Billing Code: 3510-22-P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

[Docket No. 191127-0095]

RTID 0648-XR030

Endangered and Threatened Species; Determination on the Designation of Critical Habitat for Giant Manta Ray

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of Critical Habitat Determination.

SUMMARY: We, NMFS, have determined that a designation of critical habitat is not prudent at this time. Based on a comprehensive review of the best scientific data available, we find that there are no identifiable physical or biological features that are essential to the conservation of the giant manta ray within areas under U.S. jurisdiction. We also find that there are no areas outside of the geographical area occupied by the species under U.S. jurisdiction that are essential to its conservation. As such, we find that there are no areas within the jurisdiction of the United States that meet the definition of critical habitat for the giant manta ray.

DATES: This finding is made on [*INSERT DATE OF PUBLICATION IN THE FEDERAL REGISTER*].

ADDRESSES: Electronic copies of the determination, list of references, and supporting documents prepared for this action are available from the NMFS Office of Protected Resources website at *https://www.fisheries.noaa.gov/species/giant-manta-ray*.

FOR FURTHER INFORMATION CONTACT: Maggie Miller, NMFS, Office of Protected Resources, (301) 427-8403.

SUPPLEMENTARY INFORMATION:

Background

On January 22, 2018, we published a final rule to list the giant manta ray (*Manta birostris*) as a threatened species under the Endangered Species Act (ESA) (83 FR 2916). Section 4(b)(6)(C) of the ESA requires the Secretary of Commerce (Secretary) to designate critical habitat concurrently with making a determination to list a species as threatened or endangered unless it is not determinable at that time, in which case the Secretary may extend the deadline for this designation by 1 year. At the time of listing, we concluded that critical habitat was not determinable because sufficient information was not available to: (1) identify the physical and biological features essential to the conservation of the species at an appropriate level of specificity, particularly given the uncertainty regarding habitats required to support its life history (*e.g.*, pupping and nursery grounds were unknown) and migratory movements, (2) determine the specific geographical areas that contain the physical and biological features essential to conservation of the species, particularly given the global range of the species, and (3) assess the impacts of the designation. We requested relevant information from interested persons to help us identify and describe the physical and biological features essential to the conservation of the giant manta ray, and assess the economic consequences of designating critical habitat for the species. We solicited input from the public, other concerned government agencies, the scientific community, industry and any other interested party on features and areas that may meet the definition of critical habitat for the giant manta ray within U.S. waters. We received information regarding giant manta ray occurrence in the Flower Garden Banks National Marine Sanctuary (Stewart et al. 2018b) as well as off the coast of Florida. We reviewed this information and considered it along with other available information we compiled. Together, this information comprises the best available scientific data for use in the identification of critical habitat for the giant manta ray. However, as discussed below, based on these data we find that there are no identifiable physical or biological features that are essential to the conservation of the giant manta ray within areas under U.S. jurisdiction, or unoccupied areas under U.S. jurisdiction that are essential to the conservation of the species. Therefore, at this time we find no areas within U.S. jurisdiction that meet the definition of critical habitat for the giant manta ray.

This finding describes information on the biology, distribution, and habitat use of the giant manta ray and the methods used to identify areas that may meet the definition of critical habitat. In this determination, we focus on information directly relevant to the designation of critical habitat for giant manta rays.

Giant Manta Ray Biology and Status

The following discussion of the life history and status of giant manta ray is based on the best scientific data available, including the “Endangered Species Act Status Review Report: Giant Manta Ray (*Manta birostris*) and Reef Manta Ray (*Manta alfredi*)” (Miller and Klimovich 2017).

Manta rays are large bodied, planktivorous rays, considered part of the Mobulidae subfamily. *Manta* species are distinguished from other Mobula rays in that they tend to be larger, with a terminal mouth, and have long cephalic fins (Evgeny 2010); however, misidentifications are common both between *Manta* species (*i.e.*, between *M. alfredi* and *M. birostris*) as well as between *Manta* and *Mobula* rays. In addition, recent taxonomic studies have suggested that *Manta birostris* and *Manta alfredi* may actually be closely related to the giant devil ray (*Mobula mobular*) (White et al. 2017), with genetic analyses that demonstrate support for nesting these species under the genus *Mobula* rather than *Manta* (White et al. 2017; Hosegood et al. 2019). The studies still recognize both manta rays as distinct species, but refer to them as *Mobula birostris* and *Mobula alfredi*.

The giant manta ray, *M. birostris*, can be found in all ocean basins, while the reef manta ray, *M. alfredi*, is currently only observed in the Indian Ocean and the western and south Pacific. Additionally, we note that a third, putative manta ray species has been identified (referred to here as *M. cf. birostris*), with its range extending along the Atlantic coast, Gulf of Mexico, and Caribbean, based on research conducted in the western Atlantic (A. Marshall, MMF, pers. comm. to M. Miller, NMFS OPR, 2019). A manuscript identifying this third species is expected in the near future; however, according to Dr. Andrea Marshall, this newly identified manta species is highly abundant off the U.S. east coast, with a large population also found off the Yucatán peninsula (A. Marshall, MMF, pers. comm. to M. Miller, NMFS OPR, 2019). This new species looks very similar to *M. birostris*, with only a few diagnostic features that could potentially distinguish the two (mainly small morphological and meristic ones; A. Marshall, MMF, pers. comm. to M. Miller, NMFS OPR, 2019). Without genetic testing, species identification cannot be completely validated (Hinojosa-Alvarez et al. 2016; Kashiwagi et al. 2017; Hosegood et al. 2019).

Therefore, for purposes of this critical habitat determination, we will consider any records of manta rays in the Atlantic to be *M. birostris* (even though an unknown proportion may comprise *M. cf. birostris*) and will continue to recognize *Manta birostris* as a species under the genus *Manta*.

The genus *Manta* has a complex taxonomic history due partially to the difficulty of preserving such large specimens and also the conflicting historical reports of taxonomic characteristics (Couturier et al. 2012; Kitchen-Wheeler 2013). Prior to 2009, most manta rays were categorized as *Manta birostris,* but Marshall et al. (2009) presented new data that supported the splitting of the *Manta* genus into two species: *M. birostris* and *M. alfredi.*

Both *Manta* species have diamond-shaped bodies with wing-like pectoral fins; the distance over this wingspan is termed disc width (DW). There are two distinct color types in both species: 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). The black color variants of both species 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).

Giant manta rays inhabit tropical, subtropical, and temperate bodies of water and are commonly found offshore, in oceanic waters, and near productive coastlines. It is thought to be a generally long-lived species (>28 years) (Stewart et al. 2018a) with low reproductive output. Manta rays, like all chondrichthyans, reproduce via internal fertilization (Wourms 1981), and the sexes can be differentiated by the presence of myxopterigia, or claspers, on the inner margin of the pelvic fins in males, whereas females lack these structures. Sexual maturity in males can be easily determined by examining the level of calcification in these intromittent organs. In their examination of mobulids taken as bycatch in the Indonesian drift net fishery, White et al. (2006) found that male *M. birostris* greater than 3,800 mm DW possessed fully calcified claspers and were, therefore, mature, while those less than 3,800 mm DW possessed either non-calcified or partially calcified claspers. In the same study, White et al. (2006) found that females 2,732 to 3,774 mm DW were immature and females measuring 4,126 mm DW and greater were mature. White and Last (2016) report similar ranges, with males maturing between approximately 3,750 and 4,000 mm DW and females maturing between approximately 4,100 and 4,700 mm DW. In the Flower Gardens Banks National Marine Sanctuary (FGBNMS), Stewart et al. (2018b) observed a mature male *M. birostris* with an estimated size of 3,600 mm. The age that *M. birostris* matures is not known, but it may be similar to that of reef mantas, with males maturing at 3–6 years and females at 8–10 years (Stewart et al. 2018a).

Gestation time is also not known for this species, and parturition has only been witnessed once and under unnatural conditions (Coles 1916). It is suspected that gestation would be similar to that observed in *M. alfredi*, which is generally accepted to be 12 to 13 months (Kitchen-Wheeler 2013). In addition to the Coles (1916) observation of a single embryo aborted during capture, the limited investigations of pregnant females with embryos intact have all indicated the presence of a single embryo per pregnancy (Muller and Henle 1838-1841; Beebe and Tee-Van 1941). 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 remained elusive for *M. birostris*. The embryos examined in the previous studies had sizes of 1,140 mm and 1,270 mm DW (Muller and Henle 1838-1841; Beebe and Tee-Van 1941), while the smallest free swimming individuals reported by Stewart et al. (2018b) were approximately 1,000 mm DW (however, these individuals may have been *M. cf. birostris*). Rambahiniarison et al. (2018) recently estimated size at birth of *M. birostris* to be 2,000 mm DW based on the DW of the largest fetus and the smallest free-living specimen captured in the Philippines mobulid fishery.

Very little is known about the early life stages or habitat needs or requirements of *M. birostris* because, until fairly recently, juveniles have rarely been observed in the wild. However, large numbers of juvenile *M. birostris* have been caught in Sri Lanka in offshore pelagic habitats by the gill-net fisheries, landed by fisherman in Brazil and Indonesia, and also observed in oceanic habitats off Mexico (Stewart et al. 2016a; Stewart et al. 2018b). Stewart et al. (2016a) suggests that adult and juvenile giant mantas may use similar offshore pelagic habitats, but that the juveniles may avoid cleaning stations and other near-shore areas where adults are more commonly observed to reduce predation risk. In fact, results from stable isotope analyses of muscle tissues collected from both adult and juvenile *M. birostris* off Peru, Sri Lanka, and the Philippines appear to provide further confirmation that the species may not undergo an ontogenetic shift in feeding behavior or trophic level, with both adults and juveniles sharing the same habitats and targeting the same prey (Stewart et al. 2017).

In terms of prey, giant manta rays primarily feed on planktonic organisms such as euphausiids, copepods, mysids, decapod larvae, and shrimp, with some studies noting their consumption of small and moderate sized fishes as well (Bigelow and Schroeder

1953; Carpenter and Niem 2001; Graham et al. 2012; Stewart et al. 2016b; Burgess 2017; Rohner et al. 2017). They feed by swimming with their mouths open, continuously filtering zooplankton. Their gill rakers filter out water, leaving behind food particles that are then directed to the esophagus through cross-flow (Paig-Tran 2012). This filter mechanism allows mantas to retain prey of various sizes, even if they are smaller than the filter pores, which means they can effectively feed on mixed zooplankton assemblages where prey range in size from small calanoid copepods to larger mysids and euphausiids (Stewart et al. 2016b). Given the feeding habits of the giant manta ray, it can be considered a generalist carnivore, with a trophic position of approximately 3.4 (Burgess et al. 2016; Burgess 2017).

With regards to movement, the giant manta ray is considered to be a migratory species, with satellite tracking studies measuring straight line distances of up to 1,500 km (Hearn et al. 2014). Some giant manta rays appear to migrate seasonally, possibly due to the seasonal fluctuations in food sources (Wilson et al. 2001; Luiz et al. 2009; Graham et al. 2012; Sobral and Afonso 2014; De Boer et al. 2015; Girondot et al. 2015; Stewart et al. 2016a; Hacohen-Domené et al. 2017). However, in some portions of its range, the species may actually exist as well-structured subpopulations with a high degree of residency (Stewart et al. 2016a).

As discussed in the proposed rule (82 FR 3694, January 12, 2017) and final rule (83 FR 2916, January 22, 2018) to list the giant manta ray, the most significant threat to the species is overutilization for commercial purposes. Giant manta rays are both targeted and caught as bycatch in a number of fisheries throughout their range, and are most susceptible to industrial purse-seine and artisanal gillnet fisheries. With the expansion of the international mobulid gill raker market and increasing demand for manta ray products, estimated take of giant manta rays, particularly in many portions of the Indo-Pacific, frequently exceeds numbers of identified individuals in those areas. Observations from these areas also indicate declines in sightings and landings of the species. Given the extremely low reproductive output and overall productivity of the giant manta ray, it is inherently vulnerable to threats that would deplete its abundance, with a low likelihood of recovery. So, while there is considerable uncertainty regarding the current abundance of *M. birostris* throughout its entire range, the best available information indicates that the species is likely to become an endangered species within the foreseeable future throughout a significant portion of its range (the Indo-Pacific and eastern Pacific portion) due to overutilization.

Critical Habitat Identification and Designation

Critical habitat is defined by section 3 of the ESA as: “(i) the specific areas within the geographical area occupied by the species, at the time it is listed . . . , on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed . . . upon a determination by the Secretary that such areas are essential for the conservation of the species.” This definition provides a step-wise approach to identifying areas that may qualify as critical habitat for the giant manta ray: (1) determine the geographical area occupied by the species at the time of listing; (2) identify physical or biological habitat features essential to the conservation of the species; (3) delineate specific areas within the geographical area occupied by the species on which are found the physical or biological features; (4) determine whether the features in a specific area may require special management considerations or protection; and (5) determine whether any unoccupied areas are essential for conservation. Our evaluation and conclusions as we worked through this step-wise process are described in detail in the following sections.

Geographical Area Occupied by the Species

The "geographical area occupied by the species" is defined in our regulations as "an area that may generally be delineated around species' occurrences, as determined by the Secretary (*i.e.*, range). Such areas may include those areas used throughout all or part of the species' life cycle, even if not used on a regular basis (*e.g.*, migratory corridors, seasonal habitats, and habitats used periodically, but not solely by vagrant individuals)." (50 CFR 424.02). Further, our regulations at 50 CFR 424.12(g) state: "The Secretary will not designate critical habitat within foreign countries or in other areas outside of the jurisdiction of the United States." As such, we focus the following discussion on the range of the species within waters under U.S. jurisdiction.

In the Atlantic, giant manta rays have been confirmed as far north as Long Island, New York (offshore around the Hudson Canyon region) (Normandeau Associates and APEM Ltd 2017); however, as will be discussed later, we note that they are generally rare north of Cape Hatteras, North Carolina. To the south, giant manta rays occur off the coast of North Carolina, South Carolina, Georgia, and Florida (Marshall et al. 2011). Giant manta rays can also be found throughout the U.S. Gulf of Mexico and within the U.S. Caribbean, including off Puerto Rico and the U.S. Virgin Islands (Marshall et al. 2011). In the central Pacific, giant manta rays are found off Hawaii (Clark 2010) and

Jarvis Island (K. Lino unpublished data). While there have been no confirmed sightings of giant manta rays in waters of the other Pacific Remote Island Areas, Northern Mariana Islands (Kashiwagi et al. 2011), Guam (Kashiwagi et al. 2011), or American Samoa, based on confirmed observations of the species elsewhere throughout the Pacific (*e.g.*, Ogasawara Islands, Japan (Kashiwagi et al. 2010); Philippines (Verdote and Ponzo 2014); French Polynesia (Mourier 2012); Jarvis Island (K. Lino unpublished data); Hawaii (Clark 2010)) and coupled with the migratory and pelagic nature of giant manta rays, their ability to exploit significant depths, and tolerance of tropical to temperate water temperatures, we find no known barriers to their movement that may prevent them from occurring at these locations.

In the eastern U.S. Pacific, while there is documentation of a giant manta off the west coast (*i.e.*, San Clemente Island, California), this sighting was of a single individual in 2014 (Warneke 2014) and there have been no documented sightings since (or prior to) this time. Given the amount of fishing effort, as well as the human population density in these regions, it is highly unlikely that substantial concentrations of giant manta rays would have passed unnoticed. As such, we consider this individual to be a vagrant of the species (an individual that occurs outside of the species' normal range). Therefore, as the occurrence of giant manta rays in waters off the U.S. west coast is extremely uncommon, we do not consider this geographical area to be part of the species' occupied range at the time of listing.

Conclusion

Based on the above information and analysis, we define the geographical area occupied by the giant manta ray at the time of listing as all U.S. waters off the east coast, from Florida to Long Island, New York, the entire Gulf coast, the U.S. Virgin Islands and Puerto Rico in the Caribbean, and Hawaii, the Pacific Remote Islands Areas, Guam, American Samoa, and the Northern Mariana Islands in the Pacific.

Physical or Biological Features Essential for Conservation

Within the geographical area occupied by an endangered or threatened species at the time of listing, critical habitat consists of specific areas upon which are found those physical or biological features essential to the conservation of the species and that may require special management considerations or protection. The ESA does not specifically define physical or biological features; however, court decisions and joint NMFS-USFWS regulations at 50 CFR 424.02 provide guidance on how physical or biological features are expressed. Specifically, these regulations state that the physical and biological features are those that are essential to support the life-history needs of the species, including but not limited to, water characteristics, soil type, geological features, sites, prey, vegetation, symbiotic species, or other features. A feature may be a single habitat characteristic, or a more complex combination of habitat characteristics. Features may include habitat characteristics that support ephemeral or dynamic habitat conditions. Features may also be expressed in terms relating to principles of conservation biology, such as patch size, distribution distances, and connectivity. (50 CFR 424.02).

Section 3 of the ESA (16 U.S.C. 1532(3)) defines the terms “conserve,” “conserving,” and “conservation” to mean: “to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary.” For giant manta rays, we consider conservation to include the use of all methods and procedures necessary to bring giant manta rays to the point at which factors related to population ecology and vital rates indicate that the species is recovered in accordance with the definition of recovery in 50 CFR 402.02. Important factors related to population ecology and vital rates include population size and trends, range, distribution, age structure, gender ratios, age-specific survival, age-specific reproduction, and lifetime reproductive success. Based on the available knowledge of giant manta ray population ecology and life history, we have identified four biological behaviors that are critical to the goal of increasing survival and population growth: (1) foraging, (2) pupping, (3) migration, and (4) breeding. In the following section, we evaluate whether there are physical and biological features of the habitat areas known or thought to be used for these behaviors that are essential to the species' conservation because they facilitate or are intimately tied to these behaviors and, hence, support the life-history needs of the species. Because these behaviors are essential to the species' conservation, facilitating or protecting each one is considered a key conservation objective for any critical habitat designation for this species.

Analysis of the Physical and Biological Features of Foraging Habitat that are Essential to the Conservation of the Species

Giant manta rays are filter-feeders and generalist carnivores that feed on a variety of planktonic organisms, including euphausiids, copepods, mysids, decapod larvae and shrimp, as well as small fishes. Prey needs to be of sufficient density and quality to support the energy requirements for the giant manta rays, particularly as they conduct long-distance migrations across open oceans. Sustained decreases in prey quantity, quality, availability, or accessibility can decrease foraging success of giant manta rays and eventually lead to reduced individual growth, reproduction, and development. Therefore, using the best available data, we examined the diet and energy needs of giant manta rays, including foraging behavior, to determine whether we could identify physical or biological features of habitat that facilitate successful giant manta ray feeding and, thus, are essential for the conservation of the species.

As mentioned above, planktonic organisms comprise the majority of the diet for giant manta rays. While it was previously assumed that manta rays obtain most of their energy needs from surface zooplankton, results from recent studies indicate that these feeding events may not be the primary source of the dietary intake (Burgess et al. 2016; Stewart et al. 2016b). For example, for giant manta rays off Ecuador, Burgess et al. (2016) estimated that, on average, mesopelagic food sources contribute 73 percent to the giant manta ray's diet compared to 27 percent for surface zooplankton. In the Mexican Pacific, Stewart et al. (2016b) interpreted dive profiles and submersible video data of *M. birostris* to suggest that giant manta rays frequently forage on vertically migrating zooplankton and zooplankton in the epipelagic scattering layers in addition to surface zooplankton.

Analysis of stomach contents and collection of zooplankton during observed giant manta ray feeding events reveal a varied diet, with no targeting of a specific species or size of prey (Graham et al. 2012; Armstrong et al. 2016; Stewart et al. 2016b; Burgess 2017; Rohner et al. 2017). Rather, density of the prey appears to be the driving factor that triggers giant manta ray feeding behavior. However, the levels necessary to attract giant manta rays remain unknown. For example, a study conducted by Burgess (2017) found that giant manta ray aggregations off the northwest side of Isla de la Plata, Ecuador, were unlikely associated with foraging opportunities as observations of feeding events were rare. Specifically, Burgess (2017) collected surface zooplankton during feeding events (n=5) and during non-feeding events (n=79) and calculated that the dry zooplankton biomass was 1.9 mg m^{-3} during the rare *M. birostris* feeding events and 1.4 mg m^{-3} during non-feeding events. Although comparable data are unavailable for *M. birostris* elsewhere throughout its range, these figures are substantially lower than what has been reported for the closely related reef manta ray, *M. alfredi*, in eastern Australia during regular active feeding (19.1 mg m^{-3}) and non-feeding (9.3 mg m^{-3}) events (Armstrong et al. 2016). In fact, Armstrong et al. (2016) determined that the critical prey density threshold for *M. alfredi* feeding was 11.2 mg m^{-3}. If *M. birostris* has similar prey density thresholds, these data lend support to Burgess (2017)'s finding that the aggregative behavior of giant manta rays at Isla de la Plata is unlikely related to feeding. Furthermore, the data suggest that for habitat to be characterized as providing necessary foraging opportunities, it likely requires substantially higher levels of zooplankton biomass than what was found off Isla de la Plata.

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 (Rohner et al. 2017). Using adiabatic bomb calorimetry, Rohner et al. (2017) calculated that krill (*Euphausia diomedeae*), the dominant prey species for *M. birostris* in this particular 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 (Rohner et al. 2017). This energetic contribution is significantly greater than what has been found for reef manta rays in captivity. Rohner et al. (2017), 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 percent 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. (2017) 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 author cites the particularly large capacity of the *M. birostris* stomach, as well as the branchial filter pad and filtration mechanism used 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 a particular prey item of *M. birostris* in a specific area, it is difficult to make any conclusions as to the general energy needs or requirements for the species throughout its range.

With the lack of available data regarding prey density thresholds or caloric value requirements, we next looked at areas where manta rays have been observed or assumed to be feeding to determine whether we could identify any physical or biological features of these habitats that are tied to foraging behavior. In many portions of the species' range, it is the presence of seasonal upwelling events, which concentrate plankton and create patches of high productivity, that appear to drive the occurrence of giant manta rays in areas, presumably for foraging. For example, off the northern Yucatán peninsula, Hacohen-Domené et al. (2017) found a higher probability of *M. birostris* occurrence from July through September, with the main difference being the increase in primary productivity during this time of year (with particularly high probability of occurrence when primary productivity was at 4,500 mg $C \cdot m^{-2} \cdot day^{-1}$). Other features associated with a greater probability of giant manta ray presence in this area included sea surface temperatures (SST) warmer than 27°C, shallow (< 10 m depths) and nearshore waters (< 50 km from shore), with a bottom slope of < 0.5° (Hacohen-Domené et al. 2017). However, the authors note that most of the manta rays observed in the study were not foraging but rather swimming alone or in pairs. While Hacohen-Domené et al. (2017) did not observe or analyze feeding habits in their study, Hinojosa-Alvarez et al. (2016) confirmed foraging behavior in this area (specifically between 21°46.020'N and 87°01.200'W and 21°30.00' and 86°4100), with videos of Yucatán manta rays feeding in surface waters from May through August (the same period as the seasonal upwelling).

Seasonal occurrence of manta rays was also observed off the continental shelf of French Guiana. Specifically, Girondot et al. (2015) observed a peak in the presence of manta rays between July and December in the river-ocean transition zone off French Guiana. While specific features of the habitat where giant manta rays were observed was not provided, the authors did note that phytoplankton biomass and primary productivity is generally highest during the months of manta ray presence, with a biomass of over 25 mg Chl-a m^{-3} and productivity of over 8 g $C°m^{-2}*day^{-1}$ (Girondot et al. 2015).

Similarly, in southeastern Brazil, giant manta rays are most frequently sighted in Laje de Santos Marine State Park (24°S) during seasonal upwelling, from June to August (Luiz et al. 2009). During this time, the warm Brazil Current weakens and coastal waters change direction and move northward, bringing waters from the southern Falklands Current to areas of southeastern Brazil (Luiz et al. 2009). This current displaces a low salinity front (generated by discharge from the La Plata River) from the mouth of the La Plata River during the summer to areas north in the winter (Luiz et al. 2009). It is thought that this coastal front, which accumulates plankton, may attract giant manta rays at Laje de Santos Marine State Park in the winter months (Luiz et al. 2009). However, besides the greater presence of manta rays in this region during the seasonal upwelling event (based on diver photos), no information was provided regarding foraging activities or the essential physical or biological features of the habitat that are necessary to support this behavior.

Off the coast of Suriname, De Boer et al. (2015) found that the presence of *M. birostris* coincided with the region's two rainy seasons. As the outflows of nutrient-rich waters from the Amazon and Suriname rivers lead to a low salinity front during the rainy seasons, the authors suggest that giant manta rays are visiting the coastal waters of Suriname for feeding purposes (De Boer et al. 2015). Although only a few observations of manta rays were recorded during the survey period, the authors found the behavior was likely indicative of foraging (*i.e.*, swimming just below the surface with pectoral fins curled) (De Boer et al. 2015); however, again, no physical or biological features of the foraging habitat were identified.

While upwelling events appear to be the main environmental factor driving manta ray foraging behavior, we note that 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 Yucatán peninsula in eutrophic waters and observed feeding on copepeds (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 also able to exploit different habitats when conditions arise that are suitable for foraging (Graham et al. 2012).

Overall, based on the foregoing information regarding known or presumed foraging areas for giant manta rays, the general and consistent physical oceanographic feature that appear to be associated with foraging habitat is high primary productivity from upwelling events, which favors the potential accumulation of zooplankton. Yet the levels of primary productivity necessary to produce suitable foraging habitat are unknown, and this feature is relatively ubiquitous throughout the global range of the species, with not all areas of high primary productivity providing meaningful foraging habitat for giant manta rays. Furthermore, given that the characteristics of habitat necessary to produce areas of high primary productivity varies by region and site (*e.g.*, seasonal upwelling events due to increased river discharge or wind-driven fronts), we proceeded to focus our examination on whether we could identify any physical and biological features of giant manta ray foraging areas within U.S. waters that are essential to the conservation of the species.

In general, very little published literature exists on giant manta ray occurrence and behavior in U.S. waters. Adams and Amesbury (1998) documented the presence of three giant manta rays in the estuarine waters of the Indian River Lagoon system and in Port Canaveral, Florida. Foraging behavior was not observed and the authors proposed that individuals likely enter the estuary sporadically and stay for only short durations. Freedman and Roy (2012) used Ocean Biogeographic Information System (OBIS) data on giant manta ray observations to examine the spatial distribution of the species along the U.S. east coast. They found a higher number of observations near the continental shelf edge and bordering the Gulf Stream, and suggested a seasonal distribution of the species driven mainly by temperature, with giant manta rays primarily observed in waters from 19°C to 22°C (Freedman and Roy 2012). Manta rays are also known to visit the east coast of Florida, more often in the spring and summer months, moving north as water temperatures rise above 20°C (Levesque 2019). However, while it is known that giant manta rays prefer warmer waters, there is no evidence that this is a physical or biological feature that is essential to the conservation of the species or related to foraging activity. In fact, as noted in the literature, giant manta rays can be found in waters anywhere from 18°C to 30°C (Yano et al. 1999; Freedman and Roy 2012; Graham et al. 2012; Burgess 2017; Hacohen-Domené et al. 2017). Additionally, the OBIS data, upon which Freedman and Roy (2012) based their conclusions, also has inherent flaws as it is an open-access database where any member can submit observations of marine species without validation. As will be discussed below, there are significant misidentification issues associated with *M. birostris* observations and conclusions drawn from this type of sightings data should be made with caution as there are significant uncertainties and limitations to the data.

In the FGBNMS, Stewart et al. (2018b) documented high numbers of giant manta rays but specifically noted that foraging behavior was rare. Citing a personal observation (E. Hickerson), Stewart et al. (2018b) stated that mantas were only rarely seen exhibiting barrel rolling behavior (3 of 88 observations), indicative of feeding, at the banks. In his study of the Flower Garden Banks and surrounding banks, Childs (2001) documented *M. birostris* feeding behavior in February and March of 2000 through the use of a remotely operated vehicle. He noted that *M. birostris* generally fed along escarpments and within the water column over the reef crest; however, no other details were provided regarding these events.

In our own examination of the available data, we compiled manta ray sightings data (NMFS unpublished data) from a number of available surveys (Table 1), photo databases, individual observations, and social media websites (*e.g.*, YouTube and Facebook), and plotted the information to assess whether we could determine "hot spots" of giant manta rays, or areas where manta rays appear to be visiting consistently over time. We initially made the main assumption that sightings of the species were correlated with areas of high prey (as tends to be the case with observations of giant manta rays in other portions of its range). In other words, when a manta ray was spotted, we assumed it was likely because that animal was foraging in the area, but we also looked for behavioral (*e.g.*, barrel rolling, mouth open, cephalic lobes unfurled) or environmental data (*e.g.*, high plankton biomass) that could support this assumption as foraging may not be the only reason for manta ray presence.

Because most manta sightings within surveys are opportunistic in surveys designed for other species, there are some misidentification issues and gaps in the time series. Many of the sightings data were obtained from aerial surveys aimed at collecting information on the distribution and abundance of marine mammals (for example, the Atlantic Marine Assessment Program for Protected Species (AMAPPS) and North Atlantic Right Whale Consortium data). This presents a problem as observers on these surveys are usually not trained in identifying mobulid rays to the species level. In discussions with biologist Todd Pusser, a contract observer for NOAA in the southeast region during the 1990s and early 2000s who was then contracted through the NOAA Northeast Fisheries Science Center (NEFSC) at Woods Hole and participated in these marine mammal surveys from Canada to Cape Hatteras, North Carolina, he confirmed that in both the NOAA aerial and ship surveys along the Atlantic coast, mobulid sightings were simply logged as “manta ray” or “manta spp,” thus greatly inflating the sightings data for *M. birostris* (T. Pusser, pers. comm. to C. Jones, NMFS SEFSC, 2018). In fact, when photos were available from accompanying ship and aerial surveys, the majority of the sightings logged as *M. birostris* in the northeast Atlantic were *Mobula tarapacana* or *M. mobular* (T. Pusser, pers. comm. to C. Jones, NMFS SEFSC, 2018).

Table 1 -- Available Survey Datasets with Reported Manta Sightings

Survey Name	Year(s)	Survey Location
Digital Aerial Baseline Survey - NYSERDA	2016, 2017	Atlantic (38.45°N to 41.08°N)
AMAPPS (aerial)	2010 through 2018	Atlantic (26.03°N to 45.32°N)
North Atlantic Right Whale Consortium database (various surveys)	1986 through 2017	Atlantic (25°N to 41°N)
SEFSC Mid-Atlantic Tursiops Survey (aerial)	1994, 1995	Atlantic (24.5°N to 40.50°N)
SEFSC Southeast Cetacean Aerial Survey	1992, 1995	Atlantic (26.21°N to 35.19°N)
Florida Manta Project (boat & aerial; directed manta ray survey)	2016, 2017, 2018	Atlantic (26.5°N to 27°N)
GA Aquarium (boat & aerial; directed manta ray survey)	2010 through 2017	Atlantic (29.5°N to 29.9°N
SEFSC Platform Calibration Survey (aerial)	1991	Atlantic (35.8°N to 39.3°N)
Gulf of Mexico Marine Mammal Assessment Aerial Surveys - NRDA	2010, 2011, 2012	Gulf of Mexico (98°W to 80.5°W)
GoMAPPS (aerial)	2017, 2018	Gulf of Mexico (97°W to 81°W)
GulfCet (aerial)	1992, 1993, 1994, 1996,1997	Gulf of Mexico (96.5°W to 84°W)
SEFSC GoMex (aerial)	1992, 1993, 1994, 1996	Gulf of Mexico (96.3°W to 82°W)
NOAA Coral Reef Ecosystems Program (towed diver survey)	2006, 2010	Pacific Islands (160°W; Jarvis Island)

Note: Survey locations are given as geographic regions: Atlantic, Gulf of Mexico, Pacific Islands. For Atlantic locations, the latitude range over which the surveys were conducted is given. For Gulf of Mexico and Pacific Island locations, the longitude range over which the surveys were conducted is given.

We similarly found this to be the case with another available dataset from the northeast Atlantic that documented 504 sightings of "Giant Manta Ray" (Normandeau Associates and APEM Ltd 2017). This aerial survey, conducted in 2016 and 2017 and supported by the New York State Energy Research and Development Authority (NYSERDA), encompassed the waters of the New York Bight from Long Island southeast to the continental shelf break. This dataset also had accompanying photos of each animal observation, which a NMFS species expert was able to review and confirm that only 6 of the 504 "giant manta ray" sightings were actually *Manta birostris* (C. Horn, NMFS SERO, pers. comm. to M. Miller, NMFS OPR, 2018). Similarly, in 2015, the NMFS Northeast Fisheries Observer Program database underwent a species verification review whereby NMFS scientists conducted a detailed review of observer photo records with the assistance of manta and devil ray experts (*i.e.*, Dr. Giuseppe Notarbartolo di Sciara, Dr. Andrea Marshall, and Guy Stevens). From 2009 to 2015, there were 25 manta and mobula species records with photos in the database (J. Hare, memo, addressed to R. E. Crabtree, February 1, 2019). Most of the mobula bycatch consisted of *Mobula tarapacana*, with only two confirmed records of *Manta birostris*. These individuals were observed caught off the coast of North Carolina. This observer data appears to further confirm the rare occurrence of *M. birostris* in the U.S. mid-Atlantic and northeast, and supports the advice provided by species experts that all *M. birostris* sightings north of Cape Hatteras should be questioned if there are no corresponding photos.

There may also be occasional misidentifications of *M. birostris* south of Cape Hatteras as both *Mobula tarapacana* and *M. mobular* are also common in this portion of the species' range within the Atlantic (Stevens et al. 2018a, C. Jones unpublished data).

Additionally, *M. tarapacana* co-occurs with *Manta birostris* in the Gulf of Mexico and Caribbean (Childs 2001), potentially confounding those aerial sighting records as well. Thus, while the presence of *M. birostris* south of Cape Hatteras is much more likely (based on photographic evidence), the proportion of *M. birostris* in these datasets to the other two commonly misidentified mobula rays is presently unknown, significantly increasing the uncertainty of the accuracy of the available sightings data.

In addition to misidentification rates, we found other inherent problems with the sightings data during our analysis, including the uncertainty regarding unique sightings and the large gaps in time between surveys. For aerial surveys, planes are generally flown following designated transect lines. Depending on the transect distance and timing, there is potential for double-counting the same animal if the animal is also moving. Without being able to view the ventral side of the animal, it is difficult for aerial observers to identify whether the manta ray they are spotting is the same individual from a previous observation. Aerial surveys are also subject to availability bias (*i.e.*, the percentage of time a manta would be near enough to the surface to be viewed by an aerial observer) and perception bias (*i.e.*, the probability of an observer viewing the animal when it is available). While it is possible to control for some of this uncertainty using distance-weighted sampling techniques for perception bias combined with data from satellite tags for availability bias, we do not have the data or information that would be necessary in order to conduct this type of analysis at this time, nor are we aware of any available studies that have accounted for this uncertainty in reporting and analyzing manta ray sightings.

Furthermore, as some of the aerial surveys were not regularly conducted on an annual or seasonal basis, but rather for specific research purposes that were unrelated to manta ray distribution or abundance, the resulting data was skewed in terms of effort in specific locations and over certain time periods and could not be used to identify potential areas used routinely or repeatedly by giant manta rays. For example, along the east coast, the SEFSC Mid Atlantic Tursiops Surveys (MATS), for which we have manta ray sightings information, were conducted in February of 1994 and July and August of 1995 to examine the distribution and estimate an index of relative abundance for Atlantic bottlenose dolphins inhabiting nearshore coastal waters in the mid and southern Atlantic bight. We also have data from the SEFSC Southeast Cetacean Aerial Survey, SECAS, from February to March in 1992 and March of 1995, a survey that was conducted to estimate cetacean abundance. The Gulf of Mexico Marine Mammal Assessment Aerial Surveys – Natural Resource Damage and Assessment surveys were only conducted during the spring and summer of 2010 and seasonally during 2011 to 2012 to assess the abundance and spatial distribution of marine mammals and sea turtles within the region impacted by the Deepwater Horizon oil spill. The Atlantic Marine Assessment Program for Protected Species (AMAPPS), which conducted annual aerial surveys from 2010 – 2017, had as its main objective assessing the abundance, distribution, ecology, and behavior of marine mammals, sea turtles, and seabirds throughout the U.S. Atlantic. However, again, these surveys, as well as others that were analyzed (see Table 1), varied with respect to the geographical coverage, years and even months in which they were conducted. Currently there are no available analyses of datasets or studies that control for spatial and temporal variation in sampling effort, perception and availability bias, and potential misidentification rates to distinguish areas of high giant manta ray abundance.

Recently, we became aware of an ongoing dedicated manta ray aerial survey, conducted by the Georgia Aquarium, which has documented manta ray presence off the east coast of Florida since 2010. The manta aerial surveys are conducted in spring and summer (March/April to June/July) and follow general track lines 0 to 2.5 nautical miles (0 to 4.63 km) from the beach that run parallel to the shore, from St. Augustine Beach Pier (29° 52’N) to Flagler Beach Pier (29° 29’N). The number of mantas are counted and, occasionally, dorsal photos of mantas are collected during these surveys. However, due to the murkiness of the water, photos are rather hard to obtain if the mantas are too deep in the water column, and no ventral photos are available (H. Webb, GA Aquarium, pers. comm. to M. Miller, NMFS OPR, 2019), preventing the identification of individual manta rays or analysis of potential site fidelity over the course of multiple years. Overall, the sightings data indicate the seasonal visitation of manta rays to Florida’s inshore waters; however, the specific physical or biological features that attract giant manta rays to this particular area are poorly understood. The numbers, location, and peak timing of the manta rays to this area varies by year, but with a notable decline in manta rays observed in the study area since 2015 (H. Webb unpublished data). While sea surface temperatures are thought to play a role in the initial migration of manta rays to the study site, preliminary analysis suggests that the within-season temperatures are not strongly correlated with manta ray distribution or abundance within the area (H. Webb, GA Aquarium, pers. comm. to M. Miller, NMFS OPR, 2019). Although foraging has been anecdotally observed during these surveys (H. Webb, GA Aquarium, pers. comm. to M. Miller, NMFS OPR, 2019) and mentioned in a few online fishing articles (Roberts 2016; Levesque 2019), we are unaware of any research that has determined the driving factor of manta ray occurrence in this area and/or investigated the physical or biological features of this area that may be essential to support the life history needs of the species. Without information on specific habitat characteristics or the relationship between environmental variables and manta ray abundance or distribution, the available sightings data do not allow us to identify important foraging areas at this time. A manuscript summarizing findings from the Georgia Aquarium sightings dataset is forthcoming (H. Webb, GA Aquarium, pers. comm. to M. Miller, NMFS OPR, 2019), and we intend to review any new information that becomes available regarding manta ray use of this area off Florida.

Overall, the best available information indicates that giant manta rays will feed on a variety of planktonic organisms and are not limited by the required presence of a specific prey species for successful foraging to occur. Areas of high primary productivity (*e.g.*, upwelling) are generally regarded as habitat that could potentially support giant manta ray foraging events; however, the physical and biological characteristics of high productivity areas can vary depending on the location and season. Additionally, the presence of these areas does not necessarily indicate giant manta ray foraging will occur as the available data suggest some unknown prey density threshold may be necessary to facilitate manta ray foraging or aggregations. In U.S. waters, foraging has been anecdotally observed, but the available data do not indicate any specific physical and biological features of these areas that are essential for facilitating foraging events or specific sites that are used consistently for foraging purposes. For the foregoing reasons, it is not possible to identify any physical or biological features related to foraging that are essential to the conservation of the species, nor any specific areas that are essential to support the foraging needs of the species within waters under U.S. jurisdiction.

Analysis of the Physical and Biological Features of Pupping Habitat that are Essential to the Conservation of the Species

Giant manta rays likely give birth to only one pup per pregnancy after a long gestation time (12–13 months). This very low reproductive output for the species means that the success of pupping events is essential for the conservation of the species. Identifying and protecting important pupping habitat throughout the species' range will be necessary to support recruitment of young individuals to the recovering population. Without sufficient nursery habitat, the population is unlikely to increase to a level associated with low extinction risk and delisting. Protection of the species' nurseries is crucial because the rebuilding of the population cannot occur without protecting the source (juvenile) population and its associated habitats. Therefore, using the best available data, we attempted to identify potential nursery habitats and determine whether we could identify physical or biological features of the habitat that facilitate successful giant manta ray pupping and, thus, are essential for the conservation of the species.

For the purposes of identifying potential nursery habitat, we considered giant manta rays that were less than 4,000 mm DW to be immature, with a size at birth of ~2,000 mm DW. As mentioned previously, juvenile giant manta rays are rarely observed in the wild but are present in the fishery landings data from many countries, including Sri Lanka, Brazil, Indonesia, and the Philippines. While this indicates that fishermen are accessing potentially important juvenile habitat and possibly nursery areas, we have no data on these fishing grounds that could provide insight into important physical or biological features of these areas. However, recent manta ray research in U.S. waters has documented the presence of juvenile giant manta rays in the FGBNMS in the U.S. Gulf of Mexico as well as off the east coast of Florida, suggesting the existence of juvenile and potential manta ray nursery habitat, which we discuss below.

For the FGBNMS, both Childs (2001) and Stewart et al. (2018b) suggested this area may contain potential nursery grounds for the species. Although juveniles are rarely observed globally, a high number of juveniles were sighted at several locations in the FGBNMS over multiple years. Based on an analysis of NOAA diver logs (from various coral reef and fish surveys), approximately 171 individual manta rays have been sighted within the FGBNMS since 1994 (C. Jones unpublished data). Of these, 114 have approximate recorded sizes. Around 97 percent of the individuals sighted were less than 4 m DW (*i.e.*, immature), and around 50 percent were 2 m DW (*i.e.*, estimated size at birth of *M. birostris*) or less. However, *M. cf. birostris* may comprise the majority of these sightings as Stewart et al. (2018b) noted that at least 55 percent of the manta rays identified in their study likely belong to *M. cf. birostris*, which is thought to be closer in size to *M. alfredi* (Stevens et al. 2018a) and potentially explains the observations of mantas with sizes smaller than the estimated size at birth for *M. birostris*.

Using the nursery habitat criteria proposed by Heupel et al. (2007), Stewart et al. (2018b) suggested that the FGBNMS may contain nursery habitat for giant manta rays because juveniles, which are generally rare, are found in this area, remain in the area for a period of several days to months, and have been sighted with gaps of more than a year between re-sightings. The FGBNMS is a unique area, situated over 100 miles offshore of the Texas/Louisiana border and comprised of shallow, underwater features, called salt domes, upon which diverse coral reef communities have developed and thrived. There is substantial upwelling, distinct thermoclines, and unique eddies that form in the area, presumably due to interactions between currents and the pronounced benthic features. Stewart et al. (2018b) proposed that the FGBNMS may be an optimal nursery ground because it contains habitat near the edge of the continental shelf and in 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 (Stewart et al. 2018b). The authors state that an additional benefit of the FGBNMS is that the shallow bottom habitat 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).

However, while the FGBNMS provides habitat for juvenile giant manta rays, the available data do not indicate any specific physical and biological features within the FGBNMS that are essential for supporting pupping behavior or necessary for a manta ray nursery. For example, in examining specific physical features, like temperature, we found that the majority of individuals (~75 percent) at the FGBNMS were sighted between July and September (Stewart et al. 2018b). Sea surface temperatures during these sightings ranged from 20°C to 32°C, with ~75 percent of mantas observed in 28°C to 31°C (C. Jones unpublished data). However, dives during which observations were collected were skewed towards summer months (*i.e.*, warmer temperatures) and specific sites and depths (limited to areas above 150 ft (45.7 m)), meaning that the increased observations of giant manta rays in the higher temperature range may be a consequence of the survey methodology and not a reflection of an essential feature of the habitat.

Next, we reviewed the available data regarding behavior to see if we could identify specific habitat features based on use of the habitat that are necessary to support pupping. As stated in Stewart et al. (2018b) and Childs (2001), the primary behavior of manta rays observed in the FGBNMS was mainly swimming, with manta rays swimming above reef crest and sand flats, along escarpments, and in the water column. Although more juveniles were sighted at East and West Flower Garden Banks (hermatypic coral habitat) than at Stetson Bank (silt/claystone dominated coral community), acoustic telemetry tagging has shown that juvenile mantas move between East, West, Stetson, and Bright Bank within FGBNMS (R. Graham, Wildlife Conservation Society, pers. comm. to C. Horn, NMFS SERO, 2018). Stewart et al. (2018b) suggest the FGBNMS likely provides ample feeding opportunities for juveniles, but they acknowledge that foraging behavior is only rarely observed. Similarly, Childs (2001) mentioned that foraging behavior at the FGBNMS was observed in only two months (February and March) of his study despite manta rays occurring in the area during all months.

While the presence of young giant manta rays suggest potential pupping in the vicinity of the area (Childs 2001), the available data do not allow us to identify where this pupping is occurring. Additionally, the available data do not explain why or how giant manta rays are using this particular habitat (*e.g*., foraging, transiting, resting) or allow us to identify the essential physical or biological features of the habitat. Therefore, we cannot identify any pupping areas that meet the definition of critical habitat.

Research (supported by NMFS and the National Ocean Service, in collaboration with the Manta Trust) on the movements and genetics of giant manta rays continues in the FGBNMS and may help provide answers to these questions in the future. However, at this time, the available data do not indicate any physical or biological features of this habitat that are essential for the conservation of the species.

Similar to the FGBNMS, juvenile *M. birostris* have also been regularly observed off the east coast of Florida in the past several years. Since 2016, researchers with the Marine Megafauna Foundation have been conducting annual surveys along a small transect off Palm Beach, Florida, between Jupiter Inlet and Boynton Beach Inlet (~44 km, 24 nautical miles) (J. Pate, MMF, pers. comm. to M. Miller, NMFS OPR, 2018). Results from these surveys indicate that juvenile manta rays are present in these waters for the majority of the year (observations span from May to December), with re-sightings data that suggest some manta rays may remain in the area for extended periods of time or return in subsequent years (J. Pate unpublished data). For example, one satellite tagged male has been re-sighted multiple times in the past 3 years (Marine Megafauna Foundation 2019). However, similar to the limitations of the FGBNMS data and the level of resolution, it is currently unclear what physical or biological characteristics of this habitat are necessary to facilitate successful pupping behavior or are essential for nursery habitat. Manta rays are difficult to detect using boat-based observation. When an observer spotted a manta ray, he/she would get into the water and collect habitat information, behavioral data, as well as photos of the manta ray. This type of data collection has limitations. For example, water turbidity, depth, and weather conditions may make manta rays harder to spot from a boat. As such, the fact that the majority of manta rays were spotted over sand is likely due to increased visibility over this type of habitat compared to others (such as reef habitat) (J. Pate, personal communication, 2018) as opposed to a biological necessity for this type of habitat. Additionally, the main behavior observed in the transect area was swimming, with occasional observations of foraging behavior near Jupiter Inlet (J. Pate, MMF, pers. comm. to M. Miller, NMFS OPR, 2018). In other words, similar to the FGBNMS, the available data only indicate juvenile manta ray presence in these areas and does not explain why or how giant manta rays are using the particular habitat that would help us identify any physical or biological features that are essential for the conservation of the species. We also note that the majority, if not all, of these juvenile manta rays observed off the east coast of Florida are thought to be *M. cf. birostris* (J. Pate, MMF pers. comm. to M. Miller, NMFS OPR, 2018) and not *M. birostris*. NMFS researchers are currently collaborating with colleagues at the Marine Megafauna Foundation to tag these manta rays off the Florida coast and collect genetic information in order to inform taxonomy, determine population structure, and learn more about their movements to gain a better understanding of their habitat use in this region. Anecdotal observations from some of these recent tagging trips (June and August 2019) suggest this area may provide foraging opportunities (N. Farmer, NMFS SERO, pers. comm. to M. Miller, NMFS OPR, 2019); however, further investigation is required as the available information does not indicate any specific physical and biological features of this area that are essential to support the life-history needs of the species.

We also obtained anecdotal observations of juvenile giant manta rays in the U.S. Caribbean from off Puerto Rico (n=10; sightings dating back to 2004) and the U.S. Virgin Islands (n=16; sightings dating back to 2012), and in the U.S. Pacific from off Hawaii and the Pacific Remote Island Areas (n=24; sightings dating back to 2003) that indicate the use of these waters by young giant manta rays (NMFS unpublished data). However, as stated before, simply the observation of the presence of juveniles using these waters (and further confounded by a lack of known abundance, duration, movement, or frequency of occurrence in these areas) is not enough information to indicate that these areas contain physical and biological features that are essential to the conservation of the species.

In summary, while we have evidence of the presence and use of specific areas by juvenile giant manta rays, the available information does not allow us to identify any physical or biological features within these areas that are essential to support the life-history needs of the species. Without knowledge of the essential features that create meaningful pupping and nursery grounds, we cannot identify any areas that meet the definition of critical habitat at this time.

The Physical and Biological Features of Migratory Habitat that are Essential to the Conservation of the Species

Based on the available data, it is evident that both small and large-scale migratory movements are a necessary component in the life-history of the giant manta ray. Seasonal sightings data suggests that large-scale movements are undertaken primarily for foraging purposes, correlated with the movement of zooplankton and influenced by current circulation and tidal patterns, seasonal upwelling, and seawater temperature (Luiz et al. 2009; Couturier et al. 2012; Freedman and Roy 2012; Graham et al. 2012; Sobral and Afonso 2014; De Boer et al. 2015; Girondot et al. 2015; Armstrong et al. 2016; Hacohen-Domené et al. 2017). Small-scale movements also appear to be associated with exploiting local prey patches in addition to refuging and cleaning activities (O'Shea et al. 2010; Marshall et al. 2011; Graham et al. 2012; Rohner et al. 2013; Stewart et al. 2016a; Stewart et al. 2016b; Sotelo 2018). However, as sightings of giant manta rays tend to be sporadic, with the species more commonly found offshore and in oceanic waters, it is difficult to track small-scale and large-scale migratory behavior of the species. For logistical reasons, survey effort tends to be focused in nearshore habitats. Yet, through the opportunistic tagging of giant manta rays with pop-up satellite archival tags when in these nearshore areas, researchers have been able to provide evidence of the migratory nature of giant manta rays and demonstrate the species' ability to make large-scale migrations. For example, satellite tracking has registered movements of the giant manta ray from Mozambique to South Africa (a distance of 1,100 km), around Ecuador and its islands (between the Isla de la Plata, Bajo Cope, and Isla Santa Clara (El Oro, Ecuador); around 230 km), and from the Yucatán, Mexico into the Gulf of Mexico (448 km) (Marshall et al. 2011; Guerrero and Hearn 2017; Sotelo 2018). Off Mexico's Yucatán peninsula, Graham et al. (2012) calculated a maximum distance travelled by a giant manta ray to be 1,151 km (based on a cumulative straight line distance between locations; tag period ranged from 2 to 64 days). Similarly, Hearn et al. (2014) report on a tagged *M. birostris* that was tracked from Isla de la Plata (Ecuador) to west of Darwin Island (tag was released after 104 days), a straight-line distance of 1,500 km, further confirming that the species is capable of fairly long distance migrations.

For the most part, these larger-scale migrations appear to be seasonally-based for foraging purposes, as described previously, with giant manta rays appearing in areas undergoing seasonal upwelling events. For example, through analysis of photographs and videos of mobulids from 1990 to 2013, Sobral and Afonso (2014) confirmed the presence of *M. birostris* at the Azores islands and noted that its occasional presence (several encounters per year) at these remote islands indicates a strong seasonal migratory behavior. However, the origin of these mantas, and the potential migratory paths that they use to get to these remote islands, remain unknown.

Similarly, seasonal sightings of *M. birostris* off the Isla de la Plata, Ecuador, predominantly occur from August to October, with a peak in early September (Guerrero and Hearn 2017); however, from where these mantas originate is currently under investigation. Recently, Sotelo (2018) examined the genetic diversity of these manta rays from 2010 to 2013 and found that it was moderately high, with an average expected heterozygosity value (He = 0.679) comparable to similar species that are known to undertake long-distance migrations. The results also suggest that the manta rays may migrate in family groups, but that they may not always visit the same areas consistently. For example, Sotelo (2018) found population structure between the manta rays sampled in 2013 compared to the years 2010, 2011, and 2012, with the 2013 manta rays representing a different population. The authors note that copepod numbers peaked at the Isla de la Plata in May of 2013, two months later than the previous years in the study (Sotelo 2018). As manta rays demonstrate high plasticity in terms of their movements in search of prey, Sotelo (2018) reasoned that the change in timing of the copepod peak likely explains why a different manta ray population visited the island in 2013 compared to previous years. However, again, the origin of these mantas, and the potential migratory routes traveled by these mantas to the Isla de la Plata are currently unknown.

While long-distance migratory information is lacking, scientists have tagged some of these mantas during their seasonal visitation to these nearshore areas, and have gained additional information on their smaller-scale movement patterns around and from these sites. For example, in Isla de la Plata, two mantas were tagged from September 2017 to January 2018 with tracks that revealed coastal movements between Ecuador and northern Peru (Sotelo 2018). These two mantas remained within 200 km of the shoreline and did not move more than 300 km south of Isla de la Plata, where they were originally tagged. However, based on the track lines (see Annex C; Sotelo 2018), there is no clear migratory corridor that they appear to use, with movements traversing throughout the entire area.

Off the Yucatán peninsula, Graham et al. (2012) tagged 6 giant manta rays (4 females, 1 male, and 1 juvenile) and tracked their movements for up to 64 days. The tagged manta rays traversed the frontal zones repeatedly, probably in search of prey (Graham et al. 2012), with no clear migratory route. The majority of manta ray tracks were more than 20 km offshore, in water depths of less than 50 m, and the animals traveled up to 116 km from their original tagging location (Graham et al. 2012). The authors also noted that there were no differences in movement patterns based on sex, body size, or ambient water-column temperature. Their conclusion, based on the tracking data, was that giant manta rays forage over large spatial scales (~100 km long) that are too far offshore and wide-ranging to be completely captured in the existing Marine Protected Area networks within the Mexican Exclusive Economic Zone (Graham et al. 2012). In other words, there does not appear to be a specific migratory corridor that dictates these smaller-scale foraging movements. Rather, manta rays appear to be opportunistic feeders, with movements in and around frontal zones or areas that are likely to contain prey.

While the available data indicate that giant manta rays may be capable of long-distance movements, a recent study by Stewart et al. (2016a) suggests that the species may not be as highly migratory as previously thought. Using pop-up satellite archival tags in combination with analyses of stable isotope and genetic data, the authors found evidence that *M. birostris* off the Pacific coast of Mexico may actually exist as well-structured subpopulations that exhibit a high degree of residency. For example, unlike the giant manta ray in the Hearn et al. (2014) study (that traveled from Isla de la Plata to the Galapagos Islands), tagged *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). 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). Additionally, the genetic analysis provided evidence of population structure between the coastal Mexico and offshore Mexico populations (Stewart et al. 2016a). While the authors note that the species may be capable of occasional long-distance movements, the results from their study indicate that, for some populations, these types of long-distance movements may be rare and may not contribute to substantial gene flow or inter-population mixing of individuals (Stewart et al. 2016a).

Overall, the available data indicate that giant manta rays undergo both short- and long-distance migrations; however, the space or any specific migratory corridor used by the species during these migrations remains unknown. In addition, we have no information on any potential migratory corridors that may exist within waters under U.S. jurisdiction for the giant manta ray. As mentioned previously, we are currently supporting and conducting tracking studies of giant manta rays within U.S. waters to better understand the fine-scale movements of the species off the coast of Florida and within the

FGBNMS. Data from these or similar studies may reveal potential migratory corridors preferred by giant manta rays. Similarly, survey efforts by the Georgia Aquarium off the coast of St. Augustine, Florida, may also help elucidate some of these questions in the future.

As noted previously in this determination, giant manta rays appear to have a seasonal pattern of occurrence along the east coast of Florida, showing up with greater frequencies (and in greater numbers) in the spring and summer months. In fact, sightings of manta rays in the region signal to fishermen the start of cobia fishing as fishermen have found that cobia tend to closely associate with the manta rays as they migrate along the east coast of Florida. Based on information from recreational cobia fishing articles, manta rays tend to appear off Florida's coast when water temperatures climb above 20°C to 21°C; however, Levesque (2019) notes that it is "impossible to predict when they will show up from one year to the next." Killer (2010) states that in Florida's Treasure Coast waters, mantas may not show up every year, and it is unclear where they come from or where they go after they leave the area. Quoting two charter vessel captains, Killer (2010) reports that the mantas have been observed along the coast moving from south to north as waters warm, but have also been observed doing the opposite migration, with some potentially moving from offshore to inshore waters as well during this time. McNally (2012) believes that the spring migration of rays off northeast Florida is occurring much farther offshore than in the past, noting that the mantas used to be observed just off the beach breakers but are now more than 10 miles offshore. We also note that during the migratory season, manta rays tend to be found in both shallow and deep waters (Killer 2010; Levesque 2019), with no information to suggest they are restricted to a certain area off the coast of Florida.

While the available information confirms the migratory behavior of the species in U.S. waters, the data do not indicate that there are any specific routes or corridors that are consistently used by the species during their migration. In fact, as noted previously, McNally (2012) suggests that a dedicated corridor may not exist, or that some other unknown feature may be influencing their spatial patterns during these migrations. Additionally, Roberts (2016) notes that “no studies have shown a correlation of bottom structure (reef lines, continental shelf, *etc*.) and the ray’s migration pattern,” nor have we come across any studies since that article was published. Therefore, at this time, and based on the foregoing information, we cannot identify any specific essential features that define migratory habitat for giant manta rays.

The Physical and Biological Features of Breeding Habitat that are Essential to the Conservation of the Species

Little information exists on the reproductive ecology of the giant manta ray as mating behavior of *M. birostris* is rarely observed in the wild. However, based primarily on observations of *M. alfredi* mating behavior, Stevens et al. (2018b) identified seven stages of courtship for manta rays: (1) initiation, (2) endurance, (3) evasion, (4) pre-copulation positioning, (5) copulation, (6) post-copulation holding, (7) separation. The initiation stage involves males shadowing females at normal cruising speeds. During this stage, males will often attempt to facilitate female receptiveness by using the cephalic fins to gently stroke the females’ dorsal surface. During the endurance stage, swimming speeds increase and from 1 to 8 males follow closely behind a single female. The evasion stage is characterized by continued close following at increased speeds with the female incorporating rapid maneuvers, somersaults, and flips, with males attempting to stay right behind her. Pre-copulation positioning involves the male using his cephalic fins to guide himself down the females' back along the leading edge of her pectoral fin. Once at the fin's tip, the male grasps it firmly with his mouth then rotates his body so that he is underneath the female and the two are abdomen to abdomen. Copulation then occurs, usually initiating near the surface, with the male continuing to move his fins to maintain position while the female ceases movement. The clasper is inserted in the cloaca and copulation lasts between 30 and 90 seconds, while the pair slowly sinks (Stevens et al. 2018b).

Only a few instances of courtship involving giant manta rays have actually been observed, with only a single instance resulting in copulation. On two separate occasions, in early August 1996 at the Ogasawara Islands, Japan, Yano et al. (1999) witnessed a male *M. birostris* chasing closely behind a female at relatively high speeds (~10 km/hr). In both instances, the behavior was observed for approximately 40 minutes but did not result in copulation. Stevens et al. (2018b) also witnessed two occurrences of this "endurance" stage in *M. birostris*, one involving a single female followed by a single male, and the other involving a single female followed by eight males. Both of these observations were made off of the remote island of Fuvahmulah in the Maldives, lasted approximately one minute, and neither resulted in observed copulation. The only observation of successful copulation was reported by Yano et al. (1999) who witnessed two males chasing a single female in a zigzag pattern off the Ogasawara Islands in early July 1997. Speeds were similar to those witnessed during other observations; however, these chases progressed all the way through the rest of the stages of copulatory behavior

(Yano et al. 1999). The chases occurred approximately 30 minutes apart, with both males observed inserting their claspers into the same female (Yano et al. 1999).

In terms of habitat characteristics, the mating behavior in the Maldives location occurred at a known aggregation site for the species (Stevens et al. 2018b). Females were chased along the reef crest of the atolls in the area (Stevens et al. 2018b). However, while the authors noted that most of the mating behavior for *M. alfredi* happened at cleaning stations, for *M. birostris*, the mating occurred at locations where giant manta rays tend to just pass through (Stevens et al. 2018b). In other words, the area where the mating behavior was observed did not appear to have any other significance for the species. Off the Ogasawara Islands, Japan, Yano et al. (1999) described the site of the mating behavior as 100–200 m offshore of the east coast of Chichijima (one of the Ogasawara Islands), within an area comprised of rocky reefs in 10-20 m depth. The authors noted that each copulation event happened within one meter of the surface (Yano et al. 1999).

Giant manta ray breeding sites are also thought to occur off Ecuador and the Galapagos Islands based on the presence of pregnant females and recent mating scars. In fact, some of the first pregnant females ever seen in the wild have been sighted in the productive coastal waters off Isla de la Plata in the Machalilla National Park, Ecuador. According to Guerrero and Hearn (2017), between 2009 and 2015, 8 pregnant giant mantas were observed off Isla de La Plata, with 7 of these reported in 2011. Additionally, photographic records from 2012 to 2015 showing fresh scars on the pectoral fins of mature female giant manta rays around Isla de la Plata and Bajo Copé indicate the likely use of these Ecuadorian aggregation sites as mating areas (Guerrero and Hearn 2017). In terms of habitat characteristics of these areas, the authors note that the majority of giant manta rays seen in Isla de la Plata are off the northwest area of the island, in Punta El Faro, Roca Honda, and La Pared (Guerrero and Hearn 2017). These particular areas are close to deep waters, with a bottom characterized by coarse sand and scattered rocks. Calcareous coral formations can be found between 0 and 14 m depths and soft corals (gorgonians) can be found in deeper depths (Guerrero and Hearn 2017). La Pared, in particular, contains pinnacles and rocks that extend to the northwest and create an edge with a steep drop to 52 m depths (Guerrero and Hearn 2017). The authors state that giant manta rays do not remain in the area for very long (usually around a few days to a week), but may return in multiple years and hypothesize that their purpose for visiting the island could be primarily for cleaning purposes, mating, and/or feeding as all three behaviors are observed at this site (Guerrero and Hearn 2017).

Within U.S. waters, there are very few observations of mating behavior. In our collection of manta ray sightings and videos, there are only 4 records of “chasing” or “courtship” behavior of *M. birostris.* Three of the records are from diver observations off the west coast of Hawaii (Manta Pacific Research Foundation 2019), and the fourth is from an instagram video off Avon Fishing Pier, North Carolina, taken in July 2019 (G. Stevens, Manta Trust, pers. comm. to C. Horn, NMFS SERO, 2019); however, there is no corresponding information regarding habitat features related to these records (just individual sightings data). Given that the areas where giant manta ray mating occurs remain largely unknown, with only a few, opportunistic observations of courtship behavior or evidence of breeding (*i.e.*, mating scars, pregnant females) in a couple of locations, there has not been any systematic evaluation of the particular physical or biological features that facilitate or are necessary for mating to occur. The general habitat characteristics mentioned above in relation to the observations of mating behavior, including presence of rocky and coral reefs, shallow depths, coarse sand, and reef crests adjacent to deep water, are found throughout the species' range and are commonly associated with giant manta ray sightings (Yano et al. 1999; Childs 2001; Kashiwagi et al. 2011; Marshall et al. 2011; Stevens et al. 2018b; Stewart et al. 2018b). However, not all areas with the above features provide meaningful mating habitat as, for example, many of the observations from the studies previously discussed (for foraging, pupping, and migratory habitat) also noted the presence of these habitat features but did not observe mating behavior in *M. birostris*. As such, at this time, the available information does not allow us to identify any physical or biological features within these areas where mating has been observed that are essential to support this behavior.

Unoccupied Areas

Section 3(5)(A)(ii) of the ESA defines critical habitat to include specific areas outside the geographical area occupied by a threatened or endangered species at the time it is listed if the areas are determined by the Secretary to be essential for the conservation of the species. Regulations at 50 CFR 424.12(b)(2) address designation of unoccupied area as critical habitat and the regulations at 50 CFR 424.12(g) state that critical habitat shall not be designated within foreign countries or in other areas outside of United States jurisdiction.

As discussed previously, the waters off the U.S. west coast are not considered part of the geographical area occupied by giant manta ray at the time of listing. We also conclude that it is not an unoccupied area essential to the species' conservation given the rare, errant use of the area by a vagrant giant manta ray in the past, and no information to suggest the area is essential to the conservation of the species. The other geographical areas under U.S. jurisdiction that were not included in the discussion of occupied areas by the giant manta ray (*i.e.*, U.S. waters north of Long Island, New York) are considered to be out of the species' livable range and, thus, would not be essential to the conservation of the species. As such, we find that there are no specific areas outside the geographical areas occupied by *M. birostris* that would meet the definition of critical habitat for the giant manta ray.

Critical Habitat Determination

Given the best available information and the above analysis of this information, we find that there are no identifiable occupied areas under the jurisdiction of the United States with physical or biological features that are essential to the conservation of the species or unoccupied areas that are essential to the conservation of the species. Therefore, we conclude that there are no specific areas within the giant manta ray range and under U.S. jurisdiction that meet the definition of critical habitat. Per 50 CFR 424.12(a)(1)(iv), if no areas meet the definition of "critical habitat," then we can conclude that a designation of critical habitat is not prudent.

Although we have made this "not prudent" determination, the areas occupied by giant manta rays under U.S. jurisdiction will continue to be subject to conservation actions implemented under section 7(a)(1) of the ESA, as well as consultation pursuant to section 7(a)(2) of the ESA for Federal activities that may affect the giant manta ray, as determined on the basis of the best available information at the time of the action. Through the consultation process, we will continue to assess effects of Federal actions on the species and its habitat.

Additionally, we remain committed to promoting the recovery of the giant manta ray through both domestic and international efforts. As noted in the proposed and final rules (82 FR 3694, January 12, 2017; 83 FR 2916, January 22, 2018, respectively), the most significant threat to the giant manta ray is overutilization by commercial and artisanal fisheries operating within the Indo-Pacific and eastern Pacific portions of its range, primarily in areas outside of U.S. jurisdiction. Giant manta rays are both targeted and caught as bycatch in a number of fisheries throughout their range, and while the majority of these fisheries target manta rays for their meat, there has been an increasing demand for manta ray gill plates for use in Asian medicine, primarily in the Indo-West Pacific. Efforts to address overutilization of the species through regulatory measures appear inadequate, with evidence of targeted fishing of the species despite prohibitions in a number of countries, and only one regional fisheries management organization measure to address bycatch issues (Miller and Klimovich 2017). Thus, recovery of the giant manta ray is highly dependent upon international conservation efforts. To address this, we have developed a recovery plan outline that provides our preliminary strategy for the conservation of the giant manta ray. This outline can be found on our website at: *https://www.fisheries.noaa.gov/species/giant-manta-ray#resources* and provides an interim recovery action plan as well as preliminary steps we will take towards the development of a full recovery plan.

Currently, we are actively engaged in manta ray research to gain a better understanding of the biology, behavior, and ecology of this threatened species. We are presently working on collecting and assimilating anecdotal and survey-related manta sightings and effort data to support the development of an ensemble species distribution model for the southeastern United States. We are also collaborating with partners to examine giant manta ray movements in U.S. waters off Florida and within the FGBNMS. This data will provide a better understanding of giant manta ray movements and habitat use, including environmental drivers of movement. We are also supporting research projects assessing the survivorship of giant manta rays caught in Peruvian and Indonesian artisanal gillnet fisheries.

We have developed safe handling and release guidelines for fishermen (available at: *https://www.fisheries.noaa.gov/webdam/download/91927887*). In an effort to address species identification issues during aerial surveys, we have also developed an aerial survey mobulid species identification key that will facilitate accurate species identification in the future. We added the giant manta ray to our Northeast and Southeast Observer Program capture reports, logbooks, and manuals/reports, and provided a guide to the identification of mobulid rays to observers to gain more accurate information regarding the species' distribution and prevalence in U.S. fisheries. In addition, we have set up a dedicated email (*i.e*., *manta.ray@noaa.gov*) for the public to report giant manta ray encounters to help us learn more about *M. birostris* movement patterns, habitat use, and human interactions in our waters. We will continue to work towards the conservation and recovery of giant manta rays, both on a domestic and global level, including with our international partners and within regional fisheries management organizations and other international bodies to promote the adoption of conservation and management measures for the threatened giant manta ray.

References

A complete list of all references cited herein is available upon request (see **FOR**

FURTHER INFORMATION CONTACT).

Authority

The authority for this action is the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.).

Dated: December 2, 2019.

Samuel D. Rauch III,

Deputy Assistant Administrator for Regulatory Programs,

National Marine Fisheries Service.

[FR Doc. 2019-26265 Filed: 12/4/2019 8:45 am; Publication Date: 12/5/2019]