Overview of Mobulid Fisheries in the Indian Ocean

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Acronyms

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 the Conservation of Migratory Species

CPC – Contracting Party or Cooperating non-Contracting Party

CPUE – Catch per Unit Effort

DW – Disc Width

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

Execute Summary

Overview

Manta and devil rays, collectively known as mobulids, are a mongeneric family of planktivorous rays characterized by their unique filter-feeding adaptations and large size. These species are found in tropical and subtropical waters worldwide, with seven of the nine recognized *Mobula* species inhabiting the Indian Ocean (Stevens et al., 2018). Mobulids are particularly vulnerable to overexploitation due to their conservative life history traits, including slow growth, late maturation, and extremely low fecundity. These characteristics result in some of the lowest maximum rates of intrinsic population increase among all elasmobranchs, especially for the largest manta ray species (Dulvy et al., 2014).

Persistent Threats and Declines

The primary threats to mobulids stem from both targeted fishing and bycatch in small-scale and commercial fisheries, particularly tuna fisheries (Croll et al., 2016). These fisheries have had a severe impact on mobulid populations, with some 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 classified as Vulnerable or Endangered by the IUCN (2020), primarily due to significant population declines linked to fisheries exploitation. A recent study in Indonesia revealed an 89% decline in mobulid ray catch rates from 2015 to 2024, indicating severe overfishing (Laglbauer et al., 2024; in review). In Mozambique, underwater sighting data showed dramatic declines of 99%, 92.5%, and 81.3% for reef manta rays (*M. alfredi*), oceanic manta rays (*M. birostris*) and shorthorned pygmy devil rays (*M. khulii*), respectively, between 2003 and 2023 (Rohner et al., 2013; Venables et al., 2024; in review). Similarly, a significant decline in catches between 1981 and 2021 was reported in South Africa (Carpenter et al., 2023). Despite conservation efforts by regional fisheries management organizations, the high demand for mobulid gill plates and ongoing illegal trade continue to pose significant challenges to mobulid populations in the Indian Ocean (Croll et al., 2016; Palacios et al., 2024 [In Review]; Rojas-Perea et al., [In Review]).The Indian Ocean region is a significant contributor to the global mobulid trade as reported by a recent study by Palacios et al., [In Review], with 64% of the identified countries exporting gill plates and 70% exporting meat located in this area.

Management Issues in the IOTC Area

The interactions of mobulid rays with fisheries, particularly those managed by the Indian Ocean Tuna Commission (IOTC), are complex and present significant conservation challenges. The primary threats to mobulid rays in the Indian Ocean stem from fisheries, which include both bycatch and targeted catches that often enter international trade illegally. Overall, the interplay of social, economic, and ecological factors creates a complex threat landscape for mobulid rays in the Indian Ocean, necessitating comprehensive conservation and management strategies to ensure their survival. Reports submitted to the IOTC WPEB in 2018 highlighted declines in mobulid populations due to tuna fisheries in the Indian Ocean (Shahid et al., 2018; Moazzam, 2018; Fernando, 2018). Despite the adoption of IOTC Resolution 19/03 on the conservation of mobulids in 2019, data on mobulid interactions with IOTC fisheries remains limited due to lack of rigorous data collection, especially in artisanal fisheries coupled with poor observer coverage and lack of species-level identification in landings.

Recommendations for Management

To effectively conserve mobulid rays in the Indian Ocean, several key recommendations are proposed:

- Strengthen subsistence fisheries reporting to enhance data collection on mobulid catches.
- Improve compliance with RFMOs to ensure sustainable practices.
- Enhance pre-capture methods to reduce incidental catches of mobulid rays.
- Improve safe handling and release practices to increase post-release survival rates.
- Increase observer coverage and training to improve data collection and species identification.
- Facilitate further research on mobulids to inform conservation strategies.
- Enhancing mobulid conservation efforts.

1. Introduction to mobulids

1.1 Overview

Manta and devil rays, collectively known as mobulids, are a captivating group of large, filter-feeding elasmobranchs belonging to the family Mobulidae. This family currently comprises nine recognized species found in tropical and subtropical waters worldwide. Mobulids are characterized by their unique feeding adaptations as planktivorous filter feeders. They employ a variety of feeding strategies to enhance efficiency, utilizing their distinctive 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). This specialized feeding mechanism allows them to exploit abundant planktonic resources in their marine habitats.

The taxonomy of mobulids has been a subject of ongoing research and revision due to morphological similarities and overlapping ranges among several *Mobula* species, which have historically led to taxonomic uncertainties (Couturier et al., 2012). In recent years, genetic studies have played a crucial role in resolving these ambiguities, resulting in several revisions to the Mobulidae family (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 essential for establishing accurate taxonomy, which is fundamental for effective conservation and management strategies (Stevens et al., 2018). Recent taxonomic revisions have nested the genus *Manta* within *Mobula*, resulting in all species now being classified under one genus (White et al., 2017; Notarbartolo di Sciara et al., 2019; Hosegood et al., 2019; Notarbartolo di Sciara, Stevens and Fernando, 2020). Although the four pygmy devil ray species attain maxium disc widths of only 135cm ((Notarbartolo di Sciara, 1987; Stevens et al., 2018), however, mobulid family showcases a wide range of sizes, with manta rays growing up to 6.8 meters (McClain et al., 2015; Stevens et al., 2018). Despite their size differences, all mobulid species possess similar anatomical features and biological characteristics that made them apart from other ray families. Of the nine currently recognized *Mobula* species, seven are known to inhabit the Indian Ocean (Annex I) (Stevens et al., 2018), highlighting the region's significance for mobulid diversity and conservation. These seven species are: *M. alfredi, M. birostris, M. eregoodoo, M. kuhlii, M. mobular, M. tarapacana* and *M. thurstoni.*

Upwelling zones in the Indian Ocean play a critical role in the distribution of mobulid rays by creating areas of high biological productivity, which are essential for their feeding and aggregation behaviors (Lezama-Ochoa et al., 2019; G. Stevens, 2016). These zones bring nutrient-rich waters from the deep ocean to the surface, promoting the growth of phytoplankton, which forms the base of the marine food web. This increase in phytoplankton supports large populations of zooplankton, the primary food source for mobulid rays (Lezama-Ochoa et al., 2019). Consequently, mobulid rays are attracted to these productive areas, allowing them to forage efficiently and meet their dietary needs (Martin, 2020). Additionally, the Indian Ocean, particularly areas like the Bay of Bengal, is characterized by high nutrient content and biological productivity (Haque et al., 2021; Smith et al., 2008; Amaral et al., 2017). This productivity is partly due to the debris from the largest mangrove forest and sediments from the Ganges delta, which contribute to oceanographic mixing (Somayajulu et al., 2003; Smith et al., 2008; Adnet et al., 2012; Amaral et al., 2017; Haque et al., 2021). Such conditions provide abundant plankton, the primary food source for planktivorous mobulid rays, making these waters an ideal feeding ground (Martin, 2020). Also, mobulid rays, such as *M. mobular*, exhibit preferences for specific oceanographic features associated with upwelling systems. These features include lower sea surface height, cyclonic eddies, and shallow mixed layers, which are typically found in upwelling zones (Lezama-Ochoa et al., 2019). Such conditions create ideal environments for mobulid rays, as they support the availability of prey and enhance the effectiveness of cleaning stations that serve as thermal and predator refuges, where mobulid rays engage in social and reproductive interactions (Barr & Abelson, 2019). The behavioral patterns of mobulid rays are also influenced by the environmental conditions in upwelling zones. The presence of abundant prey and suitable environmental conditions in these areas supports the aggregation and site fidelity of mobulid rays (Palacios et al., 2023; Guirhem et al., 2021). These zones provide essential resources and conditions that facilitate their feeding, social interactions, and reproductive behaviors, making them key habitats within the Indian Ocean (Martin, 2020).

1.2 Potential Threats

Despite their impressive size and unique adaptations, mobulid rays face significant conservation threats, primarily due to their extremely conservative life history traits and intense fishing pressure (Croll et al., 2016; O'Malley et al., 2016; Venables et al., 2016; Hosegood et al., 2018; Stewart et al., 2018). All mobulid species found in the Indian Ocean are classified as Vulnerable or Endangered by the IUCN (2020) (Annex 1), primarily due to significant population declines linked to fisheries exploitation. These species are characterized by late maturation, low fecundity, and long gestation periods, 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., 2018). Such reproductive strategies result in some of the lowest maximum rates of intrinsic population increase among all elasmobranchs, particularly for the largest manta ray species (Dulvy et al., 2014). In addition to their vulnerable taxonomic lineages, the primary anthropogenic threat to mobulids is fisheries exploitation, both from targeted fishing and as bycatch. The international trade in mobulid gill plates has emerged as a major driver of unsustainable fishing practices. These gill plates are highly valued in Asian markets, particularly for use in traditional Chinese medicine, leading to a dramatic increase in demand (Haque et al., 2022; Pacoureau et al., 2021). This has resulted in the expansion of targeted fisheries for mobulids and the retention of bycatch that might otherwise have been released. The gill plate trade has seen concerning growth, with estimates suggesting a threefold increase in the number of individuals traded between early 2011 and late 2013 (Fernando & Stewart, 2021). In addition to the gill plate trade, mobulid meat has also become a significant concern for conservation efforts. While historically considered poor quality, mobulid meat is now consumed in at least 34 countries, either fresh, salted, or sun-dried (Stevens et al., 2018). Some regions process it into fish meal, indicating the existence of international export and import markets for mobulid meat. This local and international consumption of mobulid meat, combined with the high-value gill plate trade, has intensified fishing pressure on these vulnerable species. Mobulids are caught in both small-scale and commercial fisheries, with particular concern for their bycatch in tuna fisheries due to the high degree of distributional overlap in epipelagic tropical habitats (Croll et al., 2016). The impact of these fisheries has been severe, with some mobulid populations exhibiting declines of over 90% (e.g., Lewis et al., 2015; Rohner et al., 2017; Moazzam, 2018). These dramatic population declines highlight the urgent need for effective conservation measures globally.

Mobulid rays, particularly in the Indian Ocean face multiple threats from social, ecological, and economic perspectives. Socially, the demand for mobulid ray products, particularly gill plates used in traditional Asian medicine, drives targeted fishing and contributes to the decline of their populations (Palacios et al., 2024 [In Review]; Couturier et al., 2012; O'Malley et al., 2016). This demand is fueled by lucrative markets, especially in China, where gill plates are highly valued (Palacios et al., 2024 [In Review]; Couturier et al., 2012; O'Malley et al., 2016). The socio-economic reliance on fisheries in countries like Sri Lanka, Indonesia, Bangladesh and India further exacerbates this issue, as local communities depend on these fisheries for their livelihoods, leading to high bycatch rates and unsustainable exploitation of mobulid populations (Shahid et al., 2018; Flounders, 2020; Moazzam, 2018; Fernando, 2018; Laglbauer et al. 2024 [in prep]; D’Costa et al 2024 [in prep]). Ecologically, mobulid rays are highly vulnerable due to their life history traits, such as low reproductive rates and long lifespans, which make them susceptible to overfishing. The Indian Ocean's expanding fisheries, particularly the tuna fisheries, have significant ecological impacts on mobulid rays, with high bycatch rates reported in both industrial and small-scale fisheries (Shahid et al., 2018). These fisheries often operate in areas of high productivity where mobulid rays are found, leading to a high level of interaction and incidental capture (Martin, 2020). The lack of comprehensive data on mobulid landings, due to limited observer coverage and species-level identification, further complicates conservation efforts (Shahid et al., 2018; Moazzam, 2018; Fernando and Stewart, 2021). Economically, the fisheries targeting mobulid rays are a significant component of the regional economy, particularly in countries like Sri Lanka and India. However, the economic benefits are short-term, as overfishing leads to population declines, threatening the long-term sustainability of these fisheries (Shahid et al., 2018; Moazzam, 2018; Fernando and Stewart, 2021; Laglbauer et al. 2024 [in prep]). The International Commission for the Conservation of Atlantic Tunas (IOTC) has introduced measures, such as Resolution 19/03, to reduce mobulid fisheries captures, but enforcement and implementation remain challenging, particularly in artisanal fisheries (Shahid et al., 2018). The economic pressures to maintain fishing activities, coupled with insufficient enforcement of conservation measures, pose significant challenges to the effective management and protection of mobulid rays in the Indian Ocean.

1.3 Global Regulatory Landscape

Mobulid rays have received increasing protection at international, regional, and national levels (Table 2) in recent years due to growing concerns about their conservation status. These protections have been implemented in response to the significant threats faced by mobulids, primarily from fishing pressure driven, in part, by the international trade in their gill plates and meat.

At the international level, the Convention on the Conservation of Migratory Species (CMS) has played an important role in mobulid conservation. All mobulid species are listed on both Appendix I and II of CMS, which requires the 130 Parties (member states) to strictly protect these species and collaborate towards regional conservation efforts (CMS, 2015; Lawson et al., 2017). This listing was achieved in stages, with the *M. birostris* first listed in 2011, followed by all other mobulid species in 2014 (Figure 1; Annex II). Another significant international protection measure is the listing of all mobulid species on Appendix II of the Convention on International Trade in Endangered Species (CITES). This listing, achieved in two stages (manta rays in 2013 and devil rays in 2016), requires the 183 CITES Parties to issue permits for the export of mobulids or their products only after demonstrating that they are sourced from legal and sustainable fishing operations (CITES, 2016; Lawson et al., 2017) (Figure 1; Annex II). At the regional level, several Regional Fisheries Management Organizations (RFMOs) have implemented measures to protect mobulids. In 2015, the Inter-American Tropical Tuna Commission (IATTC) adopted a resolution on the conservation of mobulid rays caught in association with fisheries in its Convention Area (IATTC, 2015). Following this, in 2019, both the Indian Ocean Tuna Commission (IOTC) and the Western and Central Pacific Fisheries Commission (WCPFC) implemented similar Conservation and Management Measures (CMMs) for mobulid rays in their respective areas of competence (IOTC, 2019; WCPFC, 2019). The ICCAT adopted Recommendation 23-14 in November 2023, focusing on the management of mobulid rays caught in association with ICCAT fisheries. However, the prohibition on retention will not be enforced until the Standing Committee on Research and Statistics (SCRS) provides guidance. In 2024, the SCRS is tasked with reviewing existing data on the life history and conservation status of mobulid rays to determine if they are a taxon of great biological vulnerability and conservation concern with limited data. These resolutions prohibit the retention of mobulid rays, require vessels to release mobulids alive and unharmed where possible, and mandate the recording of mobulid discards and releases (Figure 1; Annex II).

At the national level, many countries have enacted legislation to protect mobulid rays, reflecting a growing global recognition of the need to conserve these species. The scope and nature of these protections vary significantly between nations and some of these existing country-specific legislations were reported by Laglbauer et al. 2024 [in prep] from online surveys (i.e. mentioned by experts but documents not archived due to lack of accessibility in addition to language proficiency) (Figure 1; Annex II). For instance, Israel implemented comprehensive protection for all sharks and rays in 2005, prohibiting their capture, harm, trade, or possession without a specific permit. Similarly, Australia has protected all mobulid species under its Environment Protection and Biodiversity Conservation Act since 2012. Some countries have focused on specific species or groups. Bangladesh, for example, protects *M. mobular* under its national Wildlife (Conservation and Security) Act of 2012. The Maldives took early action, banning exports of all ray products in 1995 and later making it illegal to capture, keep, or harm any type of ray in 2014. Indonesia has protected both *M. birostris* and *M. alfredi* since 2014, banning their hunting, selling, and distribution. Several nations have implemented broader protections for multiple mobulid species. Ecuador, for instance, protects five mobulid species under its Official Policy 093 since 2010, prohibiting directed fishing and mandating immediate release if caught incidentally. Brazil has similar protections for five mobulid species under federal law since 2013. Mexico protects seven mobulid species under various regulations implemented between 2006 and 2019. More recent protections have been implemented in countries like Thailand, which added seven mobulid species to its national protected species list in 2018 under the 1992 Wildlife Conservation Protection Act. Iran took a comprehensive approach in 2023, protecting all mobulid species in its waters. India also expanded its protections in 2023, adding *M. birostris, M. alfredi, M. tarapacana,* and *Mobula spp.* to its protected species list under The Wildlife (Protection) Amendment Act (Figure 1; Annex II).

These national-level protections complement the international and regional measures discussed earlier. However, it's important to note that the effectiveness of these protections often depends on enforcement capacity and compliance, which can vary significantly between countries. Many nations such as Indonesia, India, Bangladesh and Thailand face challenges in implementing and enforcing these regulations, particularly in areas with limited resources for monitoring and control. The illegal trade in gill plates continues to provide incentives for unsustainable fisheries, benefiting a small number of people while often leaving fishers and lower-level participants in the supply chain in poverty. Additionally, the migratory nature of mobulid rays means that effective conservation requires coordinated efforts across national boundaries, highlighting the importance of international cooperation in mobulid conservation. Therefore, it can be concluded that despite the implementation of some international, regional and national protections (Figure 1; Annex II), enforcement remains a significant challenge (White et al., 2017; Notarbartolo di Sciara et al., 2019). Addressing these complex trade dynamics, improving enforcement of existing protections, and developing alternative livelihoods for affected communities are crucial steps in ensuring the long-term conservation of mobulid species.

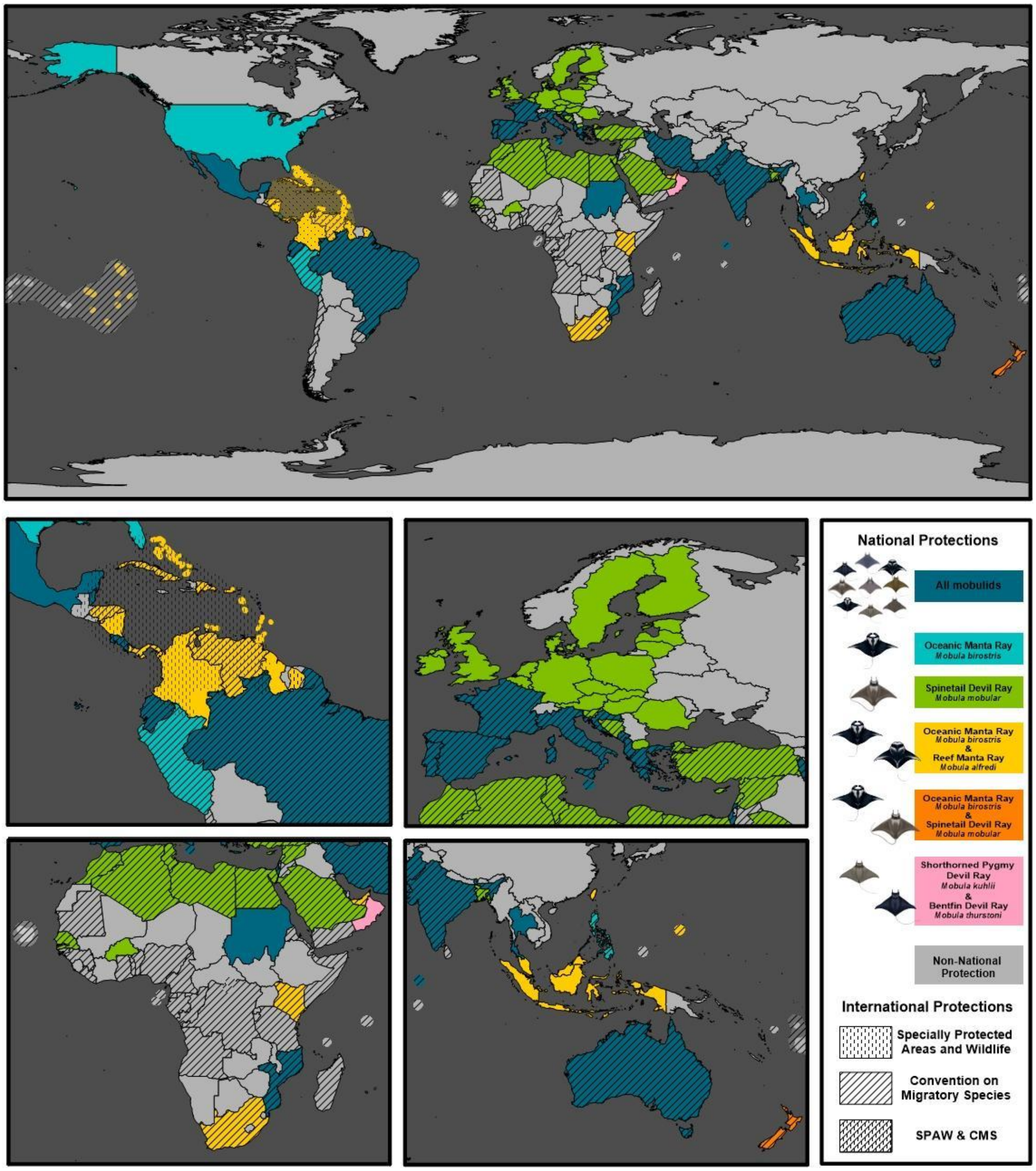

Figure 1: Mapping mobulid national and international protective legislation worldwide. From Laglbauer et al. 2024 [in prep]).

2. Management Issues in the IOTC Area

The interactions of mobulid rays with fisheries, particularly those managed by the Indian Ocean Tuna Commission (IOTC), are complex and present significant conservation challenges. The primary threats to mobulid rays in the Indian Ocean stem from fisheries, which include both bycatch and targeted catches that often enter international trade illegally. Overall, the interplay of social, economic, and ecological factors creates a complex threat landscape for mobulid rays in the Indian Ocean, necessitating comprehensive conservation and management strategies to ensure their survival. Economically, the high demand for mobulid products, particularly gill plates, in Southeast Asian markets such as mainland China, Hong Kong SAR, Singapore, South Korea, and Thailand, continues to drive the nearly global trade in these items. From an ecological perspective, the incidental capture and retention of mobulid rays in fisheries contribute to their population declines.

The following sections integrate information from various previous and recent studies and reports, highlighting the critical issues and conservation needs focusing the Indian Ocean.

2.1 Overfishing and Declines

According to national reports submitted to the FAO, only nine countries officially document the landing of mobulid rays under the categories of nominal mantas, devil rays, and unspecified species (FAO 2023). However, research by Palacios et al. (2024, in press) reveals a significant discrepancy, showing that 45 countries are actually landing mobulids, with an additional 13 countries discarding mobulid bycatch. Among these nations, 40% (n=18) are from the Indian Ocean that land mobulids and 30.7% (n=4) that discards bycatch. Also, more than half regularly target or retain mobulids, most of which are not reported to the FAO. This discrepancy highlights the widespread issue of national underreporting in FAO capture production data (Cashion et al. 2019; Fowler et al. 2021), raising concerns about the accuracy and transparency of official national fisheries data. Furthermore, this underreporting affects the assessment of CITES effectiveness, as global declines in landings reported by the FAO, which appear to correlate with the listing of mobulids (CITES, 2016; CMS, 2015), are likely due to unreported and unregulated mobulid landings rather than compliance (Okes & Sant 2022).

Mobulid rays have experienced dramatic population declines globally, with some species showing reductions of up to 92.5% (Ward-Paige et al., 2013; Lewis et al., 2015; Moazzam, 2018). Despite the adoption of conservation measures by various RFMOs and international agreements like CITES and CMS, these protections have been insufficient in halting population declines (Cronin et al., 2023; Okes and Sant, 2022). The estimated global bycatch of mobulid rays among industrial fisheries is in tuna purse seiners, approximately 13,000 individuals per year, highlights the urgency for improved management strategies (Hall and Roman 2013). Significant population declines have been observed across various regions. Reports highlight that the high fishing effort in the Indian Ocean likely exceeds sustainable exploitation levels for these slow-growing species (Shahid et al., 2018). Some of the largest mobulid landings come from India, with reports of mobulid catch as high as 8% of total elasmobranch catch in landing centres in India (Kizhakudan et al. 2022). Observer coverage on IOTC fishing vessels is limited, and mobulid landings are often not identified to species level, leading to poor data quality (Shahid et al., 2018). Studies have documented significant declines in mobulid populations due to tuna fisheries in regions such as Pakistan and Sri Lanka (Moazzam, 2018; Fernando, 2018) (Figure 2; Annex III). In Indonesia, mobulid rays are caught in small-scale fisheries, particularly in drift gillnets, which poses a significant threat to their populations. A recent study conducted in Muncar, East Java, from 2015 to 2024 highlighted a declining trend of 89% in the catch rate of mobulid rays, indicating overfishing and the urgent need for improved conservation measures (Laglbauer et al., 2024; in review) (Figure 2; Annex III). Another study in Mozambique, recorded underwater sighting data of reef manta rays (*M. alfredi*), oceanic manta rays (*M. birostris*), and shorthorned pygmy devil rays (*M. kuhlii*) between 2003–2023 and observed a 99% decline in sightings of reef manta rays, a 92.5% decline in oceanic manta ray sightings, and an 81.3% decline in devil ray sightings (Venables et al., 2024; in review) (Figure 2; Annex III). In Madagascar, the absence of confirmed sightings of certain mobulid species since 2015 suggests potential local extinctions, emphasizing the need for further monitoring and management initiatives to reduce mortality from gillnet fishing (Diamant et al., In Review). The IOTC's Resolution 19/03, adopted in 2019, aims to improve data collection and handling procedures for live releases, but these measures alone are not sufficient to address the problem fully. Major tuna fisheries, such as those governed by the Inter-American Tropical Tuna Commission (IATTC), have implemented bans on the retention of mobulid rays and mandated low-impact release methods. Despite these efforts, the high demand for mobulid gill plates and ongoing illegal trade continue to pose significant challenges (Croll et al., 2016; Palacios et al., [In Review]; Rojas-Perea et al., [In Review]).

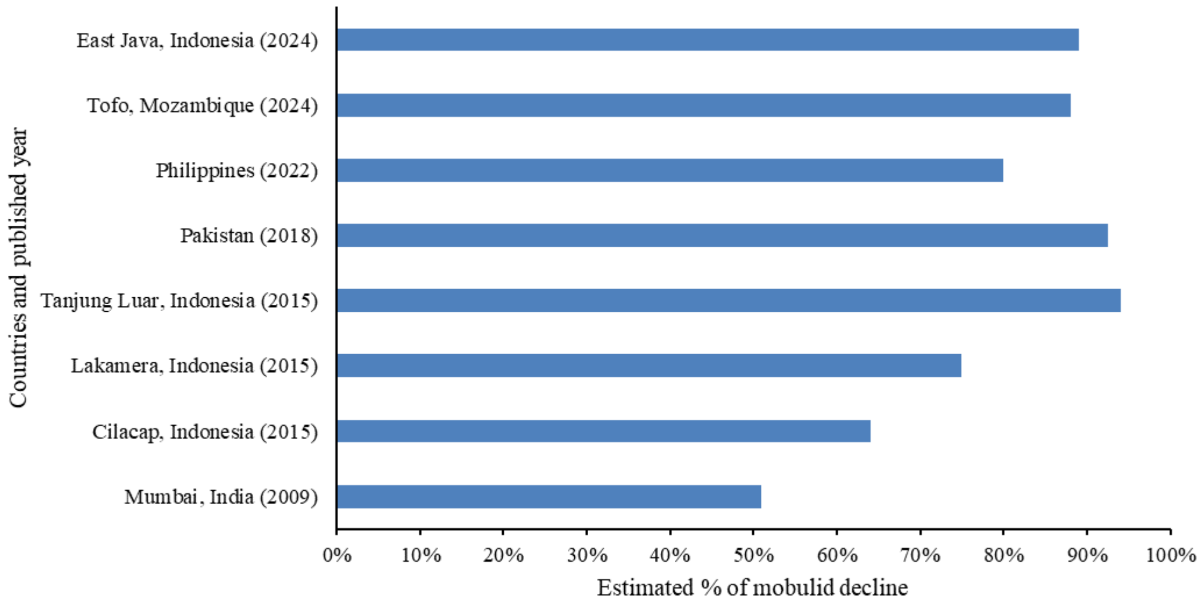

Figure 2: Examples of reported mobulid population declines in the Indian Ocean. (Source: Lewis et al. 2015; Moazzam 2018; Venables et al., 2024; Rambahiniariason et al. 2022; Raje and Zacharia 2009; Laglbauer et al. 2024. in prep)

2.2 Mobulid Trade Dynamics

Some of the largest mobulid fisheries globally are located in the Indian Ocean, particularly in Sri Lanka, Indonesia, and Bangladesh. These fisheries primarily target mobulid rays for their gill plates, which are predominantly exported to markets in Hong Kong Special Administrative Region (SAR) and mainland China (O'Malley et al., 2017; Croll et al., 2016; Fernando & Stewart, 2021).From 2017 to 2021, five CITES parties reported commercial trade in wild-caught mobulid species (Palacios et al. (2024) [In Review];CITES Trade Database, accessed May 2024) . Analysis by Palacios et al. (2024) [In Review] reveals that 80% of a mobulid carcass is used for human consumption, primarily as meat. Dried gill plates comprise only 0.2% of total carcass weight (Annex IV). Based on CITES Database data and conversion rates, an estimated 91,898 mobulids were traded as gill plates during this period, averaging 26,134 annually. Sri Lanka, responsible for 68% of the gill plate trade, exported an equivalent of approximately 70,898 mobulids. While the total numbers align with catch reconstructions from 2018-2019 (Fernando & Stewart 2021), species-specific data shows discrepancies, likely due to genus-level reporting of traded plates. The socio-economic importance of mobulid rays is driven largely by the high value of their gill plates in international markets, especially in traditional Chinese medicine (Palacios et al. (2024) [In Review]). A global assessment of the trade in manta and devil rays reveals significant findings across 75 countries (Figure 3) (Palacios et al. (2024) [In Review]). The study used expert elicitation through country-focused online surveys and interviews, along with analysis of FAO Total Production and CITES Trade databases, and surveys of online and physical stores in China and Hong Kong SAR. Gill plates are extracted in 14 countries and exported from at least 14 across Asia and Africa, with five major destination countries in Asia (Palacios et al., [In Review]) (Figure 3). Of these, 64% of the export countries (Indonesia, Myanmar, Bangladesh, Sri Lanka, India, Philippines, Yemen, Thailand, Somalia) surround the Indian Ocean (Figure 3). Despite the inclusion of mobulid rays in CITES Appendix II, the international demand for gill plates has not diminished and is more prevalent in the Indian ocean. In fact, according to Palacios et al. (2024, in press), this trade is expanding and moving to online platforms. This shift is driven by the high economic value for traders in demand countries, facilitated by a less transparent sales system that makes it more challenging for authorities to track and apprehend those involved. Market surveys conducted in Hong Kong in 2022 revealed that the prices for gill plates, especially those from manta rays, have significantly increased since 2015. Additionally, the availability of gill plates in the Hong Kong market has not decreased significantly following the CITES listings since 2015, and it is likely underestimated due to the presence of illegal, unreported, and unregulated fisheries and trade (Hau & Shea, 2023).

The study also shows that mobulid landings occur in 43 countries, with mobulid meat consumed locally in at least 34 countries and exported from ten, with five major destination countries identified (Croll et al., 2016; Palacios et al., [In Review]) (Figure 3). Of these nations, 44% (n=15) that consume meat locally and 70% that export mobulid meat (Bangladesh, India, Madagascar, Myanmar, Oman, UAE and Yemen) are located in the Indian Ocean (Palacios et al., [In Review]) (Figure 3). The trade in mobulid meat has been growing steadily, driven by increasing demand in both domestic and international markets. This trend is particularly evident in countries where mobulid meat is regarded as a delicacy or a crucial protein source (Rojas et al., 2024 in prep; D'Costa et al., 2024 in prep; Haque et al., 2020; Palacios et al., 2024 in review; White et al., 2017). For instance, in Bangladesh, there is a developing market for mobulid meat among indigenous communities due to its flavorful taste and lower cost compared to other expensive commercial marine fish (D'Costa et al., 2024 in prep). In many regions of Bangladesh, mobulid meat is now replacing stingrays, which were previously valued as a protein source (D'Costa et al., 2024 in prep). In Indonesia, mobulid ray meat is sold locally for food consumption through relatively short supply chains. The meat, along with that of other elasmobranch species, is processed into smoked meat skewers called *Iwak Pe Asap*, which enhances its value (Laglbauer et al., 2024 [In Review]). The market for mobulid meat has extended beyond traditional consumption areas, reaching new markets in Southeast Asia and other regions (Lawson et al., 2020). This expansion is further driven by the relatively high market prices for mobulid meat, which offer significant financial incentives for fishers and traders (Haque et al., 2020; Lawson et al., 2020; D'Costa et al., 2024 in prep). In many developing countries, the trade in mobulid meat is exacerbated by insufficient reporting and monitoring systems, as noted by O'Malley et al. (2017). These deficiencies in data collection and enforcement contribute to unreported and unregulated fishing activities, increasing the pressure on mobulid populations.

Prices for mobulid products vary widely, with meat and gill plates priced between 0.24 – 10 USD/kg and 4.8 – 1260 USD/kg, respectively, depending on the country and product form (Palacios et al., [In Review]). Notably, physical retailers of gill plates have declined in Guangzhou and Hong Kong SAR over the past decade, while online retailers have increased, with the number of retailers rising from 41 in 2011 to 135 in 2023 (Palacios et al., [In Review]). A significant challenge in managing this trade is the difficulty in distinguishing between mobulid species. Different stakeholders, including fishers, authorities, and enforcement personnel, often struggle to identify species accurately. After death, the pigmentation in the mucus coating of mobulid rays fades, altering their appearance and making it difficult to identify species by their patterns. Furthermore, once gill plates are extracted and dried for export, they can only be categorized into three groups based on morphological characteristics: 'Manta', '*Mobula tarapacana*', or '*M.*

mobular / other *Mobula spp*.' (O'Malley et al., 2017; Stevens et al., 2018). This makes species-level identification challenging and often impossible.

While improving capacity-building for fisheries management, enforcement, and data collection are essential steps, these efforts alone are insufficient to stop the ongoing population declines of mobulid rays. The persistent demand and complex trade dynamics require comprehensive and coordinated international efforts at all stakeholder levels to effectively address the threats facing these species.

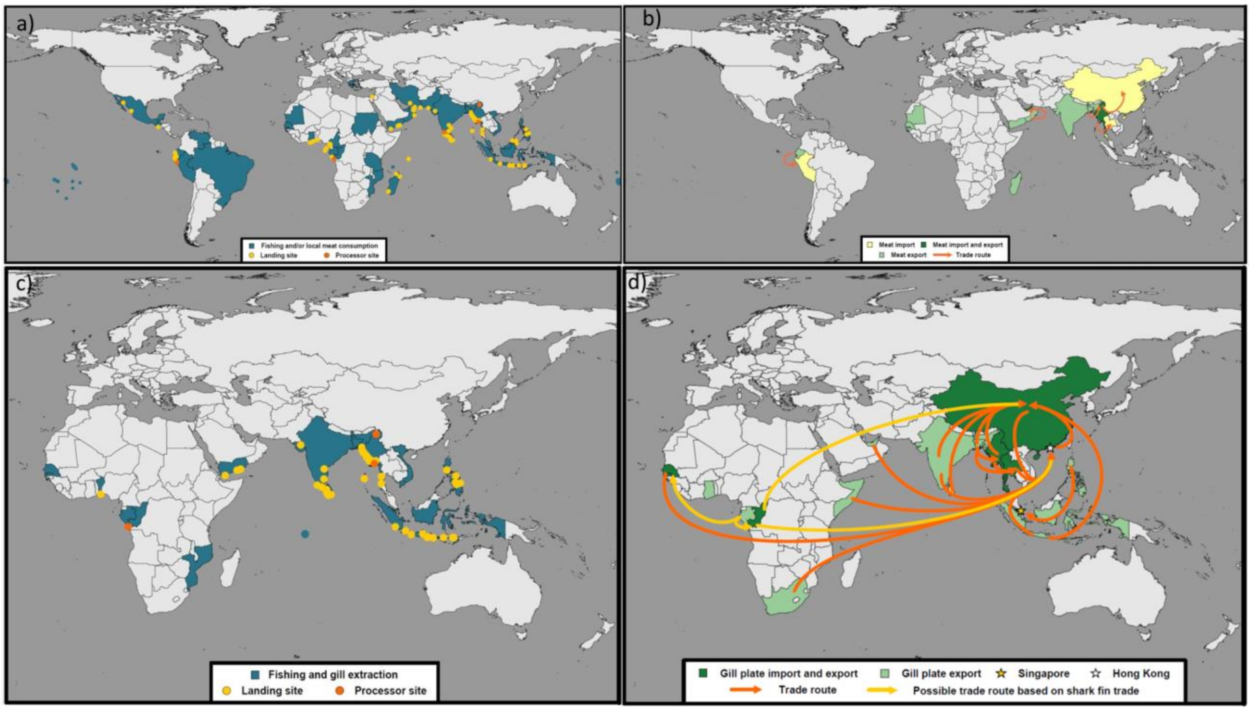

Figure 3. (a) Countries where mobulids are landed and meat is locally consumed. Specific landing sites are highlighted in yellow although landing can occur along the entire coast range. Reported processing sites for mobulid meat are highlighted in black. (b) Export and import routes of mobulid meat, exporting countries are highlighted in light green, importer countries in yellow and exporters and importers countries in dark green. Confirmed trade routes are indicated by orange arrows while possible trade routes based on shark trade are indicated in blue. (c) Countries where mobulids are fished and gill plates are extracted. Specific landing sites are highlighted in yellow although landing can occur along the entire coast range. Processor sites for mobulid gill plates are highlighted in black. (d) Export and import routes of gill plates, exporting countries are highlighted in green, importer countries in yellow and exporters and importers countries in dark green. Trade routes are indicated by arrows. Confirmed trades are in orange, while possible routes based on shark products are in blue. From Palacios et al. 2024 [In Review].

3.3 Taxonomic and Habitat Use Considerations

Genetic studies have revealed complexities in the taxonomy and population structure of mobulid rays. In the Southwestern Indian Ocean, research in Tanzania confirmed the taxonomic alignment of *Mobula mobular* and *M. japanica* as the same species, highlighting the need for unified conservation measures (Rumisha et al., 2024). The study also found limited genetic connectivity between populations, underscoring the necessity for region-specific conservation strategies. Understanding the habitat use and aggregation patterns of mobulid rays can inform management strategies. In Seychelles, studies using photo-identification and remote underwater cameras have provided insights into the residency and habitat use of *M. birostris* and *M. alfredi*, suggesting that marine protected areas could benefit their conservation (Peel et al., 2024). Mobulids' epipelagic distribution in high-productivity regions leads to a high level of distributional overlap with target species, making them particularly susceptible to incidental capture in tuna fisheries (Croll et al., 2012; Shahid et al., 2018).

3. Data Availability and Gaps

3.1 Overview

Despite the extensive regulatory frameworks established by national governments and regional bodies to manage incidental mobulid catches and the gill plate trade, global mortality rates of these species continue to rise (Haque et al., 2022; Pacoureau et al., 2021; Fernando & Stewart, 2021). A major issue is the discrepancy between reported catches and actual trade volumes of mobulids (Cashion et al., 2019; Fowler et al., 2021). Experts and studies suggest that reported catches often underestimate the true fishing pressure due to several factors: (i) underreporting, where fisheries may underreport catches to bypass regulations or maintain market access (O'Malley et al., 2017); (ii) illegal, unreported, and unregulated (IUU) fishing; and (iii) inadequate monitoring and enforcement, as many regions lack the capacity or resources to effectively oversee and enforce fishing regulations, leading to unchecked exploitation (Dulvy et al., 2014).

In many countries, especially in developing regions, there are limitations in data collection infrastructure and methodologies, resulting in incomplete and inaccurate reporting (O'Malley et al., 2017). The increasing economic value of mobulid gill plates and meat further incentivizes fishers to maximize their catch, leading to underreporting or illegal fishing practices (White et al., 2017). Additionally, widespread underreporting in FAO capture production data (Cashion et al., 2019; Fowler et al., 2021) casts doubt on the reliability and transparency of official national fisheries statistics. This, combined with inconsistent enforcement of existing regulations and loopholes in international trade laws, exacerbates the exploitation of mobulid rays (Dulvy et al., 2014).

Although efforts to regulate incidental mobulid catches and the gill plate trade have been supported by changing market forces, international agreements, and sustained advocacy by non-governmental organizations (NGOs) (White et al., 2017), the effectiveness of these regulatory instruments remains questionable. This highlights the need for evaluating and identifying gaps in mobulid management (Dulvy et al., 2014). Poor observer coverage exacerbates the issue, as limited monitoring on fishing vessels allows significant unreported and illegal fishing activities to go undetected (Worm et al., 2024). Additionally, small-scale fisheries often use unselective fishing practices, resulting in high bycatch rates that are frequently not recorded (Haque et al., 2022). These factors, along with insufficient databases on coastal fisheries catches, contribute to incomplete and inaccurate data on mobulid mortality and trade (Haque et al., 2022; Pacoureau et al., 2021; Fernando & Stewart, 2021; Haque et al., 2020).

The mislabeling of mobulid products in trade further complicates efforts to track and regulate their exploitation (Croll et al., 2016). Mislabelled products can enter markets under different names, obscuring the true scale of mobulid exploitation and undermining conservation efforts (Croll et al., 2016). Additional datasets that comprehensively document discarding practices are required to improve mortality estimates, particularly in poorly observed industrial fisheries (O'Malley et al., 2017). Furthermore, while international organizations such as Sea Around Us (SAU) capture some IUU global fishing activities, significant gaps persist, underscoring the continued threat posed by unchecked fishing practices (Dulvy et al., 2014). Addressing these data reporting shortcomings and implementing effective management measures necessitates a combination of area-based data recording and regulatory schemes that address overcapacity and disincentivize the retention of overfished and threatened mobulid species.

3.2 Key Data Gaps

Research on mobulid rays, although increasing, has been hindered by the challenges of observing and studying *Mobula* species in their vast oceanic habitats (Couturier et al., 2012; Croll et al., 2016; Lawson et al., 2017; Stevens et al., 2018). Most observations focus on *M. alfredi* due to its coastal presence on reefs, which allows data collection primarily by divers and snorkelers. However, behaviors such as courtship and mating are rarely observed, and no mobulids have been documented giving birth naturally in the wild (Stevens et al., 2018).

A systematic literature review by Stewart et al., published in September 2018, identified research priorities to enhance mobulid ray conservation. The review underscored the need for taxonomic clarifications, a deeper understanding of mobulid life history parameters, and more research on bycatch and fisheries, including post-release mortality, species distributions, and standardization of fisheries data. It also emphasized the importance of methodological consistency, long-term data sets, and the involvement of regional resource managers in research activities to improve the relevance of future mobulid research for management (Table 1).

Table 1. Priority knowledge gaps identified by Stewart *et al.* (2018) 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 2.1)	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.* (2018).

Key life history parameters, such as age at maturity, growth rate, lifespan, mortality (both natural and fisheries-induced), and fecundity, are largely unknown for most mobulid species, despite their importance for stock assessments and effective management (Croll et al., 2015; Stewart et al., 2018). It is crucial to gather these parameters across different species and locations, as biological characteristics are likely to vary, necessitating management at the population level (Stewart et al., 2018).

Future research should aim to identify life stages that significantly contribute to overall population viability and pinpoint key habitats for mobulids (Stewart et al., 2018). While reproduction and nursery areas are primarily known for *M. alfredi*, other *Mobula* species and the juvenile stages of all mobulid species remain under-researched (Stevens et al., 2018b; Stewart et al., 2018). It is known that reproductive activity in several mobulid species peaks seasonally, often at aggregation sites like seamounts (Stevens, 2016; Stevens et al., 2018b). Long-term monitoring may uncover more seasonal mating grounds for certain species, and efforts are underway to evaluate locations as potential nursery habitats (Stewart et al., 2018). Prioritizing this research will allow for management measures to protect critical habitats for mobulids at various life stages, aiming to prevent changes in natural behavior, avoid obstructions, and ensure the safety of individuals from targeted or incidental fishing (Croll et al., 2015; Stewart et al., 2018). Additionally, comprehensive stock assessments are crucial for effective management. These assessments should incorporate data on population structure, abundance estimates, and fishing mortality rates to accurately determine the status of mobulid populations and inform sustainable catch limits (Dulvy et al., 2014; Pardo et al., 2016).

There is an urgent need for increased observer coverage and bycatch reporting on tuna fishing vessels. This would enable mobulid abundance estimates through CPUE or BPUE and reveal relationships between abundance and key environmental variables (Stewart et al., 2018). Dynamic spatio-temporal management approaches can then be developed with minimal economic loss from reduced catches of target species (Stewart et al., 2018; Lezama-Ochoa et al., 2019). Evaluating post-release mortality for various gear types is essential, as is assessing the impact of handling and release methods and relevant environmental and operational covariates on mobulid post-release mortality. Studies can use pop-off satellite tags (Francis and Jones, 2016) or blood chemistry analyses (Hutchinson et al., 2015) to investigate survival post-release. Additionally, observer programs should collect fishery-wide data on covariates such as time on deck and behavior after release (Stewart et al., 2018).

Observers can also play a crucial role in gathering data to explore genetic connectivity and diversity within and between mobulid populations. Fisheries provide opportunities to obtain the large sample sizes and geographic coverage needed for such studies (Stewart et al., 2018). From these, estimates of population structure can be derived, allowing for appropriate regional management.

3.3 Recent Progress

Recent advancements in mobulid ray research have focused on understanding distribution patterns, population trends, and the impact of fisheries. Observations from recreational divers have been crucial in describing global distribution patterns, aggregation sizes, and temporal population trends, as well as understanding human use patterns like ecotourism and fishing markets (Couturier et al., 2012; Stevens et al., 2018). In Sri Lanka, studies have utilized Bayesian state-space models to estimate trends in mobulid catches from 2010 to 2020, providing insights into the demographic characteristics and reproductive biology of these species (Croll et al., 2016). Technological advancements in satellite tagging have enabled researchers to track mobulid movements and habitat use more precisely, revealing important information about their regional philopatric movements and affinity to shelf edge habitats, as well as long-distance offshore movements (Lawson et al., 2017).

Additionally, several PhD projects are currently underway to address critical knowledge gaps essential for mobulid conservation. The Mobula Project India, led by Mayuri Chopra, aims to monitor species-specific abundance of mobulids at fishing markets, provide age and growth data for devil rays, study their habitat use, and identify strategies to reduce bycatch. This project seeks to fill knowledge gaps and supply governmental institutions with crucial information to support mobulid conservation (Chopra, 2024; in prep). Furthermore, the Manta Trust has undertaken several collaborative studies, including global research on mobulid trade and fisheries, which have provided significant insights into the capture and market dynamics of mobulid rays in the Indian Ocean (Stewart et al., 2018). These efforts are contributing to a better understanding of mobulid rays and are helping to inform management and conservation strategies to protect these vulnerable species.

To address these critical data gaps, data collection protocols for observers should be standardized for mobulids across the RFMOs, with an emphasis on species identification training for observers (Stewart et al., 2018). Collaboration between various tuna RFMO fisheries observer trainers should be encouraged. The Manta Trust is currently working on developing cohesive mobulid identification guides for the IATTC, the WCPFC, the ICCAT and the IOTC. This, along with identification guides and observer training programs, will enable accurate comparisons across regions and fisheries. A comprehensive, standardized data collection manual that ensures all relevant variables, including release methods, are collected should be developed (Stewart et al., 2018). Also, Since the review by Stewart et al. (2018), the Manta Trust has undertaken several collaborative studies, including global research on mobulid trade and fisheries. These studies have provided significant insights into the capture and market dynamics of mobulid rays in the Indian Ocean.

4. Recommendations for Management

4.1 Subsistence Fisheries and Mobulid Retention Guidelines

The management of mobulid rays in the IOTC area faces significant challenges, primarily due to the exploitation of a major loophole in the current guidelines. According to IOTC Resolution 19/03, while the retention of mobulid rays is generally prohibited, there is an allowance for subsistence fisheries to retain mobulids unintentionally caught, but only for local consumption. This exception, designed to accommodate artisanal fishing practices, requires vessels to report accidental catches to relevant authorities at landing points. However, this allowance creates a substantial loophole that is being exploited. The distinction between subsistence fishing and commercial operations can be blurred, potentially leading to underreported catches and continued exploitation of mobulid populations. This situation is exacerbated by the difficulties in enforcing these regulations, particularly in regions with limited monitoring resources. Furthermore, the reliance on self-reporting by vessels at landing points may result in incomplete or inaccurate data, undermining efforts to assess the true impact on mobulid populations.

To address these management issues effectively, several steps need to be taken. Firstly, there is a need to strengthen monitoring systems at landing sites to verify the nature of fishing operations and ensure accurate reporting of mobulid catches. Secondly, clearer and more specific criteria for what constitutes "subsistence fishing" and "local consumption" should be developed to minimize potential exploitation of the exception. Additionally, standardized data collection protocols should be established across all IOTC member states to improve the accuracy and consistency of mobulid catch data. Furthermore, capacity building initiatives are crucial. Providing training and resources to local authorities would enhance their ability to identify mobulid species and enforce regulations effectively. Regional cooperation among IOTC member states should be fostered to share best practices, data, and enforcement strategies for mobulid conservation. Lastly, regular reviews of the effectiveness of current management measures should be conducted, with adjustments made based on the latest scientific data and observed trends in mobulid populations.

4.2 Challenges in RFMO Compliance for Shared Waters

Countries like Indonesia and Malaysia face significant challenges in adhering to RFMO rules due to the complexity of shared and overlapping waters. For instance, Indonesia's waters are governed by both the Indian Ocean Tuna Commission (IOTC) and the Western and Central Pacific Fisheries Commission (WCPFC) (CMS, 2015; Lawson et al., 2017). This dual jurisdiction creates enforcement difficulties, leading to challenges in complying with RFMO retention bans. The overlapping responsibilities and differing regulations between these RFMOs can result in a lack of coordinated enforcement, making it challenging for countries to implement effective conservation measures (IOTC, 2019).

The CMS Concerted Action 12.6 emphasizes the need for national protections, including reducing both target and incidental catches of mobulids, and adapting conservation strategies based on monitoring and evaluation (CMS, 2017). This situation underscores the need for streamlined regulations and enhanced cooperation between RFMOs to ensure consistent and effective management of mobulid ray populations across shared waters. Without stringent enforcement and compliance with these measures, the risk of further declines in mobulid populations remains high (Hall and Roman, 2013; Croll et al., 2016; Shahid et al., 2018; Moazzam, 2018).

4.3. Obligations and Compliance

As identified in Section 2.1 of the report, 18 countries of the IOTC and CMS party nations are still fishing and landing mobulids, highlighting the ongoing challenges in enforcing these conservation measures. Therefore, to ensure effective conservation of mobulid rays, it is crucial for the 130 Parties under the CMS Appendices I and II to strictly protect these species and collaborate on regional conservation efforts (CMS, 2015; Lawson et al., 2017). The CMS Concerted Action 12.6 emphasizes the need for national protections, including reducing both target and incidental catches of mobulids, and adapting conservation strategies based on monitoring and evaluation (CMS, 2017). An international approach is necessary, especially during their seasonal migrations through areas beyond national jurisdiction (ABNJ), to prevent further extinctions. Resolution 19/03 by the IOTC prohibits the retention of mobulids and mandates their prompt release, with the least possible harm, and requires reporting of mobulid discards and releases through logbooks or observer programs. Strict implementation and compliance with these measures are essential to reduce mobulid mortality effectively.

4.4 Pre-Capture Methods

The IOTC Scientific Committee is tasked with identifying conservation hotspots for mobulids by 2023, focusing on areas where these species seasonally aggregate (Ward-Paige et al., 2013). Spatio-temporal management, ideally dynamic, should be implemented in known key habitats without delay (Croll et al., 2016; Hutchinson et al., 2017). The precautionary principle should guide efforts to identify and protect critical habitats and times for mobulids, potentially through dynamic marine protected areas (MPAs) (Ward-Paige et al., 2013). Continued research is necessary to understand the physical and biological processes driving mobulid movements, enabling more effective conservation measures that minimize economic losses from reduced target catches.

4.3 Safe Handling and Release

Post-release mortality of mobulids is extremely high in some species, highlighting the need for effective release tools and methods (Amandè et al., 2008; Francis and Jones, 2017). Current tools, such as canvas nets, should be improved, and new equipment like modified brailer grids should be developed and tested (Grande et al., 2019). Compliance with Resolution 19/03 should be facilitated by the IOTC, and the importance of quick and safe release should be emphasized to fishing crews. Training for skippers and crew on handling techniques should be strengthened and closely monitored, with the aim of reducing onboard and post-release mortality. Additionally, the Manta Trust has developed comprehensive safe handling and release guidelines for manta and devil rays, tailored to various fishing gear types. This valuable resource offers specific instructions for longline, hook and line, purse seine, and gillnet fisheries. The handbook also includes crucial information on practices to avoid when handling and releasing mobulids. This guide serves as an essential precautionary measure to address the global concern of post-release and at-vessel mortality in mobulid populations. By providing fishers with detailed, gear-specific protocols, the handbook aims to significantly reduce the impact of fishing activities on these vulnerable species.

4.4 Observer Coverage and Training

Increased observer coverage on fishing vessels is essential to gather data on mobulid interactions and address knowledge gaps. Observers should be trained in accurate species identification, and their reports, along with logbook data, should be analyzed to assess the effectiveness of mitigation measures. The Compliance Committee should develop mechanisms to evaluate adherence to Resolution 19/03. Improved training and standardized data collection protocols across RFMOs, facilitated by organizations like the Manta Trust, will enable better management and conservation strategies for mobulid rays.

4.5 Enhancing IOTC Resolution 19/03: Supporting Research and Management of Mobulid Rays

To effectively address the conservation of mobulid rays, the IOTC has committed to conducting research to fill key knowledge gaps about these species. Supporting this research is essential, especially as many studies in the Eastern Tropical Pacific (ETP) are funded by RFMOs. In the IOTC area, most research is conducted by surveying landing sites, and existing data sets should be made available to facilitate further research and improve management recommendations, such as stock assessments for key species like *M. birostris, M. thurstoni, M. tarapacana,* and *M. mobular*.

5. Summary of Action Plans

Based on the provided recommendations, the following actions could be considered to amend IOTC Resolution 19/03 to enhance the conservation and management of mobulid rays:

5.1. Strengthen Subsistence Fisheries Reporting

- Mandatory Reporting: Enforce stricter reporting requirements for subsistence fisheries, ensuring that all incidental catches of mobulids are documented and reported to relevant authorities. This will improve data collection and help assess the impact of artisanal fishing on mobulid populations.
- Local Consumption Limits: Clearly define and limit the amount of mobulid rays that can be retained for local consumption to prevent misuse of the subsistence exemption for commercial purposes.

5.2. Address RFMO Compliance Challenges

- Harmonize Regulations: Work towards harmonizing regulations between overlapping RFMOs, such as the IOTC and WCPFC, to ensure consistent enforcement across shared waters. This could involve creating joint management plans or agreements that address the unique challenges of countries like Indonesia and Malaysia.
- Enhanced Coordination: Establish a task force to facilitate communication and coordination between RFMOs, focusing on shared waters and overlapping jurisdictions to improve compliance and enforcement.

5.3. Enhance Pre-Capture Methods

- Identify and Protect Hotspots: Accelerate the identification and protection of mobulid aggregation and nursery hotspots through dynamic spatio-temporal management. Implement measures such as dynamic marine protected areas (MPAs) to safeguard these critical habitats. This approach should be prioritized to minimize mobulid mortality in IOTC fisheries (Croll et al., 2016; Hutchinson et al., 2017).
- Develop Bycatch Reduction Technologies: Invest in research and development of new technologies, such as LED lights in gillnets, to prevent incidental capture of mobulids.
- Implement Aerial Detection and Net Set Avoidance: Utilize helicopter communication for mobulid conservation in tropical tuna fisheries. This method involves using aerial surveillance to detect the presence of mobulid rays in fishing areas and communicating this information to fishing vessels. By avoiding setting nets in areas where mobulids are observed, bycatch can be significantly reduced, contributing to more effective conservation efforts in IOTC fisheries.

5.4. Improve Safe Handling and Release Practices

- Develop New Release Tools: Collaborate with fishing crews to develop and test new tools, such as modified brailer nets or manta grids, to facilitate the safe release of mobulids with minimal harm (Grande et al., 2019).
- Incentivize Quick Release: Introduce incentives for fishing crews to quickly and safely release mobulids, and closely monitor compliance with best practice guidelines.
- Disseminate updated safe handling and release guidelines provided by the Manta Trust and include them in the supporting documentation available.

5.5. Increase Observer Coverage and Training

- Increase Observer Coverage: Significantly enhance observer coverage on IOTC vessels to gather comprehensive data on mobulid bycatch. This is crucial for understanding and mitigating interactions with fisheries.
- Enhance Training Programs: Provide thorough training for fisheries observers, skippers, and crews to ensure accurate reporting of mobulid captures. Emphasize the importance of collecting high-quality photographs for species verification, potentially facilitated by a Manta Trust-administered online identification hub.
- Develop Updated Identification Guides: Collaborate with the Manta Trust to create improved and cohesive mobulid identification guides across RFMOs, addressing key knowledge gaps and standardizing data collection protocols.

5.6. Facilitate Further Research

- Identify and Protect Critical Habitats: Conduct further research to identify and safeguard critical mobulid habitats, as highlighted by Lezama-Ochoa et al. (2019). Collaborate with third parties, such as the Manta Trust, to enhance these efforts.

- Investigate Post-Release Mortality: Implement a centralized Post-Release Mortality (PRM) program through the IOTC to study and mitigate post-release mortality rates. This research should be supported by collaborations with organizations like the Manta Trust.

5.7 Supporting Research Initiatives

- Data Sharing and Collaboration: Encourage the sharing of existing data collected from landing site surveys to support ongoing research efforts. This data is crucial for performing stock assessments and refining management strategies for the four key mobulid species.
- Research Plan Development: Collaborate with organizations like the Manta Trust to develop a comprehensive research plan. This plan should focus on key factors such as post-release survival rates and improving data collection methodologies.

5.8 Enhancing Mobulid Conservation efforts

- Integrate Retention Prohibitions with Bycatch Mitigation: Combine retention bans with strategies to reduce incidental catch, such as spatial and temporal closures in critical habitats.
- Strengthen Enforcement of Existing Regulation: Strengthening the capacity of local authorities to monitor compliance with retention prohibitions and bycatch mitigation measures. This includes increasing resources for patrols and inspections in key fishing areas, as well as fostering collaboration between governments and local communities to promote sustainable fishing practices and reduce illegal trade in mobulid products.

These recommendations aim to strengthen the implementation and compliance of IOTC Resolution 19/03, ensuring the sustainable management and conservation of mobulid ray populations.

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Annexes

Annex 1 (Table 1): 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

Annex II (Table 2): Protective legislation for mobulids.

Location	Species	Legal protection measure
	International	
CITIES 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 (CITIES).
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.
The International Commission for the Conservation of Atlantic Tunas	All mobulid species	Recommendation 23-14 by ICCAT on Mobulid Rays (family Mobulidae) Caught in Association with ICCAT Fisheries

Regional		
European Union member countries	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014.
Convention on the Conservation of European Wildlife & Natural Habitats (Bern Convention)	*M. mobular*	Annex II: list of strictly protected fauna species. Appropriate and necessary legislative and administrative measures including all forms of deliberate capture and keeping and deliberate killing; the deliberate damage to or destruction of breeding or resting sites; the deliberate disturbance of wild fauna, particularly during the period of breeding, rearing and hibernation, the possession of and internal trade in these animals, alive or dead, including stuffed animals and any readily recognisable part or derivative thereof, where this would contribute to the effectiveness of the provisions of this article.
Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (Barcelona Convention)	*M. mobular*	Annex II: list of strictly protected fauna species. Appropriate and necessary legislative and administrative measures including all forms of deliberate capture and keeping and deliberate killing; the deliberate damage to or destruction of breeding or resting sites; the deliberate disturbance of wild fauna, particularly during the period of breeding, rearing and hibernation, the possession of and internal trade in these animals, alive or dead, including stuffed animals and any readily recognisable part or derivative thereof, where this would contribute to the effectiveness of the provisions of this article.
Specially Protected Areas and Wildlife (SPAW)	*M. alfredi, M. birostris, M. cf. birostris*	Annex III: Contracting Parties to regulate their exploitation, to maintain their population at the highest possible levels. Prohibits non-selective methods that could disturb listed species; seasonal hunting periods; regulate possessing and trading of parts, products, or whole species.
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.
Israel	All mobulids	All sharks and all rays are fully protected. They may not be captured, harmed, traded or kept, without a specific permit from the Israel Nature and Parks Authority (INPA)
Bandgladesh	M. mobular	national Wildlife (Conservation and Security) Act
Maldives	All mobulid	Exports of all ray products banned 1995. Environment Protection Agency rule - illegal to capture, keep or harm any type of ray; Batoidea Maldives Protection Gazette No. (IUL) 438-ECAS/438/2014/81

Oman	M. kuhlii; M. thurstoni	
Pakistan	All mobulids	laws of maritime provincial government banning the catching, landings and marketing of species included in various appendices of CITES
South Africa	*M. alfredi; M. birostris*	Biodiversity Act of 2004 (M. birostris), Threatened or Protected Species (TOPS) regulations (Notice No. 40875 under No. 476 of the Biodiversity Act, 10 of 2004, 2017) (M. alfredi).
Thailand	*M. alfredi, M. birostris, M. tarapacana, M. thurstoni, M. mobular, M. kuhlii, M. eregoodoo*	1992 Wildlife Conservation Protection Act: National protected species list
Sudan	All mobulids	Fully protected in UAE waters
United Arab Emirates	*M. birostris; M. alfredi*	
Australia	All mobulid species	Environment Protection and Biodiversity Conservation Act (added as protected species 2012)
China- Taiwan	*M. birostris, M. alfredi*	Fisheries Act: list of protected species, making the disturbance, abuse, slaughter or capture of any of the three species punishable by up to five years in prison, and a fine of NT$300,000 to NT$1.5 million (US$10,033 to US$50,164).
Ecuador	*M. birostris, M. mobular, M. thurstoni, M. munkiana* & *M. tarapacana*	Ecuador Official Policy 093, 2010: Fishing directed at rays and manta rays is prohibited, using any fishing gear. Likewise, in the case of incidental capture, they must be immediately returned to their natural habitat. Also, the possession, transportation, processing, and/or commercialization of the whole species or any of its parts are prohibited.
Kenia	*M. birostris, M. alfredi*	National legislation through a Gazette Notice
Indonesia	*M. birostris, M. alfredi*	Kepmen KP No. 4 2014: banned the hunting, selling and distribution of both species of the manta ray.
New Zealand	*M. birostris; M. mobular*	Wildlife Act 1953 Schedule 7A (absolute protection)
Peru	*M. birostris*	Ministerial resolution N° 441-2015-PRODUCE: Prohibit the extraction of the giant manta ray with any fishing art or gear and/or any other instrument in the marine waters under Peruvian jurisdiction.
Philippines	*M. birostris*	FAO 193 1998 Whale Shark and Manta Ray Ban/ CITES Species no quoata allow for CITES species

Brazil	*M. birostris, M. mobular, M. tarapacana, M. thurstoni, M. hypostoma*	Federal law: INSTRUÇÃO NORMATIVA INTERMINISTERIAL MPA/MMA Nº 02: It prohibits targeted fishing, on-board retention, transshipment, landing, storage, transportation, and commercialization of species, products, and by-products of rays from the Mobulidae family (known as manta ray, devil ray, manta devil, small devil ray, or sea devil) in Brazilian jurisdictional waters and national territory.// Ministeral law*
Belize	All mobulid	Fisheries Resources Act
Costa Rica	All mobulid species	Decree No. 38027-MAG, Article 4: The capture, possession, storage, transportation, commercialization, industrialization, on-board retention, or landing of mobulids is not allowed. In the case of incidental capture of these species, they must be released causing the least possible harm and returned to the aquatic environment.
Mexico	*M. birostris, M. mobular, M. thurstoni, M. munkiana, M. tarapacana, M. hypostoma, M. cf birostris*	NOM-029-PESC: Prohibition of harvest, retention and trade of mobulids species. NOM-059-SEMARNAT: Special protection and regulation of any activity involving mobulids
USA	*M. birostris*	Endangered Species Act
Iran	All mobulid species	Iran's Official Gazette: Protection of all shark and rays in Iranian waters
Guam, USA Territory	*M. birostris, M. alfredi*	Bill 44-31 prohibiting sale/trade in ray parts
Malaysia	M. birostris, M. alfredi	Federal Fisheries (Control of Endangered Species of Fish) Regulations 1999, Fisheries Act 1985: No person shall fish for, disturb, harass, catch, kill, take, possess, sell, buy, export or transport any of the specified protected species except with written permission from Malaysia's Director-General of Fisheries.
Fiji	All mobulid species	Fiji's Endangered and Protected Species Act, which regulates and controls the trade of any species listed under CITES as well as indigenous species not administered by CITES. The Offshore Fisheries Management Act 2012 and its regulations regulate the use of fishing gear used to catch fish (including sharks) as well as restrictions relating to the catch, sell and possession among other things of the shark species listed under Appendix I & II of CITES. In 2019, a shark fin import and export ban was implemented.
French Polinesia	*M. birostris, M. alfredi*	Code for the Environment among category ''A'' species (Articles A 121–3 to A 121–36, Code for the Environment of French Polynesia)
Gabon	All mobulid species	regulates shark and ray catch in Gabon's fisheries. Special authorization will now be needed to target sharks and rays in fisheries, with a list of the most vulnerable species fully protected. bans the practice of shark finning and all export of shark and ray products from Gabon. second law adds a wide range of sharks and rays to Gabon's list of protected marine species, must be immediately released when caught in fisheries, and fishing techniques must be adapted to reduce any bycatch of these species to less than 1% of the total catch.

Mozambique	All mobulid species	Regulamento da Pesca Marítima (REPMAR): Protected species, by-catch must be thrown back unless the fisher has prior written permission to use it for research.
Türkiye	M. mobular	Environmental Law No. 2 872.
Portugal	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014, EU (72/2016/EU)
Spain	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014, EU (72/2016/EU)
France	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014, EU (72/2016/EU)
Italy	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014, EU (72/2016/EU)
Greece	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014, EU (72/2016/EU)
Albania	All mobulid species	Council Regulation (EU) 2015/2014 amending Regulation (EU) No 43/2014 and repealing Regulation (EU) No 779/2014, EU (72/2016/EU)
Croatia (EU)	All mobulid species	Law of the Wild Taxa 2006 Strictly prohibited
Malta (EU)	All mobulid species	Sch. VI Absolute protection
Montenegro	*M. mobular*	Official Gazette of the Republic of Montenegro No. 76/06
Belize	*M. mobular*	
Philippines	All mobulid species	
India	*M. birostris, M. alfredi, M. tarapacana and Mobula spp.*	The Wild life (Protection) Amendment Act, 2022. SCHEDULE I and II, Apendix II
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 Laglbauer et al. 2024 (in prep) and Lois Flouders, 2020.

Annex III (Table 3): Examples of reported mobulid population declines in the Indian Ocean.

Location	**Estimated decline (%)**	**Source**
Mumbai, India (2009)	51%	Raje and Zacharia 2009
Cilacap, Indonesia (2015)	64%	Lewis et al. 2015
Lakamera, Indonesia (2015)	75%	Lewis et al. 2015
Tanjung Luar, Indonesia (2015)	94%	Lewis et al. 2015
Pakistan (2018)	92.50%	Moazzam 2018
Philippines (2022)	80%	Rambahiniariason et al. 2022
Tofo, Mozambique (2024)	88%	Venables et al. 2024; Rohner et al., 2013
East Java, Indonesia (2024)	89%	Laglbauer et al. 2024. in perp

Annex IV (Table 4): Conversion values (wet to dry) for the body parts of the four most traded mobulid species. Percentage (%) given = proportion remaining by weight of the whole fresh (wet) carcass.

***Mobula* spp.**	**Disc width (cm)**	**Whole carcass (kg)**	**Meat (kg)**		**Gill plates (kg)**	
			Fresh (80%)	Dried (32%)	Fresh (~1%)	Dried (~0.2%)
M. birostris	449.4	533.2	426.56	170.62	7.70	1.54
M. tarapacana	238.3	143.7	114.96	45.98	1.24	0.25
M. mobular	206.9	88.7	70.96	28.38	0.88	0.18
M. thurstoni	162.3	45.2	36.16	14.46	0.42	0.08

a. Disc widths are based on the mean size of all individuals (n=1337, excl. foetuses) landed in the Philippines (Rambahiniarison et al. 2018).

b. Weights of whole carcass based on Rambahiniarison et al. (2018) and D'Costa & Stevens (in prep).

c. Proportion of whole carcass used (20% discard) for human consumption is based on Rojas et al. (in press).

d. Wet (fresh) / dry meat conversions (60% reduction) based on Rojas et al. (in press).

e. Wet (fresh) / dry gill plate conversions (80% reduction) based on Blue Resources Trust (in prep).