

Sympathy for the devil: A conservation strategy for devil and manta rays

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Abstract

Background. Increased interest in luxury products and Traditional Chinese Medicine, associated with economic growth in China, has been linked to depletion of both terrestrial and marine wildlife. Among the most rapidly emerging concerns with respect to these markets is the relatively new demand for gill plates, or *Peng Yu Sai* (“Fish Gills”), from devil and manta rays (subfamily Mobulinae). The high value of gill plates drives international trade supplied by largely unmonitored and unregulated bycatch and target fisheries around the world. Devil and manta rays are especially sensitive to overexploitation because of their exceptionally low productivity (maximum intrinsic rate of population increase). Scientific research, conservation campaigns, as well as international and national protections that restrict fishing or trade have increased in recent years. Many key protections, however, apply only to manta rays.

Methods. We review the state of the development of scientific knowledge and capacity for these species, and summarise the geographic ranges, fisheries and national and international protections for these species. We use a conservation planning approach to develop the Global Devil and Manta Ray Conservation Strategy, specifying a vision, goals, objectives, and actions to advance the conservation of both devil and manta rays.

Results and Discussion. Generally, there is greater scientific attention and conservation focused on Manta compared to Devil Rays. We discuss how the successes in manta ray conservation can be expanded to benefit devil rays. We also examine solutions for the two leading threats to both devil and manta rays – bycatch and target fisheries. First, we examine how can the impact of bycatch fisheries can be reduced through international measures and best-practice handling techniques. Second, we examine the role that responsible trade and demand can play in reducing target fisheries for gill plates. Our paper suggests that given similarities in sensitivity and appearance, particularly of the dried gill plate product, conservation measures may need to be harmonised particularly for the larger species in this subfamily.

Introduction

Over the past 30 years, a surge in the size and purchasing power of China's middle and upper class, an aging population, and increased government investment has elevated the demand for Traditional Chinese Medicine (TCM). The proportion of Chinese urban households considered "poor" has dropped from 99.3% of households in 1985 to 23.2% in 2015. The rapidly growing upper middle class is projected to make up the largest segment of urban households by 2025 (Farrell, Gersch & Stephenson, 2006). Additionally, China's median age is projected to rise from 35 years in 2010 to 50 years in 2050 (Feng et al., 2012). Increasing age is generally correlated with increased TCM use, but this trend reverses after age 65 (Xu & Yang, 2009). Financial investment by the Chinese government in TCM research institutes increased from 80 million to 300 million Chinese Yuan from 1999 to 2005 (Xu & Yang, 2009). These drivers are expected to boost the demand for and use of TCM, and in turn the exploitation and trade of threatened species. Wildlife threatened by TCM-driven international trade includes terrestrial fauna like the Chinese Pangolin (*Manis pentadactyla*) and Tiger (*Panthera tigris*), and marine organisms like sharks and rays (subclass Elasmobranchii). One of the most rapidly emerging wildlife trade issues is the demand for and consumption of gill plates of devil and manta rays (mobulids), marketed under the trade name *Peng Yu Sai*, translated as "Fish Gills" and the domestic markets for their meat in the developing world.

Gill plates - the thin, cartilaginous filaments used to filter plankton and small fish from the water column - are not historically considered TCM. They are used as a key ingredient in a tonic touted to boost the immune system, enhance blood circulation, and treat ailments ranging

from chicken pox to kidney issues. Despite this, TCM practitioners interviewed in Guangzhou, China and Singapore stated that *Peng Yu Sai* has no health benefits and that they do not actively prescribe it (M.P. O'Malley, unpublished data). In addition, toxicology studies suggest there are health risks from consuming the high levels of heavy metals in *Peng Yu Sai* (Wong et al., 2007; Li et al., 2012). It appears that industry marketing of *Peng Yu Sai*, rather than any credible TCM or other medical research, is responsible for its rise in popularity (Whitcraft, O'Malley & Hilton, 2014).

Prior to the emergence of the gill plate market, devil and manta rays were historically exploited for meat (consumed fresh or dried), and to a lesser extent skin (dried) and cartilage (for shark fin soup filler; White et al., 2006; Acebes, 2013), and there continues to be a market for some of these devil and manta ray products today. In the Philippines, devil and manta rays are targeted for their meat, which is consumed domestically, in addition to their gill plates (Alava et al., 2002; Acebes, 2013). In Mexico, species were historically targeted for meat but not for their gill plates (Notarbartolo di Sciara, 1988; Heinrichs et al., 2011), and in 2007 Mexico banned targeted mobulid fishing and export. Mobulid meat is used in traditional dishes as a cheap source of protein in Southeast Asia, as well as in South and Central America (Croll et al., 2015). The meat is generally consumed locally, making the monitoring and regulation of this market outside of the scope of international trade agreements.

Mobulids are targeted (Alava et al., 2002; White et al., 2006; Lewis et al., 2015) and taken incidentally as bycatch (White et al., 2006; Rajapackiam, Gomathy & Jaiganesh, 2007; Heinrichs et al., 2011; Couturier et al., 2012) in fisheries throughout their ranges. They have been recorded as target and bycatch in at least 30 large and small-scale fisheries in 25 countries (Bonfil & Abdallah, 2004; Dapp et al., 2013; Croll et al., 2015), and in a wide range of gear types

including driftnets, purse seines, gillnets, traps, trawls, and long lines (Croll et al., 2015). In particular, fisheries targeting tuna (both large and small scale) often retain mobulids as bycatch (White et al., 2006; Fernando & Stevens, 2011; Hall & Roman, 2013; Lewis et al., 2015). Whereas the term “bycatch” is often taken to mean that animals are unwanted and/or discarded, devil and manta rays, like many other elasmobranchs, are among the species often retained as a reasonably valuable secondary catch, especially when target species are unavailable due to decline, regulation, or other circumstances (Dulvy et al., 2014). Tagging studies indicate moderate-to-high rates of post-release mortality in mobulids, especially for large individuals that can be difficult to release without physical damage (Francis, 2014; Poisson et al., 2014). Increased demand for mobulid gill plates has fuelled the emergence and expansion of targeted fisheries for these species (Alava et al., 2002; Lewis et al., 2015), and encouraged increased retention of rays taken incidentally (Rajapackiam et al., 2007; Heinrichs et al., 2011; Couturier et al., 2012). Mobulids are often fished and traded under one category, yet in reality these fisheries and traded products comprise 11 species in two genera that vary considerably in catchability, abundance, and productivity.

Nine species of devil ray (genus *Mobula*) and two species of manta ray (genus *Manta*) make up the subfamily Mobulinae (see examples in Figure 1). They are broadly distributed planktivores and piscivores that occur in tropical and warm-temperate waters. The largest devil ray species can attain a maximum size of five metres disc width (Giant Devil Ray, *Mobula mobular*; Notarbartolo di Sciara, 1987), and the largest manta species can reach up to seven metres disc width (Oceanic Manta Ray, *Manta birostris*; McClain et al., 2015). Devil and manta rays also have long gestation periods (Marshall & Bennett, 2010), and are thought to produce a single pup (Hoenig & Gruber, 1990; Stevens et al., 2000) every one to three years (Notarbartolo

di Sciara, 1988; Compagno & Last, 1999; Homma et al., 1999). Consequently, maximum rates of intrinsic population increase in these large mobulid species are among the lowest of all elasmobranchs (Dulvy et al., 2014; S.A. Pardo, unpublished data). The life history and ecological traits of mobulids make them highly sensitive to overexploitation.

Protections for mobulids have expanded relatively rapidly over the past decade, yet despite similar threats, national and international measures for devil rays have lagged behind manta rays. Countries offering protection for both devil and manta rays include Australia, Brazil, the Member States of the European Union, Israel, Mexico, Ecuador, New Zealand, and the Maldives (Camhi et al., 2009; Whitcraft, O'Malley & Hilton, 2014; Council Application (EU) 2015; CITES 2016; Department of the Environment 2016), while Peru, the Philippines, United Arab Emirates (U.A.E.), and Indonesia legally protect only one or both species of manta ray. The first international action came in 2011 with the listing of just the Giant Manta Ray (*Manta birostris*) on Appendix I and II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS), obligating Parties to strictly protect the species and collaborate toward regional conservation. In 2014, the remaining ten species of mobulid were listed on Appendix I and II of CMS during the 11th Meeting of the Parties (CMS 2015). In 2013, both species of manta ray were listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) – the world's oldest and largest multilateral environmental agreement with the legal mechanisms in place to hold Parties accountable to trade restrictions. The 182 Parties are thus required to allow only permitted international trade in manta rays after it is demonstrated as legal and sustainable (CITES, 2013). Guyana is the only Party that has taken a reservation on these listings and is therefore not bound by them.

Conservation planning is a key approach to building capacity and ensuring comprehensive and collaborative action (Stanley Price & Soorae, 2003; Hoffmann et al., 2008; IUCN 2008; Harrison & Dulvy, 2014). Concern about the increasing trade in mobulid gill plates and differences in protections and conservation efforts across species led to the development of the Global Devil and Manta Ray Conservation Strategy. The process and outcomes are summarized here.

Materials & Methods

Scientific research on devil and manta rays

Scientific papers were extracted from the ISI Web of Science Core Collection on 30 November 2015, using the Search option. A search was conducted for papers where the paper title included either “mobula” or “manta”. To exclude any arts or humanities papers that contained these terms, the search was filtered to include only those categorized under “Science Technology.” These results were exported and ‘false-positive’ papers that were unrelated to devil or manta rays were removed. For example, from the manta title search, any references to the city of “Manta” in Ecuador, the survey technique called a “manta tow”, the Spanish word “manta” which means blanket, or the robotics of the manta-type unmanned undersea vehicle were excluded.

The current state of devil and manta ray expertise

The IUCN SSG convened the Global Devil and Manta Ray Conservation Strategy Workshop in Durban, South Africa from 9-12 June 2014, and initiated a survey among a wider network of devil and manta ray experts. The aim was to gage the current state of conservation, protections (e.g. trade or fishing regulations), and scientific capacity, with the ultimate goal of developing a

Devil and Manta Ray Global Conservation Strategy. During the workshop, experts summarized existing knowledge, including species names and synonyms, maximum body size, primary threats, current protections and shortfalls of these protections, and opportunities for action.

Range, fisheries, and protections mapping

Following the workshop, eleven maps of Extent Of Occurrence (EOO) and Area Of Occupancy (AOO) were generated based on current species distribution knowledge. The EOO is defined as “the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon” (IUCN, 2001; IUCN, 2012; IUCN, 2014). The AOO is defined as “the area within its 'extent of occurrence' that is occupied by a taxon for each country. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may, for example, contain unsuitable habitats” or be beyond the maximum depth distribution (IUCN, 2001; IUCN, 2012; IUCN, 2014). The AOO for devil and manta ray species was estimated by including only areas where the presence of a given species had been confirmed.

Devil ray AOO distribution maps were separated from those for manta rays to compare: (a) known fishing pressure through target and bycatch fisheries, and (b) international, regional, and national protections. Information on known fisheries and current protections was gathered primarily by consulting mobulid experts who were present at the Conservation Strategy Workshop, and those who are part of the wider network of experts. This information was confirmed or supported by gathering information from the existing literature on devil and manta rays.

Development of a Global Devil and Manta Ray Conservation Strategy

Through a series of workshop subgroup discussions and plenary sessions, participants at the Strategy Workshop developed a vision, set of goals, and series of objectives and actions, aimed at conserving devil and manta rays (IUCN, 2008). This process largely followed that for the Global Sawfish Conservation Strategy, which was the first conservation strategy to generate action for a group of elasmobranchs using a global approach (Harrison & Dulvy, 2014). The Global Sawfish Conservation Strategy argued that the development of a global strategy is an important tool for allocating limited conservation capacity to priority regions, countries, and species. The inclusion of a broad range of geographic representation and skills was key to the successful development of the Global Sawfish Conservation Strategy (Dulvy et al., 2016). Similarly, participants involved in the devil and manta ray workshop ranged from biologists to representatives of organizations focused on tourism, education, and policy.

Where possible, the group attempted to use the Specific, Measurable, Achievable, Relevant/Realistic, and Time-Bound (SMART) criteria in setting objectives and actions. After the workshop, experts revised the goals, objectives, and actions. This revision process included consulting a wider mobulid network for input, including experts participating in the Fisheries Society for the British Isles (FSBI) symposium in Plymouth, United Kingdom (27-31 July 2015).

Results

Scientific research on devil and manta rays

After filtering out the false negatives, the search term “mobula” returned 73 peer-reviewed publications, whereas “manta” returned 108 over the past 150 years from 1864-2014. The mean annual number of publications that include “manta” or “mobula” in the title have increased over the past decade. This difference in scientific attention was especially pronounced for manta rays,

rising from a mean of 1.5 (SE \pm 0.3) publications yr⁻¹ to 6.5 (SE \pm 1.3) publications yr⁻¹. The increase was less pronounced for devil rays, where the mean number of publications rose from 1.0 (SE \pm 0.2) to 2.8 (SE \pm 0.9).

The mean annual number of citations for papers that included “manta” or “mobula” in the title was also examined. For manta rays, the mean annual number of citations increased by nearly 20-fold from 2.5 (SE \pm 0.6) to 46.1 citations yr⁻¹ (SE \pm 16.6). In contrast, for devil rays the mean annual number of citations rose from only about 5-fold, from 3.3 (SE \pm 0.8) in 1994-2004 to 17.0 citations yr⁻¹ (SE \pm 3.4) in 2005-2014.

The current state of devil and manta ray expertise

The IUCN SSG Global Devil and Manta Ray Conservation Strategy workshop was attended by 18 experts, who held knowledge from nine of the 19 Major Fishing Areas (MFAs) as recognized by the Food and Agriculture Organization of the United Nations (FAO; Figure 2a). A further 14 experts contributed to the Global Devil and Manta Ray Conservation Strategy either through electronic correspondence, or during the 2015 Fisheries Society for the British Isles (FSBI) symposium (Figure 2b). These additional collaborators helped to provide expertise for mobulids in the eastern Indian or the Atlantic Ocean, as no workshop participant self-identified as having knowledge specific to these MFAs.

Geographic Range, fisheries, and protections mapping

Updated species-specific AOO and EOO maps for the eleven species of devil and manta ray show the variation in distributions within this subfamily (Figure 3). Despite several devil and manta ray species showing overlap in AOO and EOO distribution maps, protections for manta

rays at international (Figure 4), national, and state/territory levels (Figure 5) are greater than those currently in place for devil rays (Table 1). Manta rays are afforded greater fisheries and trade protections than devil rays where bycatch and target fisheries are known to occur (Figures 4, 5). There is also variation in protection among species of devil ray. For example, the Giant Devil Ray (*Mobula mobular*) has a small EOO that coincides with the Mediterranean Sea and has been the subject of numerous national, regional, and international protection commitments from surrounding countries (Table 1). In contrast, the Chilean Devil Ray (*Mobula tarapacana*) has a large EOO, but national protections are only afforded in six of the 31 countries in its recorded range (Table 1). Several devil and manta ray target and bycatch fisheries are concentrated in the Indo-Pacific region (e.g. in Indonesia, India, the Philippines, and Sri Lanka); protections in this region, however, are largely focused on manta rays (e.g. Indonesia 2014, the Philippines 1998).

Development of a Global Devil and Manta Ray Conservation Strategy

Workshop participants agreed on an overall vision for the status of devil and manta rays, three goals aimed at achieving this vision, and a series of sixteen objectives and associated actions to support these goals (see Table 2 for detailed goals, objectives, and actions).

Discussion

Recently significant progress has been made toward protecting devil and manta rays, though conservation measures benefiting the lesser-known devil rays have lagged behind. This disparity exists despite similarly high intrinsic sensitivity to overexploitation and significant threats associated with demand for their gill plates, meat, and other products. We address three key questions: (1) How can we build upon the successes in manta ray conservation to benefit devil

rays? (2) How can the impact of bycatch fisheries on mobulids be reduced? and, (3) Can responsible trade and demand help to reduce target fisheries for gill plates? In responding to these questions we also highlight those Action item numbers from the Devil and Manta Ray Conservation Strategy (Table 2) that are either underway or completed.

(1) *How can we build upon the successes in manta ray conservation to benefit devil rays?*

There has been greater interest in manta rays compared to devil rays among a wide range of people, including representatives of governments, non-governmental organizations, and foundations as well as scientists, journalists, and the diving community. This differential attention has lead to more studies, conservation campaigns, and protections involving manta rays than devil rays, although this gap is beginning to narrow.

Tourism and related income have partially motived the conservation successes of manta rays. Translating this success to devil rays, however, is challenging. Both species of manta ray reach a large body size, form predictable aggregations, and are accessible to divers (O'Malley, Lee-Brooks & Medd, 2013). Some species of devil ray also reach a large body size, form predictable aggregations, and are accessible to divers, and as a result may be incorrectly identified as manta rays by tourism operators and tourists (R.H.L. Walls, D. Fernando, personal observations). Other devil ray species, however, form unpredictable and sporadic aggregations and exhibit shy behaviour. For example, although devil ray-specific boat-based tourism opportunities exist, such as viewing the vast aggregations of leaping Smoothtail Devil Ray (*Mobula munkiana*; Figure 1d) off Baja California as featured in BBC's "Shark" (4 June 2015), these aggregations occur over short periods that can be difficult to predict.

Strategic research on life history and productivity in devil rays has been focused on establishing key parameters to fill existing biological and ecological information gaps (S.A. Pardo, unpublished data; Action 2.2). For example, recent studies in the Mediterranean have estimated total abundance, habitat preferences, and seasonal changes in distribution for the Giant Devil Ray (Notarbartolo di Sciara et al., 2015; Action 3.3, 3.5), although this has yet to be done for other devil ray species. IUCN Red List re-assessments of the largest three species – Spinetail Devil Ray, Chilean Devil Ray, and Bentfin Devil Ray (*Mobula thurstoni*) are currently underway (Action 4.1). IUCN Red List assessments, on the other hand, have been recently revised and are current for manta rays (Marshall et al., 2011a; 2011b), by contrast the 2006 devil ray assessments are considered expired and urgently need revisiting.

Some key international and national protections still continue to protect manta rays and have yet to be considered or applied to devil rays, while others are beginning to protect all mobulids. Only the two manta ray species were protected under CITES Appendix II in 2013, even though devil rays had the potential to be included as “look-alike” species - species whose specimens in trade look like those of species listed for conservation reasons (CITES, 1983). For the CITES 2016 Conference of Parties, Fiji has proposed listing the Spinetail Devil Ray and the Chilean Devil Ray (*Mobula tarapacana*) on Appendix II, with the other seven devil ray species being included as look-alike species (Action 6.10). In early 2016, signatories to the non-binding CMS Memorandum of Understanding for Migratory Sharks (Shark MOU; 39 signatories), will consider listing all eleven species on the relevant MOU Annex and thereby covered by the associated Conservation Action Plan (Action 4.4, 6.1). This Conservation Action Plan aims to achieve and maintain a favourable conservation status for migratory sharks based on the best available scientific information and taking into account the socio-economic value of these species

to people of various cultures. Success of these efforts under CMS, depends on the CMS Parties and Shark MOU signatories following up with concrete actions, such as landing prohibitions, and safe release requirements at both national and regional scales.

(2) How can the impact of bycatch fisheries on mobulids be reduced?

Bycatch mortality in both large and small-scale fisheries (predominantly targeting tuna) is a key challenge to the conservation of mobulids, given emerging evidence for low rates of post-release survival and financial incentives for crew to retain these species. Mobulids can die during capture or after discarding. Bycatch studies have shown that discarded animals can suffer physical injuries, or may experience disruption to growth, reproductive cycles, or mating and social behaviour (Rowe & Hutchings, 2003; Wilson et al., 2014), and the same is likely true for mobulids. The few available studies on post-release survival in devil rays show that handling following capture may strongly influence post-release survival (Action 5.8; Table 2), although more research is needed (Action 5.9). In a study where small (142–238 cm DW, mean 200 cm DW) Spinetail Devil Rays were not removed from the water during tagging as part of a scientific study, post-release survival was relatively high (Croll et al., 2012). In contrast, when large individuals (215–265 cm DW) of the same species were landed on the deck of commercial fishing vessels prior to being tagged and released, post-release survival was low (Francis, 2014). Clearly, removing these rays from the water causes significant physical strain with potential for post-release mortality. For tuna purse seine fisheries, releasing large rays directly from the brailer (scoopnet that removes the fish from the purse seine), or lifting them out of the brailer using a canvas sling or scoop, is considered best practice; small and medium rays landed on the fishing vessel deck can be carried by their wings to be released (Poisson et al., 2014).

A significant step toward protecting mobulids caught in eastern tropical Pacific tuna fisheries was taken in 2015. The European Union secured a prohibition on retention, transshipment, storage, landing, and sale of all devil and manta rays taken in large-scale fisheries governed by the Inter-American Tropical Tuna Commission, a Regional Fisheries Management Organization (RFMO; Action 5.13; IATTC 2015). The measure includes requirements for reporting mobulid catch data and ensuring safe releases, as well as provisions for technical assistance and capacity building (Action 5.3, 5.4, 5.5). Developing countries were granted exceptions for mobulids taken in small-scale fisheries for domestic consumption.

(3) Can responsible trade and demand help to reduce target fisheries for gill plates?

Trade regulation through international agreements can sometimes cause countries to impose stronger export limitations than what is required, completely ban trade, or require additional permitting (Vincent et al., 2014). Complete bans can sometimes even stimulate wildlife trade by driving it underground or heightening value. An analysis of mainly terrestrial species that were uplisted from CITES Appendix II (under which trade is meant to be regulated at sustainable levels) to Appendix I (under which commercial trade is essentially banned) found trade volumes increased by 135% in the year prior to the ban enforcement and then dropped to zero in CITES official records (Rivalan et al., 2007). The price of rhino horn in Korea rose by 400% within two years of uplisting, which fueled a sharp increase in poaching (Rivalan et al., 2007; Biggs et al., 2013). While CITES has been a key driver in conservation success for a variety of taxa like the Nile crocodile (*Crocodylus niloticus*; Kievit, 2000), CITES Appendix II provisions (such as permits), may not be well implemented, particularly in countries with low capacity for management (Shepherd & Nijman, 2007; Rosen & Smith, 2010).

In concert with top-down trade regulation, investigations into the socio-economic drivers of targeted mobulid fisheries reveal *Peng Yu Sai* demand reduction as a promising way to indirectly reduce fishing pressure (Whitcraft, O'Malley & Hilton, 2014; Croll et al., 2015; Actions 7.3, 7.4). The bulk of the mobulid gill plate trade is centered in Guangzhou, China, and involves only a handful of large suppliers (Heinrichs et al., 2011; Whitcraft, O'Malley & Hilton, 2014; Action 7.5). In 2015, after 18 months of a focused awareness-raising campaign (Action 7.7), gill plate traders reported a substantial decrease in trade volumes and showed reduced interest in carrying gill plates because of concerns about guaranteeing supply for their customers (M.P. O'Malley, unpublished data). If this decline in trade volumes continues it may indicate that the demand reduction campaign has been successful in altering consumer behaviour away from the consumption of gill plates. Continued monitoring of the efficacy of consumer behaviour campaigns is needed to evaluate and track success.

It is important to consider the consequences of mobulid trade regulation for tropical coastal fishing communities, as these low-volume high-value fisheries may support livelihoods and contribute to food security. Many tropical coastal communities are growing rapidly, have low income, and rely heavily on fish and fisheries for protein and income (Allison et al., 2009). Social and economic transitions required to ensure well-enforced fishing and trade regulations can be alleviated by assistance from developed nations (McClanahan et al., 2008). Under CITES Appendix II, countries independently assess the national sustainability of their manta ray fisheries and determine the allowable level of trade, if any. Fisheries managers may prohibit landings of mobulids in cases of depletion, high vulnerability, precaution, and/or CMS membership. Some species may be able to support sustainable fisheries, but this has yet to be documented in practice and would require careful management and enforcement given their

sensitive life histories. Indeed, there are few restrictions and no comprehensive fisheries management programs for devil rays. Establishing basic safeguards for long-term sustainability of devil and manta rays should be a priority, especially in developing countries like Indonesia and Sri Lanka, where fishers derive income from mobulid fisheries and meat is a source of protein (Fernando & Stevens 2011; Heinrichs et al., 2011; Lewis et al., 2015). All mobulid fisheries mortality, not just that from gill plate-driven fisheries, should be monitored, regulated and minimized when necessary to ensure sustainability.

Conclusions

Scientific research and protections for both devil and manta rays have increased over the past decade. Both devil and manta rays are sensitive to exploitation because of their extremely low productivity, and are threatened by largely unregulated targeted fisheries and bycatch mortality. Manta rays, however, have been a greater focus of scientific investment and protections given their charisma and importance to the dive tourism industry, despite the fact that devil rays face similar conservation challenges. Expanding current manta protections to include devil rays has the potential to not only benefit devil rays, but will also help prevent illegal use of manta rays. The value of a coordinated global approach to conserving a wide-ranging elasmobranch was first demonstrated with the Global Sawfish Conservation Strategy, with much success. This strategy aims to encourage conservation initiatives and management solutions for both devil and manta rays.

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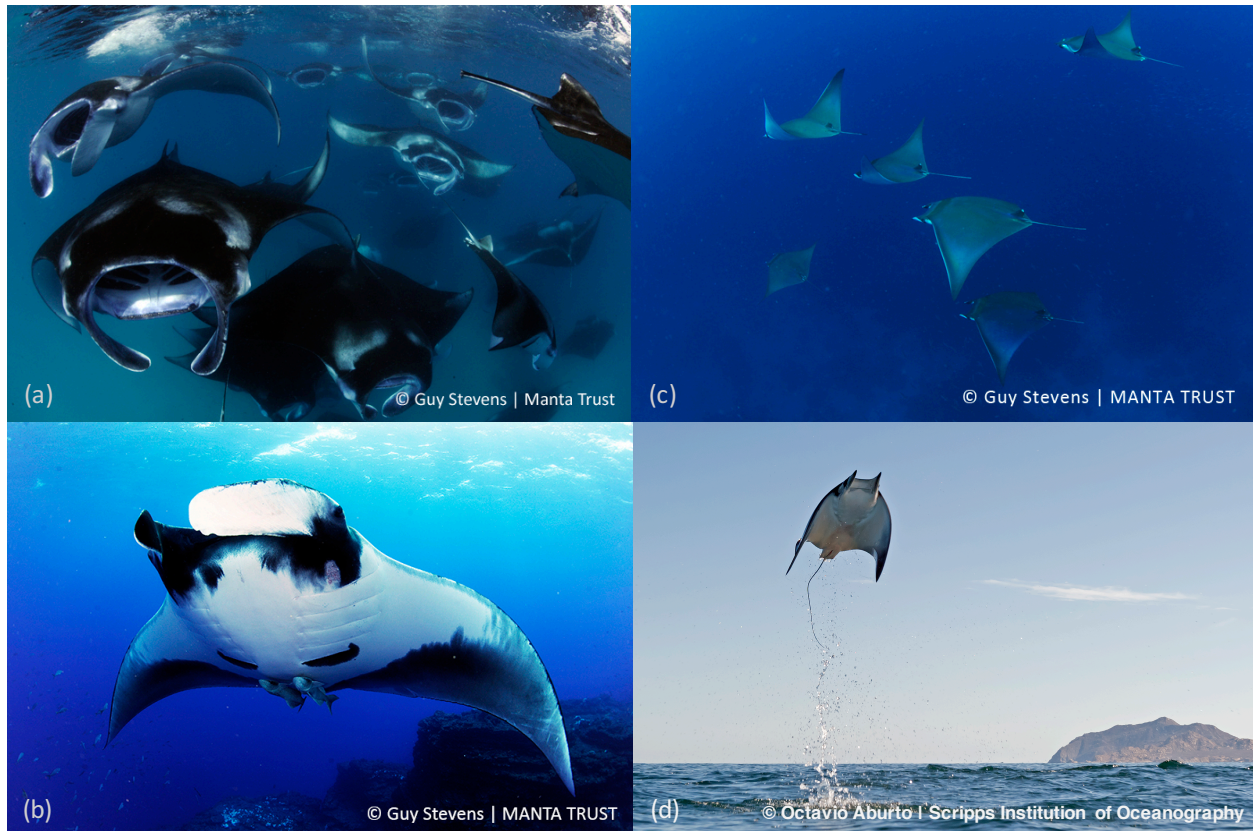


Figure 1. Images of devil and manta rays. (a) Reef Manta Ray (*Manta alfredi*); (b) Oceanic Manta Ray (*Manta birostris*); (c) Shortfin Devil Ray (*Mobula kuhlii*); (d) Smoothtail Devil Ray (*Mobula munkiana*).

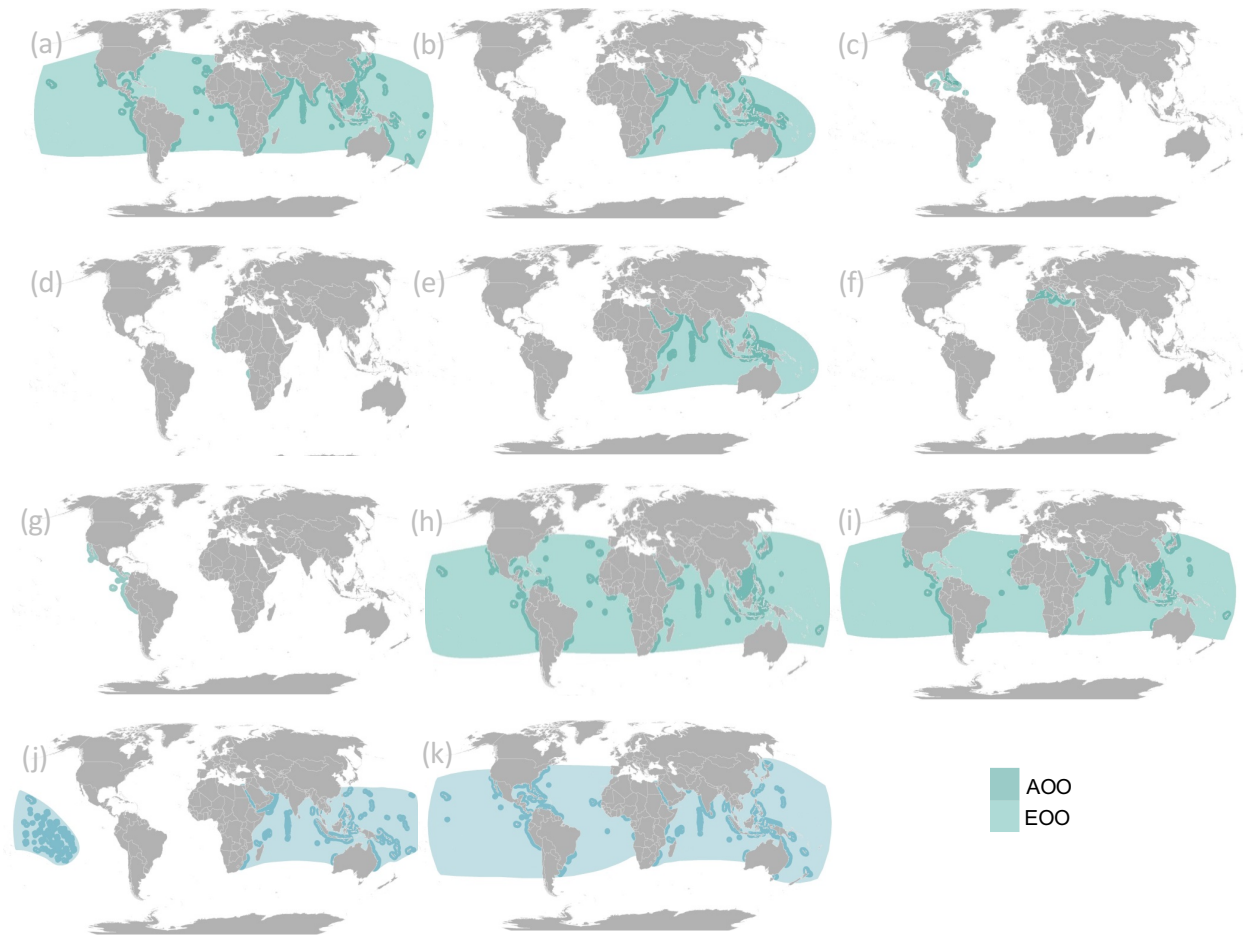


Figure 2. Distribution maps for manta and devil ray species. Area of Occupancy (AOO) and Extent of Occurrence (EOO) maps for all nine species of devil ray: (a) *Mobula japanica*, (b) *M. eregoodootenkee*, (c) *M. hypostoma*, (d) *M. rochebrunei*, (e) *M. kuhlii*, (f) *M. mobular*, (g) *M. munkiana*, (h) *M. tarapacana*, (i) *M. thurstoni*; and both species of manta ray: (j) *Manta alfredi*, (k) *M. birostris*.

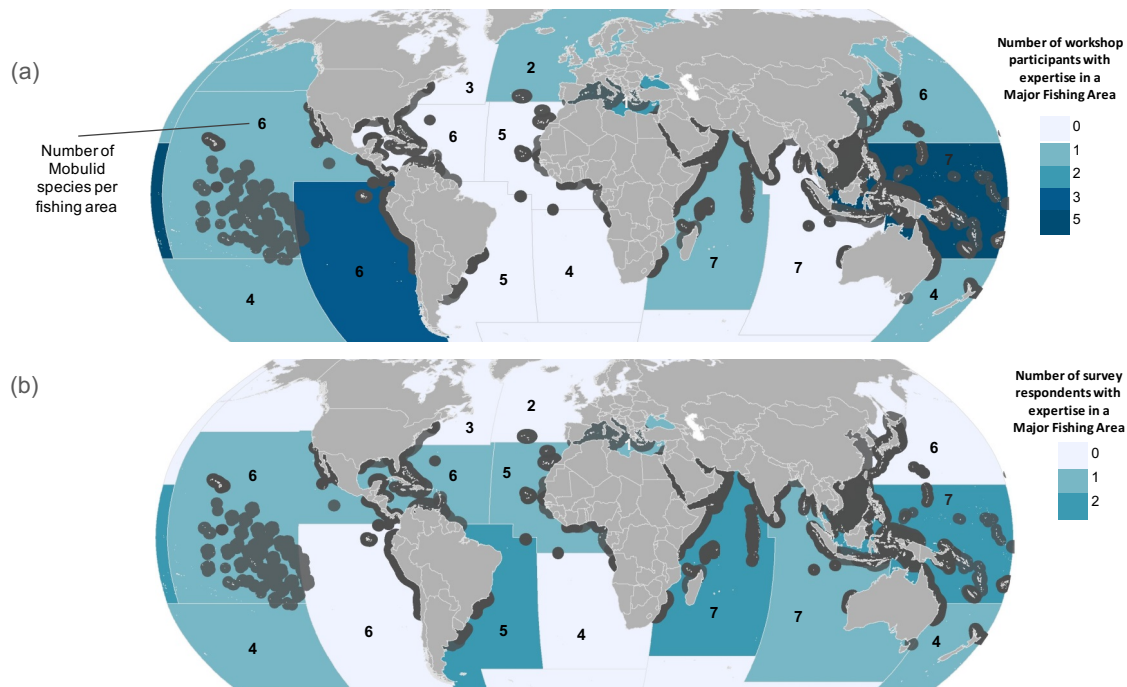


Figure 3. Expert representation at the Global Devil and Manta Ray Conservation Strategy workshop and among respondents to the devil and manta ray survey. (a) The number of workshop attendees with expertise from each Food and Agriculture Organization of the United Nations (FAO) Major Fishing Area (MFA) is represented by degree of colour saturation. (b) Geographic FAO MFA expertise of devil and manta ray survey respondents. The grey outlines around the countries indicate the presence of one or more mobulid species, with grey saturation representing areas of mobulid Area of Occupancy overlap (>1 species).

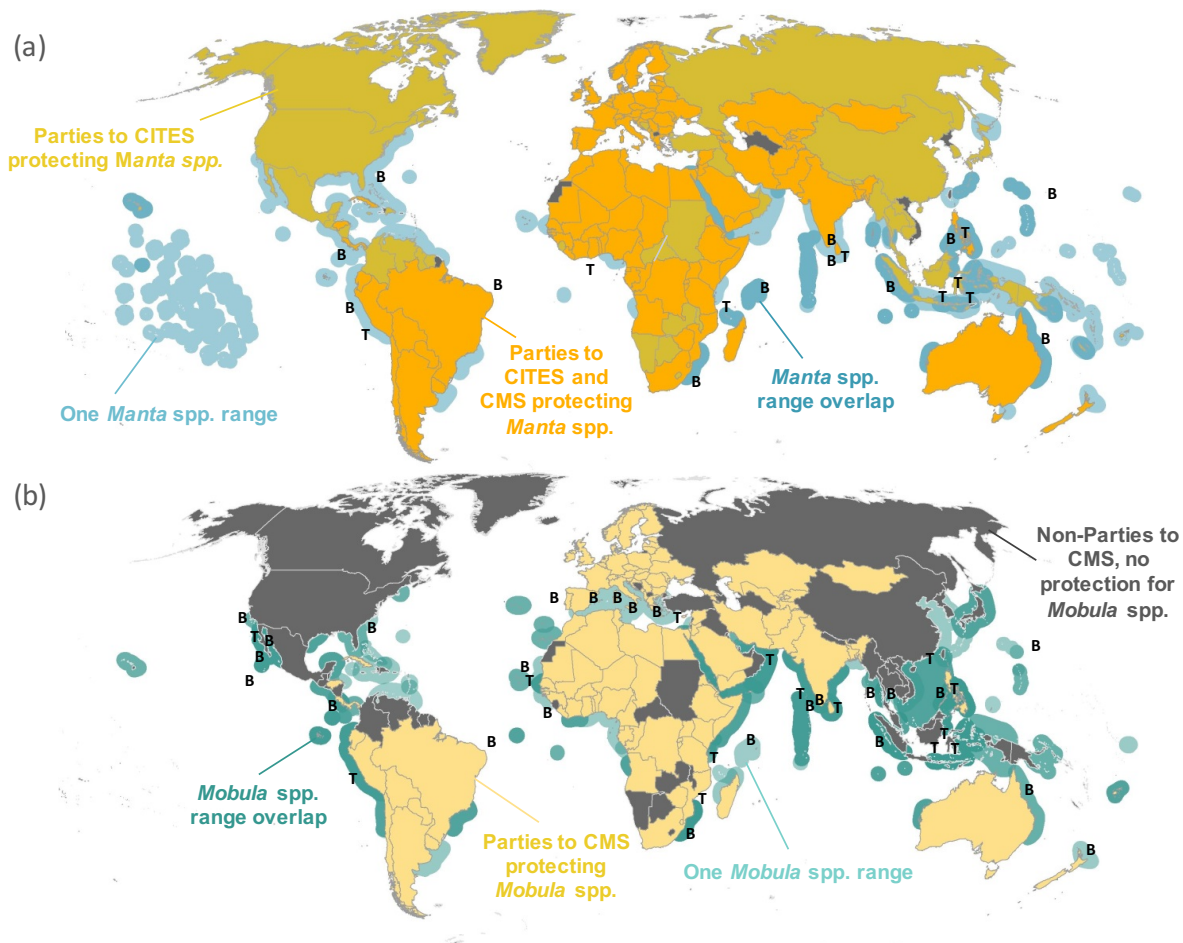


Figure 4. Distribution of Parties to CITES and CMS with respect to ranges of (a) *Manta* spp. and (b) *Mobula* spp. Area of Occupancy (AOO) maps for single or multiple species of (a) manta ray (*Manta* spp.) in blue, and (b) devil ray (*Mobula* spp.) in green. Saturation of colour represents the degree which species' ranges overlap: dark blue for manta ray and dark green for devil rays are areas with >1 species AOO. Country colour represents management implementation; Parties to both the Convention on the International Trade in Endangered Species (CITES) and the Convention on the Conservation of Migratory Species of Wild Animals (CMS) are indicated in light yellow, Parties only to CITES are light grey, Parties only to CMS are dark yellow, and Non-Parties are in black. Also indicated are known target (T) and bycatch (B) fisheries adapted from Croll et al., 2015.

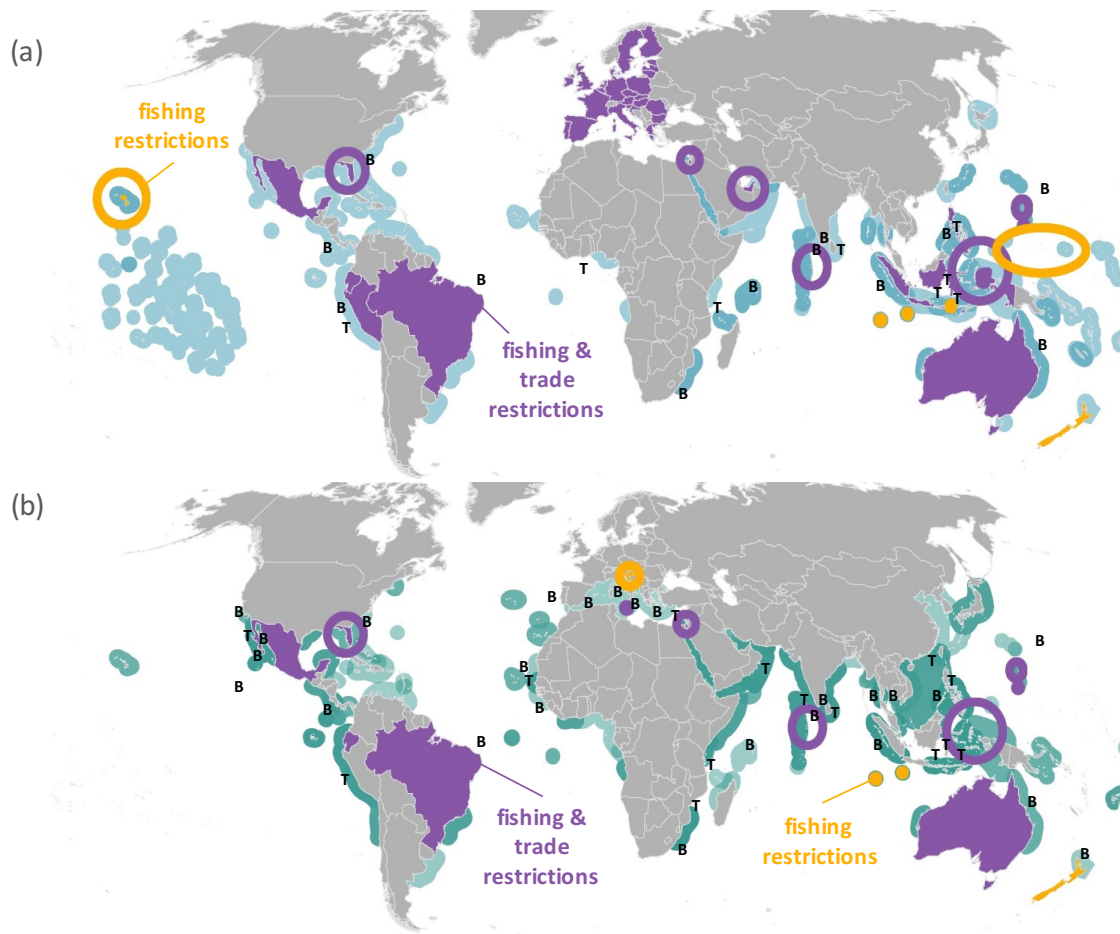


Figure 5. Distribution of national, territory, and state protections with respect to ranges of (a) *Manta* spp. and (b) *Mobula* spp. Area of Occupancy (AOO) maps for single or multiple species of (a) manta ray (*Manta* spp.) in blue, and (b) devil ray (*Mobula* spp.) in green. Saturation of colour represents the degree which species' ranges overlap: dark blue for manta ray and dark green for devil rays are areas with >1 species AOO. Country colour represents national, territory, or state protections; purple represents those countries that have implemented both a fishing and trade restriction, yellow are those countries with only a fishing restriction. Small island countries are circled for visual purposes.

Table 1. International, national, and territory/state protections currently in place for devil and manta rays. A summary of current international, national, and territory/state protections for the eleven species of devil (*Mobula* spp.) and manta (*Manta* spp.) rays, and the year that these protections were implemented.

	<i>Mobula eregoodootenkee</i>	<i>Mobula hypostoma</i>	<i>Mobula kuhlii</i>	<i>Mobula japanica</i>	<i>Mobula mobular</i>	<i>Mobula munkiana</i>	<i>Mobula rochebrunei</i>	<i>Mobula tarapacana</i>	<i>Mobula thurstoni</i>	<i>Manta alfredi</i>	<i>Manta birostris</i>
<i>International Protections</i>											
IATTC (2015)	√	√	√	√	√	√	√	√	√	√	√
GFCM (2015)					√						
CMS Appendices I & II (2014)	√	√	√	√	√	√	√	√	√	√	
CITES Appendix II (2013)										√	√
European Union (2012)											√
CMS Appendices I & II (2011)											√
Barcelona Convention SPA/BD Protocol Annex II (2001)					√						
Bern Convention Appendix II (2001)					√						
<i>National Protections</i>											
Peru (2016)											√
Australia (2015)	√	√	√	√	√	√	√	√	√	√	
European Union (2015)	√	√	√	√	√	√	√	√	√	√	
Indonesia (2014)										√	√
Maldives (2014)	√	√	√	√	√	√	√	√	√	√	√
United Arab Emirates (2014)										√	√
Brazil (2013)	√	√	√	√	√	√	√	√	√	√	√
Australia (2012)											√
Ecuador (2010)				√		√		√	√		√
New Zealand (2010)				√							√
Mexico (2007)		√		√		√		√	√		√
Croatia (2006)					√						
Israel (2005)	√	√	√	√	√	√	√	√	√	√	√
Malta (1999)					√						
Philippines (1998)											√
<i>Territory and State Protections</i>											

West Manggarai/Komodo, Indonesia Regency (2013)										✓	✓
Raja Ampat, Indonesia Regency (2012)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Guam, USA Territory (2011)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Christmas Island and Cocos (Keeling) Islands, Australian Indian Ocean Territories (2010)										✓	✓
Hawaii, USA State (2009) ¹										✓	✓
Yap, Federated States of Micronesia (2008)										✓	✓
Commonwealth of the Northern Mariana Islands, USA Territory (2007)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Florida, USA State (2006)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

¹ A bill is currently under consideration by Hawaii's state legislature to expand protection to include all sharks and rays.

Table 2. The Global Devil and Manta Ray Conservation Strategy. The complete text of the Global Devil and Manta Ray Conservation Strategy; including a vision, and a series of goals, objectives, and actions.

Vision: *Populations of devil and manta rays that flourish in resilient ocean ecosystems, harmoniously with human communities, through knowledge, sustainability, and education.*

Goal A: The knowledge required to sustain devil and manta rays is generated and communicated to relevant stakeholders.

Objective 1
TAXONOMY AND STOCK STRUCTURE
Taxonomy of devil and manta rays is resolved, and management units are defined.
The taxonomy of devil and manta rays is still unclear and substantial changes at the species and even genus level are expected. Defining management units will enable more focused and efficient conservation measures for these species, and show where trans-national regulations are necessary.
Actions
1.1 Produce peer-reviewed publications that resolve the species-level taxonomy of devil and manta rays to be used by the scientific and management community.
1.2 Undertake research to define management units of devil and manta ray populations on regional and global scales.
1.3 Refine a list of priority species and regions based on newly defined management units.
1.3.1 Potential priority species include <i>M. japanica</i> , <i>M. tarapacana</i> , <i>M. mobular</i> .
1.3.2 Potential priority regions include the Indo-Pacific, Mediterranean Sea, Eastern Pacific, and West Africa.

Objective 2
BIOLOGY
Productivity, life history, and demography of devil and manta rays are determined.
Information describing biological characteristics, such as annual fecundity and age at maturity are needed to fully understand the vulnerability of these species and enable prioritization of conservation and management actions.
Actions
2.1 Produce a standardized data collection methodology and a guide to facilitate mobulid biology data comparison among research groups and countries.
2.2 Define accurate biological parameters (age, growth, maximum age, and age at maturity data) for devil and manta ray populations for use in species assessments, scientific reports, and publications.
2.3 Use population data to determine the rate of natural mortality in devil and manta ray populations for integration into species assessments.

Objective 3
ECOLOGY
Spatial and temporal ecology of devil and manta rays is understood.
Ecological data are needed to inform appropriate management actions that prevent overexploitation of devil and manta rays, preserve connectivity among populations, and protect critical habitats.
Actions
3.1 Consolidate and synthesize available data to determine historic and core distributions of mobulid species, in order to aid recovery and assess potential reestablishment throughout historic ranges.
3.2 Update Extent of Occurrence and point distribution maps of the geographic distribution of devil and manta rays and disseminate this information.
3.3 Describe and define areas of critical habitat and population connectivity (by size, sex and reproductive status) including areas of core use (hot spots, aggregation sites), seasonality of presence, and migratory corridors to produce high resolution geographic outputs for publication and management actions (e.g. place-based protection).
3.4 Understand the role that diet and feeding ecology have in predicting aggregations, movement, and habitat use of devil and manta rays.
3.5 Estimate the abundance of devil and manta ray species using information collected by fisheries-independent research programs (e.g. line transect surveys, photo identification, tagging).

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Objective 4
STRATEGIC RESEARCH AND COMMUNICATION
Scientific research on biology, ecology, status, threats, and socio-economic value of devil and manta rays to enhance conservation and management is communicated to stakeholders and to the public.
Building an improved understanding of the status and threats that face devil and manta rays among the general public, policy makers, and the conservation and management community is helpful for the implementation of national and international conservation legislation, and will engage the public to support protecting these species.
Actions
4.1 Update International Union for the Conservation of Nature (IUCN) Red List global re-assessments for mobulid species.
4.1.1 Priority species include <i>Mobula japanica</i> , <i>M. tarapacana</i> , and <i>M. thurstoni</i> .
4.2 Produce a global status summary of devil and manta ray fisheries and catches.
4.3 Translate research for the wider conservation and management community (NGOs, fishers, tourism, divers, aquaria, etc.) through newsletters, social, print, and traditional media outlets, as information becomes available.
4.4 Interpret research for managers and policy-makers to help inform decisions related to the protection and conservation of devil and manta ray populations as opportunities arise at key management decision points (such as CITES, CMS, CBD, RFMO meetings, local management meetings, and national biodiversity initiatives).

Goal B: Devil and manta ray populations are maintained at, or recovered to, ecologically relevant levels by managing fisheries, trade, and demand.

Objective 5
FISHERIES ASSESSMENT AND MANAGEMENT
Devil and manta ray populations, and fisheries in which they are taken, are monitored and managed for long-term sustainability.
Unmanaged and mostly unmonitored fisheries pose the greatest threat to devil and manta rays. Standardized data collection is needed to assess population trends and inform conservation measures to prevent overexploitation from targeted and incidental mortality.
Actions
5.1 Non-Governmental Organizations (NGOs) create incentives for government policy makers to take action on devil and manta ray conservation and management through positive international media opportunities.
5.2 NGOs, Nations, and RFMOs to collate historical landings and market data.
5.3 Fisheries specialists and RFMOs work to develop standardized guidelines for fisheries data collection (e.g. species identification and sizing, tissue samples, reproductive status) and monitoring (e.g. landings, discards, fishing effort, gear types).
5.3.1 Observer practices are developed that are specific to devil and manta rays (e.g. tissue samples, reproductive data, size estimation, etc.).
5.3.2 Develop a multilingual identification guide/webpage/app to assist observers/customs officers/scientists/NGOs in identification, data collection, etc.
5.4 National, state, or regional fisheries departments adopt a standardized data collection system and implement at-sea and landing site observer programs that gather information on landings, bycatch, and discards.
5.5 Nations report species-specific landings of devil and manta rays to FAO and/or RFMOs.
5.6 Determine areas of overlap between relevant fisheries and devil and manta ray distributions to identify priority areas of bycatch minimization.
5.7 Estimate the total annual volume of devil and manta ray catch in fisheries bycatch globally, by region, and by gear type.
5.8 Develop gears and fishing practices that minimize bycatch.
5.8.1 Review handling and release procedures using different gears and develop and implement best practice procedures where they don't exist.
5.8.2 Produce education and outreach materials about safe release and handling.
5.8.3 Reduce purse seine sets in locations, during times of year, and in set types where mobulids have been identified as bycatch.
5.9 Estimate post-release mortality across various sizes, species, and gear types for devil and manta rays.
5.10 Develop stock assessment methods for devil and manta rays and coordinate the appropriate agencies, NGOs, and/or fisheries scientists to undertake assessments.
5.11 RFMOs, regions, and nations identify and prioritize species and stocks that require assessment.

5.12 RFMOs, regions, and nations regularly assess and report the status of devil and manta ray fisheries and estimate sustainable catch levels.
5.13 RFMOs, other regional bodies, and nations implement and enforce protections for devil and manta rays to maintain or recover stocks to ecologically relevant levels.
5.14 Adjacent nations harmonize management arrangements to ensure consistency of shared stocks and coordinate data collection, assessment, and management.
5.15 RFMOs and nations ensure that important devil and manta ray aggregation sites are protected through existing and/or revised spatial and temporal management measures.

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Objective 6
TRADE REGULATION
Imports and exports of devil and manta ray products are traceable, monitored, and regulated for sustainability.
Manta rays were listed under CITES Appendix II in 2013, meaning that CITES Parties are obliged to monitor and regulate international imports and exports of manta parts, including gill plates. Supporting efforts to monitor and regulate trade is critical to identifying sources of demand and supply and preventing unsustainable levels of trade.
Actions
6.1 International conservation agreements for devil and manta rays (e.g. CITES, CMS, and RFMOs) are enforced and implemented in legislation.
6.2 Identification guides for traded devil and manta ray products are developed and disseminated.
6.3 Customs codes are adopted for (a) CITES-listed species, and (b) gill plate products.
6.4 Development of a CITES Non-Detriment Finding (NDF) guide to support the implementation of CITES listings in key devil and manta ray fishing nations.
6.5 Country-of-origin standardized certificates are produced for all gill plate exporting and importing states.
6.6 Port-state controls (the inspection of foreign vessels by official officers) are implemented by all range states.
6.7 Catch documentation is provided by issuing authorities for individual consignment of gill plates.
6.8 Market surveys are undertaken at regular intervals.
6.9 Trade data reported by exporters and importers are compared with and confirmed by market surveys.
6.10 NGOs and scientists work with the devil and manta ray range states to propose <i>Mobula</i> spp. for inclusion on Appendix II of CITES.

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Objective 7
SOCIO-ECONOMICS AND MARKETS
Demand for devil and manta ray products is reduced, and an understanding of socio-economic drivers is informing management.
Demand for devil and manta ray gill plates (<i>Peng Yu Sai</i>) has been cited as the leading driver of increased directed fisheries since the late 1990s. Reducing demand for devil and manta ray gill plates and other products including meat, cartilage, and skin will remove a strong economic incentive that is driving overexploitation of these species.

Actions
7.1 Understand the socio-economic value and landscape of consumptive uses of devil and manta rays.
7.2 Understand the socio-economic value and landscape of non-consumptive uses of devil and manta rays.
7.3 Assess the current demand for <i>Peng Yu Sai</i> and the level of consumer awareness to the threats posed by the gill plate market.
7.4 Produce a profile of the typical consumer of <i>Peng Yu Sai</i> in order to most effectively and efficiently target the demand reduction campaign.
7.5 Determine what the current marketing channels and methods for promoting use of <i>Peng Yu Sai</i> are.
7.5.1 Determine the extent of TCM practitioner involvement in recommending or marketing <i>Peng Yu Sai</i> and the opinions and attitudes of TCM practitioners regarding <i>Peng Yu Sai</i> use and efficacy.
7.6 Update 2011 assessment of <i>Peng Yu Sai</i> markets in Guangzhou, China, by collecting samples, conducting and analysing toxicology tests, and producing a report summarizing assessment results.
7.7. Produce material, media, and social media and recruit spokespeople and media partners to join a campaign that draws attention to threats posed by the gill plate market.
7.8 Conduct a follow-up assessment both directly and by third parties to measure effectiveness of the campaign using qualitative (changes in attitudes, level of awareness) and quantitative measures (evidence of reduced consumption, reduction in gill plate sales), measured against a baseline assessment.
7.8.1 Ongoing monitoring of the distribution of Public Service Announcements, short films, and earned media across a variety of media delivery platforms, measured in economic value and target audiences reached.
7.8.2 Communication with media sources for feedback regarding changes in <i>Peng Yu Sai</i> demand and trade.
7.8.3 Communication with partners and collaborators engaged in monitoring key devil and manta ray landing sites in Indonesia and Sri Lanka for feedback regarding changes in mobulid landings, and reported changes in demand or prices from gill plate traders.

Goal C: Educated and engaged communities are supporting and benefiting from devil and manta ray conservation and management through improved livelihoods.

OBJECTIVE 8
TOURISM
A standardized best practice approach to tourism interactions with devil and manta rays that minimizes harm is adopted and enforced by tourism operators globally.
Non-consumptive use of devil and manta rays through responsibly managed tourism can provide long-term sustainable economic benefits to coastal communities as one alternative to unsustainable fisheries. A standardized best practice guidelines for tourism operators will prevent injury and stress to the animals and environments, while making

the businesses that rely on healthy devil and manta ray populations more environmentally sustainable, and ultimately, more successful.

Actions

8.1 Collate and standardize the existing best practices of devil and manta ray tourism interactions (e.g. diving, snorkelling, and watching).

8.2 Develop best practice guidelines for tourism interactions with devil and manta rays.

8.3 Secure adoption of best practice guidelines for tourism interactions with devil and manta rays by the wider tourism community.

8.5 Educate snorkelers as well as recreational and professional SCUBA divers about the conservation and management of devil and manta rays through development and dissemination of offline and online educational tools including specialty training.

621

OBJECTIVE 9

COMMUNITY ENGAGEMENT

Knowledgeable communities are contributing to devil and manta ray conservation and management at the local level.

Communicating the benefits of devil and manta ray conservation and including community stakeholders in the process is essential to adoption, implementation, and enforcement of conservation and management measures.

Actions

9.1 Produce and distribute engaging and compelling media to inspire the general public in key fishing countries and globally to support devil and manta ray conservation measures.

9.2 Engage indigenous and local fishing communities in sharing of traditional ecological knowledge and cultural value (e.g. animal totems) of historical species composition, species distribution and temporal occurrence.

9.3 Create and deliver road shows, stage shows, or film events to highlight the conservation status of devil and manta rays in coastal fishing communities that are adjacent to devil and manta ray populations in priority countries (e.g. Philippines, Indonesia, Sri Lanka, and Peru).

9.4 Create interpretive material to communicate the value of devil and manta rays tourism through social media, websites, magazines, print, and television to the government, local communities, and global supporters of NGOs.

9.5 Engage tourism operators and the public to report sightings by submitting ventral photographs to an online identification database.

9.6 Translate a global identification guide for devil and manta rays into the local languages of the priority fishing nations (e.g. Peru, Philippines Indonesia, India, Mexico, and Sri Lanka).

622

OBJECTIVE 10

ALTERNATIVE LIVELIHOODS

People in coastal communities are engaging in occupations and subsistence activities that are not based on exploitation of devil and manta rays.

Empowering coastal communities to transition away from dependence on unsustainable fishing practices and into alternative livelihoods (e.g. sustainable fisheries, aquaculture,

and tourism) is essential to the success of devil and manta ray conservation and management measures and the economic future of the communities.
Actions
10.1 Consult and work with social scientists, climate adaptation, and development agencies to identify opportunities for the development of alternative livelihoods for coastal fishing communities and work to ensure that the conservation of devil and manta rays is included in their objectives.
10.2 Identify potential markets for developing ecotourism-based alternative livelihoods in local government (e.g. tourism board and development assistance), and in sustainable tourism businesses (e.g. hotels).
10.3 Develop alternative livelihoods and income opportunities for at least five local communities in at least five of the main devil and manta ray fishing nations (e.g. Peru, Philippines Indonesia, India, Mexico, and Sri Lanka) to diversify away from fishing for devil and manta rays.
10.4 Build capacity in local communities and among artisanal fishermen through training (business, tourism management, and sustainable fishing and aquaculture practices) and assistance with raising capital for the expenses associated with implementation.

623

Objective 11
DEVIL AND MANTA RAY NETWORK
Devil and manta ray experts support government and private sector bodies by encouraging, prioritizing, facilitating, integrating, and fulfilling commitments to conservation plans and regulations.
The devil and manta ray network provides an important forum for sharing and propagating conservation knowledge, generating coordinating actions, and monitoring progress.
Actions
11.1 Conduct at least one workshop for representatives of government, policy makers, and trade officials in each priority fisheries country (e.g. Peru, Philippines, Indonesia, India, Mexico, Sri Lanka, and the Gaza Strip) on the conservation status and state of devil and manta ray international trade and provide training in the identification of gill plates and species.
11.2 NGOs (including fishing groups) engage with interested scientists to develop, fund, and implement collaborative projects aimed at gaining government buy-in and building government champions. Specific activities could include:
11.2.1 Formation of a coalition of contributors with different areas of expertise (e.g. science, policy, media, community outreach) from different regions united toward devil and manta ray conservation.
11.2.2 Identify and develop opportunities for collaborative, resource-effective, research and conservation programs (e.g. IUCN Specialist Groups, Non-Governmental Organisations with other aquatic vertebrates that share habitat and threats with Devil and Manta rays (e.g. cetaceans, whale sharks and other elasmobranchs).
11.2.4 Coordination of comments, speaking opportunities, and advocacy around key government decision meetings.

11.3 NGOs and scientists commit to ongoing participation in government processes to articulate and repeatedly promote devil and manta ray conservation plan goals. Specific activities could include:
11.3.1 Regular contact and discussion with key government officials.
11.3.2 Attendance at national or RFMO science, bycatch, and/or ecosystem committee meetings.
11.3.3 Preparation of written comments to national fisheries and/or environment government leads and/or RFMO chairs.
11.3.4 Service on government delegations to key decision meetings including CITES and CMS conferences of Parties and RFMO annual meetings.
11.3.5 Targeted side events at key meetings to bring together various interests toward a common goal.
11.4 IUCN SSG and partners review progress and revise actions under the Global Devil and Manta Ray Conservation Strategy every three years.
11.5 Ensure a continued stream of financial resources to ensure timely implementation of the Actions included in this Global Devil and Manta Ray Conservation Strategy.

624

625