The impact of the IOTC fisheries on mobulid rays: status and interactions, data availability, and recommendations for management

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Executive Summary

Introduction and status of mobulids

Manta and devil rays (collectively known as mobulids) are a family of migratory elasmobranchs. Their life history traits mean the largest *Mobula* species have maximum rates of intrinsic population increase among the lowest of all elasmobranchs (Dulvy *et al.*, 2014). Mobulids are vulnerable to both targeted fisheries and bycatch and are caught in both small-scale and commercial (e.g. tuna) fisheries (Croll *et al.*, 2016). Such fisheries are a major threat to mobulids, with some populations exhibiting declines of over 90% (e.g. Lewis *et al.*, 2015; Rohner *et al.*, 2017; Moazzam, 2018). In the Indian Ocean, all mobulid species are assessed as either Vulnerable or Endangered (IUCN, 2020; Table 3.), with steep population declines due to exploitation in fisheries playing a major role in these assessments. In response to growing concern, in 2019 the IOTC adopted Resolution 19/03 on the conservation of mobulids caught in association with fisheries in the IOTC Area of Competence (Annex 1).

Interactions with the IOTC fisheries

Mobulids are mainly caught as bycatch, primarily in the industrial purse-seine fisheries, and to a lesser extent in longline fisheries (Croll *et al.*, 2016; Shahid *et al.*, 2018). They are also incidentally captured in small-scale gillnet fisheries, usually being retained for their meat and gill plates (White *et al.*, 2006; Ardill *et al.*, 2011; Moazzam, 2018). Mobulids are particularly susceptible to incidental catch in tuna fisheries due to their epipelagic distribution in regions of high productivity, leading to a high level of distributional overlap with target species (Croll *et al.*, 2012). However, observer coverage on the IOTC fishing vessels is limited, and often mobulid landings are not identified to species level, meaning data is poor. Despite this, reports submitted to the IOTC WPEB in 2018 (Shahid *et al.*; Moazzam; Fernando) all highlighted declines in mobulid populations due to tuna fisheries in the Indian Ocean (Table 4.).

Post-release mortality of mobulids in tuna fisheries is currently high (Poisson *et al.*, 2014; Francis and Jones, 2017; Amandè *et al.*, 2008) due to a lack of available tools to safely manipulate mobulids (Grande *et al.*, 2019), and lack of awareness/compliance with safe handling and release guidelines. Potential onboard tools include “manta ray grids” and modified brailer grids. Pre-capture techniques, which should be emphasised, include dynamic spatio-temporal management of key mobulid habitats, and tools such as LEDs to prevent incidental catch.

Data availability and gaps

Research on mobulids, although increasing, has been limited by the difficulties in observing and investigating *Mobula* species in their extensive oceanic environment (Couturier *et al.*, 2012; Croll *et al.*, 2016; Lawson *et al.*, 2017; Stevens *et al.*, 2018). A systematic literature review undertaken by Stewart *et al.*, published in September 2018(a), identified research priorities to support effective mobulid ray conservation. The review highlighted the need for taxonomic clarifications, better knowledge of mobulid life history parameters, and more studies on bycatch and fisheries (including post-release mortality, species distributions and fisheries data standardisation). A number of data gaps, in addition to the lack of IOTC fisheries observer coverage and lack of research into bycatch mitigation for mobulids, are of relevance to and could be addressed by tuna RFMOs. These are outlined in Table 4.

Recommendations for management

CMM 19/03 is very positive and in order to ensure implementation and compliance, while achieving the goal of significantly decreasing the mortality of mobulid rays, the following actions are recommended:

- Action 1 - Pre-capture: Spatio-temporal management of critical key habitats for mobulids, where they are found in high abundance, should be immediately implemented. Such pre-capture methods should be prioritised to minimise mobulid mortality in the IOTC fisheries.

- Action 2 - Pre-capture: New technologies to prevent incidental capture of mobulids e.g. LED lights in gillnets, should be developed and tested.

- Action 3 - Safe handling and release: New tools for mobulid release, e.g. manta grids or modified brailer nets in purse seiners, should be developed in collaboration with fishing crew and tested under normal operations.

- Action 4 - Safe handling and release: The quick and safe release of mobulids, in a manner to cause as minimum harm as possible using the best available guidelines (e.g. Annex 2), should be incentivised and compliance of fishing crew closely monitored.

- Action 5 – Data collection: Observer coverage of the IOTC vessels should be significantly higher. This is crucial to addressing the issue of mobulid bycatch.

- Action 6 - Data collection: Thorough training should be given to fisheries observers, skippers, and fishing crew to enable accurate reporting on mobulid capture, with an emphasis on the need to collect good photographs to enable verification. This could be facilitated by a Manta Trust administered online mobulid identification hub where mobulid experts can give quick verification of species identification.

- Action 7 - Data collection: Improved and updated mobulid identification guides should be developed. The Manta Trust can facilitate this through provision of materials with the hope to create more cohesive guides across the RFMOs.

- Action 8 - Data collection: Data collection protocols, as well as safe handling and release guidelines, should be reviewed and, where possible, standardised across the RFMOs. This could be facilitated by the Manta Trust, and would help to address key knowledge gaps as outlined in section 4.2.

- Action 9 - Further research: Further work should be done to identify and protect critical key habitats (as mentioned in action 1), e.g. as carried out by Lezama-Ochoa *et al.* (2019b). Such work could be facilitated through collaboration with third parties such as the Manta Trust.

- Action 10 - Further research: Post-release mortality should be investigated through a centralised PRM program implemented by the IOTC. Such work could be facilitated through collaboration with third parties such as the Manta Trust.

Contents

1. Introduction to mobulids

1.1. Overview

Manta and devil rays (collectively known as mobulids) are a family of migratory elasmobranchs, with a circumglobal tropical and subtropical distribution. Maximum disc widths (DW) are 3.7 metres in the devil rays (Notarbartolo di Sciara, 1987; Stevens *et al.*, 2018) and 6.8 metres in the manta rays (McClain *et al.*, 2015; Stevens *et al.*, 2018). All are planktivorous filter feeders which use a variety of feeding strategies to increase efficiency; utilising their cephalic fins to guide prey into their mouths and modified gill plates to strain plankton and small fishes from the water (Couturier *et al.*, 2012; Stevens *et al.*, 2018).

Morphological similarities and overlapping ranges in a number of *Mobula* species have resulted in taxonomic uncertainties (Couturier *et al.*, 2012). In recent years, a number of genetic studies have been used to resolve such ambiguities, and a number of revisions have been made to the *Mobulidae* (e.g. White *et al.*, 2017; Notarbartolo di Sciara *et al.*, 2019; Hosegood *et al.,* 2019; Notarbartolo di Sciara, Stevens and Fernando, 2020). These studies are key in enabling effective conservation measures, which must reflect accurate taxonomy (Stevens *et al.*, 2018). Of the ten currently valid *Mobula* species (White *et al.*, 2017; Stevens *et al.*, 2018; Notarbartolo di Sciara *et al.*, 2019), seven are present in the Indian Ocean (Stevens *et al.*, 2018).

1.2. Threats

The literature concerning mobulid biology and ecology highlights their vulnerabilities to anthropogenic threats. Mobulids are late to mature and have low fecundity, giving birth to a single pup via aplacental viviparity every two to seven years, after a gestation period of about one year (Couturier *et al.*, 2012; Stevens *et al.*, 2018; Stewart *et al.,* 2018a) (Table 1). The life history traits of the largest *Mobula* species mean their maximum rates of intrinsic population increase are among the lowest of all elasmobranchs (Dulvy *et al.*, 2014). Mobulids are vulnerable to both targeted fisheries (due to the increasing demand for dried mobulid gill plates) and bycatch, and are caught in both small-scale and commercial (e.g. tuna) fisheries (Croll *et al.*, 2016). Such fisheries present a major threat to mobulids (Stevens *et al.,* 2000; Dulvy *et al.*, 2014; Croll *et al.*, 2016; Ender *et al.*, 2018; Stewart *et al.,* 2018a), with some mobulid populations exhibiting declines of over 90% (e.g. Lewis *et al.*, 2015; Rohner *et al.*, 2017; Moazzam, 2018).

1.3. Protections

A number of protections have been implemented in recent years in response to the growing concern for mobulids (Table 2). The CMS Appendices I and II requires the 130 Parties to strictly protect the species and collaborate toward regional conservation (CMS, 2015; Lawson *et al.*, 2017). The CITES Appendix II requires the 183 Parties to issue permits to export mobulids (or mobulid products) only after demonstrating that they are sourced from legal and sustainable fishing operations (CITES, 2016; Lawson *et al.*, 2017).

In 2015, the Inter-American Tropical Tuna Commission (IATTC) adopted a resolution on the conservation of mobulid rays caught in association with fisheries in the IATTC Convention Area (IATTC, 2015), which is binding on its Members. In 2019, both the IOTC and the Western and Central Pacific Fisheries Commission (WCPFC) followed with CMMs on the conservation of mobulid rays caught in association with fisheries in their relative areas of competence/convention areas (IOTC, 2019; WCPFC, 2019). These resolutions: prohibit retention of mobulid rays; require vessels to release mobulids alive and unharmed where possible, and as soon as they are seen; and require CPCs to record mobulid discards and releases. Of the 31 IOTC Parties, 8 have varying degrees of additional national protections for mobulids in place (Australia, Indonesia, Maldives, Thailand, the UK, France 'OT', the EU and the Philippines) (Table 2). Despite this, many fisheries remain open and active (Lawson *et al.*, 2017)

Table 1. Biology of mobulid species found in the Indian Ocean.

	Parameter				
Species	Range and stock structure	Longevity	Maturity (50%)	Reproduction	Size (length and weight)
Mobula alfredi	Surface to 672 m [i] Resident in shallow coastal waters [a,b] Capable of long-distance movements but do so infrequently [a] Aggregations are widely separated with low connectivity [a] Diel patterns of habitat use – inshore during the day, offshore at night [a,b]	~40 years [a,b]	Size at maturity: - Females 320-350 cm DW [b] - Males 270-300 cm DW [b] Age at maturity: - Females ~15 years [b] - Males ~9 years [b]	1 pup on average every 2-5 years [b] Median max. rate of population increase is 0.0032 per year [a] Generation time is 29 years [a]	Maximum 450 cm DW [b] Average 300-350 cm DW [b] Pup 130-150 cm DW [a]
Mobula birostris	Capable of deep dives over 1,000 m [c] Sparsely distributed, small, and highly fragmented populations [c] Suspected to be highly migratory [b,c] Decline of small subpopulations may result in regional depletions or extinctions [c] Primarily oceanic [b], seasonal visitor to coastal or offshore sites where aggregations can be observed [c]	Unknown, likely to be at least ~40 years [b,c]	Size at maturity: - Females 450-550 cm DW [b] - Males 350-400 cm DW [b] May vary slightly throughout its range. Age at maturity: - Unknown [b]	1 pup per litter [c] Generation time suspected to be 25 years [c] Little information on the reproductive biology or ecology of this species [b,c]	Maximum 680 cm DW [b,c] Average 400-500 cm DW [b]
*Mobula eregoodoo**	Surface to 50 m [d] Inshore and offshore pelagic species that occurs in continental shelf areas [d] Schooling behaviour is common [b,d]	Unknown [b,d]	Size at maturity: - Males 99 cm DW [d] - Females 92.5 cm DW [d] Age at maturity: - Unknown [b,d]	One pup possibly every 1-3 years [b,d] Gestation period estimated at least 10 months, possibly >12 [d]	Maximum 130 cm DW [b,d] Average 110 cm DW [b] Pup 43 cm DW [d]
Mobula kuhlii	Surface to 50 m [e] Mainly inshore continental shelf species that occurs in coastal areas [e] Schooling behaviour observed [b]	Unknown [b,e]	Size at maturity: - Males 115 cm DW [e] - Females 116 cm DW [e] Age at maturity - Unknown [b,e]	One pup possibly every 1-3 years [b,e] Unknown gestation period [b,e]	Maximum 135 cm DW [e] Average 100 cm DW [b] Pup 31-34 cm DW [e]

Mobula mobular	Surface to 1112 m deep, spends the majority of its time in less than 50 m [f] Pelagic, residing in coastal and continental shelf waters [f] Populations patchily distributed [f] Large-scale movements up to 1 1,800 km driven by seasonal patterns in prey availability [b,f] Often solitary but may aggregate in large numbers [b,f]	Unknown, estimated at ~20 years [b,f]	Size at maturity: - Males 200-220 cm DW [f] - Females 215-240 cm DW [f] Age at maturity: - Females 5-6 years [b,f]	One pup every 1-3 years [b,f] Gestation period of 12 months [f] Generation time is 12.8 years [f]	Maximum 320 cm DW [b] Significant geographical variation in size across its distribution [f] Average 180-280 cm DW [b] Pup 90-160 cm DW [b,f]
Mobula tarapacana	Surface to 1,896 m [b,g] Patchy distribution, populations mostly occurring in areas of high upwelling-related productivity [g] Oceanic, can be found in coastal shallow waters [g] Travel both in schools and in solitude [g] Highly mobile, capable of significant migrations up to 3,800 km [b,g]	Unknown, estimated at least 15 years [b]	Size at maturity: - Females 270-280 cm DW [b] - Males 198-250 cm DW [b,g] Age at maturity - Unknown, at least 5-6 years [b,g]	One pup every one to three years [b,g] Gestation period and generation time unknown.	Maximum 370 cm DW [g] Average 200-270 cm DW [b] Pup 120-130cm DW [g]
Mobula thurstoni	Surface to 100 m. Pelagic waters, only occasionally inshore [b,h] Occur most often in highly productive upwelling oceanic areas, where they sometimes aggregate [h]	Unknown, estimated at least 10 years [b]	Size at maturity: - Females 150-163 cm DW [h] - Males 150-158 cm DW [h] Age at maturity - Unknown [b,h]	One pup every 1-3 years [b,h]	Maximum 197 cm DW [h] Average 135 cm DW [b] Pup 70-90 cm DW [h]

Sources: [a] Marshall *et al.*, 2019a, [b] Stevens *et al.*, 2018, [c] Marshall *et al.*, 2018, [d] Rigby *et al.*, 2020a, [e] Rigby *et al.*, 2020b, [f] Marshall *et al.*, 2019b, [g] Marshall *et al.*, 2019c, and [h] Marshall *et al.*, 2019d, [i] Lassauce *et al.*, 2020.

* Recently resurrected as a valid species, and name changed from *Mobula eregoodootenkee* to *Mobula eregoodoo* (Notarbartolo di Sciara *et al.*, 2019)

Table 2. Protective legislation for mobulids.

Location	Species	Legal protection measure
International		
CITES Appendix II	All mobulid species	Listing of the genus *Manta* (2019) and *Mobula* (2016) on Appendix II of the Convention on International Trade in Endangered Species (CITES).
CMS Signatories	All mobulid species	Convention on the Conservation of Migratory Species of Wild Animals (CMS), Appendix I and II; *M. birostris* (2011), all other mobulid species (2014).
Inter-American Tropical Tuna Commission (IATTC)	All mobulid species	Resolution C-15-04 on the Conservation of Mobulid Rays Caught in Association with Fisheries in the IATTC Convention Area.
Western and Central Pacific Fisheries Commission (WCPFC)	All mobulid species	CMM 2019-05 Conservation and Management Measure on Mobulid Rays Caught in Association with Fisheries in the WCPFC Convention Area.
Indian Ocean Tuna Commission (IOTC)	All mobulid species	Resolution 19/03 on the Conservation of Mobulid Rays Caught in Association with Fisheries in the IOTC Area of Competence.
Regional		
European Union member countries and United Kingdom	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014.
National		
Indonesia	*M. birostris* and *M. alfredi*	KepMen National Protective Legislation, 2014.
Maldives	All ray species	Exports of all ray products banned 1995. Environmental Protection Agency rule – illegal to capture, keep or harm any type of ray; Batoidea Maldives Protection Gazette No. (IUL) 438-ECAS/438/2014/81.
Philippines	*M. birostris* and *M. alfredi*	FAO 193 1998 Whale Shark and Manta Ray Ban.
Thailand	All mobulid species	Protected under the Wildlife Preservation and Protection Act B.E. 2562 (2018).
State		
Australian Indian Ocean Territories	All ray species	Protected species. Dept. of Fisheries Western Australia 2010.
West Manggarai/Komodo	*Manta* spp.	Shark and Manta Ray Sanctuary Bupati Decree 2013.
Raja Ampat Regency, Indonesia	All ray species	PERDA (Provincial Law) Hiu No. 9 Raja Ampat 2012.

Source: Table from Ender *et al.* (2018), updated to include related measures from the WCPFC (2019), and IOTC (2019). Measures not relevant to the IOTC Area of Competence not included.

2. The status of mobulids

2.1. Global status and trends

The large ranges of mobulids mean assessment of status is complicated, and conservation requires abatement of varying threats across multiple jurisdictions. Previously, the IUCN assessments have not been possible for some mobulid species due to a lack of data availability (Couturier *et al.*, 2012). As studies of mobulid abundance and population status have increased, so too has the assessed level of endangerment of extinction. All mobulids are now assessed as either Vulnerable (facing a high risk of extinction in the wild) or Endangered (facing a very high risk of extinction in the wild) (IUCN, 2020) (Table 3). Steep population declines due to exploitation in fisheries have played a major role in these assessments for both the manta rays (Marshall *et al.*, 2019a; Marshall *et al.*, 2018) and the devil rays (Rigby *et al.*, 2020a; Rigby *et al.*, 2020b; Marshall *et al.*, 2019b; Marshall *et al.*, 2019c; Marshall *et al.*, 2019d) present in the Indian Ocean.

Table 3. IUCN threat status for all mobulid species which occur within the Indian Ocean.

Common name	Scientific name	IUCN threat status	Last assessed
Reef manta ray	*Mobula alfredi*	Vulnerable	09 November 2018
Oceanic manta ray	*Mobula birostris*	Vulnerable	01 November 2010
Longhorned pygmy devil ray	*Mobula eregoodoo*	Endangered	20 January 2020
Shorthorned pygmy devil ray	*Mobula kuhlii*	Endangered	20 January 2020
Spinetail devil ray	*Mobula mobular*	Endangered	20 November 2018
Sicklefin devil ray	*Mobula tarapacana*	Endangered	09 November 2018
Bentfin devil ray	*Mobula thurstoni*	Endangered	09 November 2018

Source: IUCN (2020)

Mobulids are vulnerable to local depletion and regional extinction due their small population sizes (e.g. *Mobula birostris*, Marshall *et al.*, 2018), and often low connectivity between populations where a high degree of residency is exhibited (*e.g. Mobula alfredi*, Marshall *et al.*, 2019a). Severe population declines, including suspected local extinctions, have been observed across the Indian Ocean (Table 4). These long living animals, with highly conservative life histories, are likely to recover slowly, or not at all, from such population reductions. It is imperative that effective conservation measures are implemented to prevent further decline due to fisheries, as well as other anthropogenic threats (such as tourism, and indirect threats such as reef degradation).

2.2. Conservation strategies

Three key strategies for mobulids have been published in recent years. In March 2017, Lawson *et al.* published the Global Devil and Manta Ray Conservation Strategy*.* Trends in the scientific literature and updated species distribution maps of Area of Occupancy (AOO) and Extent of Occurrence (EOO) of mobulids were examined, with subsequent review of overlapping areas of threats (fisheries) and distribution. This was used to develop the strategy which "specifies a vision, goals, objectives and actions to advance the knowledge and protection of both devil and manta rays" (Lawson *et al.*, 2017). Following this, the CMS adopted the Concerted Action for the mobulid rays at the Conference of the Parties at its 12th meeting in October 2017, which seeks to ensure the long-term conservation and sustainable management of mobulid rays and encourages Parties to implement the Global Conservation Strategy (CMS, 2017).

The Manta Trust also published a more holistic Global Strategy and Action Plan for the Conservation of Mobulids (Ender *et al.*, 2018), of which a key goal is to address the direct threat of bycatch to mobulids. In order to achieve this, effective national and regional policies (e.g. via RFMOs) need to be developed and implemented to support better gear use and its enforcement in both artisanal and commercial fisheries.

3. Interactions with the IOTC fisheries

3.1. Bycatch in tuna fisheries

Mobulids are mainly caught as bycatch, primarily in industrial purse-seine fisheries, and to a lesser extent in longline fisheries (Croll *et al.*, 2016; Shahid *et al.*, 2018). They are also incidentally captured in small-scale gillnet fisheries, usually being retained for their meat and gill plates (White *et al.*, 2006; Ardill *et al.*, 2011; Moazzam, 2018). Observer coverage on the IOTC fishing vessels is limited, and often mobulid landings are not identified to species level, meaning data is poor.

In 2018, Shahid *et al.* submitted a report to the IOTC WPEB examining mobulid interactions with surface fisheries in the Indian Ocean, stating that "considering the high fishing effort in the Indian Ocean, the total annual captures are likely to exceed sustainable exploitation of these slow growing species". The report summarises information gathered on mobulid ray interaction with surface tuna fisheries in the IOTC Area of Competence by: fishery type, gear type, target species, whether mobulids are caught as bycatch and/or targeted, the number of *Mobula* species caught, and trend. Additionally, reports submitted to the WPEB by Moazzam (2018), and Fernando (2018), have highlighted declines due to tuna gillnet fisheries in Pakistan, and due to tuna fishing vessels in Sri Lanka, respectively.

A study by Croll *et al.* (2016) investigated bycatch of mobulids in tuna purse seine fisheries and found that mobulids are frequently caught incidentally throughout their ranges, which is likely contributing significantly to their decline. Between 1981 and 2008, the estimated average annual capture (individuals year^{-1}) in Indian Ocean purse seine fisheries was 1936 – this is based on a mobulid capture rate (individuals set^{-1}) of 0.04, with 8694 sets per year, and ~8% of these sets were observed (Croll *et al.*, 2016). Amandè *et al.* (2008) found rays represented 0.7% (0.2t/1000t) of the total discard amount for the European purse seine tuna fishery (France and Spain) in the Indian Ocean for the period 2003-2007 (data from French and Spanish observer programs, total of 1958 observed fishing sets), 173 rays (15 t) were caught over the whole period. A review published by Hall and Roman in 2013 investigated bycatch in tropical tuna purse seine fisheries globally. Bycatch of mobulids was highest in school sets, but they are also caught in dolphin sets and to a lesser extent floating object sets.

Around Indonesia, *M. mobular* [previously *M. japanica* (White *et al.*, 2017)] have been recorded as the most abundant bycatch (White *et al.*, 2006). In the Indian ocean more broadly, *M. birostris* comprises the larger capture among the rays, followed by *M. mobular* and *M. tarapacana* (Amandè *et al.*, 2008). This may reflect an increased vulnerability of the primarily oceanic mobulids (*M. birostris, M. mobular, M. tarapacana* and *M. thurstoni*) to bycatch in tuna fisheries (Hall and Roman, 2013; Croll *et al.*, 2016). However, difficulties in species identification make such assumptions difficult to validate. It is likely that all seven species of mobulids found in the Indian Ocean are caught as bycatch in purse seines (Hall and Roman, 2013; Shahid *et al.*, 2018).

3.2. Mobulid landings

Mobulid exploitation is reported by the Food and Agricultural Organization (FAO) to some extent based on limited landings data (Shahid *et al.*, 2018). In 2009, Lack and Sant noted an increase in total landings of mobulids from 2000-2007, with an average of 1,593 tonnes per annum. Global total landings have since continued to increase to over 7,000 tonnes in 2018 (FAO Fishstat Capture Production Database, 2020). In the Indian Ocean (Eastern and Western), landings of mobulids (listed as 'Mantas, devil rays nei', and 'Mobula nei') were first reported in 2007 at 761 tonnes. Annual landings have since increased to 2,700 tonnes in 2012, and have subsequently decreased to 1,360 tonnes in 2018 (FAO Fishstat Capture Production Database, 2020).

These reported landings are likely to represent a fraction of total fishing-related mortality (Ward-Paige *et al.*, 2013). In many cases, only estimates are available based on limited catch reporting, with most countries not systematically reporting mobulids in fisheries data (Shahid *et al.*, 2018). This is highlighted in that two countries, Indonesia and Sri Lanka, together account for 100% of the reported landings. Further, these figures exclude the category 'Rays, stingray, mantas nei'. When included, landings are significantly higher (22,079 tonnes landed in the Indian Ocean in 2018). Landings of mobulids in the Indian Ocean are likely to be considerably higher than indicated in these figures.

3.3. Distributional overlap

The epipelagic distribution of mobulids in regions of high productivity means there is a high level of distributional overlap between the commercially desirable tunas and mobulids (Croll *et al.*, 2012; Shahid *et al.*, 2018). This, as well as their tendency to aggregate, make mobulids particularly susceptible to incidental capture in tuna fisheries (Croll *et al.*, 2016). Further, many species undertake large seasonal migrations (Couturier *et al.*, 2012) – a driver of which may be oceanographic features and their influence on prey distribution (Stewart *et al.*, 2018a). The depths and regions used by mobulids (Figure 1) coincide with many artisanal and industrial fisheries (Marshall *et al.*, 2019b), which can be intensive in parts of their range (e.g. Pakistan, India and Bangladesh) (de Young, 2006; Moazzam, 2018; Shahid *et al.*, 2018).

This overlapping distribution with tunas, as well as mobulids' particular susceptibility to fisheries (e.g. due to aggregations, slow movement), and their fragmented populations (White *et al.*, 2006) has likely contributed to a number of severe population declines (CMS, 2017). In the Indian Ocean, significant mobulid catch declines have been observed (Table 4), despite evidence of increasing fishing effort (CMS, 2017). Further, reports from fishers and traders of mobulid gill plates indicate that they are becoming harder to source (O'Malley *et al.*, 2016). Extinction and/or severe decline is suspected in some areas with intense fishing pressure, e.g. *M. alfredi* in Madagascar, Tanzania, Kenya, Somalia, Pakistan, India, Sri Lanka, Bangladesh, Myanmar, China, and Indonesia (Marshall *et al.*, 2019a). Due to a lack of data, many of the rates of decline are inferred or suspected (Rigby *et al.*, 2020a), and it is likely that more population declines have gone unnoticed in other areas (CMS, 2017).

Table 4. Examples of reported mobulid population declines in the Indian Ocean.

Location	Estimated decline in mobulid population	Reference
Cilacap, Indonesia	77%	Lewis *et al.*, 2015
Tanjung Luar, Indonesia	99%	Lewis *et al.*, 2015
Pakistan	>90%	Moazzam, 2018
Mozambique	>90%	Rohner *et al.*, 2017

Source: Ender *et al.* (2018)

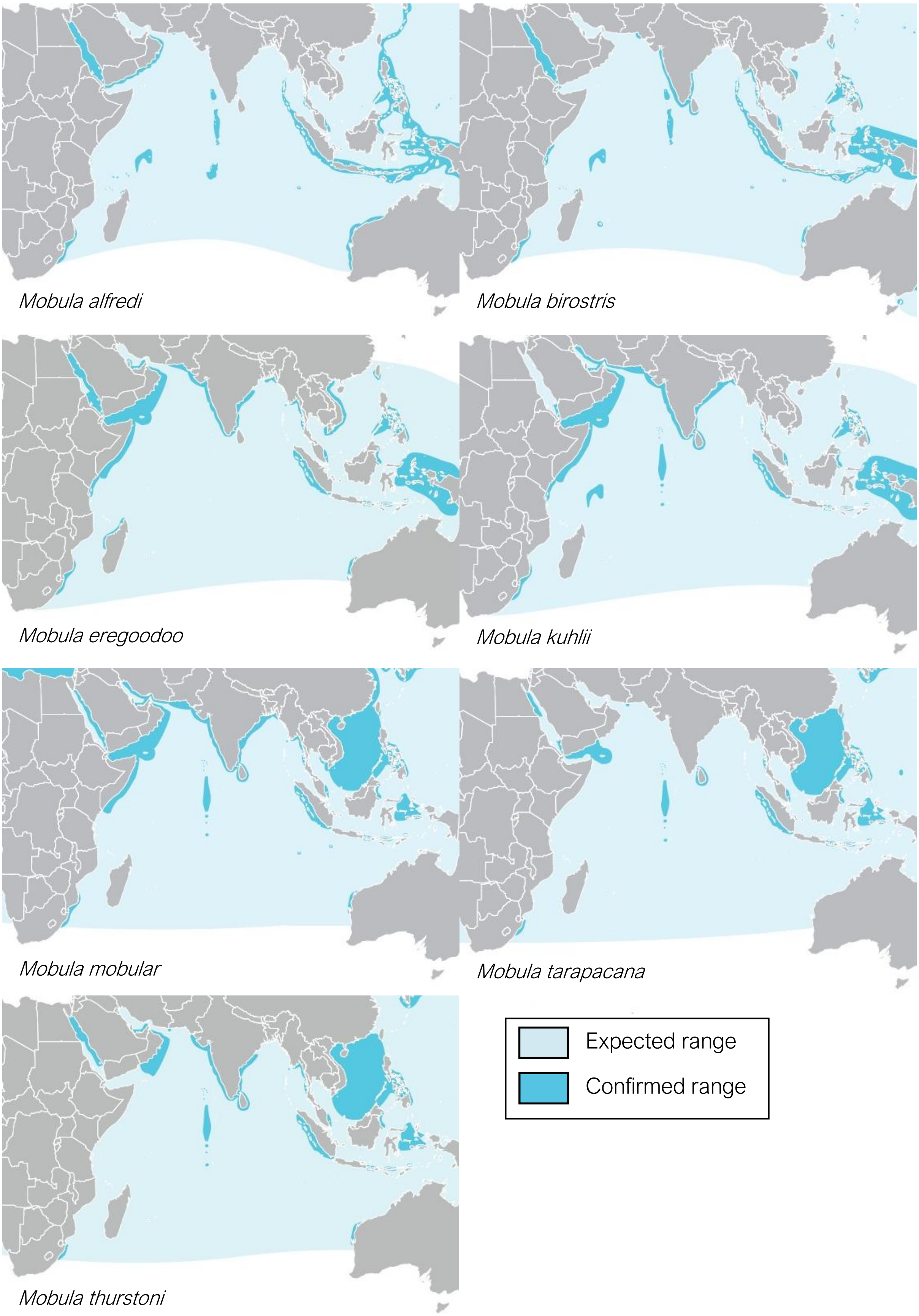

Figure 1. Expected and confirmed ranges of mobulids in the Indian Ocean (Stevens *et al.*, 2018)

3.4. Release methods and mortality

As obligate ram ventilators, mobulids require constant motion for respiration and asphyxiate if prevented from swimming (Stevens *et al.*, 2018), and as a result, are less likely to survive landings or entanglement. Additionally, the biological traits of mobulids (i.e. a lack of rigid skeleton to protect their internal organs), make them particularly vulnerable to handling on deck (Poisson *et al.*, 2014; Stewart *et al.*, 2018a). A limited number of studies have investigated post-release mortality of mobulids caught incidentally and have found low rates of survival (Poisson *et al.*, 2014; Francis and Jones, 2017). Current preliminary research by Stewart *et al.* has found a correlation between time on deck and post-release mortality, with longer periods on deck leading to a lower survival rate (M. Cronin pers. comm.).

In the Amandè *et al.* (2008) study, 33% of mobulids discarded from tuna purse seine fisheries in the Indian Ocean were released alive. However, even when mobulids are discarded alive, they are often injured and have high post-release mortality (Tremblay-Boyer and Brouwer, 2016; Francis and Jones, 2017). In the 2017 study by Francis and Jones, 62.5% of tagged mantas released alive (healthy and lively with minimal superficial injuries on discard) subsequently died within 2-4 days of release. The ones which survived were those brailed on board, while the ones entangled in the net and released did not survive (Francis and Jones, 2017; Grande *et al.*, 2019). Post-release survival data is even more scarce for mobulids discarded from longline fisheries (Mas, Forselledo and Domingo, 2015; Hutchinson, Poisson and Swimmer, 2017).

Most releases of mobulids are still done manually, with available data indicating the handling and discard practices currently utilised by fishers are inflicting injuries that reduce mobulid survival post-release (Tremblay-Boyer and Brouwer, 2016; Grande *et al.*, 2019). A key issue is the lack of available tools to safely manipulate mobulids, which are often very large (Table 1) (Grande *et al.*, 2019). Some "homemade" tools such as mobulid canvases have been proposed in the IATTC area, however, there remain issues with their implementation: there are no minimum standard construction specifications, meaning the tools are often inadequate; and fishers must still handle the animal when pulling it out the brail to lay it on the canvas (Grande *et al.*, 2019).

New tools to release mobulids in purse seiners, longlines and gillnets should be developed and tested, which are practical to use onboard and maximise mobulid post-release survival (Grande *et al.*, 2019). The IATTC have been working collaboratively with fishing crews to design potential tools for mobulid release, such as "manta ray grids" which prevent mobulids from going down into the lower deck during brailing and facilitate their lifting and release operations (Grande *et al.*, 2019; M. Cronin pers. comm.). These manta release grids have now been distributed to fishers for testing under standard commercial trips and are receiving positive feedback from fishers (M. Cronin pers. comm.). Other potential bycatch mitigation tools include modified brailer grids, and the use of LED lights to reduce bycatch of mobulids in gillnet fisheries.

4. Data availability and gaps

4.1. Overview

Research on mobulids, although increasing, has been limited by the difficulties in observing and investigating *Mobula* species in their extensive oceanic environment (Couturier *et al.*, 2012; Croll *et al.*, 2016; Lawson *et al.*, 2017; Stevens *et al.*, 2018). The majority of observations come from *M. alfredi* due to its coastal distribution on reefs, enabling data collection primarily by divers and snorkellers. Even so, events such as courtship rituals and mating are observed relatively infrequently, and no mobulids have ever been observed giving birth in the wild (Stevens *et al.*, 2018). Current knowledge of the biology of mobulid rays present in the Indian Ocean is outlined in Table 1.

A systematic literature review undertaken by Stewart *et al.*, published in September 2018(a), identified research priorities to support effective mobulid ray conservation. The review highlighted the need for taxonomic clarifications, better knowledge of mobulid life history parameters, and more studies on bycatch and fisheries (including post-release mortality, species distributions and fisheries data standardisation). It also emphasised the importance of methodological consistency, long-term data sets, and the involvement of regional management resource managers in research activities, in improving the relevance of future mobulid research for management.

4.2. Key data gaps

A number of data gaps, in addition to the lack of IOTC fisheries observer coverage and lack of research into bycatch mitigation for mobulids, are of relevance to and could be addressed by tuna RFMOs (Table 4).

Table 4. Priority knowledge gaps identified by Stewart *et al.* (2018a) which may be addressed in fisheries study systems.

Research topic	Research method
Life history	Vertebral band pair counts Size at maturity
Bycatch impacts (Detailed further in section 3.4.)	Post-release mortality tagging Bycatch prevention
Population trends	CPUE Close kin mark recapture Effective population size Catch curves LBSPR
Population structure	Genetic analyses
Foraging	Isotope / fatty acid analyses Stomach content analyses Pollutant analyses
Taxonomy	Genetic analyses Morphology

Source: Stewart *et al.* (2018a).

Key life history parameters, such as age at maturity, growth rate, lifespan, mortality (both natural and fisheries-induced) and fecundity are lacking for most mobulid species (Table 1). This is despite the requirement for such understanding in undertaking stock assessments and implementing effective management (Croll *et al.*, 2016; Stewart *et al.*, 2018a). Life history parameters should be obtained across species and locations, as biological characteristics are likely to vary, requiring management at the population level (Stewart *et al.* 2018a).

In order to direct management actions, future research should seek to identify life stages with significant contributions to overall population viability, and to identify key habitats for mobulids (Stewart *et al.*, 2018a). Reproduction and nursery areas are known mainly from *M. alfredi*. Other *Mobula* species, as well as the juvenile stage of all mobulid species, remain poorly studied (Stevens *et al.*, 2018; Stewart *et al.*, 2018a). It is, however, known that in several mobulid species, reproductive activity peaks seasonally and often occurs at aggregation sites e.g. seamounts (Stevens, 2016; Stevens *et al.*, 2018). Further long-term monitoring may reveal more seasonal mating grounds for certain species, and work is currently underway to assess locations as potential nursery habitats for mobulids (Stewart *et al.*, 2018a). Such research should be a priority area, allowing management measures to be put in place to protect critical habitats for mobulids at various life stages. Such protections should seek to prevent changes in natural behaviour, prevent obstructions to these areas, and ensure the safety of individuals within these areas (e.g. from targeted or incidental fishing) (Croll *et al.*, 2016; Stewart *et al.*, 2018a).

There is a critical need for higher observer coverage and bycatch reporting onboard tuna fishing vessels. This will enable mobulid abundance estimates through CPUE or BPUE, and relationships between abundance and key environmental variables to be revealed (Stewart *et al.*, 2018a). Dynamic spatio-temporal management approaches can then be developed, with the lowest economic loss from reduced catches of target species (Stewart *et al.*, 2018a; Lezama-Ochoa *et al.*, 2019a). Post-release mortality should be evaluated for a range of gear types. Additionally, the impact of handling and release methods and relevant environmental and operational covariates on mobulid post-release mortality should be evaluated. To achieve this, studies can utilise pop-off satellite tags (Francis and Jones, 2016) or blood chemistry analyses (Hutchinson *et al.*, 2015) to investigate survival post-release. Further, observer programs should collect fishery-wide data on covariates, such as time on deck and behaviour after release (Stewart *et al.*, 2018a).

Observers can also play a critical role in collecting data to investigate genetic connectivity and diversity within and between mobulid populations. Fisheries provide opportunities to obtain the large sample sizes and geographic coverage required for such studies (Stewart *et al.*, 2018a). From these, estimates of population structure can be drawn and appropriate regional management put in place.

To enable these critical data gaps to be addressed, data collection protocols for observers should be standardised for mobulids across the RFMOs, and further emphasis should be given to species identification training for observers (Stewart *et al.*, 2018a). To facilitate this, collaboration between the various tuna RFMO fisheries observer trainers should be encouraged. Currently work is being carried out by the Manta Trust to develop cohesive mobulid identification guides for the IATTC, the WCPFC and the IOTC. A comprehensive, standardised data collection manual that ensures all relevant variables (including release methods) are collected should be developed (Stewart *et al.*, 2018a). This, along with the identification guides and observer training programmes, will enable accurate comparisons across regions and fisheries.

4.3. Recent progress

Since the Stewart *et al.* (2018a) review, several studies have been published which seek to address one or more of the knowledge gaps identified. The primary focus of these studies has been on habitat use, regional movements, and seasonal distribution of *M. alfredi* (e.g. Axworthy *et al.*, 2019; Carpentier *et al.*, 2019; Peel *et al.*, 2020; Germanov, 2020; Harris *et al.*, 2020; Andrzeiaczek *et al.*, 2020; Venables *et al.*, 2020; Armstrong *et al.*, 2020). Other studies have investigated *Mobula* taxonomy and genomic tools for *Mobula* management (e.g. Notarbartolo di Sciara *et al.*, 2019; Hosegood *et al.*, 2019), diving and feeding behaviour (e.g. Stewart *et al.*, 2019; Burgess *et al.*, 2020; Lassauce *et al.*, 2020), and gestation and development (e.g. Murakumo *et al.*, 2020). Again, these studies tend to be of *M. alfredi*.

A number of PhDs are currently underway which also seek to address key knowledge gaps to inform mobulid conservation. The Mobula Project Indonesia, led by Betty Laglbauer, is working to: monitor species-specific abundance of mobulids at fishing markets, provide age and growth data for devil rays, study the habitat use of devil rays, and to identify means to reduce bycatch of devil rays. In doing so, the project aims to fill gaps in our knowledge and provide much-needed information to governmental institutions to support mobulid conservation. Other research is also ongoing in collaboration with other tuna RFMOs, such as IATTC, to carry out research into various bycatch mitigation measures as well as looking to identify critical habitats for protection (M. Cronin pers. comm.)

5. Recommendations for management

5.1. Obligations and compliance

The CMS Appendices I and II require the 130 Parties to strictly protect the species and collaborate toward regional conservation (CMS, 2015; Lawson *et al.*, 2017). Further, the CMS Concerted Action 12.6 calls upon Parties to implement effective national protections for mobulid rays, including reducing mobulid target and incidental catch; and monitoring, evaluating and adapting conservation and management strategies. National conservation measures intended to prevent further mobulid decline are unlikely to be successful if the animals are not protected during their seasonal migrations through ABNJ (CMS, 2017). Therefore, an international approach is required to protect mobulids and prevent further extinctions.

Commercial tuna purse seiners, as well as longline and gillnet fisheries, pose one of the most significant threats to mobulids (Hall and Roman, 2013; Croll *et al.* 2016, Shahid *et al.*, 2018; Moazzam, 2018). Their often small, spatially isolated populations suffer quick decline to extinction in areas of high fishing pressure (e.g. Moazzam, 2018; Table 4). Despite a lack of data in a number of areas, the evidence available is alarming and points to an urgent need to effectively protect key mobulid habitats, and limit mobulid mortality from both target and incidental capture in fisheries.

Resolution 19/03 (Annex 1; IOTC, 2019) prohibits the retention of mobulids and requires prompt release of animals as soon as they are seen, in a manner that will result in the least possible harm to the animal. Further, it requires the number of mobulid discards and releases to be reported through logbooks and/or observer programs. CPCs are required to report this information to the IOTC Secretariat, and are responsible for ensuring that fishers are aware of and use proper mitigation, identification, and handling and release techniques. CPCs are also required to develop sampling plans for the subsistence and artisanal fisheries, and are encouraged to investigate at-vessel and post-release mortality. Whilst Resolution 19/03 is an essential step forward in the move to protect mobulids in the IOTC Area of Competence, stringent implementation, compliance, and further research will be essential to ensure the success of this measure in reducing mobulid mortality.

5.2. Pre-capture methods

As per Resolution 19/03, the IOTC Scientific Committee is required to identify possible hotspots for conservation and management of mobulids within and beyond EEZs in 2023. Some mobulid species show an often-predictable tendency to seasonally aggregate at known productive regions (e.g. Ward-Paige *et al.*, 2013), where site fidelity has been evidenced (e.g. Dewar *et al.*, 2008; Deakos, Baker and Bejder, 2011), and are extremely vulnerable to capture particularly in these areas. Additionally, a number of potential mobulid nursing sites are currently being investigated (Stewart *et al.*, 2018b; Diaz Palacios, 2019; Pate and Marshall, in press). Post-release mortality of mobulids is high (Francis and Jones, 2017), meaning effective mobulid conservation requires crucial pre-capture methods to be implemented. Spatio-temporal management (ideally dynamic) should be implemented in known key habitats (Croll *et al.*, 2016; Hutchinson, Poisson and Swimmer, 2017; Stewart *et al.*, 2018a) without delay.

Given the evidenced and suspected declines, the precautionary principle approach should be adopted, and work should be done immediately to identify and protect these critical times and locations for mobulids, e.g. through the creation of dynamic MPAs (Ward-Paige *et al.*, 2013; Croll *et al.*, 2016). Research should be continued to identify common physical and biological processes that underlie mobulid movements and aggregations, which will allow for improved identification of these critical habitats (Stewart *et al.*, 2018a), enabling more effective measures to be implemented in the future which minimise the economic loss in terms of reduced target catch.

5.3. Safe handling and release

Post-release mortality of mobulids caught in tuna fishing vessels is suspected to be high (Amandè *et al*. 2008; Tremblay-Boyer and Brouwer, 2016; Francis and Jones, 2017; M. Cronin pers. comm.). Current research into effective mobulid release tools is limited, and proposals for preventing interactions between fishing gear and mobulids are needed (Stewart *et al*., 2018a). Existing tools for fauna release e.g. canvas nets should be improved, and/or new, more efficient equipment should be developed and tested for ease of use by fishers and post-release mortality of mobulids (Grande *et al*., 2019). Suggested methods to be investigated include modified brailer grids and manta ray grids in purse seiners, (as well as pre-capture methods e.g. LEDs in gillnet fisheries). In addition to encouraging CPCs to undertake their own investigations, funding should be made available to develop a central at-vessel and post-release mortality research program.

Compliance with Resolution 19/03 item 5 should be investigated and facilitated by the IOTC, and the importance of the quick release of mobulids to reduce mortality should be incentivised to fishing crew. Training of the skippers and crew involved in the handling should be strengthened (item 9 of Resolution 19/03) and closely monitored. Further work to identify and implement less harmful handling practices should be carried out (and, in the short term, more specific handling guidelines should be followed such as those in Annex 2), with the potential to prevent a significant amount of onboard and post-release mortality (Stewart *et al*., 2018a).

5.4. Observer coverage and training

Fisheries observers are crucial to gather data to address critical gaps in our knowledge, as previously outlined. In order to draw better conclusions concerning the interactions with IOTC fisheries and mobulid rays, observer coverage on board needs to be significantly higher. Interactions data should be stratified by season, broad area, and in the form of CPUE. To facilitate further research, a focus on observer training should be given, with a focus on achieving accurate mobulid species identification. Observer reports (as well as logbook data following Resolution 19/03) should be analysed to support assessments of the effectiveness of mitigation measures. Mechanisms should be developed by the Compliance Committee to assess compliance with Resolution 19/03, and with the ROS. Without such compliance the IOTC WPEB will continue to struggle to fully address the issue of mobulid bycatch in the IOTC fisheries.

5.5. Summary

CMM 19/03 is very positive and in order to ensure implementation and compliance, while achieving the goal of significantly decreasing the mortality of mobulid rays, the following actions are recommended:

- **Action 1 - Pre-capture:** Spatio-temporal management of critical key habitats for mobulids, where they are found in high abundance, should be immediately implemented. Such pre-capture methods should be prioritised to minimise mobulid mortality in the IOTC fisheries.

- **Action 2 - Pre-capture**: New technologies to prevent incidental capture of mobulids e.g. LED lights in gillnets, should be developed and tested.

- **Action 3 - Safe handling and release:** New tools for mobulid release, e.g. manta grids or modified brailer nets in purse seiners, should be developed in collaboration with fishing crew and tested under normal operations.

- **Action 4 - Safe handling and release:** The quick and safe release of mobulids, in a manner to cause as minimum harm as possible using the best available guidelines (e.g. Annex 2), should be incentivised and compliance of fishing crew closely monitored.

- Action 5 – Data collection: Observer coverage of the IOTC vessels should be significantly higher. This is crucial to addressing the issue of mobulid bycatch.

- Action 6 - Data collection: Thorough training should be given to fisheries observers, skippers, and fishing crew to enable accurate reporting on mobulid capture, with an emphasis on the need to collect good photographs to enable verification. This could be facilitated by a Manta Trust administered online mobulid identification hub where mobulid experts can give quick verification of species identification.

- Action 7 - Data collection: Improved and updated mobulid identification guides should be developed. The Manta Trust can facilitate this through provision of materials with the hope to create more cohesive guides across the RFMOs.

- Action 8 - Data collection: Data collection protocols, as well as safe handling and release guidelines, should be reviewed and, where possible, standardised across the RFMOs. This could be facilitated by the Manta Trust, and would help to address key knowledge gaps as outlined in section 4.2.

- Action 9 - Further research: Further work should be done to identify and protect critical key habitats (as mentioned in action 1), e.g. as carried out by Lezama-Ochoa *et al.* (2019b). Such work could be facilitated through collaboration with third parties such as the Manta Trust.

- Action 10 - Further research: Post-release mortality should be investigated through a centralised PRM program implemented by the IOTC. Such work could be facilitated through collaboration with third parties such as the Manta Trust.

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7. Acronyms

AOO – Area of occurrence
BPUE – Bycatch per unit effort
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMM – Conservation and management measure
CMS – Convention on Migratory Species
CPC – Contracting Party or Cooperating non-Contracting Party
CPUE – Catch per unit effort
DW – Disc width
EOO – Extent of occurrence
FAO – Food and Agricultural Organization
IATTC – Inter-American Tropical Tuna Commission
IO – Indian Ocean
IOTC – Indian Ocean Tuna Commission
IUCN – International Union for the Conservation of Nature
RFMO – Regional Fisheries Management Organisation
ROS – Regional Observer Scheme
WCPFC – Western and Central Pacific Fisheries Commission

Annex 1. IOTC Resolution 19/03 (2019)

Food and Agriculture Organization of the United Nations

Indian Ocean Tuna Commission
Commission des Thons de l'Ocean Indien
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RESOLUTION 19/03
ON THE CONSERVATION OF MOBULID RAYS CAUGHT IN ASSOCIATION WITH FISHERIES IN THE IOTC AREA OF COMPETENCE

Keywords: Mobula Rays, Manta Rays, Conservation,

The Indian Ocean Tuna Commission (IOTC),

RECOGNISING Resolution 12/01 On the implementation of the Precautionary Approach calls on IOTC Contracting Parties and Cooperating Non-Contracting Parties to apply the precautionary approach when managing tuna and tuna-like species in accordance with Article 5 of the United Nations Fish Stocks Agreement and that, for sound fisheries management, such an approach applies also within areas under national jurisdiction;

RECALLING IOTC Resolution 05/05 *Concerning the conservation of sharks caught in association with fisheries managed by IOTC* [superseded by Resolution 17/05];

CONSIDERING that the species of the family Mobulidae, which includes manta rays and mobula rays (hereinafter mobulid rays), are extremely vulnerable to overfishing as they are slow-growing, late sexual maturity, have long gestation periods, and often give birth to only a few pups;

RECOGNISING the ecological and cultural significance of mobulid rays in the Indian Ocean;

CONCERNED about the possible impacts on these species by the different fisheries occurring from coastal areas to the high seas;

CONSIDERING that the United Nations Food and Agriculture Organization (FAO) International Plan of Action for Sharks calls on States to cooperate through regional fisheries management organizations to ensure the sustainability of shark stocks;

CONCERNED by the lack of complete and accurate data reporting concerning fishing activities on non-targeted species;

RECOGNIZING the need to improve the collection of species-specific data on catch, catch rates, release, discards, and trade as a basis for improving the conservation and management of mobulid rays stocks;

NOTING that the mobulid rays are listed in Appendix I and Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and the range States to a migratory species shall endeavour to strictly protect them;

FURTHER NOTING that the mobulid rays are also listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) for which trade shall be closely controlled under specific conditions including, inter alia, that trade will not be detrimental to the survival of the species in the wild;

ACKNOWLEDGING that the Scientific Committee (SC21) recently noted the declines of these species across the Indian Ocean and RECOMMEND that management actions, such as no-retention measures amongst other, are required and must be immediately adopted;

ADOPTS, in accordance with the provisions of Article IX, paragraph 1 of the IOTC Agreement, the following:

1. This Resolution shall apply to all fishing vessels flying the flag of a Contracting Party or Cooperating Non-Contracting Party (hereinafter referred to collectively as CPCs), and on the IOTC record of fishing vessels or authorized to fish for tuna and tuna like species managed by the IOTC.

2. CPCs shall prohibit all vessels from intentionally setting any gear type for targeted fishing of mobulid rays in the IOTC Area of Competence, if the animal is sighted prior to commencement of the set.

3. CPCs shall prohibit all vessels retaining onboard, transhipping, landing, storing, any part or whole carcass of mobulid rays caught in the IOTC Area of Competence.

4. Provisions of paragraphs 2 and 3 above do not apply to fishing vessels carrying out subsistence fishery[1] that, anyhow, shall not be selling or offering for sale any part or whole carcass of mobulid rays.

5. CPCs shall require all their fishing vessels, other than those carrying out subsistence fishery, to promptly release alive and unharmed, to the extent practicable, mobulid rays as soon as they are seen in the net, on the hook, or on the deck, and do it in a manner that will result in the least possible harm to the individuals captured. The handling procedures detailed in Annex I, while taking into consideration the safety of the crew shall be implemented and followed.

6. Notwithstanding paragraph 3, in the case of mobulid rays that are unintentionally caught by and frozen as part of a purse seine vessel's operation, the vessel must surrender the whole mobulid ray to the responsible governmental authorities, or other competent authority, or discard them at the point of landing. Mobulid rays surrendered in this manner may not be sold or bartered but may be donated for purposes of domestic human consumption.

7. Notwithstanding paragraph 3, in the case of mobulid rays that are unintentionally caught by artisanal fishing[2], the vessel should report the information on the accidental catch to the responsible governmental authorities, or other competent authority, at the point of landing. Mobulid rays unintentionally caught may only be used for purposes of local consumption. This derogation will expire in 1 January 2022.

8. CPCs shall report the information and data collected on interactions (i.e. number of discards and releases) with mobulid rays by vessels through logbooks and/or through observer programs. The data shall be provided to the IOTC Secretariat by 30 June of the following year, and according to the timelines specified in Resolution 15/02 (or any subsequent revision).

9. CPCs shall ensure that fishermen are aware of and use proper mitigation, identification, handling and releasing techniques and keep on board all necessary equipment for the release of mobulid rays in accordance with the handling guidelines of Annex 1.

10. Recreational and sport fishing shall release alive all caught mobulid rays and shall not be entitled to retaining onboard, transhipping, landing, storing, selling, or offering for sale any part or whole carcass of mobulid rays.

11. CPCs, unless clearly demonstrate that intentional and/or incidental catches of mobulids do not occur in their fisheries, shall develop, with the assistance from the IOTC Secretariat where required, sampling plans for the monitoring of the mobulid rays catches by the subsistence and artisanal fisheries. The sampling plans, including their scientific and operational rationale, shall be reported in the national scientific reports to the Scientific Committee, starting in 2020, which will provide its advice on their soundness by 2021 at the latest. The sampling

[1] A subsistence fishery is a fishery where the fish caught are consumed directly by the families of the fishers rather than being bought by middle-(wo)men and sold at the next larger market, per the FAO Guidelines for the routine collection of capture fishery data. FAO Fisheries Technical Paper. No. 382. Rome, FAO. 1999. 113p.

[2] Artisanal fishing: fisheries other than longline or surface fisheries (i.e. purse seines, pole & line, gillnet fisheries, hand-line and trolling vessels), registered in the IOTC Record of Authorized Vessels (DEFINITION in footnote 1 of Res. 15/02).

plans, where required, will be implemented by the CPCs from 2022 onward taking into account the Scientific Committee advice.

12. CPCs are encouraged to investigate at-vessel and post-release mortality in mobulids including, but not exclusively, the application of satellite tagging programs that may be provisioned primarily through the national support complementing possible funds allocation from the IOTC to investigate the effectiveness of this measure.

13. The IOTC Scientific Committee shall review the status of *Mobula spp.* in the IOTC Area of Competence and provide management advice to the Commission in 2023 also to identify possible hot-spots for conservation and management of mobulids within and beyond EEZs. Moreover, the IOTC Scientific Committee is requested to provide, whenever considered adequate on the basis of evolving knowledge and scientific advice, further improvements to the handling procedures detailed in Annex 1.

14. Scientific observers shall be allowed to collect biological samples of mobulid rays caught in the IOTC Area of Competence that are dead at haul-back, provided that the samples are a part of a research project approved by the IOTC Scientific Committee. In order to obtain the approval, a detailed document outlining the purpose of the work, number of samples intended to be collected and the spatio-temporal distribution of the sampling effect must be included in the proposal. Annual progress of the work and a final report on completion shall be presented to the SC.

Live release handling procedures

1. Prohibit the gaffing of rays.
2. Prohibit the lifting of rays by the gill slits or spiracles.
3. Prohibit the punching of holes through the bodies of rays (e.g. to pass a cable through for lifting the ray).
4. Rays too large to be lifted safely by hand shall be, to the extent possible, brailed out of the net using best available method such as those recommended in document IOTC-2012-WPEB08-INF07.
5. Large rays that cannot be released safely before being landed on deck, shall be returned to the water as soon as possible, preferably utilizing a ramp from the deck connecting to an opening on the side of the boat, or if no such ramp is available, lowered with a sling or net.

Annex 2. WCPFC Best handling practices for the safe release of mantas and mobulids.

COMMISSION
FOURTEENTH REGULAR SESSION
Manila, Philippines
3 – 7 December 2017

BEST HANDLING PRACTICES FOR THE SAFE RELEASE OF MANTAS & MOBULIDS

At WCPFC13, the Commission designated six species of manta and mobulid rays as key shark species for assessment in December 2016 and called for the development of safe release guidelines for manta and mobulid rays during SC13.
The following are recommended non-binding guidelines of best handling practices of manta and mobulid rays for both purse seine and longline fisheries:

Purse Seine

Do's:

- Release rays while they are still free-swimming whenever possible (e.g. back down procedure, submerging corks, cutting net).
- It is preferable that larger rays (>60 kg), that are too large to be lifted safely by hand are brailed out of the net and released using a purpose built large-mesh cargo net or canvas sling or similar device as recommended in document SC08-EB-IP-12 (Poisson *et al*. 2012, Good practices to reduce the mortality of sharks and rays caught incidentally by the tropical tuna purse seiners). [Note: It is preferable that release nets or devices are prepared prior to each set.]
- It is preferable that small (< 30 kg) and medium rays (30-60 kg) are handled by 2 or 3 people and carried by the sides of its wings or preferably using a purpose-built cradle/stretcher while ensuring the safety of the crew.
- When entangled in netting, carefully cut the net away from the animal and release to the sea as quickly as possible while ensuring the safety of the crew.

Don'ts:

- Do not leave a ray on deck until hauling is finished before returning it to the sea.
- Do not punch holes through the bodies of rays (e.g. to pass a cable or line through for lifting the ray).
- Do not gaff, drag, carry, lift or pull a ray by its "cephalic lobes" or tail or by inserting hooks or hands into the gill slits or the spiracles.

Longline

Do's:

- For small rays, gently bring on board and remove as much gear as possible by backing the hook out. If hooks are embedded, either cut the hook with bolt cutters or cut the line at the hook and gently return the animal to the sea.
- For medium to large rays (>30 kg), leave the animal in the water and use a dehooker to remove the hook or a long-handled line cutter to cut the gear as close to the hook as possible (ideally leaving < 0.5 meters of line attached to the animal).

Don'ts:

- Do not hit or slam a ray against any surface to remove the animal from the line.
- Do not attempt to dislodge a deeply hooked or ingested hook by pulling on the branch line or using a dehooker.
- Do not attempt to lift medium to large (>30 kg) rays aboard vessel.
- Do not cut the tail.
- Do not gaff, drag, carry, lift or pull a ray by its "cephalic lobes" or tail or by inserting hooks or hands into the gill slits or the spiracles.

Additional recommendation:
Knowing that any fishing operation may catch rays, several tools can be prepared in advance (e.g. canvas or net slings or stretchers for carrying or lifting, large mesh net or grid to cover hatches/hoppers in purse seine fisheries, long handled cutters and de-hookers in longline fisheries).