provided by the author:

"We used an historical longline survey from 1966 to 1989 in the Indian Ocean basin to calculate standardized CPUEs for the endangered shortfin mako shark (Isurus oxyrinchus). CPUEs were generated using a zero-inflated negative binomial (ZINB) generalized additive model (GAM). These CPUEs represent an important basin-wide baseline for shortfin mako abundance at the start of industrialization of Indian Ocean fisheries. We also demonstrate how they can be used in combination with effort data to generate estimates of catch. Regressed with CPUEs from other fleets, we demonstrate a significant decline in shortfin mako abundance from the 1960s to present. Finally, we show a decline in median fork length between the USSR and IOTC data."

112. With regards to the catch estimation, the WPEB **NOTED** that the analysis has combined research survey catch rates with total fishing effort reported for the IOTC to estimate total catch of shortfin mako shark. It was **NOTED** that effort data are underreported, especially in that historical period, and, therefore, the total catch information could be an underestimation.

113. Moreover, the WPEB **NOTED** that the standardized CPUE index from those surveys represents a relative index of abundance that is representative of those surveys and within their seasonal, gear, fleet, and other effects. If such relative CPUE is used to estimate the total catch for the total effort of all fleets combined, there is an underlying assumption that the survey CPUEs would be representative and comparable to the catch rates of all other fleets, which is unlikely to be correct. The catchability and catch rates of different gears, fleets, areas, time periods, etc. are different among fleets and, thus, they should not be combined in such a way to estimate an ocean wide catch estimation of shortfin mako.

114. The WPEB **NOTED** that the research survey conducted 4,678 sets over 28 years with a very low catch of shortfin mako individuals (around 1,000 individuals). The WPEB further **NOTED** some concerns about its representativeness as an abundance index for the whole Indian Ocean for the studied period.

115. The WPEB **NOTED** that the USSR research survey sampling strategy and gear configuration/characteristics are not included in the paper and, thus, the WPEB considered that it is difficult to evaluate its representativeness as an abundance index for the Indian Ocean without that information.

116. The WPEB is concerned with the analysis of combining different fleets, with different characteristics, spatial distribution, and time series, into a single joint CPUE index. The WPEB **NOTED** that the joint CPUE analysis (i) modelled the CPUE outputs of different CPCs CPUE to create a combined CPUE and (ii) combined relative abundance indices of different fleets with different catchability coefficient (q) or catch rates, which the WPEB **CONSIDERED** to be an incorrect approach. Thus, the WPEB **AGREED** not to use the joint abundance index as an input CPUE in the shortfin mako stock assessment; however, the WPEB **AGREED** to consider the USSR index for the for sensitivity analyses in the stock assessment .

117. The WPEB **SUGGESTED** that set-by-set data be made available to try to develop a combined joint index using different fleet data as it is done with bigeye, yellowfin, and other IOTC species.

6.2 Other abundance indices

6.3 Development of shark research work plan for scalloped hammerhead shark

118. The WPEB(DP) **NOTED** the information document IOTC-2024-WPEB20(DP)-INF25, which provides the Terms of Reference for the shark research plan for the Scalloped Hammerhead. The WPEB(DP) **NOTED** that the Terms of Reference were drafted in response to the Commission's request to initiate the shark research plan. This plan, initially focusing on the Hammerhead shark, will serve as a template for research plans for other shark species.

119. The WPEB **NOTED** the South African expert's offer to lead the draft research plan outlined in the Terms of Reference. This work is expected to build upon extensive experience gained from developing research plans for various shark species within South African fisheries, including the Hammerhead shark. The WPEB **THANKED** South Africa for its willingness to spearhead this initiative. The work is expected to be presented to the WPEB in September.

120. The WPEB **NOTED** that the SC already adopted a Shark Research Program (IOTC-2014-IOShYP01-R[E]) in 2014 and, therefore, the WPEB **REQUESTED** experts developing the draft shark research plan to build upon the Shark Research Program adopted by the SC in 2017.

7 Stock assessment and indicators for shortfin mako shark

7.1 Review of indicators

121. The WPEB **NOTED** that the standardized CPUE index available for the stock assessment includes data from the Portuguese longline (2000-2022), Spanish longline (2001-2022), Japanese longline (1993-2018), Taiwanese longline (2005-2018), and the USSR longline survey index (1961-1989). The WPEB **NOTED** some conflicts among the indices, which may be further examined through clustering analysis. The WPEB **NOTED** significant contractions in Portuguese and Spanish longline fishing effort to the southwest Indian Ocean over the past decade and increasing uncertainty around whether recent CPUEs will be reflective of broader regional abundance. The WPEB **AGREED** to investigate various options as sensitivities, **NOTING** that the Japanese index is likely to be the most informative but will only be available up to 2018.

7.2 Discussion on shortfin mako assessment models to be developed and their specifications

122. The WPEB ***NOTED*** the preliminary assessment conducted in 2018 (IOTC-2018-WPEB14-37) and in 2020 (IOTC-2020-WPEB16-17). The assessments explored a range of models including the catch only method (CMSY) and biomass dynamic models (JABBA).

123. The WPEB **NOTED** some of the major challenges in the stock assessment relating to the availability of data and uncertainty in model inputs and extensively discussed various aspects of the assessment options including modelling platform, biological parameters, catch estimates, and CPUE series.

124. The WPEB **AGREED** that the assessment should focus on the use of the biomass dynamic model based on the JABBA platform. Should time permit, alternative models like CMSY and JARA may be considered. The WPEB **NOTED** that JABBA utilizes the Bayesian method and provides considerable flexibility in model configurations.

125. The WPEB further **NOTED** that tuna assessments in the IOTC typically use a grid approach to address structural uncertainty. A similar method may be applied to the JABBA assessment model where results can be assembled across various credible model options, such as different life history options, CPUE scenarios and production functions, thus addressing both structural and estimation uncertainties.

126. The WPEB **NOTED** several alternative prior distributions for the intrinsic growth rate parameter, r, were estimated from various values of biological parameters such as growth, lifespan, reproductive cycles, and natural mortality. These r values are generally quite low (less than 0.1) for Lamniformes sharks such as shortfin mako, indicating the species' low productivity. It was noted that another approach might be to derive a single prior with a broad distribution to encompass the extensive range of uncertainty in the biological parameters.

127. The WPEB **DISCUSSED** available age and growth studies of shortfin mako sharks in the Southern Indian Ocean and in the North Pacific. The WPEB **AGREED** that identifying appropriate estimates of crucial biological parameters is essential for the stock assessment. Therefore, the assessment team shall synthesize available biological information on shortfin mako and disseminate it to WPEB participants to reach an agreement on parameter estimates for use in the assessment. This task will be undertaken intersessionally.

128. The WPEB **NOTED** that r is derived from a demographic analysis based on the Leslie matrix. A Monte-Carlo type of approach was used to include parameter uncertainty and to generate a distribution of r. The WPEB **NOTED** that there are R packages available to conduct such analysis.

129. The WPEB **NOTED** that the production function's shape parameter has a large impact on the assessment outcomes. The assessment team plans to use the Pella-Tomlinson Thompson model, available in JABBA, which is flexible in exploring various shape parameter values that represent the potential productivity traits of the mako shark.

130. The WPEB **NOTED** that due to the late maturity of species and that the fishery mainly catches juvenile animals, there is a delay in the impact of fishery removals on the population. This delay may not be properly reflected in an aggregated biomass dynamic model. A delay-difference model or a fully age-structured model would be more capable of accounting for such effects. The WPEB also **NOTED** that the newer version of JABBA (JABBA-Select: https://github.com/jabbamodel/JABBA-Select) can incorporate life history traits and fisheries' selectivity into surplus production models. The WPEB **AGREED** that the assessment team should investigate the use of JABBA-Select in the assessment. The WPEB also **NOTED** that data limited versions of Stock Synthesis have recently been developed (https://github.com/shcaba/SS-DL-tool) which may be of use to the assessment team.

131. The WPEB **NOTED** that the catch estimates for shortfin mako sharks are highly uncertain and constitute a major source of uncertainty in the assessment. The WPEB **NOTED** that a ratio-based method, which relates shark catches to target tuna or swordfish catches, was previously used to derive catch estimates. The WPEB further **NOTED** that this approach has been used in several ICCAT assessments and for blue sharks within IOTC. The WPEB **NOTED** that it may be useful to explore available observer data from the key catching fleets to check assumptions around the level of discarding and if that may have changed through time. Discarding practice were noted to have changed in recent years in some fleets due to CPC regulations implemented in response to CITES outcomes for this species. The WPEB **AGREED** that the assessment team will collaborate with the analyst from the previous assessment and the Secretariat to provide an updated catch series.

132. The WPEB **AGREED** on the schedule of plan for various assessment tasks as below:

Section	Item	Deadline	Lead
Biology	Final decision on biological parameters to use	30-May	Assessment team to coordinate with WPEB intersessionally. Prepare an online template of needed parameters for filling/discussing
CPUE	Explore feasibility to use SMA catch and effort from ROS for a combined CPUE	15-Jun	Secretariat to extract data form ROS on SMA / Assessment team to make a standardised CPUE (if feasible)
Size data	Provide available size data (by year/fleet)	30-Jun	Secretariat
Biology	Re-estimate r priors (Leslie matrices)	30-Jun	Assessment
Catches	Reconstructing catch time series	30-Jun	Assessment / Secretariat
CPUEs	Provide any needed updates on standardized CPUE series	30-Jun	CPC scientists

8 Review of the draft, and adoption of the Report of the 20th Session of the WPEB

133. The WPEB **RECOMMENDED** that the WPEB20(AS) consider the consolidated set of recommendations arising from WPEB20(DP), provided at Appendix V.

134. The report of the 20th Session of the Working Party on Ecosystems and Bycatch Data Preparatory meeting (IOTC–2024–WPEB20(DP)–R) was **ADOPTED** by correspondence.

APPENDIX I
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APPENDIX II
AGENDA FOR THE 20TH WORKING PARTY ON ECOSYSTEMS AND BYCATCH DATA PREPARATORY MEETING

Date: 22-26 April 2024

Location: Online

Time: 12:00 – 16:00 (Seychelles time, GMT+4)

Chair: Dr Mariana Tolotti (EU, France)

Vice-Chairs: Mr Mohammed Koya (India) and Dr Charlene da Silva (South Africa)

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

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

3. **LONGLINE BYCATCH MITIGATION MEASURES WORKSHOP**

    3.1. All/several measures combined

    3.2. Leader type/shark lines

    Discussion point: Benefits in reduction of shark mortality via a ban of wire traces and shark lines

    3.3. Hook type

    Discussion point: benefits from other longline gear modifications such as hook type

    3.4. Other

    Discussion points:

    - Additional measures and practices potentially suitable to reduce bycatch of sensitive shark species and increase their survival after release
    - Discussion of additional benefits and/or trade offs for other species and priorities for implementation

4. **REVIEW OF THE DATA AVAILABLE AT THE SECRETARIAT FOR BYCATCH SPECIES AND BYCATCH DATA ESTIMATION APPROACHES** (All)

5. **REVIEW INFORMATION ON BIOLOGY, ECOLOGY, FISHERIES AND ENVIRONMENTAL DATA RELATING TO SHORTFIN MAKO SHARK** (all)

    5.1. Review new information on the biology, stock structure, their fisheries and associated environmental data for shortfin mako shark

    - Catch and effort
    - Observer data
    - Catch at size
    - Catch at age
    - Biological indicators, including age-growth curves and age-length keys

6. **REVIEW OF NEW INFORMATION ON THE STATUS OF SHORTFIN MAKO SHARK** (all)

    6.1. Nominal and standardised CPUE indices

    6.2. Other abundance indices

7. **STOCK ASSESSMENT AND INDICATORS FOR SHORTFIN MAKO SHARKS** (all)

7.1. Review of indicators (all)
7.2. Discussion on shortfin mako assessment models to be developed and their specifications

8. REVIEW OF THE DRAFT, AND ADOPTION OF THE REPORT OF THE 20TH SESSION OF THE WORKING PARTY ON ECOSYSTEMS AND BYCATCH (DATA PREPARATORY) (Chair)

APPENDIX III
LIST OF DOCUMENTS FOR THE 20TH WORKING PARTY ON ECOSYSTEMS AND BYCATCH

Document	Title
IOTC-2024-WPEB20(DP)-01a	Agenda of the 20th Working Party on Ecosystems and Bycatch
IOTC-2024-WPEB20(DP)-01b_rev3	Annotated agenda of the 20th Working Party on Ecosystems and Bycatch Assessment Meeting
IOTC-2024-WPEB20(DP)-02_rev3	List of documents of the 20th Working Party on Ecosystems and Bycatch Assessment Meeting
IOTC-2024-WPEB20(DP)-03	Review of the statistical data and fishery trends for ecosystems and bycatch species (IOTC Secretariat)
IOTC-2024-WPEB20(DP)-04	A review of reported effects of pelagic longline fishing gear configurations on target, bycatch and vulnerable species (C. C. Santos, D. Rosa, J. M. S. Gonçalves and R. Coelho)
IOTC-2024-WPEB20(DP)-05	A cross-taxa assessment of pelagic longline bycatch mitigation measures: conflicts and mutual benefits to elasmobranchs (E. Gilman, M. Chaloupka, Y. Swimmer and S. Piovano)
IOTC-2024-WPEB20(DP)-07	What's the catch? Examining optimal longline fishing gear configurations to minimise negative impacts on non-target species (M. Scott, E. Cardona, K. Scidmore-Rossing, M. Royer, J. Stahl and M. Hutchinson)
IOTC-2024-WPEB20(DP)-08	Technical mitigation techniques to reduce bycatch of sharks: there is no silver bullet (D. Drynan and G. B. Baker).
IOTC-2024-WPEB20(DP)-09	Statistical and Monte Carlo Analysis of the Hawaii Deep-Set Longline Fishery with Emphasis on Take and Mortality of Oceanic Whitetip Shark (K. Bigelow and F. Carvalho)
IOTC-2024-WPEB20(DP)-10	Review of potential mitigation measures to reduce fishing-related mortality on silky and oceanic whitetip sharks (Project 101) (K. Bigelow and F. Carvalho)
IOTC-2024-WPEB20(DP)-11	A review of the influence of wire leaders and shark lines on shark bycatch in pelagic longline fisheries (B. D'Alberto, H. Patterson and D. Bromhead)
IOTC-2024-WPEB20(DP)-12	A review of the effect of circle hooks on retention and at-haulback mortality (B. Keller and J. Reinhardt)
IOTC-2024-WPEB20(DP)-13	Multifacted effects of bycatch mitigation measures on target/non-target species for pelagic longline fisheries and consideration for bycatch management (D. Ochi, K. Okamoto and S. Uneo)
IOTC-2024-WPEB20(DP)-14	Effect of pelagic longline bait type on species selectivity: a global synthesis of evidence (E. Gilman, M. Chaloupka, P. Bach, H. Fennell, M. Hall, M. Musyl, S. Piovano, F. Poisson and L. Song)
IOTC-2024-WPEB20(DP)-15	Quantitative estimates of post-release survival rates of sharks captured in Pacific tuna longline fisheries reveal handling and discard practices that improve survivorship (M. Hutchinson, Z. Siders, J. Stahl and K. Bigelow)

Document	Title
IOTC-2024-WPEB20(DP)-16	Review of research on future projections and potential mitigation measures to reduce fishing related mortality on oceanic whitetip sharks (J. Rice)
IOTC-2024-WPEB20(DP)-17	A summary of key information pertaining to pelagic shark catches, status and management in the IOTC (H. Patterson, B. D'Alberto, and D. Bromhead)
IOTC-2024-WPEB20(DP)-19	Information on the catch of shortfin mako (Isurus oxyrinchus) caught by Japanese longline fishery in the Indian Ocean after 2018 (Y. Semba and M. Kai)
IOTC-2024-WPEB20(DP)-20	Updated fishery indicators for shortfin mako shark (Isurus oxyrinchus) caught by the Portuguese pelagic longline fishery in the Indian Ocean, between 1999-2022: Catch, effort and standardised CPUEs (R. Coelho, D. Rosa and P. G. Lino)
IOTC-2024-WPEB20(DP)-21	Updated standardized catch rates of shortfin mako (Isurus oxyrinchus) inferred from the Spanish surface longline fishery in the Indian Ocean during the period 2001-2022 (J. Fernández-Costa, A. Ramos-Cartelle, B. García-Cortés and J. Mejuto)
IOTC-2024-WPEB20(DP)-22	Historical standardised CPUEs for the Indian Ocean shortfin mako (*Isurus oxyrinchus*) for 1966 through 1989 with catch estimation (E. Gee, E. V. Romanov, D. Curnick, B. Block and F. Ferretti)
Information papers	
IOTC-2023-WPEB19-23	A review of the effectiveness of gear modifications to reduce shark bycatch mortality in longlining (I. Ziegler)
IOTC-2023-WPEB19-20	Historical standardised CPUEs of seven shark species in the Indian Ocean with preliminary catch estimation (E. Gee, E. Romanov, D. Curnick, B. Block and F. Ferretti)
IOTC-2024-WPEB20(DP)-INF01	Bycatch mitigation of protected and threatened species in tuna purse seine and longline fisheries (Y. Swimmer, E. A. Zollett and A. Gutierrez)
IOTC-2024-WPEB20(DP)-INF02	Bycatch in longline fisheries for tuna and tuna-like species: a global review of status and mitigation measures (S. Clarke, M. Sato, C. Small, B. Sullivan, Y. Inoue and D. Ochi)
IOTC-2024-WPEB20(DP)-INF03	Robbing Peter to pay Paul: Replacing unintended cross-taxa conflicts with intentional tradeoffs by moving from piecemeal to integrated fisheries bycatch management (E. Gilman, M. Chaloupka, L. Dagorn, M. Hall, A. Hobday, M. Musyl, T. Pitcher, F. Poisson, V. Restrepo and P. Suuronen)
IOTC-2024-WPEB20(DP)-INF04	Identification of factors influencing shark catch and mortality in the Marshall Islands tuna longline fishery and management implications (D. Bromhead, S. Clarke, S. Hoyle, B. Muller, P. Sharples and S. Harley)
IOTC-2024-WPEB20(DP)-INF05	Analyses of the Potential Influence of Four Gear Factors (leader type, hook type, "shark" lines and bait type) on shark catch rates in WCPO tuna longline fisheries (D. Bromhead, J. Rice and S. Harley)
IOTC-2024-WPEB20(DP)-INF06	Shark bycatch and mortality and hook bite-offs in pelagic longlines: Interactions between hook types and leader materials (A. S. Afonso, R. Santiago, H. Hazin and F. H. V. Hazin)

Document	Title
IOTC-2024-WPEB20(DP)-INF07	Fisheries bycatch of Sharks: Options for Mitigation (A. Cosandey-Godin and A. Morgan)
IOTC-2024-WPEB20(DP)-INF08	Monte Carlo simulation modelling of possible measures to reduce impacts of longlining on oceanic whitetip and silky sharks (S. Harley, B. Caneco, C. Donovan, L. Tremblay-Boyer and S. Brouwer)
IOTC-2024-WPEB20(DP)-INF09	Effects of leader material on catches of shallow pelagic longline fisheries in the southwest Indian Ocean (M. N. Santos, P. G. Lino and R. Coelho)
IOTC-2024-WPEB20(DP)-INF10	Large-scale experiment shows that nylon leaders reduce shark bycatch and benefit pelagic longline fishers (P. Ward, E. Lawrence, R. Darbyshire and S. Hindmarsh)
IOTC-2024-WPEB20(DP)-INF11	Catch rate and at-vessel mortality of circle hooks versus J-hooks in pelagic longline fisheries: A global meta-analysis (J. Reinhardt, J. Weaver, P. J. Latham, A. Dell'Apa, J. E. Serafy, J. A. Browder, M. Christman, D. G. Foster and D. R. Blankinship)
IOTC-2024-WPEB20(DP)-INF12	Fishing gear modifications to reduce elasmobranch mortality in pelagic and bottom longline fisheries off northeast Brazil (A. S. Afonso, F. H. V. Hazin, F. Carvalho, J. C. Pacheco, H. Hazin, D. W. Kertstetter, D. Murie and G. H. Burgess)
IOTC-2024-WPEB20(DP)-INF13	Effects of hook and bait on targeted and bycatch fishes in an equatorial Atlantic pelagic longline fishery (R. Coelho, M. N. Santos and S. Amorim)
IOTC-2024-WPEB20(DP)-INF14	The effect of hook type and trailing gear on hook shedding and fate of pelagic stingray (Pteroplatytrygon violacea): New insights to develop effective mitigation approaches (F. Poisson, S. Catteau, C. Chiera and J-M. Groul)
IOTC-2024-WPEB20(DP)-INF15	The effect of circle hooks vs J hooks on the at-haulback survival in the US Atlantic pelagic longline fleet (G. A. Diaz)
IOTC-2024-WPEB20(DP)-INF16	Influence of hook type on catch of commercial and bycatch species in an Atlantic tuna fishery (H-W. Huang, Y. Swimmer, K. Bigelow, A. Gutierrez and D. G. Foster)
IOTC-2024-WPEB20(DP)-INF17	Circle hooks in commercial, recreational and artisanal fisheries: research status and needs for improved conservation and management (J. E. Serafy, S. J. Cooke, G. A. Diaz, J. E. Graves, M. Hall, M. Shivji and Y. Swimmer)
IOTC-2024-WPEB20(DP)-INF18	Circle hook effectiveness for the mitigation of sea turtle bycatch and capture of target species in a Brazilian pelagic longline fishery (G. Sales, B. B. Giffoni, F. N. Fiedler, V. G. Azevedo, J. E. Kotas, Y. Swimmer and L. Bugoni)
IOTC-2024-WPEB20(DP)-INF19	Effects of 17/0 circle hooks and bait on sea turtles bycatch in a Southern Atlantic swordfish longline fishery (M. N. Santos, R. Coelho, J. Fernandez-Carvalho and S. Amorim)
IOTC-2024-WPEB20(DP)-INF20	Individual and fleetwide bycatch thresholds in regional fisheries management frameworks (E. Gilman, M. Chaloupka, L. Bellquist, H. Bowlby and N. Taylor)
IOTC-2024-WPEB20(DP)-INF21	Phylogeny explains capture mortality of sharks and rays in pelagic longline fisheries: A global meta-analytic synthesis (E. Gilman, M. Chaloupka, L. R. Benaka, H. Bowlby, M. Fitchett, M. Kaiser and M. Musyl)

Document	**Title**
IOTC-2024-WPEB20(DP)-INF22	Global governance guard rails for sharks: Progress towards implementing the United Nations international plan of action (E. Gilman, M. Chaloupka, N. Taylor, L. Nelson, K. Friedman and H. Murua)
IOTC-2024-WPEB20(DP)-INF23	Postrelease survival, vertical and horizontal movements, and thermal habitats of five species of pelagic sharks in the Central Pacific Ocean (M. Musyl, R. Brill, D. S. Curran, N. M. Fragoso and L. McNaughton)
IOTC-2024-WPEB20(DP)-INF24	Modeling bycatch abundance in tropical tuna purse seine fisheries on floating objects using the Δ method (A. Dumont, A. Duparc, P. S. Sabarros, D. M. Kaplan)
IOTC-2024-WPEB20(DP)-INF25	Draft terms of reference for a consultancy to develop a research prioritisation plan for scalloped hammerhead shark
IOTC-2024-WPEB20(DP)-INF26	Assessing the effects of hook, bait and leader type as potential mitigation measures to reduce bycatch and mortality rates of shortfin mako: a meta-analysis with comparisons for target, bycatch and vulnerable fauna interactions (D. Rosa, C. C. Santos and R. Coelho)
IOTC-2018-WPEB14-37	A preliminary stock assessment for the shortfin mako shark in the Indian Ocean using data-limited approaches (T. Brunel, R. Coelho, G. Merino, J. Ortiz de Urbina, D. Rosa, C. Santos, H. Murua, P. Bach, S. Saber and D. Macias)
IOTC-2024-WPEB20(DP)-INF27	Future Stock Projections of Oceanic Whitetip Sharks in the Western and Central Pacific Ocean (Update on Project 101) (K. Bigelow, J. Rice and F. Carvalho)

APPENDIX IV
THE STANDING OF A RANGE OF INFORMATION RECEIVED BY THE IOTC SECRETARIAT FOR SHORTFIN MAKO

Extract from IOTC–2024–WPEB20(DP)–03.
(Appendix references in this Appendix, refer only to those contained in this appendix)

Overall bycatch levels & trends

Reported retained catches of species of interest to the WPEB are largely dominated by sharks with estimates from some artisanal fisheries dating back to the early 1950s (**Fig. A1**). Overall levels and quality of reported catches of shark and ray species have increased over time due to the development and expansion of tuna and tuna-like fisheries across the Indian Ocean, the increased reporting requirements for some sensitive species such as thresher and oceanic whitetip sharks, and the implementation of retention bans in some fisheries. In 2022, the total retained catches of sharks reported to the Secretariat amounted to 76944 t, with rays representing a very small component of the reported bycatch at 1518t, i.e., about 2% of total reported shark and ray catches for the same year (**Fig. A1**).

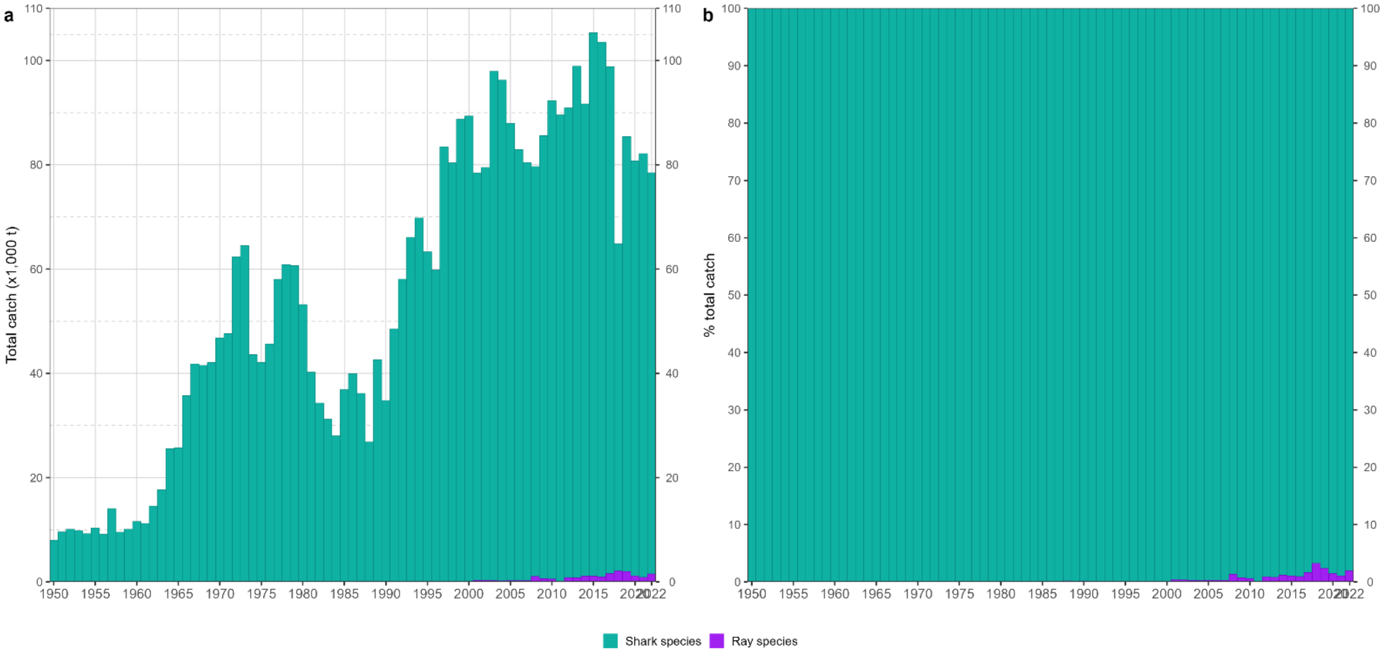

Figure A 1: Annual time series of cumulative nominal absolute (a) and relative (b) catches (metric tons; t) of all IOTC tuna and tuna-like species by species category for the period 1950-2022

Very few fleets reported catches of sharks and rays in the 1950s, but the number of reporting fleets has increased over time (**Fig. A2**). Total reported catches of sharks and rays have also increased over time, reaching a recent peak of over 100,000 t in 2015-2016. Since then, retained catches have decreased below 80,000 t in 2022.

In 2018, reported catches of sharks and rays declined significantly when compared with 2017 and 2019 levels, mostly due to a complete disappearance of catches of aggregated shark species previously reported by India (that were not replaced by detailed catches by species) as well as to marked decreases in reported shark catches from other CPCs (Mozambique and Indonesia) which in some cases are thought to indicate reporting issues rather than a true reduction in catch levels.

In the case of mako shark species, catches have been dominated by artisanal fisheries until the early 1990s (**Fig. A3**). With the expansion of industrial fisheries, there was a steady increase to a peak of around 5,000 t in 2016, after which the trend reversed, with catches falling by around 50% in the last year.

In 2021, Japan provided a detailed species breakdown of retained shark catches from their deep-freezing longline fisheries for the years 1964-1993, which replaces the original re-estimates made by the IOTC Secretariat for the period concerned (Kai 2021). The revised Japanese catch series is now an integral part of the IOTC databases and is disseminated through the nominal catch data set prepared for the meeting.

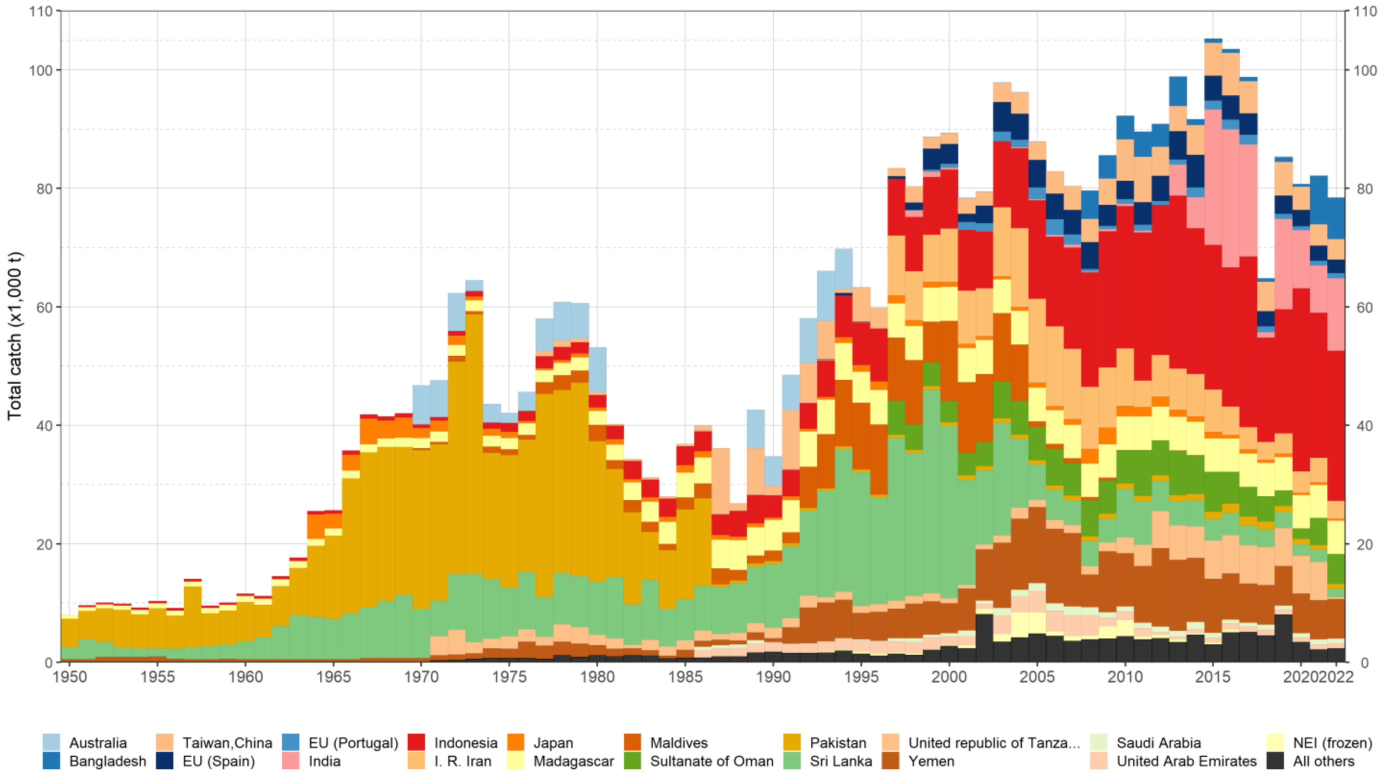

Figure A 2: Annual time series of nominal catches (metric tons; t) of sharks and rays by fleet during 1950-2022

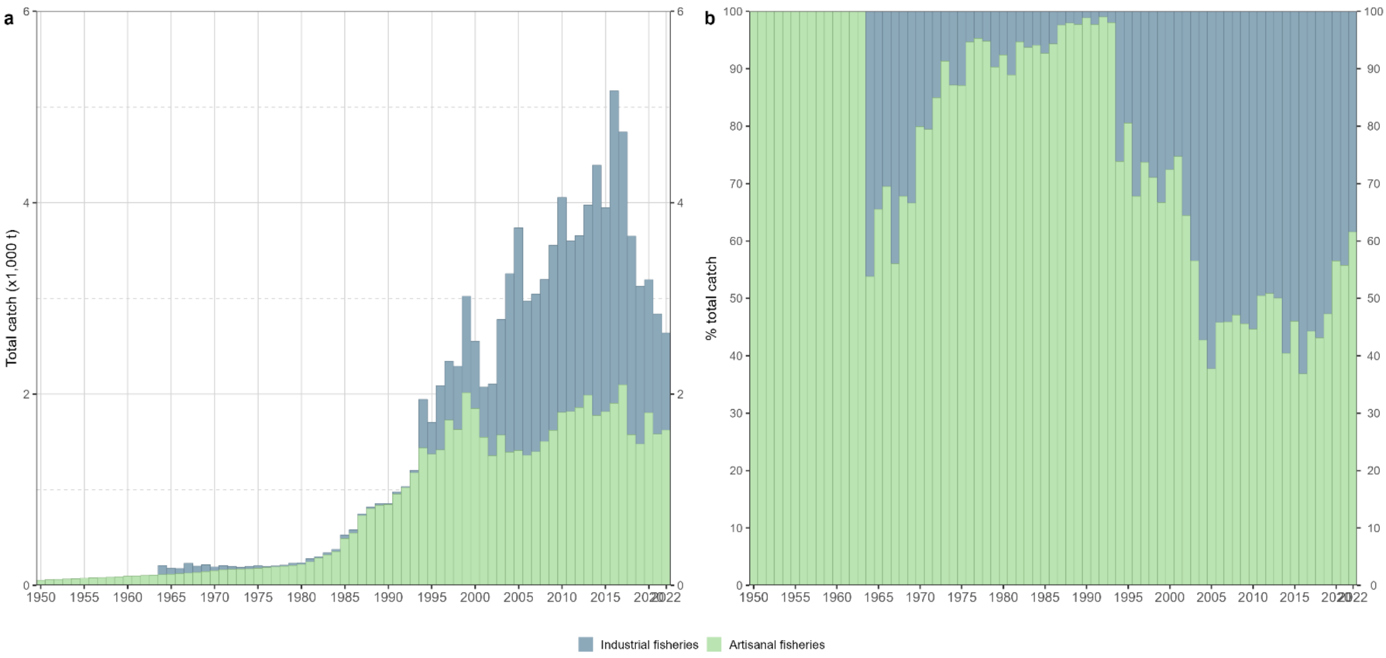

Figure A 3: Annual cumulative absolute (a) and relative (b) time series of retained catches (metric tonnes; t) of mako shark species by fishery type for the period 1950-2022.

Sharks and rays

Levels of reported retained catches for sharks and rays strongly vary with fishing gear and over time but are generally increasing, contrary to the trend for mako shark species. Shortfin mako shark received the highest vulnerability ranking (No. 1) for longline gear in the ecological risk assessment (ERA) conducted for the Indian Ocean by the WPEB and SC in 2018 because it was characterized as one of the least productive shark species and with a high susceptibility to longline gear (Murua et al., 2018). Catches of mako shark species have increased sharply from early 1990s to mid-2010s, period in which longline and line fisheries accounted for more than 70% of total catches of these species (**Fig. A4**).

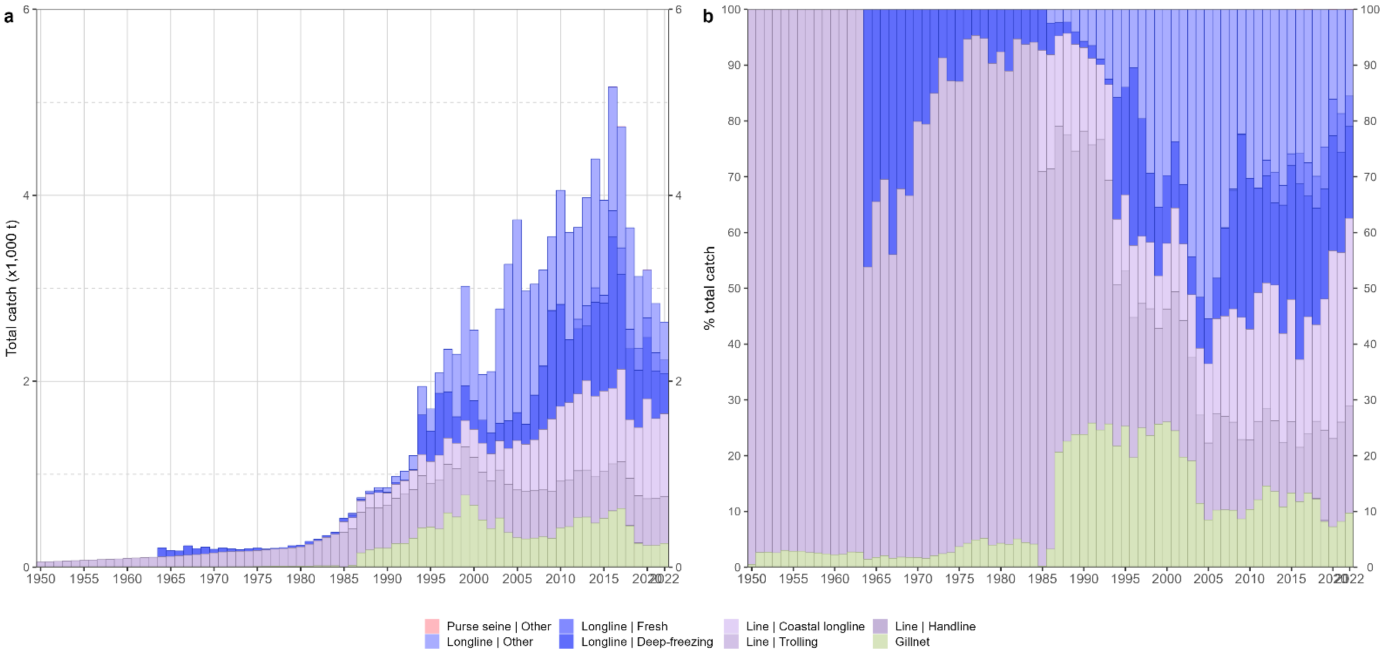

Figure A 4: Annual time series of nominal absolute (a) and relative (b) catches (metric tons; t) of sharks and rays by fishery for the period 1950-2022. 'Other' corresponds to all other fisheries combined

Longfin makos are poorly recorded in the Indian Ocean and catches reported to the Secretariat in recent years represent less than 1% of mako species (**Fig. A5**). However, the percentage of reported catches of mako species aggregated remains considerable. Between the two species, shortfin mako dominates the catches reported by industrial fisheries, although it varies from year to year, accounting for between 50% and 70% of catches of these species. For artisanal fisheries around 80% of catches reported for mako species are aggregated.

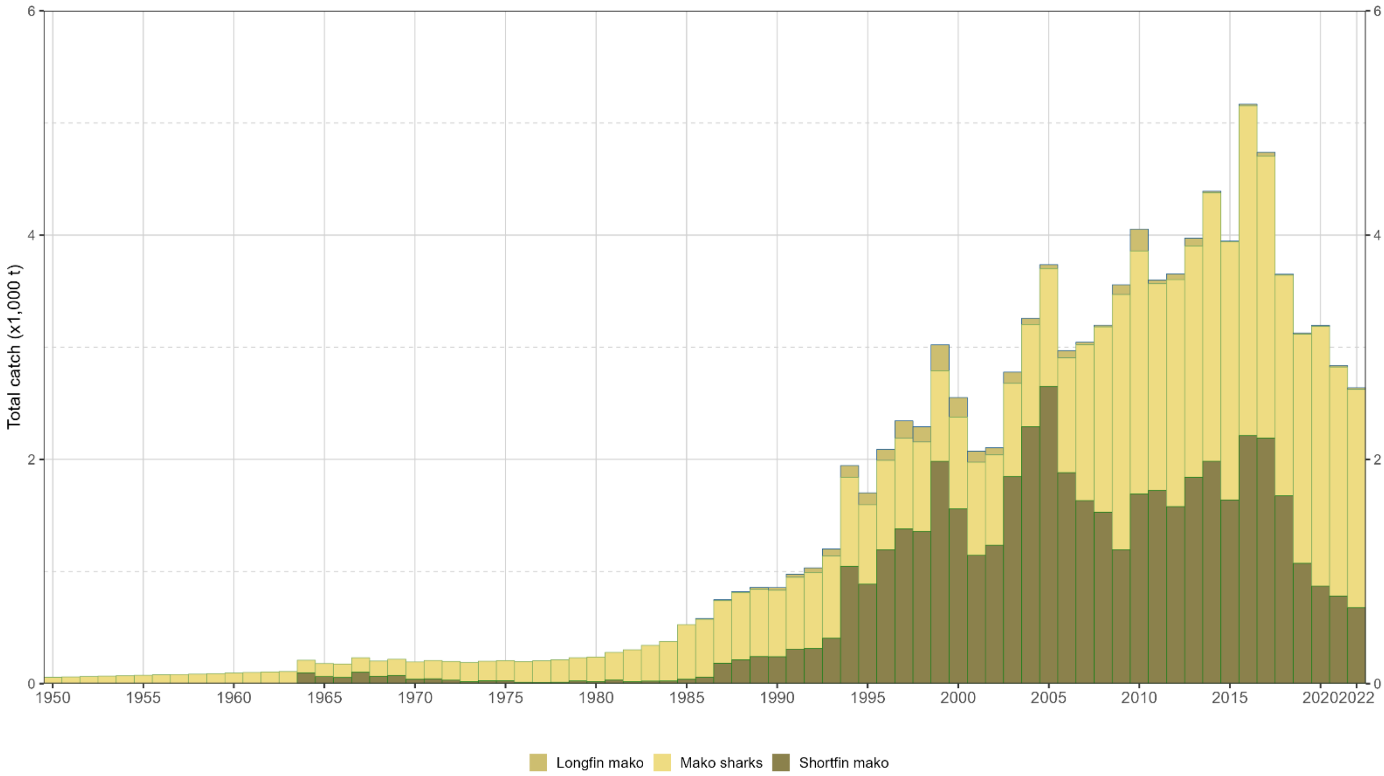

Figure A 5: Annual time series of retained catches (metric tonnes; t) of mako sharks by species for the period 1950-2022.

Recent fishery features (2018-2022)

Most tuna and tuna-like fisheries of the Indian Ocean show a decline in reported catches of mako sharks in recent years (**Table A1**) except for Indonesia line fishery with a smooth increase trend (**Fig. A6**). The main fleets accounting with 74% of total catches of mako shark species are Indonesia, Taiwan, province of China, Madagascar and EU, Spain (**Fig. A7**). Nevertheless, is important to note that data for Madagascar are repeated for the coastal fisheries in recent years. Furthermore, revisions to Pakistani gillnet catches from 1987 onwards, endorsed by the SC in December 2019, introduced a mean annual decrease of around 17,000 t in total catches of shark species during the concerned period when compared to previously available official data reported by the country.

Table A1: Retained catches (metric tonnes; t) of mako sharks by year and fishery for the period 2013 -2022.

Fishery	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Purse seine | Other	0	0	0	4	1	0	0	1	0	0
Longline | Other	1,163	1,387	1,022	1,332	1,303	1,093	771	513	530	410
Longline | Fresh	217	154	84	282	283	208	237	211	196	144
Longline | Deep-freezing	585	1,010	947	1,625	1,024	763	617	659	511	434
Line | Coastal longline	965	861	866	814	992	632	735	1,075	862	889
Line | Trolling	505	505	505	505	505	505	505	505	506	505
Line | Handline	0	0	0	1	0	6	7	0	0	0
Gillnet	539	474	523	605	631	444	256	232	233	256
Total	3,974	4,391	3,947	5,168	4,739	3,651	3,127	3,195	2,837	2,638

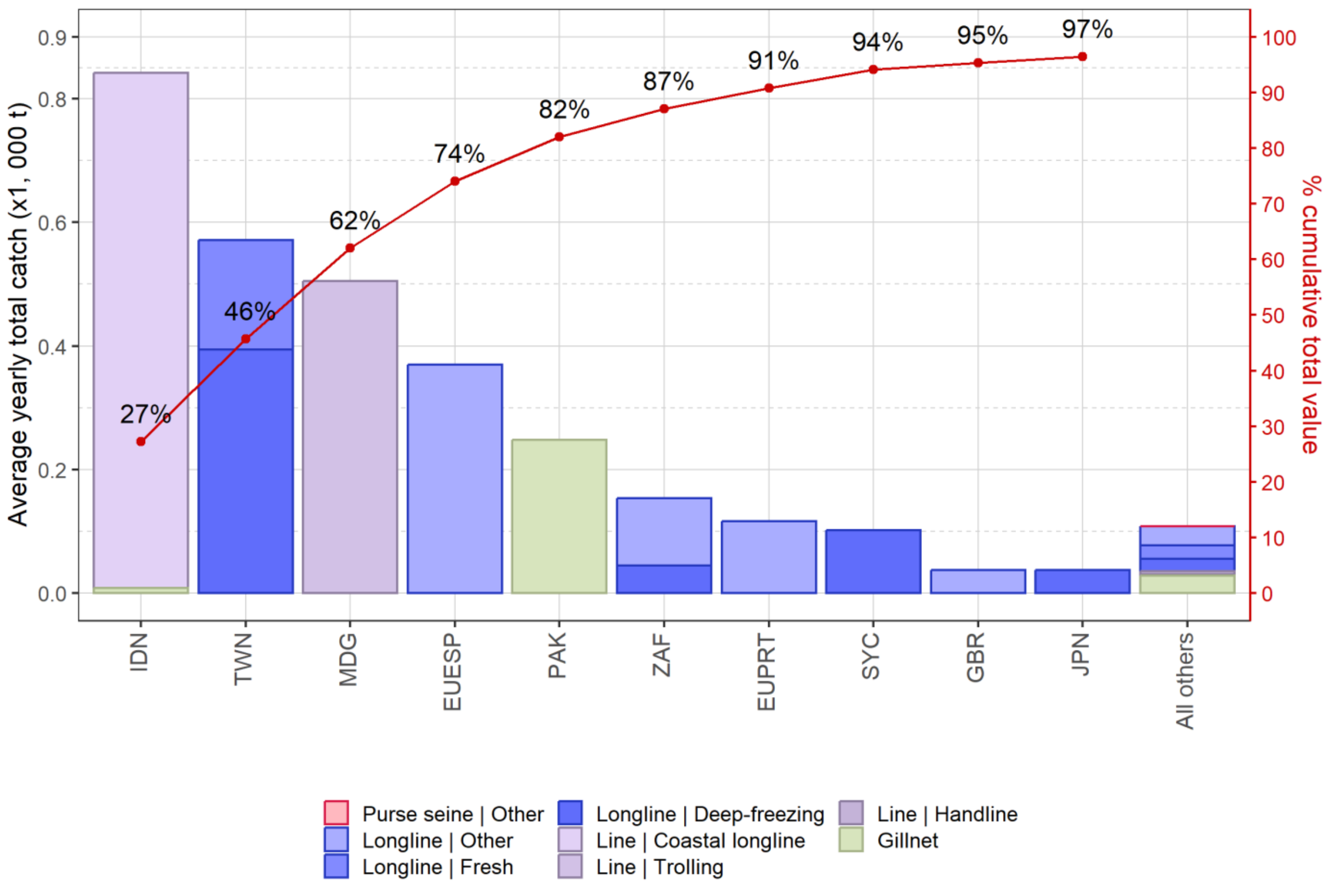

Figure A 6: Mean annual retained catches (metric tonnes; t) of mako sharks 2018-2022 by fishery and fleet ordered according to the importance of catches. The solid line indicates the cumulative percentage of the total combined catches of the species for the fleets concerned.

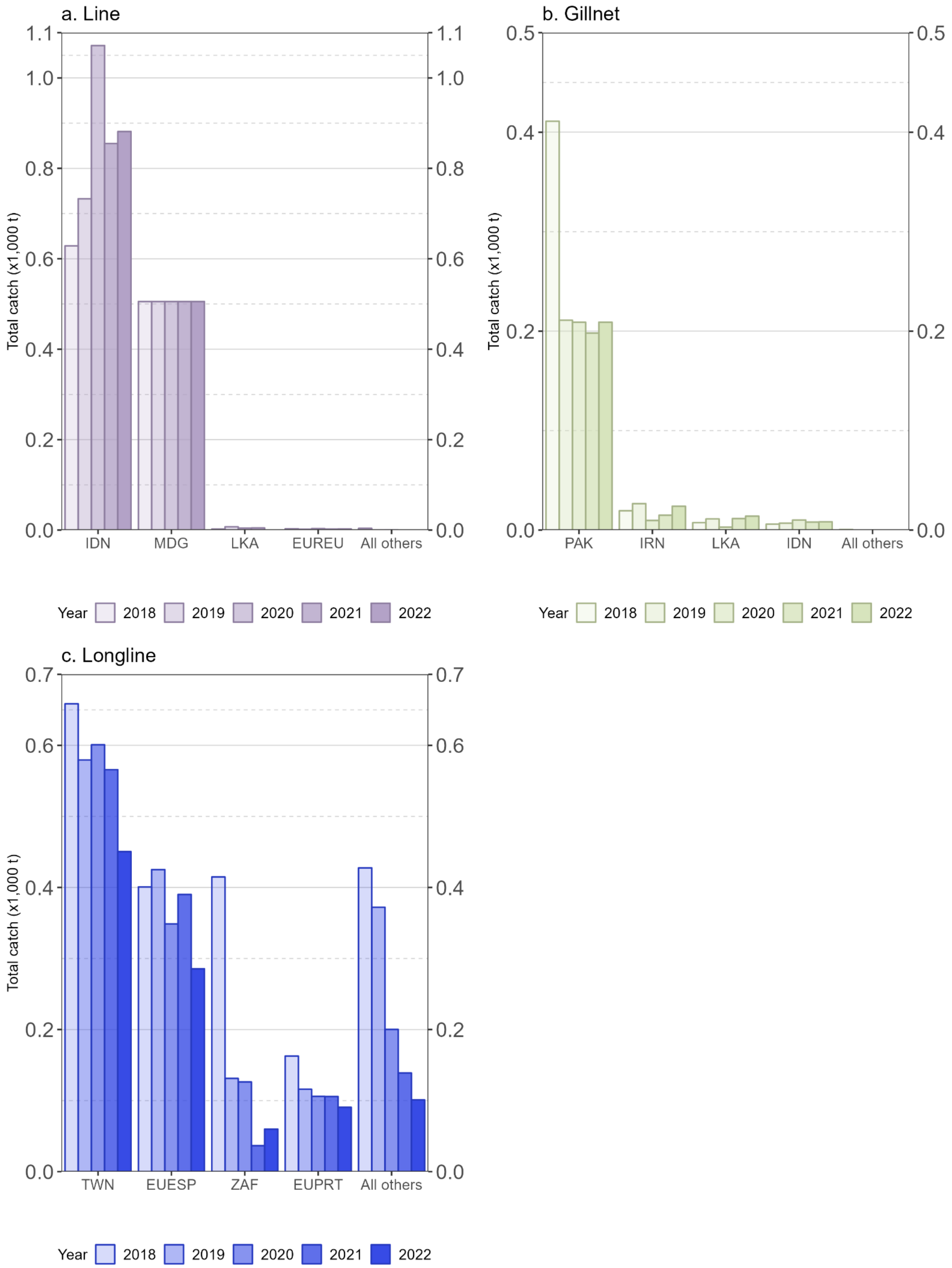

Figure A 7: Annual catch trends (metric tonnes; t) of mako shark species by fishery group between for the period 2018-2022

APPENDIX V

CONSOLIDATED RECOMMENDATIONS OF THE 20TH SESSION OF THE WORKING PARTY ON ECOSYSTEMS AND BYCATCH

Note: Appendix references refer to the Report of the 20th Session of the Working Party on Ecosystems and Bycatch Data Preparatory meeting report (IOTC–2024–WPEB20(DP)–R)

Section 3. Longline bycatch mitigation workshop

Section 3.1.1 All taxa

WPEB20(DP).01 (para. 26) The WPEB **RECOMMENDED** that the SC request that CPCs carry out training with fishers to ensure that they are aware of the best practices for handling and release of sharks including the minimisation of trailing gears. The WPEB **REQUESTED** that CPCs provide information on how they are monitoring the implementation of these best practices in the form of training materials, number of training/handling workshops etc.

Section 3.2 Leader type/shark lines

WPEB20(DP).02 (para. 46) The WPEB **RECOMMENDED** that the collection of information on leader material type should be made mandatory under the Regional Observer Scheme Minimum Data Requirements and reported to the Secretariat. The WPEB also **RECOMMENDED** that these data collected under the ROS are strictly used for scientific purposes in research.

WPEB20(DP).03 (para. 47) The WPEB **RECOMMENDED** that mitigation surveys should be developed by CPCs in the IOTC areas and with different gear types and configurations to assess mitigation measures such as the type of leaders and other factors to be tested and implemented. The WPEB **NOTED** that the increase of bite offs by the prohibition of wire leaders could lead to the decrease in the basic information necessary for stock assessment or monitoring abundance of shark species. **ACKNOWLEDGING** the importance of these data, the WPEB **SUGGESTED** that bite offs are recorded by observers to further inform bycatch estimates.

Section 3.3 Hook type

WPEB20(DP).04 (para. 57) The WPEB **NOTED** that some studies using large circle hook have reduced injury to sharks by increasing rates of mouth hooking. The WPEB further **NOTED** that decreasing injury rates associated with large circle hooks results in a reduction in at-vessel mortality for some species. Circle hooks use also reduces observed retention of some vulnerable taxa, such as sea turtles and marlins. The WPEB also **NOTED** that some experimental sea-trials from other Oceans have reported increases in observed retention of some shark species when using large circle hooks, especially blue shark and crocodile shark, and that the results from a global meta-analysis and multiple experimental sea-trials have found that the use of large circle hooks reduces retention of target species like swordfish. The WPEB further **NOTED** that there are still many information gaps regarding their effectiveness for sharks, and the number of case studies on deep-setting operations and effect of hook size is still too few and there is also concern that circle hooks may increase shark catches, the WPEB **RECOMMENDED** continued accumulation of information on circle hook effectiveness including in deep-setting operations.

Section 3.5 Workshop summary

WPEB20(DP).05 (para. 74) The WPEB **NOTED** on the basis of its review of global research that a prohibition on the use of wire leaders and shark lines by longline and other fisheries operating in the IOTC would likely result in a reduction in both the observed catch and the fishing mortality of shark species. The WPEB NOTED supporting evidence from a range of research studies as seen in Table 2 (in Appendix VI). The WPEB **NOTED** that these results are likely to be similar in the Indian Ocean. Based on these studies and on the basis of taking the precautionary approach, and consistent with existing SC advice on the need to reduce fishing mortality for shortfin mako, oceanic whitetip and silky shark, the WPEB **RECOMMENDED** that additional mitigation measures such as, but not limited to, the non-use of wire leaders and shark lines should be implemented. The WPEB **AGREED** to further discuss this issue at the WPEB Assessment meeting in September.

Section 7. Review of the draft, and adoption of the Report of the 20th Session of the WPEB (Data Preparatory)

WPEB20(DP).06 (para. 133) The WPEB **RECOMMENDED** that the WPEB20(AS) consider the consolidated set of recommendations arising from WPEB20(DP), provided at Appendix V.

A summary of the stock status for some of the most commonly caught shark species caught in association with IOTC fisheries for tuna and tuna-like species is provided in Table 1

APPENDIX VI

SUMMARY OF THE BYCATCH MITIGATION WORKSHOP

The WPEB **NOTED** on the basis of its review of global research that a prohibition on the use of wire leaders and shark lines by longline and other fisheries operating in the IOTC would likely result in a reduction in both the observed catch and the fishing mortality of shark species. The WPEB **NOTED** supporting evidence from a range of research studies as seen in Table 2.

Table 2: Studies examined during the WPEB mitigation workshop

Species	Wire leaders			Shark lines
	Meta-analysis	Experimental Fishing trials	Observer data modelling	Observer data modelling
Blue shark	Santos et al 2022 (Atlantic and Indian Oceans)	Scott et al 2022 (Pacific Ocean); Afonso et al 2012 (Atlantic Ocean) ; Santos et al 2017 (Indian Ocean)		
Shortfin mako		Scott et al 2022 (Pacific Ocean); Vega and Licandeo, 2009 (Pacific Ocean)	Bigelow and Carvalho, 2021 (Pacific)*(check)	
Oceanic whitetip		Ward et al 2008 (Pacific Ocean)	Harley et al 2015; Bigelow and Carvalho 2022 (Pacific Ocean)	Harley et al 2015; Bigelow and Carvalho 2022; Bromhead et al 2012 (Pacific Ocean)
Silky shark			Harley et al 2015; Bigelow and Carvalho 2022 (Pacific Ocean)	Harley et al 2015; Bigelow and Carvalho 2022; Bromhead et al 2012 (Pacific Ocean)
Pelagic thresher		Ward et al 2008 (Pacific Ocean)		Bromhead et al 2012 (Pacific Ocean)
Sharks grouped		Ward et al 2008 (Pacific Ocean); Scott et al 2022 (Pacific Ocean); Afonso et al 2012 (Atlantic Ocean); Vega and Licandeo, 2009 (Pacific Ocean); Santos et al 2017 (Indian Ocean);		

The WPEB **NOTED** that these results are likely to be similar in the Indian Ocean. Based on these studies and on the basis of taking the precautionary approach, and consistent with existing SC advice on the need to reduce fishing mortality for shortfin mako, oceanic whitetip and silky shark, the WPEB **RECOMMENDED** that additional mitigation measures such as, but not limited to, the non-use of wire leaders and shark lines should be implemented. The WPEB **AGREED** to further discuss this issue at the WPEB Assessment meeting in September.

A summary of the pros and cons of mitigation measures discussed during the workshop can be found in **Table A2**.

Table A2. Summary of the pros and cons of mitigation measures discussed during the workshop

	General conclusions	Pros	Cons
Banning wire leaders and shark lines	A prohibition on the use of shark lines and wire leader would likely strengthen current IOTC shark conservation measures by reducing initial capture rates (shark line prohibition) and increase escapement post capture (bite-offs from wire leader prohibition), resulting in reduced retention and likely overall mortality.	Monofilament leaders result in significantly lower at-vessel catch rates of pelagic sharks: - Blue shark (meta-analysis IOTC-2024-WPEB20(DP)-04) - Shortfin mako, pelagic thresher and oceanic whitetip shark from experimental fishing trials/surveys (review compiled in IOTC-2024-WPEB20(DP)-11). - Species combined: In a paired trial in the US deep-set longline fishery shark catch rates were 41% higher on wire leaders versus monofilament leaders. At-vessel mortality rates of sharks were also significantly higher on wire leaders versus mono (IOTC-2024-WPEB20(DP)-07) Many studies reviewed found that target bony fish species at-vessel catch rates were the same or significantly higher on monofilament leaders (IOTC-2024-WPEB20(DP)-04). Prohibiting the use of shark lines can significantly reduce the mortality of some shark species, in situations where the use of shark lines is common. Prohibiting shark lines would also prevent increases in future mortality as a result of an increase in the use of shark lines which may occur if they were not prohibited.	The degree to which a reduction in shark mortality would occur depends on the current level of use of these gears in IOTC, which is uncertain and requires further investigation. Some gear configurations may take over a year to break down (i.e. stainless hooks with monofilament leaders (IOTC-2024-WPEB20(DP)-07). Thus, recommendations to reduce trailing gear will improve post release survival probabilities Some safety concerns over other leader materials which may be more prone to snap than wire leader causing crew injuries. The increase of bite offs by the prohibition of wire leaders could lead to the decrease in the basic information necessary for stock assessment or monitoring abundance of shark species.

		Predictive modelling research conducted in the Western and Central Pacific determined that banning both shark lines and wire traces in the WCPFC Area had the potential to reduce fishing mortality by 30.8% and 40.5% for silky sharks and oceanic whitetip sharks respectively in that region (IOTC-2024-WPEB20(DP)-10). At vessel mortality rates were also significantly higher on wire leaders compared to monofilament leaders (IOTC-2024-WPEB20(DP)-07)	
Using large circle hooks	A recommendation to use large circle hooks has the potential to reduce the mortality of sea turtles and sharks as it minimises internal organ damage caused by hook swallowing. In the case of sea turtles, these hooks reduce retention rates. For sharks, circle hooks reduce at-vessel and post-release mortality by reducing injury due to increased rates of mouth hooking, but can lead to increases in shark retention/catch rates. Circle hooks would also reduce the catch of swordfish, the main target species of shallow pelagic longlines, and would likely increase retention rates of some shark species	Circle hooks reduce sea turtle retention rates (meta-analysis IOTC-2024-WPEB20(DP)-04) Have been shown to result in significantly lower rates of deep hooking than J-hooks, reducing injury by increasing rates of mouth hooking (review in IOTC-2024-WPEB20(DP)-12). The decreasing injury rates associated with large circle hooks results in a reduction in at-vessel and post-release mortality for numerous species (IOTC-2024-WPEB20(DP)-12 & IOTC-2024-WPEB20(DP)-15)	Circle hooks have been shown to a decrease swordfish retention, the main target species of shallow-set pelagic longlines (IOTC-2024-WPEB20(DP)-04). Circle hooks can lead to increase in shark retention/catch rates (IOTC-2024-WPEB20(DP)-05, IOTC-2024-WPEB20(DP)-INF12, IOTC-2024-WPEB20(DP)-INF18)
Ensuring best handling practices	Implementing best practices for handling and release of sharks significantly decrease post-release mortality, consisting of an effective mitigation measure for species with low at-vessel-mortality. The best handling and release practices for sharks captured in longline fisheries include leaving the sharks the water for gear removal (line cutting) and removing as much trailing gear as	Sharks released in good condition and without trailing fishing gear had the highest rates of survival. The study also showed that fisher behavior can have a significant impact on pelagic shark post-release mortality. (IOTC-2024-WPEB20(DP)-15).	

	possible. Fishers should also ensure that weights are removed from the animals prior to release.		
Use of finfish bait	The use of finfish instead of squid bait to mitigate bycatch is not a straightforward measure because the effects of the different baits is complex and conflicting between species. It reduces bycatch and mortality of sea turtles but may increase the catch of unwanted species including sharks, while reducing catches of some target species.	Fish bait significantly reduces catch per unit of effort (CPUE), haulback mortality, and mortality per unit effort of (MPUE) of loggerhead turtles (IOTC-2024-WPEB20(DP)-13)	Replacing squid with fish results in a 4 times increase in shortfin mako MPUE (IOTC-2024-WPEB20(DP)-13). The at-haulback mortality rate for blue shark was also significantly higher with fish bait (IOTC-2024-WPEB20(DP)-04). May increase catches of other species such as dolphinfish and escolar (IOTC-2024-WPEB20(DP)-13). May reduce catches of target species such as bigeye and blue shark (IOTC-2024-WPEB20(DP)-13)
Reducing soak time	Reducing the soak time is thought to decrease the haulback mortality of many species but may decrease this for target species such as bigeye.	Reduced mortality of some tuna, swordfish and sharks with reduced soak time (IOTC-2024-WPEB20(DP)-13)	May decrease haulback mortality for bigeye tuna but this is not clear (IOTC-2024-WPEB20(DP)-13)