DRAFT REPORT: Developing robust multi-taxa bycatch mitigation measures for gillnets/drift nets in the Indian Ocean

First Driftnet/gillnet Multi-taxa Bycatch Mitigation Workshop

29-31 August 2022

Zoom (virtual)

Executive Summary

The World Wide Fund for Nature (WWF) held a technical workshop on multi-taxa bycatch mitigation focusing on drift/gillnets in collaboration with the Indian Ocean Tuna Commission from 29 – 31 August 2022, virtually via zoom platform. The workshop was attended by 86 participants on the first day, 76 on the second and 75 on the third day. The workshop had representation from independent experts, national country scientists, NGOs, IGOs, and civil society organisations from the Indian Ocean and other Oceans. The workshop was organised as a direct result of discussions held at the Indian Ocean Tuna Commission (IOTC)'s 17th Working Party on Ecosystem and Bycatch for developing a proposal for a gillnet focused multi-taxa bycatch mitigation workshop which was endorsed by the IOTC – Scientific Committee (SC) in December 2021. The objective of the workshop was to undertake an evaluation of existing mitigation measures for their sustainability to reduce bycatch of multiple taxa in drift/gillnet fisheries (gears) and to scope and assess the feasibility of novel or experimental measures being developed for this purpose in the Indian Ocean. One of the secondary objectives of the workshop was to better understand the nature of using artificial lights as a potential mitigation tool considering that the IOTC has banned their use, which may be hampering efforts to reduce the ecological impacts of the gillnet fishery.

The workshop was designed to understand the current state of information and knowledge available on the extent of bycatch in drift/gillnet fisheries in the Indian Ocean. The agenda was designed to review the existing information and evaluate the effectiveness of the conservation and management measures that have been adopted by the IOTC. An in-depth discussion was held with regards to improving the data collection and reliability from gillnet fisheries considering that the majority of these vessels are small-scale and/or artisanal in nature. The IOTC Secretariat provided a snapshot of the quality of data available, such as catch-and-effort, size frequency and discards. It was discussed that the IOTC is responsible for the management of tuna and tuna-like species (16 species) across the Indian Ocean.

One of the key challenges associated with gillnet fisheries is their large contribution to the overall catch contribution of tuna and tuna-like species as gillnets account for almost 30% of overall catches of which a large majority (more than 75%) are taken on what are considered to be artisanal vessels. There is a major issue with data paucity and reliability from these fisheries, especially for bycatch species. According to the IOTC, around 600,000 tonnes of tuna are caught by gillnets alone in the Indian Ocean and this gear has the highest impact on the ocean ecology, accounting for about 40% of sharks and ray catches, mostly associated with Pakistan, I.R. Iran, India, Sri Lanka and Indonesia. In several of these countries, the gillnet fleets are considered to be of either small-scale or artisanal nature and fish in coastal areas. According to IOTC catch statistics, around 90% of the catch of sharks and rays are taken by artisanal vessels, and several IOTC conservation and management measures have limited application to these vessels which is one of the reasons why they remain data-deficient.

The workshop highlighted that bycatch in gillnets is of greatest concern in terms of impacts on cetaceans and other marine megafauna (such as shark, rays, sea turtle) populations (Lewison et al., 2004; Read et al., 2006; Reeves et al., 2013). Drift gillnets are used by around 21 countries in the Indian Ocean and some of the countries have vessels which are non-compliant with UNGA resolution (46/215) banning high seas gill/driftnets >2.5 km (Aranda, 2018). The IOTC adopted the UNGA resolution and recently extended the scope of the moratorium on large-scale drift/gillnets on the high seas to cover the IOTC's entire area of competence (Resolution 17/07) from January 2022 (IOTC, 2017).

In the Indian Ocean, there are also growing concerns about the magnitude of marine mammal bycatch in both coastal (Kiszka et al., 2009; Temple et al., 2018) and offshore gillnet fisheries (Anderson et al., 2020). Moreover, in gillnet fisheries, sharks and rays also have a very high mortality rate (Bettis, 2017) which ranges from 70% to 93% for some species (Jordan et al., 2013; Cosandey-Godin et al. 2015). Bycatch in gillnet fisheries has also been implicated as a significant source of mortality and subsequent population declines for numerous sea turtle species (Wang et al., 2010; Chan et al.1988, Chan & Liew 1996, Lewison et al. 2004, Lum 2006, Lewison & Crowder 2007, Peckham et al. 2007). Coastal trawl and gillnet fisheries are considered the biggest contributors to sea turtle bycatch, although uncertainty estimates for different gear categories and locations are very high (Abdulqader et al., 2017; Burgess et al., 2018). Lastly, the seabird bycatch in drift/gillnet fisheries is not well studied and constitutes a significant information gap.

The workshop allowed for robust discussions on evaluating a suite of options and diving deeper into mitigation strategies, allowing for an exchange of information on trials being undertaken in other parts of the world but primarily focused on gillnets, whether small-scale or large-scale in nature. Among these, experts working on gillnet illumination, different gear settings (surface, sub-surface), use of acoustic deterrents, magnetic or electric fields, area-based measures among others which have been fairly successful in minimising the bycatch of endangered, threatened and protected species were invited to the workshop to share their work. It has been generally perceived that while some measures may work well, some mitigation measures might have negative impact on target species and may be subject to having ecological impacts by increasing the catch of other non-target species as well as target species which may already be overfished such as yellowfin tuna. The workshop also noted that some mitigation methods may have a limitation either due to their experimental design, their nature and/or to an extent where they may be insufficient to halt population declines.

In such cases, the discussion also allowed for a constructive exchange on the use of mitigation methods and their social implications, economic incentives required for adoption or scaling and the consideration of elements, such as spending additional time, for which there was general agreement that it will be necessary to explore whether these measures will remain to be socially acceptable, economically viable and ecologically sustainable. In order to build the narrative for mitigation methodologies to work, the enabling conditions require strengthened data collection and reporting, with sufficient accuracy for it to be able to provide fine-scale resolution in order to develop indices of abundance from ensuring human on board observer coverage, as well as alternate methods including the use of remote electronic monitoring or other.

The workshop participants noted that there is a drastic need to improve data from gillnet fisheries for both target and non-target species, however, since the workshop focused on bycatch, it was largely agreed that the best way of collecting data from gillnet fisheries (whether small or large-scale) is to focus on scientific observers. While this was not opposed by the participants, several difficulties and

challenges were noted relating to facilitating independent observer coverage as the situation or conditions on small-scale vessels could possibly lead to observer security and health risks. The gaps on data collection were also noted as there were few guidelines present for data collection mechanisms for smaller or artisanal vessels. The reliance on data collection via port sampling for small or artisanal vessels was observed to be too high, which leads to issues such as providing incomplete information, in particular for discards at sea, or create complexities for species which landing or retention is prohibited due to conservation and management measures agreed by the IOTC members. In addition, workshop participants also recognized that there was no requirement for having onboard human observers for vessels which are less than 24 m which may be critical to solving the solution, however without proper data collection protocols for bycatch species the small-scale and artisanal fishers may not be able to implement such a system. Having said that, some scientists encouraged the need to explore measures which are alternatives to human observers for such vessels and fisheries, where continued data deficiency has led to creating a very challenging situation in terms of management. A brief update on evaluating such methods was provided by the IOTC Secretariat where workshop participants were made aware of such work being commissioned to undertake a feasibility study on alternative data collection and improvement mechanisms.

Furthermore, workshop participants were also made aware of the use of different gear settings in gillnet/driftnet fisheries. The participants were intrigued by the use of sub-surface gear setting in Pakistan and its potential effectiveness in reducing bycatch of several species. The workshop participants noted the presentation from the author which explained that 'no one size fits all' and bycatch mitigation solutions would need to be tailored to different situations and might require coupling of different technological solutions in order to have a multi-species approach. Moreover, workshop participants noted the engagement of fishers/citizen science based approach for improving data, identifying bycatch species, while being able to also measure length and weight. The engagement of fishers also helped to learn the motivations behind the gear modification i.e. gear setting for gillnets which basically resulted in increase of the target catch, whereas, the subsurface gear setting for bycatch prompted a positive result (i.e. reduced catches). While several fleets started to move towards the use of sub-surface gears, mainly due to the economic incentive from the target catch, it was revealed later due to data analysis, that bycatch of cetaceans, sharks and rays and sea turtles had drastically declined in fishing operations. A closer review of the data and the fishery, while being able to triangulate the information from hand-held digital cameras and fisher interviews, found a major decline in cetacean bycatch. During the course of the workshop, it was noted that the trials undertaken in Peru and/or South America of sub-surface gears in gillnet fisheries were observed to have reduced catches for target/commercially important stocks unlike the case of Pakistan/Arabian Sea. The experts also identified caveats with the use of subsurface gears, while there may be reduced bycatch of some species, for some deep-diving cetaceans and/or mobulids bycatch rates still seemed higher and this area required further investigation.

The use of artificial lights (a visual deterrent) in gillnet fisheries as a potential bycatch mitigation device was discussed at length and the need to explore this further received support from workshop participants. The work undertaken by experts showcased the effectiveness of using different wavelengths for various ETP species. It was also noted that this work has been undertaken extensively in different regions notably, in the Atlantic and some trials have also successfully been undertaken in South-East Asia. The use of LEDs or artificial lights have been seen to successfully mitigate bycatch of sea turtles, whereas, other trials have focused on mobulids and in some cases cetaceans, however, during the presentation and the work undertaken by NOAA it also showcases positive impacts on reducing bycatch from a multi-species approach, which still requires more attention, and speculated

that results may vary based on oceanographic conditions. However, the workshop noted that use of artificial lights is banned in the Indian Ocean and in order to undertake scientific trials in pelagic or surface fisheries, a request would need to be made to the IOTC Commission to allow this.

The workshop also helped to evaluate and explore options around gear transformation/transition, considering that drift/gillnets have a high ecological impact, it could make sense to move towards a fishing gear with low ecological impact, which in many cases could be either handline or troll for small-scale or artisanal vessels operating in countries which target tuna and tuna-like species primarily with gillnets/driftnets.

In addition, several other areas of work were also discussed at length such as the effectiveness of retention bans along with spatio-temporal closures which may be more effective if there are enough economic incentives for a fishery to completely stop fishing and move towards an alternate source of livelihoods and the potential to explore market-based measures where possible.

The three-day workshop successfully identified a suite of options, which may be ready to test/pilot and/or scale mitigation measures which benefit multi-taxa, with a focus on having improved monitoring and data collection systems in place so information from such trials is robust and scientific and shared at the IOTC's upcoming Working Party on Ecosystems and Bycatch. The recommendations of the workshop are outlined below which were principally agreed by workshop participants to be presented at the IOTC's 18th working party on ecosystem and bycatch:

- Workshop participants **recommended** that a feasibility study of alternative data collection mechanisms should be undertaken, recalling that the SC has tasked the Working Party on Data Collection and Statistics (WPDCS) with this and workshop participants recalled that the WPDCS **recommended** the SC evaluate the validity of alternative data collection tools, and a combination of these (such as the crew as observers, electronic monitoring, and port sampling) as potential alternatives to onboard human observer coverage for the collection of the minimum standard data fields for small-scale vessels.
- Noting the WPEB's concern about the small amount of scientific analysis that has been conducted to assess the effectiveness and impacts of sub-surface gillnet setting, workshop participants **recommended** that the WPEB support trials for sub-surface setting across a wider area and facilitate a request for sharing of data from CPCs such as Indonesia and Sri Lanka where sub-surface gear settings are thought to be in operation already in order to help to fill the current data gaps which are making the WPEB reluctant to facilitate the development of CMMs on this topic.
- Recalling the IWC-BMI **recommendation** to "discuss the possibility of adding information on depth setting to IOTC data reporting forms for gillnet fisheries", and noting that the WPDCS is already considering potential revisions to the IOTC data reporting forms and reference data classifications in order to also include, among other things, provisions to record information on the different types of gillnet settings (i.e., surface vs. sub-surface), workshop participants **recommended** that the WPEB and WPDCS further discuss whether multiple categories of sub-surface setting should be considered, so as to record the different depths at which the net could be set which will help to facilitate the scientific analysis of the impact of different gillnet settings.
- Noting the strong support for the rolling out of future LED trials across the Indian Ocean, workshop participants suggested that a small working group be formed to work on details for these trials. Workshop participants **recommended** that the WPEB seek clarification from the

Commission (through the SC) on whether Resolution 16/07 applies to gillnet fisheries and to scientific studies as the current wording is somewhat ambiguous.

- Workshop participants **recommended** the WPEB to explore the cost-benefit advantages of converting Indian Ocean gillnet fleets into fleets using low impact gears such as handline and/or troll fisheries, and if not possible, to lower impact gears such as longline which is thought to have a low impact on marine mammals. Tuna handline fisheries have a low barrier to entry, have low environmental impacts with negligible bycatch rates and are capable of landing the highest quality 'sashimi grade' tuna which can result in increased earning potential fishers (financial incentivizing for the conversion), whilst also minimising post-harvest losses.
- Noting some of the drawbacks of retention bans which lead to a loss of potentially valuable information from these species, workshop participants **recommended** that the discards data collection mechanisms on board vessels be strengthened and the at-vessel and post-release mortality be studied for those species currently under retention bans.
- Workshop participants noted the need to consider whether to trial measures individually or in combination and **recommended** that the WPEB consider the methods, time costs, experimental design considerations and uncertainties that might make the study of multiple measures challenging if commissioning work to be done in this area
- Noting the work that has been done by the whale entanglement response network to assess and roll out mitigation measures to reduce entanglements which has been achieved through a series of exchanges between different CPCs to demonstrate and learn from different measures, workshop participants **recommended** that a similar approach is taken in order to roll out trials into a range of different areas
- Workshop participants **recommended** that the WPEB continues to support the development of Ecological Risk Assessments, and that Important Marine Mammal Areas, Important Bird Areas, EBSAs and other tools that highlight important or sensitive habitat for ETP species are used and requested financial support in designing measures to reduce bycatch risk.

1.0 Opening of the meeting (Co-Chairs)

The first multi-taxa bycatch mitigation workshop focusing on drift/gillnets was held from 29-31 August 2022 virtually via zoom platform where a total of 86 participants on the first day, 76 on the second day and 75 on the third day, attended the meeting. The workshop agenda, participants list, and meeting documents are provided in this report (see annex I). Mariana Tolotti and Umair Shahid were co-chairs of the meeting/workshop and Lauren Nelson, Paul De Bruyn and Fabio Fiorellato provided technical support from the IOTC Secretariat, in addition to Heidrun Frisch-Nwakanma (IOSEA Marine Turtle MoU/CMS Secretariat), Zeynep, Seren and Viviane Komati (CMS Secretariat), Alexia Morgan (Sustainable Fisheries Partnership), Cecilia Passadore (International Whaling Commission - Bycatch Mitigation Initiative), Iris Ziegler (Shark German Project), Gianna Minton (Independent Scientist) and the experts who provided abstracts for their contributions/presentations.

2.0 Adoption of the Agenda and arrangements for the session (Co-Chairs)

The meeting was opened by the Chairs and the agenda was adopted by Workshop participants. The co-chairs opened the meeting by welcoming the participants and thanked the supporters and collaborators who helped with the organisation, meeting agenda, linking with international experts and for representation of their organisations.

3.0 Introduction of the workshop, background, updates and progress

3.1 Background of the workshop/ToRs and summary of outcomes from WPEB and SC (Co-Chairs)

The Co-chair provided some background on why the multi-taxa gillnet bycatch mitigation workshop had been called noting that it was first discussed during the IOTC's Working Party on Ecosystems and Bycatch (WPEB17) in 2021 where the idea for a workshop focused on gillnets was recommended to the Scientific Committee (SC) for endorsement due to the high levels of bycatch that the gears are thought to be responsible for. The WPEB also discussed the need for detailed discussions about mitigation measures that are being trialled on gillnets such as the use of artificial lights and the sub-surface setting of gears. The SC endorsed the recommendation and a draft set of terms of reference for the workshop.

Workshop participants noted the general objective of the workshop was to evaluate existing mitigation measures for their suitability to reduce bycatch of multiple taxa in drift/gillnet gears, and to scope and assess the feasibility of novel or experimental measures being developed for this purpose in the Indian Ocean. Specific objectives of the workshop were to:

- Provide an overview of the existing and new potential bycatch mitigation measures applicable for drift/gillnet fisheries
- Replicate, scale, strengthen data collection protocol to assess the effectiveness of multi-taxa bycatch mitigation measures in IOTC
- Develop recommendations for the IOTC WPEB to be discussed

3.2 Review of Conservation and Management Measures relevant to bycatch in IOTC fisheries (IOTC-Secretariat)

Workshop participants noted a presentation by the IOTC Secretariat on the Conservation and Management Measures (CMM) currently in place for gillnets and bycatch species in the Indian Ocean.

Workshop participants noted that there is currently only one CMM specifically for gillnets (Resolution 17/07) which prohibits the use of large-scale gillnets (those longer than 2.5km) in the entire IOTC area[1] but also noted that gillnets are included in a number of other measures such as the yellowfin rebuilding CMM (Resolution 19/01) which states that gillnets should be set at a depth of at least 2m below the surface. Workshop participants further noted that gillnets are also subject to the requirements of Resolution 22/04 which states that fleets must cover 5% of their operations per year with observer coverage as well as a range of data recording and reporting requirements.

Workshop participants noted that there are several CMMs relating to bycatch species which include measures such as the prohibition of retention, safe release and data recording requirements. However, many CMMs focus on measures to mitigate the impact of other gears such as purse seine and longlines rather than gillnets and some measures do not apply to the entire IOTC area – several apply only to vessels operating on the high seas. Workshop participants also noted that there are two CMMs relating to bycatch species (relating to whale sharks and all cetaceans) which provide exemptions for reporting of species interactions to the IOTC Secretariat if the CPC in question has national and state legislation for those species highlighting a data gap.

Finally, workshop participants noted Resolution 16/07 which prohibits the use of artificial lights for the purpose of aggregating tuna and tuna-like species, noting that LED lights are being investigated as a potential mitigation measure for bycatch in gillnet fisheries.

Workshop participants noted that there currently are no restrictions on the number of gillnets that vessels are permitted to use and noted that it is thought that some fleets are using this fact as a way to circumvent the maximum length rule. Workshop participants noted that verification of net lengths comes only from self-reporting by CPCs as port inspections are not conducted by the IOTC.

3.3 Effectiveness of bycatch CMMs in IOTC (Sarah Martin)

Workshop participants noted a presentation by Sarah Martin on the effectiveness of bycatch CMMs in the IOTC including the following summary:

“Over the past decade, the IOTC has adopted a number of CMMs, supporting the conservation of vulnerable species interacting with IOTC fisheries as bycatch. The adoption of a CMM represents the first step in management, however, it is vital to subsequently evaluate the effectiveness of these following implementation. The main overall aim of the bycatch CMMs is to minimise the fishery impacts on the species of concern, while the specific objectives are typically three-fold, involving; (i) a direct reduction in mortality (often in the form of a retention banor modification of gear/practices to reduce harmful interactions), (ii) improvements to data quality and(iii) research-related objectives.”

Workshop participants noted several recommendations from this presentation relating to mortality reductions, ecosystem considerations, management approaches and data reporting and research which formed a good framework for discussions later on during the workshop.

Workshop participants noted that there is currently no real definition of artisanal in the IOTC but it is generally taken to mean vessels under 24m in length operating within their EEZ but noted that in

[1] With the exemption of Pakistan who objected to this Resolution and so are bound only by Resolution 12/12 which prohibits the use of large-scale driftnets on the high seas only and so does not apply within the EEZ

reality many fleets do not follow this general definition. Workshop participants noted that FAO is working on this definition alongside small-scale fisheries and the IOTC intends to trial some metrics with FAO and five interested CPCs to help to better categorise this issue which should help to refine future Resolutions.

Workshop participants noted that currently many of the IOTC CMMs focus a lot more on the industrial fleets using purse seine and longline gears rather than artisanal fleets using gears such as gillnets which needs to be addressed. Workshop participants noted that this paper and workshop does not intend to penalise these smaller fleets (noting that there is also still concern about bycatch in industrial fleets) but instead to look at the relative impacts on bycatch across fleets and highlight some gaps. The WPEB and other IOTC working parties have identified the data deficiency in gillnet fleets so wanted to focus on these at this time to try to bring measures more in line with other gears.

3.4 **Guidelines on reducing sea turtle mortality (IOTC Secretariat)**

Workshop participants noted a presentation on the FAO turtle mortality reduction guidelines. Workshop participants noted that guidelines for gillnets included: setting nets perpendicular to shore; use of deterrents such as pingers, shark silhouettes and chemical repellents; net illumination and more visible gear components; anchoring gillnets deeper and with a lower vertical profile; and eliminating tie downs. The guidelines also reviewed several approaches for bycatch mitigation that are applicable across all gear types covering handling and release methods, input controls on effort and output controls on catch and mitigating Abandoned, Lost and Discarded Fishing Gear (ALDFG), the risks of which are thought to be a relatively high risk in gillnet fisheries.

Workshop participants noted that these guidelines are now more than 10 years old and are in need of a major update. This includes revisions to: cover new promising turtle bycatch mitigation methods; account for multispecies conflicts (ideally by integrating these guidelines with those for seabirds and sharks); expand the scope of the guidelines to cover bycatch management measures that are applicable across gear types and taxa; account for key criteria that can be used to assess alternative bycatch management strategies; and to produce Guidelines for Integrated Fisheries Bycatch Management so that any unavoidable conflicts can be accounted for in bycatch management strategy evaluation to result in planned and acceptable trade-offs.

4.0 Information on bycatch, existing gaps and knowledge

4.1 Review of data, information and current existing gaps in knowledge on extent of bycatch and driftnets/gillnets in the Indian Ocean (IOTC-Secretariat)

The Indian Ocean Tuna Commission (IOTC) Secretariat provided an overview of data available at the IOTC Secretariat for Indian Ocean gillnet fisheries. This paper aimed to provide a summary on the retained catches in gillnet fisheries and share the quality of data available, such as catch-and-effort, size frequency and discards. It was discussed that the IOTC is responsible for the management of tuna and tuna-like species (16 species) across the Indian Ocean. Workshop participants noted the provisions for reporting requirements, regional observer schemes, new data collection and bycatch mitigation strategies within the IOTC. It was discussed that since 2010, the IOTC has developed a regional observer scheme (ROS) to monitor tuna fisheries and their bycatch. A five (5%) percent coverage of fishing activities is required by IOTC however, this has been difficult and challenging to implement for small-scale fisheries/artisanal fisheries. While detailed data collection and reporting protocols have been developed and there are pilot projects underway to improve knowledge on tuna

fisheries and their bycatch, to date, there are very few estimates available on the impact of gillnet/driftnet tuna fisheries.

Workshop participants noted that the nominal catches are only available for sharks and rays and interactions with marine turtles, seabirds and cetaceans are mostly reported through the ROS, however, there are limitations as gillnet fleets do not have on-board scientific coverage and there is little or no reporting. Due to the lack of on-board human observer coverage the data is poor and limited and species composition data is missing and largely inaccurate. The level of discards are not adequately reported and made available by CPCs. Although shark and ray data is reported on a frequent basis, it is submitted in an aggregated form which means that in many cases, sharks and rays are reported under one category.

One of the key challenges associated with gillnet fisheries is their large contribution to the overall catch contribution of tuna and tuna -like species. Gillnets comprise almost 30% of overall catches of which a large majority (more than 75%) are considered artisanal vessels. According to the IOTC, around 600,000 tonnes of tuna are caught by gillnets alone in the Indian Ocean and this gear has the highest impact on the ocean ecology, accounting for about 40% of sharks and ray catches, mostly associated with Pakistan, I.R. Iran, India, Sri Lanka and Indonesia. In several of these countries, the gillnet fleets are considered to be of either small-scale or artisanal nature and fish in coastal areas. Based on the IOTC report, around 90% of the catch of sharks and rays is from artisanal vessels, and several IOTC conservation and management measures have limited application to these vessels which is one of the reasons why they remain data-deficient.

Workshop participants noted that sharks and rays are rapidly declining and based on 2020 data sets, the bycatch of rays is assessed to be less than 2% of the total catch where non-aggregated catch data includes devil rays and spinetail mobula in highest proportions. Workshop participants also noted that based on historical catch data, the trends are largely declining for sharks and rays and a dramatic decline has been observed in the last decade (2010-2020).

Moreover, the data sets from gillnet fisheries are noted to be poor for bycatch and historically the key fleets belong for drift/gillnet vessels belonging to I.R. Iran, Pakistan, India, Sri Lanka and Indonesia have not provided fine-scale resolution data and require immediate attention.

Workshop participants noted the uncertainties in data and suggested whether a focused workshop on how bycatch/discard data collection from artisanal or small-scale gillnet fleets could be improved and made easier for a CPCs to report at a sufficient level to make informed decisions. Workshop participants also inquired about the level of information that needs to be made available by a CPC to fulfil reporting requirements and how scientific data collection can be strengthened.

Workshop participants further inquired whether any alternate sources of information or data collection for gillnet fleets is being considered, in addition to exploring alternate methods for vessels less than 24 m to be made part of the ROS reporting requirements. It was further noted that vessels less than 24 m do not have adequate room and facilities for having additional members on board, i.e. human observer and if alternate data collection methods are applied, for instance, skipper or crew based reporting systems, also known as improved logbook data, at current they are not considered as scientific or independant and therefore do not meet the requirements of the ROS. In these circumstances, port sampling is encouraged. However, with port sampling, bycatch and/or discards are not taken to port and therefore unlikely to be reported.

Workshop participants also noted that the level of information available is not able to determine abundance estimates for species, even though data quality has improved for sharks and rays. This information is still not sufficient to be able to derive any abundance indices.

Workshop participants inquired whether data from anchored gillnets (bottom-sets) is required to be reported to the IOTC. The IOTC Secretariat clarified that the Commission is mandated to manage tuna and tuna-like species. If the fishery is targeting tuna, CPCs are obligated to report any associated bycatch. However, anchored gillnets are generally not considered to be targeting tuna, and so they are not mandated to report interactions/entanglements to IOTC.

4.2 Status of Sharks and Rays in South East Asia (Naomi Clark Shen)

Workshop participants noted a presentation by Naomi Clark Shen on the status of sharks and rays in South East Asia including the following summary:

The Southeast Asian region comprises 11 countries, four of which (Indonesia, Malaysia, Thailand and the Philippines) fish in the Indian Ocean and are members of the IOTC. The region is plagued by geopolitical tensions, overcapacity, and a paucity of data, funds, manpower, enforcement and research. Sharks and rays in this region are reportedly primarily caught as bycatch, or 'byproduct' (as they have a market), from a variety of gears including gillnets, trawlers and longlines. As 'bycaught' elasmobranchs have value, there are few measures to mitigate their catch, and an uncertainty of how to best manage them. This paper summarises the status of sharks and rays in Southeast Asia, including their fisheries and management.

Workshop participants requested clarification as to whether the information presented was available by gear. The authors noted that gear specific information is not clearly reported by the majority of countries in the region, however, it would appear anecdotally that trawls have the largest impact on habitats and bycatch species.

4.3 A summary of the Blue Corridors report by WWF (Chris Johnson)

Workshop participants noted a presentation by Chris Johnson on the Blue Corridors report including following summary:

A new collaborative report from WWF and the marine mammal science community provides the first comprehensive look at whale migrations and the threats they face across all oceans, highlighting how the cumulative impacts from industrial fishing, ship strikes, pollution, habitat loss, and climate change are creating a hazardous journey. Protecting Blue Corridors report visualises the satellite tracks of over 1000 migratory whales of eight species worldwide. The report outlines how whales are encountering multiple and growing threats along their migration routes, or ‘blue corridors’, breeding and feeding habitats. The report is a collaborative analysis of 30 years of scientific data contributed by more than 50 research groups. Case studies highlight hotspots and risks that whales navigate on their migrations. Protecting Blue Corridors calls for a new conservation approach to address these mounting threats and safeguard whales, through enhanced cooperation from local to regional to international levels. Information highlighted about the Indian Ocean notes data deficiency in both bycatch information and critical habitat of cetaceans, but addresses opportunities to develop a regional collaborative action plan using the best available science, filling gaps in knowledge and opportunities to implement

a range of tools to safeguard cetaceans across their ranges in national and international waters. Of particular urgency is engagement with the ongoing negotiations of the United Nations on a new treaty for the high seas (Areas Beyond National Jurisdiction).

Workshop participants noted that the blue corridors report draws on conservation practice which is widely used on land known as 'connectivity conservation' but applies it to the world's seas and through a singular focus on whales. Connectivity conservation is a concept that recognizes that species survive and adapt better when their habitats are managed and protected as large, interconnected networks.

To help inform this work, the report identifies key conservation opportunities globally and some innovative solutions available to governments, policymakers, and industry to safeguard whales, their migrations, and their critical habitats for future generations. In terms of their execution, we require a suite of responses to tackle the multiple threats, from reducing bycatch and shipping impacts in key hotspots to establishing networks of marine protected areas.

Workshop participants congratulated the work by WWF and noted the lack of data for Indian Ocean on cetacean migrations and mapping out broader level issues, such as bycatch highlighting the need for urgent action and attention.

4.4 Bycatch of tuna gillnet fisheries of Pakistan: Spatial and temporal assessment (M. Moazzam Khan)

Workshop participants noted a presentation by Moazzam Khan on bycatch in gillnet fisheries of Pakistan including the following summary:

Tuna gillnetting is an important fishing activity in Pakistan which is carried out in the coastal waters as well as in the offshore waters of Exclusive Economic Zone (EEZ) and Area beyond National Jurisdiction (ABNJ). Analysis of the data collected through WWF-Pakistan's Crew-based Observer Programme revealed major differences in spatial and temporal distribution of catches of target species (tunas and billfish) as well as bycatch species. Analysis of data for 2013 indicated that major fishing operations were carried out in coastal waters on shelf areas, Murray Ridge and in Arabian Sea Basin off Indus Delta mainly because of Somali Piracy. Coastal tuna species were observed to be dominating in these waters as well as high bycatch of coastal species were also noted. Marketed seasonal variation in catches of both tuna and bycatch species were also noticed in 2013. Since surface gillnetting was practised in 2013, therefore, high catches of dolphin and turtles was observed. During 2019, sub-surface gillnetting (placing gillnet 2 metres below sea surface) was used for catching tuna and bycatch species. Analysis of data for 2019 indicated that catches of yellowfin and skipjack were substantially higher as compared to 2013 as well as major reduction in bycatch species was observed in 2019. No entanglement of dolphins was reported and only 1 single case of turtle was reported in March 2019. Although temporal and spatial variations in the catches of tuna, billfish and bycatch species were also noticed in 2019 but major reduction in bycatch was observed during 2019.

Workshop participants noted that data collection and information presented was made possible through crew-based observer programmes which were posted on 75 vessels from October 2012 to September 2019. The data collected provided details of temporal and spatial variations of target and bycatch species and indicated differences for tuna and billfishes mainly, whereas, for bycatch data, it

was revealed that majority of gillnet vessels had shifted to the use of sub-surface gears and moved from coastal areas to oceanic/deep sea waters.

4.5 **Bycatch and marine fisheries of India: Status and Challenges (Biju Kumar)**

Workshop participants noted a presentation by Biju Kumar on the status and challenges of bycatch in marine fisheries of India, including the following summary:

The marine fisheries sector of India supports the livelihood of about four million people by ensuring direct employment through fishing and nearly two million people (including one million fishers) through allied activities. The industry also generates impressive foreign exchange for the country, and the exports of marine products reach USD 7.74 Billion in 2022. With higher demand for marine fishery products, the focus is on expanding fisheries production through aquaculture and expanding marine fisheries through expanding fishing areas with emerging technologies to support the proposed new blue economy policies. While the marine capture fisheries of India show symptoms of reaching their plateaus, ensuring sustainability should be of paramount importance in sustaining the huge population that earns their livelihoods from fishery resources and meeting the international commitments towards conservation, fisheries management and sustainable development.

Over the past few decades, there has been a substantial increase in fishing efforts by all sectors and, therefore, greater bycatch outputs, both from active and passive fishing gears. The census estimates of the Central Marine Fisheries Research Institute (CMFRI) reveal the total number of fishing crafts in the marine fisheries sector of the country as 1,66,333, and there were 194,490 crafts in the fishery out of which 72,559 (37.3%) were mechanised, 71,313 (36.7%) motorised and 50,618 (26.0%) non-motorized. Around 20,257 gill netters operate in Indian waters, with the mechanised gillnetters using small (<12.0 m LOA), medium (12.1-16 m LOA) and large (16.1 -24.6 m LOA) nets with 60, 120 and 193 hp engines respectively. The increasing demand for fishery resources, coupled with high fishing pressure and diminishing returns, had led to the shift towards multi day fishing in coastal waters of India, with an increased amount of bycatch.

The major megafauna bycatch associated with Indian marine fisheries as bycatch includes fish (sharks and rays in particular), turtles, sea snakes and cetaceans. Of late, there are reports of deepsea swarming crab, *Charybdis smithii* and other miscellaneous species regularly caught in gill netting. While the publications on cetacean bycatch project mortalities of 9000–10,000 cetaceans by gillnets every year along the Indian coast (Anderson et al., 2020), there is an urgency for benchmark data on actual population estimates of cetaceans to support conservation arguments, not to speak of shifting baselines and their associated issues for sustainable resource management. Expansion of fishing grounds and the use of modern technologies by the Indian fishers might have contributed to higher tuna landings and the number of cetacean bycatch.

Around 60 species of fish are reported as regular items of bycatch of gill nets, while resource limitation and the prevailing taxonomic impediment prevent species-specific documentation of bycatch data. Targeted fishing for chondrichthyans is limited, especially after the ban on shark fins, and sharks and

rays are primarily landed in India as bycatch. The available historical data on elasmobranch landings in India indicate that gillnetting contributes to more than 70 per cent of landings in India. The juveniles and sub-adults of less commercial value thus form the discarded bycatch, and the bulk of these with low turnover in the fishery are converted into fish manure and animal feed. The increased demand for fish meal and oil has increased the trash fish price from the bycatch, and the majority of the species are in the threatened category of the IUCN red list. When these k-selected species live in fishing zones with intense fishing pressure, data deficient species of batoids should be considered as threatened.

All the five species of marine turtles occurring in the Indian waters are listed in Schedule I of the Indian Wildlife (Protection) Act, 1972, and therefore protected. However, in a multispecies fishing scenario, the amount of bycatch is phenomenally high, especially during the breeding season of olive ridley. About two-thirds of turtle mortality is contributed by gillnets, warranting appropriate regulatory measures to reduce the impact of gill net fishery, along with the prevailing popularisation of TEDs (though it is limited to few regions of the country, and bycatch reduction devices are not mandatory anywhere in India). Further, there is an urgent need to identify population size, vulnerable areas and seasons in various marine zones of India, with the total involvement of fishers.

Officially there are no reported instances of sea bird interactions with gillnet fishery in India, and this is rather a reflection of the absence of targeted research. The reports of pelagic birds with entangled fishing nets point towards greater interactions in the ecosystem.

In managing bycatch, the research priority in India should be to plug the data gaps and enhance community and citizen science involvement in marine biodiversity/bycatch documentation and monitoring. Resource-limited systems would work effectively only by augmenting international collaborations and adopting field-tested technologies. Further, there is a greater need to strengthen special marine planning and mainstream bycatch reduction in conservation planning, particularly in Marine Protected Areas of India (existing and proposed). One of the severe impediments in planning bycatch management is the involvement of multiple stakeholder departments, which can be solved only by better fisheries governance and agreements on conservation and trade paradigms that support development (and blue economy) paradigms. In countries like India, better conservation/bycatch management plans work only by involving stakeholders and local communities to develop practical on-ground fisheries management, including managing critical habitats and providing feasible alternative livelihood options. Simultaneously, greater consensus can be achieved to regulate the trade of threatened bycatch species, change consumer choices for seafood, and introduce bycatch awareness as part of ocean literacy programmes.

Workshop participants thanked the author for the presentation and noted the important information regarding bycatch in Indian fisheries, particularly the issues with data collection systems which are more focused on target species.

5.0 Review of existing bycatch mitigation measures in gillnet/drift net fisheries in Indian Ocean

5.1 Use of sub-surface gear setting in driftnet/gillnet fisheries of Pakistan and impacts on bycatch (M. Moazzam Khan)

Workshop participants noted a presentation by Moazzam Khan on the use of sub-surface gear setting in driftnet/gillnet fisheries of Pakistan, including the following summary:

Gillnet is a popular fishing method used for catching tuna and tuna-like species especially by small scale fisheries of coastal states of the Indian Ocean. However, gillnets are known for extremely high bycatch which includes not only commercially important fish species but also a large number of non-target endangered, threatened and protected (ETP) species. Information about gillnet bycatch is not well known from major coastal states, however, studies initiated by WWF-Pakistan provide comprehensive information about bycatch of gillnet fisheries of Pakistan. It is estimated that more than 12,000 cetaceans and 29,000 sea turtles used to be annually entangled in the gillnet fisheries of Pakistan alone.

Considering the high bycatch of ETP species, WWF-Pakistan introduced sub-surface gillnetting in Pakistan as a means for reducing entanglement and mortality of at least cetaceans and turtles. Placing gillnets below 2 m proved to be a success, as catches of target species of gillnet fisheries including yellowfin, longtail and skipjack tunas increased substantially whereas catches of some important species such as billfish and dolphinfish substantially decreased. However, high catches of target species i.e. yellowfin, longtail and skipjack tunas compensate for the losses incurred due to decreased catches of these two species groups.

There was a major reduction in entanglement and mortality of cetaceans and turtles in sub-surface gillnet. Entanglement and resultant mortality of cetaceans was observed to decrease from 12,000 in 2013 to zero in 2019. Increase in landings of commercially important species including yellowfin, longtail and skipjack tunas is the main incentives for the tuna fishermen to shift from surface gillnetting to sub-surface operations; however, there are a number of other benefits which resulted in its immediate and large scale adaptability by the tuna fishermen. By 2017, the entire tuna fleet was converted from surface to sub-surface gillnetting in Pakistan.

The operation of sub-surface gillnetting is comparatively hassle-free as compared to surface gillnetting because the chances of fouling during deployment and retrieval are reduced. Reduction in the entanglements of ETP species helped in saving time which otherwise lost during disentanglement and process of discard. Considering these merits, the gillnet fishermen of Pakistan shifted from surface to sub-surface gillnetting within a span of less than two years.

Workshop participants noted that gillnets that have been set below the surface are impacted much less by wind and currents than nets set at the surface which reduces problems such as nets rolling up.

Workshop participants noted that a full cost-benefit analysis of the socio-economic impacts has not yet been finalised but further noted that fishermen appear to be seeing the benefits of the increased catches of yellowfin and skipjack tuna which has led to them continuing to set nets in this way. Workshop participants further noted that there is currently no legislation in Pakistan requiring the sub-surface setting of gillnets but IOTC does have a Resolution (19/01) which requires vessels to set gillnets at 2m below the surface.

5.2 Net illumination and its effectiveness in reducing bycatch from a multi-species perspective (John Wang and Mike Osmond)

Workshop participants noted a presentation by John Wang and Mike Osmond on net illumination and its effectiveness in reducing bycatch, including the following summary:

Small-scale fisheries are vital for food security, nutrition, and livelihoods in coastal areas throughout the world's oceans. As intricately linked social-ecological systems, small-scale fisheries require management approaches that help ensure both ecological and socioeconomic sustainability. Given their ease of use and lucrative nature, coastal gillnet fisheries are globally ubiquitous. However, these fisheries often result in high discarded capture of non-target organisms (bycatch) that can lead to significant cascading effects throughout trophic chains and costly fisheries restrictions that result in important revenue losses in coastal communities with scarce economic alternatives. Despite these challenges, few solutions have been developed and broadly adopted to decrease bycatch in coastal gillnet fisheries, particularly in developing nations. Here we used controlled experiments along Mexico's Baja California peninsula to show that illuminating gillnets with green LED lights—an emerging technology originally developed to mitigate sea turtle bycatch—significantly reduced mean rates of total discarded bycatch biomass by 63%, which included significant decreases in elasmobranch (95%), Humboldt squid (81%), and unwanted finfish (48%). Moreover, illuminated nets significantly reduced the mean time required to retrieve and disentangle nets by 57%. In contrast, there were no significant differences in target fish catch or value. These findings advance our understanding of how artificial illumination affects operational efficiency and changes in catch rates in coastal gillnet fisheries, while illustrating the value of assessing broad-scale ecological and socioeconomic effects of species-specific conservation strategies.

Workshop participants noted that while the authors reported that one of the trials resulted in a decrease in bycatch of seabirds, there was only a reduction in the catch of one species (guanay cormorant). Similar trials have been conducted in the Baltic Sea where LED lights did not decrease the bycatch of seabirds and in some cases even led to an increase of bycatch of certain species. Workshop participants noted that bycatch reductions with the use of LED lights appears to reduce a lot by species, area and type of gillnet fishing so while this did not work well in the Baltic Sea, it may work in the Indian Ocean.

Workshop participants noted that there was interest in conducting pilot studies with LED lights in Kenya and other countries in the Indian Ocean and encouraged collaboration between organisations in this work.

5.3 Experiences and lessons learned from mitigation of mobulids in small-scale gillnet fisheries (Andrew Harvey)

Workshop participants noted a presentation by Andrew Harvey on experiences and lessons learned from mitigation of mobulids in small-scale gillnet fisheries in Indonesia, including the following summary:

Bycatch is a significant issue in marine capture fisheries, accounting for as much as 40 percent of total global catches. To date, management and conservation measures have focussed primarily on industrialised fisheries, however small-scale fisheries are a significant and overlooked component of

global bycatch. While bycatch affects many species and taxonomic groups, elasmobranchs are particularly vulnerable due to high capture mortality rates and poor post-release survival, and hence require bycatch mitigation strategies that minimise interactions. Here we report on a randomised control trial to evaluate the feasibility of using light to mitigate mobulid ray bycatch within small-scale fisheries. The study was conducted within the drifting gillnet fishery operating from the Port of Muncar, Indonesia and whose main targets are marlin, swordfish and neritic tuna. The trial consisted of a treatment group (T) of fishers who attached red LEDs to their gillnets at 30m intervals and a control group, and was implemented over a six-month period coinciding with the main fishing season (September to March). It primarily aimed to investigate fisher perceptions towards bycatch mitigation technologies and the factors influencing uptake. Mobulid landings occurred throughout the study period, with a seasonal trend detected and peak landings during October. One-third of fishing grounds generated two-thirds of mobulid catches, with these grounds primarily associated with lower value species such as mackerel tunas. Half of mobulid landings came from 10 percent of vessels. These findings have implications for the design of temporal and spatial management measures, gears and operational strategies, and warrant further study. When LEDs were deployed, a smaller proportion of fishing trips landed mobulids (T = 6.21%, C = 14.76%), and when mobulids were encountered catches were smaller (T = 40.00 kg, C = 82.25 kg). Participating fishers reported that LEDs are useful (T = 87%, C = 73%). The design characteristics that most influence uptake of bycatch mitigation technology are cost of purchase (T = 100%, C = 97%), cost of operation and maintenance (T = 97%, c = 86%), and ease of deployment (T = 100%, C = 68%). Fishers reported sensitivity to exogenous factors including risk of technology theft (T = 35%, C = 72%) and risk of illuminated gears attracting competing fishers (T = 74%, C = 82%). This study highlights the potential of LED technologies to mitigate bycatch, as well as the need for further study to improve understanding of the spectral sensitivity of different species, evaluate impacts on both target and non-target species, and inform the design of technologies that are appropriate for the needs of fishers and operational characteristics of target fisheries.

Workshop participants noted that landings occurred throughout the trial period with an uneven distribution across fishing grounds and vessels and that higher catches of mobulids were recorded in areas associated with catches of lower value species such as neritic tunas.

Workshop participants noted that for the group using the lights, there was a significant reduction in per-hour and per-trip bycatch CPUE for mobulids but a non-significant increase in CPUE for target species.

Workshop participants noted that fishermen's perceptions were an important part of this study. Fishermen reported that they found the lights helpful but suggested that the purchase price was too high and also reported low ease of use due to deployment time and effort. Fishermen also expressed concern about the risk of theft and attraction of competitors which are elements that would need to be considered and incorporated into designs in order to encourage adoption of these measures.

Workshop participants noted the need to consider incentive structures for the uptake of these measures noting that government support of the gillnet fisheries is highest of all gears and could potentially be put towards providing support for the purchasing of the lights.

Workshop participants noted the need to improve the scientific understanding of the mechanisms for this measure noting that improvements to accessibility and usability of this technology are required noting some innovation such as lights with adjustable wavelengths and sensors which could be

investigated. Workshop participants further noted the need to replicate and scale such studies across a wider variety of fisheries and fishing types.

5.4 Investigations and approaches to mitigation of marine mammals and sea turtle bycatch in Oman (Andy Wilson)

Workshop participants noted a presentation by Andy Wilson on investigations and approaches to mitigation of marine mammals and sea turtle bycatch in Oman, including the following summary:

This paper reviewed recent bycatch mitigation assessment projects conducted in Oman and plans to refine that work into the future. Wilson detailed that work on bycatch mitigation was initiated based on photographic assessment of interaction of Arabian Sea humpback whales with fishing gear (accounting for 2/3 of the population), and engagement with locals of Masirah Island regarding the steep (79% over a 20-year period for the NWIO research management unit) from the what was the most important rookery for loggerheads turtles globally. Collaborators initiated bycatch assessment studies in 2012 with fisher interviews on Masirah which revealed 84% of the skiff fishery and 100% of the dhow fishery used gillnets and that all turtle bycatch (estimated at 1640-1770 per year) was attributed to net-based fishing gear. Subsequent efforts up until 2018 focused on using crew-based observer approaches (logbooks and cameras), GPS systems and deck mounted time-lapse cameras. Each approach was found to have different strengths and weaknesses concerning the adoption and the value of the metrics produced. Whilst generating data on fishing effort has been possible with the REM approach, it has been more difficult to gather data on bycatch CPUE due to difficulties in detection of bycatch. During these studies partners realised that ALDFG was a large problem with no nets being properly disposed of, all either fall to the beach or are lost to the ocean. The most recent study conducted by the collaborators from Oman was a regional co-occurrence study of loggerheads with commercial and IUU fishing data from GFW which revealed areas of interest throughout the north west Indian Ocean (particularly the Gulf of Aden) that require further focus for bycatch assessment efforts and evaluation of the new Chinese fleet squid fishery in the high seas of the Arabian Sea. Efforts in Oman currently include 1) continuation of behaviour change assessment experiments to reduce ALDFG in the pilot test site on Masirah 2) collaboration with San Francisco State University to run existing spatial data of target taxa and remotely sourced data on fishing vessel presence through an established GIS process to undertake bycatch risk assessment in along the Arabian Sea coast of Oman, and 3) collaboration with WWF Pakistan to trial the transfer of sub-surface gillnet experiments win the skiff and dhow artisanal dhow fleets.

Workshop participants noted that while loggerhead turtles are one of the species nesting on the Oman coast, the majority of the population is thought to move south to the Gulf of Aden for foraging which may be the reason that Pakistan has low rates of entanglement of this species.

Workshop participants noted that the size of bycatch species cannot be accurately measured by the deck-mounted video systems being trialled in Oman as the system requires coordination and cooperation with the crew – e.g. for moving a turtle into the frame of a camera where video measurements will not be distorted. Crew-based techniques for size measurements are thought to be more accurate however, crew have shown reluctance to take photographs for this purpose. Incentivization of the crew for this study has been found to be very important but challenging.

Workshop participants noted work being done in Oman by IPNLF to aid with the transition of fleets from using gillnets to other gears and noted that this could be scaled up elsewhere in the Indian Ocean.

5.5 Use of plastic coke bottles for bycatch mitigation (Per Berggren)

Per Berggren provided a presentation on trials of low-cost mitigation methods using upcycled glass and plastic drink bottles to reduce dolphin bycatch in gillnets. There are two main conditions to be met for fishers to use mitigation methods to reduce bycatch: firstly, that the method should not reduce catch of target species, and secondly that the method should have no or very low cost. Electronic acoustic alarms represent one possible solution to mitigate cetacean bycatch but the cost of fitting out fishing gear with devices limits their implementation, particularly in small scale fisheries in developing countries. To address this, Berggren and colleagues have developed low-cost solutions from upcycled plastic and glass bottles to create passive acoustic reflectors and mechanical alarms. Empty, recycled 500ml-2000ml plastic bottles produce a -27dB to -16dB acoustic backscatter (reflection) when exposed to a 70kHz broadband dolphin click representing 80-40,000 fold increase in target strength compared to gillnets (-46 to -62 dB). Recycled 350ml glass bottles with a suspended metal pendulum bolt produce a "clinking" sound (@10kHz, 117-123dB re 1uPa/√Hz @ 1m). The bottle reflectors and sound producers should facilitate gillnet detection by dolphins at sufficient distance to avoid entanglement.

The plastic and glass bottles were tested in an offshore (100nm), small scale (vessels <15m) shark driftnet fishery off Salaverry, Peru between March 2019 and October 2021. Previous trials in the same fishery with 10kHz acoustic alarms (pingers) have demonstrated to reduce dolphin bycatch (Mangel et al. 2013 Oryx 47:595-606). The fishery uses multifilament 3km driftnets (20-40 panels, 84-91m length, 14-22m height, 8-inch mesh size). Twenty-five week-long trips were conducted with a total of 468 sets fished and all data were collected onboard the vessels by independent observers. Trips were randomised as control (no bottles attached to the net) or treatment (plastic (spaced 50m) or glass bottles (spaced 93m) attached to the net. Data were analysed in R using a two-step Generalised Linear Hurdle Model accounting for fishing effort (km*hrs) with truncated negative binomial distribution to assess the effect of glass/plastic bottles on the likelihood of presence/absence of taxa catch in driftnet sets (Hurdle model), and the level of catch in sets where catches were present (Conditional model). The results showed that there were no significant effects of glass bottle alarms on the presence of dolphins, turtles or teleosts or subsequent level of catches for dolphins and turtles. However, there was a significant positive effect on the presence of shark catch and significant negative effect on presence of ray catch when using glass bottles but no effect on subsequent levels of shark and ray catches when catch occurred. Further, there was a significant positive effect on the level of teleost catch when catch occurred. For the plastic bottle treatment, the results showed no significant effects of plastic bottle reflectors on the presence for any megafauna group or subsequent level of catches for dolphins, turtles, rays or teleosts. However, when shark catch occurred there was a significant increase in the level of shark catch in nets with plastic bottles.

The plastic bottle acoustic reflectors are also currently being tested in an ongoing trial in Torres, southern Brazil in a bottom set trammel fishery targeting teleosts (Brazilian flounder and whitemouth croaker). This fishery uses 2.7 km nets (2m high, soak time 30 hrs) set at 20m depth and has bycatch of franciscana dolphin (Pontoporia blainvillei) and sea turtles. Sets are randomised as control (no bottles attached to the net) or treatment (250ml plastic bottles attached to the net spaced 150m) and all data are collected by independent observers. Initial results from the 89 sets to date (52 control and 37 treatment) indicate that plastic bottles in the nets may reduce dolphin bycatch, have no effect on

turtle catch and increase target species catch compared to control sets without bottles. Further, sets in this ongoing trial are needed to confirm the initial results and allow statistical analysis.

Berggren and co-workers would be interested to assist colleagues who would consider testing either glass or plastic bottles in their local fisheries as potential low-cost mitigation methods.

5.6 Harnessing the power of innovation and partnership to reduce bycatch of sensitive marine species (Pete Kibel)

Pete Kibel gave a presentation on technologies that have been developed by FishTek marine for bycatch mitigation with a particular focus on pingers and net lights. Workshop participants noted that the effectiveness of pingers in reducing bycatch of cetaceans has ranged from between 10-100% and this is very species dependent. Workshop participants noted a trade-off between spacing of pingers and battery replacement rates as pingers which are spaced further apart are required to be louder which uses more battery. Workshop participants noted that the net lights have shown a decrease in bycatch of turtles of between 74-100% depending on the species and noted that it has been found to be more effective when using a flashing light which also saves on battery. This technology has been trialled in Northern Cyprus and is now ready for further roll-out.

Workshop participants noted that both the pinger and net lights are available commercially and can be distributed globally either through distributors or directly.

6.0 Evaluating ecological trade-offs and ecosystem based management

6.1 Update on characterising the Pakistani tuna gillnet fleet through satellite imagery (Brianna Elliot)

Brianna Elliott presented an update on a collaborative project leveraging very high resolution (VHR) satellite imagery, ground-truthing, and interviews to characterise tuna drift gillnet fleets in the Arabian Sea, starting with Pakistan as a case study. The overall objective of this work is to better understand baseline information on the Pakistani tuna drift gillnet fleet (e.g. number of vessels, their size, spatial distribution, and detectable gear on board) that can be used to inform bycatch estimates. A secondary objective is to develop a transparent and transferable methodology that can be used to provide more information about fishing fleets in other data-poor fisheries, including tuna drift gillnets in the Indian Ocean. Early work has focused on manual detection in very high resolution satellite imagery and machine learning to characterise the Pakistani tuna drift gillnet fleet, counting and characterising tuna drift gillnet vessels in the ports of Karachi and Gwadar. Results are not yet available but will be shared with relevant stakeholders in due course. This is a two-year project that began in July 2022. Workshop participants noted the project and welcomed results as they become available.

6.2 Ecological Risk Assessment and productivity – Susceptibility analysis of sea turtles overlapping with fisheries in the IOTC region (Ronel Nel)

Ronel Nel presented on the ecological risk assessment and productivity susceptibility analysis on sea turtles overlapping with fisheries in the IOTC region that was conducted in 2013. The following summary is taken from the paper.

Interactions between sea turtles and fishing activities have been listed as a significant threat to sea turtles. This study aimed to assess which sea turtle species/populations in the Indian Ocean (IO) are

at risk from interactions with tuna-related fisheries. The approach used was a desktop study to compile (1) all available data on sea turtle population demographics, rookery sizes and at-sea distributions; and (2) collate all information of longline, purse seine and gillnet effort and sea turtle interactions in the Indian Ocean.

A paucity of data on fishing effort for certain gear types, bycatch rates and sea turtle life history militated against a fully quantitative ecological risk assessment approach, and hence a semiquantitative, categorical scoring approach was adopted to assess the relative risks of different gear types to different sea turtle species and populations. Combining all population demographic information with rookery size information, and rating each category as low (1), medium (2) and high (3) productivity, allowed for species-independent productivity scores (P) to be generated. The available fishing effort and spatial distribution of tuna-related fisheries, plus other species-specific attributes (such as turtle distributions) were used to rate the susceptibility of each sea turtle population to being caught per fisheries gear type (longlines, purse seine, and gillnets). The likelihood of being caught (as Susceptibility, S) was also rated according to low (1), medium (2) and high (3). An overall Euclidian value rating vulnerability (V) to each of the three fisheries was obtained per sea turtle population in the IOTC region.

In total, 20 populations or regional management units (RMUs) were identified for the six species of sea turtles across the Indian Ocean. Satellite tracking information indicated that sea turtles occur at high densities in coastal (neritic) waters. However, these data are heavily biased towards tagged post-nesting female distributions. The distributions do however reflect the 'high value', breeding age-classes (i.e. sub-adults and adults). Limited data on sea turtle bycatch (numbers and rates) were obtained from participating countries, with total data contributions constituting three longline data sets, one summary, and one report on purse seine activities. In the absence of fishing effort or turtle bycatch data in gillnets, catches (and bycatch) were inferred.

For gillnetting, after the extensive literature survey, and recognising the important differences between artisanal and commercial gillnetting and between drift and anchored gillnets, we were forced to lump all gillnet data into a single category. Using the two approaches to estimate gillnet impacts on sea turtles, we calculated ~ 52,425 turtles.y-1 and 11,400 – 47,500 turtles.y-1 are caught in gillnets (with a mean of the two methods being 29,488 turtles.y-1). These values do not seem unrealistic as anecdotal/published studies reported values of >5000 – 16 000 turtles y -1 for each of just India, Sri Lanka and Madagascar. Of these reports, green turtles are under the greatest pressure from gillnet fishing, constituting 50-88% of catches. Loggerhead, hawksbill and olive ridley turtles are caught in varying proportions depending on the region.

The Ecological Risk Assessment (ERA) methodology requires that where data are missing, a precautionary approach is adopted and a low productivity or high risk score assigned. The highest vulnerability ratings were obtained for data deficient species or small RMUs. Results were mixed with no particular gear type or species rating as consistently highly vulnerable. Generalising though, it seems like loggerheads have mixed vulnerabilities but the small RMUs (i.e. Bay of Bengal, BoB and South Western Indian Ocean, SWIO) are vulnerable to all fisheries types but in particular gillnets. Green turtles are generally the least vulnerable as they have the largest populations, but are still vulnerable to gillnetting in the Arabian Gulf (AG). All three leatherback turtle RMUs (southwest Indian Ocean, Bay of Bengal and South Pacific) are small and hence vulnerable to all fishing pressures. Similarly, small populations of hawksbill turtles (like the East Central Indian Ocean) are vulnerable to all fisheries (particularly gillnetting) whereas hawksbill turtles in the Arabian Gulf and the SWIO are reasonably balanced by rookery size and pressure. Olive ridley turtles have low productivity scores

(mostly as a result of data deficiencies) but from the reports do not seem to interact with the reported fisheries. However, the data paucity is a great concern so there is low confidence in this result. The information available for flatback turtles in the South East Indian Ocean suggests that this population can sustain the current fishing pressures: the RMU is large, with an increasing trend and few reports of interactions with fisheries.

Workshop participants noted that the Western Indian Ocean marine turtle task force is still active in coordinating work relating to marine turtles including data collection noting that much of their recent project work will be presented at the upcoming 10th Meeting of the Western Indian Ocean Turtle Task Force.

Workshop participants noted that Global Fishing Watch is currently working on non-AIS derived fisheries effort estimates at the moment which could be valuable in the future for these types of studies.

6.3 Important Marine Mammal Areas in the Indian Ocean (Gianna Minton)

Gianna Minton and Gill Braulik provided a brief overview of Important Marine Mammal Areas (IMMAs), a tool developed by the IUCN Joint SSC WCPA and Marine Mammal Protected Areas Task Force. IMMAs are 'discrete portions of habitat, important for one or more marine mammal species, that have the potential to be delineated and managed for conservation'. They do not have formal legal status, and as such are not Marine Protected Areas. The identification of IMMAs is an evidence-driven, purely biocentric process based on the application of scientific criteria and on the best available science.

To qualify as an IMMA, an area must meet a minimum of one selection criterion providing strong evidence that the habitat is important for at least one marine mammal species. Areas of Interest are identified and evaluated during regional workshops, during which experts draft proposals for candidate IMMAs. These proposals are reviewed by an independent expert panel to determine whether the evidence provided is sufficient to support the relevant criteria for each species that is addressed. Those areas that pass the independent review progress to full IMMA status and are displayed on the IMMA eAtlas, a map-based tool that allows users to search and filter under different criteria. Users can also request spatial layer downloads so that they can use IMMA shape files and the data associated with them to design protected areas or effective threat mitigation measures. IMMAs are identified on a region-by-region basis, and the regions covered by the IOTC were addressed in expert workshops held between March 2018 and February 2020. A 2020 study using AIS data to assess vessel traffic in IMMAs highlighted IMMAs with particularly high densities of fisheries-related vessel traffic. Two of these areas were developed into case studies that examined the overlap of cetacean distribution and fisheries activities, demonstrating how IMMAs can be used as a tool to identify bycatch risk hotspots where mitigation efforts should be focused.

7.0 Cooperation with International Organisations and enabling conditions

7.1 IWC Focus on cetacean bycatch in the Indian Ocean (Cecilia Passadore)

The International Whaling Commission (IWC) Secretariat presented a summary of their initiatives and activities related to cetacean bycatch with focus in the Indian Ocean.

Workshop participants discussed the pros and cons of using acoustic pingers versus LED lights as deterrence methods to reduce the bycatch of cetaceans in fisheries since in the past pingers have

been the preferred method used to reduce bycatch of cetaceans. Workshop participants noted that there is not enough evidence of the effectiveness of LED lights in reducing cetaceans bycatch and that more trials are needed to test the effectiveness of this measure, especially in the Indian Ocean where trials have not been conducted with the focus of reducing cetaceans bycatch. Yet workshop participants noted that there are some robust trials in the Indian Ocean using LED lights for reducing bycatch in other taxonomic groups, for example some trials have been conducted in Indonesia with mobulids that have shown some promising results. Workshop participants also noted that there have been successful trials using LED lights for reducing bycatch across several bycatch species groups in many parts of the world but there is a need to test these in the Indian ocean to ensure they are as effective in the context of IOTC fisheries and across relevant bycatch taxa.

Workshop participants were reminded that IOTC Resolution 16/07 is not thought to allow trials on the use of lights to be carried out (although the wording is somewhat ambiguous) and that this resolution might need to be revised or amended before these trials can be conducted in IOTC fisheries.

Participants of Indonesia showed interest in several activities carried out by the IWC Secretariat for reducing bycatch of cetaceans in fisheries. Workshop participants noted that Indonesia is not a member country of the IWC and as a result there are no focal points organised by the IWC in place in Indonesia. Yet the Secretariat of the IWC encouraged Indonesia to contact them to find ways to collaborate in common areas of interest such as the training programs organised by the IWC Secretariat.

7.2 Safe release guidelines for ETP species (Shoaib Abdul Razzaq)

Workshop participants noted a presentation by Shoaib Abdul Razzaq on the Guidelines for safe release for ETP species. The abstract provided by the author(s) is as follows;

Pakistan is an important gillnet coastal state with well-known marine biodiversity. Around 709 tuna fishing vessels are operating in Pakistani waters. These boats have high ETP/ CITES-listed bycatch species such as whale shark, mobulids and sea turtles. These bycatch animals are protected by several national and international instruments and encouraged their safe releases to ensure the survivability of these protected species. The data of the crew-based observer programme helped into the development of guidebooks for safe handling and release of these bycatch species in tuna gillnet fisheries. This guidebook focuses on three main possible levels of entanglement of animals in fishing operations. It follows and guides the target group to follow ‘key’ of different precautionary and handling and steps for every situation. The guidebook also encourages the user for the collection of the information and reporting of the entangled animal including the recording of the whole process of operation. This guidebook can be served and adopted by conservation institutes and organisations as best practices of safe handling and release of bycatch animals in ghost nets/ gillnet fisheries.

In Pakistan, there are around 709 wooden gillnet vessels primarily targeting tuna and tuna-like species operating within the Exclusive Economic Zone. These vessels target yellowfin and skipjack tuna but also catch neritic tuna, such as longtail, kawakawa, frigate and bullet tuna. The gillnet fisheries have high bycatch as it is not very selective, however, species composition varies from the area of operations. Bycatch of sea turtles, whale sharks and mobulid rays are extremely common. These bycatch species are considered as endangered, threatened and protected (ETP) in addition to being listed under Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Laws.

The Indian Ocean Tuna Commission (IOTC) resolution 12/04 on the conservation of marine turtle identifies the need for safe handling and release, in addition to resolution 13/05 and 19/03 on whale sharks and mobulids also calls for action on releasing alive, having non-retention measures and ensuring the safe release of these species. While all target catches are retained including bycatch of sharks, other species such as cetaceans, sea turtles, sunfish, sea snakes are discarded back into the sea6. Pakistani waters are well known for its rich marine biodiversity and comprise of around 134 species of shark and rays, 19 species of cetaceans and five species of sea turtles.

In this regard, WWF has trained fishers for data collection which has been pivotal in outlining methods for ensuring safe handling and release of whale sharks, sea turtles and mobulids rays.

Workshop participants noted that the safe release guidelines presented have very nice illustrations, are very practical and provide a very nice set of tools for awareness.

Workshop participants suggested that when developing the guidelines perhaps the condition (dead or alive) should be a consideration prior to the size of the individuals. The presenter clarified that the status of the individuals are already considered in the guidelines, and that there are steps set out for each case accordingly.

Workshop participants also suggested to use instead of "diet" perhaps include something like "biologically relevant information" (since it would add more than only diet) and in the sections including the "don'ts" (the handling practices which are not recommended), a clear visual such as a little "X" or another symbol could be included to make it very clear that these practices are not recommended. Workshop participants also suggested considering reflecting regional differences in the guides as some experiences have shown that fishers using guidelines where they can easily recognise themselves and their vessel/gears and practices can be more effective than others which are more generic.

Workshop participants noted that a smartphone application approach could also be used as a source to provide data directly to the Secretariat building up an additional source of data for monitoring bycatch to complement the formal reporting of data by CPCs to the Secretariat which obviously is not providing sufficient good quality information to drive conservation measures. There is a need for more bycatch data and the data collected using methods such an application might help to make data more readily available to all scientists and the Commission.

Workshop participants noted that crew safety is shown to be a priority in these guidelines but queried whether it is ever safe for a crew member to enter the water with any kind of entangled animal, since the risk of crew entanglement and injury or drowning seems quite high. Workshop participants clarified that the safety of the crew is the utmost priority and that in fact the guidelines discourage crew from diving into the water and advise fishers to conduct all the operations from onboard the vessel.

Workshop participants noted that for anyone interested there are more detailed guidelines focusing on the release of small cetaceans only. Furthermore, there is another document published by the CMS and available on the CMS website (https://www.cms.int/en/publication/guidelines-safe-and-humane-handling-and-release-bycaught-small-cetaceans-fishing-gear) which was reviewed by experts from multiple organizations, including the IWC Expert Panel on Bycatch.

7.3 Sighting data for improved bycatch reporting (M. Moazzam Khan)

Workshop participants noted a presentation by M. Moazzam Khan on using sighting data for improved bycatch reporting in Pakistan, including the following summary provided by the author:

WWF-Pakistan initiated an observer programme to monitor tuna gillnet operations in the coastal and offshore waters of Pakistan in 2012. In addition to collecting information about tuna and tuna-like species, observers were assigned to report observations of whales encountered during fishing operations. Funding for the programme expired in September 2019. However, some of the observers are still providing information on a voluntary basis, enabling WWF-Pakistan to document sightings of whales in the coastal and offshore waters of Pakistan, in the northern Arabian Sea. During 2021 a total of 4 sightings of Arabian Sea humpback whales, 1 sighting of a blue whale, 1 stranding of a Bryde's whale and 28 sightings of unidentified whales were made. The number of whales reported during 2021 (34 reports) is higher than 2019 and 2020 when fewer whale sightings (26 and 19 respectively) were recorded. This may be attributed to more active outreach to the volunteer observers as well as a major shift in operation of tuna gillnet vessels in coastal waters over continental shelf during 2021 as compared to previous years when most of the vessels were operating in deeper oceanic waters.

8.0 Programme of work and Research priorities (areas of improvements)

8.1 Discussion on scaling, barriers to implementation, use of artificial lights, strengthening data and measuring the effectiveness of bycatch mitigation in gillnet fisheries (Co-chairs)

The co-chairs opened up the discussion by summarising the key issues that were brought up for discussion during the course of the workshop, aiming to better understand what mitigation measures discussed at the workshop were economically feasible/viable, ecologically sound and socially acceptable. The co-chairs reminded workshop participants of some of the expressions of interest received during the workshop on replicating the use of sub-surface gears in Oman, and there were other discussions focusing around the extended use of LEDs, as visual deterrents which hold promise for mitigating bycatch in gillnet fisheries. The co-chairs encouraged the participants to have focused discussions around these areas where there was genuine interest in the replication of scaling the experimental designs. Some opportunities with regards to sharing of technology, in particular for LEDs were noted for discussion.

However, there were concerns also raised with regards to evaluating the effectiveness of these measures, considering that the gillnet vessels and fisheries are known for lack of data and the challenges associated with their small-scale/artisanal nature. In this regard, further research areas were also introduced based on the discussions from the past-two days, evaluating how retention bans can be successfully implemented and/or may require complementary support from other measures, such as assessing at-vessel or post-release mortality.

The co-chairs re-introduced some discussion points around improving data quality, collection, reporting in particular while aiming to reduce the gap, by exploring areas, such as port sampling and/or combination of other i.e. alternate methods for data collection, combining 1-2 or more for strengthening data collection in small-scale/artisanal fisheries, while recognizing that human onboard observer coverage may not be possible for vessels which are less than 24 m due to safety and security

concerns. Lastly, it was suggested that workshop participants could consider important details with regards to data standardisation or looking at protocols to help build indices of abundance in the long-term.

The key questions introduced for discussion were as follows;

- What mitigation measures currently exist for gillnets that are ecologically sound, economically viable and socially acceptable?
- What trials can be scaled/replicated in gillnet fisheries?
- How can we measure their effectiveness?
- Can we undertake experiments for sub-surface gillnet settings in Oman, I.R. Iran, Sri Lanka, India, Indonesia?
- What barriers exist for implementation of mitigation measures in small-scale/artisanal gillnet fisheries?
- Are retention bans effective? Do they need to be complemented by other measures?
- What exemptions should be removed in current conservation and management measures?
- How can we reduce at-vessel and post-release mortality? How can we monitor it?
- Visual deterrents/use of artificial lights effective?
- What provisions are required? What support is needed?
- Robust experimental design? Requirements…and are there volunteers to support trials in gillnet fisheries?
- Would these be effective in large-scale gillnet vessels? Tests/Trials? Resource requirements
- What are the data gaps? How can we improve data quality from gillnet fisheries?
- Can Port sampling alone, fulfil all data requirements? How do we measure discards?
- What alternate means of data collection may be considered?
- Do we need to focus on market-based measures? What incentives may be required for change?
- Data needs and data collection, measuring the effectiveness - standardisation and minimum data requirements, such as proposing mechanisms for improving data quality on gillnet fleets, fine-scale resolution obtaining, support to develop CPUE indices, long-and-short term measures, consideration of specific requests to WPEB and SC of IOTC, how to tackle the issue of vessels which are less than 24 m, how to ensure bycatch is data is adequately reported

The key questions introduced (above) during the discussion allowed for deep dive into identifying future areas of work, research priorities and recommendations. Based on the questions and discussion points introduced, workshop participants noted that data collection for bycatch is very challenging, with many countries unable to properly conduct this collection and reporting to the IOTC Secretariat. The problem with gaps in data is due to the capacity of the governments and a potential approach may be to support data collection through CSOs, fisher groups or support groups where data on tuna and tuna-like species can be collected on a regular basis and provided to the IOTC Secretariat.

The workshop participants noted that a skipper or crew based data collection mechanism exists in countries like Pakistan, where independent coverage by humans has not been made possible due to the nature of small-scale fishing vessels. It was mentioned that since these vessels are small, there are little economic benefits or incentives and there is a resistance to change. The workshop participants also noted that there is a need to work directly with fishers which could serve multiple purposes, as it would also help in data collection, considering that from skipper based reporting or crew reporting

data shows significant improvements and that there should be some special provisions within the IOTC, which may allow for adoption of this methodology for data collection.

The workshop participants noted the use of sub-surface net setting as a potential bycatch mitigation solution, and inquired about the technical elements of sub-surface settings in gillnet/driftnet fisheries. The workshop participants inquired about the weight of buoys on net, spacing, floats, among other controls that may be required to better understand how wave action, or tidal action may be manoeuvred during the fishing trip. Furthermore, workshop participants inquired about the bycatch reduction in sub-surface gears and suggested using acoustic soundtraps to help monitor bycatch, in order to better understand that the decline in bycatch is not merely due to decline in the abundance of a species. Based on this observation, it was further indicated that in recent years several free-swimming schools of dolphins have been observed and reported within the timeframe of when the experiments of the bycatch mitigation were undertaken, speculating that abundance might not be a big factor in the apparent reduction of bycatch using different gear settings.

The workshop participants also noted that a resolution exists which includes some provisions for sub-surface setting of gillnets, however, countries have not been able to provide information on its implementation and the IOTC WPEB were concerned with regards to the small amount of scientific information generated. While some researchers felt otherwise, and shared their experiences on implementing independent observer coverage on small/artisanal vessels. The workshop participants further noted that in East Africa, most fishers do not go fishing for a longer period of time, and actively return to daily or night fishing which contrasts with other areas where vessels are known to go out to sea for many days (or longer) at a time. Moreover, workshop participants noted that one key detail that this workshop should emphasise is the problem of bycatch associated with small-scale coastal fisheries. This is a bigger problem to deal with considering their wide-spread nature, with large numbers of vessels, and the difficulty in managing these, and due to their large number, their cumulative impact might be enormous and tools must be made available to assess the catch. In order to do so, the coastal tuna fishing vessels must be prioritised by this workshop.

The workshop participants noted that gillnet vessels can easily be converted to handline fisheries, which is a low-level conversion and has extensively been undertaken in Oman. The issue with gillnet caught tuna is that it is of relatively low quality and high in histamine considering that post-harvest losses are immense and the fishery does not meet any quality standards for which there is no market incentive for change. However, with handline fisheries the trials undertaken in Oman to upscale the fishery, has been a big success as high quality tuna is being landed which means market forces can align and a positive change can be brought about. The workshop participants indicated that perhaps a cost-benefit analysis of gillnet conversion to handline might help with both improving the overall target catch and reducing bycatch, and the economic incentive would be able to make this shift socially acceptable.

Workshop participants shared their concern with regards to the bycatch of artisanal fisheries and how data collection could be improved from such fisheries. An example of a World Bank funded project from Kenya was shared with workshop participants which has a vested socio-economic element to it. In support of this workshop, NPOAs were developed beforehand and validated by the stakeholders, which made good governance possible. In Kenya, partners have worked with the government to implement remote electronic monitoring on small-scale/artisanal vessels. There is also good momentum to train observers (dry and field-based) and fishers have also been trained for collection

of data through mobile applications. Workshop participants noted the consideration of application of such low-cost data collection and monitoring tools, including bycatch reporting.

While discussing low-cost monitoring or data collection and/or mitigation methods, workshop participants also noted the request to harmonise data protocols for small-scale/artisanal vessels. At the moment they are widely accepted by the IOTC, considering that skipper or other means of data collection may not fulfil the reporting requirements or scientific standards especially for bycatch species. The workshop participants encouraged the use of citizen science based approaches and the need for engagement from the beginning by building trust and cohesiveness so that the traditional ecological knowledge of the fishers can be used most effectively. It was recognized that there is value in utilising the knowledge but it needs to be supported through training.

Workshop participants inquired about the potential knock-on effects of the bycatch reduction measures, considering that several fisher communities in the Indian Ocean rely heavily on such species (such as sharks and rays) for domestic consumption and if the gaps in these fisheries are plugged, efficiency in target catch could be increased to the point where coastal fish stocks may face overfishing. The workshop participants also raised concerns with regards to fishing activities remaining unmonitored and unregulated, where some countries may start fishing with poor or deleterious fishing gears while others may shift or transition their fisheries. The workshop participants noted the concerns raised. Through this discussion workshop participants further inquired about the number of bycatch technologies/tools to be used in order to be most effective, to which it was noted that a suite of options need to be made available for countries and fisheries so they can make their own choices based on best practices as certain reduction or mitigation measures might work well and others may not given the oceanographic conditions.

Workshop participants discussed the financial viability of the mitigation methods and inquired about how bycatch mitigation data collections protocols for mitigation methods could be standardised. With regards to this discussion point, workshop participants also raised observations with regards to the number of mitigation measures available for gillnets. It seems that some have benefits over others, for different taxa, and different implications for convenience and adoption by fishermen. It is quite possible that looking at multi-method mitigation will become challenging, due to the financial constraints and resources required. Such trials would need to be undertaken in parallel, i.e. one by one, considering how or what be prioritised for monitoring. In addition, these trials are highly dependent on the participation by fishers, the engagement with fishers and their participation and any economic incentives to make this practically or realistically possible may also be taken into consideration .

Based on the discussion points, the following recommendations were brought forward to the attention of workshop participants.

8.2 Developing Recommendations for IOTC – WPEB (Co-Chairs)

The following recommendations were discussed and agreed to by workshop participants:

Data collection and reporting

Workshop participants agreed on the need to improve data on bycatch from gillnets operating in the Indian Ocean. Many agreed that the most robust data would come from scientific observers onboard fishing vessels but noted the difficulties in accommodating observers onboard many smaller vessels which are operating further offshore for a number of days at a time. Workshop participants also

acknowledged the fact that currently the IOTC Resolution on a regional observer scheme does not apply to vessels under 24m in length so they are not required in most small-scale fisheries which is a major data gap.

Workshop participants highlighted a need for a common protocol for bycatch data collection which ideally can work within the normal data collection systems of the CPCs as well as the need to build capacity for data collection within many CPCs. Workshop participants noted that many small-scale and artisanal fishers and their communities would like access to such mechanisms.

Workshop participants discussed the possibility of a series of alternative data collection techniques which could complement the data already being provided by CPCs to the IOTC Secretariat. Suggestions included electronic monitoring and electronic data collection tools that can be used by crew and port samplers using mobile phones. These techniques could be trialled in various regions around the Indian Ocean and exchange programmes between CPCs could take place to increase knowledge across the region. Workshop participants noted a study for the IOTC which will assess the feasibility of such alternative data collection mechanisms which is currently in the planning stages and should yield some useful information on this topic.

There is an urgent need to improve data on fishery effort for most countries in the Indian Ocean and in particular for small scale fisheries. Ideally these data should include the number of vessels per gear type, effort (e.g. km x hours fished per month) per fishing area and include all gear types used as currently in some countries only certain gillnets are reported in national reports which result in a serious under-reporting of the total gillnet effort used. There is also need for better data on bycatch CPUEs for the different gear types which then can be used with total fishing effort to extrapolate total catch/bycatch per fishing area and species. This information will help further identify areas and fisheries of particular concern.

Workshop participants **recommended** that a feasibility study of alternative data collection mechanisms should be undertaken, recalling that the SC has tasked the Working Party on Data Collection and Statistics (WPDCS) with this and workshop participants recalled that the WPDCS **recommended** the SC evaluate the validity of alternative data collection tools, and combination of these (such as the crew as observers, electronic monitoring, and port sampling) as potential alternatives to onboard human observer coverage for the collection of the minimum standard data fields for small-scale vessels

Workshop participants encouraged the WPEB and interested parties to work collaboratively on standardising bycatch data collection mechanisms.

Sub-surface setting of nets

Workshop participants stressed the need for more scientific data collection to help to test the efficacy of sub-surface setting of gillnets as well as the need to roll out trials to other regions noting that this has previously been mentioned by the WPEB.

Workshop participants noted that in some areas sub-surface setting of gillnets has been seen to lead to a large impact on target catch noting that this was particularly applicable in the gillnet fishery targeting sharks offshore in Peru, however, this may be less applicable in the Indian Ocean where

there are not thought to be significant gillnet fisheries targeting sharks and in fact this may provide more evidence to show the potential effectiveness of the measure in reducing shark bycatch.

Workshop participants noted that the results from Pakistan showing that the sub-surface setting of nets may cause higher levels of bycatch for deep-diving cetaceans requires more investigation.

Workshop participants noted that there is also a need to assess the socio-economic implications of changing to this gear setting which WWF Pakistan intends to carry out for the vessels that they have worked with. This will also help to understand the social acceptability of these measures which can help to increase their uptake.

Noting the WPEB's concern about the small amount of scientific analysis that has been conducted to assess the effectiveness and impacts of sub-surface gillnet setting, workshop participants **recommended** that the WPEB support trials for sub-surface setting across a wider area and facilitate a request for sharing of data from CPCs such as Indonesia and Sri Lanka where sub-surface gear settings are thought to be in operation already in order to help to fill the current data gaps which are making the WPEB reluctant to facilitate the development of CMMs on this topic.

Recalling the IWC-BMI recommendation to "discuss the possibility of adding information on depth setting to IOTC data reporting forms for gillnet fisheries", and noting that the WPDCS is already considering potential revisions to the IOTC data reporting forms and reference data classifications in order to also include, among other things, provisions to record information on the different types of gillnet settings (i.e., surface vs. sub-surface), workshop participants **recommended** that the WPEB and WPDCS further discuss whether multiple categories of sub-surface setting should be considered, so as to record the different depths at which the net could be set which will help to facilitate the scientific analysis of the impact of different gillnet settings.

LEDs/Artifical lights

Workshop participants noted that to date, the work investigating the effectiveness of using lights appears to have been applied to species groups separately rather than in combination (e.g., one study will focus only on the effects on turtle bycatch while another will focus on the effect on cetacean bycatch). However, it will be important to consider the effects of lights on all taxa in the future, perhaps through an experiment with multiple trials taking place in parallel. Workshop participants noted that a lot of funding and effort would be required in order to conduct such trials and to roll out trials to other areas.

Workshop participants further noted the constraints of such trials will also include engagement with fishermen who have often found to have limited patience for conducting these trials noting that it may be best to begin with trials with techniques and measures that have been proven to be most successful or most applicable to the relevant areas so fishermen are able to directly see the advantages.

Workshop participants noted the suggestion from the Secretariat to ask the WPEB to recommend that the SC ask for clarification from the Commission on whether Resolution 16/07 applies to gillnet fisheries and to scientific studies as the current wording is somewhat ambiguous. This is likely to be more efficient and will better follow IOTC procedure.

Workshop participants highlighted the will of various organisations to work together to facilitate the regional roll-out of trials on sub-surface gillnet setting and the use of lights as mitigation measures. Workshop participants also noted work that has been done by the whale entanglement response network to assess and roll out mitigation measures to reduce entanglements, further noting that this has been achieved through a series of exchanges between different CPCs to demonstrate and learn from different measures. This approach could be taken in order to roll out trials into a range of different areas.

Noting the strong support for the rolling out of future LED trials across the Indian Ocean, workshop participants suggested that a small working group be formed to work on details for these trials. Workshop participants **recommended** that the WPEB seek clarification from the Commission (through the SC) on whether Resolution 16/07 applies to gillnet fisheries and to scientific studies as the current wording is somewhat ambiguous.

Vessel gear transition

Workshop participants noted work being done by the International Pole and Line Foundation (IPNLF) in Oman where they have provided upskilling training for existing handline fishers with great results and over the next year will be developing a project in Oman to trail conversion from gillnet to handline using traditional vessels. Handline vessels are considered to be of lower impact in that region with negligible bycatch and this gear tends to catch high-grade tuna of higher value. IPNLF are working with private sector market partners to enable market access for high-quality tuna landed by handline fisheries, ensuring offtake of fish. Workshop participants noted that a cost-benefit analysis for this transition has not yet been completed but would be of interest for the business case and its potential as a scalable solution to gillnet bycatch in other regions.

Workshop participants **recommended** the WPEB to explore the cost-benefit advantages of converting Indian Ocean gillnet fleets into fleets using low impact gears such as handline and/or troll fisheries, and if not possible, to lower impact gears such as longline which is thought to have a low impact on marine mammals. Tuna handline fisheries have a low barrier to entry, have low environmental impacts with negligible bycatch rates and are capable of landing the highest quality ‘sashimi grade’ tuna which can result in increased earning potential fishers (financial incentivising the conversion), whilst also minimising post-harvest losses.

Retention bans

Workshop participants discussed the effectiveness of retention bans as an incentive for reducing bycatch in gillnet fisheries, noting that this is a complex topic that could have a whole workshop dedicated to it.

Workshop participants noted that retention bans have been known to be implemented quite aggressively in Sri Lanka however, there is known to be landings of fins of oceanic whitetip and thresher sharks (both of which CPCs are prohibited from retaining due to Resolutions 12/09 and 13/06) as these are of very high value and markets have been developed to facilitate the sale and distribution of these products.

Workshop participants highlighted the need to regularly evaluate the effectiveness of CMMs and revise them as necessary.

Noting some of the drawbacks of retention bans which lead to a loss of potentially valuable information from these species, workshop participants **recommended** that the discards data collection mechanisms on board vessels be strengthened and the at-vessel and post-release mortality be studied for those species currently under retention bans.

Other considerations

Workshop participants noted that it is important to bear in mind the fact that any negative effect on target catches will ultimately lead to resistance to change or adoption of such measures and may lead to greater IUU activity.

Workshop participants noted the need to consider the impacts of reduction of bycatch on target species such as yellowfin tunas which are already known to be overfished and subject to overfishing. There is also the possibility that other fisheries will start to land more sharks as a result of reductions in bycatch of sharks in gillnet fisheries.

Workshop participants noted the need to consider whether to trial measures individually or in combination and **recommended** that the WPEB consider the methods, time costs, experimental design considerations and uncertainties that might make the study of multiple measures challenging if commissioning work to be done in this area.

Noting the work that has been done by the whale entanglement response network to assess and roll out mitigation measures to reduce entanglements which has been achieved through a series of exchanges between different CPCs to demonstrate and learn from different measures, workshop participants **recommended** that a similar approach is taken in order to roll out trials into a range of different areas.

Workshop participants **recommended** that the WPEB continues to support the development of Ecological Risk Assessments, and that Important Marine Mammal Areas, Important Bird Areas, EBSAs and other tools that highlight important or sensitive habitat for ETP species are used and **requested** financial support in designing measures to reduce bycatch risk.

8.3 Identification and development of priorities for Multi-taxa bycatch mitigation workshop in 2023 (Co-Chairs)

Workshop participants **recommended** that priorities for the next multi-taxa bycatch mitigation workshop be discussed in more detail at the WPEB, including undertaking a follow up workshop focusing on gillnets/driftnets and/or other fishing gears.

9.0 Others

9.1 Identify partners, roles and responsibilities and next steps for developing work programme and workshop in 2023 (Co-Chairs)

The identification of partners, role and responsibilities and next steps for developing work programme including identification of gears to focus on in a follow up workshop for 2023 would be discussed at the IOTC's 18th Working Party on Ecosystem and Bycatch planned to be held from 5-9 September 2022.

9.2 **Adoption of Recommendations (All participants)**

The recommendations provided in the report (section 8) were principally agreed by workshop participants participants and will be adopted intersessionally.

The workshop ended with a vote of thanks from the IOTC Secretariat and by the Co-Chairs of workshop participantss.

Annex - I

Workshop Agenda (Revised version 2.0)

Developing robust multi-taxa bycatch mitigation measures for gillnets/drift nets in the Indian Ocean: First Driftnet/gillnet Multi-taxa Bycatch Mitigation Workshop

Date: 29-31 August 2022

Platform: Zoom (virtual)

Co-Chairs: Mariana Tolotti and Umair Shahid

Time: 4 hours a day (virtual)/3 days workshop (1-5 pm Karachi, Pakistan - GMT+5)

Note: All files, documents, papers and presentations will be uploaded on a dropbox link and shared with workshop participants by 25 August 2022.

Objective: *Undertake evaluation of existing mitigation measures for their sustainability to reduce bycatch of multiple taxa in drift/gillnet fisheries/gears and to scope and assess the feasibility of novel or experimental measures being developed for this purpose in the Indian Ocean. The outcome of the workshop would allow for the identifications of a suite of options, ready to test/pilot and/or scale mitigation measures which benefit multi-taxa, are monitored and further information is shared during the IOTC Working Party on Ecosystem and Bycatch, recommending technical measures for adoption/endorsement by the IOTC - SC.*

Agenda of the Meeting

1.0 Opening of the meeting (Co-Chairs)
2.0 Adoption of the Agenda and arrangements for the session (Co-Chairs)
- MBMW01-2022-Rev2: Annotated agenda of the workshop
- MBMW01-2022-Rev2: List of documents

3.0 Introduction of the workshop, background, updates and progress
- 3.1 Background of the workshop/ToRs and summary of outcomes from WPEB and SC (Co-Chairs)
- 3.2 Review of Conservation and Management Measures relevant to bycatch in IOTC fisheries (IOTC-Secretariat)
- 3.3 Evaluating gaps and knowledge on Resolution 17/07 (IOTC – Secretariat)
- 3.4 Effectiveness of bycatch CMMs in IOTC (Sarah Martin)
- 3.5 Guidelines on reducing sea turtle mortality (IOTC – Secretariat)

4.0 Information on bycatch, existing gaps and knowledge
- 4.1 Review of data, information and current existing gaps in knowledge on extent of bycatch and driftnets/gillnets in the Indian Ocean (IOTC-Secretariat)
- 4.2 Status of Sharks and Rays in South East Asia (Naomi Clark Shen)
- 4.3 A summary of the Blue Corridors report by WWF (Chris Johnson)
- 4.4 Bycatch of tuna gillnet fisheries of Pakistan: Spatial and temporal assessment (M. Moazzam Khan)
- 4.5 Bycatch and marine fisheries of India: Status and Challenges (Biju Kumar)

5.0 Review of existing bycatch mitigation measures in gillnet/drift net fisheries in Indian Ocean
- 5.1 Use of sub-surface gear setting in driftnet/gillnet fisheries of Pakistan and impacts on bycatch (M. Moazzam Khan)

5.2 Net illumination and its effectiveness in reducing bycatch from a multi-species perspective (John Wang and Mike Osmond)
5.3 Experiences and lessons learned from mitigation of mobulids in small-scale gillnet fisheries (Andrew Harvey)
5.4 Investigations into bycatch and future approaches to mitigation of marine mammals and sea turtle bycatchin Oman (Andy Wilson)
5.5 Trials of glass and plastic bottles as potential low-cost mitigation to megafauna bycatch in gillnet fisheries (Per Berggren)
5.6 Harnessing the power of innovation and partnership to reduce bycatch of sensitive marine species (Pete Kibel)

6.0 Evaluating ecological trade-offs and ecosystem based management
6.1 Update on characterizing the Pakistani tuna gillnet fleet through satellite imagery (Brianna Elliot)
6.2 Ecological Risk Assessment and productivity – Susceptibility analysis of sea turtles overlapping with fisheries in the IOTC region (Ronel Nel)
6.3 Important Marine Mammal Areas in the Indian Ocean (Gianna Minton)

7.0 Cooperation with International Organizations and enabling conditions
7.1 IWC Focus on cetacean bycatch in the Indian Ocean (Cecilia Passadore)
7.2 Safe release guidelines for ETP species (Shoaib Abdul Razzaq)
7.3 Sighting data for improved bycatch reporting (M. Moazzam Khan)

8.0 Programme of work and Research priorities (areas of improvements)
8.1 Discussion on scaling mitigation trials, barriers to implementation, use of artificial lights, and assessing data needs in drift/gillnet fisheries
8.2 Developing Recommendations for IOTC – WPEB (Co-Chairs)
8.3 Identification and development of priorities for Multi-taxa bycatch mitigation workshop in 2023 (Co-Chairs)

9.0 Others
9.1 Identify partners, roles and responsibilities and next steps for developing work programme and workshop in 2023 (Co-Chairs)
9.2 Adoption of Recommendations (All participants)

Annex - II

List of meeting documents presented at the workshop (Revised version 2.0)

Document	Title
MBMW01-2022-1	Annotated Agenda of the Workshop
MBMW01-2022-1-Rev1	Annotated Agenda of the Workshop
MBMW01-2022-1-Rev2	Annotated Agenda of the Workshop
MBMW01-2022-2	List of documents
MBMW01-2022-2-Rev1	List of documents
MBMW01-2022-2-Rev2	List of documents
MBMW01-2022-3	Background of the workshop/ToRs and summary of the outcomes of WPEB and SC
MBMW01-2022-4	Review of Conservation and Management Measures relevant to bycatch in IOTC fisheries
MBMW01-2022-6	Effectiveness of bycatch CMMs in IOTC
MBMW01-2022-7	Guidelines on reducing sea turtle mortality by FAO
MBMW01-2022-9	Review of data, information and current existing gaps in knowledge on extent of bycatch and driftnets/gillnets in the Indian Ocean
MBMW01-2022-10	Status of Sharks and Rays in South East Asia
MBMW01-2022-11	A summary of the Blue Corridors report by WWF
MBMW01-2022-12	Bycatch of tuna gillnet fisheries of Pakistan: Spatial and temporal assessment
MBMW01-2022-13	Bycatch and marine fisheries of India: Status and Challenges

MBMW01-2022-14	Use of sub-surface gear setting in driftnet/gillnet fisheries of Pakistan and impacts on bycatch
MBMW01-2022-15	Net illumination and its effectiveness in reducing bycatch from a multi-species perspective
MBMW01-2022-17	Experiences and lessons learned from mitigation of mobulids in small-scale gillnet fisheries
MBMW01-2022-18	Investigations into bycatch and future approaches to mitigation of marine mammals and sea turtle bycatch in Oman
MBMW01-2022-21	Trials of glass and plastic bottles as potential low-cost mitigation to megafauna bycatch in gillnet fisheries
MBMW01-2022-22	Harnessing the power of innovation and partnership to reduce bycatch of sensitive marine species
MBMW01-2022-23	Update on characterizing the Pakistani tuna gillnet fleet through satellite imagery
MBMW01-2022-24	Ecological Risk Assessment and productivity – Susceptibility analysis of sea turtles overlapping with fisheries in the IOTC region
MBMW01-2022-25	Important Marine Mammal Areas in the Indian
MBMW01-2022-26	IWC Focus on cetacean bycatch in the Indian Ocean
MBMW01-2022-28	Safe release guidelines for ETP species
MBMW01-2022-29	Sighting data for improved bycatch reporting

Annex - III

Workshop Participants (196 participants registered for the workshop)

Pete Kibel Fishtek Marine	Mohammad Koya India	Ada Natoli
Corrine Rahoeliaris	Mona Zia WWF-Pakistan	Ahsaan Ali
Shoaib Abdul Razzaq WWF-Pakistan	Edward Kimakwa	Dalila Sequeira WWF-Mozambique
Ranny Yuneni WWF-Indonesia	Alberto Gonzalez	AbdiiKarim Mogeh
Andrew Harvey Manta Watch	Seren Irwin CMS	Fabio Fiorellato IOTC
Mohammad Wasim Khan FAO-Pakistan	Benedict Kiilu Kenya	Nina Wambiji
Mohammad Shamsadoha CMS	GM Masum Billah WCS	Ruth Leeney
Robiul Kauser WCS	Elisabeth Farhni Mansur WCS	Biju Kumar
Hayley Swanlund WWF-UK	Divon Mwamba	Alexandra Moufroy Orthongel
Lauren Nelson IOTC	Andrew Wilson Future Seas	Elizabeth Mueni Kenya
Earl Possardt	Jess Rattle Blue Marine Foundation	Ghazi Salahuddin WWF-Pakistan
Louis Flounders Manta Trust	Charlene da Silva South Africa	Daniel Fernando Blue Resources Trust

Sarah Martin Lancaster University	Larissa Fitzsimmons BMIS	Beatrice Kenyu SFACT
Naomi-Clark Shen WWF-Singapore	Zeynep Karacouglu CMS	Viviane Komati CMS
Emma Kelman DEFRA	Rhett Bennet WCS	Yann Rouxel
Salim Mohamed	Roy Bealey IPNLF	Sachiko Tsuji Japan
Iris Ziegler Shark German Project	Andrew Temple	Farhad Kaymaran Iran
Hilario Marua ISSF	Manjula Tiwari NOAA	Per Berggren NewCastle University
Cecilia Passadore IWC	M Moazzam Khan WWF-Pakistan	Alexia Morgan SFP
Maria Jose Juan Jorda	Paul De Bruyn IOTC	Gianna Minton
Heidrun Frisch-Nwakanma CMS	Dipani Sutaria	Gill Braulik
Gavin Jolis	Brianna Elliot	