Endangered Species Act Recovery Status Review for the Giant Manta Ray

(*Mobula birostris*)

Photo Credit: NOAA; Flower Garden Banks

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National Marine Fisheries Service

National Oceanic and Atmospheric Administration

Silver Spring, MD

EXECUTIVE SUMMARY

This report was originally produced in response to a petition received from Defenders of Wildlife on November 10, 2015, to list the giant manta ray (*Mobula birostris*) and reef manta ray (*M. alfredi*) as endangered or threatened under the Endangered Species Act (ESA). On January 22, 2018, the National Marine Fisheries Service (NMFS) published in the Federal Register a final rule to list the giant manta ray as threatened under the ESA (83 FR 2916). This document, the Recovery Status Review, contains a comprehensive collection of information for the giant manta ray, with updated information collected since 2018.

This Recovery Status Review is one part of the three-part format in which recovery planning components for the giant manta ray are divided into three separate documents. We intend for this Recovery Status Review to be a comprehensive living document that we update with significant new information as it becomes available. A Recovery Status Review does not result in a decision. Rather, it provides the best scientific and commercial data available to inform management and recovery actions for ESA listed species. The Recovery Status Review also provides information to help inform other ESA processes and activities such as Section 7 consultations, grant decisions, permits, conservation plans developed under Section 10 of the ESA, and 5-year reviews.

The giant manta ray is found worldwide in tropical, subtropical, and temperate bodies of water. It is commonly found offshore, in oceanic waters, and near productive coastlines. Yet, despite its large range, the species is infrequently encountered (with the exception of a few areas noted for manta ray aggregations). There are no current or historical estimates of the global abundance of *M. birostris*, with most estimates of subpopulations based on anecdotal diver or fisherman observations, which are subject to bias. In most regions, the number of giant manta rays observed over the years appear to be small (less than 1,000 individuals).

The most significant threat to the giant manta ray is overutilization for commercial purposes. Giant manta rays are both targeted and caught as bycatch in a number of global fisheries throughout their range, and are most susceptible to artisanal/small-scale

fisheries. With the expansion of the international mobulid gill plate market and increasing demand for manta ray products, estimated take of giant manta rays, particularly in many portions of the Indian Ocean, Western Pacific Ocean, and Eastern Pacific Ocean frequently exceeds numbers of identified individuals in those areas. Observations from these areas also indicate declines in sightings and landings of the species. Efforts to address overutilization of the species through regulatory measures appear inadequate, with evidence of targeted fishing of the species and retention as bycatch despite prohibitions, and a lack of local, regional, and international measures and/or enforcement.

Given the species' extremely low reproductive output and overall productivity, it is inherently vulnerable to threats that would deplete its abundance, with a low likelihood of recovery. Although there is considerable uncertainty regarding the species' current abundance throughout its range, the best available information indicates that the species has experienced population declines of potentially significant magnitude due to fisheries-related mortality within the Indian Ocean and the Western Pacific and Eastern Pacific subregions of its range, which we determined qualifies as a "significant portion its range" under the final Significant Portion of Its Range (SPR) policy (79 FR 37577; July 1, 2014). And while larger populations of the species still exist in this SPR, including off Ecuador, Mexico, Indonesia, and Mozambique, they continue to face fishing pressure and experience fisheries-related mortality particularly in the artisanal/small-scale fisheries and industrial fisheries operating throughout the SPR. As such, we conclude that overutilization continues to be a threat to the giant manta ray through the foreseeable future.

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INTRODUCTION

History of Giant Manta Ray ESA Listing, Regulatory Actions, and Recovery Planning

On November 10, 2015, we, NOAA Fisheries, received a petition from Defenders of Wildlife to list the giant manta ray (*Mobula birostris*), reef manta ray (*M. alfredi*) and Caribbean manta ray (*M. c.f. birostris*) as threatened or endangered under the ESA throughout their respective ranges, or, as an alternative, to list any identified distinct population segments (DPSs) as threatened or endangered. On February 23, 2016, we determined that the petitioned action may be warranted for the giant manta ray and reef manta ray and announced the initiation of status reviews for these species, but found that the Caribbean manta ray was not a taxonomically valid species or subspecies for listing at that time, and explained the basis for that finding (81 FR 8874). On January 12, 2017, after reviewing the best scientific and commercial information available, including the status review report (Miller and Klimovich 2016), and after taking into account efforts being made to protect these species, we determined that the giant manta ray is likely to become an endangered species within the foreseeable future throughout a significant portion of its range. Therefore, we proposed to list the giant manta ray as a threatened species under the ESA (82 FR 3694, January 12, 2017). We also made a 12-month determination that the reef manta ray did not warrant listing under the ESA (82 FR 3694, January 12, 2017).

On January 22, 2018, after reviewing the status of the giant manta ray, including the best scientific and commercial information available, efforts being made to protect this species, and taking into consideration public comments submitted on the proposed rule as well as new information received since publication of the proposed rule, we made a final determination to list the giant manta ray as a threatened species under the ESA (83 FR 2916). This final rule became effective on February 21, 2018.

In 2022, we held a meeting to elicit expert opinion on the challenges associated with recovering a wide-ranging species and potential ways to facilitate the recovery of the giant manta ray. We invited experts from a range of relevant disciplines to participate in the meeting. Information provided at this meeting was used to prioritize threats that are most urgent and significant and will need to be minimized/controlled for the recovery of the species. This helped serve as the foundation for our recovery criteria, actions and activities.

Approach to the Recovery Status Review

This document is a Recovery Status Review for the giant manta ray. It contains information on the giant manta ray's biology and status to inform ESA actions, and can be periodically updated with new information. This Recovery Status Review is the most comprehensive source for the giant manta ray's biological and status information needed for many ESA decisions (e.g., section 7 consultations, grant allocations, permitting, section 10 conservation plans, 5-year reviews, and recovery planning).

In this Recovery Status Review, we compiled pertinent information from the original 2017 biological status review report (Miller and Klimovich 2017), additional biological and ecological information from the final listing rule (83 FR 2916, January 22, 2018), relevant publications since the giant manta ray was listed in early 2018, and information from the Recovery Outline (NMFS 2019). In some sections, we placed information from the original status review pertaining to both manta species (*M. birostris* and *M. alfredi*) as we believe the information pertaining to reef manta rays could serve as a good proxy, at this time, for those life history and ecology attributes where significant data gaps exist for *M. birostris*. In the future, as new information becomes available to fill those data gaps for *M. birostris*, the sections pertaining to *M. alfredi* will be removed.

The intent of a Recovery Status Review is to provide a succinct yet comprehensive and regularly updated characterization of a species' status. A Recovery Status Review does not result in any decisions. Rather, it provides the best scientific and commercial data available to inform management and recovery actions for ESA listed species.

GIANT MANTA RAY LIFE HISTORY AND ECOLOGY

Taxonomy

Scientific Classification	
Kingdom	Animalia
Phylum	Chordata

Scientific Classification	
Class	Chondrichthyes
Subclass	Elasmobranchii
Superorder	Batoidea
Order	Myliobatiformes
Family	Myliobatidae
Subfamily	Mobulidae
Genus	*Mobula*
Species	*birostris* (Walbaum, 1792)
Common	Oceanic Manta Ray, Giant Manta Ray, Pacific Manta Ray, Pelagic Manta Ray

The manta ray was first described by Walbaum in 1792. These large bodied, planktivorous rays are considered part of the Mobulidae, a subfamily that appears to have diverged from Rhinoptera around 30 million years ago (Poortvliet et al. 2015). The taxonomic history of the manta rays have been complex (Couturier et al. 2012; Herman et al. 2000; Adnet et al. 2012; Naylon et al. 2012; Kitchen-Wheeler 2013; Paign-Tran et al. 2013; Poorviet et al. 2015), with more recent studies supporting a split of the previous Manta genus into two species: *Manta birostris* and *M. alfredi* (Marshall et al. 2009). However, in 2018, White et al. published a paper on the phylogeny of the manta and devil rays, showing that the two manta rays, *M. birostris* and *M. alfredi,* are actually nested within the genus Mobula (White et al. 2018). These taxonomic changes have been accepted by scientists and a number of national and international renowned organizations, and in 2023, NMFS published a direct rule recognizing the taxonomy of the giant manta ray as *Mobula birostris* (88 FR 81351, November 22, 2023).

Distinctive Characteristics

Mobula birostris has a diamond-shaped body with wing-like pectoral fins; the distance over this wingspan is termed disc width (DW). There are two distinct color types: chevron and black (melanistic). Most of the chevron variants have a black dorsal surface and a white ventral surface with distinct patterns on the underside that can be used to identify individuals (Marshall et al. 2008; Kitchen-Wheeler 2010; Deakos et al. 2011). While these markings are assumed to be permanent, there is some evidence that the pigmentation pattern of *M. birostris* may actually change over the course of development (based on observation of two individuals in captivity), and thus caution may be warranted when using color markings for identification purposes in the wild (Ari 2015). The black color variants are entirely black on the dorsal side and almost completely black on the ventral side, except for areas between the gill-slits and the abdominal area below the gill-slits (Kitchen-Wheeler 2013).

Since *M. birostris* and *M. alfredi* have similar shapes and overall colors, Marshall et al. (2009) provided a key to distinguishing between these two species based on physical characteristics such as specific colorations, dentition, denticles, spine morphology, size at maturity, and maximum DW. Only *M. birostris* has a caudal thorn (Marshall et al. 2009). *M. birostris* is also larger than *M. alfredi*, having been documented to grow as large as 6.8 meters DW (Kunjipalu and Boopendranath 1982). Additionally, the skin of *M. birostris* forms prominent dermal denticles with pronounced bifid cusps randomly distributed along sagittally oriented ridges in the skin on both the ventral and dorsal surfaces, giving their skin a much rougher appearance than that of *M. alfredi* (Marshall et al. 2009).

In terms of coloration, the chevron variant of *M. birostris* can be distinguished from the chevron *M. alfredi* color type by its large, white, triangular shoulder patches that run down the middle of its dorsal surface, in a straight line parallel to the edge of the upper jaw (Marshall et al. 2009; **Figure 1**). The species also has dark (black to charcoal grey) mouth coloration, medium to large black spots that occur below its fifth gill slits, and a grey V-shaped colored margin along the posterior edges of its pectoral fins (Marshall et al. 2009). In contrast, the chevron *M. alfredi* has pale to white shoulder patches where the anterior margin spreads posteriorly from the spiracle before curving medially, a white to light grey mouth, dark spots that are typically located in the middle of the abdomen, in between the five gill slits, and dark colored bands on the posterior edges of the pectoral fins that only stretch mid-way down to the fin tip (Marshall et al. 2009).

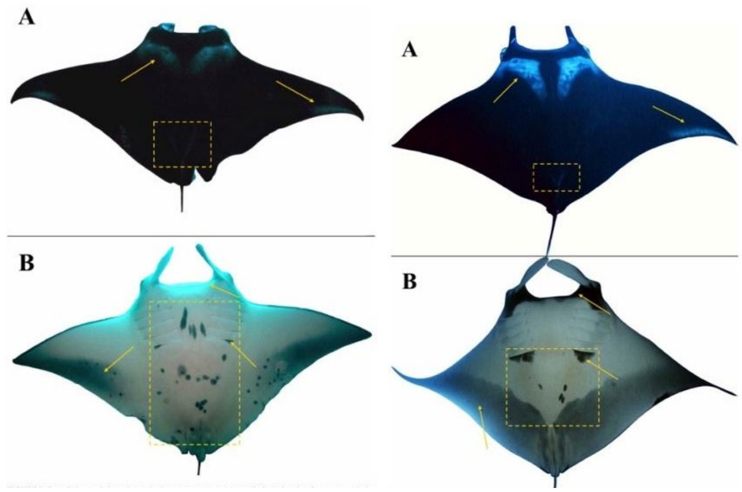

Figure 1. General characteristics and natural coloration patterns in *Mobula alfredi* (left) and *Mobula birostris* (right) (A) dorsal surface, arrows pointing to the shape and coloration of the shoulder patches and the coloration on the pectoral fins, box showing chevron shaped marking anterior to dorsal fin. (B) ventral surface, box showing region of highest spot density and distribution, arrows showing size of spot anterior to the 5th gill slit, coloration of mouth region, and coloration of the pectoral fin margin. Source: Marshall et al. (2009).

The melanistic form of both species, as mentioned before, are entirely black dorsally and black on the ventral side as well with the exception of areas around the gill-slits and posterior to the gill-slits. Spot patterns similar to those seen in the respective chevron types are usually visible along the white abdominal region in the mid-line area, with spot patterning absent between the gill-slits for *M. birostris* but present for *M. alfredi* (Marshall et al. 2009). A leucistic color form (mostly white) has also been documented for both species, but appears to be rare (Marshall et al. 2009), with the exception of those *M. birostris* found off Puerto Princesa City, Philippines, where 53% of the 73 individuals identified being leucistic (Rambahiniarison et al. 2023).

Historical Range

In terms of historical range, within the Northern hemisphere, the giant manta ray has been documented as far north as New York in the USA and the Azores Islands in the Atlantic Ocean region, the Sinai Peninsula, Egypt in the Indian Ocean region, and Mutsu Bay, Aomori, Japan and southern California USA in the Pacific Ocean region (Gudger 1922; Kashiwagi et al. 2010; Moore 2012; CITES 2013; Sobral and Alfonso 2014; Knochel et al.

2022; Farmer et al. 2022). In the Southern Hemisphere, the species has been observed as far south as Peru in the eastern Pacific Ocean, Uruguay and St. Helena Island in the Atlantic Ocean, South Africa and Australia in the Indian Ocean, and off Tasmania, New Zealand and French Polynesia in the western and central Pacific Ocean (Mourier 2012; CITES 2013, Couturier et al. 2015; Carpentier et al. 2019, Beard et al. 2021). While historical reports of distribution do not take into account the recent splitting of the genus (Marshall et al. 2009), there is no information to suggest a change in the historical range of *M. birostris*.

Based on information collected for a recent IUCN Red List Assessment of the species (see Marshall et al. 2022), **Figure 2** provides a map of the geographic range of the giant manta ray.

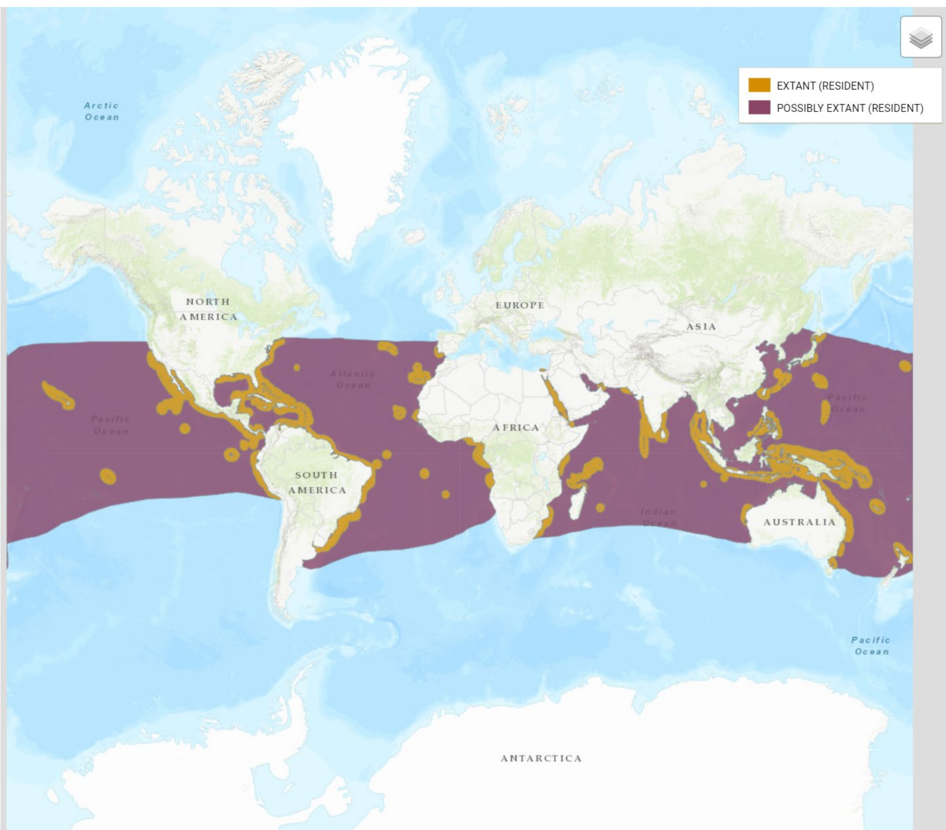

Figure 2. Geographic range of *Mobula birostris* showing confirmed locations (extant) as well as presumed range (possibly extant). (© IUCN SSC Shark Specialist Group 2018. *Mobula birostris*. The IUCN Red List of Threatened Species. Version 2022-2)

Distribution and Habitat Use

Within its range, *M. birostris* inhabits tropical, subtropical, and temperate bodies of water and is commonly found offshore, in oceanic waters, and near productive coastlines, with water temperatures generally between 20°C and 30°C (Duffy and Abbott 2003; Marshall et al. 2009; Kashiwagi et al. 2011; Freedman and Roy 2012; Graham et al. 2012; Hacohen-Domené et al. 2017; Farmer et al. 2022). The giant manta ray can exhibit diel patterns in habitat use, moving inshore during the day to clean and socialize in shallow waters, and then moving offshore at night to feed to depths of 1,000 meters (Hearn et al. 2014; Burgess 2017). The species has also been observed in estuarine waters near oceanic inlets, with use of these waters as potential nursery grounds (Adams and Amesbury 1998; Milessi and Oddone 2003; Medeiros et al. 2015; Pate and Marshall 2020; Farmer et al. 2022).

Giant manta rays are commonly sighted in aggregations at many locations throughout their range, including: Similan Islands (Thailand), Raja Ampat (Indonesia), Sharm el-Sheikh (Egypt), Fuvahmulah and Addu Atolls (Maldives), northeast North Island (New Zealand), Kona, Hawaii (USA), eastern Atlantic and Gulf of Mexico (USA), Brazil, Cabo Verde, Isla de la Plata (Ecuador), Ogasawara Islands (Japan), Isla Margarita and Puerto la Cruz (Venezuela), northern coast of the Yucatan Peninsula, Isla Holbox, Revillagigedo Islands, and Bahia de Banderas (Mexico) (Notarbartolo-di-Sciara and Hillyer 1989; Homma et al. 1999; Duffy and Abbott 2003; Luiz et al. 2009; Clark 2010; Kashiwagi et al. 2010; Marshall et al. 2011a; Stewart et al. 2016a; Hacohen-Domené et al. 2017; Hilbourne and Stevens 2019; Farmer et al. 2022; Knochel et al. 2022; Domínguez-Sánchez et al. 2023; Garzon et al. 2023).

The timing of these sightings varies by region (for example, the majority of sightings in Brazil occur during June and September; in the archipelago of Cabo Verde, reliable sightings occurred between July and January; in Raja Ampat, Indonesia, sightings are higher during the months of February to July; in New Zealand sightings mostly occur between January and March; and in Bahía de Banderas, Mexico occurrences peaked from January to March and again from May to October). These occurrences seem to correspond with the movement of zooplankton, climatic fluctuations (e.g., El Niño Southern Oscillation), current circulation and tidal patterns, seasonal upwelling, seawater temperature, and possibly mating behavior (Couturier et al. 2012; De Boer et al. 2015; Armstrong et al. 2016;

Hacohen-Domené et al. 2017; Beale et al. 2019; Nicholson-Jack et al. 2021; Domínguez-Sánchez et al. 2023, Garzon et al. 2023). For example, in the eastern Atlantic and Gulf of Mexico, the distribution of manta rays was found to be influenced primarily by sea surface temperature, with a clear expansion to the north during warmer months (Farmer et al. 2022). Additionally, within the preferred thermal range (approximately 20–30°C), manta rays occurred most frequently either nearshore or along the continental shelf-edge, at locations best predicted by proxies for productivity such as thermal fronts, bathymetric slope, and high chlorophyll-a concentration.

Throughout the western Central Atlantic, Garzon et al. (2020) also found similar results that showed that the chlorophyll-a concentration followed by bathymetric slope were the most important variables in explaining manta ray distribution. Manta ray predicted suitable habitat, and thus distribution, tended to vary seasonally, likely linked to patterns of primary production and seasonal upwellings, with an expansion of habitat during the colder, dry season (December to March, with peak in January). The authors also determined "core habitats," or areas that are suitable to manta rays year-round based on their analysis (**Figure 3**). These "core habitats" are largely located close to the coastline (mean 47 km = minimum distance from coastline to core habitat centroids; range 0.7-306 km) and mainly within waters of the U.S. (contained 37% of core habitat), Mexico (17%), Venezuela (11%), and The Bahamas (10%) (Garzon et al. 2020).

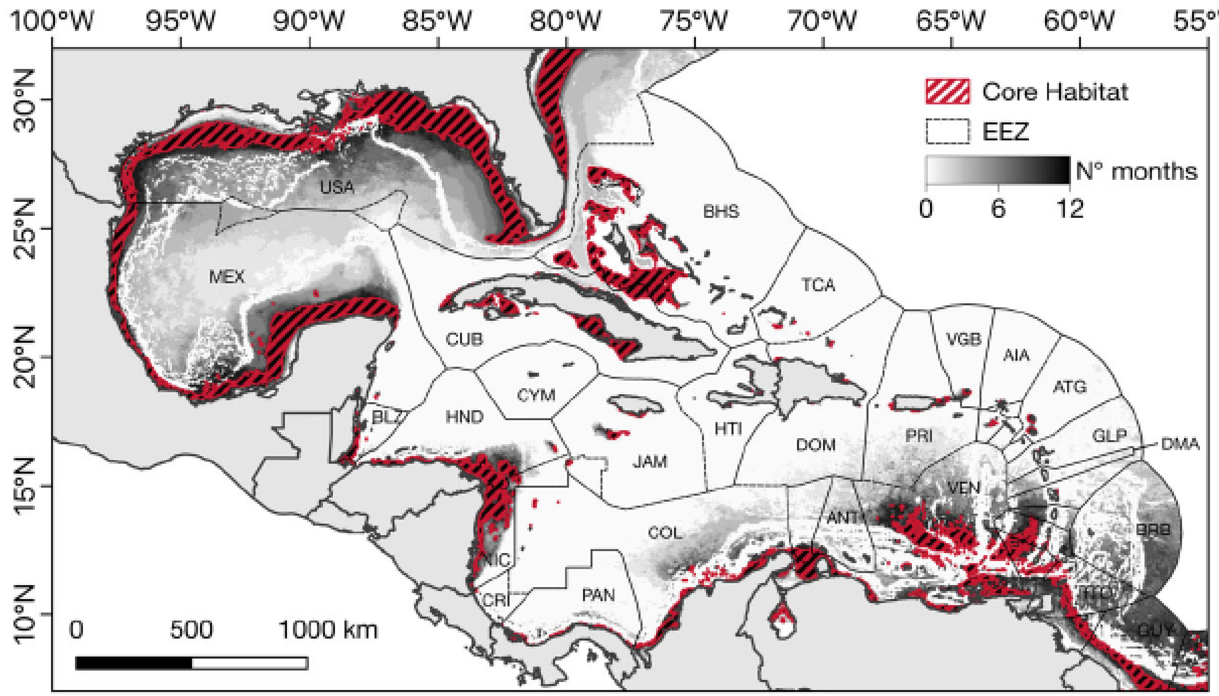

Figure 3. Predicted core habitat areas for manta rays in the western central Atlantic derived from ensemble ecological niche models. Source: Garzon et al. (2020)

Giant manta rays also appear to exhibit a high degree of plasticity in terms of their use of depths within their habitat. Recent research has found that during the day, manta rays tend to primarily keep to surface waters (<5 m) with limited vertical movements, while at night, they have been observed continuously oscillating up and down through the water column, likely to forage on vertically migrating zooplankton (Andrzejaczek et al. 2021). Tagging studies have shown that the species conducts night descents of up to 200-450 m depths (Rubin et al. 2008; Stewart et al. 2016b) but is capable of diving to depths exceeding 1,000 m (Marshall et al. 2022; Erdmann et al. 2023). The species has a rete mirabile cranica as a counter-current heat exchanger around the brain that possibly facilitates its use of these cooler habitats (Alexander 1996).

In terms of horizontal movement, the giant manta ray is considered capable of making long-distance movements of 100s to >1000 km. Using pop-up satellite archival tags, registered long-distance movements of the giant manta ray include from Mozambique to South Africa (a distance of 1,100 km), from Ecuador to Peru (190 km), and from the Yucatan, Mexico into the Gulf of Mexico (448 km) (Marshall et al. 2011a). Andrzejaczek et al. (2021) tagged a giant manta off northern Peru which eventually was tracked traveling north to Ecuador and then all the way to the Galapagos Islands (~1,300 km from the tag site) before heading south (~530km). Erdmann et al. (2023) tagged a giant manta ray in Hauraki Gulf, New Zealand, and, over the course of 310 days, tracked it moving ~2,500 km to the northeast of its original tagging position before returning to New Zealand waters. Juvenile manta rays have also been observed traveling long distances, with Knochel et al. (2022) noting a juvenile that traveled at least 525 km within the Red Sea.

However, while the species is thought to be highly migratory, given these recorded long-distance movements as well as a lack of genetic sub-structuring (see **Population Structure**), a global photo-identification database has not verified any individual movement across ocean basins (Marshall and Holmberg 2018), indicating a low degree of interchange between ocean basins. On an even smaller scale, a study by Stewart et al. (2016a), which incorporated tagging and stable isotope and genetic data, found evidence that *M. birostris* may actually exist as well-structured subpopulations that exhibit a high degree of residency and low migratory rates. Using pop-up satellite archival tags, *M. birostris* individuals from locations nearshore to Mexico (Bahia de Banderas ; n=5) and offshore Mexico (Revillagigedo Islands; n=4) showed no movements between locations (tag deployment length ranged from 7 days to 193 days) (Stewart et al. 2016a). Additionally, the stable isotope analysis showed higher $\delta^{13}C$ values for the nearshore mantas compared to those offshore, indicating these mantas were foraging in their respective locations rather than moving between nearshore and offshore environments (Stewart et al. 2016a). While the authors note that the species may be capable of traveling long-distances, the results from their study indicate that these movements may be rare and may not contribute to substantial gene flow or interpopulation mixing of individuals (Stewart et al. 2016a). Instead, the seasonal occurrence of the species, which has been noted in many regions in addition to Mexico and Indonesia, may simply demonstrate the movement transition of the species from coastal aggregation sites, where they are observed, to nearby offshore habitats, where survey effort is much lower and, therefore, fewer sightings are recorded (Stewart et al. 2016a).

Overall, based on the available information, it appears that both broad and small-scale migrations are important to this species, and, although environmental factors such as temperature, chlorophyll-a, and primary production seem to be a factor correlated with giant manta ray presence, we still do not know as to why some populations may display broad migratory patterns while others do not. Further research is needed to better understand life history traits and apparent variability among populations.

Feeding and Diet

Giant manta rays primarily feed on planktonic organisms such as euphausiids, copepods, mysids, decapod larvae and shrimp, but some studies have noted their consumption of small and moderate sized fishes as well (Bertolini 1933; Bigelow and Schroeder 1953; Carpenter and Niem 2001; Rohner et al. 2017a; Stewart et al. 2017; Medeiros et al. 2022). In terms of energy needs, the only available data that provides insight for *M. birostris* is from a study that examined the stomach contents of giant manta rays collected within the Bohol Sea (Philippines) in 2015. Using adiabatic bomb calorimetry, Rohner et al. (2017a) calculated that krill (*Euphausia diomedeae*), the dominant prey species for *M. birostris* in this area, contributed 24,572 kJ (±20,451 kJ s.d.) per 100 g of stomach content in *M. birostris*. When scaled up based on the total number of euphausiids per stomach, the authors estimated that *E. diomedeae* contributed up to 631,167 kcal in the giant manta ray diet. This energetic contribution is significantly greater than what has been found for reef manta rays in captivity. Rohner et al. (2017a), citing a personal communication, reports that in aquaria, a 350 cm DW *M. alfredi* is fed 3,500 kcal per day and a 450 cm DW *M. alfredi* is fed 6,100 kcal per day, with captive reef manta rays consuming 12.7% of their body weight in euphausiids weekly (Homma et al. 1999). Although energy requirements and caloric intake for captive manta rays will likely be different than those found in the wild, Rohner et al. (2017a) proposes that the significant calorific value of the *M. birostris* stomach contents suggests that giant manta rays partake in numerous feeding events over several days or, alternatively, engage in a few, sporadic, opportunistic feeding events on large aggregations of prey that can be used to sustain them until their next meal. Burgess (2017) tends to agree with the latter. The authors cite the particularly large capacity of the *M. birostris* stomach as well as the branchial filter pad and filtration mechanism utilized by manta rays, which allows for the capture of numerous macroscopic zooplankton and small fishes of varying sizes, to support the assumption that manta rays likely exploit large patches of zooplankton for a high net energy gain in a short period of time (Burgess 2017). However, with only one study that has examined the energy contents of prey from *M. birostris* stomachs in a specific area, it is difficult to make any conclusions as to the energy needs or requirements for the species.

While there are no studies that compare diet requirements for the different life stages of the giant manta ray, recent studies do suggest that both juvenile and adult giant manta rays may occupy the same habitats within a location and, thus, target the same prey (Stewart et al. 2016b, Stewart et al. 2017, Graham et al. 2012). Based on results from stable isotope analysis, Stewart et al. (2017) found a weak relationship between disc width and δ13C and δ15N values collected from both adult and juvenile *M. birostris* muscle tissues off Peru, Sri Lanka, and the Philippines. As changes in δ13C and increases in δ15N denote changes in marine foraging habitats and higher trophic levels, respectively, the weak relationships for both in the Stewart et al. (2017) study suggest the species does not undergo an ontogenetic shift in feeding behavior or trophic level.

While it was previously assumed, based on field observations, that manta rays feed predominantly during the day on surface zooplankton, results from recent studies (Couturier et al. 2013; Burgess et al. 2016) indicate that these feeding events are not an important source of the dietary intake for the species. For *M. birostris*, Burgess et al. (2016) used stable isotope analysis of muscle tissues of individuals collected off Ecuador and surface zooplankton to examine the giant manta ray diet. The authors found that, on average, mesopelagic sources contributed 73% to the giant manta ray's diet, compared to 27% for surface zooplankton (Burgess et al. 2016). The results also indicated that *M. birostris* has a trophic position of approximately 3.4, making it a secondary consumer (Burgess et al. 2016). As such, it appears that manta rays have a more complex depth profile of their foraging habitat than previously thought (Andrzejaczek et al. 2021), and may actually be supplementing their diet with the observed opportunistic feeding in near-surface waters (Couturier et al. 2013; Burgess et al. 2016).

The feeding behaviors of manta species have also been studied to provide insight into their cognition and response to sensory stimuli. When feeding, groups of mantas hold their cephalic fins in an "o" shape and open their mouths wide. They tend to swim at a speed around 30 pectoral fin beats per minute when feeding, which is almost twice as fast as they swim when being cleaned (Kitchen-Wheeler 2013). After collecting water with zooplankton in their mouths, mantas use a transverse curtain on the roof of the mouth as a valve to hold the water in as the pharynx contracts during swallowing (Bigelow and Schroeder 1953). This movement of the pharynx pulls plankton towards the stomach when the gills are closed (Kitchen-Wheeler 2013). Intestinal eversion was also observed, probably to clear the intestines of indigestible material and parasites (Clark and Papastamatiou 2008). The positioning of the cephalic fins was found to be a good indicator of feeding motivation, triggered by underwater visual stimuli or olfactory stimuli (Ari and Correia 2008). Known manta feeding areas that have been reported in the literature are summarized below (**Table 1**); however, it is likely that additional feeding areas exist throughout the species' respective ranges.

Table 1. Locations of observed feeding areas for *Mobula birostris* with site-specific details and timing and of the species at these locations.

Source	Location	Site Specifics
Indian Ocean		
MantaMatcher (2016)	Thailand	West coast off Khao Lak and Koh Lanta
Wilson et al. (2001)	Australia	Observed feeding in surge channels at Ningaloo Reef (Western Australian coast)
Pacific Ocean		
Clark (2002); Clark (2010)	Hawaiian Islands, USA	French Frigate Shoals (all with high plankton abundance); along Kona Coast
Gordon and Vierus (2022)	Fiji	Laucala Bay and Yasawa Island Group
Duffy and Abbott (2003)	New Zealand	Nine Pin and Cavalli Islands; west of Poor Knights Islands on euphausiids; between Hen & Chickens and Mokohinau Islands (April)
Stewart et al. (2016b)	Mexico	Revillagigedo Archipelago, seen year round with seasonal shifts in habitat use probably corresponding to plankton movement

Source	Location	Site Specifics
López-Angarita et al. (2021)	Costa Rica	Isla Tortuga and Punta Roca, Reserva Curú and Islas Negritos (December – April)
López-Angarita et al. (2021)	Panama	Coiba National Park (March)
López-Angarita et al. (2021); Mejia-Falla et al. (2014)	Colombia	Gorgona Island National Natural Park (March – September); Northern Choco
Atlantic Ocean		
Graham et al. (2012)	Gulf of Mexico	Southern Gulf of Mexico near Yucatan Peninsula
Pate and Marshall (2020)	Florida, USA	Coastal waters off the east coast of Florida, high site fidelity and feeding behavior.
Notarbartolo-di-Sciara and Hillyer (1989)	Venezuela	Between Puerto la Cruz and Isla Margarita (March - December)
De Boer et al. (2015)	Suriname	Coastal waters off Suriname, particularly during rainy season
Girondot et al. (2015)	French Guiana	Peak between July and December when primary production is high
Luiz et al. (2009); Medeiros et al. (2015, 2021, 2022); Bucair et al. (2021)	Brazil	Laje de Santos Marine State Park during austral winter (June - September); Paranaguá Estuarine Complex during austral summer and early autumn; Ilha Comprida; Fernando de Noronha archipelago (juvenile manta ray feeding ground)

While seasonal upwelling events appear to be the main environmental factor driving manta ray foraging behavior, Graham et al. (2012) also observed a giant manta ray feeding in oligotrophic waters during a seasonal fish spawning event. The giant manta ray was initially tagged off the northern Yucatan peninsula in eutrophic waters and observed feeding on copepods (Graham et al. 2012). However, 57 days later, it was re-sighted in oligotrophic waters foraging on fish eggs released during a seasonal spawning event of little tunny (*Euthynnus alletteratus*), suggesting that giant manta rays are able to exploit different habitats when conditions arise that are suitable for foraging (Graham et al. 2012).

The search patterns used by giant manta rays to locate their prey have not been well studied. A study on the closely-related, but coastal dwelling, *M. alfredi* indicated that at large spatial scales (>330 m) the rays demonstrated home ranging behavior, but at smaller scales they used straighter correlated random walks to move between patches of zooplankton. Once a high density patch of zooplankton was located, the rays used area-restricted searching, slowing down their movements and turning frequently to remain in a small area and maximize the prey captured (Papastamaiou et al. 2012).

Giant manta rays spend more time foraging in the pelagic zone than *M. alfredi* and may use different search patterns to locate zooplankton, but a study of captive *M. birostris* suggested that they may build a cognitive map of their environment and recognize feeding locations (Ari and Correia 2008). Once those patches are located they likely switch to area-restricted searching. Stewart et al. (2016b) observed a manta ray feeding at depth in this way, making continuous barrel rolls and repeatedly turning through the densest zooplankton patches. Burgess et al. (2017) observed barrel rolling at the surface and suggested that it appears to be used for small, dense patches of zooplankton. When at the surface, *M. birostris* has also been observed capturing prey through short (< 5 min) bursts of continuous ram feeding (Burgess et al. 2017). Rays have been observed targeting isolated patches of zooplankton in surface slicks by ram-feeding with their upper jaw above the water and then turning back towards the patch (Stewart et al. 2016b). When there were large, dense patches of zooplankton at the surface, individual rays formed long feeding chains as they continuously ram fed (Burgess et al. 2017).

Cleaning

In addition to foraging, many observations of giant manta rays have been at sites that appear to be used for cleaning purposes. At these areas, cleaner fish tend to swim alongside the rays, removing parasites and dead or diseased tissue (O'Shea et al. 2010; Marshall et al. 2011a; Rohner et al. 2013, Burgess 2017, Beale et al. 2019, Murie et al. 2020, Cabral et al. 2023). Some of the main cleaner fish that have been identified include blue streaked cleaner wrasses (*Labroides dimidiatus*) and moon wrasses (*Thalassoma lunare*) (Barr and Abelson 2019; Murie et al. 2020).

A study conducted in Isla de la Plata in Ecuador suggested that key factors that make a habitat ideal for giant manta ray cleaning stations are a clear, undisturbed environment which enables the rays and cleaners to visually recognize each other, and a weak current strength that may lessen the energy needed by rays and cleaners to swim together during the interaction (Burgess et al. 2017). Near Ticao Island, Philippines, Barr and Abelson (2019) found that manta ray presence at those cleaning stations was primarily correlated with factors that cause low light intensity, such as time of day, sea surface state, and cloud coverage. However, they note that their occurrence at cleaning sites is likely due to a trade-off between foraging and cleaning as during those environmental conditions, plankton concentration will be low and scattered, hence making foraging less efficient, and, therefore, increasing the trend for the manta rays to visit cleaning stations instead (Barr and Abelson 2019).

Interestingly, Murie et al (2020) documented recurring visits from giant manta rays to a cleaning station located at Monad Shoal, a seamount in the Central Visayan Sea characterized by a shallow Acropora-dominated fringing coral reef that crests down 250 m to a valley below. Observations were most common between the months of April and September, and 7 of the identified 15 individual manta rays were re-sighted at the cleaning site in consecutive years, suggesting potential seasonal fidelity to this particular cleaning site. Beale et al. (2019) also documented individual giant manta rays returning to cleaning stations in the Misool Region in southern Raja Ampat, Indonesia, with 23 giant manta rays returning in at least two different years and 10 visiting the cleaning stations in consecutive years.

Reproduction and Growth

The giant manta ray may be the largest living ray species, attaining a maximum size of 800 cm disc width (DW) with anecdotal reports up to 910 cm DW (Compagno 1999; Alava et al. 2002; Carpenter et al. 2023). Males mature at 350–400 cm DW and females mature at 380–500 cm DW (White et al. 2006; Last et al. 2016; Stewart et al. 2018b).

Female age-at-maturity is estimated as 8.6 years of age, but first pregnancy may be delayed by up to 4 years (making first age of pregnancy 12 years) depending upon food availability

(Rambahiniarison et al. 2018). The maximum age is estimated at 45 years, based on the longevity of the reef manta ray (Marshall et al. 2022) and generation length is estimated at 29 years (Marshall et al. 2022) and 20 years (J. Carlson, unpublished). The giant manta ray is among the longest-living ray and has an extremely conservative life history; with the average female producing 4-7 pups during its estimated lifespan (Marshall et al. 2022).

In terms of mating, characteristics exist to distinguish between male and female manta rays. Female manta rays have a simple cloaca opening between their paired pelvic fins. Males may be identified by the presence of a pair of claspers extending from the pelvic fins (Kitchen-Wheeler 2013). Additionally, sexual dimorphism is present, with female manta rays as much as 18% larger than males, making it unlikely that a male could force a female to mate against her will (Deakos 2010; Marshall and Bennett 2010b). The manta ray mating displays can last hours or days, with the female swimming rapidly ahead of the males and occasionally somersaulting or turning abruptly (Deakos et al. 2011). Males were never observed to compete with each other directly for the attention of the female, so these mating trains may function as a kind of endurance rivalry (Andersson 1994; Deakos 2012). It may be assumed that females leading a mating train are ovulating, as males in the mating trains were observed to ignore other adult females in the area aside from briefly investigating behind the females. Ari and Correia (2008) have already recorded *M. birostris* using its acute sense of smell to locate food, while others have recorded male elasmobranchs using scent to identify if females are receptive to mating, so it seems safe to assume that these females leading the mating trains are indeed ovulating (Johnson and Nelson 1978; Gordon 1993). Very few copulations have been observed in the wild, so it is difficult to determine which males have a mating advantage, but this kind of endurance trial usually selects for the success of larger males (Andersson and Iwasa 1996; Deakos 2012).

Known breeding or reproductive sites include the Ogasawara Islands (Japan) (with mating behavior occurring in July-August), off the coast of Ecuador, in the Galapagos Islands, off the coast of southeastern Brazil, and in the Bohol Sea, Philippines, and possibly the eastern Arabian Sea, with pregnant females observed specifically off Isla de la Plata in the Machalilla National Park (Ecuador), and Galapagos Marine Reserve, caught at landing sites in Bohol (Philippines) and Kerala (India), and stranded on the coast of Ilha Comprida (southeastern Brazil) (Hearn et al. 2014; Rambahiniarison et al. 2018; Medeiros et al. 2022; Rambahiniarison et al. 2023). Additionally, significant female-biased female to male sex ratios are observed in many of the giant manta ray aggregations (7.4:1 in Mozambique, 2.6:1 in Indonesia, 1.4:1 in Revillagigedo Archipelago, Mexico, 2.1:1 in Philippines); however, whether this means that these areas are close to locations of mating, pupping, or nursery grounds or if females are simply there for foraging or cleaning purposes remains largely unknown (Marshall 2008; Beale et al. 2019; Cabral et al. 2023; Nair et al. 2022; Rambahiniarison et al. 2023).

Similarly, not much is known about manta growth and development. *M. birostris* is ovoviviparous with gestation lasting around 12-13 months, based on *M. alfredi* data (Murakumo et al. 2020). This is consistent with a lone observed captive *M. birostris* birth where the gestation period was 374 days (The Guardian 2007). The limited investigations of pregnant females with embryos intact have all indicated the presence of a single embryo per pregnancy (Müller and Henle 1841, Beebe and Tee-Van 1941, Rambahiniarison et al. 2018). Similarly, reports of reef manta ray births and dissections have also all revealed only a single embryo (Homma et al. 1999; Uchida et al. 2008). Size at birth has similarly remained elusive for *M. birostris*. The embryos examined have been 1,140 mm DW, 1,270 mm DW, and 1,994 mm DW (Müller and Henle 1841, Beebe and Tee-Van 1941, Rambahiniarison et al. 2018). A captive manta ray (identified as *M. birostris*) gave birth to a 1.8 m DW 66 kg neonate (The Guardian 2007), while the smallest free swimming individuals reported by Stewart et al. (2018b) in the Gulf of Mexico were approximately 1 m DW. In the Bohol Sea, Philippines, Rambahiniarison et al. (2018) estimated size at birth for *M. birostris* to be a bit larger, ~2–2.1 m DW based on measurements of the largest fetus (1.994 m DW) and the smallest free-swimming *M. birostris* (2.3 m DW) landed by fishermen.

As young mantas are only able to swim properly after a few minutes when their wings fully unfurl, neonates would be at increased risk for predation during this time. Thus, the mother's choice of birth site may make a difference in survival rate (Berriman 2007;

Kitchen-Wheeler 2013) as mantas do not provide any parental care to their offspring after birth. Over the last decade, several areas have been identified as nursery habitats for the giant manta rays. In U.S. waters, Childs (2001) and Stewart et al. (2018b) provided evidence that suggests that the Flower Garden Banks National Marine Sanctuary (FGBNMS) serves as an important nursery habitat for *M. birostris*. Size estimates of mantas sighted at FGBNMS over 25 years of monitoring efforts indicate that 95% of individuals are smaller than the size at maturity for male *M. birostris* and males have underdeveloped claspers further supporting the use of this area by juveniles. Temporal patterns of use and the prevalence of juveniles suggest that this region may serve as nursery habitat for *M. birostris* and *M. cf. birostri*. Stewart et al. (2018b) proposed that the FGBNMS may be an optimal nursery habitat because of their location near the edge of the continental shelf and proximity to abundant pelagic food resources. Important prey for manta rays, like euphausiids, are abundant in the deep scattering layers in the basin waters of the Gulf of Mexico. An additional benefit of the FGBNMS is that the shallow bottom habitat of the FGBNMS may protect juvenile rays from predation while they rest and recover their body temperature in the warm mixed layer after deep foraging dives (Stewart et al. 2018b). In addition, Pate and Marshall (2020) provided evidence that southeastern Florida also serves as nursery habitat for *M. birostris* and *M. cf. birostri*. Pate and Marshall (2020) encountered 150 manta rays, 59 unique individuals, along southeastern Florida. All males observed were immature and 96% of females were of immature size without mating scars. The manta ray individuals in the south Florida population remained over time with 42% of individuals being sighted more than once within the 3-year study period. Since the original publication (Pate and Marshall 2020) researchers have identified a total of 152 individual manta rays (including the 59 individuals from previous study) within the southeastern Florida study area (J. Pate pers comm to C. Horn, May 23, 2023). Juvenile manta rays were observed feeding on approximately 33% of these encounters (J. Pate pers comm to C. Horn, May 23, 2023). Furthermore, J. Pate (pers comm) noted they expanded the survey areas to include Central Florida, Cape Canaveral area, where they have identified 34 unique individuals, as well as documented 6 different courting pairs, and 138 breaching events (J. Pate pers comm to C. Horn, May 23, 2023).

Outside of U.S. waters, there are only a few other regions where juvenile manta rays have been observed, which suggest possible nursery habitats. This includes Fernando de Noronha, an island part of a submerged volcanic chain off northeast Brazil (Bucair et al. 2021), Sharm el-Sheikh, Egypt (Knochel et al. 2022), and possibly KwaZulu-Natal, South Africa (Carpenter et al. 2023). Juvenile manta rays are also fairly common at Sri Lanka and Indonesian landing sites; however, where they are being caught remains unknown (White 2006; Fernando and Stewart 2021). It has been suggested that coastal and lagoon habitats may serve as important nursery grounds for juvenile manta rays, providing benefits such as reliable food availability, refuge from predators (e.g., large pelagic sharks), or the opportunity for thermoregulation via basking behavior after deep foraging dives (Heupel et al. 2007; McCauley et al 2014; Stevens 2016; Stewart et al. 2018b; Germanov et al. 2019; Pate and Marshall 2020). Known life history characteristics of *M. birostris* are summarized below in **Table 2.**

Table 2. Available life history parameters for *Mobula birostris* (f = female; m = male; DW = Disc Width).

Parameter	Estimate	Reference
Max length (DW, meters)	6.7 (W. North Atlantic)	Bigelow and Schroeder (1953)
	5 (Gulf of Mexico)	Stewart et al. (2018b)
	6 (f; Brazil)	Medeiros et al. (2022)
	6.8 (f; India)	Kunjipalu and Boopendranath (1982)
	5.9 (m; India)	Nair et al. (2015)
	4.5 (m; Sri Lanka) 4.8 (f; Sri Lanka)	Fernando and Stewart (2021)

Parameter	**Estimate**	**Reference**
	4.9 (f; Indonesia)	White et al. (2006)
	4.1 (m; Indonesia)	White et al. (2006)
	>6.0 (Mozambique)	Marshall et al. (2009)
	8.0 (f; South Africa)	Carpenter et al. (2023)
	4.7 (m; Philippines) 5.5 (f; Philippines)	Rambahiniarison et al. (2018)
	~5 (f; Japan) ~4 (m; Japan)	Yano et al. (1999)
	5.5 (f; Galapagos)	Beebe, W. & Tee-Van, J. (1941)
	7 (f; Peru)	Main (2015)
Age at maturity (years)	8.6 (with 12.6 age at pregnancy)	Rambahiniarison et al. (2018)
DW at Maturity (meters)	>3.5 (m; W. North Atlantic) 4.3-4.6 (f; W. North Atlantic)	Bigelow and Schroeder (1953)
	3.6 (m; Gulf of Mexico)	Stewart et al. (2018b)
	~4.0 (m; Mozambique)	Marshall et al. (2009)
	>4.7 (f; Mozambique)	Marshall et al. (2009)

Parameter	**Estimate**	**Reference**
	4.1 (India)	Nair et al. (2015)
	>3.9 (m; Sri Lanka)	Fernando and Stewart (2021)
	>3.8 (m; Indonesia) >4.1 (f; Indonesia)	White et al. (2006)
	3.8 (m; Philippines) 4.5 (f, Philippines)	Rambahiniarison et al. (2018)
Longevity (years)	45 (based on *M. alfredi*)	Marshall et al. (2022)
Gestation period	12-13 months	Yamaguchi (2007)
Reproductive periodicity	4-5 years (*based on M. alfredi*)	Marshall et al. (2022)
Size at birth (DW, meters)	1.14 (W. North Atlantic)	Bigelow and Schroeder (1953)
	1 (Gulf of Mexico)	Stewart et al. (2018b)
	2 (Philippines)	Rambahiniarison et al. (2018)
	>1.4 (fetal size; Peru)	Cabanillas-Torpoco et al. (2019)
Litter size (# of pups)	1	Beebe, W. & Tee-Van, J. (1941)
Generation Time	29 (based on IUCN)	Marshall et al. (2022)

Parameter	Estimate	Reference
	20	J. Carlson (unpublished)
von Bertalanffy growth coefficient (*k*)	0.03-0.1	Dulvy et al. (2014)
Productivity (maximum intrinsic rate of population increase; rmax, yr-1	0.019 to 0.046 per year (median 0.033 per year)	Rambahiniarison et al. (2018); J. Carlson unpubl. data
Survivorship	0.9636 per year	J. Carlson unpubl. data (following Pardo et al. (2016)

Population Structure

There are currently varying thoughts on the population structure of *M. birostris.* Several authors have reported that giant manta rays likely occur in small regional subpopulations (Lewis et al. 2015; Stewart et al. 2016a; Beale et al. 2019; Marshall et al. 2022) and may have distinct home ranges (Stewart et al. 2016a). For example, Stewart et al. (2016a) studied four subpopulations of giant manta ray using genetics, stable isotopes, and satellite tags. They found that these subpopulations appeared to be discrete with little evidence of movement between them. The home ranges for three of these subpopulations, defined as the areas where tagged animals were expected to spend 95% of their time, encompassed areas of 79,293 km^2 (Raja Ampat, Indonesia), 70,926 km^2 (Revillagigedo Islands, Mexico), and 66,680 km^2 (Bahia de Banderas, Mexico). These findings indicate that giant manta rays form discrete subpopulations that exhibit a high degree of residency. Stewart et al. (2016a) states that this does not preclude occasional long-distance migrations, but that these migrations are likely rare and do not generate substantial gene flow or immigration of individuals into these subpopulations. This is in contrast to Hosegood et al. (2020), which found a lack of differentiation and no evidence of population structure, including between ocean basins, based on results from ddRAD sequencing of *M. birostris* samples from Sri Lanka, Philippines, Mexico Caribbean, Mexico Pacific, and Flower Garden Banks (Gulf of Mexico, USA). Similarly, using single nucleotide polymorphisms (SNPs) data and four analytical approaches (discriminant analysis of principal components, admixture, pairwise FST and isolation by distance analysis), Humble et al. (2023) also found that giant manta rays did not exhibit a strong population structure, both globally and regionally. However, they note that data was lacking (small sample sizes) and populations separated by greater distances did tend to display higher differentiation (Humble et al. 2023). Overall, based on their analyses, Humble et al. (2023) suggested that a likely large historical population size for giant manta rays and their contemporary gene flow is what led to the resulting high levels of heterozygosity and genetic homogeneity in the species, covering a potentially high degree of contemporary demographic separation.

For the manta rays observed at a single location, Isla de la Plata, Ecuador, Sotelo (2018) found them to have a moderately high degree of genetic diversity and consisted of different populations over three years, likely undertaking long-distance migrations for foraging in this area. In contrast, Lopez et al. (2022) sampled manta rays off mainland Ecuador and the Galapagos, and found moderately high levels of genetic diversity in both areas, suggesting the presence of 2 different populations of giant manta rays, with reduced/limited gene flow between mainland Ecuador and Galapagos. Clearly, further research is required in order to determine the extent of genetic connectivity and population structure of *M. birostris* throughout its global range.

The population structure of giant manta rays — the number of populations and subpopulations that comprise the species, whether they are linked by immigration and emigration, and the strength of those links — is largely unknown. At a minimum, the evidence suggests that giant manta rays in the Atlantic and giant manta rays in the Indo-Pacific represent separate populations because this species does not appear to migrate to the Pacific through Drake Passage (or vice versa) and they do not appear to migrate around the Cape of Good Hope to the Indian Ocean (**Figure 2**; Lawson et al. 2017; Marshall et al. 2022).

Furthermore, for over a decade, a third putative species of manta ray has been hypothesized to occur in the Atlantic and Caribbean (Hinojosa-Alvarez et al. 2016; Marshall et al. 2009). Using the mitochondrial *ND5* region (maternally-inherited DNA), Hinojosa-Alvarez et al. (2016) found shared haplotypes between Yucatán manta ray samples and known *M. birostris* samples from Mozambique, Indonesia, Japan, and Mexico, but discovered four new manta ray haplotypes, exclusive to the Yucatán samples. While analysis using the nuclear *RAG1* gene (bi-parentally-inherited DNA) showed the Yucatan samples to be consistent with identified *M. birostris* sampled, the authors suggest that the *ND5* genetic evidence indicates the potential for a third, distinctive manta genetic group or possibly *M. birostris* subspecies. Yet, the authors note that molecular support remains inconclusive due to reliance on relatively few genetic markers displaying conflicting evolutionary signals (Hinojosa-Alvarez et al. 2016). However, more recently, Hosegood et al. (2020) used ddRAD sequencing to analyze *M. birostris* samples taken from the Gulf of Mexico and found further support for the identification of a putative new species of manta ray. In fact, the results from the maximum likelihood consensus trees suggest a sister relationship between this new species and *M. birostris*, with these taxa reflecting genetically distinct and independently evolving lineages.

At this time, additional studies, including in-depth taxonomic studies and genetic sampling and adaptive divergence between populations are needed to better understand the population structure of the giant manta ray throughout its entire range.

Population Demographics

Given their large sizes, manta rays are assumed to have fairly high survival rates after maturity (e.g., low natural predation rates). Survivorship for *M. birostris* was estimated to be 0.96 yr -1 (J. Carlson unpublished data following Pardo et al. (2016)).

Using estimates of known life history parameters for both giant and reef manta rays, and plausible range estimates for the unknown life history parameters, Dulvy et al. (2014) calculated a maximum population growth rate of manta rays and found it to be one of the lowest values when compared to 106 other shark and ray species. Specifically, the median maximum population growth rate (R_{max}) was estimated to be 0.116, a rate that is more similar to those calculated for marine mammal species than chondrichthyan species (Dulvy et al. 2014; Croll et al. 2015). After taking into consideration different model assumptions, and the criteria for assessing productivity in Musick (1999), Dulvy et al. (2014) estimated realized productivity (r) for manta rays to be 0.029 (Dulvy et al. 2014). This value is similar to the productivity estimate from Kashiwagi (2014) who empirically determined an r value of 0.023 using capture-mark-recapture analyses. Rambahiniarison et al. (2018) calculated a much lower intrinsic population growth rate for *M. birostris* in the Philippines related to age at maturity (r = 0.019) and age-at-pregnancy (r = 0.0001) based on size-at-maturity and size-at-pregnancy analyses using specimens landed by fishermen. In contrast, Ward-Paige et al. (2013) and Mardhiah et al. (2019) both calculated higher estimates for the intrinsic rate of population increase, with r = 0.042 for *M. birostris*. Based on the above, and as noted by Marshall et al. (2022) (citing J. Carlson 2019 unpublished data), it appears that the maximum intrinsic rate of population increase could range anywhere from 0.019 to 0.046 per year; however, all these estimates still place the giant manta ray into the "very low" productivity category (r <0.05), based on the productivity parameters and criteria in Musick (1999).

In order to determine how changes in survival may affect populations, Smallegange et al. (2016) modeled the demographics of reef manta rays. In their own observations of the population off the southern coast of Mozambique, the authors estimated an annual adult survival rate of 0.67 (± 0.16 SE). Results from the population modeling (based on *M. alfredi* demographics) showed that increases in yearling or adult annual survival rates resulted in much greater responses in population growth rates, mean lifetime reproductive success, and cohort generation time compared to similar increases in juvenile annual survival rates (Smallegange et al. 2016). Based on the elasticity analysis, population growth rate was most sensitive to changes in the survival rate of adults (Smallegange et al. 2016). In other words, in order to prevent populations from declining further, Smallegange et al. (2016) found that adult survival rates should be increased, such as through protection of adult aggregation sites or a reduction in fishing of adult manta rays (Smallegange et al. 2016). For those populations that are currently stable, like the Yaeyama Islands (Japan) population (where adult annual survival rate is estimated at 0.96; noted above), Smallegange et al. (2016) note that any changes in adult survival may significantly affect the population.

Overall, given their life history traits and productivity estimates, particularly their low reproductive output and sensitivity to changes in adult survival rates, giant manta ray populations are inherently vulnerable to depletions, with low likelihood of recovery.

HISTORICAL AND CURRENT ABUNDANCE AND TRENDS

There are no current or historical estimates of the global abundance of *M. birostris*. However, in some regional areas, abundance has been estimated based on a series of sightings at diving sites or fisherman observations, which are subject to bias. Although the global population size is not known, regional populations have been estimated in Ecuador, Mozambique, Indonesia, and Mexico (Revillagigedos Archipelago and Banderas Bay). At 22,316 individuals, Ecuador is thought to be home to the largest identified population of *M. birostris* in the world, with large aggregation sites within the waters of the Machalilla National Park and the Galapagos Marine Reserve (Hearn et al. 2014; Harty et al. 2022). The next largest population has been noted in Raja Ampat, Indonesia, but is clearly a lot smaller, estimated at around 1,875 individuals (Beale et al. 2019). The other estimated populations are similar in size, with 1,172 in the Revillagigedo Archipelago, Mexico (Cabral et al. 2023), more than 400 individuals in Banderas Bay, Mexico (Domínguez-Sánchez et al. 2023), and 600 in Mozambique (Marshall 2008). Locally, abundance varies substantially and may be based on food availability and the degree that they were, or are currently, being fished. In most regions, the number of giant manta rays observed over the years appear to be small (less than 1,000 individuals) (**Table 3**).

Table 3. Numbers of recorded individuals and population estimates of *Mobula birostris* at identified locations.

Location	Recorded Individuals	Population Estimate	Reference
Indian Ocean			
Mozambique	180 - 254	600	Marshall (2008); Marshall et al. (2009) & pers. comm. cited in CITES (2013); MantaMatcher (2016)

Location	Recorded Individuals	Population Estimate	Reference
Red Sea	267		Knochel et al. (2022)
Egypt	60		Marine Megafauna Foundation unpubl. cited in CITES (2013)
Republic of Maldives	678 - 1,000		Hilbourne and Stevens (2019); Manta Trust (2024)
Sri Lanka	>1,000 to 7,961 (estimated catches)		Fernando and Stewart (2021)
Thailand	>288 - 365		MantaMatcher (2016); J. Stewart pers. comm. to A. Garrett citing Manta Trust data (2021)
Pacific Ocean			
Indonesia (Raja Ampat)	588	1,875	Beale et al. (2019)
Japan (Ogasawara Islands)	42		Kashiwagi et al. (2010)
Kona, Hawaii	29		Clark (2010)
Ecuador	2,803	22,316	Harty et al. (2022)
Mexico (Revillagigedos Archipelago.)	1,141	1,172	Gomez-Garcia et al. (2021); Cabral et al. (2023)
Mexico (Banderas Bay)	286	>400	Harty et al. (2022); Domínguez-Sánchez et al. (2023)
Atlantic Ocean (including Gulf of Mexico and Caribbean)			
United States (east coast of Florida)	186		Pate and Marshall (2020); J. Pate to C.Horn pers comm (2023)
United States (Flower Garden Banks National Marine Sanctuary)	85		Graham and Witt (2008) cited in CITES (2013); Stewart et al. (2018b)
Mexico (northeastern coast of the Yucatan Peninsula)	> 200		R. Graham, pers. comm. cited in CITES (2013); Trujillo-Cordova et al. (2019)
Venezuela (Margarita Island)	295		Notarbartolo di Sciara and Hillyer (1989)
Brazil (southeastern, Laje de Santos Marine State Park)	79		Luiz et al. (2009)
Brazil (Fernando de Noronha archipelago)	85		Bucair et al. (2021)
Azores, Portugal	128		Sobral and Afonso (2014)

In areas where the species is not subject to fishing, populations may be stable. However, in regions where giant manta rays are (or were) actively targeted or caught as bycatch, such as the Philippines, Mexico, Sri Lanka, and Indonesia, populations appear to have significantly declined and/or may be decreasing (**Table 4**). In Indonesia, declines in manta ray landings are estimated to be on the order of 71% to 95%, with potential extirpations noted in certain areas (Lewis et al. 2015). Given the migratory nature of some populations, declines in waters where mantas are protected have also been observed but attributed to overfishing of the species in adjacent areas within its large home range. For example, White et al. (2015) provide evidence of a substantial decline in the *M. birostris* population in Cocos Island National Park, Costa Rica, where protections for the species have existed for over 20 years. Using a standardized time series of observations collected by dive masters on 27,527 dives conducted from 1993 to 2013, giant manta ray relative abundance declined by approximately 89% (95% CI 85-92%) (**Figure 4**). Years of higher abundance of the species were correlated with lower El Niño activity. However, based on the frequency of the species' presence on dives (4%), with a maximum of 15 individuals observed on a single dive, the authors suggest that Cocos Island may not be a large aggregating spot for the species, and suggest that the decline observed in the population is likely due to overfishing of the species outside of the National Park (White et al. 2015).

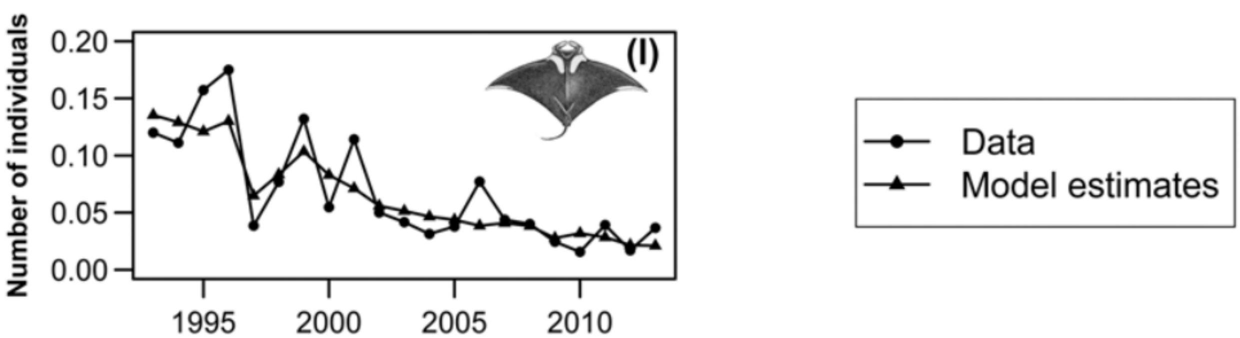

Figure 4. Observed and modeled estimates of mean annual numbers of *Mobula birostris* individuals in Cocos Island National Park, based on diver observations from 1993 to 2015. Source: White et al. (2015)

Table 4. Observed and anecdotal declines in manta ray populations, reported by area. Methodology, time period, notes, and sources of reported declines are also provided. Adapted from CITES (2013).

Area	Species	Time Period	Methodology	% Decline	Notes	Source(s)
Indian Ocean						
Sri Lanka	*M. birostris*	2006-2019	Interviews with fishermen; mean catch rates	75% (**catches**; 2011-2018)	Decrease in numbers of mantas caught	Fernando and Stevens (2011); Herath et al. (2019); Fernando and Stewart (2021)
Pakistan	*M. birostris*	1988-present (general – over past 25 to 30 years	Anecdotal from fishermen	Unknown	Previously abundant and now rarely observed or caught	Moazzam (2018)
Madagascar	Manta rays (*unknown*)	2003-2013 (general – over past 10 years)	Anecdotal scuba diver and fishermen sighting observations	Unknown	Large decline in sightings	R. Graham, pers. comm. cited in CITES (2013) and pers. comm. (2016)
Mozambique (Inhambane province)	*M. birostris*	2003 – 2016 (14 years of data provided)	Scuba diver sightings data – standardized and adjusted to take into account short-term environmental variables	94%	No clear trend based on data from 2003-2011; however, with expansion of data set to 2016, showed steep decline in observations.	Rohner et al. (2013); Rohner et al. (2017b)

Area	Species	Time Period	Methodology	% Decline	Notes	Source(s)
Thailand	Manta rays (*unknown; likely M. birostris)*	2006-2012 (2 years of data provided)	Local dive professional detailed sightings data	76%	Sightings of *Manta spp.* decreased from 59 in 2006-2007 season down to 14 during 2011-2012 season	R. Parker, pers. comm. cited in CITES (2013)
Indonesia (throughout)	Manta rays (*unknown; likely M. birostris)*	2001-2014 (13 years of data provided)	Historical and current landings from published literature, unpublished data from anecdotal reports, field surveys, casual and semi-structured interviews, direct observations	71-95% **(landings)** Potential areas of extirpation based on anecdotal reports include Lembeh Strait and Selayer Islands.	Shift in fishing grounds due to declining catches of manta rays	Dewar (2002); Setiasih et al in prep. cited in CITES (2013); White et al. (2006); Lewis et al. (2015)
Western Pacific Ocean						
Bohol Sea, Philippines	Manta rays (*unknown; likely M. birostris)*	1990s – 1997 (general - memory recall of	Standardized questionnaire to artisanal fishermen (n=85) to	Unknown	15% of fishermen noted a decrease in landings of whale	Alava et al. (2002)

Area	Species	Time Period	Methodology	% Decline	Notes	Source(s)
		1990s data)	assess catch and effort		shark/manta resources	
Bohol Sea, Philippines	Manta rays (*unknown; likely M. birostris)*	1997 – 2013 (general - memory recall of previous years)	Interviews with fishermen	Unknown	Shift in fishing grounds due to declining catches of manta rays	Acebes and Tull (2016)
Sulu Sea, Philippines	Manta rays (*unknown; possibly M. alfredi?)*	End of 1980s-1990s (general - over past 7 years)	Personal (amateur) scuba diver sightings data	50-67%	Location reported to be off Palawan Island	Michiyo Ishitani, pers. comm. cited in Homma et al. (1999)
Yaeyama Islands, Japan	Manta rays (*unknown; possibly M. alfredi?)*	1980 – 1997 (3 years of data provided)	Local dive professional (T. Itoh) sightings data	Unknown; number of individuals in school decreased from 50 to 14-15	Authors note that while the school size has decreased, this does not necessarily mean that the population abundance has declined; both pregnant females and young were part of the school groups	Homma et al. (1999)

Area	Species	Time Period	Methodology	% Decline	Notes	Source(s)
Papua New Guinea	Manta rays (*unknown; possibly M. alfredi?)*	1994-2006 (12 years of data provided)	Monitored catch and surveys of fishermen	Unknown	Sharp decline noted in bycatch after a prior steady increase from 1994-2005/2006.	C. Rose, pers. comm. cited in Marshall et al. (2011b)
Eastern Pacific Ocean						
Cocos Island, Costa Rica	*M. birostris*	1993 -2013 (20 years of data provided)	Observations by dive masters	89%	Local dive professional sightings data	White et al. (2015)
Sea of Cortez, Mexico	*M. birostris*	1981-1992 (2 years of data provided)	Underwater filmmaker observations from 1981 and 1991-1992 film projects	Unknown	Observed 3-4 per dive in 1981 and then zero individuals in 1991-1992	CITES (2013)

THREATS TO THE GIANT MANTA RAY

In determining whether to list, delist, or reclassify a taxon under the ESA, five factors are evaluated:

- Factor A - the present or threatened destruction, modification, or curtailment of its habitat or range;
- Factor B - overutilization for commercial, recreational, scientific, or educational purposes;
- Factor C - disease or predation;
- Factor D - the inadequacy of existing regulatory mechanisms; and
- Factor E - other natural or manmade factors affecting its continued existence

The final listing rule (83 FR 2916, January 22, 2018) identified substantial levels of fishing mortality due to overutilization of the species (Factor B) primarily by artisanal/small-scale fisheries within the Indian Ocean and Western Pacific and Eastern Pacific Ocean subregions (**Figure 5**), a significant portion of its range, all driven by the high demand for manta ray gill plates in the international mobulid gill plate trade. The inadequacy of existing regulatory mechanisms (Factor D), with poor enforcement and illegal fishing, was also deemed a significant factor affecting the survival of the species. The following sections describe threats to the giant manta ray categorized into the above ESA 4(a)(1) factors.

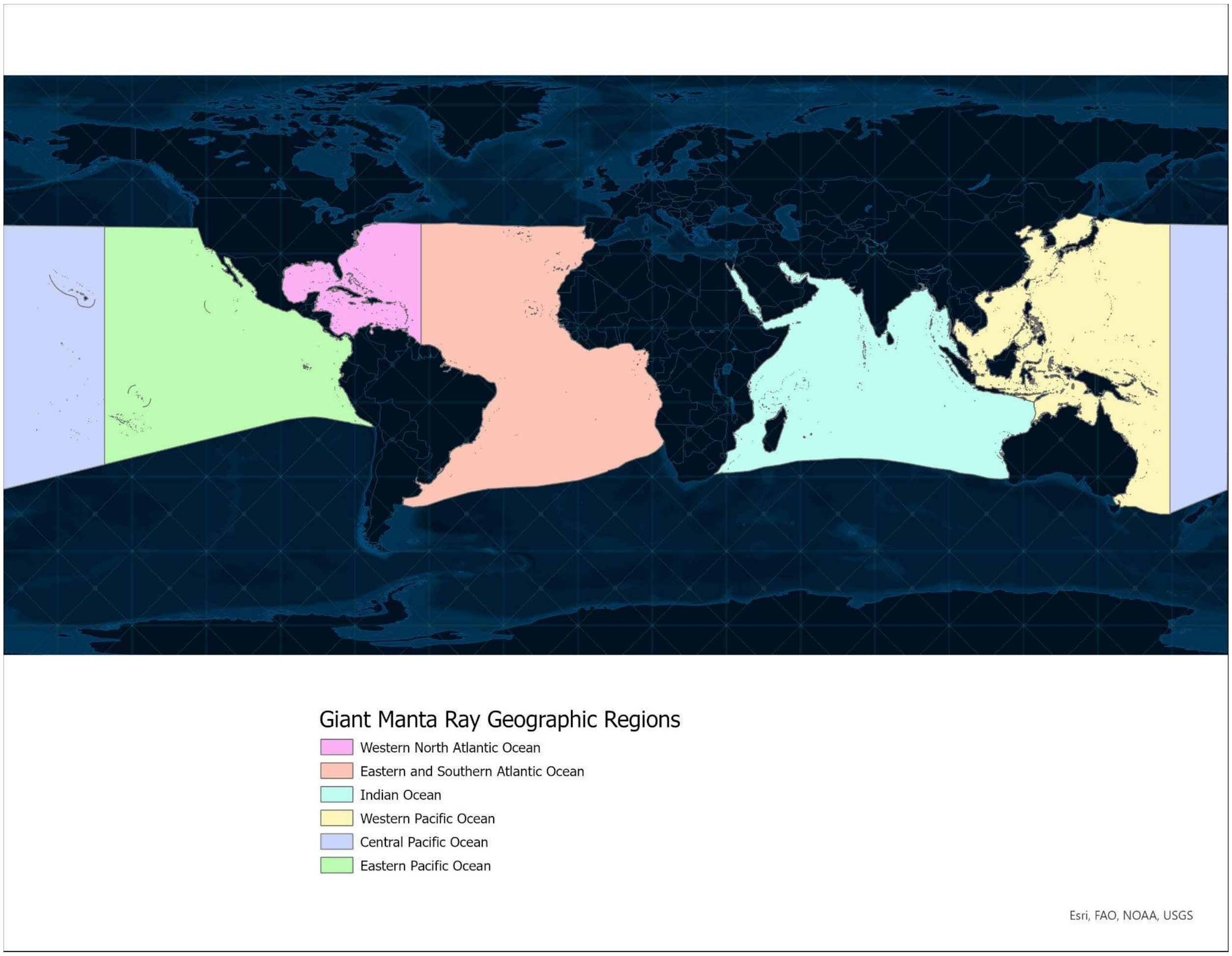

Figure 5. Map displaying the range of the giant manta ray divided into regions and subregions: Western North Atlantic (including Gulf of Mexico and Caribbean Sea; 57°W longitude & north of equator boundary line), Eastern and Southern Atlantic (east of 57°W longitude & north of equator boundary line, and all waters south of the equator line), Indian Ocean, Western Pacific Ocean (163°E longitudinal boundary line; excludes New Caledonia), Central Pacific Ocean (163°E longitudinal boundary line; includes New Caledonia, extends to 150°W longitude - the IATTC boundary line), and Eastern Pacific Ocean (east of the 150°W longitudinal boundary line).

Factor A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

This section analyzes potential threats to giant manta ray habitat, including impacts from environmental contaminants and pollution and climate change.

Environmental Contaminants

Giant manta rays may be susceptible to ingesting marine pollutants and contaminants such microplastics, heavy metals, and oil. Microplastics can contain added pollutants and toxins such as phthalates, bisphenol A, flame retardants, styrenes, and adsorb and concentrate persistent organic pollutants (POPs) and heavy metals from the marine environment (Worm et al. 2017). Microplastics are now present in every marine environment, easily permeate food webs, and are vectors for toxins (Germanov et al. 2018). These pollutants typically enter oceans through wastewater, poor industry practices, and deteriorating marine debris, among other sources (Germanov et al. 2018). The highest concentrations of plastics are in the subtropical gyres, with the largest mass reservoir in the North Pacific Ocean, presumably because of its vast area and also the large inputs of plastic waste from coastlines of Asia and the United States (Jambeck et al. 2015).

Microplastic pollution hotspots are also known to overlap with giant manta ray habitat and range including within the Gulf of Mexico, North Atlantic Gyre, Bay of Bengal (Northeastern Indian Ocean), Coral Triangle (Western Pacific Ocean), North Pacific Gyre, South Pacific Gyre, and Indian Ocean Gyre (See Table 1 in Germanov et al. 2018). For example, in Thailand, where recent sightings data have identified up to 365 giant manta rays, mismanaged plastic waste is estimated to be on the order of 1.03 million tonnes annually, with up to 40% of this entering the marine environment (Jambeck et al. 2015). Approximately 1.6 million tonnes of mismanaged plastic waste is being disposed of in Sri Lanka, again with up to 40% entering the marine environment (Jambeck et al. 2015), potentially polluting the habitat used by the nearby Maldives aggregation of manta rays. Within the Arabian Sea, Goswami et al. (2023) found the average microplastic concentration in surface water to be 0.013 particles/m3.

Given that giant manta rays are filter feeders, they are particularly susceptible to the high levels of microplastic ingestion and exposure to toxins within these hotspots (Worm et al. 2017; Germanov et al. 2018; Stewart et al. 2018a; Kahane-Rabbort et al. 2022). This is because filter-feeding megafauna have a high probability of ingesting microplastics as they must filter hundreds to thousands of cubic meters of water daily to obtain adequate nutrition (Paig-Tran et al. 2013; Germanov et al. 2018). The effects of ingesting indigestible particles include blocking adequate nutrient absorption and causing mechanical damage to the digestive tract. Manta rays may also be ingesting microplastics and toxins through their prey since zooplankton can be contaminated with pollutants, oil, and toxins (Fossi et al. 2014) and ingest microplastics and nanoplastics as well (Cole et al. 2013; Setälä et al. 2014; Goswami et al. 2023). Additionally, POPs can also be introduced through ingestion of microplastics and these toxins can bioaccumulate over decades in long-lived filter-feeding megafauna, such as manta rays, leading to a disruption of biological processes, and potentially altering reproductive fitness (Germanov et al. 2018).

However, rates of microplastic ingestion for giant manta ray, bioaccumulation of pollutants, and the impacts of plastic pollution on mobulid biology, ecology, and population viability have not been studied (Stewart et al. 2018a). While the ingestion of plastics is likely to negatively impact the health of the species, the extent of these impacts on individuals and populations of giant manta rays currently remain unknown.

This is also true for other potential environmental contaminants, such as spilled oil. For example, in the Gulf of Mexico, giant manta rays were found to have the highest ecological vulnerability to oil spills compared to other elasmobranchs and bony fishes (Romo-Curiel et al. 2022). This is largely due to their low productivity (based on life history traits) and high susceptibility (based on being a planktonic filter feeder) (Romo-Curiel et al. 2022). However, based on the species' suitable habitat and simulated oil spills from 3 major wells in the western Gulf of Mexico, Romo-Curiel et al. (2022) estimated that the giant manta ray has an exposure probability of less than 16%. Despite these findings, the authors note that there was limited information available, which resulted in low data quality, with further research efforts required.

Overall, the implications of exposure to pollution and contaminants for the giant manta ray is still unknown, especially at the level of individual fitness and population viability.

Climate Change

Because manta rays are migratory and considered ecologically flexible (e.g., low habitat specificity), they may be less vulnerable to the impacts of climate change compared to other sharks and rays (Chin et al. 2010). However, as manta rays frequently rely on coral reef habitat for important life history functions (e.g., feeding, cleaning) and depend on planktonic food resources for nourishment, both of which are highly sensitive to environmental changes (Brainard et al. 2011; Guinder and Molinero 2013), climate change is likely to have an impact on the distribution and behavior of *M. birostris*.

Coral reef degradation from anthropogenic causes, particularly climate change, is projected to increase through the future. According to the IPCC (2019) report, it is virtually certain that the ocean will continue warming throughout the 21st century and by 2100, the top 2000 m of the ocean will very likely take up 5 to 7 times more heat under representative concentration pathway 8.5 (RCP8.5) than observed heat uptake since 1970. Heron et al. (2016) predicts annual coral bleaching for almost all reefs by 2050 based on available climate models. As declines in coral cover have been shown to result in changes in coral reef fish communities (Jones et al. 2004; Graham et al. 2008), the projected increase in coral habitat degradation may potentially lead to a decrease in the abundance of manta ray cleaning fish (e.g., *Labroides* spp., *Thalassoma* spp., and *Chaetodon* spp.) and an overall reduction in the number of cleaning stations available to manta rays within these habitats. Decreased access to cleaning stations may negatively impact the fitness of the mantas by hindering their ability to reduce parasitic loads and dead tissue, which could lead to increases in diseases and declines in reproductive fitness and survival rates.

Warming oceans cause changes in ocean acidity, oxygen content, oceanic circulation and primary productivity dynamics, ultimately affecting food web structure and the distribution and availability of mobulid prey (Moloney et al. 2011). The major impact of climate change on manta rays is likely to be the projected decline in zooplankton biomass in tropical waters (Stewart et al. 2018a). Biogeochemical models project a decline in zooplankton biomass in the future of about 10% globally (Chust et al. 2014; Stock et al. 2014; Woodworth-Jefcoats et al. 2017), but some regions, particularly those in the tropics, could experience >50% declines (Stock et al. 2014). While it is unknown how this broad-scale decline in zooplankton biomass at the tropics could impact local areas where giant manta rays feed, the most likely outcome is that there will be lower zooplankton biomass available for manta rays and other zooplanktivores. In addition, changes in climate and oceanographic conditions, such as acidification, are also known to affect zooplankton structure (size, composition, diversity), phenology, and distribution (Guinder and Molinero 2013). As such, the migration paths and locations of both resident and seasonal aggregations of manta rays, which depend on these animals for food, may similarly be altered (Australian Government 2012; Couturier et al. 2012). For example, in Indonesia, Beale et al. (2019) found that giant manta sightings in the Raja Ampat archipelago increased exponentially during an El Niño-Southern Oscillation (ENSO) event. Many of the individuals were mature adults that were not previously sighted during the four years prior to the ENSO event. The authors hypothesize that many of these individuals likely spend the majority of their time in the Ceram Sea and do not migrate into Raja Ampat. However, during the ENSO event, Beale et al. (2019) suggested that the cooler waters from the Ceram Sea were pushed north into the study area, increasing vertical mixing of the water column and the availability of plankton and foraging opportunities, and expanding the regional range for *M. birostris*. Given the giant manta ray's apparent sensitivity to changes in oceanographic conditions, Beale et al. (2019) cautioned that large-scale climate change impacts that affect zooplankton distribution could similarly alter the species' distribution and potentially separate foraging grounds from other important habitat areas, such as cleaning stations or nursery areas, which could have profound impacts on the species viability. As research to understand the exact impacts of climate change on marine phytoplankton and zooplankton communities and the effects on *M. birostris* behavior and distribution is still ongoing, the severity of this threat to the giant manta ray has yet to be fully determined.

Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Given their global distribution, manta rays are both targeted and caught as bycatch in fisheries worldwide. In fact, according to Lawson et al. (2016), manta ray catches have been recorded in at least 30 large and small-scale fisheries covering 25 countries. The majority of fisheries that target mobulids are artisanal (Croll et al. 2015), with mobulids traditionally targeted for their meat; however, since the 1990s, a market for mobulid gill plates has significantly expanded, increasing the demand for manta ray products, particularly in China. The gill plates of mobulids are used in Asian medicine and are thought to have healing properties, from curing chicken pox to cancer, with claims that they also boost the immune system, purify the body, enhance blood circulation, remedy throat and skin ailments, cure male kidney issues, and help with fertility problems (Heinrichs et al. 2011). The use of gill plates as a remedy, which was popular in Southern China many years ago, has recently gained renewed popularity over the past decade as traders have increased efforts to market its healing and immune boosting properties directly to consumers (Heinrichs et al. 2011). As a result, demand has significantly increased, incentivizing fishermen who once avoided capture of manta rays to directly target these species (Heinrichs et al. 2011; CITES 2013). According to Heinrichs et al. (2011), it is primarily the older population in Southern China as well as Macau, Singapore, and Hong Kong, who ascribe to the belief of the healing properties of the gill plates; however, the gill plates are not considered "traditional" or "prestigious" items (*i.e.,* shark fins) and many consumers and sellers are not even aware that gill plates come from manta or mobula rays (devil rays). Meat, cartilage, and skin of manta rays are also utilized, but valued at significantly less than the gill plates, and usually enter local trade or are kept for domestic consumption (Heinrichs et al. 2011; CITES 2013). It is estimated that the value of the manta ray market is around $5 million per year (S. Heinrichs pers. comm cited in O'Malley et al. (2013)). Based on market surveys conducted in China in Sheung Wan (Hong Kong), Yide Lu (Guangzhou), and Qingping (Guangzhou), manta gill plate prices ranged from $333.12 (USD) to $438.50 (USD) per kilogram, with the highest being $861.52 (Hau et al. 2016).

Indonesia, Sri Lanka, and India presently represent the largest manta ray fishing and exporting range state countries, accounting for an estimated 90% of the world's manta ray catch for gill plates; however, Chinese gill plate vendors have also reported receiving mobulid gill plates from other regions as well, including Malaysia, China, Taiwan, Vietnam, South Africa, Thailand, Australia, Philippines, Mexico, South America (e.g., Brazil), the Middle East, and the South China Sea (CMS 2014; Hau et al. 2016; O'Malley et al. 2017). Hong Kong, Guangzhou, Singapore, Taiwan, and Macau are the largest importers of manta ray gill plates in Asia (O'Malley et al. 2017; Hau et al. 2016). In 2011, Guangzhou was identified as the main trade center for gill plates (responsible for 99.5% of the estimated total annual market volume), and between 2011 and 2013, the total estimated market volume in Guangzhou had doubled, from 60.15 t to 120.45 t (O'Malley et al. 2017). Based on a conversion of dried gills to an estimated number of mobulids, *Manta* spp. comprised 4% (or 4,762 individuals) of the total estimated number of mobulids (n = 130,614) represented in the Guangzhou annual sales (O'Malley et al. 2017). By 2015, Guangzhou saw a significant drop in their market (with estimated total gill plate stocks down to 55% of 2011 levels) (O'Malley et al. 2017). In contrast, the Hong Kong market saw a significant increase in gill plate sales between 2011 and 2015 (from 125 kg to 3,500 kg) (O'Malley et al. 2017), emerging as a new key market for the trade (Hau et al. 2016).

To examine the impact of this growing demand for gill plates on manta ray populations, information on landings and trends are evaluated for fisheries that target manta rays and fisheries that catch mantas as bycatch. Much of the data come from localized study sites, is anecdotal/observed, or covers short time periods and thus is difficult to extrapolate to the global population. Thus, the information below is primarily organized by oceanic region and subregion.

Indian Ocean Region

Within the Regional Fisheries Management Organization - Indian Ocean Tuna Commission (IOTC) area of competence, which covers the entire Indian Ocean, manta rays (primarily *M. birostris*) are mainly caught as bycatch in the IOTC purse-seine and gillnet fisheries. In a study of elasmobranch bycatch patterns, Oliver et al. (2015) found that manta rays comprised the greatest proportion of ray bycatch in commercial purse-seine fisheries operating in the Indian Ocean (specifically, *M. birostris* made up ~40% of the ray bycatch). Romanov (2002) also estimated mobula and manta ray bycatch from the western Indian Ocean using observer data collected on Soviet tuna purse-seine vessels from 1985-1994 and further extrapolated the observer data across the principal fishing nations operating within the western Indian Ocean (France, Spain, USSR, Japan, and Mauritius). In terms of numbers of individuals, Romanov (2002) estimated that between 253 and 539 mobulas and mantas (lumped together) were taken per year, with bycatch generally increasing over the time period.

More recent data suggest that giant manta rays continue to be caught as bycatch by the industrial tuna purse-seine fisheries, particularly in the western Indian Ocean. Based on data from the European tuna purse-seine fishery, both *M. birostris* and *Mobula spp.* are caught in similar amounts, primarily in Fish Aggregating Device (FAD) sets. Based on 1,958 observed sets from 2003-2007 (**Figure 6**), less than 35 giant manta rays were observed in the bycatch, with around 60% discarded dead and 40% discarded alive (Amandè et al. 2008). However the observer coverage is extremely low, averaging 4.04% during the 5 study years (Amandè et al. 2008). As such, the total annual bycatch of giant manta rays by the European tuna purse-seine fishery is likely much larger. Given the small populations of giant manta rays within the Indian Ocean, with the highest population estimate of 600 off Mozambique (Marshall 2008), and the evidence of significant declines in catch and sightings of manta rays within this region (**Table 4**), even a small number of giant manta rays caught as bycatch by the IOTC tuna purse-seine fisheries will likely contribute to the species' extinction risk.

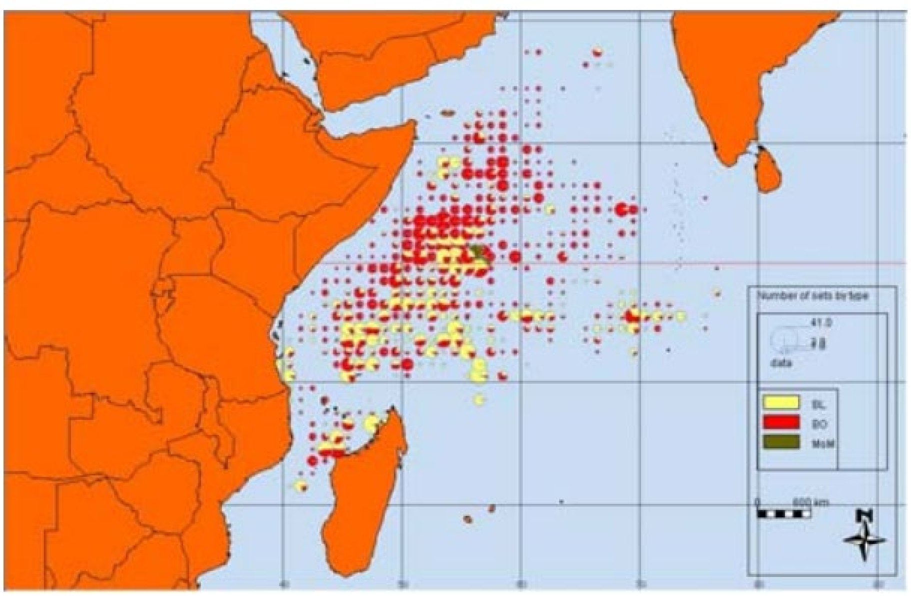

Figure 6. Map showing location of 1,958 observed sets of the European purse seine tuna fishery in the Indian Ocean from 2003-2007. Yellow = Free school sets; Red = FAD sets; Green = seamounts). Source: Amandè et al. (2008)

In addition to the IOTC data, information on the catch of giant manta rays by nation and the impacts on the populations is provided below.

Mozambique

Mobula birostris has experienced declines in southern Mozambique, within the Inhambane province. This province is thought to contain Africa's largest population of giant manta rays. Whereas previous time-series data, from 2003-2011, showed no clear trend in *M. birostris* sightings in this province (Rohner et al. 2013), expansion of this dataset to include sightings data out to 2016 showed a 94.2% decline in the number of giant manta ray sightings (Rohner et al. 2017b). The authors attribute the decline to a recent and significant increase in the use of large-mesh gillnets off the Inhambane coast; however, landings of manta rays from these fisheries are unquantified. Yet, given the small, estimated population size (~600; Marshall 2008), even a low number of individuals caught per year could be considered overutilization of the species and would likely result in significant declines in the population (Rohner et al. 2017b).

Kenya

Kenya's artisanal fisheries (including both commercial and subsistence), which comprises more than 13,400 fishermen, provides 90% of the total annual marine landings (Osuka et al. 2021). Manta rays tend to be caught as bycatch, but the fishery data is extremely limited. In a recent study on Kenya's coastal gillnet fishery, *M. birostris* was caught in both medium mesh (10.2 cm and 15.2 cm) and large mesh (20.3 cm and 25.4 cm) gillnets (Osuka et al. 2021). Given that the gillnet fishery is poorly monitored and regulated, it could be overexploiting manta ray populations in Kenyan waters; however, at this time, there is little information.

Pakistan

Mobulids are caught as bycatch in surface gillnets by fishermen targeting tuna and tuna-like species in Pakistan; however, it appears that *M. birostris* are only rarely landed. Based on landings observed from May 2013 to August 2018 at Karachi Fish Harbour (one of the two main landing centers for commercial fisheries), only three *M. birostris* were observed (Moazzam 2018). Fishermen note that giant manta rays were abundant 25 to 30 years ago, but due to overfishing, they are now rarely observed or caught (Moazzam 2018).

India

In India, mobulids are both targeted by fisheries and landed as bycatch, particularly during tuna gillnetting and trawling operations. The manta rays are then auctioned off for their gill plates, which are characterized as “First Grade'' and fetch the highest price at India fisheries harbor auctions (Nair et al. 2013), while the meat enters the local markets. Historical reports (from 1961 – 1995) indicate that the species was only sporadically caught by fishermen along the east and west coasts of India, likely due to the fact that the species was rarely found near the shore (Pillai 1998). However, based on available information, it appears that landings have increased in recent years, particularly on the southwest coast. In a snapshot of the Indian tuna gillnet fishery, Nair et al. (2013) provides evidence of the significant number of mobulids being taken off the coast of Vizhinjam, Kovalam and Colachel, documenting over 1,300 mobulids (50 t) that were landed by fishermen over the course of only 7 days. Of these mobulids, 5 individuals were identified as *M. birostris.* For the years 2003 and 2004, Raje et al. (2007) reported 647 t of *M. birostris* from the southwest coast by the trawl fisheries. From 2007-2010, landings increased from ~790 t to ~1,600 t, largely due to the targeting of manta and mobula rays for the gill plate market (Nair et al. 2015). Landings saw a slight decline in 2011 to ~1,400 t (Nair et al. 2015). In more recent years, Nair et al. (2022) reported an estimate of around 133 t of *M. birostris* landed specifically in Kerala in 2020. Off Mangalaru, Karnataka, a fisherman received significant publicity for catching two large manta rays, including a 750 kg individual (TNM 2020). However, while the size of the manta ray seemed quite large, the former President of the Fishermen's Association in coastal Karnataka noted that the size was not rare but simply tended to vary, with manta rays caught fairly regularly in the region (TNM 2020). This is particularly shown by data from 2021, where, on a single day, Nair et al. (2022) observed the landing of 20 giant manta rays by gillnets at Chochin Fisheries Harbour. Finally, in addition to the gillnet and trawl fisheries, a harpoon fishery at Kalpeni, off Lakshadweep Islands, is also noted for “abundantly” landing manta rays (Raje et al. 2007).

On the east coast of India, manta rays are thought to be less frequently caught but have been targeted and landed as bycatch as well, primarily in gillnet gear. Raje et al. (2007)

documented 43 t of *M. birostris* caught on the east coast in 2003 and 2004 (with 81% by gillnets and 19% by trawls). From 2007-2010, Nair et al. (2015) noted landings of *Manta spp*. to be scarce, yet fishery data from gillnetters of Tharuvaikulam, Thoothukudi (Tamil Nadu) operating in the Gulf of Mannar Biosphere Reserve showed *M. birostris* comprised roughly 10% of the pelagic ray catch from 2015-2016 (Manojkumar et al. 2019). Additionally, in 2020, a group of six fishermen received publicity for landing a giant manta ray that weighed ~1,150 kg off the Masula coast in the Krishna district and fetched $445 at the Kakinada harbour auction (TH 2020).

Overall, there has been a significant increase in targeted fisheries and landings of manta rays in India since the mid-1990s. Additionally, given the number and size of India's fishing fleets, and limited fisheries oversight, the actual landings of manta rays are likely significantly underreported (Zacharia et al. 2017). Populations of giant manta rays are clearly being overexploited in India, with the driver being the demand for the species' gill plates.

Sri Lanka

In Sri Lanka, manta rays are primarily caught as bycatch in the artisanal gillnet fisheries (Fernando and Stewart 2021). Fishermen note that catches of *M. birostris* tend to increase from May to September off the west coast of Sri Lanka and from October to March off the east coast (Fernando and Stewart 2021). While fishermen note that they generally tend to avoid deploying nets near large aggregations of mantas, or regularly release particularly large mantas (due to the difficulties associated with entanglement and killing the species and loss of boat time), manta rays comprised 72.4% of the shark and ray landings in Negombo and 34.8% in Beruwala from 2010-2016 (Herath et al. 2019). Additionally, as recently as 2020 and 2021, giant manta rays were observed being sold at the fish markets throughout Sri Lanka (Fernando and Stewart 2021), with gill plates exported in large quantities to Hong Kong (**Table 5**). According to Fernando (2021), there are 22 major fishery harbors and at least another 883 minor fish landing centers along the entire coastline of Sri Lanka, making monitoring of the artisanal fisheries extremely challenging.

Table 5. Recent information on the amount of *Mobula birostris* gill plates exported by Sri Lanka. (CITES Trade Database; version 2023.1)

Year	Taxon	Importer	Exporter	Importer reported quantity	Exporter reported quantity	Term and Unit
2019	Mobula birostris	Hong Kong	Sri Lanka	250	750	gill plates; kg
2020	Mobula birostris	Hong Kong	Sri Lanka	640	1024.5	gill plate; kg
2021	Mobula birostris	Hong Kong	Sri Lanka	275.5	275.5	gill plates; kg

Within Sri Lanka, Negombo is the most popular fish market (Fernando and Stevens 2011). The primary fishing grounds for boats landing at the Negombo market are west and northwest of Sri Lanka, with some venturing as far as the western coast of southern India (Fernando and Stevens 2011). Catches from these boats mostly consist of tuna, sharks, billfishes, mobula, and manta rays (Fernando and Stevens 2011). According to Fernando and Stevens (2011), the gill plate dealers at the Negombo market specialize in manta and mobula rays and sell to Asian exporters. On the other side of Sri Lanka, vessels tend to serve the Mirissa fish market and fish in the south and southeast of Sri Lanka, sometimes as far as Indonesia, with catches consisting of tuna, billfishes, mobula and manta rays, and some sharks (Fernando and Stevens 2011). However, due to longer at-sea times and unloading practices, the quality of the manta catch is generally lower than that found at the Negombo market (Fernando and Stevens 2011).

While Sri Lankan fishermen state that they try to release pregnant and young manta rays alive, based on 40 observed *M. birostris* being sold at markets (from May through August 2011), 95% were juveniles or immature adults (Fernando and Stevens 2011). Extrapolating the observed numbers to a yearly value, Fernando and Stevens (2011) estimated annual landings of *M. birostris* at Negombo to be 194 individuals and at Mirissa to be 126 individuals. Using these values, and after making general assumptions about the landings at all of the other fish markets within the country, the authors estimated total annual landings for *M. birostris* in Sri Lanka to be around 1,055 individuals (Fernando and Stevens 2011). In a follow-up study, Fernando and Stewart (2021) expanded the dataset to include 1,346 surveys at 38 landings sites throughout Sri Lanka covering a period of 2010 – 2020. Based on catches at these landing sites, Fernando and Stewart (2021) estimated that country-wide catches of *M. birostris* exceed 1,000 individuals annually. Additionally, the catches were comprised of predominantly immature and juvenile *M. birostris*, suggesting that fishermen are potentially accessing a nursery area for giant manta rays while fishing for target species, which could have potentially damaging consequences for the manta ray population. Using a state-space model of fisheries landings, the authors estimated a minimum catch over the survey period of 1,025 *M. birostris* (in 2017) and a maximum catch of 7,961 individuals (in 2014) (Fernando and Stewart 2021). The authors note that catches declined 75% from 2011 to 2018 and then doubled from 2018 to 2019, but had an overall trend of -0.012 (and an 81.7% probability of being negative) (Fernando and Stewart 2021). Similarly, comparing mean catch rates in Negombo and Beruwala from 2010-2016, Herath et al. (2019) found a significant decrease in annual manta ray catches beginning in 2013 and 2014.

While it is difficult to determine the level of overutilization of the species within the Indian Ocean, given the lack of baseline population estimates throughout most of the species' range, the authors concluded that the Sri Lankan small-scale fisheries are likely having a "significant and detrimental impact" on the *M. birostris* population that may result in a population crash, with catches that likely exceed those from the industrial fisheries operating in the region (Fernando and Stevens 2011; Fernando and Stewart 2021).

Bangladesh

In Bangladesh, based on interviews with fishermen, devil rays (*Mobula* spp.), including *M. birostris*, are not targeted but rather caught as bycatch, primarily in gillnets, trawl nets, set-bag nets, and longlines (Haque et al. 2020). The majority of interviewed fishermen (n=156; 78%) stated that they proceeded to sell the devil rays, with only 18% claiming to release them when bycaught (Haque et al. 2020). The fishermen also acknowledged that there appears to be a decline in devil rays, with some noting that they have to travel farther to fishing grounds to observe the rays (Haque et al. 2020). Specific catch figures for *M. birostris* were unavailable; however, the species was confirmed in landings from opportunistic sampling (Haque et al. 2020).

Thailand

According to Heinrichs et al. (2011), dive operators in the Similan Islands have observed an increase in fishing for manta rays, including in protected Thai national marine parks. Between 2006 and 2012, sightings of manta rays (likely *M. birostris*) had decreased by 76% (CITES 2013b).

Indonesia

Indonesia is reported to be one of the top countries that catch mobulid rays (Heinrichs et al. 2011). Manta and devil ray fisheries span the majority of the Indonesian archipelago, with most landing sites along the Indian Ocean coast of East and West Nusa Tenggara and Java (**Figure 7**) (Lewis et al. 2015).

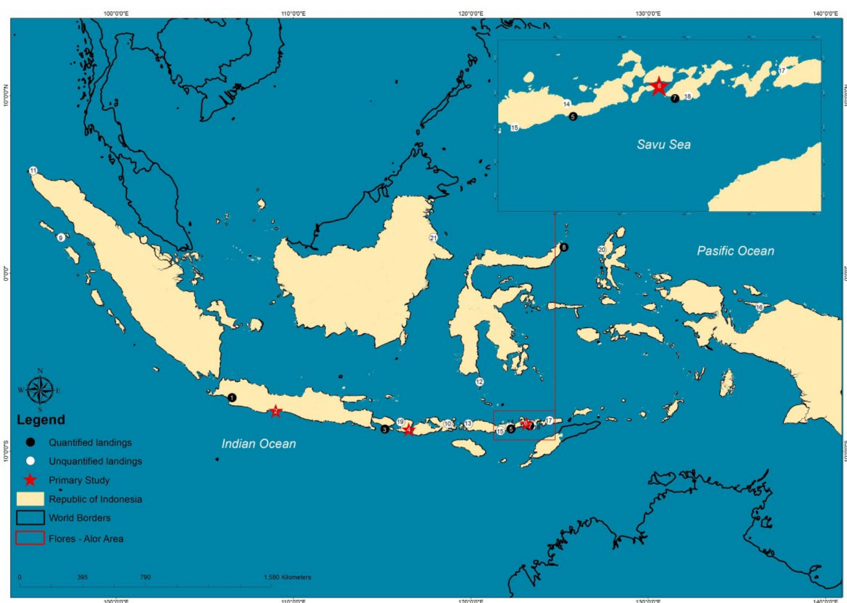

Figure 7. Map of Indonesia showing identified landing sites of mobulids (represented by black circles, white circles, and red stars). Source: Lewis et al. (2015)

Manta rays (presumably *M. birostris,* but identification prior to the split of the genus) have traditionally been harvested in Indonesia using harpoons and boats powered by paddles or sails, with manta fishing season lasting from May through October. Whereas historically the harvested manta rays would be utilized by the village, the advent of the international gill plate market in the 1970s prompted the commercial trade of manta ray products, with gill plates generally sent to Bali, Surabaya (East Java), Ujung Pandant (Sulawasi), or Jakarta (West Java) for export to Hong Kong, Taiwan, Singapore and other places in Asia (Dewar 2002; White et al. 2006; Marshall and Conradie 2014). This economic incentive, coupled with emerging technological advances (e.g., motorized vessels) and an increase in the number of boats in the fishery, greatly increased fishing pressure and harvest of manta rays in the 1990s and 2000s (Dewar 2002). In Lamakera, Indonesia, one of the main landing sites for mobulids, and particularly manta rays, Dewar (2002) estimates that the total average harvest of "mantas'' during the 2002 fishing season was 1,500 (range 1,050-2,400), a significant increase from the estimated historical levels of around 200-300 mantas per season; however, Lewis et al. (2015) note that this estimate likely represents all mobulid rays, not just mantas. Fishermen from Lamalera, whose fishing grounds overlap with the Lamakera fishing fleet, reported landings of around 200-300 per season but noted that very few mantas were caught from 1998-2001, and attributed the low catch to the presence and competition of Taiwanese fishing ships, which also began fishing off Lamalera in large numbers in the 1990s (Barnes 2005).

Given these amounts, it is perhaps unsurprising that anecdotal reports from fishermen indicate possible local population declines, with fishermen noting that they have to travel farther to fishing grounds as manta rays are no longer present closer to the village (Dewar 2002; Lewis et al. 2015). In fact, using the records from Dewar (2002) and community (local) catch records, Lewis et al. (2015) show that there has been a steady decline in manta landings at Lamakera since 2002 (despite relatively unchanged fishing effort), with estimated landings in 2013-2014 comprising only 25% of the estimated numbers from 2002-2006 (**Figure 8**).

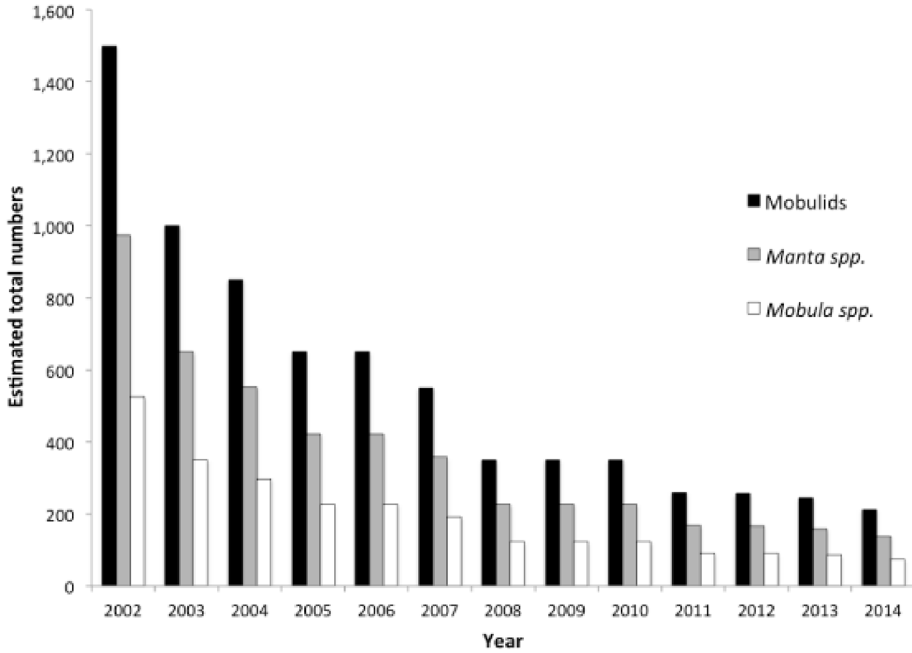

Figure 8. Estimated mobulid landings from Lamakera, Indonesia. Data from 2014 are actual recorded landings by genus. Source: Lewis et al. (2015)

These declines in manta ray landings are not just limited to Lamakera, but also appear to be the trend throughout Indonesia at the common mobulid landing sites (see **Figure 7** – red star locations). In Tanjung Luar, Lewis et al. (2015) reported a 95% decline in the number of manta landings between 2001-2005 and 2013-2014 (from 272 annual individuals to only 14), with a decrease in the average size of mantas being caught (**Figure 9**). Although effort varied over the time period, the authors suggest that the evidence of substantial decline over periods of both increasing and decreasing effort, as well as decreased size of mantas, strongly indicates an overall decline in the abundance of the species. In the Cilacap gillnet fishery, where mantas are caught as bycatch during tuna gillnet fishing, the decrease in landings was on the order of 71% between 2001-2005 and 2014 (from an average of 53 mantas per year down to 15) (**Figure 10**) (Lewis et al. 2015).

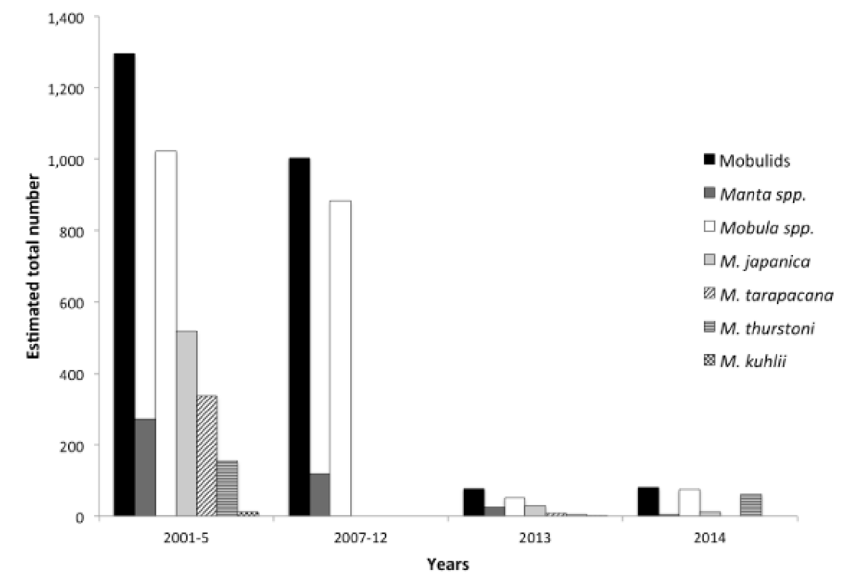

Figure 9. Estimated mobulid landings from Tanjung Luar, Indonesia. Source: Lewis et al. (2015)

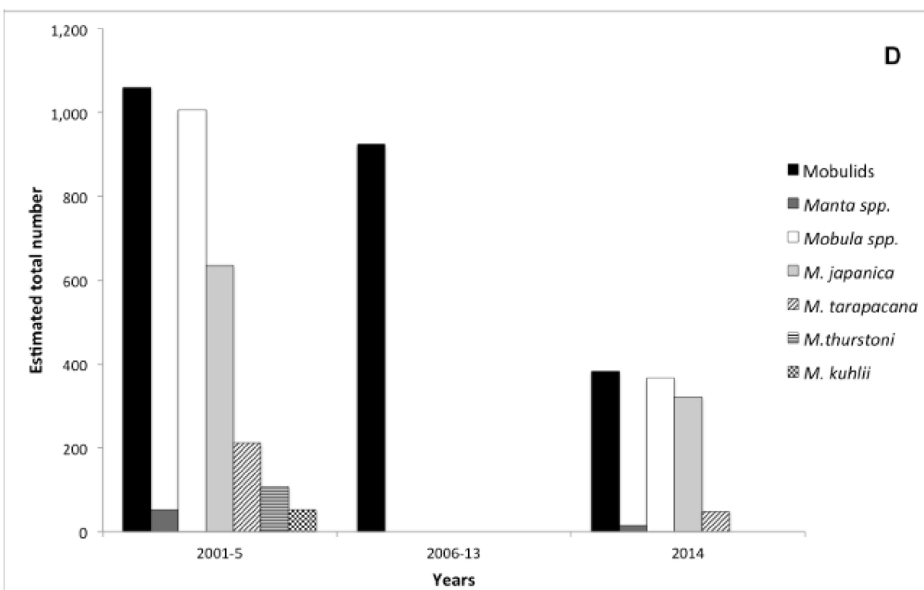

Figure 10. Estimated mobulid landings in gillnet fishery from Cilacap, Indonesia. Source: Lewis et al. (2015)

Areas in Indonesia where manta rays have potentially been fished to extirpation, based on anecdotal reports (e.g., diver sightings data and fishermen interviews), include Lembeh

Strait in northeast Sulawesi (after trap nets were installed in the Lembeh Strait channel), Selayer Islands in South Sulawesi, and off the west coast of Alor Island, which may have been an *M. alfredi* population that disappeared within 5 years after a local village installed drift nets in the middle of the channel separating Alor and Pantar Islands (Lewis et al. 2015). Local fishermen who fish in Pulau Banyak off the west coast of Sumatra and catch mantas as bycatch in gillnets have also reported a significant decrease in sightings, possibly a result of bycatch fishing pressure (Lewis et al. 2015).

Although fishing for manta rays was banned within the Indonesian exclusive economic zone (EEZ) in February 2014 (see ***Inadequacy of Existing Regulatory Measures***), in May 2014, manta rays were still being caught and processed at Lamakera, with *M. birostris* the most commonly targeted species (Marshall and Conradie 2014). Around 200 fishing vessels targeting mantas were in operation; however no more than 100 went out at one time, with usually between 30 and 60 per day (Marshall and Conradie 2014). Most of the fishing occurs in the Solor Sea and occasionally in the Lamakera Strait, with landings generally comprising around one to two dozen manta rays per day. Taking into account the manta ray fishing season in Lamakera (June to October), Marshall and Conradie (2014) estimate that between 625 and 3,125 manta rays (likely majority *M. birostris*) may be landed each season. Lewis et al. (2015), however, report a much smaller number, with 149 estimated as landed in 2014. Simeon et al. (2019) also observed *M. birostris* being landed at the Tanjung Luar Fishing Port from 2014 – 2017, after the manta ray prohibition went into effect, but did note a decrease in the landing of vulnerable ray species from bottom longline trips during this time period and suggested that the prohibition may have influenced some fishermen to decrease targeting of mobulid species.

However, given most of the available information, it is unlikely that fishing effort and associated utilization of the species will significantly decrease in the foreseeable future. Interviews with Indonesian fishermen indicate that many are excited for the prohibition on manta rays because it is expected to drive up the price of manta ray products, significantly increasing the current income of current resident fishermen (Marshall and Conradie 2014). Based on unpublished data, O'Malley et al. (2013) estimates that the total annual income from the manta ray fisheries in Indonesia is around $442,000 (with 94% attributed to the gill plate trade). In fact, significant amounts of *Mobula spp*. gill plates are still being exported from Indonesia to Hong Kong (**Table 6**).

Table 6. Recent information on the amount of *Mobula spp.* gill plates exported by Indonesia. (CITES Trade Database; version 2023.1)

Year	Taxon	Importer	Exporter	Importer reported quantity	Exporter reported quantity	Term and Unit
2018	Mobula spp.	Hong Kong	Indonesia	574.85		gill plates; kg
2019	Mobula spp.	Hong Kong	Indonesia	1717.3	1096.65	gill plate; kg
2021	Mobula spp.	Hong Kong	Indonesia	1017.1	1017.1	gill plates; kg

Dharmadi et al. (2015) noted that there are still many fishermen, particularly in Raja Ampat, Bali, and Komodo, whose livelihood depends on shark and ray fishing. Without an alternative for income, it is unlikely that these fishing villages will stop their traditional fishing practices. Additionally, enforcement of existing laws appears to be lacking in this region, with Marshall and Conradie (2014) also observing the practice of blast fishing in the waters surrounding Lamakera, despite this practice being illegal in Indonesian waters. The high market prices for manta products (see **Table 7**) drives the incentive to continue fishing the species, and evidence of continued targeted fishing despite prohibitions suggests that overutilization of the Indonesian manta ray populations is likely to continue to occur into the foreseeable future.

Table 7. Market prices (in rupees (Rp) and U.S. dollars) for mobulid products in Indonesia in A) Tanjung Luar and B) Lamakera. *Estimated for manta ~5m DW. Source: Lewis et al. (2015)

A) Tanjung Luar

	2005 (Aug)	2010 (Jul)	2014 (Jan)	2015 (Jun)
Whole *Manta**	1.67 mill. Rp	4.1 mill. Rp		3-6 mill. Rp*
	$169	$453		$225 - $450
Whole *Mobula*		1.67 mill. Rp		500K-3 mill. Rp
		$184		$38 - $225
Dried gills / kg - *Manta* (~ 3-6kg per manta)	275K Rp	800K Rp	2 mill. Rp	1.2 mill. Rp
	$28	$88	$169	$90
Dried gills /kg - *Mobula* (~ .5-3kg per mobula)	137.5K Rp			500,000Rp
	$14			$38
Mobulid meat / kg (~ 10-50kg per mobuild)	3K Rp	8K Rp	8K Rp	10K Rp
	$0.30	$0.88	$0.68	$0.75
Skin / cartilage - per *Manta*	330K Rp			
	$33			

B) Lamakera

	2002 (May)	2011 (Jul)	2014 (Jan)	2015 (Jun)
Whole *Manta**		2 mill. Rp	1 mill. Rp	
		$234	$84	
Dried gills / kg - *Manta*	280K Rp	1 mill. Rp	1.5 mill. Rp	1 mill. Rp
	$30	$117	$127	$75
Dried gills /kg - *Mobula*		250K Rp		400K Rp
		$29		$30
Mobulid meat / kg	1.5K Rp	6K Rp	6K Rp	6K Rp
	$0.16	$0.70	$0.51	$0.45
Skin / cartilage - per *Manta*	60K Rp			
	$6			

Australia

In Australian waters, manta rays (identified as *M. birostris*) were identified as potential bycatch in the Commonwealth Skipjack Tuna Fishery and Western Tuna and Billfish Fishery. However, in a sustainability assessment of these fisheries, Zhou et al. (2009) determined that the current fishing effort poses a low risk to many non-target species caught within this fishery, including manta rays. This is likely due to the minimal spatial overlap between the fishing effort and the species' distribution, with the fraction of distribution area within the fishery area of operation equating to <0.005 for both fisheries (Zhou et al. 2009). Overall, Simpfendorfer (2014) states that there is no data to suggest that *M. birostris* are caught with any frequency or retained in Australian fisheries.

Pacific Region

Western Pacific Subregion

In the western Pacific fisheries, *Manta* spp. are reported in the bycatch. In the tropical tuna purse seine fisheries, Hall and Roman (2013) note that *M. japonica* represents the most abundant mobulid in the fishery bycatch. However, analysis of the catch of Western and Central Pacific Fisheries Commission (WCPFC) purse seine and longline fisheries from 1995-2015 (based on observer data) showed that *M. birostris* is regularly caught as bycatch (Tremblay-Boyer and Brouwer 2016). In purse seine sets, the species is observed at a rate of 0.0017 individuals per associated set and 0.0076 individuals per unassociated set (Tremblay-Boyer and Brouwer 2016). Yet the available standardized purse seine CPUE data (**Figure 11**) from the Western and Central Pacific Ocean show strong reporting bias trends as observers reporting down to species-level did not became prevalent until after 2008. Therefore, the purse seine CPUE data is not particularly useful for accurately assessing abundance trends (Tremblay-Boyer and Brouwer 2016). The most recent bycatch estimate of mobuild rays in the large-scale equatorial purse seine fishery was 2,654 individuals in 2020.

In the longline fisheries, *M. birostris* is observed at a rate of 0.001-0.003 individuals per 1,000 hooks (Tremblay-Boyer and Brouwer 2016). The longline standardized CPUE data, while short, provides a more accurate representation of the species' abundance trend due to traditional focus on species in longline observer programs. The data indicate that *M. birostris* is observed less frequently in recent years compared to 2000-2005 (**Figure 10**) (Tremblay-Boyer and Brouwer 2016). Based on the distribution of longline effort from 2000-2015 in the WCPFC longline fisheries, effort has been concentrated around Indonesia and the Philippines (Williams and Terawasi 2016), where significant declines in the species have been observed. Williams and Terawasi (2016) also note that there has been a growth in the domestic fleets operating in the South Pacific over the past decade, with effort clearly increasing between 2004 and 2015. It is important to note that in an Ecological Risk Assessment done by Kirby and Hobday (2007) for the WCPFC, *M. birostris* was assessed as having a medium to high risk from fisheries interactions.

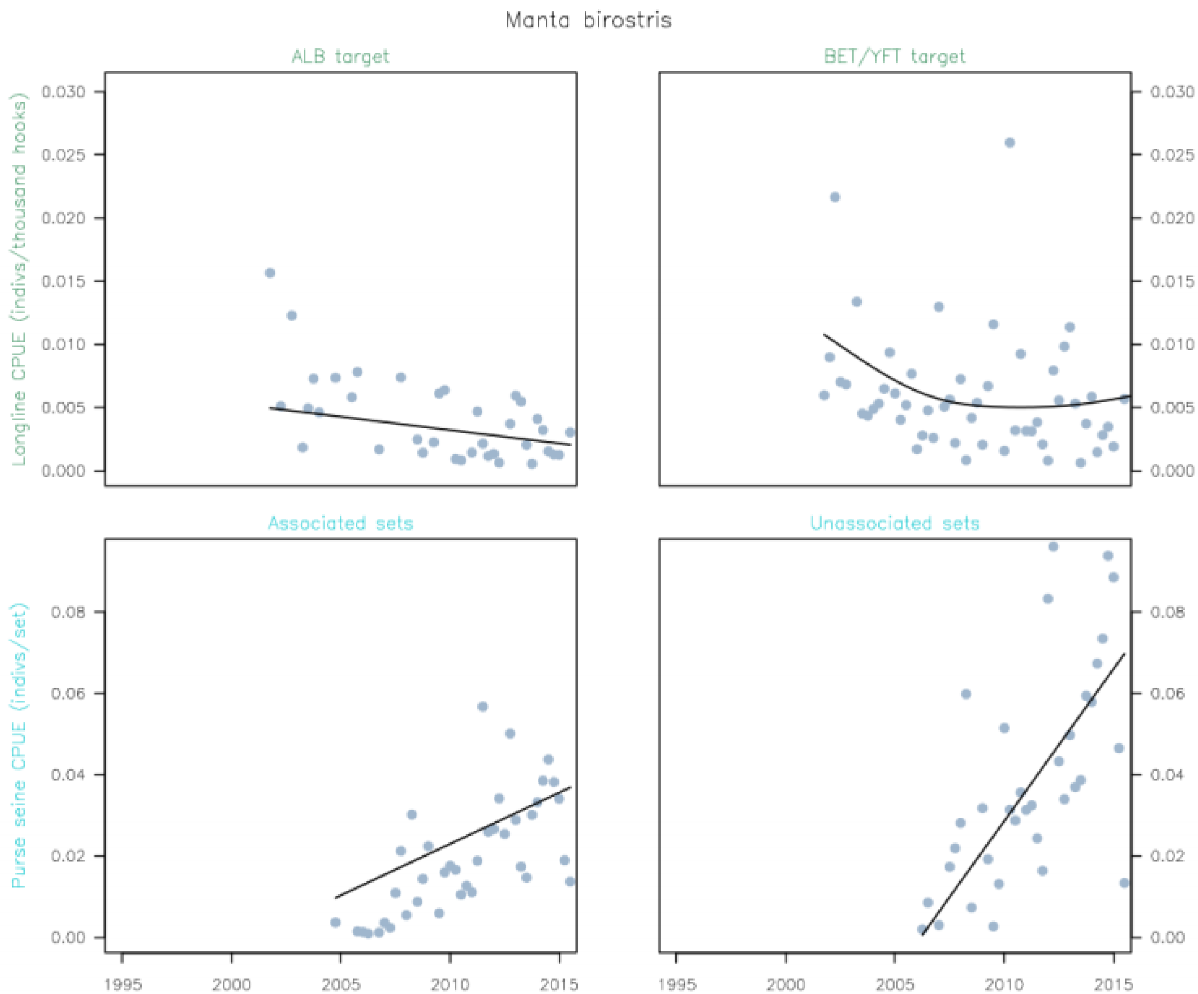

Figure 11. Observed catch per unit effort (CPUE) of *M. birostris* from 1995-2015 in longline sets (albacore (ALB) and bigeyes and yellowfin tuna (BET/YFT) target sets) and purse seine sets (associated and unassociated) within the Western and Central Pacific Ocean, standardized to observed number of individuals per observed hook using 95th percentile. Source: Tremblay-Boyer and Brouwer (2016)

Philippines

In the Philippines, fishing for manta rays mainly occurs in the Bohol Sea Region, emanating from Bohol, Camiguin, and Mindanao Islands (Alava et al 2002; Acebes 2009) and dates back to at least the late 19th century. Based on interviews and historical records, manta rays were hunted by fishermen from the villages in Lila, Pamilacan, Jagna, Sagay, Guinsiliban, and Limasawa (see **Figure 12**), and utilized primarily for their meat (Acebes and Tull 2016). According to Acebes and Tull (2016), the manta ray fishery can be divided into two distinct periods based on technology and fishing effort: 1) 1800s to 1960, when mantas were mainly hunted in small, non-motorized boats using harpoons from March to May and 2) 1970s to 2013 (present), when boats became bigger and motorized and the fishing technique switched to drift gillnets, with the manta hunting season extending from November to June.

In the earlier period, the manta fishing grounds were fairly close to the shore (<5 km), noted along the coasts of southern Bohol, northwestern and southern coasts of Camiguin and eastern coasts of Limasawa. Boats would usually catch around one manta per day, with catches of 5-10 mantas for a fishing village considered a "good day" (Acebes and Tull 2016). Based on interviews with fishermen from Jagna, there were around 30 to 50 manta ray fishing boats in operation in the 1950s catching mature manta rays (mantas described as being 4-7 m DW) (Acebes and Tull 2016). In Limasawa Island, around 10-20 boats hunted adult manta rays (usual manta size was ~5.5 m DW) although villagers noted that by the 1950s, catching mantas was not a guarantee, with 5 mantas caught over an entire fishing season considered to be "lucky" (Acebes and Tull 2016). As the fishery became more mechanized in the 1970s, transitioning to larger and motorized boats, and as the primary gear changed from harpoons to non-selective driftnets, fishermen were able to access previously unexplored offshore fishing grounds, stay out for longer periods of time, and catch more manta rays (Acebes and Tull 2016). Additionally, it was during this time that the international gill plate market opened up, increasing the value of gill plates, particularly for manta species. By 1997, there were 22 active mobulid ray fishing sites in the Bohol Sea (Acebes and Tull 2016). In Pamilacan, 18 boats were fishing for mobulids in 1993, increasing to 40 by 1997, and in Jagna, at least 20 boats were engaged in mobulid hunting in the 1990s (Acebes and Tull 2016). Catches from this time period, based on the recollection of fishermen from Pamilacan and Baclayon, Bohol, were around 8 manta rays (for a single boat) in 1995 and 50 manta rays (single boat) in 1996 (Alava et al. 2002). However, it should be noted that the mobulid fishery ended in Lila and Limasawa Island in the late 1980s and in Sagay in 1997, around the time that the whale fishery ended and a local ban on manta ray fishing was imposed (Acebes and Tull 2016).

Despite increases in fishing effort, catches of mantas began to decline, likely due to a decrease in the abundance of the population, prompting fishermen to shift their fishing grounds farther east and north (**Figure 12**).

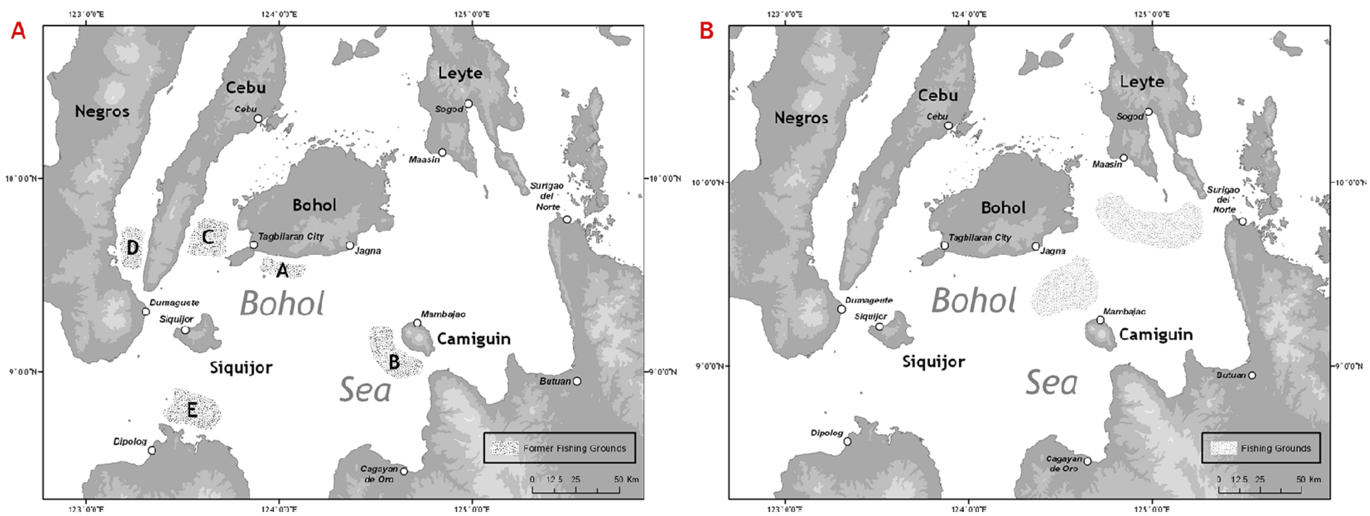

Figure 12. Maps depicting shifts in mobulid fishing grounds in the Bohol Sea, Philippines. Mobulid fishing grounds are shaded in light gray. A) Mobulid fishing grounds in 1997; B) Mobulid fishing grounds in recent years. Source: Acebes and Tull (2016)

Although a ban on hunting and selling giant manta rays was implemented in the Philippines in 1998 (see ***Inadequacy of Existing Regulatory Measures***), this has not seemed to impact the mobulid fishery in any way. In Pamilacan, there were 14 mobulid hunting boats reported to be in operation in 2011 (Acebes and Tull 2016). In the village of Bunga Mar, Bohol, there were 15 boats targeting mobulids in 2012, and out of 324 registered fishermen, over a third were actively engaged in ray fishing (Acebes and Tull 2016). Due to their size, the boats can only catch a maximum of 4 giant manta rays per trip (Acebes and Tull 2016). Acebes and Tull (2016) monitored the numbers of manta rays landed at Bunga Mar over a period of 143 days from April 2010 to December 2011 (during which there were around 16-17 active fishing boats targeting mobulids), and in total, 40 *M. birostris* were caught. In 2013, records from a single village (location not identified) showed over 2,000 mobulids landed from January to May, of which 2% (n=51 individuals) were *M.*

birostris (Verdote and Ponzo 2014). On the island of Bohol, fishermen are known to target *Mobula* rays using drift gillnets (Bessey et al. 2019), with Rambahiniarison et al. (2023) estimating that at least 100 *M. birostris* were landed per season up to 2017. As there is little evidence of enforcement of current prohibitions on manta ray hunting, and no efforts to regulate the mobulid fisheries, it is unlikely that fishing for mantas will decrease in the future, particularly since fishing is the primary source of income for the people of Jagna and Pamilacan and a "way of life," with mobulid fishing providing the greatest profit (Acebes and Tull 2016). Based on market surveys and interviews between 2010 and 2012, dried manta meat in the Philippines markets was selling for around $16-$23 per kg (Acebes and Tull 2016). Dried gill plates, which are usually sold to middlemen from Cebu who export them to China or Manila, sold for around $69 per kg for white gills and up to $115 per kg for dark gills (Acebes and Tull 2016). Based on these figures, an average manta ray of around 3 m DW could likely fetch up to $808 (Acebes and Tull 2016).

Although there is a lack of baseline population data for the giant manta rays within the Bohol Sea, it is likely that the continued unregulated fishing on the species will only have negative impacts on the population. This is especially true given the historical fishing pressure on adults (Smallegange et al. 2016) and the evidence of the species being fished out of areas of the Bohol Sea. Additionally, sightings records further support the likely decline in populations as the available data, which span between 2005 and 2020, show a significant decrease in observations of the species throughout the Bohol Sea (Rambahiniarison et al. 2023). In Daanbantayan, the frequency of sightings declined from 73 individuals, seen between 2006 and 2012, to only 16 individuals between 2013 and 2019, despite an increase in diving efforts. Similarly, in San Jacinto, 15 individuals were sighted between 2013 and 2014 but only 3 were sighted between 2017 and 2018 (Rambahiniarison et al. 2023). Overall, manta ray populations appear to be in decline and subject to the continuing threat of overutilization.

Papua New Guinea

A sharp decline in the catches of manta rays off Papua New Guinea, where WCPFC fishing effort is high, was observed in Papua New Guinea purse seiner bycatch in 2005/2006 (C. Rose pers. comm. cited in Marshall et al. 2011b). This occurred after a previously steady rise in manta ray catches from 1994 to 2005/2006, where manta rays comprised, on average, 1.8% of the annual bycatch (C. Rose pers. comm. cited in Marshall et al. 2011b).

Central Pacific Subregion

New Zealand

Off New Zealand, manta rays (*M. birostris*) are frequently reported as bycatch in the skipjack tuna (*Katsuwonus pelamis*) purse seine fishery, which operates around the northern North Island (Jones and Francis 2017). Interviews with fishermen indicate that manta ray sightings and encounters peak in January/February as they follow the influx of warm water (20°C) to the area, with manta rays found in around 40-50% of the tuna schools (Jones and Francis 2017). However, the interviewees noted that manta rays are seen as a nuisance, scaring away the tuna from the purse seine net, so when observed in a school, fishermen will generally not target that school (Jones and Francis 2017). Additionally, when caught, fishermen will often attempt to release the manta ray from the net while still in the water (Jones and Francis 2017). As such, they indicate that only rarely are manta rays actually landed on the boat deck (Jones and Francis 2017). In contrast, observer data from 2004/2005 through 2010/2011 indicate that "manta rays" are actually brought on the deck of the boat in a high proportion of these occurrences, which may result in unknown but potentially high levels of post-release mortality (Jones and Francis 2017). However, based on photographic evidence of these occurrences, it is thought that the majority (if not all) of these "manta rays" are actually spinetail devil rays (*Mobula japonica*) and not *Mobula birostris* (Jones and Francis 2017).

United States

Manta rays have been identified in U.S. bycatch data from fisheries operating primarily in the Central and Western Pacific Ocean, including the U.S. Western and Central Pacific Ocean (WCPO) purse seine fishery, the Hawaii-based deep-set and shallow-set longline fisheries for tuna and swordfish, and the American Samoa pelagic longline fishery. However, based on the low estimates of *M. birostris* bycatch, impacts on giant manta ray populations, survival, and recovery are likely to be minimal.

U.S. Western and Central Pacific Ocean Purse Seine Fishery

In the U.S. WCPO Purse Seine Fishery, giant manta rays are caught as bycatch, but at levels that are not impacting survival or recovery. Since 2010, the U.S. WCPO purse seine fishery has had 100% observer coverage. Fisheries observers are the only independent data collection source for some types of at-sea activities. From 2010 to 2018, 1,523 giant mantas were reported to be caught incidentally. By including an estimate of those unidentified animals that would be expected to be giant manta rays, and adding in an additional two years, NMFS (2021a) estimated that a total of 3,676 giant manta rays were captured by the U.S. WCPO purse seine fishery between 2008 and 2018. However, it is important to note that this number is likely an overestimate based on misidentification, as explained below. The observed incidental captures of giant manta rays occurred mainly around the Republic of Nauru, Tapiwa, Kiribati, and to the west abutting the western coast of South Tawara, Kiribati, with interactions occurring throughout the year but peaking in November and December (**Figure 13**, NMFS 2021a).

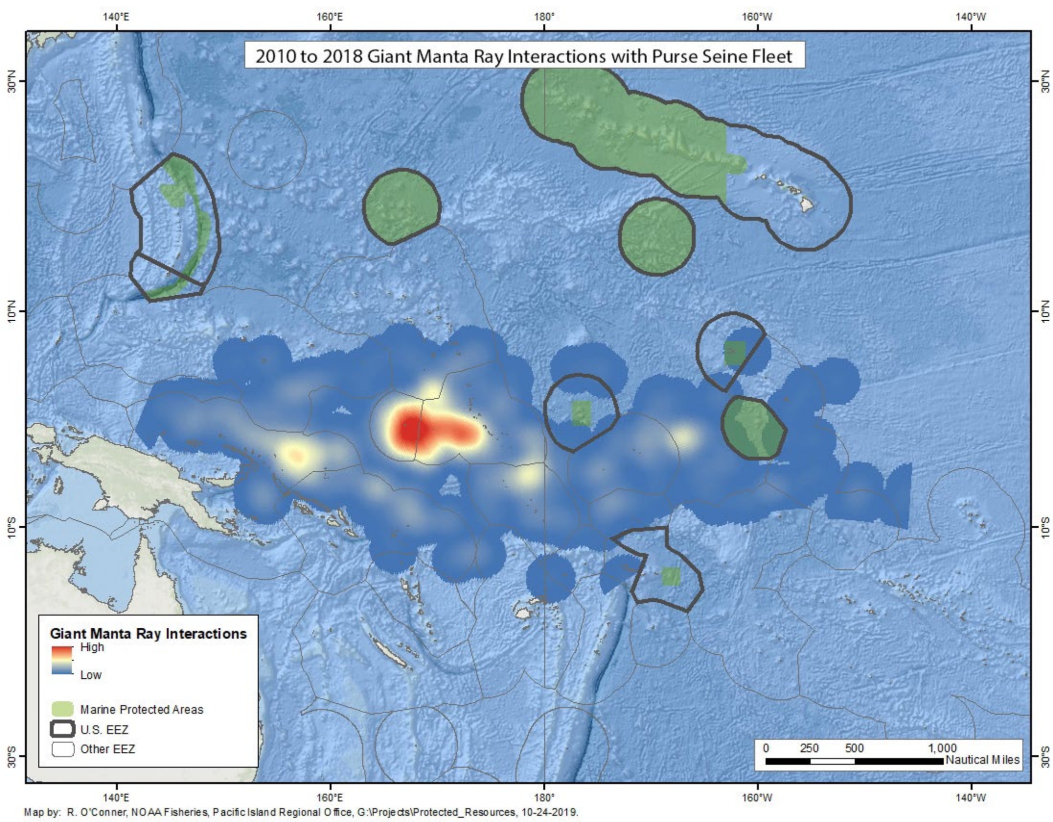

Figure 13. Geographical representation of aggregate observed giant manta ray interactions from 2010 to 2018 in the United States WCPO purse seine fishery. Source: NMFS (2021a)

Based on historical handling procedures (e.g., gaffing, hooks and pulleys, etc.), it was assumed that all individuals released with unknown conditions were dead, resulting in an assumed 96% mortality rate. Using this mortality rate, as well as the assumption that 75% of giant manta ray captures (1,523) were misidentified by observers and that 75% fewer of the unidentified mobulids are giant manta rays, NMFS (2021a) estimated that, on average, the U.S. WCPO purse seine fishery will likely interact with 45 giant manta rays each year and of those, 43 would be expected to die as a result of the interaction (**Table 8**). The maximum 5-yr running average was calculated to be 47 giant manta rays with 45.2 of those expected to die.

Table 8. Anticipated annual and maximum 5-year running average number of giant manta rays captured and likely to die as a result in the U.S. WCPO purse seine fishery, with the adjustment to account for the likely 75% misidentification of species by observers. Source: NMFS (2021a)

	U.S. WCPO Purse-Seine Fishery Encounters			
Rate	Mean (number of captures)	95th Percentile	Mean (number likely to die)	95th Percentile
Annual	45	50	43	48
Maximum 5-Yr Running Average	47	N/A	45.2	N/A

Based on the best available data, including examination of the observer data, fishery interaction rates, population abundance, and the median maximum population growth rate (rmax) values to assess the potential impact of the fishery on giant manta ray subpopulations in the U.S. WCPO fishing area, NMFS (2021a) found that the U.S. WCPO purse seine fishery does not have biological consequences to the species' numbers, reproduction, or distribution that could reduce appreciably the likelihood of the survival or recovery of the giant manta ray in the wild.

Hawaii deep-set longline fishery

In the Hawaii deep-set longline fisheries (DSLL), giant manta rays are caught as bycatch, but at pretty low levels. Based on observed incidental captures and using an expansion factor, it was estimated that around 239 giant manta rays were likely incidentally captured in the DSLL fishery from 2004 to 2022 (a 19-year period) (**Figure 14**; NMFS 2023a). By including an estimated portion of the unidentified *Mobulidae spp*, this increased to 328. These observed incidental captures of giant manta ray occurred mainly south of the Main Hawaiian Islands and in or near the Palmyra EEZ, and largely during the month of April.

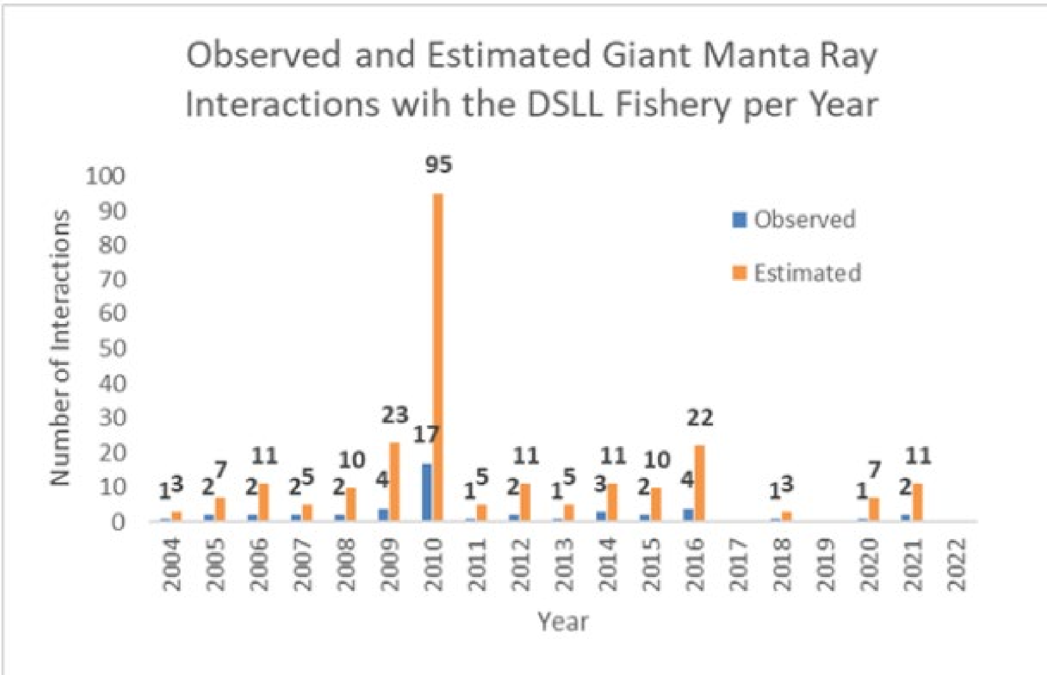

Figure 14. Giant manta ray interactions per year in the DSLL fishery between 2004 and 2022 for observed interactions (blue bars) and estimated interactions (orange bars). Source: NMFS (2023a)

When examining the mortality rate of the observed captured manta rays, only one was dead at capture, resulting in a mean at-vessel mortality rate of 2.10%. The post-release survival rate is unknown. However, in order to determine the anticipated annual and 5-year average exposures of giant manta rays in the DSLL fishery and potential mortality rates, NMFS (2023a) used a surrogate species to assess potential post-interaction mortality. The result showed that, on average, the Hawaii DSLL will likely interact with only 23 giant manta rays each year and of those, 10 would be expected to die as a result of the interaction (**Table 9**). The maximum 5-yr running average was calculated to be 39.7 giant manta rays with 16.9 of those expected to die.

Table 9. Anticipated annual and maximum 5-year running average number of giant manta rays captured and likely to die as a result in the DSLL fishery. Source: NMFS (2023a)

	DSLL Encounters			
Rate	Mean (number of captures)	95th Percentile	Mean (number likely to die)	95th Percentile
Annual	23	68	10	
Maximum 5-Yr Running Average	39.7	N/A	16.9	N/A

Based on a number of combinations of fishery interaction rates, initial population abundance, and rmax values to assess the potential impact of the fishery on giant manta ray subpopulations in the DSLL fishing area, NMFS (2023a) found that the DSLL fishery does not have biological consequences to the species' numbers, reproduction, or distribution that could reduce appreciably the likelihood of the survival or recovery of the giant manta ray in the wild.

Hawaii shallow-set longline fishery

In the Hawaii shallow-set longline fisheries (SSLL), giant manta rays are caught as bycatch, but at pretty low levels. The Hawaii SSLL has 100% observer coverage. From 2004 to 2018, 17 giant manta rays were incidentally caught (a 15-year period; NMFS 2019). By including an estimated portion of the unidentified *Mobulidae spp*, this increased to 21. These observed incidental captures of giant manta ray occurred mainly in the Liliuokalani Ridge, and largely during the month of July (**Figure 15**; NMFS 2019).

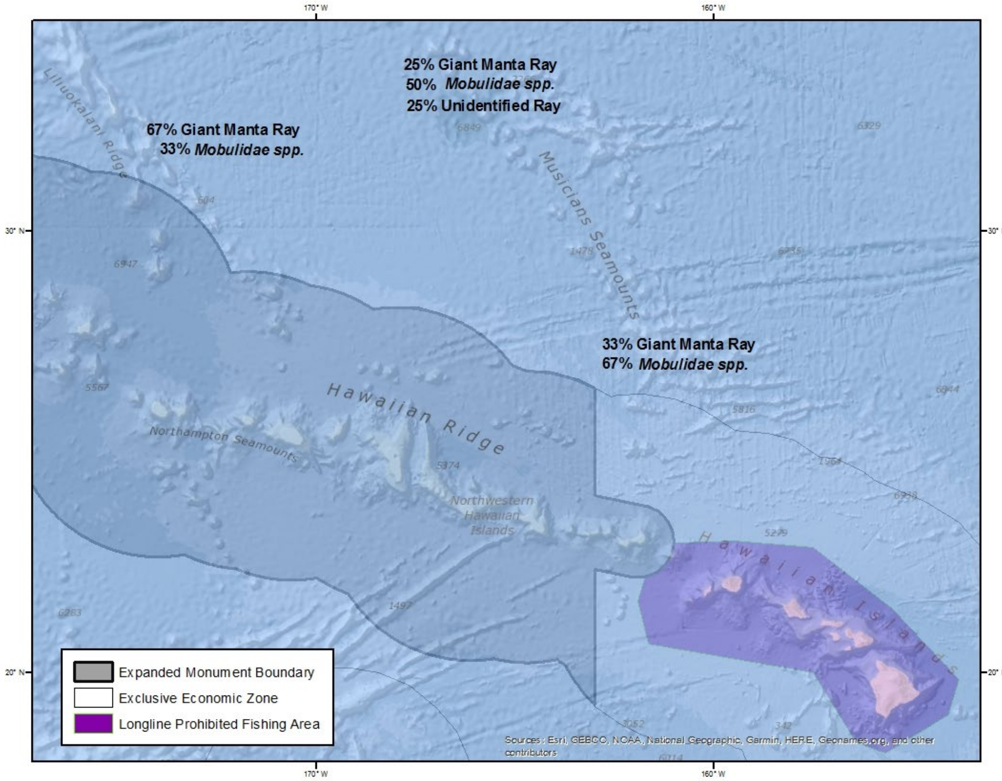

Figure 15. General location of interactions with giant manta ray, manta/mobula and unidentified ray and the percentage of each classification in each area. Source: NMFS (2019)

When examining the mortality rate of the observed captured manta rays, four were dead at capture (out of the 17 total). The post-release survival rate is unknown. In order to determine the anticipated annual encounter of giant manta rays in the SSLL fishery and potential mortality rates, NMFS (2019) used a surrogate species to assess potential post-interaction mortality. The result showed that, on average, the Hawaii SSLL will likely interact with a mean of 7 and up to 13 giant manta rays each year (**Table 10**). Over a 3-year time period, the Hawaii SSLL is estimated to capture a mean of 12 and up to 22 giant manta rays. The number of giant manta rays that would likely die from capture would be up to 4 in any year (mean = 2) or up to 9 over a 3-year period.

Table 10. Anticipated average number of giant manta rays captured and likely to die as a result in the SSLL fishery over a 3-year period. Source: NMFS (2019)

	SSLL Encounters			
No. of Years	Mean (number of captures)	95th Percentile	Mean (number likely to die)	95th Percentile
1	7	13	2	4
2	9	18	4	7
3	12	22	4	9

Based on the evidence available, NMFS (2019) found that the incidental take and resulting mortality of giant manta rays associated with the direct and indirect effects of NMFS' continued authorization of the Hawaii SSLL fishery would not affect the giant manta ray's ability to meet its lifecycle requirements or retain the potential for recovery.

American Samoa Longline Fishery

In the American Samoa longline fishery (ASLL), giant manta rays are caught as bycatch at low levels. Based on observed incidental captures and using an expansion factor, it was estimated that around 64 giant manta rays were likely captured incidentally in the ASLL fishery from 2010 to 2019 (a 10-year period) (NMFS 2023b). By including an estimated portion of the unidentified *Mobulidae spp*, this increased to 86.

When examining the mortality rate of the observed captured manta rays, none were dead at capture, resulting in a mean at-vessel mortality rate of 0%. The post-release survival rate is unknown. However, in order to determine the anticipated annual and 5-year average exposures of giant manta rays in the ASLL fishery and potential mortality rates, NMFS (2023b) used a surrogate species to assess potential post-interaction mortality. The result showed that, on average, the ASLL will likely interact with only 11 giant manta rays each year and of those, 3 would be expected to die as a result of the interaction (**Table 11**). The maximum 5-yr running average was calculated to be 11.4 giant manta rays with 3.3 of those expected to die.

Table 11. Anticipated annual and maximum 5-year running average number of giant manta rays captured in the ASLL fishery and number likely to die as a result. Source: NMFS (2023b)

	ASLL Encounters			
Rate	Mean (number of captures)	95th Percentile	Mean (number likely to die)	95th Percentile
Annual	11	33	3	10
Maximum 5-Yr Running Average	11.4	N/A	3.3	N/A

Based on a number of combinations of fishery interaction rates, initial population abundance, and rmax values to assess the potential impact of the fishery on giant manta ray subpopulations in the ASLL fishing area, NMFS (2023b) found that the ASLL fishery will not have biological consequences to the species' numbers, reproduction, or distribution that could reduce appreciably the likelihood of the survival or recovery of the giant manta ray in the wild.

Kiribati

In Kiribati, manta rays (likely *M. alfredi*) are reportedly caught as bycatch in gillnets. According to a local dive operator, the local population has suffered significant declines (O'Malley et al. 2013); however, no data are available and no other information could be found regarding the fishery or the manta ray population.

Eastern Pacific Subregion

In the eastern Pacific subregion, giant manta rays are frequently reported as bycatch in the tuna-RFMO, the Inter-American Tropical Tuna Commission (IATTC), purse seine fisheries; however, identification to species level is difficult, and, as such, most manta and devil ray captures are pooled together (Hall and Roman 2013). According to data provided in Hall and Roman (2013), prior to 2005, catch and bycatch (defined as individuals retained for utilization and individuals discarded dead, respectively) of manta rays in these purse seines remained below 20 t (data from 1998-2004), but by 2005, it was around 30 t and jumped to around 150 t in 2006. In 2008, catch and bycatch had dropped to 40 t and in 2009 decreased further to less than 10 t (Hall and Roman 2013).

Based on reported *M. birostris* catch to the IATTC, including available national observer program data, an average of 135 giant manta rays were estimated caught per year from 1993-2015 in the eastern Pacific purse seine fishery by IATTC vessels (**Table 12**) (Hall unpublished data; Lezama-Ochoa et al. 2019). Bycatch per set ranged from 0.001 individuals (in log associated sets) to 0.027 individuals (in school associated sets) (Hall unpublished data). More recent data show a decline in mobulid catches, despite an increase in fishing effort by the purse-seine fishery, with catches dropping from 5,022 individuals in 2010 to 705 individuals in 2018 (Griffiths and Lezama-Ochoa 2021).

Table 12. Bycatch of giant manta rays and unidentified manta and devil rays (in numbers per set and average numbers per year) in the Eastern Pacific Ocean by the Inter-American Tropical Tuna Commission purse-seine vessels from the time period of 1993-2015.

Species	**Time Period**	**Bycatch per set**	**Average annual capture (individuals per year)**	**Total (all years)**
Giant manta	1993-2015	0.001 – 0.027 (depending on type of set)	136	2,997
Unidentified manta/devil ray	1993-2015	0.012-0.221	1,865	41,032

While the impact of these bycatch levels on giant manta ray populations is uncertain, effort in the fishery appears to coincide with high productivity areas, such as the Costa Rica Thermal Dome, west of the Galapagos, off the Guayas River estuary (Ecuador), and off central and northern Peru (see **Figure 16**), where giant mantas are likely to aggregate and have been observed caught in sets (Hall and Roman 2013). If effort is concentrated in manta ray aggregation areas, this could lead to substantial declines and potential local extirpations of giant manta ray populations. In fact, a recent preliminary productivity and susceptibility analysis (PSA) indicates that the giant manta ray is one of the most vulnerable species to overfishing in the purse seine fishery by IATTC vessels (Duffy and Griffiths 2017). Specifically, the PSA compared 32 species and calculated vulnerability scores as a combination of the species' productivity and susceptibility to the fishery (Duffy and Griffiths 2017). Out of the three models run, giant manta rays were always one of the top five most vulnerable species (Duffy and Griffiths 2017).

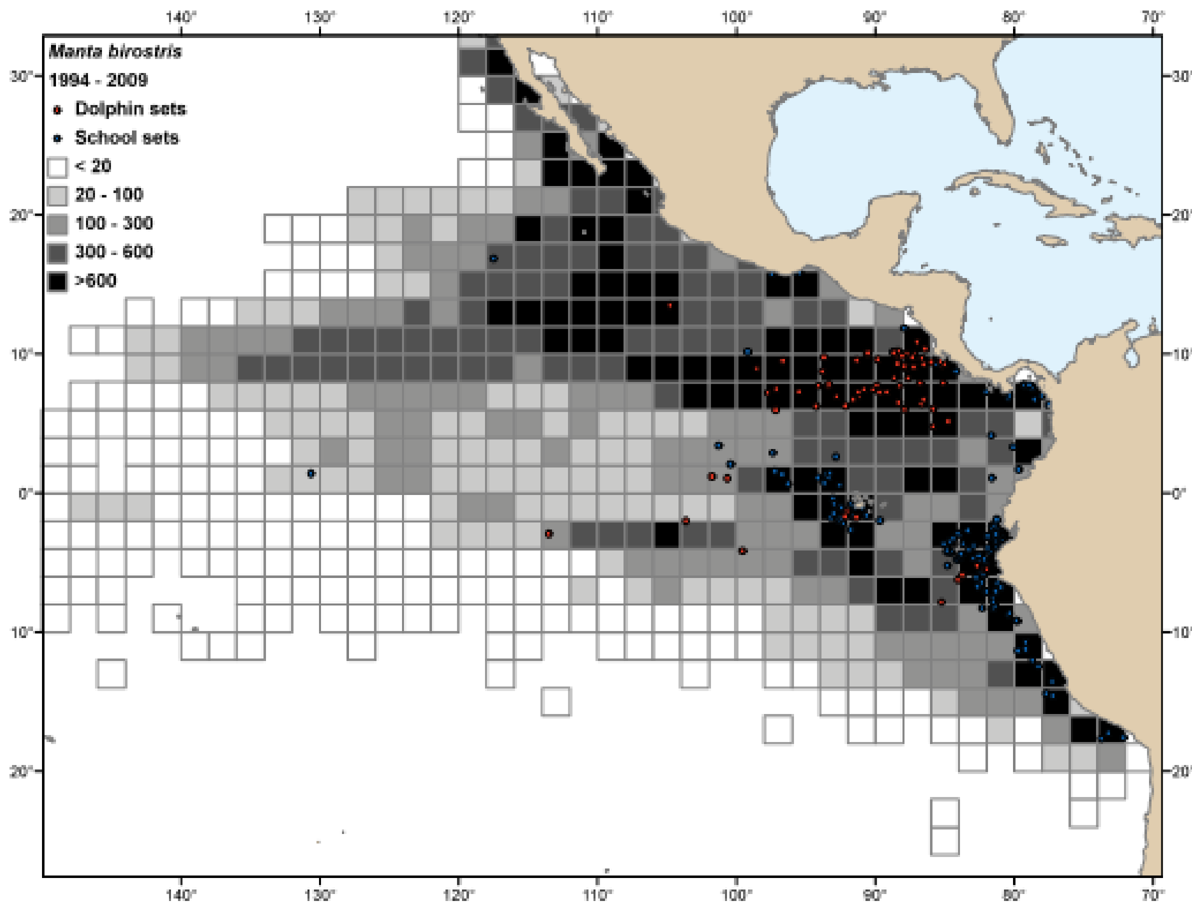

Figure 16. Distribution of purse-seine effort and capture of *M. birostris* in dolphin and school sets in the Eastern Pacific Ocean from 1994-2009. Blue dots = presence of giant manta rays in school sets; Red dots = presence of giant mantas in dolphin sets. Blocks and shading represent effort (i.e., number of sets). Source: Hall and Roman (2013)

Already, evidence of declines in this portion of the giant manta ray's range is apparent, with White et al. (2015) estimating an 89% decline in the relative abundance of *M. birostris* off Cocos Island, Costa Rica. Presently, the largest population of *M. birostris* is thought to reside within the waters off Ecuador (Harty et al. 2022) and given the distribution of the fishing effort (**Figure 16**), it is likely that individuals from this population are highly susceptible to being caught by the purse seine fisheries operating in the area.

In addition to the IATTC tuna purse seine vessels, giant manta rays are also caught as bycatch by the IATTC longline vessels, primarily the deep-set longline vessels. Most recent information, based on observer coverage of vessels associated with China, the U.S., Korea, Colombia, Spain and Venezuela, showed a total catch of 89 *M. birostris* and 34 *Mobula spp*. individuals in 2022 (see https://www.iattc.org/en-US/Data/Other-reports). However, it is important to note that IATTC requires only a minimum of 5% coverage for these longline vessels, so the actual number of bycatch is likely significantly greater.

United States

In U.S. west coast fisheries, *M. birostris* is occasionally observed as bycatch in the California drift gillnet fishery targeting swordfish and threshers, but in low numbers and only during El Niño events. In fact, from 1990 – 2006, giant manta rays were only observed as bycatch in 1992, 1997, and 1998 - all strong El Niño years (Larese and Coan 2008). A total of 14 giant manta rays were observed caught, with 36% released alive and 57% discarded dead (Larese and Coan 2008). Since 2006, no giant manta rays have been observed caught in the California drift gillnet fishery (data available from: http://www.westcoast.fisheries.noaa.gov/fisheries/wc_observer_programs/sw_observer_program_info/data_summ_report_sw_observer_fish.html).

Mexico

Manta and mobula rays were historically targeted for their meat in the Gulf of California. In 1981, Notarbartolo di Sciara (1988) observed a seasonally-active mobulid fishery located near La Paz, Baja California Sur. Mobulids were fished in the Gulf of California using both gillnets and harpoons, with their meat either fileted for human consumption or used as shark bait. The giant manta ray was characterized as "occasionally captured" by the fishery. While it is unclear how abundant *M. birostris* was in this area, by the early 1990s, Homma et al. (1999) reported that the mobulid fishery had collapsed and CITES (2013), referencing anecdotal dive reports by a filmmaker, noted a decrease in manta ray sightings from 3-4 individuals per dive in 1981 to zero in 1991-1992.

Peru

In terms of global batoid landings, from 2005 to 2011, Peru was responsible for 11% of the total landings, ranking 15th in the world. Mobulids, which are primarily caught off the northern coast by gillnets, comprised 28% of the batoid landings (Alfaro-Cordova et al. 2017; Guirkinger et al. 2021). In 2005, interviews with northern Peruvian fishermen (off Salaverry and Chimbote) indicated that manta rays were frequently caught in gillnet gear, with 55% of respondents noting *Manta spp*. as bycatch (Ayala et al. 2008). During that year, gillnet boats comprised 33% of the total artisanal fishing fleet of Peru (Ayala et al. 2008). However, the fishermen did not view manta rays as a commercially viable species. Additionally, Ayala et al. (2008) noted that catching manta rays is actually dangerous for the fishermen operating the smaller artisanal vessels, as the animals tend to cause nets to be lost and can also potentially sink the small boats (Ayala et al. 2008). Yet Heinrichs et al. (2011), citing a rapid assessment of the mobulid fisheries in the Tumbes and Piura regions of Peru, reported estimated annual landings of *M. birostris* on the order of 100-220 rays for one family of fishermen. As such, total landings for Peru are likely to be much larger.

More recently, between January 2015 and February 2016, Alfaro-Cordova et al. (2017) monitored captures and fish-market landings of manta and devil rays by small-scale gillnet fisheries at three landings sites in northern Peru. The authors found that while mobulid ray catch (particularly immature *Mobula japanica*) was relatively high (mean nominal CPUE = 1.6 ± 2.8 mobulids $[km.day]^{-1}$ and peak CPUE of 10.17 ± 2.3 mobulids $[km.day]^{-1}$), no manta rays (*M. birostris*) were observed caught, although one was observed landed (Alfaro-Cordova et al. 2017), suggesting that fishermen may be actively avoiding manta rays. Additionally, fishermen were banned from catching manta rays in Peruvian waters in 2015; however, compliance with the ban seems to be primarily motivated by economics, with fishermen noting the lack of enforcement or consequences and acknowledging targeting or opportunistically catching mantas when target species were rare and quotas were not met (Guirkinger et al. 2021). As such, as other, more profitable species become overfished, there is a higher likelihood that manta rays may be targeted or kept in the foreseeable future.

Atlantic Region

Western North Atlantic Subregion (including Gulf of Mexico and Caribbean Sea)

United States

The giant manta ray is caught as bycatch in a number of U.S. commercial fisheries operating in the Northwest Atlantic Ocean and Gulf of Mexico.

Much of the data comes from fisheries observer programs in the Southeast, United States. It is important to note that the new bycatch information is the result of the observer program efforts to expand data collection and species identification following the listing of the giant manta ray under the ESA. Federal fisheries observer programs in the Southeast began identifying and recording bycatch for the giant manta ray in 2019/2020, respectively, providing a better understanding of giant manta ray interactions with U.S. commercial fisheries.

Based on the observer data, the Southeast U.S. commercial fisheries that use trawls, pelagic and bottom longlines, gillnet and hook and line gears incidentally capture giant manta rays. Of these fisheries, shrimp trawl and pelagic longline gears appear to be interacting with giant manta rays the most, followed by bottom longline, and gillnet. Dispositions of the giant manta rays are recorded at the vessel (i.e., released alive, discarded dead, or disposition unknown). In addition, it is important to note that numerous records exist within the bycatch data where species identification was not determinable and thus generically recorded as “ray” or “mobulid.” This information does not include potential post-release mortality.

The Southeast Shrimp Trawl Fisheries

The Southeast U.S. shrimp fisheries operate within the EEZ in the Gulf of Mexico and South Atlantic. Based on data collected by the observer program, between 2019 and July 2023, approximately 36 individual giant manta rays were caught as bycatch in the trawl gear (NMFS unpublished data). It is likely that total giant manta ray bycatch is higher because the observer coverage in this fishery is less than 2%, meaning that bycatch data is only recorded for a very small percentage of the shrimp trawl fishery. Of the individuals observed captured, 24 were released alive, 4 were dead, and 7 were discarded with an "unknown" disposition (NMFS unpublished data). Giant manta ray bycatch is occurring in the Mississippi Delta area off the coast of Louisiana and to a lesser extent off the coast of Georgia and Florida. While the majority of giant manta ray bycatch has occurred within federal waters, several reports have been documented in State waters as well (NMFS unpublished data).

On April 26, 2021, the NMFS Southeast Regional Office (SERO) issued a Biological Opinion (Opinion) on the implementation of the sea turtle conservation regulations under the ESA and the authorization of the southeast U.S. shrimp fisheries in federal waters under the Magnuson-Stevens Act (NMFS 2021b). As part of the Opinion, an incidental take statement was issued that anticipated the non-lethal capture of 16,780 giant manta rays over 10 years (averaging 1,678 giant manta rays per year) in the shrimp trawl fishery. No giant manta ray mortalities were anticipated because there were no records of lethal interactions at that time. The incidental take estimate was based on 1 year of data, which included 12 interactions documented during that time, and is highly uncertain (Carlson 2020). In 2023, the Opinion was reinitiated because there were mortalities documented by the observer program.

The Pelagic Longline Fishery

The Pelagic Longline Fishery for Atlantic Highly Migratory Species incidentally captures giant manta rays during fishing operations. This fishery comprises relatively distinct segments including: Caribbean, Gulf of Mexico, Florida east coast, South Atlantic bight, Mid-Atlantic bight, Northeast coastal Atlantic, Northeast distant waters, Sargasso Sea, and Offshore waters. Observer coverage is maintained at a minimum of 8%, but some years have higher coverage (NMFS 2020a). From 2020 through 2022, observers (9.9% coverage) recorded 8 giant manta rays captured in pelagic longline gear, of which 3 resulted in mortalities (NMFS unpublished data). These captures occurred in the Atlantic (i.e., mid-Atlantic bight, northeast coastal Atlantic) and Gulf of Mexico. An additional four giant manta rays as bycatch in the Gulf of Mexico in 2008, 2013, and 2014 using photographs as the Southeast observer program did not historically record giant manta ray bycatch (C.

Jones, NMFS, pers. comm. to C.Horn, NMFS, December 20, 2018). Of note, the majority (approximately 60%) of mobulid bycatch records from 2019-2023 lacked identification to the species level. Instead, records were reported more generically as “ray” or “mobulid” species.

On May 15, 2020, NMFS SERO issued a Biological Opinion on the operation of the Pelagic Longline Fishery for Atlantic Highly Migratory Species in federal waters under the Magnuson-Stevens Act (NMFS 2020a). As part of the Opinion, an incidental take statement was issued that anticipated the non-lethal capture of 366 giant manta rays and 6 mortalities over 3 years in the Pelagic Longline Fishery. At that time, the incidental take estimate was uncertain as there was limited incidental capture data of giant manta rays, including mortality data. In addition, uncertainty surrounded species identifications made by the observers as most records pre-dated the ESA listing of giant manta rays and subsequent observer training. In 2022, the Opinion was reinitiated because the number of mortalities documented by the observers have exceeded what was authorized in the 2020 Opinion.

The Shark and Reef Fish Bottom Longline Fisheries

The shark and commercial reef fish bottom longline fisheries are active in the Atlantic Ocean from about the Mid-Atlantic Bight to south Florida and throughout the Gulf of Mexico. Observer data coverage is 3.9% total fishing effort (Decossas and Mathers 2023). NMFS has documented four observations of giant manta ray captures in both the shark and reef fish bottom longline fisheries (NMFS unpublished data, 2023). These captures occurred in the Southeast Atlantic and Gulf of Mexico. All individuals were released alive.

The Coastal Migratory Pelagic Fishery

The Coastal Migratory Pelagic (CMP) Fishery is managed by the Fishery Management Plan for the Coastal Migratory Pelagic Resources in the Gulf of Mexico and Atlantic Region. The fishery primarily targets king mackerel, Spanish mackerel, and the Gulf of Mexico Migratory Group of cobia. The main gear types used in the CMP fishery are hook-and-line (including trolling), cast net, and gillnet. Diver-held spear guns are also a main gear type specific to cobia. On May 1, 2023, NMFS SERO issued a Biological Opinion on the operation of the CMP Fishery in federal waters under the Magnuson-Stevens Act (NMFS 2023c). As part of the Opinion, an incidental take statement was issued that anticipated the non-lethal capture of 714 giant manta rays and 63 mortalities (including post-release mortality) over 3 years in the CMP Fishery. The incidental take is highly uncertain and is based on discard logbook and observer program data from 2010 to 2020. The discards have percent standard error values over 100 indicating a high level of uncertainty (NMFS 2023c).

The U.S. Southeast Gillnet Fishery

The U.S. Southeast Gillnet Fishery is active year round from North Carolina and into the Gulf of Mexico. Many states have banned gillnet fishing in state waters over the last decade and most gillnet fishing is restricted to Federal waters. Observer coverage in the gillnet fishery has ranged from 5-15% depending on the year and available funding (Kroetz et al. 2020). Between 2001 and 2023, observers recorded eight giant manta ray captures, including one mortality (NMFS unpublished data). Giant manta rays were captured in drift (n=7) and strike (n=1) nets primarily targeting sharks and mackerel. All these interactions occurred in the South Atlantic region, with the majority occurring along Florida's east coast, followed by nearshore North Carolina (Kroetz et al. 2020).

The Gulf of Mexico Menhaden Purse Seine Fishery

The Gulf menhaden fishery is the second largest commercial fishery in the U.S. by weight (Bernshtein et al. 2023). The fishery uses large purse seines to harvest an average of 600,000 metric tons of Gulf menhaden each year (SEDAR 2018). This fishery is managed by the individual States under the Gulf States Marine Fisheries Commission Interstate Gulf Menhaden Fishery Management Plan (SEDAR 2018). The fishery occurs in state waters, primarily off Louisiana and Mississippi, with limited effort off Texas and Alabama, and is prohibited in Florida (SEDAR 2018). The fishing season runs for approximately 140 days, and the median number of sets per day is 4-5 (SEDAR 2018; Mroch 2018).

Within the Gulf of Mexico menhaden purse seine fishery, there are no known observed or reported interactions with the giant manta ray. However there is no consistent observer coverage or monitoring of protected species bycatch in this fishery. While there is limited direct bycatch data, the available information indicates that this fishery is a potential threat to the species within this region.

As discussed above, purse-seine fisheries, particularly those operating in the eastern Pacific subregion, are a significant threat and source of known mortality for giant manta rays. The gear and fishing methods used by these tuna purse-seine fisheries with known mortalities of giant manta rays are analogous to those used in the menhaden purse-seine fishery in the Gulf of Mexico. While the menhaden purse-seine fishery appears to deploy shorter nets (i.e., 1400 ft) (SEDAR 2018) compared to the tuna purse-seine fisheries (4900-6500 ft) (Hall and Roman 2013), the menhaden purse-seine fishery operates in much the same way as the tuna purse-seine fisheries.

The likelihood of potential interactions between the Gulf of Mexico menhaden purse-seine fishery and giant manta rays is heightened further because of the significant spatiotemporal overlap between giant manta ray abundance and distribution and the fishery. The menhaden purse-seine fishery operates from the third week of April through the first week of November (SEDAR 2018), which corresponds with the highest nearshore occurrence of giant manta rays within the region (Farmer et al. 2022). Using the Species Distribution Model framework, Farmer et al. (2022) predicted the highest nearshore occurrence of giant manta rays occurs around coastal Mississippi from April to June and again from October to November. This indicates that the menhaden purse-seine fishing season completely overlaps, temporally and spatially, with the greatest nearshore occurrence of giant manta rays in the Gulf of Mexico. In addition, researchers conducting giant manta rays surveys in May and September of 2023 in coastal Louisiana have also documented several giant manta rays within close proximity of purse-seine fishing operations (NMFS unpublished data).

Currently there is no direct evidence that the menhaden purse-seine fishery is interacting with giant manta rays. However, given that this fishery has inconsistent observer coverage and no requirements for reporting giant manta ray bycatch, unreported interactions may be occurring. This belief is bolstered by the information presented above regarding the documented interactions between giant manta rays and other purse-seine fisheries and the spatiotemporal overlap of high species abundance in the Gulf of Mexico and the fishery's operation in the region. Taken together, these lines of evidence suggest the Gulf of Mexico menhaden purse-seine fishery may potentially be a threat to this species; however, more information is needed.

The Cobia Fishery

Cobia is managed in two distinct migratory groups under the Coastal Migratory Pelagics Fishery Management: the Atlantic migratory cobia group (Georgia to New York) and the Gulf migratory cobia group (Texas to Florida's east coast) (84 FR 4733, February 19, 2019). In Federal waters the Gulf migratory cobia group is managed by NOAA Fisheries and the South Atlantic and Gulf Fisheries Management Councils, and in state waters it is managed by the respective state. The Atlantic migratory cobia group is managed by the respective states and the Atlantic States Marine Fisheries Commission, and is no longer federally managed (84 FR 4733, February 19, 2019). While relatively small by the standards of the major recreational fisheries in Florida, it has the highest landings of cobia among recreational fisheries within the Atlantic and Gulf Coast states (84 FR 4733, February 19, 2019; ASMFC 2020).

On the Atlantic coast of central and north Florida there is a locally well-known and historically active cobia fishery in which recreational fishermen track giant manta ray migrations for the purpose of targeting and landing cobia (Pate 2023; Braun et al. 2024). This is a fishing practice where recreational fishermen will seek out giant manta rays and cast at or near them to target the cobia that are associated with the manta rays (Bishop 1999; McNally 2012; Roberts 2022). In Florida, giant manta rays are often seen trailing fishing gear, which is not necessarily or immediately fatal, but may impair feeding and swimming behaviors or cause serious bodily injury and direct mortality as a result of entanglement and subsequent drowning (Deakos et al. 2011; Gallagher et al. 2014; Pate et al. 2020; Pate and Marshall, 2020). Recently, Braun et al. (2024) conducted a study that gathered data on recreational fishermen knowledge, perceptions, and behavior in relation to the cobia fishery in central and north Florida and its relationship with resident and migrating giant manta ray. This study found that 60% of recreational fishermen actively tracked temperature changes in coastal waters to predict migration trends of both giant manta rays and cobia (Braun et al. 2024). Over 86% of recreational fishermen interviewed reported they or their clients (charters) had incidentally hooked giant manta rays when fishing for cobia (Braun et al. 2024). In addition, 93% of recreational fishermen observed giant manta rays with hooks and training lines or vessel strike injuries (Braun et al. 2024). The recreational fishermen described the hooked and entangled manta rays as looking "like a christmas tree" or "like Mardis Gras," suggesting individual manta rays are having a multitude of interactions with recreational fishermen in this fishery (Braun et al. 2024).

Overcrowding and increased vessel activity is also a vessel strike concern as recreational fishermen have reported seeing an average maximum of 22 boats (range: 1-50) surrounding a single ray or group of rays at the same time (Braun et al. 2024). The available information indicates that this fishing practice results in a potentially significant amount of incidental hookings and an increased risk of vessel strike to the species in this area. As previously stated, incidental hookings cause injury, and in the cases where trailing line remains on the manta ray, it can lead to amputations or truncated cephalic and pectoral fins as has been observed in Florida. These injuries can impede the individual's ability to feed, swim effectively or possibly communicate with other giant manta rays (Perryman et al. 2021).

Venezuela

Based on nominal catch information submitted to the International Commission for the Conservation of Atlantic Tunas (ICCAT), Venezuelan longline fishing vessels appear to annually catch giant manta rays as bycatch, primarily in the northwest Atlantic portion of the ICCAT convention area. However, the catch is pretty minimal, ranging from 1 t to 3 t from 2016 to 2021 (see https://www.iccat.int/en/accesingdb.html).

Eastern and Southern Atlantic Subregion

In the European purse-seine fishery, which primarily operates in the Eastern Atlantic off western Africa, *M. tarapacana* is the predominant mobulid caught as bycatch (Amandè et al. 2010; Hall and Roman 2013). While *M. birostris* is also caught, primarily in Fish

Aggregating Device (FAD) purse-seine sets, it does not appear to be caught in large numbers (Amandè et al. 2010; Hall and Roman 2013). Based on data from French and Spanish observer programs, collected over the period of 2003-2007 (27 trips, 598 sets), only 11 *M. birostris* were observed caught by the European purse-seine fleet, with an equivalent weight of 2.2 mt (Amandè et al. 2010). However, it is important to note that the observer coverage was extremely low, averaging 2.93% during the 5 study years (2003, 1.5%; 2004, 1.82%; 2005, 3.68%; 2006, 3.55%; 2007, 6.2%) (Amandè et al. 2008). Since 2015, 100% of the fishing trips on European purse seiners in the Atlantic have been covered by observers (human or electronic monitoring systems) (Grande et al. 2019). Based on bycatch data collected between 2005 and 2021 by observers aboard French tropical tuna purse-seine vessels, only 4 giant manta rays were verified as caught (P. Sabarros unpublished data). Grande et al. (2019) note that mobula rays are primarily released by hand, with time of release less than 7 minutes. However, due to their size, manta rays tend to take more time to release as they also may require the use of specific release tools or nets (Grande et al. 2019). The level of post-release mortality rates for giant manta rays in this fishery is unavailable; however, both the numbers caught as bycatch and the fishing effort by the Atlantic tuna purse seine fishery is significantly less compared to the bycatch and effort of the purse-seine fisheries in the other ocean basins. In fact, the Atlantic tuna purse seine fishery accounts for only 7% of the total number of tuna purse seine sets a year (Croll et al. 2015).

Cabo Verde

Cabo Verde is an archipelago and island country of West Africa in the central Atlantic Ocean. Garzon et al. (2023) described the spatial ecology of the giant manta ray population in Cabo Verde and found that giant manta rays reliably occur between July and January in the archipelago. There is no directed fishery for giant manta rays within Cabo Verde, however, large industrial vessels, mainly coming from Europe, Japan, and China, are active within and outside Cabo Verde's EEZ and may represent a threat to the species (Garzon et al. 2023). In addition, given the suitable habitat near the islands, manta rays may also be interacting with small-scale or semi-industrial fisheries where mobulid bycatch has been observed (Garzon et al. 2023). However, there is very little information available on bycatch or targeted fishing of giant manta rays within this area.

Mauritania

Off Mauritania, Zeeberg et al. (2006) documented *M. birostris* in the bycatch of the European pelagic freezer-trawler fishery. However, a subsequent review of the images of the bycaught rays from this study reveal that these individuals were, in fact, mobula ray species, not manta rays (A. Marshall pers comm. 2022). Additionally, as a result of an agreement between the European Union and Mauritania, which set technical conditions that, according to the Pelagic Freezer-trawler Association, made commercial fishing economically non-viable, the European freezer-trawler fleets have rarely operated in Mauritanian waters since 2012 (PFA 2016).

Ghana

There is no available data on the amount of manta rays landed in Ghanaian fisheries; however, Debrah et al. (2010) observed that giant manta rays were targeted using wide-mesh drift gillnets in artisanal fisheries between 1995 and 2010. D. Berces (pers. comm. 2016) confirmed that mantas are taken during artisanal fishing for pelagic sharks, and not "infrequently," with manta rays consumed locally.

Suriname

In Suriname, shrimp trawling, snapper trawling, and snapper longlining take place in depths of up to 80 m, which overlap with the observed depths of *M. birostris* within these waters; however, available information on bycatch of manta rays within these fisheries is largely unavailable (De Boer et al. 2015). No other information could be found regarding manta ray bycatch within these waters.

Brazil

In Brazil, manta rays are not targeted (as they are protected by law and are not of commercial interest), but there is evidence that they have been caught as bycatch in surface gillnets, longlines, purse seines, trawls, and harpoons, and illegally sold for the gill plate trade (Bucair et al. 2021). Reported capture and landings of giant manta rays have occurred at Itajaí Harbor, southern Brazil, off Ceará State in Arcati Bank and Mucuripe

Embayment, Fortaleza, and off the coast of Rio Grande do Sul and Santa Catarina states (Bucair et al. 2021). Bucair et al. (2021) reviewed scientific literature and analyzed fisheries interactions with manta rays from 2000 to 2020 and found a total of 270 interactions, with 41 manta rays displaying wounds and 29 dead. The majority of the injured individuals were recorded in the state of São Paulo (31.4%; n = 22), followed by Pernambuco (20.0%; n = 14), Rio de Janeiro (10.0%; n = 7), Bahia (8.6%; n = 6), Rio Grande do Norte (7.1%; n = 5), and Espírito Santo (5.7%; n = 4). In the states of Rio Grande do Norte, Ceará, Sergipe, Pará, Piauí and Santa Catarina, all of the manta rays observed were either killed by fishermen, actively entangled in fishing gear, or displaying scars on their bodies from fishing gear. For some of the accidentally entangled manta rays, the fishermen would drag them to the beach, kill them, and have their bodies sliced for a possible trade, sharing or consumption (Bucair et al. 2021). Overall, roughly half of the manta ray records were from the southeast coast (states of São Paulo, Rio de Janeiro, and Espírito Santo) and associated with ghost fishing and incidental capture. Even within sustainable use protected areas (such as the Ilha Comprida coast, São Paulo state, located in the Estuarine-Lagoon Complex of Cananéia-Iguape), stranded manta rays showed the impact of fishing, with fins removed and bodies attached to fishing nets or showing fishing net marks and bleeding (Medeiros et al. 2022). The other half of the manta ray records were from the Brazilian north and northeast regions, which were largely associated with both incidental catch (although further landed for the gill plate trade) and targeted catch, with most lethal records associated with small artisanal fishing boats (Bucair et al. 2021).

Factor B Summary

Overall, it is clear that the majority of observed declines in landings and sightings of manta rays originate from the Indian Ocean region and the Western Pacific and Eastern Pacific Ocean subregions of the species' range (**Table 4**). Manta rays appear to be targeted and caught as bycatch by a number of artisanal fisheries for the gill plate trade. Additionally, pressure through bycatch mortality by commercial fisheries are also likely having significant negative effects on local populations within this region and these subregions. This fishing pressure has already contributed to declines in the species (of up to 95%) throughout many areas (i.e., Indonesia, Philippines, Sri Lanka, Thailand, Madagascar; **Table**

4). Given the high market prices for manta ray gill plates, the practice of both targeting and landing the species as valuable bycatch will likely continue through the foreseeable future, posing a significant threat of overutilization of the species.

For the other regions of the giant manta rays range (Atlantic Ocean and Central Pacific Ocean subregion), information is lacking on population abundance and trends and/or the impacts of fisheries throughout those regions. This is the case for the Eastern and Southern Atlantic Ocean subregion, where little to no data exists on giant manta ray populations (Bucair et al. 2021; Garzon et al 2023). Additionally, within the eastern Atlantic, there are no known key aggregation sites or regional descriptions of the distribution, movement and connectivity of manta ray populations (Garzon et al. 2023), unlike the ones formally described for other parts of their range, making it extremely difficult to identify the potential threats and impacts on these populations. For the other subregions, the Western North Atlantic subregion and Central Pacific subregion, the available observer data has allowed for the assessment of fishery interactions. Yet, given the lack of population abundance and trend data in these subregions, as well as unknown post-release mortality rates, these assessments, and the potential threat of overutilization by these fisheries on the species, remains highly uncertain.

Factor C: Disease and Predation

Manta rays are frequently observed congregating at inshore cleaning stations where small cleaner fish remove parasites and dead tissue from their bodies (Marshall and Bennett 2010a; O'Shea et al. 2010; CITES 2013). They may remain at these cleaning stations for large periods of time, sometimes up to 8 hours a day, and may visit daily (Duinkerken 2010; Kitchen-Wheeler 2013; Rohner et al. 2013). These cleaning stations are often associated with inshore coral reefs. While there is no information on manta ray diseases, or data to indicate that disease is contributing to population declines in either species, impacts to these cleaning stations (such as potential loss through habitat degradation) may negatively impact the fitness of the mantas by decreasing their ability to reduce their parasite load.

In terms of predation, manta rays are frequently sighted with non-fatal injuries consistent with shark attacks, although the prevalence of these sightings varies by location (Homma et al. 1999; Ebert 2003; Mourier 2012). Deakos et al. (2011) reported that scars from shark predation, mostly on the posterior part of the body or the wing tip, were evident in 24% of *M. alfredi* individuals (n=70 individuals with injuries) observed at a manta ray aggregation site off Maui, Hawaii. At Lady Elliott Island, off eastern Australia, Couturier et al. (2014) observed 23% of individuals had shark scars. In contrast, in southern Mozambique, between 2003 and 2006, 76.3% (n=283) of the *M. alfredi* identified by Marshall and Bennett (2010a) exhibited shark-inflicted bite marks, the majority of which were already healed. Rohner et al. (2013) found a lower rate for *M. birostris*, with only 35% of individuals observed with bite marks. Marshall and Bennett (2010a) also recorded two mid-pregnancy abortions by pregnant female *M. alfredi* attributed to damage from shark attacks. The authors observed that the rate of shark-inflicted bites in southern Mozambique appears to be higher than predation rates in other manta ray populations, which is generally noted at <5% (Ito 2000; Kitchen-Wheeler et al. 2012). It is unknown why this difference exists.

In terms of fatal encounters, there are a couple of records of killer whales feeding on manta rays. In Papua New Guinea, Visser and Bonoccorso (2003) observed on two separate occasions orcas fatally attacking and feeding on manta rays. Killer whales were also recorded preying on manta rays in the Galapagos Islands (Fertl et al. 1996).

Because the damage from a shark bite usually occurs in the posterior region of the manta ray, there may be disfigurement leading to difficult clasper insertion during mating or inhibited waste excretion (Clark and Papastamatiou 2008). Given the already low reproductive ability of these species, attacks by sharks or killer whales may pose a threat to the species by further impairing the manta rays' ability to rebuild after depletion. However, at this time, the impact of shark bites on manta ray reproduction is speculative.

Factor D: Inadequacy of Existing Regulatory Mechanisms

Protections for manta rays are increasing, yet there are still a number of areas where manta rays are targeted, allowed to be landed as bycatch, or illegally captured for the gill plate trade. A list of current protections for manta rays can be found in the **Appendix** of this report.

International Regulatory Mechanisms

Currently, most of the tuna-RFMOs (i.e., IATTC, IOTC, and WCPFC) have prohibited retention of the giant manta ray by commercial/industrial fishing vessels. However, given that *M. birostris* is primarily caught as bycatch in the purse-seine fisheries, particularly in the IATTC, as well as the gillnet fisheries, particularly in the IOTC, the adequacy of this prohibition in protecting the species from overutilization really depends on the at-vessel mortality and post-release survival rate of the species. While injuries from entanglements in fishing gear have been noted (Heinrichs et al. 2011), at this time, post-release mortality rates for giant manta rays are unknown. For other *Mobula* species, Francis and Jones (2016) provided preliminary evidence that may indicate a potential for significant post-release mortality of the spinetail devil ray (*Mobula japanica*) in purse-seine fisheries; however, the study was based on only 7 observed individuals and, because of this, the authors caution that it is "premature to draw conclusions about survival rates." Although decreasing fishing effort in manta ray hotspots would significantly decrease the likelihood of bycatch mortality, without further information on post-release survival rates, it is highly uncertain if the prohibition ban by these RFMOs will be adequate in decreasing the mortality of the species.

Furthermore, while the commercial/industrial fishing vessels are prohibited from catching manta rays, the small-scale/artisanal fishing vessels within the IOTC and IATTC are still allowed to target or catch the species if categorizing it as subsistence fishing. Given that the IATTC does not mention the prohibition of sale of any part of the ray by subsistence fishing vessels, it is likely that this measure has allowed encouraged some small-scale/artisanal fishermen to catch manta rays for "domestic consumption" and also sell some of their parts, such as their gill plates, locally to gill plate traders. Additionally, while the IOTC resolution prohibits any part of the manta ray entering trade, information on the implementation and compliance with the resolution as well as the level of monitoring and enforcement of the small-scale/artisanal fishing vessels is severely lacking (MRAG 2019).

In addition to the tuna-RFMOs, there has been effort by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) parties to monitor and manage trade efforts of manta rays so they do not negatively affect wild populations. In 2014, CITES listed the giant manta ray (*Mobula birostris*) under Appendix II, which includes those species that CITES finds are not necessarily now threatened with extinction but may become so unless trade is closely controlled. Under Appendix II, international trade in specimens (such as the gill plates of giant manta rays) requires export permits or re-export certificates that are granted only if the relevant authorities find that the trade will not be detrimental to the survival of the species. However, no import permit is necessary. In 2016, four entries documenting the trade of gill plates collected from wild, giant manta rays were recorded for educational purposes, with Sri Lanka importing gill plates from the Maldives (four unknown units) and South Africa (four unknown units), and exporting equal amounts back to both countries. Since the listing of the giant manta ray on the endangered species list in 2018, the quantities of gill plates being traded has increased dramatically. Between 2019 - 2021, Sri Lanka has been the main exporter of gill plates to Hong Kong, reporting 750 kg, 1024.5 kg and 275.5 kg for each respective year for commercial use. Interestingly, Hong Kong has reported different imported quantities in 2019 and 2020, instead submitting quantities of 250 kg and 640 kg. As the recent levels of international *Mobula spp*. trade by Sri Lanka appear to be unsustainable and non-compliant with the CITES Convention, in June 2023, the CITES's Review of Significant Trade process was triggered. At the 34th CITES Animals Committee meeting in July 2024, the Committee determined that further action is needed and Sri Lanka will remain in the Review of Significant Trade process with the following recommendations (CITES 2024):

Recommended Action	**Time-frame for implementation**
Short-term Actions i. Establish an annual zero export quota within 90 days for *Mobula* spp. and communicate the quota to the Secretariat. ii. No exports should occur until the quota has been published on the Secretariat's website.	90 days following receipt of notification from the CITES Secretariat of the recommendations of the 33rd meeting of the Animals Committee

iii. Before making any increases to this quota, the planned changes should be communicated by the range State to the Secretariat and Chair of the Animals Committee along with a justification of how the change is conservative, based on estimates of sustainable off-take that make use of available scientific information, for their agreement.	
<u>Long-term Actions</u> iv. Undertake science-based studies on the status of the species (e.g. delineation of stocks, population estimates, trends, distribution) including an evaluation of the threats to the species for use as the basis for Certification to the effect that the competent scientific institution has advised that the export will not be detrimental to the survival of the species. v. Develop NDFs, in consultation with fisheries agencies, which are time-bound (no more than 5 years) for all stocks of *Mobula* spp. where catch for export occurs, which could, inter alia, include the following elements: A) consideration of each stock as a separate management unit for conservation and harvest purposes, paying particular attention to any RFMO measures, as appropriate, in place; B) adaptive management, with a review period of no more than 5 years, to take into consideration signals from the stock; C) a precautionary approach, where a cautionary offtake is initially considered, and revised with further information; D) all sources of mortality within the stock. vi. Establish an export quota proportionate to the harvest quota with a clear justification.	36 months following receipt of notification from the CITES Secretariat of the recommendation of the 33rd meeting of the Animals Committee
<u>Long-term Actions</u> vii. Upon completion of other recommendations, provide the scientific basis	36 months following receipt of notification from the CITES Secretariat of the recommendation of the 33rd meeting of the Animals Committee

by which it has established that exports are not detrimental to the survival of the species and are compliant with Article IV, paragraphs 2(a), 3 and 6(a) of the Convention. Particular focus should be given to how the actions the range State has taken, or will take, address the concerns/problems identified in the Review of Significant Trade process.	

Should these recommendations not be implemented, recommended trade suspensions by the CITES Standing Committee may result at the conclusion of the process.

National Regulatory Mechanisms

In terms of national regulatory measures, many countries have passed legal protections or implemented conservation measures in order to prevent overutilization of the species (see **Appendix**). However, despite these national protections for the species throughout its range, poor enforcement and illegal fishing have essentially rendered the existing regulatory mechanisms inadequate to achieve their purpose of protecting the giant manta ray from fishing mortality. Based on the available data, *M. birostris* appears to be most at risk of overutilization by countries in the Indian Ocean Region and Western and Eastern Pacific Ocean subregions. Specifically, targeted fishing and incidental capture of the species in Indonesia, Philippines, Sri Lanka, Mozambique, and India and throughout much of the eastern Pacific has led to observed significant declines in *M. birostris* populations.

In Indonesia, *M. birostris* was provided full protection in the nation's waters in 2014 (4/KEPMEN-KP/2014), with the creation of the world's largest manta ray sanctuary at around 6 million km^2. Fishing for the species and trade in manta ray parts are banned. Despite this prohibition, fishing for manta rays continues, with evidence of the species being landed and traded in Indonesian markets (AFP 2014; Marshall and Conradie 2014; Dharmadi et al. 2015; Simeon et al. 2019). As mentioned previously (see ***Overutilization for commercial, recreational, scientific, or educational purposes***), many fishermen throughout Indonesia rely on shark and ray fishing for their livelihoods and, without an alternative source of income, are unlikely to stop their traditional fishing practices, including the targeting of manta rays. Additionally, in interviews with fishermen, many viewed the prohibition as a positive because it would likely drive up the market price of manta ray products (Marshall and Conradie 2014). Given the size of the Indonesian archipelago, and current resources, Dharmadi et al. (2015) note there are many issues with current enforcement of regulations. For example, the collection of data is difficult due to insufficient fisheries officers trained in species identification and the large number of landing sites that need to be monitored (over 1,000). Catch data tend not to be accurately recorded at the smaller landing sites, with coastal waters heavily fished by artisanal fishermen using non-selective gear (Dharmadi et al. 2015). Given the issues with enforcement and evidence of illegal fishing, existing regulatory mechanisms are inadequate to protect the species from further declines due to overutilization.

In 1998, the Philippines introduced legal protection for manta rays; however, similar to the situation in Indonesia, enforcement of the prohibitions is lacking and illegal fishing of the species is evident. For example, in a random sampling of 11 dried products of sharks and rays confiscated for illegal trading, Asis et al. (2016) found that four of the products could be genetically identified as belonging to *M. birostris.* Dried manta meat and gill plates were frequently observed in markets between 2010 and 2012, and fishing boats specifically targeting mobulids (including mantas) were identified in a number of local fishing villages in the Philippines, with landings consisting of *M. birostris* individuals. Fishing for mobulids is a "way of life" and the primary source of income for many fishermen, and with the high prices for manta gill plates in the Philippine markets, it is unlikely that pressure on the species will decrease. With essentially no efforts to regulate the mobulid fisheries in the Philippines, and a severe lack of enforcement of the current manta ray hunting prohibition, current regulations to protect *M. birostris* from overutilization in the Philippines are inadequate.

In the Indian Ocean region, very few national protections have been implemented for *M. birostris*. Essentially, fishing for the species and retention of bycatch is allowed except within the Republic of Maldives, Bangladesh, Israel, United Arab Emirates, Mozambique, and within specific marine parks of Western Australia (**Appendix**). Given the declines observed in the species throughout the Indian Ocean (**Table 5**), and the migratory nature of the animal, with the potential for the species to move in and out of protected areas into active fishing zones (e.g., from the Maldives to Lakshadweep, Sri Lanka – a distance of ~820 km, well within the ability of *M. birostris*), it is likely that existing regulatory measures within this portion of the species' range are inadequate to protect it from overutilization. This is particularly true in Sri Lanka. Despite being a party to the Convention on the Conservation of Migratory Species of Wild Animals (CMS), of which *M. birostris* is listed on both Appendix I and II (where parties should strive toward protecting the species), as well as party of the IOTC, Sri Lanka currently supports one of the world's largest manta ray fisheries. Recently, one of the largest interceptions of manta ray gill plates, around 330 kg from Sri Lanka, was seized at the Hong Kong International Airport due to a lack in the required CITES permit (Earth.org 2020). As mentioned above, Sri Lanka is currently in the CITES significant trade review process. Clearly, Sri Lanka currently lacks national legal protections for giant manta rays and is unable to meet its regional and international commitments, ultimately allowing the significant overutilization of the species. Additionally, even for those countries with prohibitions on fishing for manta rays, illegal fishing and trade is occurring, with many nations requiring improved monitoring, reporting, and enforcement.

In the eastern Pacific Ocean, prohibitions on the fishing and sale of *M. birostris* and requirement for immediate release of mantas caught as bycatch were implemented in Peru in 2016 (where manta rays are generally caught as bycatch in trawl and gillnet fisheries). Ecuador banned the fishing, landing and sale of manta rays in its waters back in 2010. Given that the largest population of *M. birostris* is found in the waters between Peru and Ecuador (with a superpopulation estimated at around 22,316 individuals), these prohibitions should provide some protection to the species from fishing mortality when in these waters. However, illegal fishing still occurs in these waters. For example, in Ecuador's Machalillia National Park (a major *M. birostris* aggregation site), researchers have observed large numbers of manta rays with life-threatening injuries as a result of incidental capture in illegal wahoo (*Acanthocybium solandri*) trawl and drift gillnet fisheries operating within the park (Heinrichs et al. 2011; Marshall et al. 2011a). In June 2022, the Ecuadorian Navy seized 600 kg of manta rays in Anconcito, and less than a year later, seized 6 manta ray fins in the sea off Puerto Bolívar, El Oro province (Vega 2023). Recently, Vega (2023) discovered that the main smuggling route for this illegal fishing is between southern Ecuador and northern Peru, with many of the manta rays being illegally retained in Ecuador and exported to Peru. Given the significant lack of enforcement and monitoring, particularly within Peru, the smuggling, selling, and exporting of manta ray parts to China frequently occurs with no major problems (Vega 2023).

Clearly, many of the national regulatory mechanisms for manta rays are inadequate to prevent overutilization of the species, leading to the continued decline of giant manta ray populations, particularly in the Indian Ocean and Western and Eastern Pacific subregions. Even if stronger enforcement is provided for these measures, given the distribution of some populations, these national protections may not be adequate to protect populations from decline, particularly when the species crosses boundary lines where protections no longer exist.

Factor E: Other Natural or Human Factors Affecting its Continued Existence

Manta rays are known to aggregate in various locations around the world, in groups usually ranging from 100-1,000 for *M. birostris* (Notarbartolo-di-Sciara and Hillyer 1989; Graham et al. 2012; Venables 2013). These sites function as feeding sites, cleaning stations, or sites where courtship interactions take place (Heinrichs et al. 2011; Graham et al. 2012; Venables 2013). The appearance of manta rays in these locations is generally predictable with high productivity events (i.e., food availability) playing a significant role in feeding site aggregations (Notarbartolo-di-Sciara and Hillyer 1989; Heinrichs et al. 2011; Jaine et al. 2012). Manta rays have also been shown to return to a preferred site of feeding or cleaning over extended periods of time (Dewar et al. 2008; Graham et al. 2012; Medeiros et al. 2015). For example, recreational fishermen have long been aware of seasonal giant manta ray aggregations in northeastern Florida and use the giant manta rays to target cobia which frequently results in foul-hooking and entanglement (C. Horn pers comm. 2023). Another example of a preferred site is the dive spot off a hotel in Hawaii that was used to operate a manta observation spot. The hotel would use artificial lights to concentrate plankton and manta rays would frequently visit the hotel's specific diving spot (Clark 2010). However, the hotel closed in 2004, and afterwards, very low numbers of manta rays were observed returning to the spot. When the hotel was re-bought and flood lights turned back on, many manta rays returned, demonstrating learned behavior and their preferred feeding site (Clark 2010). Overall, the predictable nature of their appearance, combined with their slow swimming speeds, large size, and lack of fear towards humans, may increase their vulnerability to other threats, such as recreational fishery interactions, tourism, entanglement, and vessel strikes (discussed below) (O'Malley et al. 2013; CMS 2014).

Tourism

Potential impacts of unregulated tourism activities at mobulid aggregation sites have been widely recognized (Stewart et al. 2018a). Swimming with manta rays is a significant tourist attraction throughout the range of reef and giant manta ray species. In fact, O'Malley et al. (2013) estimated that the manta ray tourism industry provides $140 million annually in direct revenue or economic impact (estimated tourist expenditures on dives and associated spending on lodging, food, local transportation) (**Figure 17**). In countries where manta rays are known to be targeted or caught as bycatch, the value of the fishery is substantially less than the estimated value of the tourism industry, suggesting that manta rays are worth significantly more alive than dead. For example, in Indonesia, O'Malley et al. (2013) estimates that the total annual income from the manta ray fisheries is around $442,000 (with 94% attributed to the gill plate trade) whereas economic benefits from manta ray tourism is estimated at over $15 million per year. Globally, O'Malley et al. (2013), citing a personal communication, states that the total trade in manta ray gill plates is around $5 million per year, less than 4% of the estimated global economic benefit obtained from the tourism industry ($140 million per year). In fact, the lifetime value of a manta ray for the tourism industry has been estimated to range anywhere from $100,000 per animal (Anderson et al. 2011) to $1.9 million (O'Malley et al. 2013), significantly greater than any value of a manta ray on the market ($130/kg local trade up to $860/kg market value; Hau et al. 2016; Rathnayake 2023) .

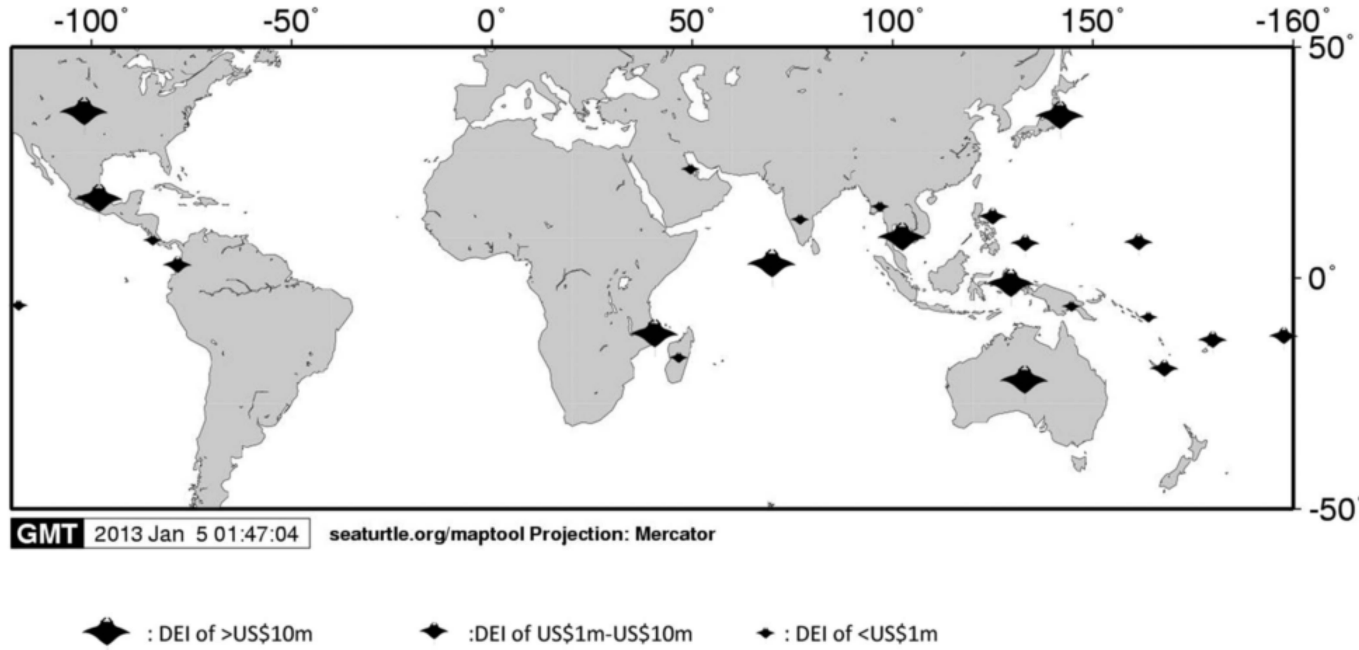

Figure 17. Map showing the direct economic impact (DEI) of manta watching tourism by country. The DEI includes tourist expenditures on manta ray dives and associated costs dives (e.g., food, lodging, transportation). Source: O'Malley et al. (2013).

Regular manta ray concentrations off Mozambique, the Maldives, southern Japan, parts of Indonesia, Philippines, Micronesia , Australia, Hawaii, and Mexico have all become tourist attractions where manta dives are common (Anderson et al. 2011). In the Maldives, which is thought to be home to the largest population of reef manta rays, Anderson et al. (2011) identified 91 manta ray dive sites and estimated that around 143,000 dives and at least 14,000 snorkeling excursions were conducted annually to view the manta rays from 2006-2008. Five marine protected areas in the Maldives were designated specifically because of the seasonal presence of mantas that create so much tourism revenue, and tourism companies capitalize on this fact with their advertising (Anderson et al. 2011b). Kashiwagi (2014) notes that Yayeyama Islands in Japan are one of the world's "top hotspots" for manta ray watching and supports around 200 dive operations. Yap is promoted as Micronesia's manta ray hotspot by The Manta Ray Resort (https://www.mantaray.com/experiences/manta-diving/). Clark (2010) estimates that over 10,000 people per year interact with mantas at Hoona Bay in Hawaii. Recent records document that these diving sites are visited by 30 tour boats and 300 participants each day

(Needham et al. 2018). Although there are no established manta ray dive spots due to the population being too small for dedicated dive operations, certain locations in Tonga do seasonally encounter manta rays and this plays into tourism selection (O'Malley 2013). It is important to note that many of these tourism sites are commonly visited by the reef manta ray, with the giant manta ray being much less frequent.

However, while manta ray tourism is far less damaging to the species than the impact of fisheries, this increasing demand to see and dive with the animals has the potential to lead to other unintended consequences that could harm the species. For example, Osada (2010) found that a popular manta dive spot in Kona, Hawaii, had fewer emergent zooplankton and less diversity compared to a less used dive spot, and attributed the difference to potential inadvertent habitat destruction by divers. Tour groups may also be engaging in inappropriate behavior, such as touching the manta rays. Given the increasing demand for manta ray tourism, with instances of more than 10 tourism boats present at popular dive sites with over 100 divers in the water at once (Anderson et al. 2011; Venables 2013), without proper tourism protocols, these activities could have serious consequences for manta ray populations. Already, evidence of tourism activities potentially altering manta ray behavior has been observed (Anderson et al. 2011, O'Malley et al. 2013, De Rosemont 2008, Venables 2013, Gómez-García et al. 2021). For example, from 2007-2008, low numbers of mantas were observed at normally popular manta dive sites in the Maldives (Anderson et al. 2011). It is unknown whether this was primarily due to these tourism practices or some change in oceanographic conditions, but manta numbers remained healthy at less visited sites, providing support for the hypothesis that tourism can change their behavior. O'Malley et al. (2013) also reported a dive operator who observed a decrease in manta ray sightings at a notably crowded manta site (location was not specified), indicating tourism may be altering manta ray behavior. Similarly, De Rosemont (2008) noted the disappearance of a resident manta colony from a popular cleaning station in a Bora Bora lagoon in 2005, and attributed the absence to new hotel construction and increased tourism activities; however, by 2007, the author notes that the mantas had returned to the site. In a study of the tourism impacts on *M. alfredi* behavior in Coral Bay, Western Australia, Venables (2013) observed that mantas exhibited a variety of behavioral changes in response to swim group interactions (i.e., their response was different than their behavior prior to the approach of the swim group). **Figure 18** shows the types of responses that were observed.

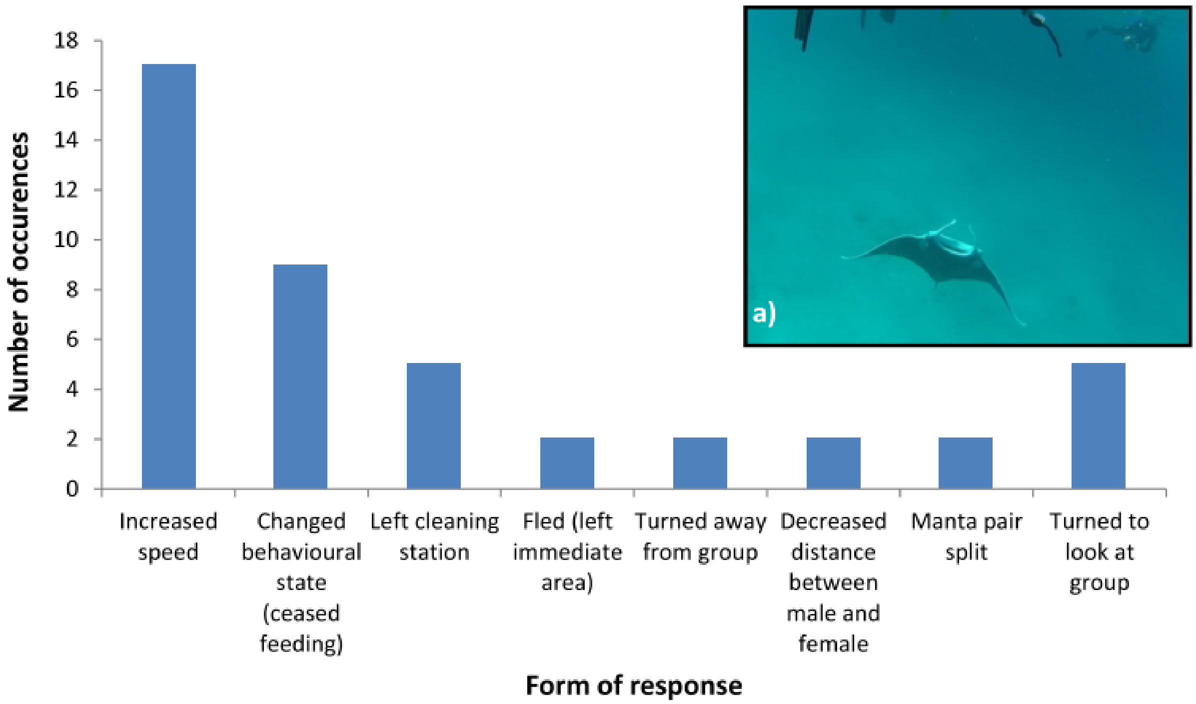

Figure 18. Different behavioral responses of manta rays, and frequency of these responses, to swim group interactions in Coral Bay, Western Australia. Source: Venables (2013)

The tour operators that were observed voluntarily followed a code of conduct for manta ray interactions that was designed to minimize disturbance to the species, and out of the 91 observed swim group interactions, manta rays exhibited a behavioral response in about a third of these interactions (Venables 2013). However, the author notes that out of the 14 manta rays that were specifically observed at a cleaning station, 9 of them left immediately as a response to a tour vessel approaching, a swim group interaction, or an attempt to obtain photo identification, and did not return during the observation period (Venables 2013). Although the long-term effects of tourism interactions are at this time unknown, the results from the Venables (2013) study provide a preliminary estimate of the potentially minimum response of the species to interactions with tourists, and indicates that these interactions can cause the species to alter (and even stop) behavior that serve critical biological functions (such as feeding and cleaning).

In Hawaii, the Department of Land and Natural Resources Division of Boating and Ocean Recreation has publicly raised concerned regarding the large manta ray viewing operations in the Makako Bay (also known as Garden Eel Cove) and Kaukalaelae Point (also known as Keauhou Bay) Ocean Recreation Management Areas (HI DLNR 2022). In order to address overcrowding at these manta ray diving spots, associated safety concerns, user conflicts, and environmental impacts, the Board of Land and Natural Resources approved the initiation of rulemaking proceedings, including public hearings, on a set of proposed new rules as of October 2022 (HI DLNR 2022). These rules, along with House Bill 1090 which would prevent permit renewals based on seniority and other factors, would limit tours to 24 commercial boats and a maximum of 60 passengers to each site per day. A guide would be required for every eight customers, with a two-hour viewing limit between the hours of 4 p.m. until 4 a.m. Changes to specific vessel lighting, propeller guards or a safety lookout would be some of the newly proposed safety requirements (HI DLNR 2022).

While laws or rules that regulate manta ray diving or viewing activities are highly encouraged, additional studies on both the short-term and long-term impact of tourist interactions with manta rays are needed in order to evaluate if this interaction is a potential threat to the survival of the species.

Vessel Strikes

Vessel strikes are evident in every monitored manta ray population across the globe (Stewart et al. 2018a). Spending considerable time at the surface while feeding and basking, manta rays are especially susceptible to severe injuries from boat strikes (Braun et al. 2014; Braun et al. 2015; McGregor et al. 2019; Stevens and Froman 2019; Armstrong et al. 2020; Augliere 2020). Documenting vessel strikes on manta rays is challenging because lethal impact will cause the animal to sink (i.e., manta rays are negatively buoyant) and non lethal impacts are commonly recorded by divers and may not be recognizable (e.g., contributed to predation or fishing related injuries and entanglements) (McGregor et al. 2019). Further complicating documentation, manta rays have shown resilience to a range of non-lethal injuries (Marshall and Bennett 2010; Pate and Marshall 2020), including wounds from boat propellers (McGregor et al. 2019). This rapid wound healing suggests that vessel strikes are underestimated (McGregor et al. 2019). While such wound recovery is beneficial it likely incurs significant energy cost and metabolic processes, which may shift energy allocation from reproductive effort, growth, and ability to feed, thereby reducing individual fitness (Archie 2013; Chin et al. 2015; Harvey-Carroll et al. 2021; Womersley et al. 2021).

Marine traffic in the world's oceans is increasing. With increased traffic, more vessels strike marine fauna, which may have lethal or non-lethal outcomes. Based on satellite altimetry, global ship density increased by a factor of 4 between 1992 and 2012, with the greatest increase in the Indian Ocean (Tournadre 2014). Occurrence of vessel strikes are spatially variable and are more likely to occur where vessel density and manta ray aggregation along surface waters is high. For example, off the Ningaloo Coast, vessel strikes were highest during the seasonal aggregation of manta rays, which was attributed to an abundance of zooplankton around the area (McGregor et al. 2019). In French Polynesia, manta rays near inhabited islands are more likely to be observed with sublethal injuries caused by fishing gear or boat strikes than manta rays near uninhabited islands (Carpentier et al. 2019). In southeast Florida, United States, boat propellers (30%) and fishing line (27%) were the most common sources of injuries to the population of juvenile giant manta rays which frequent the shallow coastal waters in the region, where human activity is heavily concentrated (Pate and Marshall 2020).

In some parts of their range, such as the Western North Atlantic subregion, it is likely that the seasonal contraction of suitable manta ray habitat during the warmer months increases their proximity to busy ports and could pose a serious threat to the species (Garzon et al. 2020). For example, Garzon et al. (2020) found that the Southeast United States followed by Venezuela and The Bahamas had the largest areas of overlap between predicted core manta ray habitat areas and intense recreational and commercial ship traffic (**Figure 19**). It is important to note that recreational traffic tends to be underestimated and can be locally extremely high in certain areas, and thus responsible for a large number of giant manta ray vessel strikes.

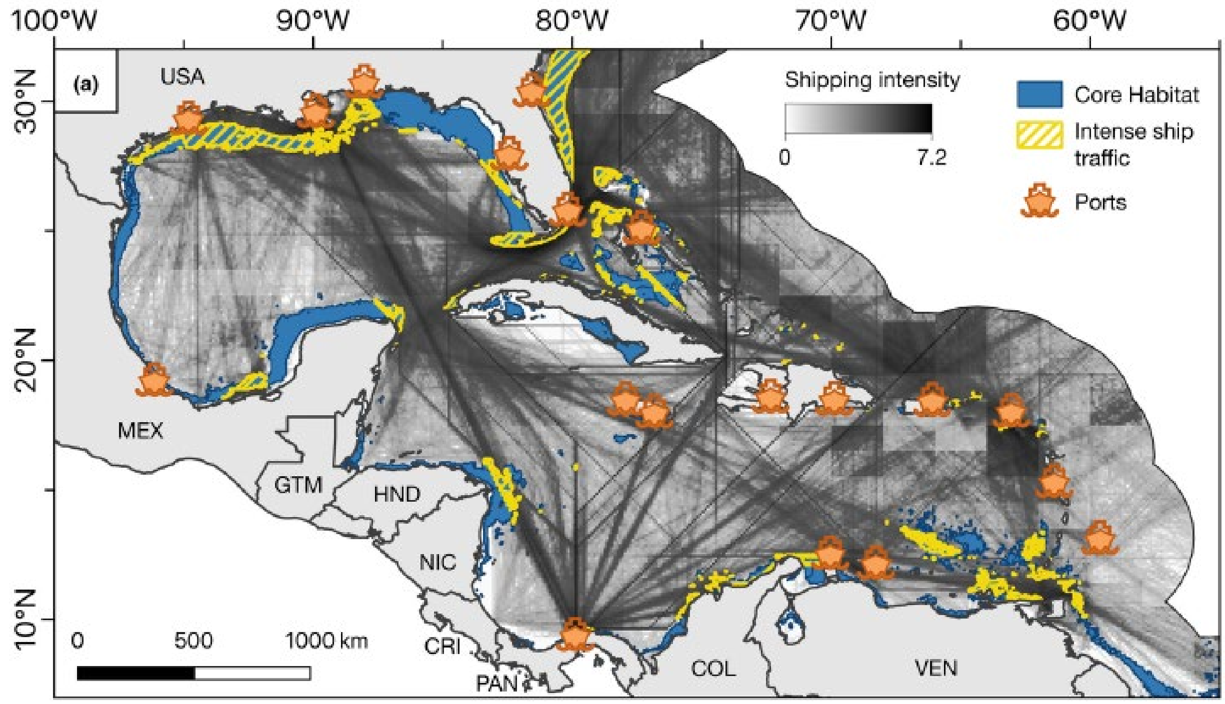

Figure 19. Core manta ray habitat predicted through ensemble ecological niche models with ship traffic, shipping routes and major ports displayed across the western central Atlantic. Source: Garzon et al. (2020)

When comparing the likelihood of vessel strikes on juveniles versus adults, the observed habitat use of juveniles may make them more prone to this threat. For example, juvenile manta rays in the Maldives (Stevens 2016), Indonesia (Germanov et al. 2019; Setyawan et al. 2020), Palmyra Atoll (McCauley et al. 2014), southeast Florida, United States (Pate and Marshall 2020), and the Gulf of Mexico (Stewart et al. 2018b) have been shown to reside in shallow reef habitats for longer periods than adults, and in higher numbers, and exhibit long-term habitat use of these areas (Strike et al. 2022). Unfortunately, these sheltered and easily accessed lagoons are often areas of increased human activity, such as coastal development and fishing, and, subsequently, boat traffic, which can result in potentially fatal vessel strikes (Blumenthal et al. 2010; Pate and Marshall 2020; Strike et al. 2022).

Recreational Fishing Interactions

Manta rays have also been accidentally caught by recreational fishermen. In a study on manta rays in southern Florida waters, Pate and Marshall (2020) found that 27% of the observed giant manta rays were foul-hooked or entangled in fishing line, and, of those, 38% interacted with fishing gear more than once. More recent data found that of the 152 individual manta rays recorded in southern Florida, 23.7% had interactions with recreational fishing gear and, of those, 61% had multiple interactions (J.H. Pate personal communication to C. Horn. 2023). These manta rays were commonly seen in the vicinity of fishing piers and inlet jetties (Pate and Marshall 2020) and recreational fishermen have been observed casting at juvenile manta rays (J.H. Pate unpublished data). NMFS has also documented several manta ray captures by recreational fishermen targeting sharks from the shore and also from vessels (C. Horn unpubl. data). While some fishing interactions may result in minimal permanent injury to the manta ray, they likely cause considerable stress and possible sub-lethal effects. When fishermen have accidentally hooked manta rays, fight times have been over one hour (J. Pate unpubl. data cited in Pate and Marshall 2020). Fight time is correlated with physiological stress (i.e. lactate production) in elasmobranchs, with smaller sharks producing more lactate than larger sharks (Gallagher et al. 2014). Fishing line entanglement can have sub-lethal effects including truncated cephalic fins (Deakos et al. 2011), deep lacerations to the body, stress (Gallagher et al. 2014), and impaired feeding or swimming. In addition, amputations and disfigurements, specifically those of the cephalic fin, may reduce feeding efficiency, and the absence of this fin may negatively affect size, growth rate and reproductive success (Marshall and Bennett 2010, Deakos et al. 2011, Couturier et al. 2012, Stewart et al. 2018a). While no manta ray deaths have been directly attributed to recreational fishing, mortality may be cryptic as manta rays are negatively buoyant, reducing the likelihood of dead animals washing ashore.

Entanglement

Entanglement in fishing nets is considered a risk to manta rays worldwide (Stewart et al. 2018a). Anthropogenic injuries resulting from entanglements are evident in every monitored mobulid population across the globe, including severe injuries such as amputation or deformity of cephalic and pectoral fins, and damage to the eyes (Deakos et al. 2011; Heinrichs et al. 2011; Stewart et al. 2018a; Pate et al. 2020). Entanglement in fishing line, nets, and mooring ropes can cause serious injury and death (Couturier et al.

2012; Carpentier et al. 2019). Because manta rays are obligate ram ventilators (i.e., they need to swim constantly to move water over their gills and "breathe"), severe entanglements (i.e., those that prohibit swimming) can result in mortality through asphyxiation, as has been seen in bather protection nets off the coast of South Africa (Marshall et al. 2008). In the Maldives, entanglement in fishing line is the most common anthropogenic injury recorded in both reef manta ray and giant manta ray (Strike et al. 2022). Strike at el. (2022) recorded 143 injuries between 1996 and 2019 with 30% of those injuries to giant manta rays attributed to fishing lines. Similarly, one out of every ten individual reef manta rays in the Hawaii's Maui population shows evidence of entanglement in fishing line through scars or amputated cephalic fins (Deakos et al. 2011). Strike et al. (2022) observed similar damage to the cephalic fins with 23% of injuries involving fishing line. In southeast Florida, United States, fishing line was found to be the most common source of injuries to the population of juvenile *M. birostris,* which frequent the shallow coastal waters in the region (Pate and Marshall 2020). Internet searches also reveal photographs of giant manta rays with injuries consistent with fishing line entanglements (Deakos et al. 2011; Heinrichs et al. 2011; Couturier et al. 2012; CMS 2014; Germanov and Marshall 2014; Braun et al. 2015). Severe injuries to the cephalic fins may impair feeding efficiency and reduce the fitness of those afflicted individuals (Deakos et al. 2011). While individuals with only one cephalic fin appeared to be healthy (Deakos et al. 2011; Strike et al 2022) there is little data available on how the loss of a cephalic fin may affect an individual's growth rate, size, or reproductive success.

Giant manta ray mortalities resulting from entanglement in vertical lines (i.e., mooring line, buoy line, rope, cable, etc.) have been documented in most monitored giant manta ray populations (Manta Trust 2019). Entanglement in vertical lines significantly restricts a manta ray's ability to swim which can rapidly lead to asphyxiation and death (Manta Trust 2019). Increased development of resorts, dive, and water-sports centers can lead to the installation of new mooring lines resulting in an increased entanglement risk for giant manta rays, such as the increasing number of entanglements in the Maldives (Manta Trust, 2019; Strike et al. 2022). In the Maldives, the Manta Trust (Manta Trust 2019) has recorded dozens of manta ray mortalities due to mooring line entanglements and it is thought that the number is higher as many incidents are unreported. In the continental United States, a giant manta ray was documented dead and entangled in a vessel exclusion line (steel cable) in Florida (Pate and Marshall 2020) and in September 2023, local media reported a giant manta ray entangled in a mooring line off South Carolina (WRAL News 2023). In 2021, a giant manta ray was also entangled in what was believed to be a crab trap line off the east coast of Florida (J. Pate pers comms to C.Horn; December 20, 2021). In addition, multiple giant manta rays (with one resulting in a known mortality) have become entangled in vertical lines (i.e., buoy lines, ropes, tethers, hoses, cables etc.) deployed by oil and gas industries in the Gulf of Mexico (NMFS unpublished data; NMFS 2020).

While known mortalities have been reported due to entanglements in vertical lines throughout the giant manta ray range, there is little quantitative information on the frequency of these occurrences and the impact of such events on the overall health of those impacted populations. The majority of existing information related to vertical line entanglements comes only from specific locations where researchers are actively studying manta rays (e.g., Maldives and Hawaiian islands).

Aquariums and Public Display

The giant manta ray is traded internationally for display in public aquariums around the globe. Yet, there is limited information available on the number of animals taken from wild populations for the aquarium trade. There are several known aquariums that display manta rays harvested from wild populations for public display. These aquariums include the Georgia Aquarium (United States), Okinawa Churaumi Aquarium (Japan), Nausicaá National Sea Center (France), Atlantis Resort (The Bahamas), S.E.A Aquarium (Singapore), and uShaka Marine World (Durban, South Africa). The available information indicates that while some manta rays have died in captivity, others are transferred among aquariums. For example, the manta ray at UShaka Marine World outgrew its tank, and was eventually transferred to the Georgia Aquarium (Banks 2008). While most wild harvested individuals remain in captivity, the Atlantis Resort is one facility that has successfully returned 13 individuals to the wild populations (Rutger 2018).

There is limited information available on the total number of individuals harvested for exhibition/aquarium purposes and whether those individuals are giant manta rays or reef manta rays. Further, there is limited information available on where and when those individuals were harvested. The only international trade data available comes from the CITES Trade Database. Since the giant manta ray was listed under Appendix II in 2016, the CITES Trade Database (https://trade.cites.org/) reports that two giant manta ray export permits were issued, both in 2018, for France to receive two giant manta rays from the United States for exhibition purposes. It is important to note that the CITES database does not capture domestic trade in CITES-listed species, illegal trade in CITES-listed species, and trade in species not covered by CITES. With respect to domestic trade, Florida is the only state within the U.S. that authorizes giant manta ray harvest for aquarium and exhibition purposes. While giant manta rays are prohibited from harvest in Florida, the Florida Fish and Wildlife Conservation Commission's (FWC) authorizes harvest under a Special Activity License (SAL) for exhibition purposes. In 2009 and 2010, three giant manta rays were harvested from Florida's waters for exhibition purposes for the Georgia Aquarium. More recently, from 2019 to 2022, the FWC has issued 17 SALs for harvest for exhibition purposes. These SALs were issued to a number of aquarium facilities that were not previously known to exhibit/display manta rays, including: Nausicaá National Sea Center (France), Hainan Ocean Paradise (Hainan, China), Rizhao Ocean Park (Shandog, China), Changxing Taihu Longzhimeng Sea World (Shanghai, China), Chongqing Andover Ocean Park (Chongqing, China), SeaWorld Abu Dhabi (United Arab Emirates), and The National Aquarium LLC (Maryland, United States) (L. Gregg pers comm to C.Horn July 18, 2023). Yet, despite the SALs being issued, the facilities were not successful in harvesting any individuals from Florida waters. In addition, no CITES export permits were issued for the harvest licensed by the FWC. The FWC sets its annual harvest quota based on the traditional level of harvest request that the state has received for exhibition purposes (L. Gregg pers com to C. Horn, July 18, 2023).

The number of manta rays being removed from the wild for aquarium and exhibit purposes is unknown at this time. At this time, there appears to be a relatively small number of aquariums globally that display giant manta rays, but the number of SALs requested from

Florida by various aquariums from around the globe suggests that interest may be increasing. It is apparent given the paucity of available information that studies are needed to evaluate this potential threat to the survival of the species.

Shark Control Programs

In addition to targeted fisheries and bycatch, manta rays may also suffer mortality in nets deployed to control sharks off the coasts off Australia and South Africa; however, this potential threat appears to be minimal and decreasing. Additionally, based on the available information, it does not appear that *M. birostris* is impacted to any meaningful extent by shark control nets.

In Australia, shark control nets are deployed off the east coast of Queensland and New South Wales (NSW). Since 2001, 194 manta rays have been observed caught in the Queensland nets, with around 52% released alive (https://data.qld.gov.au/dataset/shark-control-program-non-target-statistics-by-year). The manta ray species was not identified; however, based on the findings from Armstrong et al. (2020), *M. birostris* are rare in this geographic location. In New South Wales, only 2 *M. birostris* individuals were caught in 2014 by the shark control nets, both released alive. Prior years (2010-2013) reported no captures of manta rays (annual reports of the NSW Shark Meshing Program) and more recently, during two 6-month fishing trials conducted between December 2016 and May 2018, no *M. birostris* were observed caught during the 1,135 checks of bather protection gillnets deployed off 5 beaches in northern NSW (Broadhurt and Cullis 2020). Still, Queensland and the NSW has been encouraged to alter their strategies to mitigate unwanted bycatch and have since began implementing the use of Smart catch-and-alert drumlines. Areas like Western Australia use drones and electronic deterrents and encourage others to do the same to decrease shark mortalities and reduce the lethal impact on other species, like manta rays (The Guardian 2023).

In South Africa, the KwaZulu-Natal shark control program began efforts to mitigate shark-human interactions in 1952 by setting nets off the eastern coast, where shark attacks are historically recorded as being very high (Cliff and Dudley 1992). Unfortunately, South Africa is an important seasonal habitat for manta rays. Between 1981 and 2021, 1,423 manta rays were captured by the KwaZulu-Natal bather protection program, with at least one capture from every beach with a net. This study found more catches occurred during the summer time and during spring tides under a new and full moon, with more than half of the manta rays captured to be juveniles (Carpenter et al. 2023). Catches from this program, adapted from Cliff and Dudley (2011), are provided in **Table 13**.

Table 13. Annual catch (mean) of *Manta* spp. individuals in the KwaZulu-Natal shark control program nets off the coast of South Africa from 1981 – 2009. The percent of the catch released alive is also provided. SD = standard deviation. Source: Cliff and Dudley (2011)

Species	**Annual catch (1981-1989)**			**Annual catch (1990-1999)**			**Annual catch (2000-2009)**		
	Mean	SD	% released alive	Mean	SD	% released alive	Mean	SD	% released alive
Manta spp. (but likely *M. alfredi*)	52	32.6	65	70	33.9	67	43	28.8	59

The data from Cliff and Dudley (2011) are broken up into three decades based on differences in reporting and effort over the entire time period. The last decade (2000-2009) saw a significant reduction in effort (i.e., decrease in km of net/ year), with drumlines replacing almost half of the nets at the 17 southernmost beach locations on Hibiscus Coast (Cliff and Dudley 2011). In fact, in these locations, catches of manta rays were significantly reduced, with an average annual catch of <1 between 2007 and 2010 on the drumlines, and a 100% release alive rate (Cliff and Dudley 2011). The Carpenter et al. (2023) study further supports these results citing that manta ray catches have been decreasing since the end of the 20th century (Carpenter et al. 2023). It is likely that catch of manta rays on shark nets will decrease in the future as efforts to reduce bycatch, such as through a combination of drum lines and nets, and the removal of gear at beaches (for example, three of the four beaches with the highest manta ray CPUE were removed; Carpenter et al. 2023), continue to be explored into the future.

THREATS ASSESSMENT

In this section, we present an assessment of threats and stressors identified as affecting or potentially affecting the status of the giant manta ray in terms of recovery planning. **Table 14** below is largely based on the threats assessment conducted in the 2017 Status Review Report (Miller and Klimovich 2017) and the 2018 final listing rule for the giant manta ray (83 FR 2916) along with new updates and some modifications. For instance, in the final listing rule we assessed the threat of overutilization as the culmination of bycatch-related mortality and targeted mortality. In this Recovery Status Review, however, we re-assessed the threats of overutilization in more detail by individually analyzing each major fishery by ocean basin and gear type to better tailor the Recovery Plan and prioritize recovery actions and activities. We will update the threats assessment portion of this Recovery Status Review as we learn more about how threats and stressors continue to act on the species, both individually and synergistically.

Table 14 below presents a summary of the threats assessment. We assessed the stressors for each region within the species' range (Atlantic Ocean, Indian Ocean, Pacific Ocean) to identify the threats. We also identified subregions within the Atlantic and Pacific Ocean regions, based on the available data (see section 3.3.1 in the Recovery Plan for detailed explanation and rationale for identifying these subregions). We prioritized threats that are most urgent and significant for the recovery of the species according to the following criteria: 1) the frequency with which the stressor occurs, 2) the severity of the stressor, 3) the trend of the stressor, 4) the certainty that the stressor is affecting the species, and 5) the relative concern regarding the effect of the stressor, relative to other stressors, on the subregional/regional population.

The **major effect** is the effect(s) of the stressor on a specific aspect of life history or behavior of the giant manta ray.

The **frequency** of the stressor refers to its occurrence and regularity over time and is ranked as:

- High: very likely to occur (ex. will be fished or caught as bycatch) and occurs on a yearly basis.
- Moderate: may occur (ex. possibly caught as bycatch) some years and not others.
- Low: infrequent

The **severity** of the stressor refers to the effect it has on individuals of the species. Severity is ranked as:

- High: causes high probability of direct mortality, including at-vessel or post-release mortality for fisheries threats.
- Moderate: causes moderate probability of direct mortality, including post-release mortality and/or sublethal impacts that result in decreased productivity and fitness.
- Low: does not cause direct mortality and has a negligible or unknown impact on productivity and fitness.

The **trend** refers to the change in frequency or extent of the stressor over time and is ranked as: increasing, stable (i.e., neither increasing or decreasing), decreasing, or unknown.

The **certainty** of the stressor refers to the amount of evidence regarding the effects of the stressor in a subregion or region. Certainty is ranked as follows:

- High: direct evidence or multiple lines of indirect evidence.
- Moderate: indirect, limited, or unclear evidence.
- Low: little or no evidence.

The **relative concern within region** of the stressor refers to the amount of concern regarding the effect of the stressor, relative to other stressors, on the subregion/regional population. Relative Concern is ranked as follows:

- Minimal: stressor is unlikely affecting local populations to a degree that would influence long-term recruitment and survival at a subregion/regional scale.
- Moderate: stressor is contributing to a reduction in local populations that may impact long-term recruitment and survival at a subregion/regional scale.

- Significant: stressor is contributing to reduction in local populations that is causing significant declines in populations at a subregion/regional scale.

To determine the **overall risk** of each stressor to the species, the factors described above were evaluated together qualitatively to determine an overall "risk" at the species level. The risk ranking is based on the following scale: low, low to moderate, moderate, moderate to high, high. The overall risk ranking identifies stressors that are considered to be threats that impede the overall recovery of the species or drive the manta ray's extinction risk throughout its range.

Table 14. Giant Manta Ray Stressor/Threats Assessment Summary Table

Atlantic Ocean Region							
Stressor (Cause)	**Major Effect**	**Frequency**	**Severity**	**Trend**	**Certainty**	**Relative Concern within Region**	**Overall Extinction Risk Ranking**
1A Western North Atlantic							
Commercial fisheries bycatch; trawl	Injury/ Mortality	High	Moderate - High	Unknown	High	Moderate	Low-Moderate
Commercial fisheries bycatch; longline	Injury/ Mortality	High	Low - Moderate	Unknown	High	Minimal	Low
Commercial fisheries bycatch; gillnet	Injury/ Mortality	Moderate	Moderate	Unknown	High	Minimal	Low
Commercial fisheries bycatch: purse seine	Injury/ Mortality	Low	Moderate	Unknown	Low	Minimal	Low
Recreational fisheries interactions	Injury/ Mortality	High	Low	Increasing	High	Minimal	Low

Inadequacy of fisheries regulations	Injury/ Mortality	n/a	Moderate	Stable	Moderate	Moderate	Low-Moderate
1B Eastern and Southern North Atlantic							
Commercial fisheries bycatch; longline	Injury/ Mortality	Moderate	Low - Moderate	Unknown	Low	Minimal	Low
Commercial fisheries bycatch; purse seine	Injury/ Mortality	Moderate	Moderate	Unknown	Low	Minimal	Low
Commercial fisheries bycatch;trawls	Injury/ Mortality	Moderate	Moderate - High	Unknown	Low	Minimal	Low
Artisanal/small- scale fisheries (for commercial or subsistence)	Injury/ Mortality	High	High	Unknown	Low	Moderate	Low-Moderate
Illegal retention/ enforcement issues	Mortality	High	Moderate - High	Unknown	Low	Moderate	Low-Moderate
Inadequacy of fisheries regulations	Injury/ Mortality	n/a	Moderate - High	Stable	Moderate	Moderate	Low-Moderate
Indian Ocean Region							
Stressor (Cause)	**Major Effect**	**Frequency**	**Severity**	**Trend**	**Certainty**	**Relative Concern within Region**	**Overall Risk Ranking**
Artisanal/small- scale fisheries (for commercial or subsistence)	Injury/ Mortality	High	High	Increasing	High	Significant	High

Commercial fisheries bycatch; purse seine	Injury/ Mortality	Moderate-High	Moderate	Unknown	Low	Moderate	Low-Moderate
Commercial fisheries bycatch; longline	Injury/ Mortality	Moderate	Low	Unknown	Low	Moderate	Low-Moderate
Commercial fisheries bycatch; gillnet	Injury/ Mortality	High	Moderate	Unknown	Low	Moderate	Low-Moderate
Inadequacy of fisheries regulations	Injury/ Mortality	n/a	Moderate - High	Stable	Moderate	Significant	Moderate
Illegal retention/ enforcement issues	Mortality	High	High	Stable	High	Significant	High
Pacific Ocean Region							
Stressor (Cause)	**Major Effect**	**Frequency**	**Severity**	**Trend**	**Certainty**	**Relative Concern within Region**	**Overall Risk Ranking**
3A Western Pacific Ocean							
Commercial fisheries bycatch; purse seine	Injury/ Mortality	Moderate	Moderate	Unknown	Moderate	Moderate	Low-Moderate
Commercial fisheries bycatch; gillnet	Injury/ Mortality	Moderate	Moderate	Unknown	Moderate	Moderate	Low-Moderate
Commercial fisheries bycatch; longline	Injury/ Mortality	Moderate	Low - Moderate	Unknown	Moderate	Moderate	Low-Moderate
Artisanal/small- scale fisheries (for	Mortality	High	High	Unknown	Moderate	Significant	Moderate-High

commercial or subsistence)							
Illegal retention/ enforcement issues	Mortality	High	High	Stable	High	Significant	Moderate-High
Inadequacy of fisheries regulations	Injury/ Mortality	n/a	Moderate - High	Stable	Moderate	Moderate	Low-Moderate
3B Central Pacific Ocean							
Commercial fisheries bycatch; longline	Injury/ Mortality	Moderate	Low - Moderate	Unknown	Moderate	Minimal	Low
Commercial fisheries bycatch; purse seine	Injury/ Mortality	Moderate	Moderate	Unknown	Moderate	Minimal	Low
Inadequacy of fisheries regulations	Injury/ Mortality	n/a	Low	Stable	Moderate	Minimal	Low
3C Eastern Pacific Ocean							
Stressor (Cause)	**Major Effect**	**Frequency**	**Severity**	**Trend**	**Certainty**	**Relative Concern within Region**	**Overall Risk Ranking**
Commercial fisheries bycatch; purse seine	Injury/ Mortality	High	Moderate	Unknown	Moderate	Moderate	Low-Moderate
Artisanal/small- scale fisheries (for commercial or subsistence)	Injury/ Mortality	High	High	Decreasing	High	Significant	Moderate-High

Illegal retention/ enforcement issues	Mortality	High	High	Unknown	High	Significant	Moderate-High
Inadequacy of fisheries regulations	Injury/ Mortality	n/a	Moderate - High	Stable	Moderate	Moderate	Low-Moderate

Globally / International						
Stressor (Cause)	**Major Effect**	**Frequency**	**Severity**	**Trend**	**Certainty**	**Overall Risk**
Climate change	Fitness, Productivity, Reproduction	n/a	Unknown	Increasing	Low	Low
Entanglement (e.g., ghost-fishing/ marine debris; mooring lines)	Injury/ Mortality	High	Moderate	Increasing	Moderate	Low
Tourism	Fitness, Productivity, Reproductio n	High	Unknown	Increasing	Low	Low
Aquarium Trade	Fitness, Productivity, Reproductio n	Low	Unknown	Unknown	Moderate	Low
Environmental contaminants/ pollutants	Fitness, Productivity, Reproductio n	n/a	Unknown	Unknown	Low	Low

Vessel strikes	Injury/ Mortality	High	Moderate	Increasing	Moderate	Low

Of the identified stressors to the giant manta ray, those we identified as a high, moderate-to-high, or moderate risk of being a threat that impedes the overall recovery of the species or drives the manta ray's extinction risk (as they appear in **Table 14**) are as follows: targeted catch and bycatch in artisanal/small-scale fisheries, inadequate regulatory mechanisms to address targeted fishing and/or bycatch and retention of the species for the international gill plate trade, and illegal retention and enforcement issues. These threats occur in a significant portion of the species' range, which comprises the Indian Ocean, Western Pacific Ocean Subregion and Eastern Pacific Ocean Subregion. The stressors that we consider to be "lesser" threats are those that we identified as being of moderate concern within the subregion or region and that are threats that have a low to moderate risk of impeding the overall recovery of the species throughout its range, or driving the giant manta ray's extinction risk. These lesser threats are as follows: bycatch in commercial fisheries, particularly purse seines, gill nets, longlines, and trawls, and the inadequacy of fisheries regulations and enforcement throughout the species' range. Finally, there are several other stressors that are of lesser concern but may work synergistically to cause negative effects to giant manta rays and, thus, should be monitored. These stressors are as follows: climate change, environmental contaminants/pollutants, vessel strikes, entanglement, recreational fishery interactions, tourism, and aquarium trade. We will update the threats assessment portion of the Recovery Status Review as we learn more about how threats and stressors continue to act on the species, both individually and synergistically.

For information on NMFS' strategy for recovering the giant manta ray based on the biology, life history, and threats assessment presented in this Recovery Status Review, please refer to the **Recovery Plan for the Giant Manta Ray** and the **Recovery Implementation Strategy for Giant Manta Ray.**

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APPENDIX

Legal Protections for Manta Rays (adapted from CITES 2013)

Location	Species	Legal Protection / Conservation Measure
International		
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Signatories	*Manta* spp.	CITES Appendix II , 2013
Convention on the Conservation of Migratory Species of Wild Animals (CMS) Signatories	*M. birostris*	CMS Appendix I and II, 2011 & 2014, respectively
Regional		
The Inter-American Tropical Tuna Commission (IATTC) members	*Manta* spp.	Resolution C-15-04
The Indian Ocean Tuna Commission (IOTC)	Mobulid rays	Resolution 19/03
Western and Central Pacific Fisheries Commission (WCPFC)	Mobulid rays	CMM 2019-05
Micronesia: Federated States of Micronesia, Guam, Mariana Islands, Marshall Islands, Palau	All ray species	Micronesia Regional Shark Sanctuary Declaration to prohibit possession, sale, distribution and trade of rays and ray parts, 2012
National		
Australia	*Manta* spp.	Listed as migratory species under the Environment Protection and Biodiversity Conservation Act 1999
Bangladesh	Mobulid rays	Schedule I of the Bangladesh Wildlife (Conservation and Security) Act, 2012 (updated 2020); No killing, trade, consumption permitted
Brazil	*Manta* spp.	Instrução Normativa Interministerial no 2, de 13 de Março de 2013; Directed fishing and marketing of species,

		products and by-products of Mobulidae are prohibited. Additionally, gillnets and longlines are restricted between December and May, which is referred to as “manta ray season,” in order to avoid incidental captures of the species (Medeiros et al. 2015).
Ecuador	*M. birostris*	Ecuador Official Policy 093, 2010
European Union	*M. birostris*	Article 1 of COUNCIL REGULATION (EU) No 692/2012
Honduras	All elasmobranchs	Ban on fishing for elasmobranchs, 2010
Indonesia	*Manta spp.*	Minister of Marine Affairs and Fisheries 4/KEPMEN-KP/2014; established full protected status of *M. birostris* and *M. alfredi* in Indonesian waters (creating world’s largest manta ray sanctuary at around 6 million km^2).
Israel	All elasmobranchs	Protected in Israeli waters, 1980.
Maldives	*Manta spp.*	Exports of all ray products banned in 1995 and specifically the export of ray skins in 1996. Indirect forms of protection include prohibitions of most net fishing (including pelagic gillnets, trawling , and purse seining).
Mexico	All ray species	NOM-029-PESC-2006 Prohibits harvest and sale

Mozambique	Mobulid rays	REPMAR, Decree 89/2020; Prohibits capture
New Zealand	*M. birostris*	Wildlife Act 1953 Schedule 7A (absolute protection), 2010
Peru	*M. birostris*	Ministerial Resolution 441-2015-PRODUCE; prohibits the landing, transport, capture, retention, processing, and/or sale of giant manta rays within marine Peruvian waters. Mantas that are caught as bycatch are to be immediately released alive and cannot be commercialized or used for human consumption, 2016.
Philippines	*M. birostris*	FAO 193 1998 Whale Shark and Manta Ray Ban
United Arab Emirates	*Manta* spp.	Manta rays fully protected in UAE waters, 2014
Yap (FSM)	*Manta spp.*	Manta Ray Sanctuary and Protection Act 2008; harming, killing, or destroying manta ray habitat is prohibited – covers an 8,243 square mile area around Yap, comprising 16 main islands and atolls and 145 islets.
State		
Florida, USA	Genus *Manta*	FL Admin Code 68B-44.008 – no harvest
Guam, USA Territory	All ray species	Article 1, Chapter 63 of Title 5, Guam Code Annotated, Sec. 63114.2
Commonwealth of the Northern Mariana Islands	All ray species	Public Law No. 15-124
Hawaii, USA	*Manta spp.*	HI Rev Stat Sec. 188-39.5

Puerto Rico, USA Territory	*M. birostris*	Fishery Management Plan for Puerto Rico; 50 CFR §622.438
Raja Ampat Regency, Indonesia	*Manta spp.*	Shark and Ray Sanctuary Bupati Decree 2010; Regional Regulation 9/2012 (Regional law PERDA #9) prohibits the capture of manta rays in Raja Ampat waters.
West Manggarai, Indonesia	*Manta spp.*	No. DKPP/1309/VIII/2013; protection for mantas in the Komodo National Park
Marine Protected Areas (covering areas with observed manta presence)		
Cocos Island, Costa Rica	*Manta spp.*	Cocos Island National Park, 1978.
Guam	*Manta* spp.	Limited take MPA zone along northwest coast that covers around 57% of shore line where mean densities of manta rays for recent years (2008-2012) were highest (Martin et al. 2015).
Gulf of Mexico, USA	*Manta* spp.	Flower Garden Banks National Marine Sanctuary; Regulations prohibit killing, injuring, attracting, touching, or disturbing rays or whale sharks, except for incidental catch by conventional hook and line gear, 2012.
Eastern Australia	*Manta* spp.	Mantas occur in the Great Barrier Reef Marine Park, protected from fishing within “green zones.”
Maldives	*Manta* spp.	32 designated marine protected areas, of which 5 were specifically designated because of presence of mantas.

Pacific Remote Islands	*Manta* spp.	Pacific Remote Islands Marine National Monument, comprises approximately 370,000 square nm, encompassing 7 islands and atolls in Central Pacific Ocean. Commercial fishing is prohibited and no fishing is allowed within 12 nm of islands, 2009, 2014.
Philippines	*Manta* spp.	Tubbataha Reefs Natural Park was declared an MPA in 1988 and was expanded to include the Jessie Beazley Reef and a 10 nm buffer zone in 2010.
Revillagigedo Islands, Mexico	*Manta* spp.	Marine Protected Area, 1994, with 12-mile no-fishing zone surrounding each island.
Western Australia	*M. birostris*	16 Marine Parks designated along Western Australia's coast; includes Ningaloo Marine Park where manta rays are frequently observed and where *M. birostris* is protected from fishing and harassment. Protection for *Manta* spp. from recreational fishing only within "green zones" within state waters.
Yaeyama Islands, Japan	*Manta spp.*	Marine Protected Areas, 1998.