BEFORE THE SECRETARY OF INTERIOR

PETITION TO RECLASSIFY THE WEST INDIAN MANATEE (*TRICHECHUS MANATUS*) AND SUBSPECIES THEREOF, INCLUDING THE FLORIDA MANATEE (*TRICHECHUS MANATUS LATIROSTRIS*) AND ANTILLEAN MANATEE (*TRICHECHUS MANATUS MANATUS*), AS ENDANGERED SPECIES UNDER THE ENDANGERED SPECIES ACT

Keith Ramos, USFWS

Center for Biological Diversity
Harvard Law School Animal Law & Policy Clinic
Save the Manatee Club
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Notice of Petition

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Petitioners

The **Center for Biological Diversity** works through science, law, and policy to secure a future for all species, great or small, hovering on the brink of extinction. The Center has more than 1.7 million members and supporters throughout the United States, including more than 99,000 members and supporters who live and recreate in Florida. The Center and its members are concerned with the conservation of endangered and threatened species, including the West Indian manatee, and the effective implementation of the ESA.

The Brooks McCormick Jr. **Animal Law & Policy Program** at Harvard Law School is committed to analyzing and improving the treatment of animals by the legal system. In 2019, it launched the Animal Law & Policy Clinic to provide students with direct hands-on experience in animal advocacy on behalf of both captive animals and wildlife, including litigation, legislation, administrative practice, and policymaking.

Miami Waterkeeper is a South Florida-based non-profit. Our mission is to protect the water you love. We work to ensure swimmable, drinkable, fishable water for all, ultimately working for clean and vibrant waters and associated coastal culture for generations to come.

Save the Manatee Club is the world's leading manatee conservation organization. It was founded 1981 by singer/songwriter Jimmy Buffett and former Florida Governor and U.S. Senator Bob Graham with a mission to protect manatees and their aquatic habitat.

Frank S. González García is a registered Professional Engineer and nature enthusiast. He is a former President of the Puerto Rican Ornithological Society where he also collaborated as editor of the Bienteveo's quarterly newsletter. He was a founding member of non-profit organizations such as Centro Eco Educativo de Puerto Rico, Hacer and Coalición Bosque Seco Ventanas Verraco. His area of interest focuses on local endangered species and habitat restoration.

<u>Submitted this 21st day of November, 2022:</u>

Pursuant to Section 4(b) of the Endangered Species Act (ESA), 16 U.S.C. § 1533(b), Section 553(3) of the Administrative Procedure Act, 5 U.S.C. § 553(e), and 50 C.F.R. § 424.14(a), the Center for Biological Diversity hereby petitions the Secretary of the Interior, through the United States Fish and Wildlife Service (USFWS), to list the West Indian manatee (*Trichechus manatus*) and subspecies thereof, including the Florida manatee (*Trichechus manatus latirostris*) and Antillean manatee (*Trichechus manatus manatus*), as endangered.

USFWS has jurisdiction over this Petition. 50 C.F.R. § 17.11; *see also* Reclassification of the West Indian Manatee From Endangered to Threatened, 82 Fed. Reg. 16,668 (Apr. 5, 2017) (hereinafter "Final Rule 2017"); *Fla. Key Deer v. Paulison*, 522 F.3d 1133, 1138-39 (11th Cir. 2008). The Petition sets in motion a specific process, placing definite response requirements on USFWS. USFWS must issue an initial finding as to whether the Petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted," and must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." 16 U.S.C. § 1533(b)(3)(A). Petitioners need not provide "conclusive evidence of a high probability of species extinction;" rather, Petitioners must only present information demonstrating that listing "*may* be warranted." *Ctr. for Biological Diversity v. Morgenweck*, 351 F. Supp. 2d 1137, 1141 (D. Colo. 2004) (emphasis added). If a positive 90-day finding is made, the USFWS must determine whether the petitioned action is warranted within 12 months of receiving the Petition. 16 U.S.C. § 1533(b)(3)(B).

The term "species" is defined broadly under the ESA to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." 16 U.S.C. § 1532(16). As described in this petition, the Florida manatee (*Trichechus manatus latirostris*) and Antillean manatee (*Trichechus manatus manatus*) are currently recognized subspecies of the West Indian manatee (*Trichechus manatus*), and each therefore meets the definition of a "species" eligible for listing as endangered under the ESA. In the event USFWS does not recognize the taxonomic validity of the Florida or Antillean manatee species as described in this Petition, we request that USFWS evaluate whether the manatee populations of the continental United States or Caribbean, respectively, represent a significant portion of the range of the full West Indian manatee species and are therefore eligible for listing as endangered on such basis.

Acknowledgement

We wish to thank Jaclyn Lopez, Benjamin Rankin, Savannah Bergeron, Max Hantel, Barbara Tsao, and Max Lupin, who played a significant role in developing this petition.

Sincerely,

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Glossary of Terms

AMO:	Atlantic Multidecadal Oscillation
AMPA:	Aminomethylphosphonic acid, a degradation product of the herbicide glyphosate
BMAP:	Basin Management Action Plan
BMP:	Best Management Practices
CBMv6:	Core Biological Model version 6
CITES:	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSS:	Cold Stress Syndrome
CWA:	Clean Water Act
DDT:	Dichloro-diphenyl-trichloroethane (an insecticide)
ECE:	Extreme Cold Event
ESA:	Endangered Species Act
FDACS:	Florida Department of Agriculture and Consumer Services
FDEP:	Florida Department of Environmental Protection
FWC:	Florida Fish and Wildlife Conservation Commission
GHG:	Greenhouse Gas
HAB:	Harmful Algal Bloom
IPCC:	Intergovernmental Panel on Climate Change
IRL:	Indian River Lagoon
IUCN:	International Union for Conservation of Nature
MFL:	Minimum Flows and Levels
MMC:	Marine Mammal Commission

MMPA:	Marine Mammal Protection Act
MPA:	Marine Protected Area
NDC:	Nationally Determined Contribution (a carbon reduction target)
NPDES:	National Pollutant Discharge Elimination System
PCB:	Polychlorinated biphenyl (an environmentally persistent pollutant)
PON1:	A functional gene that mitigates oxidation damage to lipids, absent in manatees
PTB:	Passive Thermal Basin
PVA:	Population Viability Analysis
RMU:	Regional Management Unit
SLR:	Sea Level Rise
SPAW:	Specially Protected Areas and Wildlife
TMDL:	Total Maximum Daily Load
UNEP:	United Nations Environment Programme
USACE:	The United States Army Corps of Engineers
USFWS:	The United States Fish and Wildlife Service
USGCRP:	The United States Global Change Research Program
WMD:	Water Management District

I. Introduction

The West Indian manatee (*Trichechus manatus*) is the only sirenian native to the continental United States (Marsh et al. 2011, p. 371). The manatee is a marine mammal characterized by its rotund, dark gray body averaging 3 meters in length and 1,000 kg in weight (USFWS Recovery Plan 2001, p. 6). USFWS recognizes two subspecies of the West Indian manatee: the Florida manatee (*T. manatus latirostris*) and the Antillean manatee (*T. manatus manatus*). Final Rule 2017, 82 Fed. Reg. at 16,669. Florida manatees' habitable range varies seasonally; in the summer, they have been found from Texas to Massachusetts, but in the winter, they are almost exclusively confined to the rivers, springs, and coastal waters of Florida (Marsh et al. 2011, p. 376). Specifically, in winter, manatees congregate in warm water, including artesian springs and artificial discharge points such as power plant outfalls (Valade et al. 2020, 2). Antillean manatees are found in coastal and riverine waters of the United States (Puerto Rico, and rarely the U.S. Virgin Islands), Mexico, Belize, Jamaica, Haiti, Cuba, the Dominican Republic, the Bahamas, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Trinidad and Tobago, Guyana, French Guiana, Brazil, and Suriname (Lefebvre et al. 2001, p. 429-454).

The populations of both subspecies of manatees are decreasing. From its peak in 2017 until 2019, the Florida manatee's observed population decreased by an average of 6.94% annually (*See* Abundance and Population Trends, *infra*). A subsequent unusual mortality event on the Atlantic coast has driven greater population decline, and more than 1,100 Florida manatees died in 2021 alone, representing over 13% of the subspecies' estimated population (*See* Abundance and Population Trends, *infra*). High mortality continues into 2022—735 manatees have died this year through November 04 (FWC *2022 Preliminary Manatee Mortality Report* 2022, entire). Preliminary data indicate 1,219 deaths have been recorded in the mortality event area for all causes from December 1, 2020, through March 31, 2022. (USFWS *Stock Assessment Report: Florida Stock* 2022, p. 5). Although the Antillean manatee lacks reliable population estimates, researchers believe the population is in decline (Edwards et al. 2014, p. 71; Deutsch et al. 2008, p. 1).

Habitat destruction constitutes one of the largest threats to manatees. Seagrasses on which manatees depend are increasingly being destroyed. Warm-water refugia where manatees overwinter are threatened. Coastal development also threatens manatee habitat.

Manatees depend on seagrass for most of their nutrition, and loss of seagrass habitat has led to the malnutrition and death of thousands of manatees since 2020 (Lefebvre et al. 2000, p. 290; FWC *Manatee Mortality Summary 2020,* entire; FWC *2021 Preliminary Manatee Mortality Report* 2021, entire; FWC *2022 Preliminary Manatee Mortality Report* 2022, entire). Seagrass has been lost due to turbidity and algal blooms. In the Indian River Lagoon on Florida's east coast, excessive nutrient pollution has caused algae blooms that have completely extirpated seagrasses from 58% of their previous area between 2011 and 2019 (Morris et al. 2022, p. 1; Lapointe et al. 2020, passim). 89% of all seagrass cover in the Lagoon is estimated to have been lost (*Miami Standard News* 2022, entire). Elsewhere, the phytoplankton *Karenia brevis* produces blooms known as "red tide," emitting a neurotoxin that accumulates in seagrasses and causes a potentially lethal condition called brevetoxicosis in exposed manatees. Red tide not only directly kills seagrasses, but also transforms surviving areas of seagrass into toxic vectors that attract foraging manatees to their peril (Flewelling et al. 2005, p. 2). Other causes of seagrass loss include boating; coastal development, including dredging; storms, including stormwater runoff; and contaminants, including fertilizers and herbicides from agricultural pollution, legacy nutrients, and septic tank leaks (Miami-Dade County 2019, entire; Santos et al. 2020, p. 7). Climate change is expected to worsen these causes of seagrass loss, particularly through water temperature increases, ocean acidification, salinity changes, and sea level rise.

Warm-water refugia—the winter homes of Florida manatees—are also at risk. In many parts of the state, manatees depend on warm water discharges from power plants (Valade et al. 2020, p. 2). Such discharges, however, have been banned from new plants since 1972, meaning these power plants—which are now an average of 64 years old and will be phased out soon—will no longer provide warm water as a result of their operations (Valade et al. 2020, pp. 7–11). Given the age of these plants, power companies are expected to shut them down within 30 years; in the meantime, climate change makes plants particularly vulnerable through increasingly frequent and severe storms and rising sea levels (Edwards 2013, p. 731). Natural springs provide more sustainable warm-water refugia, but consumptive withdrawal of groundwater has reduced their flow rates and threatens their sustainability as manatee habitats (Valade et al. 2020, p. 4). Other manatees rely on passive thermal basins, but these can only support a limited number of individuals and are also threatened by human use and climate change. Currently, there are no concrete plans or funding sources to ensure adequate warm-water refugia for manatees in the future.

Existing regulations do not adequately protect manatees. In parts of Florida and other countries in the species' range, recreational users harass manatees, and outside the United States, manatees still face poaching. Florida's increasing human population compounds many other threats to manatees. Florida is one of the fastest growing states in the country, and its population is expected to reach 25.5 million by 2035, an annual net increase of 300,000 (EDR 2018, p. 79). Increased coastal development to house new residents destroys manatee habitat by worsening water pollution that kills seagrass, blocking manatees' access to biologically important areas like springs and mangroves, and increasing hazards in the water such as construction equipment or marine debris (*See* Coastal Development*, infra*). Increases in coastal development are also occurring in the range of Antillean manatees, but monitoring efforts also are insufficient in these countries to track individual threats to manatee populations with precision (*See* Regulatory Inadequacy: International and Foreign Mechanisms, *infra*).

Manatees face threats from numerous other sources. Watercraft-related deaths, frequently referred to as boat strikes, are a leading cause of anthropogenic manatee mortality (Reinert et al. 2017, p. 416). Boat strikes accounted for 86% of anthropogenic mortality from 2010 to 2021. Additionally, 96% of adult manatees have watercraft-related scars (Bassett et al. 2020, p. 395). Human population increase inevitably leads to even more watercraft joining the boats already in Florida waters, which may already exceed 2 million (*See* FWC *2021 Boating Accident Statistical Report* 2022, pp. IV, 2). From 2010 to 2021, at least 1,153 manatees were killed by watercraft with an average of 104.8 manatees killed per year (FWC *Manatee Mortality Summaries,* 2010-2020; FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire). While some regulations exist to protect manatees, they are underenforced and ineffective at changing boater behavior (Gorzelany 2013, p. 35; Jett and Thapa 2010, p. 180; s*ee* Boat Speed Zones, *infra*).

Marine debris, particularly entanglement with fishing gear also threatens and kills manatees, by both entanglement and ingestion. Water control structures crush manatees. Contaminants, particularly the herbicide glyphosate, are extensively used in Florida and found in high concentrations in waters inhabited by manatees (*See* Glyphosate, *infra*). While the precise effects on manatees are unstudied, glyphosate causes kidney and liver toxicity in other animals, and certain features of manatees' metabolic processes may make them more vulnerable to adverse impacts. (De María et al. 2021, p. 2). Limited genetic diversity and fragmented habitat also potentially increase manatees' risk of extinction. Climate change also magnifies threats to the manatee and its habitat. (Edwards 2013, entire; Marsh et al. 2017, entire). These threats—including temperature increases, ocean acidification, harmful algal blooms, disease, rainfall changes, hurricanes and other storms, extreme cold events, and sea level rise—also imperil the manatee's continued survival. Under even the most ambitious voluntary emission reduction targets under the Paris Agreement, the United States and other countries are not expected to keep climate change to manageable levels. (UNEP 2021, Executive Summary, p. xvi).

This Petition presents the best available commercial and scientific information on the natural history of the West Indian manatee, its population status, and current threats to the manatee and its habitat. The Petition demonstrates that, in the context of the ESA's five statutory listing factors, the U.S. Fish and Wildlife Service must promptly list the manatee as endangered.

II. Natural History and Biology

A. Species Description

The West Indian manatee (*Trichechus manatus*) is a fusiform, or spindle-shaped, marine mammal of the order Sirenia—the only extant sirenian native to the continental United States (Marsh et al. 2011, p. 371). The slow-moving manatee is characterized by its rotund, dark gray body, which averages 3 meters in length and weighs an average of 1,000 kgs, though specimens as long as 4.5 meters and weighing as much as 1,600 kgs have been observed (USFWS Recovery Plan 2001, p. 6; *see* Figure 1). The manatee's skin is rubbery, slightly wrinkled, and sparsely covered in hair; manatees' surfaces are also frequently covered in algae, barnacles, small invertebrates, remoras, and scarring from watercraft strikes or debris entanglements (USFWS Recovery Plan 2001, p. 30; Nico et al. 2009, p. 514; *see* Boat Strikes, Marine Debris, *infra*). The manatees has a broad, paddle-shaped tail, two front flippers, and a powerful, prehensile, bristled upper lip that it uses to manipulate the vegetation on which it feeds (USFWS Recovery Plan 2001, p. 6). These sensitive bristles—similar to those on the trunk of the closely related elephant—allow manatees to sense objects they encounter with enough precision to detect particle displacements of less than a micron (Marsh et al. 2011, p. 149). The manatee's teeth are adapted to its diet, and it continuously grows new molars, which migrate conveyor-style from the back of its jaw to the front, as old teeth are worn down by plant fibers and sand particles (FWC - *Florida Manatee Facts and Information*, n.d.). The manatee is well suited to the marine, brackish, and fresh waters in which it resides (Marsh et al. 2011, p. 8). Its nostrils are automatically closed by a valve when it submerges, and it possesses transparent, nictitating membranes in place of eyelids, allowing it to protect its eyes while seeing underwater (USFWS Recovery Plan 2001, p. 6). Though the manatee is an obligate inhabitant of the water, like all mammals, it requires fresh air to breathe and must return to the surface periodically to do so (Martin and Reeves 2002, p. 4).

Figure 1 - West Indian manatee, *Trichechus manatus* (Keith Ramos USFWS 2010)

USFWS recognizes two subspecies of the West Indian manatee: the Florida manatee (*T. manatus latirostris*) and the Antillean Manatee (*T. manatus manatus*). While there are significant geographic and genetic divergences between these subspecies, morphological differences between the subspecies are comparatively minute. Antillean manatees have slightly smaller bodies and paddle sizes than their Florida counterparts, and visual inspections report differences in the subspecies' intraocular eye distance, orbital placement, and snout size (Converse et al. 1994, abstract). Differences in hematology and serum chemistry have also been recorded; however, DNA analysis remains the most reliable method to identify a manatee's subspecies (Converse, et al. 1994, abstract).

Though the species is generally considered monomorphic, there are some slight physical differences between male and female manatees (Ralls and Mesnick 2009, p. 1009). Female manatees nurse their calves using two axillary mammary glands, one located underneath each flipper (Rathbun 1984, p. 545). A manatee's sex is also determinable by recording its anal-genital distance, which is greater in males than in females (Rathbun 1984, p. 545).

Differences between manatee and dugong tail shapes affect their respective swimming kinematics (Kojeszewski and Fish 2007, p. 2411). While dugongs and cetaceans locomote quickly by oscillating a rigid fluke, manatees are less-efficient undulatory swimmers, meaning that they generate propulsion by passing a dorso-ventrally oriented wave down the posterior end of their body ending in their paddle-shaped tail (Kojeszewski and Fish 2007, p. 2411). Manatees' lack of predators and subsistence on stationary forage may explain why they were not pressured to converge with cetaceans' efficient oscillatory mode as was the dugong (Kojeszewski and Fish 2007, p. 2416–17). Manatees also demonstrate diverse uses for their flippers during locomotion; they use them as steering rudders, to anchor themselves to the seabed, to manipulate food while grazing, and in "swim-walking," wherein the manatee balances itself on the seabed with alternating pectoral flippers while propelling itself forward using its tail (Frankini et al. 2021, p. 2–3). Their dense, heavy bones, twin diaphragms, long, horizontal lungs, powerful abdominal muscles, heavy skin, and ability to control their volume of intestinal gas make manatees excellent at controlling their own buoyancy (Rommel and Reynolds 2000, p. 42). As a result, manatees are surprisingly agile swimmers, with the ability to swim vertically or upside-down and perform twists and somersaults in the water (FWC - *Florida Manatee Facts and Information*, n.d.)

B. Taxonomy

The West Indian manatee belongs to the order Sirenia, within which two families survive: (1) *Dugongidae*, containing the dugong (*Dugong dugon* MÜLLER, 1776) and the extinct Steller's sea cow (*Hydrodamalis gigas* ZIMMERMANN, 1780); and (2) the monotypic *Trichechidae*, containing the genus *Trichechus*, to which the three allopatric manatee species belong (de Souza et al. 2021, p. 1). Along with the West Indian manatee (*T. manatus* LINNAEUS, 1758), *Trichechus* includes the Amazonian manatee (*T. inunguis* NATTERER, 1883) and the African manatee (*T. senegalensis* LINK, 1795) (de Souza et al. 2021, pp. 1-2; *see* Figure 2). As mentioned above, two subspecies of the West Indian manatee are recognized: the Florida manatee (*T. manatus latirostris* HARLAN, 1824) and the Antillean manatee (*T. manatus manatus* LINNAEUS, 1758) (ITIS, n.d.).

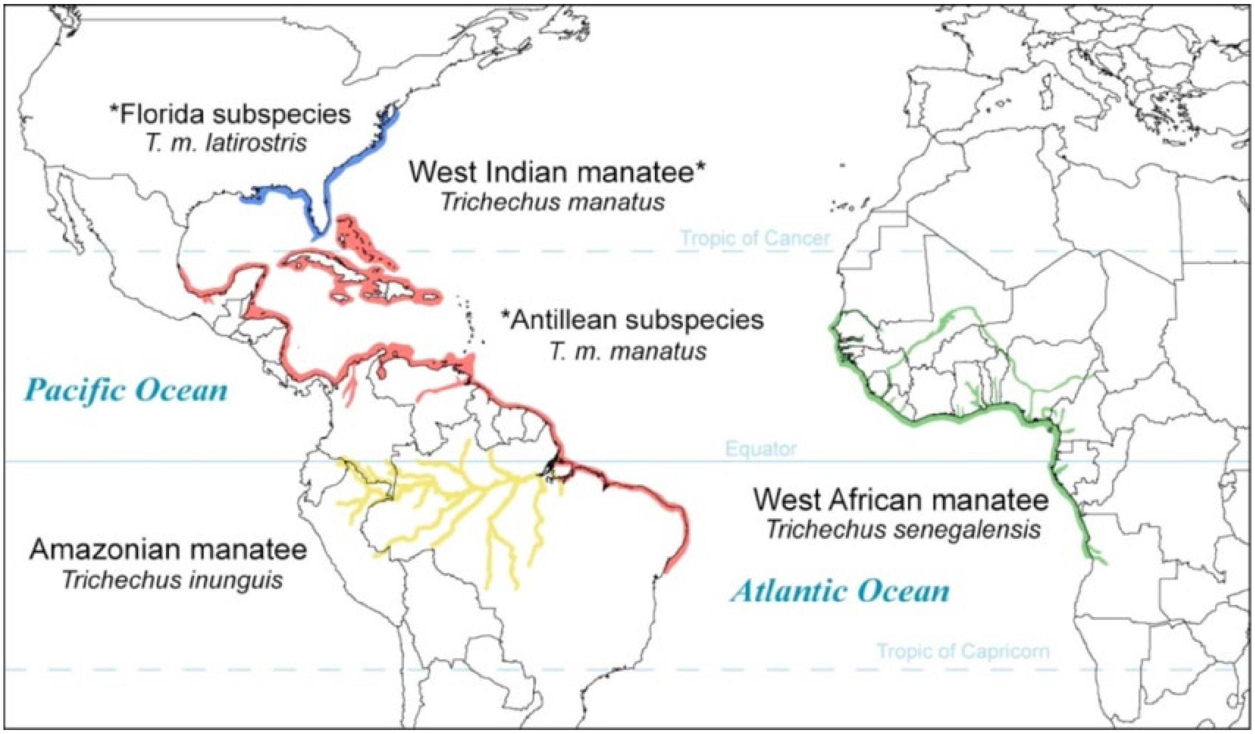


Figure 2 - Geographic distribution of extant manatee species. Range data adapted from IUCN (Gonzalez-Socoloske & Olivera-Gomez 2012, p. 2)

Despite morphological similarities with other marine mammals such as pinnipeds and cetaceans, sirenians' ancestral relations to those taxa are remote; instead, they are most closely related to Proboscidea, an order containing modern elephants (Uhen 2007, p. 515). The fossil record documents how sirenians, appearing in the early Eocene Epoch as four-legged amphibious mammals, underwent extreme reductions in their hind limbs and pelvises over time until developing into their fully aquatic forms around the Eocene's conclusion (Domning 2000, p. 115–17). The genus *Trichechus* is itself estimated to have originated in the rivers of South America during the late Miocene, from which nexus the manatees colonized the coastal Atlantic marine ecosystem and, eventually, reached Africa on transoceanic currents (de Souza et al. 2021, p. 2). While the scant fossil record for *Trichechus* makes it difficult to confirm this evolutionary history, a mitochondrial DNA phylogenetic analysis suggests that West Indian and Amazonian manatees do constitute a clade of their own, to which African manatees are a sister group (de Souza et al. 2021, p. 1). A phylogenetic tree illustrating this relationship can be seen in Figure 3 below:

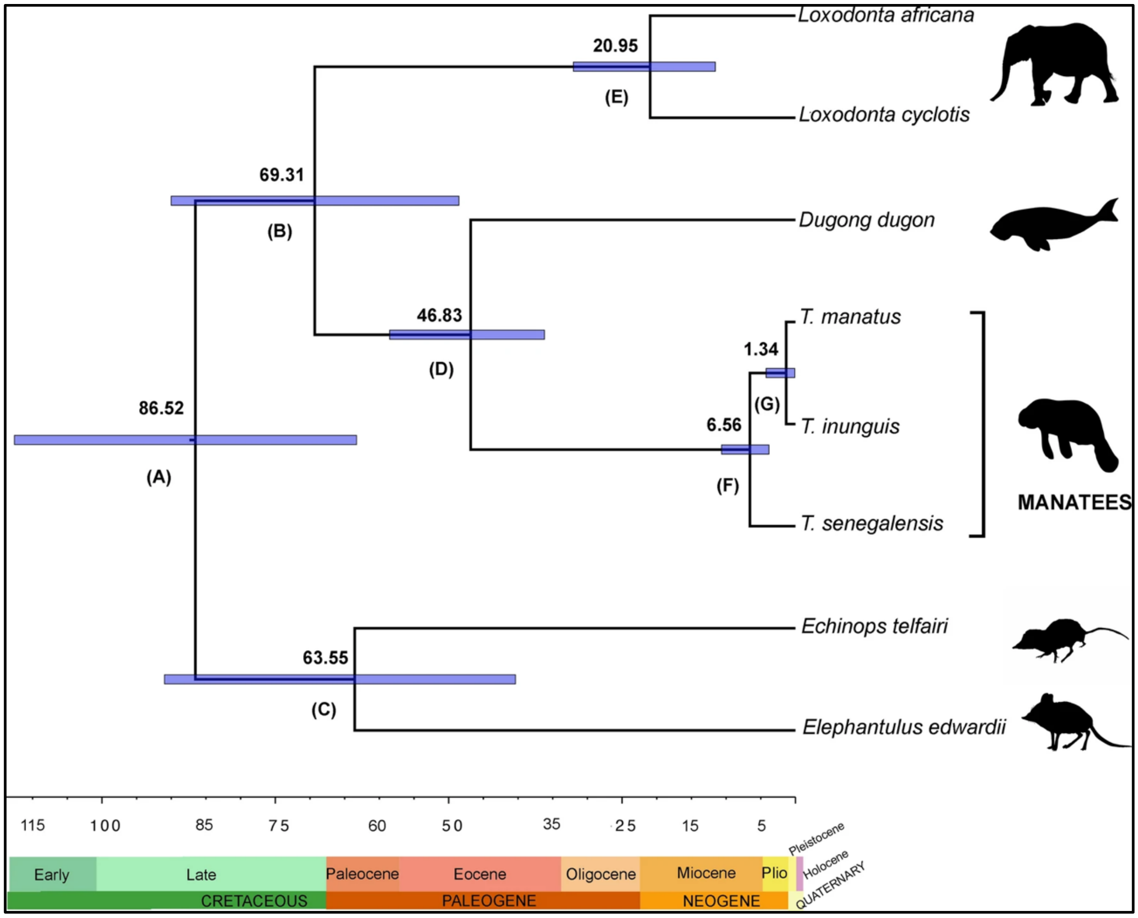


Figure 3. The purple bars represent the mean age of lineages split (de Souza et al. 2021).

C. Diet

Although manatees feed on a wide variety of submerged, emergent, and floating aquatic plants, seagrass is their primary source of nutrition (Smith 1993, p. 8; Marsh et al. 2017, pp. 342–43; Allen et al. 2018, p. 1836). They spend much of their day foraging and feed for 6 to 8 hours at any one time (Hartman 1979, p. 42). Manatees may consume up to 11% of their body weight per day in aquatic plants (Smith 1993, p. 9). Observational studies have shown opportunistic omnivorous behavior from manatees, such as consuming small invertebrates from dock pilings or eating fish caught in nets (Courbis and Worthy 2003, p. 104; Smith 1993, p. 10). As hindgut digesters, they are adapted to living off large amounts of aquatic vegetation (Reynolds and Rommel 1996, entire). Because manatees must spend so much time feeding to fulfill their metabolic needs, they are acutely sensitive to environmental disruptions (Marsh et al. 2011, p. 142)

Manatees exhibit other adaptations for benthic foraging. They have two muscular lips that move independently, similar to an elephant's trunk (Marshall et al. 1998, p. 282). They also use their forelimbs to dig into sediment so they can excavate rhizomes or roots (Lefebvre and Powell 1990, entire). Manatees have unique whiskers that serve both sensory and prehensile purposes while foraging (Marshall et al. 1998, entire; Marshall et al. 2000, entire).

In general, manatees forage at depths of up to 5 meters, but manatees can adjust their feeding technique depending on the type and the location of plant being consumed (Marsh et al. 2011, pp. 94–95). Manatees can access forage at the bottom, middle, and surface of the water column (Marsh et al. 2011, p. 96). For instance, when foraging at the bottom, manatees tilt their bodies and use their flippers to touch the substrate (Hartman 1979, p. 52). Manatees occasionally haul themselves partly out of the water using their flippers to access waterside forage (Messenger 2014; *see* Figure 4).

Figure 4 - Florida manatee crawling onto the shoreline to feed on banana tree leaves (Messenger 2014, photo credit Edgar Stout).

The Florida manatee's preferred habitat is characterized by the availability of submerged aquatic vegetation, such as seagrass beds (Smith 1993, p. 4). These sources of submerged aquatic vegetation are most common in shallow, nearshore waters. Manatees have been observed returning to the same seagrass beds and displaying preferences for certain areas (Smith 1993, p. 15). Seagrasses are perhaps even more vital to Antillean manatees in Belize and Puerto Rico where other food sources are limited (Alves-Stanley et al. 2010, p. 265).

D. Distribution & Migration

The West Indian Manatee is the most widely distributed of the three *Trichechus* species, and there are considerable differences in range and migratory behavior between the Florida and Antillean subspecies (Lefebvre et al. 2001, p. 425; *see* Figure 5).

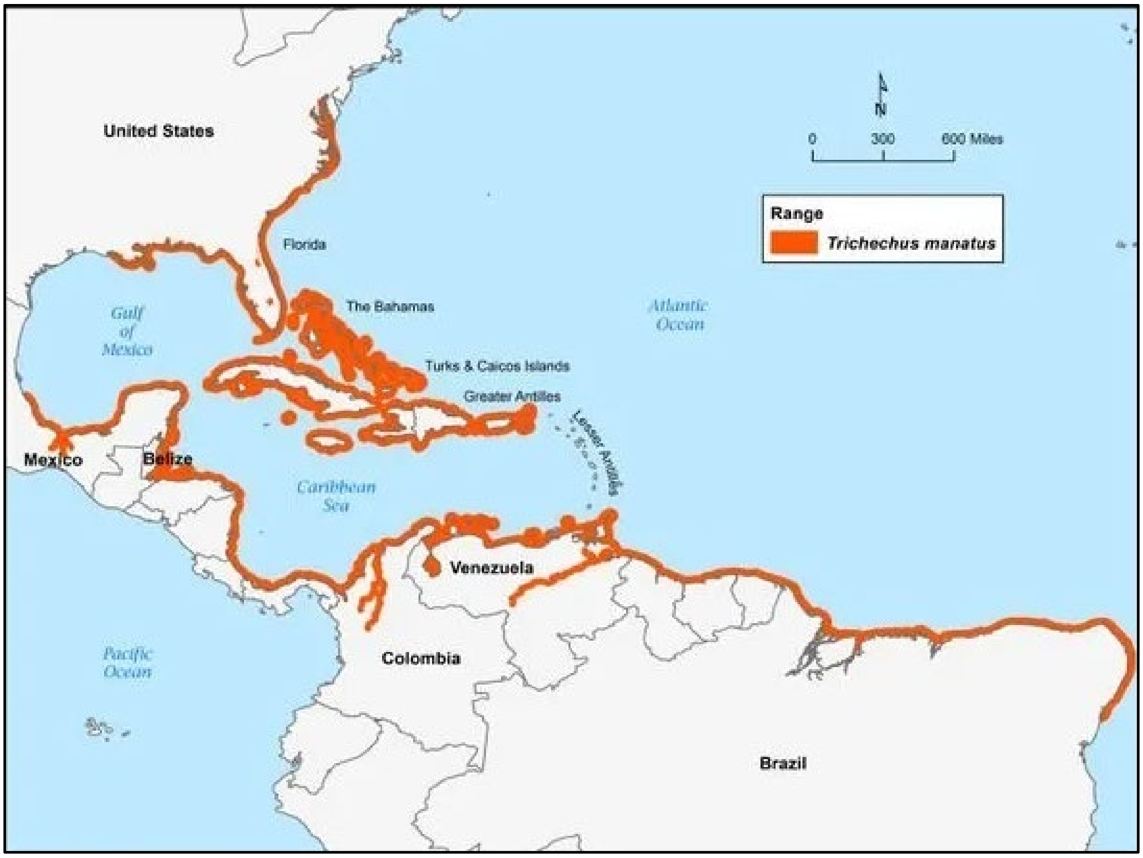


Figure 5 - Range of the West Indian manatee. Data from IUCN (Jane Cooke, USFWS)

1. Florida Manatee

The Florida manatee's habitable range varies seasonally because of its extreme sensitivity to cold temperatures. In warm months, Florida manatee populations are concentrated in Florida, Alabama, and coastal Georgia, though manatees have been sighted in coastal waters from Texas to Massachusetts (Florida SAR 2014, entire). By contrast, in the winter, Florida manatees are almost entirely constrained to rivers, springs, and coastal waters of peninsular Florida (Marsh et al. 2011, p. 376). The cold waters in the northern United States and the northern Gulf of Mexico, along with the strong currents in the Straits of Florida, are thought to constitute effective geographic limits on the Florida manatee's range (Florida SAR 2014, entire). A small number of Florida manatees have ventured to Cuba and the Bahamas, but such incidents are rare (Florida SAR 2014, p. 1; Knowles et al. 2016, entire). The subspecies' seasonal and year-round ranges are illustrated in Figure 6 below:

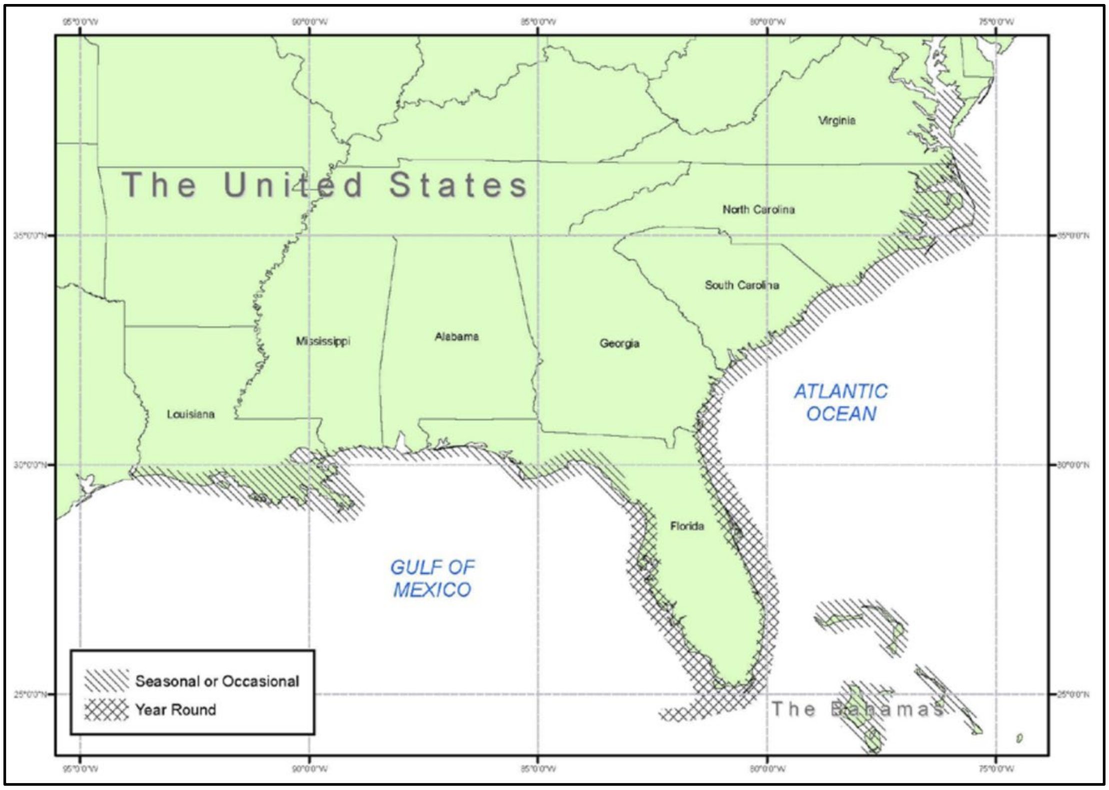


Figure 6 - Range of the Florida manatee (USFWS *Stock Assessment Report: Florida Manatee* 2014, p. 2)

As water temperatures cool in the later months of the year, Florida manatees undertake significant southerly migrations to congregate at natural or artificial warm-water refugia—typically warm springs, heated effluent from power plants, temperate waters at the southern tip of peninsular Florida, and other passive thermal sites (USFWS Recovery Plan 2001, p. 15). A 12-year longitudinal study using manatee tagging and geolocation found that the median travel distance for manatees undertaking this migration was 280 kilometers in one direction, with a maximum travel distance of 830 km (Deutsch et al. 2003, pp. 1, 18).

Despite their long migratory distances, manatees demonstrate high levels of site fidelity to both their winter and summer ranges; 90% of recorded daily manatee locations fell within 1 or 2 core areas within each seasonal range, and 12% of manatees remained within a 50 km^2 range year-round (Deutsch et al. 2003, pp. 2, 20). Patterns of seasonal migration do not vary according to a manatee's sex, but males have been observed to travel more quickly than females (Deutsch et al. 2003, p. 22). While individual manatees exhibit a high degree of variance in the timing of their arrival or departure during seasonal migrations, these variations are not explained by sex or calf-rearing (Deutsch et al. 2003, p. 23). Variability in timing is increased by the presence of artificial warm-water refugia along migration routes, which manatees may use as "stepping stones" to begin their migration north in the spring sooner than they might otherwise have been able to (Smith 1993, p. 4). Synoptic aerial surveys have observed that 82% of traveling manatees stayed within 5 meters of the shoreline, while the remainder utilized boating channels (Deutsch et al. 2003, p. 64).

USFWS divides Florida manatees into four regional management units (RMUs; formerly “subpopulations”): Northwest (NW), Upper St. Johns River (USJ), Atlantic (ATL) and Southwest (SW) (Florida SAR 2014, entire). The Northwest unit occupies the Florida Panhandle south to Hernando County. The Upper St. Johns River unit encompasses the St. Johns River south of Palatka. The Atlantic unit occupies the east coast of Florida from the lower St. Johns River south of Palatka to the Florida Keys. The Southwest unit occurs from Pasco County south to Whitewater Bay in Monroe County (Florida SAR 2014, entire).

2. Antillean Manatee

The Antillean manatee is native to the rivers, lakes, estuaries, and coastal waters of eastern Mexico and Central America, northern and eastern South America, and the Greater Antilles (Puerto Rico SAR 2014, entire). Countries with known Antillean manatee populations include the United States (Puerto Rico, and rarely the U.S. Virgin Islands), Mexico, Jamaica, Haiti, Cuba, the Dominican Republic, the Bahamas, Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Trinidad and Tobago, Guyana, French Guiana, Brazil, and Suriname (Lefebvre et al. 2001, p. 429-453; *see* Figure 7).

Figure 7 - Range of the Antillean manatee (Deutsch et al. 2008)

Unlike their northern counterparts, Antillean manatees are largely unaffected by cold stress in their tropical environments, and accordingly do not migrate to seek shelter from cold weather (Deutsch et al. 2003, p. 57). However, some Antillean manatees in Mexico, Honduras, Costa Rica, and Trinidad have displayed seasonal migratory behavior based on patterns of rainfall (Deutsch et al. 2003, p. 57). These movements are possibly motivated by food availability; in the dry season, as water levels recede, aquatic vegetation becomes scarcer, and manatees congregate inland towards troughs and basins in river systems where they can wait until the next rainy season to disperse again in search of new plant growth to feed on (Deutsch et al. 2003, p. 57). But this behavior is not fully understood; in one Panamanian study, manatees were less abundant in the wettest months (Guzman and Condit 2017, pp. 15–16). Aside from these migratory patterns, Antillean manatees demonstrate relatively sedentary behavior compared to their Floridan counterparts (Deutsch et al. 2003, p. 58). Though Antillean manatees may still undertake occasional long-distance movements, they similarly exhibit high site fidelity and generally return to their home ranges (*see* Deutsch et al. 2003, p. 58).

E. Habitat Requirements

Constraints on suitable manatee habitat include water temperature, forage availability, salinity, bathymetry, currents, and wave action (Lefebvre et al. 2000, p. 289).

1. Warm Water

Water temperature is the most significant factor determining the habitable range of West Indian manatees (Smith 1993, p. 2). Manatees lack a blubber layer and have high metabolic rates and high levels of thermal conductance, making them vulnerable at temperatures below 20 °C, at which their metabolic processes are unable to replace body heat lost to their environments (Valade et al. 2020, p. 35). While this is hardly a constraint on the tropical Antillean subspecies, large swaths of the Florida manatee's warm-weather range become uninhabitable in the colder months, forcing manatees to congregate at warm-water access points.

Most manatees gather at active discharge points of warm water, including artesian springs and effluent from industrial operations such as power plant cooling systems, wastewater treatment facilities, and desalination plants (Valade et al. 2020, p. 3). A substantial number of manatees also congregate at passive thermal basins (PTBs), where physical conditions slow cooling processes and retain sources of warm water (Valade et al. 2020, p. 3). While artificial and passive refugia are useful—often essential—sources of refuge to manatees, they lack the consistency and reliability of natural springs and are less effective at sustaining manatees in the wintertime (Valade et al. 2020, p. 3).

2. Aquatic Vegetation

To survive, manatees must consume large volumes of aquatic vegetation; studies have suggested that manatees are capable of ingesting between 4% and 11% of their body mass in wet-weight vegetation in a day (Smith 1993, p. 9). While manatees are generalists and will consume almost any vegetation in the water or near its surface, seagrass is the largest component of the West Indian manatee's diet throughout its Florida and Caribbean ranges (Smith 1993, p. 6). Most aquatic macrophytes struggle to grow at depths of 10 meters or greater due to the rapid attenuation of light in the water column; this and the manatee's own limited diving ability constrains its habitable zone (Smith 1993, p. 11; *see* Bathymetry, Currents, and Wave Action *infra*). Manatees have been documented to prefer gathering with their young at the edges of seagrass beds adjacent to deeper water with little boat traffic, presumably to allow avenues of escape from danger for themselves and their calves (Smith 1993, pp. 4–5).

3. Fresh Water

While manatees inhabit freshwater rivers, marine coastal waters, and the brackish estuaries between them, they require sources of fresh water to survive. Patterns of manatee attraction to fresh water are well documented. Christopher Columbus observed manatee congregations at a freshwater spring in Cuba (Lefebvre et al. 2001, 426), and contemporary news reports document manatees approaching docks and marinas to drink fresh water from hoses (FOX 13 Tampa Bay 2017, entire). Though some data suggest their renal systems could be capable of filtering salt from their bloodstream, and they can tolerate long periods swimming and foraging in salt water, studies have found that manatees refuse to engage in mariposia (deliberate saltwater ingestion) (Ortiz et al. 1999, p. 36). Wild manatees will interrupt foraging in offshore seagrass beds every 2 to 8 days to travel inland to visit fresh water sources (Stith et al. 2006, p. 18). While captive manatees have been observed to tolerate up to nine days without fresh water—longer if their diet is supplemented with water-dense vegetation—incidental ingestion from chronic saltwater exposure causes manatees to reduce food intake and lose body mass (Ortiz et al. 1999, p. 36).

4. Bathymetry, Currents, and Wave Action

Bathymetry, or water depth, also plays a role in limiting suitable manatee habitat. Manatees are not deep divers—their maximum forage depth is 5 meters (Marsh et al. 2011, pp. 94–5), and they may spend over three quarters of their time within 1.25 meters of the water's surface (Edwards et al. 2016, p. 8). Their typical food sources grow in shallow, clear waters, and their lung capacity only permits them to dive for an average of three to five minutes before they must surface for air (Smith 1993, p. 4), although manatees have been observed engaging in submerged resting for up to 20 minutes (Edwards et al. 2007, p. 2053). As a result, manatees are typically drawn to nearshore waters as shallow as 0.4 meters (USFWS Recovery Plan 2001, p. 18). However, manatees also use deeper channels in transit between food sources, in the course of seasonal migrations, or in other long-range movements (USFWS MSRP 1999, p. 4-29).

Finally, powerful currents or waves can make habitat unsuitable for manatees (*See* Sea Level Rise; Storms, *infra*). Manatees are naturally slow swimmers, and they are at risk of death if they are swept to sea or ashore and stranded (*See* Strandings and Separations, *infra*). Accordingly, manatees show a strong preference for slow-moving waterways and coastal ecosystems protected from wave action by barrier islands (Smith 1993, p. 4). It is thought that the strong currents in the Straits of Florida play a significant role in limiting the southern range of the Florida subspecies (Lefebvre et al. 2001, p. 425).

F. Reproduction & Reproductive Behavior

Environmental changes and differences in the population density in a community of manatees affect the age at which male and female manatees reach sexual maturity (Marsh et al. 2011, p. 255). As a result, manatees can attain sexual maturity at ages ranging from 2.5 to 6 years; however, within a single population, both sexes of manatee experience these variations similarly and tend to achieve sexual maturity at comparable ages (Marsh et al. 2011, p. 255).

Male manatees engage in a roving mating strategy, traveling more frequently and over longer distances than females to procure mates (Marsh et al. 2011, p. 181). When males encounter an oestrous female, they can congregate in large mating herds to compete for the opportunity to reproduce (Marsh et al. 2011, p. 181). Males in these herds frequently engage in vigorous cavorting with the female and, in apparent contests of strength and stamina, with each other (Marsh et al. 2011, p. 181). While these collisions often appear violent, they have not been documented to result in serious manatee injuries (Marsh et al. 2011, p. 181). The female foci of these herds sometimes attempt to avoid male pursuit by entering very shallow water or even stranding themselves at the water's edge (Hartman 1979, p.100).

Over the duration of these mating congregations, which typically last between a week to a month, females copulate with multiple males, strongly suggesting that manatee reproduction is characterized by sperm competition (Marsh et al. 2011, p. 182; Reynolds and Rommel 2004, p. 464). Among other cavorting behavior, manatee bulls court females by mouthing their body surfaces and embracing them with their forelimbs; when a female manatee is receptive, the male will roll onto his back and swim underneath the female, grasp her with his flippers, quickly inseminate her, and swim away before promptly resuming precopulatory pursuing behaviors (Hartman 1979, p. 104).

Manatees exhibit some level of seasonality in their mating behavior (Marsh et al. 2011, p. 240). Florida manatees tend to concentrate their mating activity in the summer and spring seasons, while some Antillean manatees in ecosystems with seasonal rainfall will mate during the low-water period while confined to deep-water refuges in the upper reaches of inland waterways they inhabit (Marsh et al. 2011, p. 240).

Pregnant manatees gestate single offspring called calves, (although occasional twin births occur) for a period estimated to last between 12 and 14 months (Marsh et al. 2011, p. 229–31). The sex ratio for manatee calves is approximately 1:1 (Marsh et al. 2011, p. 229–31). Calving, like mating behavior, tends to be concentrated in the spring and summer months; in the Florida subspecies, it is suspected that this timing reduces the likelihood that calves will be born in winter when food is scarcer, improving the calf's survival odds (Marsh et al. 2011, p. 240). It is unclear that Antillean manatees derive an advantage from seasonal calving due to the comparatively mild reductions in temperature and photoperiod during wintertime at lower latitudes (Marsh et al. 2011, p. 240). Female manatees do not leave the water to give birth; instead, they seek quiet, sheltered areas in which to calve and raise their young (Marsh et al. 2011, p. 201).

Male manatees do not participate in calf-rearing, which is performed entirely by females (Marsh et al. 2011, p. 232). As with other large mammals, manatee calves undergo phases of dependence upon their mothers: first, in which they are exclusively reliant on milk for nourishment, and second, in which they are weaned and subsist on a mixed diet of milk and plants (Marsh et al. 2011, p. 232). The period of calf dependency can vary significantly; calves have been documented nursing for between 12 and 24 months before weaning (Marsh et al. 2011, p. 233). Female manatees reliably alternate nursing calves between their left and right teats and dissuade calves from repeatedly nursing at the same side by refusing to open their axilla to provide nursing access (Marsh et al. 2011, p. 184). Nursing bouts last for around two minutes and occur one or two times per hour until the end of dependency (Marsh et al. 2011, p. 184). Allomaternal care of orphaned calves has been documented, and these "adopted" calves are often permitted to suckle for the entire duration of their dependency (Marsh et al. 2011, p. 187).

Dependent calves tend to remain in very close proximity to their mothers, rarely straying more than a meter from their mothers' sides (Marsh et al. 2011, p. 184). Calves and mothers communicate through vocalizations, nuzzling, mouthing, and kissing, and females will position themselves between their calves and perceived threats (Marsh et al. 2011, p. 184).

Studies suggest that female manatees have a stable calving interval of 2.5 years (Marsh et al. 2011, p. 234). Unlike dugongs, Florida manatees do not appear to delay calving in adverse conditions, and rates of calving do not appear to drop significantly even during particularly harsh winters (Marsh et al. 2011, p. 244). Likewise, there is no empirical evidence to suggest that manatees experience reproductive senescence in old age or have a post-reproductive stage (Marsh et al. 2011, p. 248–249).

G. Ecological Role

Herbivores can have major effects on seagrass characteristics such as biomass, productivity, and species diversity (Scott et al. 2018, p. 1) via both consumptive and non-consumptive pathways (Wirsing et al. 2022, p. 196). The direct effects of herbivory on seagrass, however, are difficult to predict and generally non-linear (Scott et al. 2018, p. 4). However, at least one study posits that manatee herbivory in Florida increases the net primary productivity of seagrasses, resulting in more robust seagrass recovery after seagrass losses due to phytoplankton blooms (Lefebvre et al. 2017, p. 43). Sirenian grazing behavior also has been linked to increased nutritional quality of seagrass beds for up to a year after grazing occurs (Aragones et al. 2006, p. 645).

There is some evidence of positive feedback loops in sirenian-seagrass ecosystems, where the seagrasses benefit from sirenian waste or plant dispersal (Aragones et al. 2006, 636). One study has suggested manatee foraging may contribute to nutrient recycling in seagrass meadows, and thus manatee population reductions may ultimately degrade aquatic ecosystems (Castelblanco-Martínez et al. 2012a, p. 71). In fact, paleobiologists postulate that the loss of other large aquatic herbivores in the region, including other sirenians, resulted in less diverse, depauperate Caribbean and Western-Atlantic seagrass populations (Domning 2001, abstract).

Florida manatees positively contribute to seagrass biodiversity (Lefebvre et al. 2017, p. 41). Field studies first observed this correlation, noting that in the 10,000 Islands, areas frequented by manatees had on average at least 2, 3, or 4 different species of seagrasses, whereas other areas had only one seagrass species present (Slone et al. 2013, p. 295). Further empirical studies have confirmed that manatee grazing activity contributes positively to the growth of diverse seagrass communities (Lefebvre et al., 2017, p. 41). Certain grazing behaviors of manatees, such as uprooting seagrasses, may also promote the spread and creation of new seagrass patches, because manatees both create and disperse clonal seagrass fragments while grazing (Lefebvre et al. 2017, p. 42).

As large herbivorous animals, manatees also may have significant impacts as "ecosystem engineers," because their foraging behaviors likely cause bioturbation (disturbance of sediments), and as nutrient vectors between different habitats, because of their high levels of food consumption, long gut retention times, and seasonal travel between habitats and ecosystems

(Wirsing et al. 2022, p. 201). In essence, manatees have the potential to move nutrients to oligotrophic areas from more nutrient-rich ones by eating in one area and defecating in another as they travel (Wirsing et al. 2022, p. 201; Aragones et al. 2006, p. 643). Further study is needed to fully identify manatees' biogeochemical impacts (Wirsing et al. 2022, p. 201).

While additional research is needed to fully elucidate grazer-mediated changes in aquatic ecosystems (Scott et al. 2018, p.1), it is nonetheless certain that aquatic megafauna, including manatees, play a significant role in supporting and shaping the ecology of the habitats in which they dwell (Wirsing et al. 2022, p. 206).

H. Social Behavior

West Indian manatees are semi-social but lack cohesive social structure. Observational studies suggest that they may form transitional groups around, for instance, seagrass concentrations, warm-water areas during winter, or freshwater sources (Marsh et al. 2011, p. 172). Hundreds of manatees may aggregate around warm water during cold spells. But group stability is low, other than mother-calf pairs (Marsh et al. 2011, p. 175).

Manatees do socialize when they encounter other manatees. Manatees "kiss" at the water's surface during respiration, for example, possibly to exchange information (Hartman 1979, p. 109). Manatees also engage in cavorting, a low intensity version of mating behavior. Manatees of all ages and sexes have been observed cavorting, but cavorting groups are primarily male. Cavorting manatees mouth each other using the perioral bristles, embrace, thrash, and roll. Ten percent of the daily time budget is sometimes spent cavorting during the warm season (Bengston 1981, p. 53).

Manatees communicate through underwater sound. Their vocalizations, audible to humans, sound like squeals, chirps, grunts, or groans (Marsh et al. 2011, p 185). Although all manatees vocalize, communication is most frequent between mother and offspring. Researchers have found evidence of mutual recognition between mothers and calves based on vocalizations (O'Shea and Poche 2006, p. 1067). Communication rates vary depending on behaviors and ambient noise levels, such as decreased vocalization during traveling or under high noise levels (Miksis-Olds and Tyack 2009, entire).

I. Sources of Natural Mortality

Sources of natural mortality among manatees include cold stress syndrome, toxic algae blooms, disease, stranding and separation exacerbated by severe weather events, and predation (Marsh et al. 2011, ch. 6).

1. Cold Stress Syndrome

Manatees are highly sensitive to changes in ambient water temperature. At temperatures of 20 °C or lower, manatees begin to undergo cold stress syndrome (CSS), a disorder that compromises the afflicted manatee's immunological, nutritional, and metabolic processes and can lead to emaciation, lymphoid depletion, epidermal hyperplasia, pustular dermatitis, enterocolitis, myocardial degeneration, atrophy, and death (Bossart et al. 2003, entire; Marsh et al. 2011, p. 289–90). Additional symptoms include pulmonary and gastrointestinal infections, bizarre skin lesions, and dehydration (Tzar and McClintock 2003, p. 5). CSS weakens manatees' otherwise robust immune systems, making them vulnerable to secondary opportunistic diseases or synergistic malignant effects from contaminants like toxins from red tide (Bossart et al. 2003, p. 14). Juvenile manatees are especially vulnerable (Waymer 2022, p. 2). Lipid depletion and starvation are strongly associated with CSS mortality (Martony et al. 2019, p. 89). CSS is likely a major contributing factor to recent manatee deaths in the Indian River Lagoon, where manatees lack adequate fat reserves due to seagrass loss (Waymer 2022, entire; *see* Habitat, *infra*). As described below, cold stress syndrome should also be considered anthropogenic because of manatee dependence on industrial warm-water refugia and the effects of climate change on manatee habitat, like more frequent cold snaps (Bossart et al. 2004, p. 438; *see* Habitat, *infra*; Other, *infra*).

2. Toxic Algae

There are multiple species of toxic algae that occur in the West Indian manatee's range. Where concentrations of these algae are high due to, for instance, human stressors including nutrient pollution, manatees can be injured or killed by the poisonous compounds they produce.

For example, the dinoflagellate *Karenia brevis*—which causes blooms known as "red tide" (*See* Figure 8)—produces a neurotoxin that causes a potentially lethal condition called brevetoxicosis when ingested or inhaled by manatees (Flewelling et al. 2005, p. 2; Bossart et al. 1998, entire; Walsh 2014, entire). Upon consuming seagrasses containing the toxin, manatees can suffer from edema, inflammation, immunosuppression, oxidative stress, internal and external lesions, pulmonary congestion, fatty acid composition change, liver and kidney damage, seizures, necrosis, comas, and death (Bossart et al. 1998, pp. 278–80; Walsh 2014, p. 14). Over 21% of Florida manatee deaths attributed to natural mortality from 2009–2017 had brevetoxicosis as a contributing cause (Weisbrod et al. 2021, p. 116).

Figure 8 - Red tide off the coast of Florida (Erickson 2018)

Cyanobacteria, or blue-green algae, also produce toxic compounds. One such cyanotoxin, β-N-methylamino-l-alanine (BMAA), bioaccumulates in the marine food chain and has already been associated with dolphin die-offs (Davis et al. 2021, p. 1). Once ingested and absorbed into an animal's tissue, the elimination half-life of this neurotoxin can be as long as 120 days; thus, "the slow removal of these molecules from the brain provides a toxic reservoir that can cause neuronal injury over the course of years" (Davis et al. 2021, p. 8). BMAA causes neurodegenerative disease in humans, and exposed dolphins similarly "possessed the hallmarks of Alzheimer's disease" (Davis et al. 2021, p. 1). The cytotoxins microcystin and saxitoxin have been measured in Florida's Indian River Lagoon at concentrations of up to 85.68 and 2.43 µg/L, respectively (Laureano-Rosario et al. 2021, p. 7). These chemicals have been shown to cause cytotoxic effects in mammalian cell lines, and sub-lethal saxitoxin exposure can compromise animal fitness (Laureano-Rosario et al. 2021, p. 7; Capper et al. 2013, p. 6). Cyanotoxins are suspected to be causative agents in some manatee die-offs—including 48 manatee deaths in Tabasco, Mexico—but more research into their effects in sirenians is required (SEMARNAT 2018, p. 35; Rodríguez et al. 2019, pp. 1, 14; *see* Eutrophication, *infra*).

3. Disease

Numerous diseases and parasites have been found in West Indian manatees, but the mortality caused by these factors has historically been regarded to be low (Marsh et al. 2011, p. 429; Bossart et al. 2002, p. 37; *see* Disease and Predation, *infra*). Ectoparasitic fauna on manatees such as crustaceans and remoras are not thought to be harmful (Marsh et al. 2011, p. 300). However, mortality from disease may be rising as climate change and human interference alter the manatee's environment (*See* Disease and Climate Change, *infra*). Florida manatees' dietary shift to macroalgae in response to habitat loss has caused infections of clostridial bacteria that have driven recent mortality events in the Indian River Lagoon (Landsberg et al. 2022, pp. 1-2, 12). And studies of Florida manatee calves found significant mortality due to "severe parasitic infections" such as enteric trematodiasis (Weisbrod et al. 2021, p. 121).

4. Stranding and Separation

Some natural mortality results when manatees are stranded on land or at sea, or when manatee calves are separated from their mothers. Strandings and separations are exacerbated as climate change causes sea level rise and intensifying storms (*See* Climate Change: Storms; Sea Level Rise, *infra*). Storm surges can cause mass strandings of sirenians as high waters recede, and slow-moving manatees are vulnerable to being swept out to sea by strong currents, resulting in direct mortality (Marsh et al. 2017, p. 339; Edwards 2013, p. 730).

Due to their relative lack of strength, calves are less able to react to tidal fluctuations or ocean currents (Balensiefer et al. 2017, p. 5). They are at imminent risk of death if they are not reunited with a nursing manatee or rescued by humans (Marsh et al. 2017, p. 337). In northeastern Brazil, calf stranding is a persistent source of manatee mortality despite the efforts of rehabilitation programs (Balesefier et al. 2017, pp. 2, 6). Siltation and coastal ecosystem degradation drive calf stranding by limiting access to in-shore birthing habitat, forcing offshore births in which calves are more likely to be stranded on beaches (Balensiefer et al. 2017, p. 5).

5. Predators

Functionally, West Indian manatees do not have natural predators. There are anecdotal reports of attacks by sharks or alligators (Marsh et al. 2011, p. 167), but predators are not a major source of mortality (*See* Disease and Predation, *infra*).

J. Demographic Rates

Demographically, manatees exhibit longevity, long gestation, litter sizes of one, long calving intervals, sometimes prolonged periods until sexual maturity, and high adult survival (Marsh et al. 2011, pp. 209–262). Thus, like other long-lived slow breeding mammals, the manatee's adult survival rates are the most important determinant of population growth (Eberhardt 2002, 2841; Marsh et al. 2011, p. 249). Based on direct observation of wild and captive Florida manatees, the calving interval is estimated at every 2.5 years (Marsh et al. 2011, p. 235). This interval is relatively stable over time.

Rigorous estimates of survival are only available for Florida manatee populations. In one study, adult survival rates varied between .91 and .96 (Langtimm et al. 2004, p. 438). In the same study, calf and subadult survival rates could only be measured at a single site (upper St. Johns river). First-year calves had the lowest estimated survival probability at 0.81, CL 0.73–0.87. Second-year calves were estimated at .91, CL 0.83-0,96. The study found no evidence for differences in survival probability of older subadults from adults (0.96, CL 0.93-0.99). In the absence of human-caused mortality, adult survival should be very high, in the range of 0.95-0.99 per year (Marsh et al. 2011, p. 258).

The average lifespan of the manatee is uncertain. The maximum longevity found in Florida manatees in the wild was 59 years, with multiple cases of over 55 years (Marsh et al. 2011, pp. 217–18). The average age of non-calves recovered in Florida between 1976 and 1991 was 12.6 years. The manatee population sex ratio is considered to be 1:1 for both adults and calves (Rathbun et al. 1995, p. 135).

III. Abundance and Population Trends

There are several challenges that make estimating the abundance of sirenian species, including the West Indian manatee, particularly difficult. Namely, manatees tend to be found in turbid waters with poor visibility, surface only occasionally, spend unpredictable lengths of time submerged—up to 20 minutes in some instances (Edwards et al. 2007, p. 2053)—occupy irregularly shaped habitat, and undertake erratic movements over variable spatial scales (Marsh et al. 2011, pp. 331–32). Accordingly, assessments of manatee abundance tend to be highly uncertain depending on the methodology used (Marsh et al. 2011, pp. 331–32).

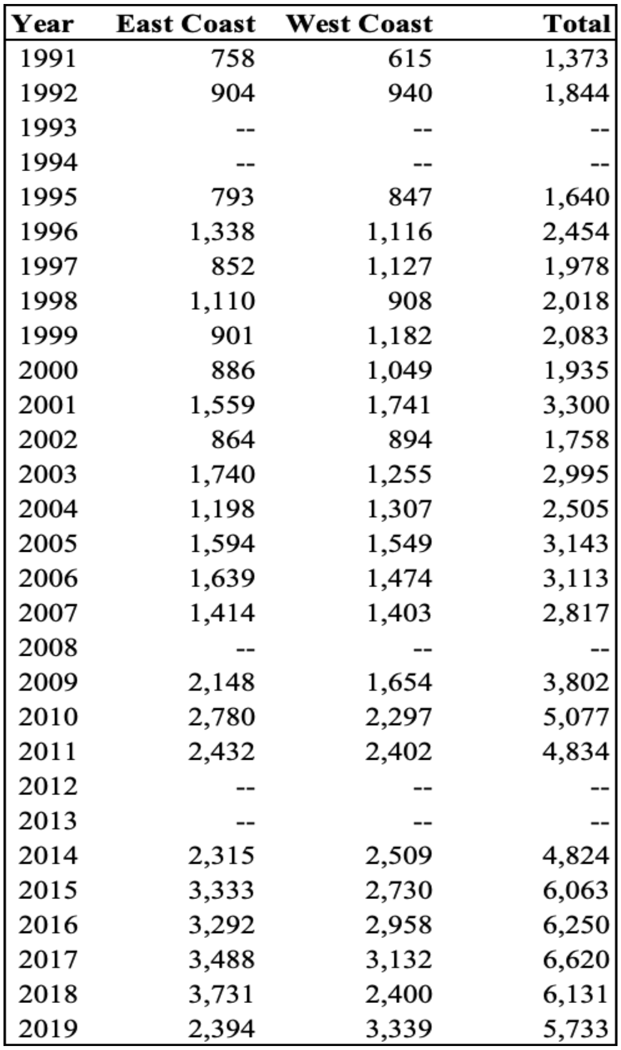
One technique used to estimate manatee populations is the aerial survey (Marsh et al. 2011, p. 332). While these surveys are the main surveillance tool for the Florida manatee, and are broadly used to track the Antillean subspecies, the results of aerial surveys are not necessarily reliable due to the difficulty of random sampling and limits in human observers' ability to detect manatees (Marsh et al. 2011, p. 333). Furthermore, because these biases can vary in magnitude across settings, or even over the course of a few minutes in the same setting (changes in water turbidity can be sudden), it is extremely difficult to generate a useful rate of error to estimate a total population size (Marsh et al. 2011, p. 334). Thus, aerial surveys can at best be regarded as minimum population counts, although double counting is impossible to eliminate with certainty (FWC *Manatee Aerial Surveys*, n.d., entire).

Mark-recapture is another technique used to estimate manatee population size (Marsh et al. 2011, p. 335). This labor-intensive method involves: (1) identifying wild manatees using tagging, photographic identification, or genetic tissue analysis; (2) releasing identified animals; (3) capturing wild manatees randomly; and (4) estimating the population size based on the number of identified manatees captured (Marsh et al. 2011, p. 335). Because mark-recapture assumes equal capture probability of all individuals in a group, researchers try to account for as much behavioral heterogeneity as possible through probability models of catchability (Marsh et al. 2011, p. 335). Mark-recapture methods have a long sampling period and estimate abundance over a period of time, whereas aerial surveys typically take place over a few days and provide a snapshot of the moment in time at which they were taken (Marsh et al. 2011, p. 335). An advantage of mark-recapture over aerial counting is that, when done properly, it eliminates the risk of double counting (Marsh et al. 2011, p. 335).

A. Florida Subspecies (*T. manatus latirostris*)

Because the Florida manatee is almost exclusively confined to peninsular Florida during the winter months, aerial surveys taken during the wintertime are the main tool used to estimate its abundance (Marsh et al. 2011, p. 378). The Florida Fish and Wildlife Conservation Commission (FWC) utilizes two kinds of aerial surveys to estimate manatee population levels: (1) "synoptic"—i.e., geographically broad—surveys taking place up to three times a year; and (2) infrequent "abundance" surveys that use stricter control parameters to obtain, theoretically, a more accurate count (FWC *Manatee Population Monitoring*, n.d., entire).

FWC did not develop its abundance survey methodology until 2011; as such, most data on the Florida manatee's historical numbers come from the relatively inaccurate synoptic aerial technique (*FWC's Second Update*, n.d., entire). Since the results of these photo-identification studies are not statistically significant, USFWS does not typically rely on their counts to make managerial decisions; instead, the data are used to infer trends and demographic rates in the subspecies (Florida SAR 2014, entire). Averaged annual counts from FWC's synoptic aerial program for each available year from 1991 to 2019 are reflected in Table 1.



Year	East Coast	West Coast	Total
1991	758	615	1,373
1992	904	940	1,844
1993	--	--	--
1994	--	--	--
1995	793	847	1,640
1996	1,338	1,116	2,454
1997	852	1,127	1,978
1998	1,110	908	2,018
1999	901	1,182	2,083
2000	886	1,049	1,935
2001	1,559	1,741	3,300
2002	864	894	1,758
2003	1,740	1,255	2,995
2004	1,198	1,307	2,505
2005	1,594	1,549	3,143
2006	1,639	1,474	3,113
2007	1,414	1,403	2,817
2008	--	--	--
2009	2,148	1,654	3,802
2010	2,780	2,297	5,077
2011	2,432	2,402	4,834
2012	--	--	--
2013	--	--	--
2014	2,315	2,509	4,824
2015	3,333	2,730	6,063
2016	3,292	2,958	6,250
2017	3,488	3,132	6,620
2018	3,731	2,400	6,131
2019	2,394	3,339	5,733

Table 1. FWC, population monitoring. Annual averages calculated by Petitioner. Data from 2008, 2012, 2013 and 2020 unavailable because of warmer-than-average weather. Data from 2021 unavailable because of the Covid-19 pandemic. (FWC, *Manatee Synoptic Surveys*, n.d., entire).

The number of manatees counted in these synoptic surveys grew from their minimum of 1,373 in 1991 to their maximum of 6,620 in 2017, for an average rate of annual growth of 6.24% in that time. However, for the years in which observations have been recorded since 2017, the rate of annual change has inverted to a loss of 6.94% of manatees per year (FWC *Manatee Population Monitoring*, n.d., entire).

In addition to synoptic surveys, FWC also uses abundance surveys to estimate manatee populations. FWC touts four primary benefits of the abundance survey methodology: (1) unlike synoptic surveys, the abundance methodology takes place over the course of a week or more for each coast (the two coasts are flown in consecutive years); (2) the methodology is scheduled for a time of year when all Florida manatees should be in the state but are spread out instead of congregated at refugia; (3) instead of a prescribed flight path, FWC samples thousands of locations that are randomly selected (within guidelines) by a computer; and (4) two observers on each flight independently count the number of manatees they see at each location (*FWC's Second Update*, n.d., entire). The first abundance aerial survey was conducted in 2011–2012 and, after updates to the model, estimated that there were 6,810 manatees statewide—40.88% higher than the 2011 synoptic count (Hostetler et al. 2018, p. 8; *see* Table 1, *supra*). The second abundance survey took place in 2015–2016, from which an estimate of 8,810 manatees statewide was derived—43.10% higher than average synoptic counts in those years (Hostetler et al. 2018, p. 8 *see* Table 1, *supra*).

FWC's abundance surveys describe considerable changes in the distribution of manatees among the four Florida RMUs between 2011–2012 and 2015–2016. They indicate that the Northwest unit shrank 59.10% from 660 to 270 individuals; the Southwest unit grew 96.48% from 2,270 to 4,460 individuals; the Upper St. Johns River unit shrank 22.22% from 90 to 70 individuals; and the Atlantic unit grew 3.43% from 3,790 to 3,920 individuals (Hostetler et al. 2018, p. 8). The estimated population of the combined RMUs grew by 29.37% over the four years, or 6.65% per year (Hostetler et al. 2018, p. 8). The next abundance survey is scheduled to be completed in December of 2022 (Ward-Geiger 2021, p. 3). The most recent Stock Assessment Report for the Florida manatee estimated a minimum population of 8,237 based on the 2015–2016 survey results (USFWS *Stock Assessment Report: Florida Stock*, 2022, p. 5).

Mass mortality events in the years since the last observation indicate that population decline may now be the rule rather than the exception for the Florida subspecies. More than 1,100 manatees died in 2021—over 13% of the estimated minimum population—and another 735 have perished in 2022 as of November 11 (FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire; FWC *2022 Preliminary Manatee Mortality Report* 2022 entire; *see* USFWS *Stock Assessment Report: Florida Stock* 2022, p. 5). Especially acute deaths among the Atlantic subpopulation are likely driving this decline; over 66% of recorded 2021 mortalities were in Atlantic-adjacent counties (Nassau, Duval, St. Johns, Flagler, Volusia, Brevard, Indian River, St. Lucie, Martin, Palm Beach, Broward, Miami-Dade, Monroe) (FWC *2021 Preliminary Manatee Mortality Report* 2021, entire). The death of large numbers of female manatees—at least 415 identified in 2021 alone—exacerbates population loss by decreasing calving rates and orphaning existing calves (FWC *2021 Preliminary Manatee Mortality Report* 2021, entire; *see* Reproduction, *supra*). As seagrass cover in mortality hotspots like the Indian River Lagoon continues to decrease, manatee populations can be expected to likewise decrease (Morris et al. 2021b, p. 3).

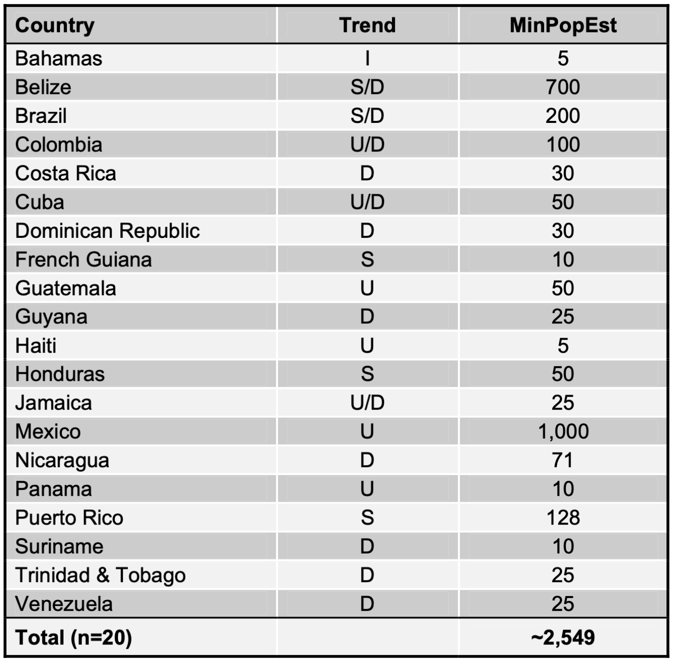
In 2016, Runge et al. published the results of the Core Biological Model version 6 (CBMv6), a predictive model that attempted to estimate the future population viability of the Florida manatee (Runge et al. 2016, entire). Because this model was released before the analysis of the 2015/2016 FWC abundance aerial survey was complete, its parameters were based on the FWC's analysis of the 2011/2012 survey (Runge et al. 2016, p. 13). CBMv6's baseline scenario predicted that manatee populations would steadily increase until doubling their 2011 numbers by 2060, before stabilizing (Runge et al. 2016, p. 20). The study's authors acknowledged that the model was limited in its analytic scope: it did not take into account any of the effects of seagrass loss, algal blooms, or unusual mortality events (UMEs) caused by factors not included in the model (Runge et al. 2016, pp. 35–36). One key and unexplained assumption was that "[t]he phenomenon in the [Indian River Lagoon] is a short-lived event that will not persist as a chronic source of mortality" (Runge et al. 2016, p. 14).

Considering subsequent increases in the frequency and severity of harmful algal blooms (HABs) (*See* Eutrophication; Harmful Algal Blooms, *infra;* Toxic Algae, *infra*), unprecedented seagrass loss (*See* Loss of Seagrass, *infra*), and the deaths of at least 1,219 manatees in the area of the Atlantic UME, by far the largest manatee UME ever recorded (USFWS *Stock Assessment Report: Florida Stock*, 2022, p. 5; NOAA, *Active and Closed UMEs* 2022, entire), the assumptions implicit in CBMv6 appear to significantly limit its utility. Predictions of steady population growth for the Florida manatee have failed to materialize ever since the results of CBMv6 were published in 2016. While new manatee abundance data have been unavailable since 2019, unprecedented levels of mortality were recorded in 2020–2022, suggesting that the trend of population decline may be accelerating (FWC *Manatee Mortality Summary 2020,* entire; FWC *2021 Preliminary Manatee Mortality Report* 2021, entire; FWC *2022 Preliminary Manatee Mortality Report* 2022, entire). These deaths prompted the study's lead author to concede in 2021 that the ongoing "[Indian River Lagoon] die-off does raise questions about whether the assumptions in [CBMv6's] baseline scenario were correct" (Pittman 2021, p. 5).

B. Antillean Subspecies (*T. manatus manatus*)

The Antillean manatee is distributed throughout the subtropical Western Atlantic Coastal Zone, including in eastern Mexico, Central America, northeastern South America, and the Caribbean (Lefebvre et al. 2001, p. 425). While Antillean manatees are present throughout the Caribbean, their abundance is low, their distribution is patchy, and human impacts to the species in some of their range is considerable (Quintana-Rizzo and Reynolds 2010, p. iii). Within the jurisdictional waters of the United States, Antillean manatees are found in Puerto Rico, with rare sightings in the U.S. Virgin Islands (Lefebvre et al. 2001, p. 427).

There are no statistically derived population estimates for the Antillean manatee across its range. Manatee populations in the Caribbean are either unknown or thought to be stable or declining (Edwards et al. 2014, p. 71). Deutsch et al. (2008) compiled the available peer-reviewed literature, supplemented by questionnaires for local scientists across 29 different countries, to estimate the rough minimum population numbers for Antillean manatees (*See* Table 2). While confidence levels varied from country to country, the researchers found a consistent trend toward decreasing population, with a few localized exceptions. Only one small subgroup (<10 manatees) reported an increase in population over the last 30 to 50 years.



Country	Trend	MinPopEst
Bahamas	I	5
Belize	S/D	700
Brazil	S/D	200
Colombia	U/D	100
Costa Rica	D	30
Cuba	U/D	50
Dominican Republic	D	30
French Guiana	S	10
Guatemala	U	50
Guyana	D	25
Haiti	U	5
Honduras	S	50
Jamaica	U/D	25
Mexico	U	1,000
Nicaragua	D	71
Panama	U	10
Puerto Rico	S	128
Suriname	D	10
Trinidad & Tobago	D	25
Venezuela	D	25
Total (n=20)		**~2,549**

Table 2 - Population trends of Antillean manatees (I = Population Increasing; S = Population Stable; D = Population Declining; U = Uncertain) **(**Deutsch et al. *Supplemental Information* 2008, entire).

Official population counts for Antillean manatees in Mexico have not been updated since 1999. It is estimated that around 1,000 manatees remain in Mexico, although some researchers report the number much lower (Deutsch et al. 2008, p. 8; Núñez-Nogueira and Uribe-López 2020, p. 257). Reported estimates of 1,000–2,000 manatees in Mexico "could be overstated" and should be treated as "appropriate maximum rather than minimum population sizes" (Puc-Carrasco et al. 2017, p. 297). Distribution information is only available for two localities—one in the coastal state of Tabasco and one on the Caribbean coast of the Yucatan peninsula—although there are reports of manatees farther north as well (Rodas-Trejo et al. 2008, p. 332). Researchers who found strikingly low manatee density in a traditional hotspot concluded there is an "urgent need" to study the Antillean manatee's status in Mexico (Puc-Carrasco et al. 2017, p. 297). Since then, there have been multiple mortality events for Antillean manatees in Mexico, signaling the increased risk of local extinction (Núñez-Nogueira and Uribe-López 2020, p. 257).

Belize is a "central location" for Antillean manatees and provides "important habitat for the long-term survival of the subspecies" (Allen et al. 2018, p. 1831). There are probably fewer than 900 manatees left in Belize, although the population segments between Mexico and Belize are likely intermixed (ECOMAR Belize, n.d., entire). The most recent aerial survey found around 500 manatees (Belize Forest Department 2015, p. 2). Population researchers suggested in 2017 that as few as 700 manatees represent the "approximate maximum" population size (Puc-Carrasco et al. 2017, p. 297). This may be an overestimate in light of "record-breaking" mortality in 2018, an "exponential" year-over-year increase that "is not sustainable." (Kase 2018, p. 4).

The Antillean manatee population in Brazil is estimated to be between 500 to 1000 manatees (Luna et al. 2021, p. 1). Manatee numbers in Brazil have been "severely reduced," and they are considered endangered due to low genetic variability, habitat loss and modification, fishing, calf stranding, and hunting (Balensiefer et al. 2017, p. 2). Other serious risks include "habitat degradation caused by effluent dumping, leading to toxic water systems on coasts and estuaries; accidental death in fishing gear; and a high degree of water vessel strikes" (Luna et al. 2021, p. 2). Their habitat is highly fragmented, and in some historic portions of their Brazilian range, including the states of Sergipe (SE), Bahia (BA), and Espírito Santo (ES), manatees have been completely extirpated (Luna et al. 2021, p. 2). A recent study applying 18 different population models predicted that Brazilian manatee populations would decline by 80% or more in every scenario; in 4, the population would go extinct (Oliviera de Meirelles et al. 2022, abstract). According to the study, this warrants the classification of this manatee population as *critically* endangered (Oliviera de Meirelles et al. 2022, abstract).

Estimates of the manatee population in Puerto Rico vary. The Puerto Rican manatee population has been monitored since 1976, primarily using aerial surveys. Total aerial survey counts from 1976 to 2009 ranged from 8 to 125 (Collazo et al. 2019, p. 1341). A 2005 study conducting an island-wide helicopter survey estimated a possible range of 150-360 manatees (Collazo et al. 2019, p. 1341). Most recently, researchers conducting an aerial survey and using multi-pass removal sampling estimated the population at 386 +/- 89 (Collazo et al. 2019, p. 1344). The Puerto Rico Department of Natural and Environmental Resources estimates a population range of 60 to 250 individuals and designates the manatee in Puerto Rico as endangered (PRDRNA 2016, p. 3).

To estimate the total population of the Antillean manatee, Deutsch et al. (2008) used the age structure of the Florida manatee population. The researchers estimated the population size somewhere between 2,600 and 5,100 for an average of around 4,100. Based on the estimated age structure, that would reflect approximately 2,378 mature individuals. The researchers expressed little confidence in these average numbers but found it reasonable to conclude that the population trend is decreasing (Deutsch et al. 2008, pp. 1, 5). This conclusion comports with broader anecdotal and historical evidence that Antillean manatees used to be common, leading some to hypothesize that significant declines have in fact occurred (Self-Sullivan and Mignucci-Giannoni 2012, p. 37).

Castelblanco-Martínez et al. (2012) performed a population viability analysis (PVA) for the metapopulation of the Antillean manatee. They used a baseline metapopulation of 6,700 Antillean manatees split into six subpopulations (Greater Antilles, Gulf of Mexico, Mesoamerica, Colombia, Venezuela, Brazil) defined by genetic structure, geographic barriers, and typical ranging behavior (Castelblanco-Martínez et al. 2012b, Table 1 and Figure 1). The authors assumed an optimistic baseline scenario of positive population growth with low human pressure and rare stochastic events (Castelblanco-Martínez et al. 2012b, p. 131). The authors then modeled best and worst-case scenarios for the metapopulation based on human impacts and habitat fragmentation. In all but the most optimistic cases, increasing human related mortality led to extinction (Castelblanco-Martínez et al. 2012b, p. 138).

In 2016, Castelblanco-Martínez et al. clarified the scope of their PVA model. First, the PVA model treated all potential threats as equal and did not consider climate change (Castelblanco-Martínez et al. 2016, p. 3). Second, the authors clarified that the baseline model is an "*optimistic*" scenario, yet the introduction of risk in all other models led to less-than-optimistic results (Castelblanco-Martínez et al. 2016, p. 3). Third, their PVA model led to the conclusion that human impact and habitat fragmentation are the most important challenges for the viability of the Antillean manatee. That conclusion remains true. However, the effects of those factors across the distribution range of the Antillean manatee are unknown. The model looked to the entire study area for the metapopulation baseline but was not sensitive to potentially important local differences. In some cases, Antillean manatee populations in certain parts of its range may already be critically low (Castelblanco-Martínez et al. 2016, p. 3).

IV. The West Indian Manatee, Florida Manatee, and Antillean Manatee Warrant Listing as Endangered under the Endangered Species Act

Criteria for Listing Species as Endangered

Congress enacted the Endangered Species Act of 1973, in part, "to provide a program for the conservation of . . . endangered and threatened species" and their ecosystems. 16 U.S.C. § 1531(b). One of USFWS's many duties under the ESA is to list species as either threatened or endangered. 16 U.S.C. § 1533(a)(1). USFWS must list a species as endangered if it is "in danger of extinction throughout all *or a significant portion* of its range." 16 U.S.C. § 1532(6) (emphasis added).

USFWS must consider whether a species should be reclassified as endangered based on the individual or cumulative effects of five statutorily prescribed factors, in any combination. *Humane Soc. of U.S. v. Kempthorne*, 579 F. Supp. 2d 7, 11 (D.D.C. 2008); *WildEarth Guardians v. Salazar*, 741 F. Supp. 2d 89, 102–03 (D.D.C. 2010); *In re Polar Bear Endangered Species Act Listing & 4(d) Rule Litig.*, 794 F. Supp. 2d 65, 111 (D.D.C. 2011); 50 C.F.R. § 424.11(c); *Ctr. for Biological Diversity v. U.S. Fish and Wildlife Serv.*, 488 F. Supp. 3d 1219, 1224 (S.D. Fla. 2020). These factors are:

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

16 U.S.C. § 1533(a)(1)(A)–(E); 50 C.F.R. § 424.11(c)(1)–(5). In recent decisions, USFWS has chosen to evaluate the five factors according to their effects on a species' ability "to withstand annual variation in its environment (resiliency), novel changes in its biological and physical environment (representation), and catastrophes (redundancy)." *See, e.g.*, Gray Wolf Final Rule, 85 Fed. Reg. 69,778, 69,880 (Nov. 3, 2020).

In making its listing determination, USFWS "must give independent meaning to the phrase 'significant portion of range.'" *Desert Survivors v. U.S. Dep't of Interior*, 321 F. Supp. 3d 1011, 1072 (N.D. Cal. 2018). USFWS's recent interpretations of "significant portion of range" have asked whether a portion "contribute[s] meaningfully to resiliency, redundancy, or representation of the . . . entity being evaluated without prescribing a specific 'threshold'." *Defs. of Wildlife v. U.S. Fish & Wildlife Serv.*, 584 F. Supp. 3d 812, 827 (N.D. Cal. Feb. 10, 2022); *see also* 12-Month Petition Finding and Endangered Species Status for the Missouri Distinct Population Segment of Eastern Hellbender, 84 Fed. Reg. 13223–01, 13230 (Apr. 9, 2019) ("To [identify a significant portion of range], we look for any portions that may be *biologically important in terms of the resiliency, redundancy, or representation of the species*.") (emphasis added). Courts have rejected vague interpretations of this language as "not a reasonable construction of the phrase 'significant portion of its range,'" and USFWS must instead explain its interpretation in terms of guideposts—"defined factors, thresholds, or evidentiary considerations"—by which a court can judge its exercise of discretion. *Defs. of Wildlife*, 584 F. Supp. 3d at 828. USFWS may not interpret "significant" so that "the only circumstance in which a species would be in danger of extinction in a significant portion of its range is one in which it was in fact in danger of extinction throughout all of its range." *Survivors*, 321 F. Supp. 3d at 1071; *accord Nat'l Wildlife Fed'n v. Norton*, 386 F. Supp. 2d 553, 566 (D. Vt. 2005).

Furthermore, where a species is undergoing considerable reductions in habitat—as is the case with the manatee—it is the government's burden to explain why "the area in which the species can no longer live is not a significant portion of its range." *Defs. of Wildlife v. Norton*, 258 F.3d 1136, 1145 (9th Cir. 2001) (internal quotation marks omitted); *Tucson Herpetological Soc'y v. Salazar*, 566 F.3d 870, 876–77 (9th Cir. 2009) (USFWS must "develop some rational explanation for why the lost and threatened portions of a species' range are insignificant before deciding not to designate the species for protection."); *see also* Habitat, *infra*.

When USFWS makes a listing determination, it must do so "solely on the basis of the best available scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A). The purpose of this requirement "is to ensure that the ESA not be implemented haphazardly, on the basis of speculation or surmise" *Bennett v. Spear*, 520 U.S. 154, 176 (1997). However, USFWS "may not ignore evidence simply because it falls short of absolute scientific certainty" *Nw. Ecosystem All. v. U.S. Fish & Wildlife Serv.*, 475 F.3d 1136, 1147 (9th Cir. 2007); *see also Defs. of Wildlife v. Babbitt*, 958 F. Supp. 670, 679–80 (D.D.C. 1997) (USFWS applied the wrong legal standard in dismissing scientific evidence because it was not "conclusive").

"[T]he decision to list a species as . . . endangered is highly fact-specific." *In re Polar Bear*, 794 F. Supp. 2d at 89. "Although there is no single metric for determining if a species is 'in danger of extinction,'" broad, non-exhaustive categories of past "endangered" listings include (1) "Species facing a catastrophic threat from which the risk of extinction is imminent and certain;" (2) "Narrowly restricted endemics that, as a result of their limited range or population size, are vulnerable to extinction from elevated threats;" (3) "Species formerly more widespread that have been reduced to critically low numbers or restricted ranges and, consequently, are at a high risk of extinction due to threats that would not otherwise imperil the species;" and (4) "Species with relatively widespread distribution that have nevertheless suffered ongoing major reductions in numbers, range, or both, as a result of persistent threats." *Id.* at 83.

Where a "prior review [of that species] resulted in a final agency action," USFWS advises petitioners to "provide[] new information not previously considered" *See* 50 C.F.R. § 424.14(h)(iii). In the case of the West Indian manatee, because the same threats persist as when it was listed as "endangered" less than a decade ago, and because it faces *new and worse* threats today, USFWS must conclude that the species is currently in danger of extinction.

Listing History

USFWS listed the Florida manatee as endangered in 1967, 32 Fed. Reg. 4,001 (Mar. 11, 1967), pursuant to the Endangered Species Preservation Act of 1966, Pub. L. 89–669; 80 Stat. 926. Congress passed the expanded Endangered Species Conservation Act of 1969 to protect species in danger of "worldwide extinction." Pub. L. 91–135; 83 Stat. 275. The Department of Interior subsequently amended the manatee listing in 1970 to include the West Indian manatee throughout its range, including in the Caribbean Sea and South America. List of Endangered Foreign Fish and Wildlife 35 Fed. Reg. 18,319 (Dec. 2, 1970). Species listed under the Endangered Species Conservation Act maintained their listing status under the Endangered Species Act of 1973. 16 U.S.C. § 1531 *et seq.* Thus, USFWS listed and managed the West Indian manatee as endangered beginning in 1973.

FWS designated critical habitat for the Florida manatee population subspecies in 1976. No critical habitat has been designated for the Antillean manatee in Puerto Rico or other areas of the West Indian manatee's range. The original designation listed waterways where manatees were known to concentrate in Florida but did not describe any additional "physical or biological" features essential to conservation. Determination of Critical Habitat for Ameri-can Crocodile, California Condor, Indiana Bat, and Florida Manatee, 41 Fed. Reg. 41,914 (Sept. 24, 1976). Congress added those requirements in the 1978 amendments to the ESA. The Florida manatee's critical habitat has not been updated since its original designation more than 45 years ago. In 2010, USFWS found that revision was warranted because the critical habitat designation no longer matched the best available scientific or commercial information. 12-month Finding on a Petition To Revise Critical Habitat for the Florida Manatee, 75 Fed. Reg. 1,574, 1,577 (Jan. 12, 2010). Of particular concern to USFWS was new information about warm-water sites. "Given the significance of warm water to the survival of the manatee in Florida, the most essential feature will be the availability and adequacy of warm water refugia." *Id*. Despite these findings, USFWS did not revise the critical habitat due to a lack of funding at that time. *Id*. USFWS has only recently agreed to revise the critical habitat for the Florida manatee following litigation by Center for Biological Diversity, Defenders of Wildlife, and Save the Manatee Club in February of 2022. Under a court-ordered agreement, USFWS has until 2024 to complete revisions, meaning that the Florida manatee's critical habitat will not be updated for another few years, even though these revisions should have happened a long time ago (Center for Biological Diversity, 2022, entire).

In 2017, USFWS issued a final rule reclassifying the West Indian manatee from endangered to threatened. Final Rule 2017, 82 Fed. Reg. 16,668. USFWS found that the manatee no longer met the definition of endangered "due to (1) significant recovery efforts made throughout parts of its range to address threats, and (2) a better understanding of manatee population demographics." *Id.* at 16,702. In particular, "updated adult survival rate estimates and estimated growth rates" in the Runge et al. 2015 study (Core Biological Model version 5.03) suggested positive manatee population growth in the Southeastern United States. *Id*. at 16,669 (Runge et al. 2015, p. 2). USFWS acknowledged that the Runge 2015 study relied on data available through 2009 and "did not evaluate" unusual mortality events that occurred from 2010–2013. Final Rule 2017, 82 Fed. Reg. at 16,684.

In its 2017 decision, USFWS warned that anthropogenic threats remain, which could make the manatee "likely to become endangered in the foreseeable future" *Id*. at 16,702. USFWS emphasized threats from habitat loss, loss of warm-water refugia, watercraft collisions, and poaching. *Id*. USFWS stressed that these threats are all intensified by "human population growth." *Id*. at 16,700.

This Petition contains significant information related to the survival of the West Indian manatee that was not considered by USFWS when it downlisted the manatee to threatened status in April 2017. This information includes:

- The response of Castelblanco et al. (2016) correcting USFWS's "misinterpretations" of their 2012 study and objecting to its use in supporting the manatee downlisting decision, noting: (1) only the "optimistic" scenario predicted Antillean manatees' survival, and all other scenarios "led to extinction" for the subspecies; and (2) the model did not account for any of the effects of climate change (e.g., ocean warming, acidification, extreme cold events, storms, rainfall changes, sea level rise);
- The objection of Castelblanco et al. (2016) to the USFWS manatee downlisting decision's: (1) reliance on Runge et al. (2015)—which used "data available as of 2012"—since the model's data did not represent recent mortality events; and (2) conclusion that "threats are being addressed and reduced throughout the [West Indian manatee's] range," since the most recent information "strongly shows that the opposite is true";
- The effects of thermal stress on seagrasses caused by ocean warming and exacerbated by acidification;
- The effects of extreme cold weather events on seagrasses;
- The effects of sea level rise on seagrasses;
- The effects of hypersalinity on seagrasses;
- The effects of contaminants on seagrasses;
- The effects of phytotoxic sulfide compounds on seagrasses, which are worsened by ocean warming, presence of decomposing vegetation, and salinity changes;
- Ongoing seagrass loss in the Caribbean outside of Puerto Rico;
- The effects of glyphosate on manatees and seagrasses;
- The ubiquitous exposure of manatees to glyphosate;
- The effects of population growth, septic tanks, agricultural pollution, legacy nutrients, and phosphogypsum stacks on eutrophication;
- The effects of eutrophication on HABs that kill manatees and seagrasses;
- The effects of ocean acidification, including exacerbated thermal stress on seagrass and proliferation of toxic HABs;
- The effects of climate change on red tides;
- The effects of groundwater depletion on passive thermal basins;

- Potentially irreversible effects of aquifer degradation due to over-extraction;
- The effects of the worst multi-year drought in the recorded history of the Caribbean from 2013–2016 outside Puerto Rico;
- The effects of drought on manatee survival related to freshwater scarcity, particularly with respect to vulnerable Antillean subpopulations;
- The effects of precipitation extremes on surface water runoff regimes and related changes in sediment, nutrients, contaminants, and pathogens entering waterways;
- Sublethal impacts of boat strikes, marine debris ingestion, and entanglement;
- The effects of climate change on the proliferation of disease;
- The effects of climate change on the prevalence of extreme cold events; and
- The effects of sea level rise and coastal development limiting the manatee's habitable range.

Summary of Factors

All five listing factors threaten the future existence of the West Indian manatee and its component subspecies, the Florida manatee and Antillean manatee. Habitat loss poses an urgent threat to both subspecies and is already causing populations to decline. Seagrass degradation has been documented throughout the West Indian manatee's range due to algal blooms, turbidity, boating, development, storms, toxins, and temperature, and salinity changes. In Florida, where seagrass destruction has been especially acute, mass mortality of manatees has occurred; thousands of Florida manatees have likely died of starvation since 2020. Florida manatees are also uniquely pressured by the loss of warm-water habitat due to impending power plant closures and reductions in spring flows caused by water overconsumption driven by human population growth. Coastal development destroys, obstructs, and fragments manatee habitat; it is believed to be the largest threat driving the Antillean species' decline. Limited access to fresh water disproportionately harms Antillean manatees. Human recreation, including boating, harasses manatees and drives them away from essential habitats.

Poaching also remains a sizable threat to Antillean manatees in many countries. West Indian manatees are injured and killed by watercraft strikes, marine debris entanglement and ingestion, crushing in water control structures, and toxins from algal blooms or chemical contamination. These anthropogenic impacts can be expected to increase with human population growth and related coastal development. Throughout the West Indian manatee's range, the worsening effects of climate change—e.g., warming oceans, acidification, precipitation changes, storms, and sea level rise—further harm manatees and their habitat, including seagrasses. Existing regulatory mechanisms have proven inadequate in preventing or mitigating these threats.

This Petition presents significant new information related to the survival of the West Indian manatee that has become available after USFWS downlisted the manatee to threatened status in April of 2017. This new information includes:

- The failure of past PVA modeling attempts (Runge et al. 2015 & 2016) to anticipate the Florida manatee population crash in light of multiple factors (seagrass loss, algal blooms, and unusual mortality events) not considered by model parameters;

- The failure of optimistic PVA model baseline scenarios (Castelblanco-Martínez et al. 2012b) to predict trends in local Antillean manatee populations;
- Challenges to critical-care capacity at rehabilitation organizations in light of unprecedented mortality;
- Worsening seagrass loss in Florida since 2017, including in the Indian River Lagoon, Tampa Bay, and Biscayne Bay;
- Increasingly frequent and destructive influxes of *Sargassum* seaweed, which cause sargasso brown tides and the loss of seagrass habitat;
- The deaths of thousands of Florida manatees driven in part by an unprecedented and ongoing mortality event starting in 2020;
- Updated adult survival and population growth rate estimates following recent manatee mortality events;
- Updated population estimates since USFWS's 2017 final rule that relied on outdated population data from 2012;
- Updated population models of manatee populations in Brazil, which predict an 80% reduction in population or worse across all scenarios, indicating that the Brazilian manatee populations are critically endangered;
- The interruption of data collection by the COVID-19 pandemic, challenging accurate population monitoring;
- Updated estimates of the number of both registered and unregistered boats in Florida's waterways and coasts;
- Increased mortality statistics for manatee deaths caused by boat strike in Belize;
- New reports on the high mortality risk of Antillean manatee calves in Brazil;
- Updated projections of power plant retirements;
- Information regarding the dual impacts of Hurricanes Irma and Maria in the fall of 2017;
- Reports of a negative Atlantic Multidecadal Oscillation in September 2017, indicating increased risk of a long-term dry phase;
- Information about the Piney Point disaster and resultant discharge of phosphogypsum and process wastewater into Tampa Bay in 2021;
- Projections that climate change will contribute to significant rainfall reductions in Florida, the Caribbean, and Central America;
- The continuing failure to implement vital proactive management measures in response to power plant retirements, despite declarations that federal and state agencies would work with the power industry to preserve manatee habitat;
- Newly discovered effects of endoparasites and pathways for disease transmission in manatees;
- New research into the harmful effects of cyanotoxins like BMAA on marine mammals and associated die-off events;
- Reports by the Mexican government of at least 48 manatee deaths in the Tabasco region attributed to algal blooms and polluted waters;
- Increased risk of Antillean manatee extinction in Mexico associated with recent die-offs, evidenced by strikingly low manatee density at traditional hotspots; and
- The inadequacy of existing regulatory mechanisms to address existing and new threats listed above.

West Indian manatees have suffered major reductions in number and range since they were downlisted to threatened in April 2017 due to persistent and worsening threats summarized above. Florida manatees' range is narrowly restricted by the availability of warm-water winter habitats, which are being degraded and destroyed. Manatees' current precarity makes them especially vulnerable to ongoing and future threats such as climate change. Facing these dire circumstances, it is imperative that the West Indian manatee, Florida manatee, and Antillean manatee are afforded the maximum protective effect of the ESA that only listing as "endangered" can provide.

A. Present or Threatened Destruction, Modification, or Curtailment of Manatees' Habitat or Range

1. Loss of Seagrass

Seagrasses are an irreplaceable feature of the West Indian manatee's habitat; manatee well-being is inextricably linked with access to this critical food source (Marsh et al. 2017, pp. 342–43; *see* Habitat Requirements: Aquatic Vegetation, *supra*). Although manatees are generalist herbivores, seagrasses are their primary sources of nutrition (Lefebvre et al. 2000, p. 290; *see* Diet, *supra*). When seagrass meadows die, manatee populations that depend upon them can experience acute injuries from starvation—including loss of up to 40% of their body weight, widespread degeneration of muscle and fat, and severe atrophy of the liver, heart, and other organs—often culminating in death (McRae and Tucker 2021, pp. 7, 9-10; *see* Figure A.1).

Figure A.1 - Clockwise from top left to bottom: (A) Emaciated carcass. There is a distinct dip in the neck region ('peanut-head') and sunken eyes; **(B) Tissue section of fat and muscle from two emaciated manatees.** The manatee on the left died from cold stress disease and still had seemingly normal fat despite it being thin and depleted. The fat and muscle of the manatee on the right that died from primary starvation was depleted but also very watery ('serous atrophy'), further emphasizing the prolonged state of wasting; **(C) Microscopic view of liver atrophy.** The liver cells (light pink with purple nucleus) are smaller than normal. The brown pigment in the cells is from the breakdown of the components that make up the cell; **(D) Emaciated carcass.** The body is flattened. Image credit Dr. Dave Rotstein (FWC *Carcass examinations in the Atlantic Unusual Mortality Event*, 2022).

Despite the interventions of officials—including the supplemental feeding of manatees by USFWS—thousands of Florida manatees have likely died of starvation since 2020 due to loss of seagrass habitat (FWC *Manatee Mortality Summary 2020,* entire; FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire; FWC *2022 Preliminary Manatee Mortality Report,* 2022, entire; *see* Regulatory Inadequacy, *infra*). Manatees that shift to a predominantly macroalgal diet in response to seagrass loss may also be more vulnerable to clostridium infection and related lethal and sublethal effects (Landsberg et al. 2022, entire; *see* Disease and Predation, *infra*).

a) Seagrass Biology

Despite their name, seagrasses are not true "grasses," but marine monocotyledons of the families *Cymodoceaceae*, *Zosteraceae, Posidoniaceae* and *Hydrocharitaceae* (Hartog and Kuo 2007, p. 1). They have one of the highest light requirements of any plant group—as much as 25 times more incident radiation than other angiosperms—and are extremely sensitive to environmental disturbances that affect water clarity (Orth et al. 2006, p. 988). Seagrasses tend to prefer shallow, clear waters, although some species can grow at depths of 30 meters or greater (Duarte et al. 1991, p. 365). The only flowering plants able to tolerate marine environments, seagrasses form meadows that can cover sections of seabed from as small as 1m^2 to tens of thousands of continuous hectares (Jiang et al. 2020, p. 2; Statton et al. 2015, p. 3).

Seagrass meadows are frequently composed of an array of seagrass species that share space on the seafloor (Moreira-Saporiti et al. 2021, p. 1). The species composition of these meadows tends to be similar throughout Florida and the Caribbean, where native seagrasses including *Thalassia testudinum* (turtle grass, Figure A.1), *Syringodium filiforme* (manatee grass, Figure A.2), and *Halodule wrightii* (shoal grass, Figure A.3) perform valuable ecosystem services (Edwards 2013, p. 733; Muthukrishnan et al. 2020, p. 2).

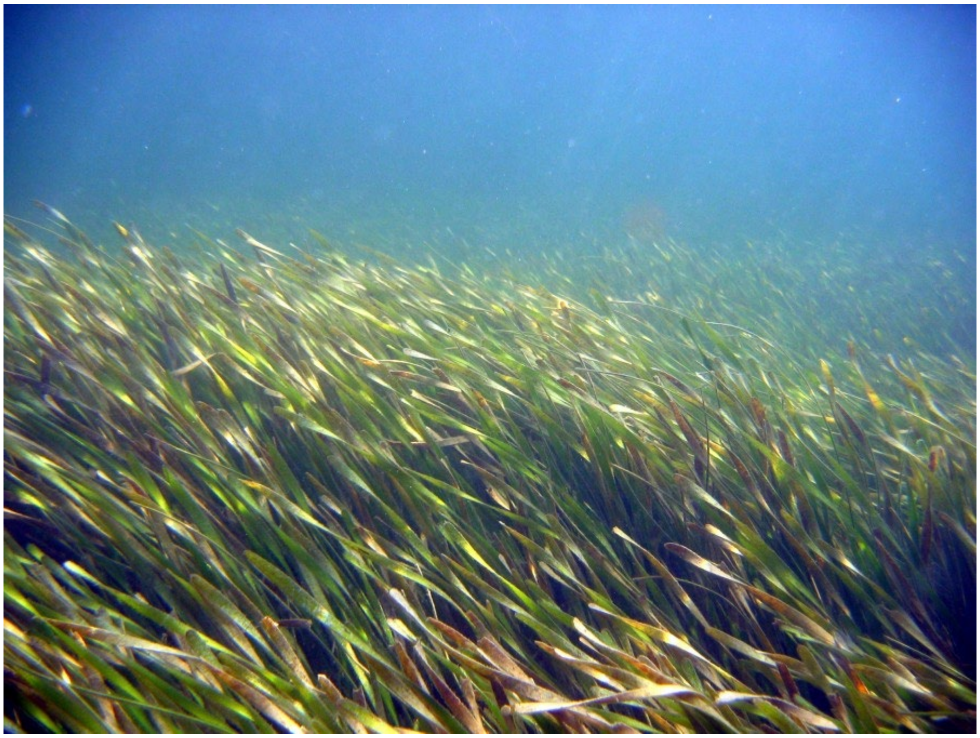


Figure A.2 - Turtle Grass. *Thalassia testudinum* is the largest Florida seagrass, with deep root structures and ribbon-like leaves 4 to 12 mm wide and 10 to 35 mm long (*Florida Seagrasses*, n.d.).

Figure A.3 - Manatee Grass. *Syringodium filiforme* is recognizable by its cylindrical, thin leaves up to half a meter long. Manatee grass is usually found in mixed seagrass beds or small, dense monospecific patches (*Florida Seagrasses*, n.d.).

Figure A.4 - Shoal Grass. *Halodule wrightii* is an early colonizer of vegetated areas and usually grows in water too shallow for most other species (*Florida Seagrasses*, n.d.).

Seagrasses can reproduce both sexually and through clonal propagation, a process that begins when new rhizomes grow onto unoccupied areas of seabed (Morris et al. 2022, p. 12; Paulo et al. 2019, p. 358). As rhizomes expand across the seafloor, a growing meadow's overall area increases, but seagrass shoots temporarily cover a decreased percentage of the meadow while new sections remain bare of leaves (Morris et al. 2022, p. 12). In good conditions, these rhizomes can quickly grow new blades using their starch reserves, restore the balance of photosynthetic to rhizomal tissue, and expand the meadow's outermost productive edge (Smith 1993, p. 20).

Seagrass meadows suffer, however, when they are persistently shaded by turbidity, algal blooms, or deepening water driven by sea level rise, and start to die at their outermost, deepest edges (Morris et al. 2022, pp. 11–12; Short and Neckles 1999, p. 175). Responses to shading vary according to the species, meadow condition, amount of light deprivation, and presence of concurrent stressors. Seagrasses deeper than a meter seem to be especially vulnerable, although light deprivation can eliminate seagrasses at any depth (Morris et al. 2022, pp. 11–12). Meadows with low percentage cover—whether damaged, recovering, or midway through expansion—experience the effects of shading especially harshly because their limited photosynthetic capacity may be unable to satisfy the plant's respiratory requirements in low light (Morris et al. 2022, pp. 1, 12). The death of meadows' root systems destabilizes seabed sediments and increases turbidity, producing a feedback loop that exacerbates seagrass decline (Morris et al. 2022, pp. 9, 12). Even sublethal levels of light deprivation impair seagrasses and diminish meadows' productivity (Erftemeijer and Lewis 2007, pp. 1555).

Seagrass meadows are modular organisms with the capacity to survive when portions of their above-ground and below-ground structures are destroyed (Marsh et al. 2011, p. 81). However, degraded seagrass beds regenerate slowly. After a hypersalinity event caused a catastrophic seagrass die-off in Florida Bay from 1987–1991, seagrasses there showed almost no evidence of recovery for 8–10 years; natural ecosystem restoration took between 17 and 23 years (Hall et al. 2021, p. 3). The results of a 1999 eelgrass restoration project near the Chesapeake Bay in Virginia reproduced this approximate timeline (Orth et al. 2020, p. 3; *see* Figure A.5). Thus, even when recovery measures are implemented, benefits may not follow for decades, if at all (*See* Regulatory Inadequacy: Seagrass Restoration, *infra*).

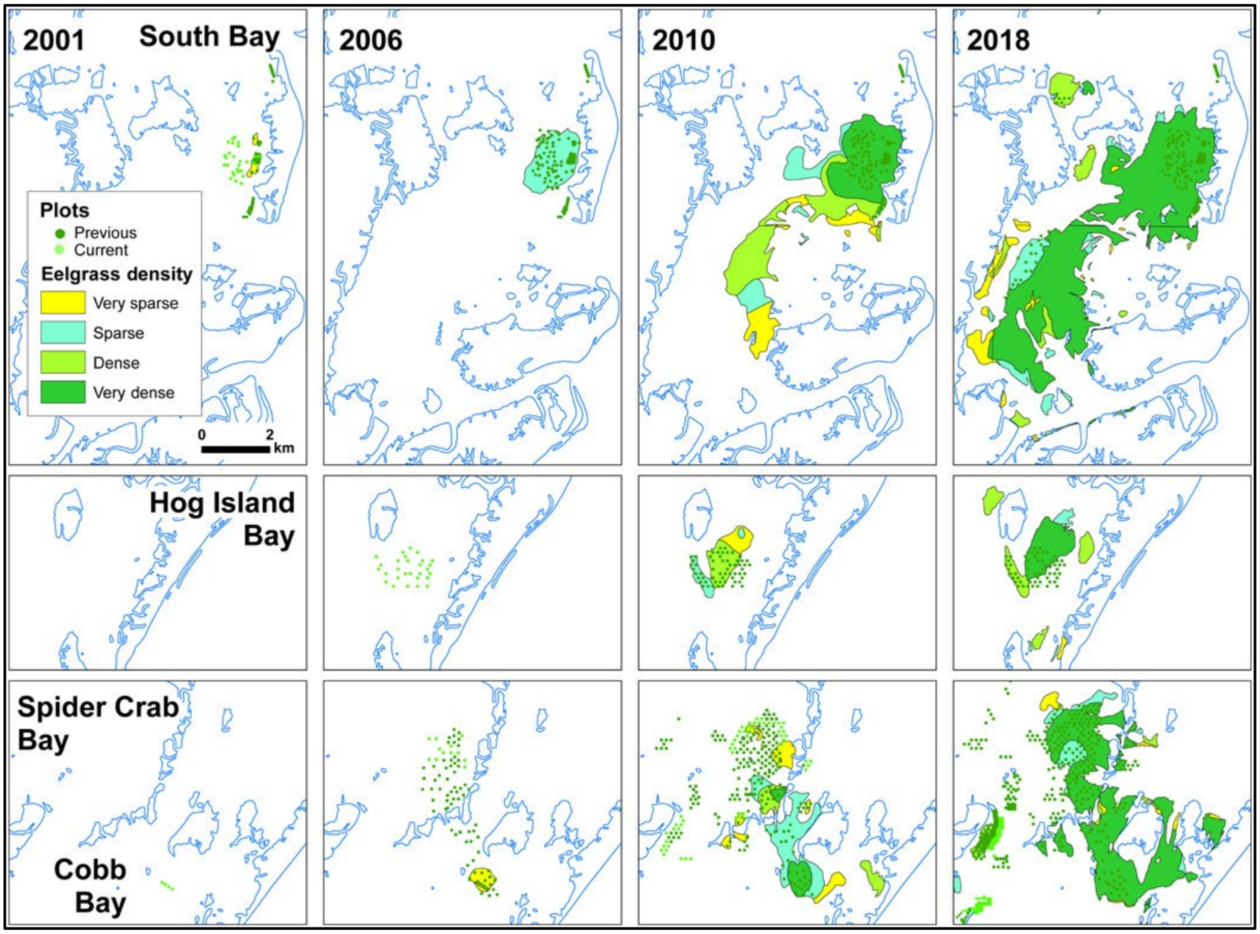


Figure A.5 - Seagrass recovery in Virginia coastal bays following 1999 restoration project (Orth *et al*. 2020, p. 3)

b) Seagrass Decline in the Manatee's Range

Due in large part to their environmental sensitivity, seagrasses have fared poorly around the globe since the industrial revolution. From 1880 to 2013, seagrass cover declined 19.1% worldwide (Dunic et al. 2021, p. 4101). The Tropical Atlantic bioregion (*See* Figure A.6), which the West Indian manatee inhabits, experienced the greatest destruction of seagrass at 3,485 km^2 —a net loss of 32.3% (Dunic et al. 2021, p. 4101).

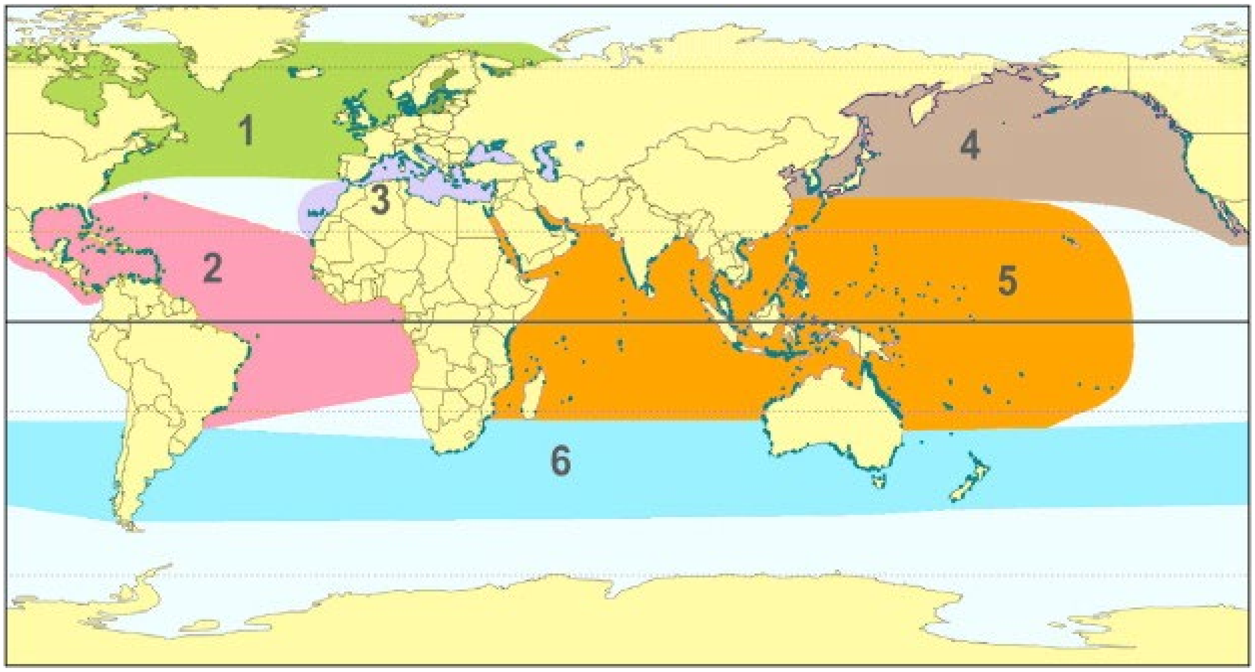


Figure A.6 - Seagrass bioregions. Global seagrass distribution shown as blue points and polygons. Geographic bioregions: 1. Temperate North Atlantic, **2. Tropical Atlantic**, 3. Mediterranean, 4. Temperate North Pacific, 5. Tropical Indo-Pacific, 6. Temperate Southern Oceans (Short et al. 2007, p. 6)

While seagrass loss in the Tropical Atlantic appeared to have slowed in 2013, recent mortality events suggest it may again be accelerating (Dunic et al. 2021, p. 4101; *see* Morris et al. 2022, p. 10). Some of the most acute recent losses have occurred in Florida, where Florida manatees are confined during the winter; this is especially concerning since winter access to forage is essential to that subspecies' ability to survive the cold (Griffin et al. 2021, pp. 1, 7).

The Indian River Lagoon (Figure A.7, Reaches 1-9), a 250-kilometer-long estuary spanning 40% of Florida's eastern coast, is one site where major, recent seagrass loss has caused the mass death of manatees (St. Johns River Water Management District 2007, p. 4; FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire; FWC *2022 Preliminary Manatee Mortality Report,* 2022, entire). Dominant seagrass species in the estuary included shoal grass, manatee grass, turtle grass, and widgeon grass (Morris et al. 2022, p. 3).

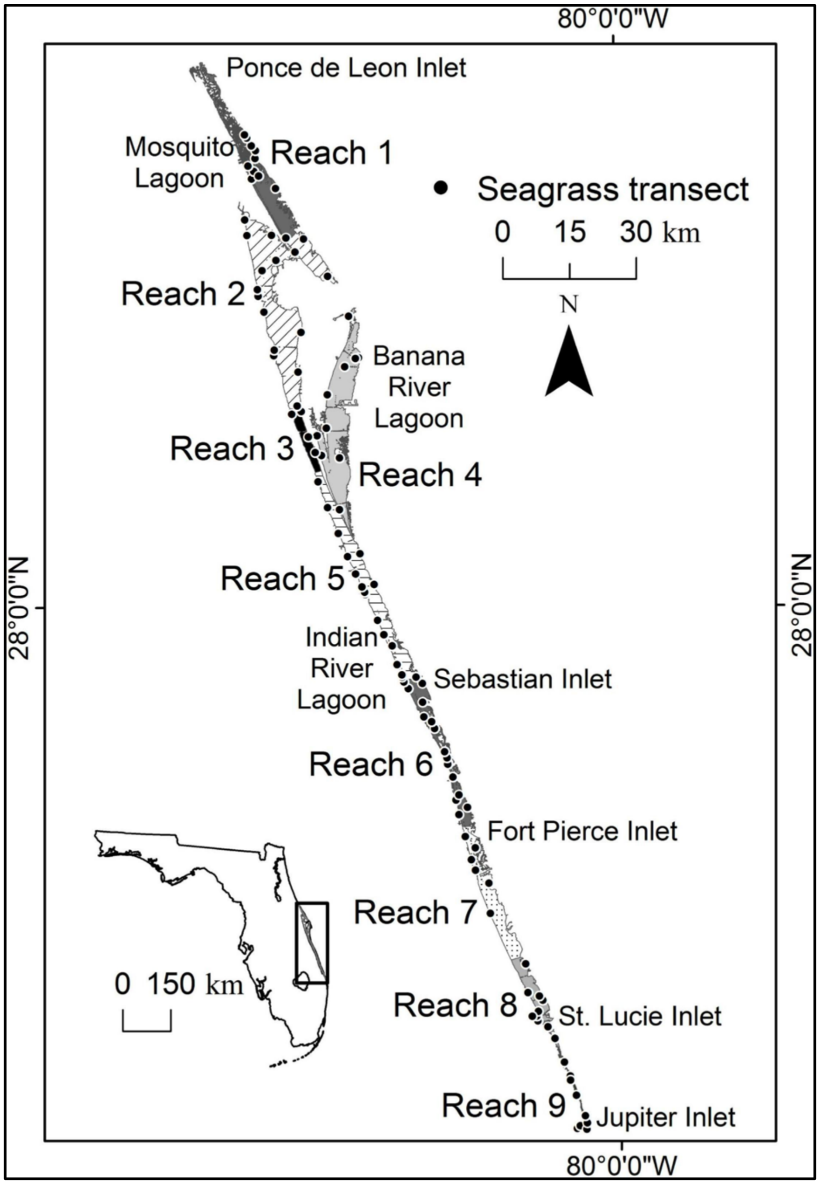


Figure A.7 The Indian River Lagoon system (Morris et al. 2022, p. 3)

Between 2011 and 2019, seagrasses were completely extirpated from 58% of their previous area—an absolute loss of 47,000 acres—after intense blooms of phytoplankton and macroalgae (seaweed) shaded the Indian River Lagoon (Morris et al. 2022, p. 1; Lapointe et al. 2020, p. 2; *see* Figure A.8). Remaining meadow area has become so patchy and sparse that St. Johns River Water Management District officials estimate 89% of all seagrass cover in the Indian River Lagoon to have been lost (*Miami Standard News* 2022, entire). As of 2021, mean percent cover of seagrass was less than 5% in every section of the lagoon, and five of the nine studied areas appeared to have essentially zero seagrass cover (Morris et al. 2021b, p. 3; *see* Figure A.9). Even secondary sources of forage that are less preferred by manatees, such as macroalgae, have declined significantly (FWC *Frequently Asked Questions* 2022, entire; Worthy and Worthy 2014, p. 77).

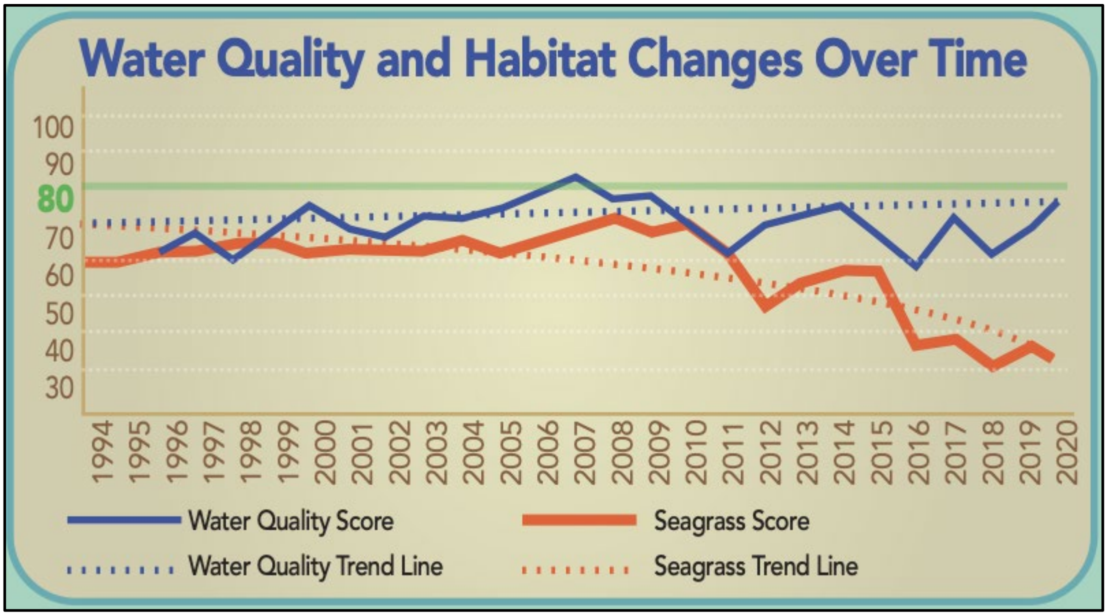


Figure A.8 - Water quality and seagrass indices in the Indian River Lagoon. An "80" meets regulatory targets (Marine Resources Council 2022, p. 2; *see* Regulatory Inadequacy, *infra*).

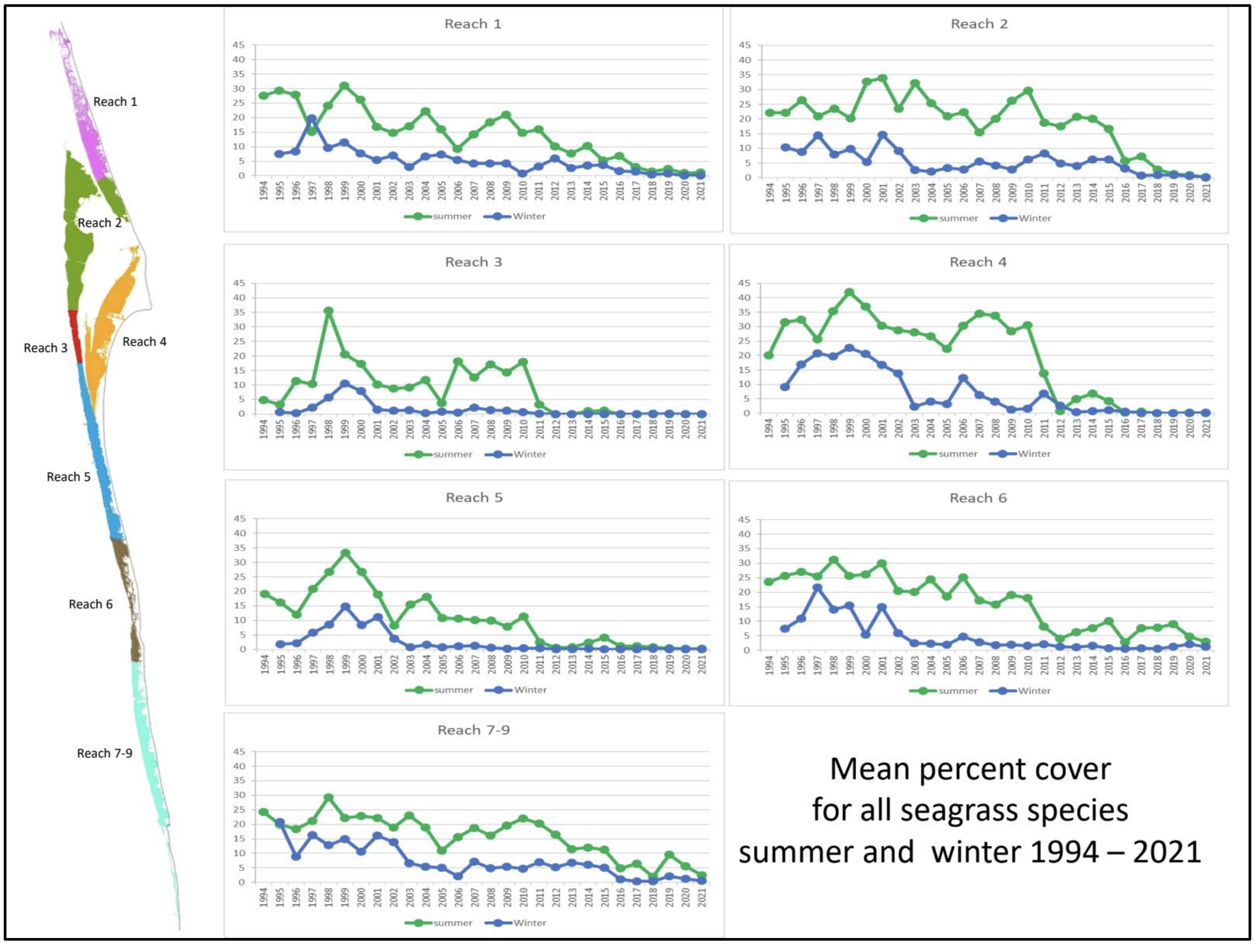


Figure A.9 - Seagrass loss in the Indian River Lagoon (Morris et al. 2021b, p. 3)

The Indian River Lagoon system has subsequently become a hotbed of manatee mortality, and sightings of manatee bones or corpses on the lagoon's shoreline have become commonplace (Chesnes 2021a, entire; *see* Figure A.10). In 2020, 288 dead manatees were recovered in the six counties adjacent to the lagoon: Volusia, Brevard, Indian River, St. Lucie, Martin, and Palm Beach (FWC *Manatee Mortality Summary 2020,* entire; *see* Figure A.7). In 2021, 552 manatee deaths were recorded in counties adjacent to the Indian River Lagoon—over half of that year's unprecedented wave of Florida manatee mortality (FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire). This unusual mortality event is continuing into 2022; as of November 04, another 436 manatees have died in lagoon counties this year (FWC *2022 Preliminary Manatee Mortality Report*, 2022, entire). An average of 186 manatees died in Indian River Lagoon counties over the five years preceding 2017 (FWC *Manatee Mortality Summaries 2012-2017,* entire). As of 2022, five-year average manatee mortalities have increased by over 75% to 328 (FWC *Manatee Mortality Summaries 2017-2020*, entire; FWC *2021 Preliminary Manatee Mortality Report* 2021, entire; FWC *2022 Preliminary Manatee Mortality Report* 2022, entire).

Figure A.10 - Manatee ribs, vertebrae, and dozens of decomposing carcasses line shores in the northern Indian River Lagoon. Photo was taken east of FPL Cape Canaveral Power Plant, a primary warm-water habitat for manatees (Chesnes 2021a, entire).

Tampa Bay has also undergone acute seagrass die-offs in recent years. Nutrient-driven blooms of the toxic algae *Pyrodinium bahamense*—which causes Paralytic Shellfish Poisoning (PSP) in humans—and red tides have intermittently shaded Tampa Bay since 2015 (Beck et al. 2022b, p. 2; *see* Figure A.11). Particularly dramatic seagrass losses began in 2018 following severe red tides in southwest Florida; 6,354 acres of seagrass cover in the Tampa Bay ecosystem died by 2020, a two-year decline of 15.6% (*See* Figure A.12; Beck et al. 2022b, p. 2; Resnick

2018). Seagrass cover in Tampa Bay is now estimated at 34,298 acres, short of the 40,000-acre restoration target set in 2014 and the 38,000-acre target that preceded it (Beck et al. 2022b, p. 2; Tampa Bay Estuary Program 2020, p. 104).

The accompanying rise in manatee mortality in and around Tampa Bay has been stark. In 2016, 62 dead manatees were recovered in the three counties bordering the Bay: Hillsborough, Manatee, and Pinellas (FWC *Manatee Mortality Summary 2016*, entire). In 2021, 129 manatee deaths were recorded across the same area, an increase of 108.1% (FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire).

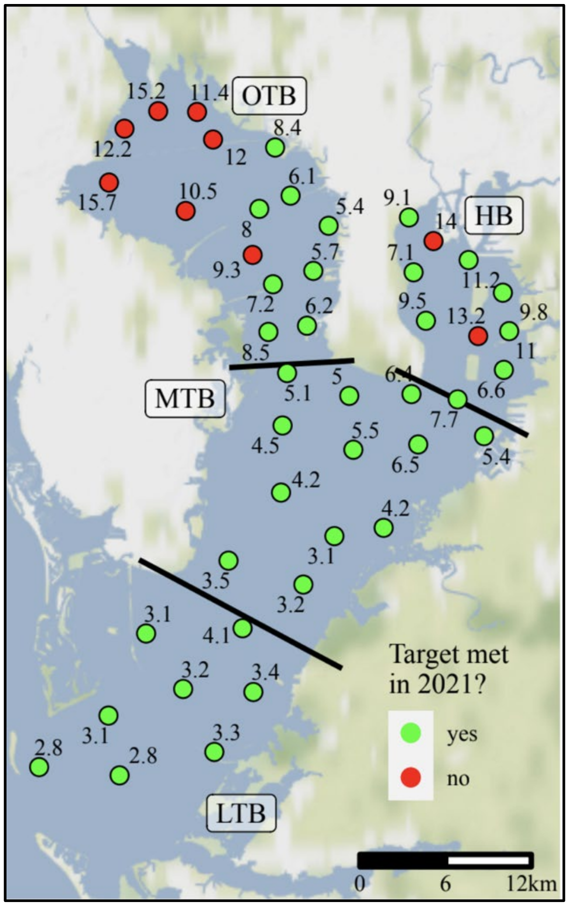


Figure A.11 - Tampa Bay chlorophyll target attainment by site, 2021 (Beck et al. 2022b, p. 2; *see* Regulatory Inadequacy, *infra*)

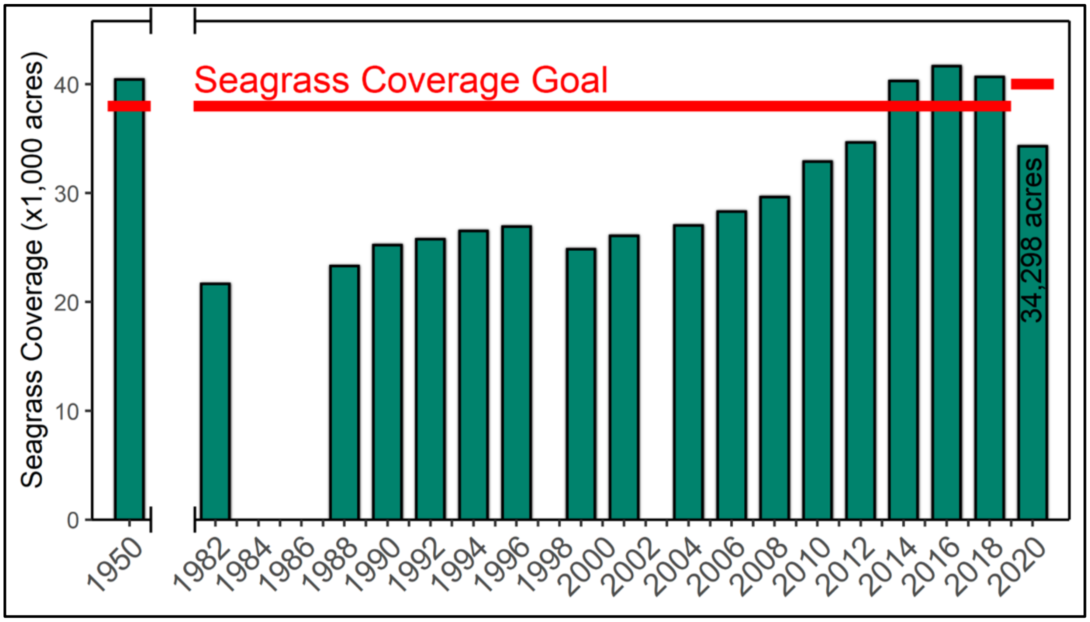


Figure A.12 - Tampa Bay seagrass coverage (Beck et al. 2022b, p. 2)

Further seagrass die-offs have taken place in Biscayne Bay. Between 2005, when blooms of *Anadyomene* macroalgae began to shade the estuary, and 2018, seagrasses declined precipitously throughout the bay, with decreases in cover area ranging from 63 to 93% (*See* Figure A.13; Miami-Dade County 2019,pp. 8-9 ; Santos et al. 2020, entire). Despite the precarity of the Biscayne Bay ecosystem, the local government authorized the 2022 Miami International Boat Show to take place there this winter, when manatee concentrations were at their highest (Putney et al. 2021, entire; *see* also Regulatory Inadequacy, *infra*; Boat Strikes, *infra*).

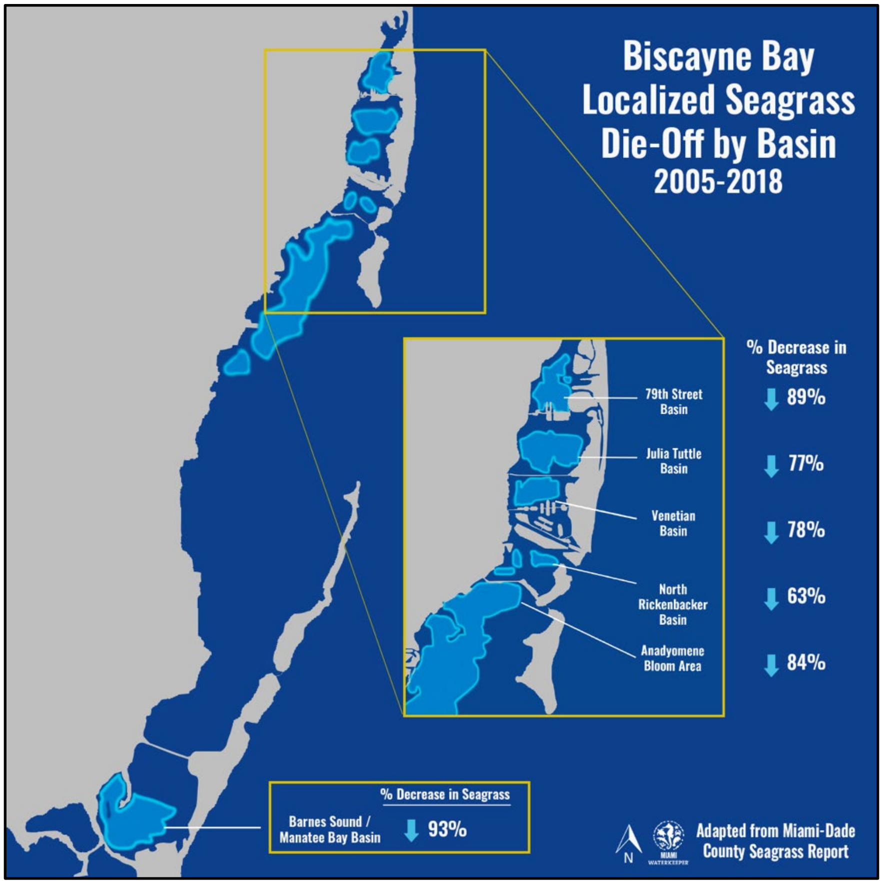


Figure A.13 - Biscayne Bay seagrass declines by basin (Miami Waterkeeper 2020)

Florida Bay experienced an acute, 10,000-acre seagrass die-off, which triggered a positive feedback loop that ultimately destroyed 60,000 acres of seagrass the late 1980s due to drought, hypersalinity, and incorrect management of the quality, quantity, timing, and distribution of fresh water discharged from the Everglades and Lake Okeechobee (Kavanagh 2016, p. 5). It took nearly 25 years for Florida Bay's seagrass populations to recover from this event, but in 2015 roughly 40,000 acres of seagrass were again destroyed by an "acute, catastrophic loss of seagrass in the north-central and western basins of the bay," due to similar environmental conditions and regulatory failures (Kavanagh 2016, pp. 4-5). Florida Bay's seagrass beds are some of the most extensive in continental North America, which means that even the most robust populations of seagrasses in Florida are experiencing significant amounts of degradation (*Florida Seagrasses*, n.d., entire). This is particularly harrowing when viewed in combination with the other more recent losses of seagrass around Florida, including declines in the Indian River Lagoon, Biscayne Bay, and Tampa Bay, which cumulatively indicate that seagrass populations are rapidly declining across the range of the Florida manatee.

Caribbean seagrasses upon which Antillean manatees rely are also believed to be in decline. Between 1993 and 2007, 43% of seagrass beds studied across plots in Colombia, Bermuda, Panama, Tobago, Bahamas, Cuba, Mexico, Jamaica, Belize, Barbados, Venezuela, Costa Rica, and Puerto Rico showed "worrying" evidence of degradation (van Tussenbroek et al. 2014, pp. 7–9; *see* Figure A.14).

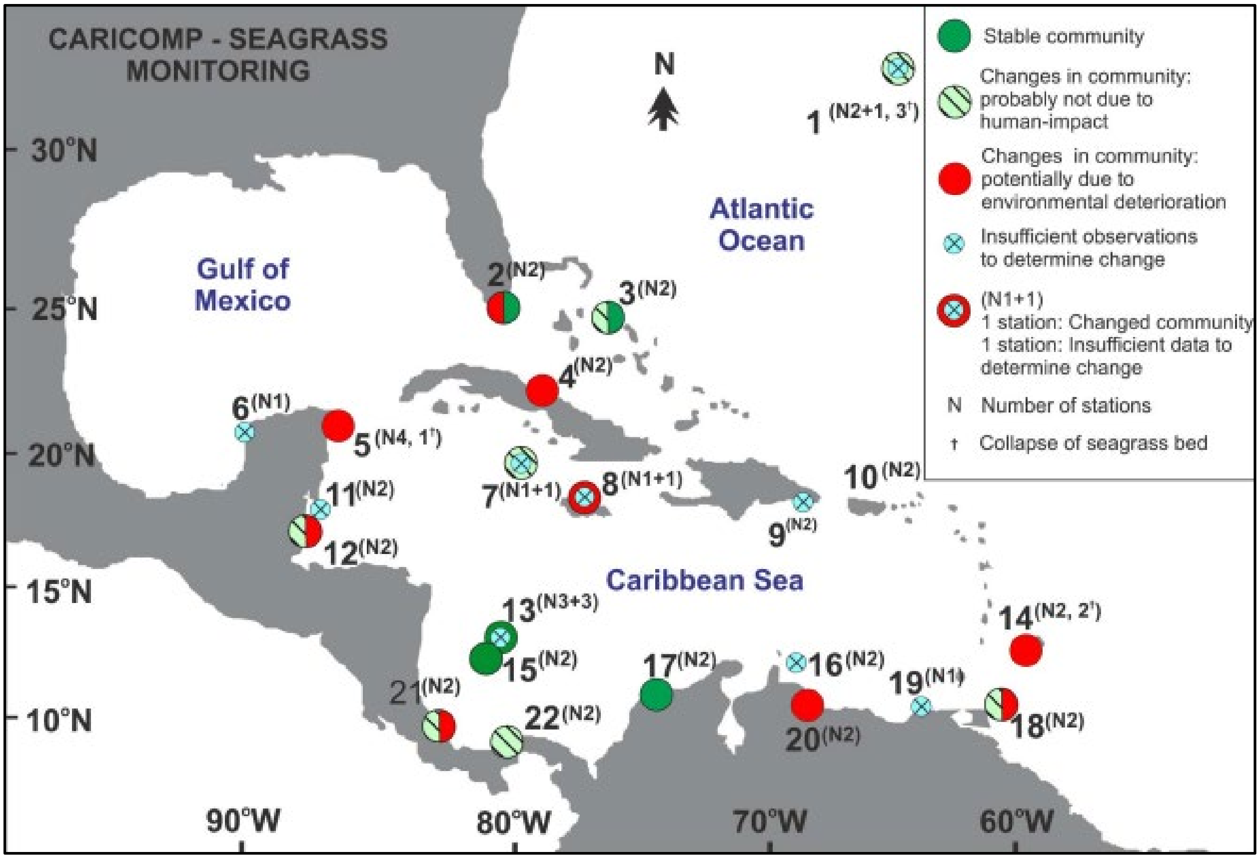


Figure A.14 - Changes in Caribbean seagrasses, 1993–2007 (van Tussenbroek et al. 2014, p. 3)

Essential seagrass habitats in Florida and the Caribbean continue to be threatened by ongoing and anticipated factors that destroy and degrade them, including eutrophication and algal blooms, turbidity and sedimentation, boating, coastal development, extreme weather, contaminants, thermal stress, salinity changes, and sea level rise.

c) Eutrophication

Eutrophication, or the over-enrichment of a waterway with nutrients, is one of the most significant drivers of seagrass loss throughout the West Indian manatee's range (Mvungi 2011, p. 10). Like other plants, seagrasses need nutrients like nitrogen and phosphorus to live and grow (Mvungi 2011, pp. 9–10). But an overabundance of these nutrients in the water column can cause explosive growth of bloom-forming macroalgae and phytoplankton, which subsequently out-compete seagrasses for light and nutrients (Mvungi 2011, p. 9–10).

Where they occur, macroalgae blooms can become so thick that they block out over 90% of sunlight (Han and Liu 2014, p. 793). Single-celled phytoplankton also form blooms that cause severe, prolonged ecosystem shading (Han and Liu 2014, p. 791; *see* Morris et al. 2022, p. 2). These blooms may have minor effects in the short term, but when they are persistent, they can devastate seagrass meadows. In a study of turtle grass, 100% macroalgae cover for 2–3 months destroyed 25% of the meadow's aboveground biomass (Han and Liu 2014, pp. 794). In an eelgrass study, shaded portions lost 50% of their shoots within four weeks, and up to 80% died within six weeks (Kim et al. 2014, p. 566). Shading events can span *years*—the blooms that have ravaged seagrasses in the Indian River Lagoon began in 2011 and continue to degrade the remnants of those meadows, with observations of blue-green algae blooms in the Indian River Lagoon as recent as February 2022 (Morris et al. 2022, entire; FDEP *Blue-Green Algal Bloom Weekly Update Feb. 18–24,* 2022, entire).

Red tides, caused by the dinoflagellate *Karenia brevis*, also pose unique challenges to the manatee's habitat. Like other blooms, red tides significantly reduce light at the seabed (Kim et al. 2014, pp. 558–59, 556). But *K. brevis* also produces a potent neurotoxin, which causes a potentially lethal condition called brevetoxicosis when ingested or inhaled by manatees (Flewelling et al. 2005, p. 2; *see* Toxic Algae, *supra*). In studies of manatees that have died from brevetoxicosis caused by red tides, the animals' stomach contents were found to be exclusively composed of seagrass (Flewelling et al. 2005, p. 2). Indeed, seagrasses that manatees eat, and particularly the incidentally consumed epiphytic organisms attached to their blades, accumulate high concentrations of brevetoxins during red tide events (Flewelling et al. 2005, p. 2). Thus, seagrasses are not only damaged themselves when red tides affect coastal ecosystems, but surviving portions become toxic vectors that attract foraging manatees to their peril (Flewelling et al. 2015, p. 2).

In Florida, nutrient contamination has caused extensive seagrass losses. Agricultural land use has caused intensifying nitrogen and phosphorus concentrations and resultant algal blooms in Lake Okeechobee, which discharges into and feeds eutrophication in numerous waterways where manatees and seagrasses reside (*See* Agricultural Pollution, *infra*). Florida's reliance on septic tanks for wastewater management is another significant source of nutrient introduction (*See* Septic Tanks, *infra*). These nutrients accumulate in sediments where they form "legacy muck," a constant source of nutrient reintroduction that fuels continuous algal blooms until the polluted sediment is manually removed (*See* Legacy Nutrients, *infra*).

In the Indian River Lagoon, excessive nutrients have caused recurrent blooms of cyanobacteria and macroalgae, contributing to the destruction of 47,000 acres of seagrasses and 89% of estuarine seagrass cover (Morris et al. 2022, p. 1; Sneed et al. 2017, entire; Lapointe et al. 2020, p. 1). So many nutrients have accumulated in Indian River Lagoon sediments that the decay of legacy muck is now believed to be the single largest source of nutrient pollution in the lagoon (Tetra Tech, Inc. 2022, p. xii).

Eutrophication has also caused worsening algal blooms around Tampa Bay in recent years, destroying over 15% of the Bay's seagrasses from 2018–2020 (Beck et al. 2022b, p. 2). These data do not reflect new eutrophication and blooms since 2020. Notably, over 814 million liters of nutrient-rich wastewater were discharged into the Bay after a leak was found in the Piney Point phosphogypsum stack in March of 2021 (Bausback and Miller 2021, entire; Beck et al. 2022a, p. 4; *see* Phosphogypsum Stacks, *infra*). 186 metric tons of legacy nitrogen were delivered to the bay in just ten days, followed by a severe red tide bloom that spiked in July; low-to-medium concentrations of algae continued until the end of observations in September of 2021 (Beck et al. 2022a, p. 21; *see* Figure A.15). Between June and December of that year, more than 30 manatees died of brevetoxicosis in surrounding counties (FWC Red Tide Mortalities 2021, entire).

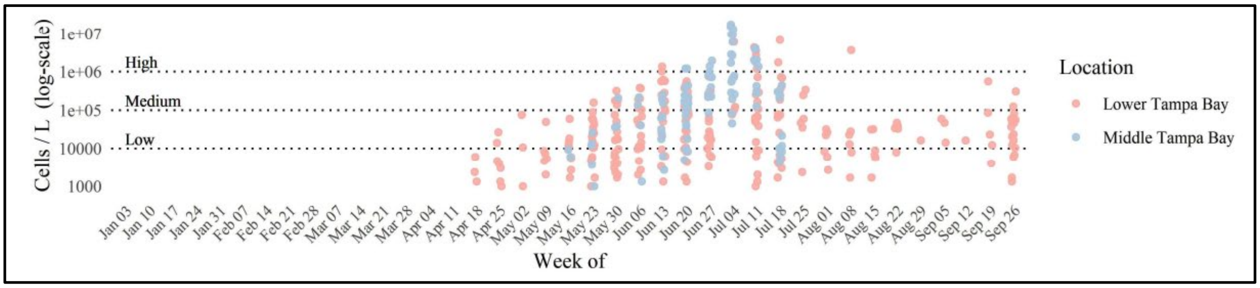


Figure A.15 - *K. brevis* concentrations in 2021 by week, lower/middle Tampa Bay (Beck et al. 2022a, p. 21)

Storms have contributed to the recent spate of red tides off Florida's southwest coast by washing nutrients into waterways, altering ocean currents, and disturbing sediments containing legacy nutrients (Chesnes 2022c, entire). The 2018 red tide, one of the most severe in recent history, began to peak in the months following Hurricane Irma in 2017, and blooms are again forming offshore in the aftermath of Hurricane Ian (Resnick 2018, entire; Chesnes 2022c, entire; Mendoza 2022, entire; *see* Figure A.16).

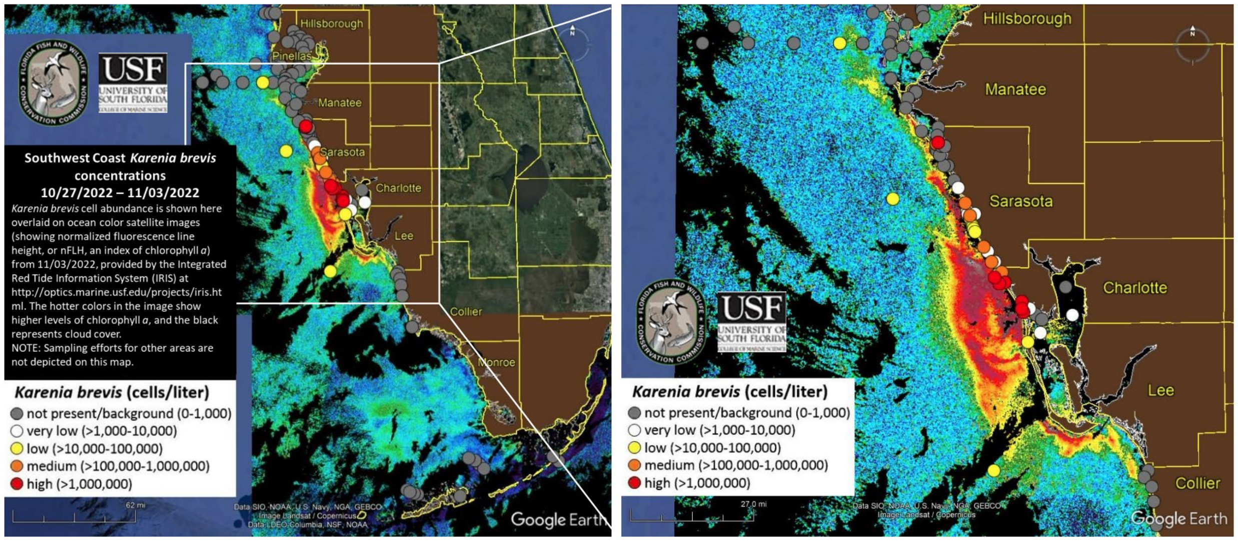


Figure A.16 - *K. brevis* concentrations off Florida's southwest coast, week ending 11/03/2022 (USF-FWC 2022, entire)

Blooms of *Anadyomene* macroalgae have caused massive seagrass losses in Biscayne Bay due to human interventions in the watershed including dredging, stormwater runoff, and septic tank leaks (Miami-Dade County 2019, entire; Santos et al. 2020, p. 7).

In Mexico, population growth is contributing to nutrient runoff and algal blooms are believed to have contributed to the deaths of at least 48 manatees in the state of Tabasco (Núñez-Nogueira and Uribe-López 2020, p. 257; *see* Regulatory Inadequacy: Mexico, *infra*). Decreasing annual precipitation and rising water temperatures have produced favorable local conditions for massive reproduction of blue-green algae, which may be a causative agent behind manatee die-offs (SEMARNAT 2018, p. 35; *see* Toxic Algae, *supra*; Rainfall Changes, *infra*; Temperature Increases, *infra*).

In Belize, primary manatee habitat at the Placencia Lagoon "deteriorated rapidly" after nutrient runoff from shrimp farms and community septic systems caused algal blooms that destroyed over 90% of seagrass coverage over seven years (Auil Gomez 2011, p. 21; *see* Regulatory Inadequacy: Belize, *infra*).

Threats to seagrasses will increase as eutrophication worsens in the near future. For the most part, factors that drive eutrophication and resultant HABs are anthropogenic (Mvungi 2011, p. 10). As coastal populations grow and watersheds become increasingly developed, more anthropogenic nutrients will be introduced into waterways, causing HABs to become more frequent and severe in the tropical and coastal zones manatees occupy (Santos et al. 2020, p. 1).

Climate change is expected to accelerate this trend. Rising ambient water temperatures simultaneously stress seagrasses and advantage red-tide dinoflagellates, increasing the risk and magnitude of toxic HABs (*See* Temperature Increases, *infra*; Harmful Algal Blooms, *infra*). Precipitation extremes cause soil erosion and increased surface water runoff, which washes more nutrients into waterways (Masroor et al. 2022, p. 2; *see* Sediment and Turbidity, *infra*). Furthermore, rising quantities of nutrients are introduced to waters in Florida and the Caribbean as mineral-rich Saharan dust blows across the Atlantic, and the quantity of this transported dust increases when rainfall in Africa declines (Marsh et al. 2017, p. 346).

d) Sediment and Turbidity

Like algal blooms, sediments suspended in the water column by waves, tidal action, or other natural and anthropogenic factors can cloud coastal waterways where seagrasses are found (Carr et al. 2016, p. 317). Resultant turbidity decreases the sunlight available at the seabed, causing seagrasses to suffer or die as their especially high light requirements (15 to 25% of incident light) are unmet (Carr et al. 2016, p. 317; Smith 1993, p. 19). A feedback loop results as bare seabeds exposed by die-offs become new sites of sediment resuspension, further decreasing water clarity (Carr et al. 2016 p. 317; Morris et al. 2022, p. 9, 12; Collins et al. 2019, p. 23; Smith 1993, p. 19). Even sublethal levels of light deprivation can decrease seagrasses' below-ground biomass and rhizome carbohydrates, tissue nutrient contents, chlorophyll counts, and "various photosynthetic growth parameters" (Erftemeijer and Lewis 2007, p. 1555). Sediment resuspension can cause secondary impacts on water quality by releasing contaminants and legacy nutrients accumulated in the seabed material (Erftemeijer and Lewis 2007, p. 1554; *see* Eutrophication, *supra*; Contaminants, *infra*; Regulatory Inadequacy, *infra*).

Turbidity and resultant damage to seagrasses are exacerbated by anthropogenic activities. Dredging, vessel activity, and bottom fishing disturb seabed sediments and cause turbidity (Erftemeijer and Lewis 2007, p. 1554). One study found that "expanding urban and agricultural development has caused resuspension of sediments and increased the amount of [land-based] material deposited in [Florida's] Manatee River by as much as an order of magnitude" over the last century (Schwing and Johnson 2014, p. 12). And Florida's population is expected to continue to increase by nearly 4 million between 2020 and 2035 (Florida Demographic Estimating Conference (FDEC) 2021, entire).

Climate change is also expected to worsen water clarity throughout the West Indian manatee's range. A dry-phase weather pattern, with increasingly intense rainfall events, is expected to wash more sediment into Florida waterways and drive turbidity (*See* Rainfall Changes, *infra*). Droughts dehydrate and crack soils, changing their texture and capacity to retain water, while killing anchoring vegetation (Masroor et al. 2022, p. 1). In such conditions, a few major precipitation events can account for significant soil loss; in the Santa Barbara Channel, for instance, over half of the annual sediment load was transported into the waterway by just 1–5 days of flooding (Li et al. 2021, p. 2). And increasingly powerful and frequent storms cause strong wave and wind action, that increase turbidity by disturbing seabed sediments and uprooting seagrasses (Erftemeijer and Lewis 2006, p. 1554; *see* Loss of Seagrass: Storms, *infra*).

Sediment harms more than just the water column. When it eventually settles to the seabed, the resulting sedimentation can bury entire seagrass beds, depriving the beds of light and killing them (Erftemeijer and Lewis 2006, pp. 1555–58). Sedimentation also harms seagrasses by causing siltation, an increase of silt in the substrate (Terrados et al. 1998, p. 758). Seabed sediment containing less than 10% of silt and clay is ideal seagrass habitat; where that figure is exceeded, meadows experience sharp declines in species representation and biomass (Terrados et al. 1998, pp. 758, 763).

e) Boating

Boating activities are another major factor contributing to seagrass decline in the manatee's range. Vessels' propellers can scar shallow-water meadows as they pass through them, excavating swaths of seagrass tens of meters long (Smith 1993, p. 21). Chains from block-and-chain vessel moorings can drag across the seabed and similarly create large areas of scarring around the mooring (Glasby and West 2018, p. 385). Similar damage occurs when boats drag fishing gear along the seafloor, run aground, or anchor in meadows (Smith 1993, pp. 21, 24).

The resultant "prop scars" are persistent, lasting for up to five years, and can be abundant in high-traffic areas; for example, most areas of the Florida Keys had lost 10–20% of their seagrass by 1991 from repeated prop scarring and vessel groundings (Smith 1993, p. 21). Furthermore, wake from vessel uproots seagrasses and disturbs seabed sediments, which reduces light availability by increasing waterway turbidity and directly smothering seagrasses (Smith 1993, p. 22; *see* Sediment and Turbidity, *supra*). Navigational inexperience, noncompliance with existing speed regulations, and seagrasses' tendency to grow in the shallowest waters also exacerbate boating damage to seagrass ecosystems (PRDNER 2012, entire; *see* Regulatory Inadequacy, *infra*).

This problem is anticipated to worsen in the foreseeable future. As Florida's population grows every year, so too does the number of registered and unregistered watercraft in the state, increasing the risk of seagrass scarring proportionally (Florida Demographic Estimating Conference (FDEC) 2021, entire; FWC *2021 Boating Accident Statistical Report* 2022, p. IV; *see* Seagrass Scarring by Boat, *infra*; Prevalence of Boat strikes, *infra*). The number of registered vessels in Florida officially surpassed one million in 2022 (Knowles 2022, entire).

f) Coastal Development

In many areas throughout the West Indian manatee's range, humans have altered large sections of coast with seawalls, residential and commercial development, marinas, ports, canals, harbors, industrial facilities, and other infrastructure (Orth et al. 2006, p. 990). Shoreline alterations inherently have the greatest effect in the shallowest waters—optimal seagrass habitat upon which the manatee depends. Not only does shoreline development destroy and fragment existing meadows, but resultant coastal hardening prevents shoreward migration when light becomes scarce due to sea level rise, algal blooms, or turbidity (Orth et al. 2006, p. 990; *see* Sea Level Rise, *infra*).

Dredging, or the excavation, transportation, and disposal of seabed materials associated with coastal construction projects, has been particularly harmful for seagrasses. Not only does dredging damage and destroy seagrasses directly, but sediments are also introduced to the water column during excavation, during transport, from overflow and leakage, and at the site of disposal, intensifying turbidity (Erftemeijer and Lewis 2006, p. 1554; *see* Sediment and Turbidity, *supra*). For example, 15,000 hectares of seagrasses were destroyed in Laguna Madre, Texas, by dredging-related turbidity in the late 20th century (Erftemeijer and Lewis 2006, pp. 1562–63).

g) Storms

Severe storms, such as hurricanes, can be a significant source of disturbance to seagrasses. The effects can be direct, via the physical impacts of waves, currents, winds, and storm surge on seagrasses and their substrate; and indirect, such as the effects of increased rainfall on salinity, pollutant runoff and water clarity (Marsh et al. 2017, p. 343; Tomasko et al. 2020, p. 2). Other impacts from hurricanes include excessive nutrient loading, algal blooms, elevated biochemical oxygen demand, hypoxia (low oxygen levels) and anoxia (no oxygen levels), large-scale release of pollutants, sewage, debris, and spread of exotic species and pathogens (Edwards 2013, p. 730).

Seagrasses in the Florida manatee's range have been battered by extreme weather in recent years. In September of 2017, Hurricane Irma, a category 4 storm, made landfall in six contiguous estuaries in the state of Florida St. Joseph Sound, Clearwater Harbor, Tampa Bay, Sarasota Bay, Lemon Bay, and Charlotte Harbor, resulting in a 3% decrease in acreage system-wide—a 3,000-acre loss (Tomasko et al. 2020, p. 1). Because these six estuaries had lower than average pollutant loads at the time, and Hurricane Irma did not cause an unprecedented pattern of regional rainfall (as did Hurricane Agnes in 1972), effects on seagrass were relatively restrained (Tomasko et al. 2020, pp. 5–6). In October of 2022, Hurricane Ian made landfall in Southwest Florida as a category 4 storm. The storm's winds and excessive rain washed leaves, organic matter and contaminants into streams and bays, and high concentrations of red tide organisms have followed (Patel 2022, entire; *see* Eutrophication, *supra*).

Antillean manatees have also lost important seagrass habitat to recent extreme weather events. Puerto Rican seagrass meadows suffered extensive damage from the dual impact of Hurricanes Irma and Maria in 2017 (Hernández-Delgado et al. 2018, p.1). Sediment transported by the storms buried and suffocated seagrasses, and major scars left on the sea bottom uncovered plant structures, leaving them susceptible to further erosion (Hernández-Delgado et al. 2018, p. 103).

As climate change increases the frequency and severity of storms, damaged seagrass ecosystems will have less time on average to recover between extreme weather impacts (*See* Climate Change: Storms, *infra*).

h) Contaminants

The extent of harm caused by non-nutrient contaminants on seagrasses depends on the kind and concentration of the contaminant, seagrass species, and hydrological features of the waterway. Studies of seagrass species in southern Australia and the Indo-Pacific found them to be relatively resistant to the herbicides diuron and atrazine, while the antifoulant paint additive Irgarol 1051 had toxic effects at low concentrations (Haynes et al. 2000, p. 289; Lewis and Deveraux 2009, pp. 651, 653–55). Responses to environmental toxins, including trace metals, were extremely species-specific, and even varied considerably intraspecifically (Lewis and Deveraux 2009, pp. 653–55). Other studies on copper and Irgarol suggest that doses of toxic chemicals in successive pulses or in “cocktail” combinations can have especially damaging effects on seagrasses and reduce their resilience to other stressors (Macinnis-Ng and Ralph 2004, entire; Devault and Pascaline 2013, pp. 364–65).

Some seagrasses in the West Indian manatee’s range may be vulnerable to glyphosate contamination. *Ruppia maritima*, or widgeon grass, experienced harmful changes to biomass, leaf growth, and chlorophyll content following experimental glyphosate exposure; high concentrations caused a “significant lethal effect” (Castro et al. 2015, p. 506). Use of this herbicide is significant in areas of the manatee’s range, including notably Florida and Brazil (Castro et al. 2015, p. 506–07; *see* Glyphosate, *infra*).

Oil spills can also negatively affect seagrasses with varying degree depending on “proximity . . . to the point of oil release, the kind of oil, the tidal stage, range and circulation patterns and the location of the seagrass in the tidal frame” (Fonseca et al. 2016, p. 36). For example, 271 acres of seagrass in the Gulf of Mexico were lost due to oil exposure from the MC-252 spill in 2010 (Fonseca et al. 2016, p. 29). And, in the Antillean manatee’s range, turtle grass beds in Puerto Rico were devastated by a 1973 oil spill when strong wind and wave action in shallow waters exposed shallow-water seagrasses and substrate to oil (Smith 1993, p. 20). Deeper seagrass beds are often insulated from oil spills’ effects and may suffer little to no damage (Smith 1993, p. 20). But chronic petroleum exposure can occur where seagrass beds are near watercraft access points or industrial facilities, with harmful effects on plant productivity (Smith 1993, p. 20).

Some contamination is naturally introduced. “High temperatures, abundant organic matter, and low sulfide-binding capacity can result in extremely high porewater sulfide concentrations in sediments of Florida Bay seagrass beds,” for example (Carlson et al. 1994, p. 734). These sulfides (H_2S) are highly toxic to seagrasses; a 1989–1990 study found “extremely high” concentrations in active die-off patches in Florida Bay (Carlson et al. 1994, pp. 735, 739). Microbes breaking down decomposing plants appear to emit even more sulfides, creating a feedback loop and accelerating the decline of remaining seagrasses (Carlson et al. 1994, p. 744).

Rising temperatures and high salinity exacerbate the effects of sulfides on seagrasses, while both factors have independent harmful effects on seagrasses at the same time (Carlson et al. 1994, p. 734; Johnson et al. 2018, pp. 49–51; Collier et al. 2018, p. 1006).

Overall, contamination is hypothesized to be responsible for more seagrass death than researchers have been able to document (Marine Resources Council 2022, entire). Seagrasses have been dying even in parts of the Indian River Lagoon with clear water, leading researchers to posit that an unknown contaminant may be at work (Marine Resources Council 2022, p. 2).

The problem of contamination is expected to worsen as coastal zones become increasingly developed, altering watersheds' surface runoff regimes and washing more contaminants into waterways (Herren et al. 2021, pp. 1–2; *see* Coastal Development, *infra*). Increasingly intense and sporadic precipitation events are also expected to increase contaminant runoff (*See* Rainfall Changes, *infra*).

i) Thermal Stress

Warming and acidifying oceans are predicted to have increasingly harmful effects on seagrasses in the West Indian manatee's range (*See* Temperature Increases, *infra*; Acidification, *infra*).

When seagrasses' optimum temperatures are exceeded, their productivity declines, photosynthetic and respiratory processes become inefficient, and energy balances are depleted (Collier et al. 2018, p. 1005–06). Below thermal stress thresholds, which vary by species, seagrasses benefit from warmer temperatures (Collier et al. 2018, p. 1005). However, when these optima are achieved or only slightly exceeded for prolonged periods, seagrasses can suffer large declines in net productivity, growth, and shoot density (Collier et al. 2018, p. 1013). Globally, marine heatwaves have doubled in frequency since the 1980s. (IPCC 6th Assessment Report 2021, p. SPM-10). Climate models now estimate that ocean surface temperatures within the West Indian manatee's range may rise by 2.6ºC or more by 2080 (USGCRP 2017, p. 365). For seagrasses at the limits of their thermal tolerance, these increases could be significant sources of stress (Collier et al. 2018, p. 1006).

Ocean acidification may exacerbate the effects of thermal stress on seagrasses. As oceans absorb more than 1 million metric tons of CO_2 per hour, dissolved inorganic carbon in the water increases; this can benefit seagrass growth (Collier et al. 2018, p. 1005; *see* Acidification, *infra*). But when seagrasses are experiencing heat stress, the direction of the relationship reverses, and increased carbon can instead cause plant productivity to decline significantly (Collier et al. 2018, p. 1013; *see also* Figure A.17). Light limitation also strongly affects seagrass productivity response to thermal stress, so shading from algal blooms, turbidity, and sea level rise could have worsening effects as oceans warm (Collier et al. 2018, p. 1015–16). Furthermore, acidification may contribute to the formation of red tides, which shade seagrasses and cause them to accumulate neurotoxins that poison foraging manatees (*See* Acidification, *infra*).

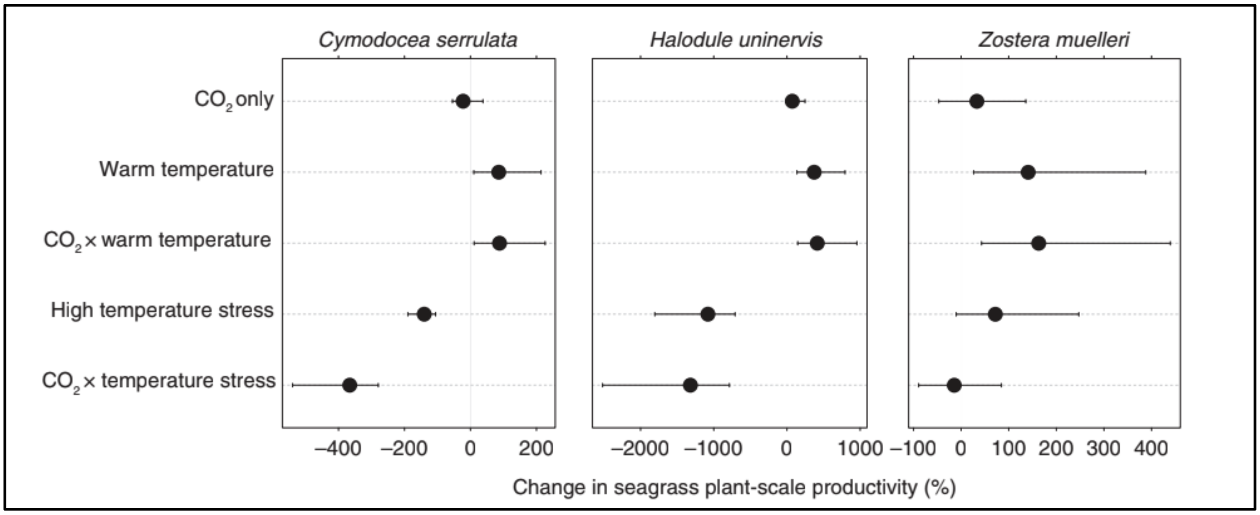


Figure A.17 - Change in productivity of tropical seagrass species under CO_2 and temperature control conditions (Collier et al. 2018, p. 1013)

j) Extreme Cold

In the wintertime, seagrasses in the Florida manatee's range—like manatees themselves—become stressed when temperatures drop below 20 °C (Morris et al. 2022, p. 4–6; Morris et al. 2021a, p. 130). Even as average water temperatures in Florida increase, minimum winter temperatures have dropped in most Florida counties, and climate change may produce erratic and extreme cold-weather events in the future (Marsh et al. 2017, p. 339; Edwards 2013, p. 731; *see* also Extreme Cold Events, *infra*). Cold stress interacts with other factors like light attenuation to produce combined negative effects on seagrasses (Morris et al. 2021a, p. 130–31).

k) Salinity

Changes in salinity can also be major sources of seagrass mortality. For instance, seagrasses in Florida Bay suffered hypersalinity-related die-offs in the years 1987 (95 km^2 lost) and 2015 (88 km^2) (Johnson et al. 2018, p. 48). The plants' respiration was impaired by the hypersaline conditions, forcing them to consume more oxygen than normal to survive (Johnson et al. 2018, p. 48). Furthermore, this high respiratory O_2 cost caused Florida Bay seagrasses to absorb more of the naturally occurring phytotoxic sulfides in their environments (Johnson et al. 2018, pp. 48–51; *see* Contaminants, *supra*).

Salinity changes can have indirect effects on manatees and the seagrasses that support them by causing red tides. Red tide dinoflagellates like *K. brevis* favor saline conditions, making the HABs they cause more frequent as salinity increases (Tominack et al. 2020, p. 2).

Changing climatic conditions are expected to increase the risk of harmful salinity changes in the West Indian manatee's range. As rainfall declines overall and trends towards intense, torrential downpours, the amount of diluting fresh water reliably delivered to estuarine environments will decrease, while storms are expected to provide only short-term freshwater flushing effects (Havens 2015, p. 4; *see* Rainfall Changes, *infra*). At the same time, sea level rise will cause saltwater intrusion, moving salty ocean water further into estuaries (Havens 2015, p. 4; *see* also Sea Level Rise, *infra*). These concurrent effects are expected to produce significant long-term salinity increases in coastal wetlands, as illustrated in Figure A.18 below (Havens 2015, p. 4).

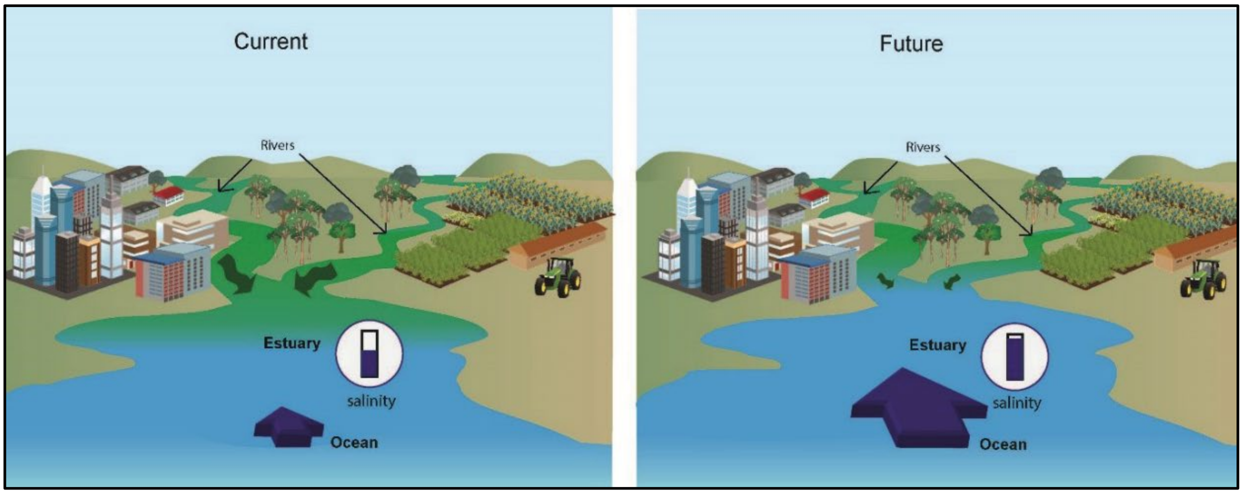


Figure A.18 - Estuary salinity changes due to sea level rise and precipitation decline (Havens 2015, p. 4)

l) Sea Level Rise

Sea level rise (SLR) may pose the greatest threat to seagrasses of all climate change-associated impacts (Marsh et al. 2017, p. 343; Short and Neckles 1999, entire). Global mean sea levels have risen at an accelerating rate since the 1960s; by 2100, models predict that sea levels may rise by over a meter compared to the 1995–2014 average (IPCC 6th Assessment Report 2021, p. TS-44; *see* also Sea Level Rise, *infra*).

The largest direct impact of rising sea levels on seagrasses will be light attenuation (Short and Neckles 1999, p. 175). Light attenuates at an exponential rate as depth in the water column increases (Weiskerger et al. 2018, p. 8952). Thus, small increases in sea level can cause relatively large decreases in the amount of sunlight that makes it to the seabed, an effect that is exacerbated by turbidity (Macdonald 2015, p. viii; Short and Neckles 1999, p. 177). Seagrasses are sensitive to these changes, and sea level rise is expected to reduce meadows' productivity and distribution (Short and Neckles 1999, p. 175). By the end of the century, this effect is expected to reduce global light availability by 50%, and seagrass growth by 30–40% (Edwards 2013, p. 733). Expansions of tidal range driven by sea level rise are expected to further increase water depth and result in a loss of seagrass area (Short and Neckles 1999, p. 179). Although shallow zones currently exposed at high tide could be sites for shoreward seagrass expansion as seas rise, this effect is anticipated to have a negligible benefit due to coastal hardening and construction projects protecting expensive shoreline real estate from rising waters (Edwards 2013, p. 733; *see* Coastal Development, *supra*).

Sea level rise also contributes to saltwater intrusion, which harms seagrasses by making estuaries more saline (Edwards 2013, p. 733; *see* Salinity, *supra*). Hypersalinity will force some seagrass species out of their established range as they are unable to tolerate estuarine salt concentrations (Short and Neckles 1999, pp. 181–83). Areas with low to moderate salinity that are beneficial for seagrass reproduction are expected to decline, with negative effects on germination rates and seagrass distribution (Short and Neckles 1999, p. 182).

Rising sea levels will also result in stronger tidal flows in estuaries, with mixed effects for seagrasses (Short and Neckles 1999, p. 180). Low velocity water movement is beneficial for seagrass growth and pollination (Short and Neckles 1999, p. 180). In some instances, this could flush macroalgae away from seagrass beds (Short and Neckles 1999, p. 181), but turbidity and siltation are also expected to rise as sea level rise produces erosion in coastal areas (Martínez-Daranas and Suárez 2018, p. 276). Stronger currents will destabilize seabed sediments directly and indirectly, by destroying anchoring vegetation, while increased circulation keeps particles in the water column longer (Short and Neckles 1999, pp. 180–81). This additional light deprivation would be a negative indicator for seagrass habitat's survival, as would increased deposition of silt and other sediments (Short and Neckles 1999, p. 181; *see* Sediment and Turbidity, *supra*).

m) Invasive Seagrass

A Red Sea seagrass species, *Halophila stipulacea* (Figure A.19), is invasive in the Caribbean, where it displaces native seagrasses (Muthukrishnan et al. 2020, p. 1). This invasive seagrass is of lower nutritional quality, containing less nitrogen and protein than native species (Muthukrishnan et al. 2020, p. 11). Herbivores strongly prefer high quality native forage, and their selective grazing behavior may provide a competitive advantage for *H. stipulacea*, which can significantly expand its range where native seagrasses decline (Christianen et al. 2019, p. 45). Indeed, *H. stipulacea* has also been observed to rapidly outcompete native seagrasses and dominate local ecosystems in the aftermath of hurricane damage in Puerto Rico, an effect that is exacerbated where other stressors such as runoff or sedimentation are present (Hernández-Delgado et al. 2020, p. 1). As *H. stipulacea* replaces nutritional seagrasses in the West Indian manatee's range, manatees that must subsist on it will receive fewer resources for equivalent consumption (Muthukrishnan et al. 2020, p. 1). This is a particularly dangerous phenomenon for manatee health and nutrition because there is less seagrass overall in their range, and the seagrass that is left may be significantly less nutritious than native seagrass populations previously in the area.

Figure A.19 - *Halophila stipulacea.* Invasive Red Sea seagrass; photograph taken in the Caribbean Sea (SeagrassSpotter 2018)

n) Sargasso Brown Tides

Since 2014, large quantities of *Sargassum* seaweed have been swept into the coasts of the Mexican Caribbean (Chávez et al. 2020, p. 1). Possible causes include eutrophication, an increase in Sahara dust, changing wind and current regimes, and ocean warming (Chávez et al. 2020, p. 1). This is a very new phenomenon; in fact, there are no records of arrivals of *Sargassum* seaweed in such massive quantities, meaning the full scope of this influx is uncertain (Chávez et al. 2020, p. 1). However, what is known is that when these algal masses wash ashore and decay, they "produce leachates and particulate organic matter causing sargasso brown tides, which deplete oxygen, reduce light and deteriorate water quality. This leads to the death of the nearshore benthic communities (including seagrasses)" (Chávez et al. 2020, p. 1). These sargasso brown tides block light from traveling through the water column, which then triggers seagrass die-offs as photosynthesis declines and water becomes hypoxic or even anoxic, in some cases (van Tussenbroek et al. 2017, p. 277). The decline in water quality and increase in turbidity remains long after *Sargassum* seaweed is no longer present in the ecosystem.

In Mexico, sargasso brown tides along the Mexican-Carribean coastline have dramatically altered seagrass meadows. For example, in one area studied, 47% of a seagrass meadow had been fully replaced by species of algae (van Tussenbroek et al. 2017, p. 276). Since seagrasses have underground root systems but algal species generally do not, shifts in below-ground biomass is a useful proxy for measuring declines in seagrass populations. When researchers measured below-ground biomass in some near-shore habitats in Mexico that had experienced sargasso brown tides, below-ground biomass decreased by up to 99.5%, indicating a massive seagrass die-off (van Tussenbroek et al. 2017, p. 276).

In Puerto Rico, satellite imaging has been used to confirm that *Sargassum* inundation—independent of the disastrous effects of recurrent hurricanes on the island—has resulted in a 28% decline in coastal vegetation since 2010, or an absolute loss of over 3 million square meters of benthic flora (Hernández et al. 2022, p. 24). The impacts of Sargassum inundation also appear to be accelerating; while 17% of the impacts were attributable to the period from 2010-2018, 11% of the impacts were attributable to the comparatively shorter period from 2018–2020 (Hernandez et al. 2022, p. 29). This trend also precludes the possibility any negative trends are reversing (Hernandez et al. 2022, p. 29).

Since the recovery time of seagrass meadows is so long, it is also likely that these ecological changes and loss of seagrass will be permanent, if *Sargassum* influx events continue in the future (van Tussenbroek et al. 2017, p. 280). In fact, the influx of *Sargassum* may altogether lead to the complete "disappearance of near-shore well-developed seagrass beds" if influxes become recurrent on a scale of just one every several decades (van Tussenbroek et al. 2017, p. 280).

2. Loss of Warm-Water Refugia

Adequate access to warm-water habitat in the wintertime is "the most critical factor to [the] long-term survival" of the Florida manatee (Valade et al. 2020, p. 2). To avoid the potentially lethal effects of cold-stress syndrome, Florida manatees seek warm water in three types of refugia: power plant effluent discharges, natural springs, and passive thermal basins (PTBs) (Valade et al. 2020, p. 1; Figure A.20; *see* Cold Stress Syndrome, *supra*). They rely on a network of 67 primary and secondary warm-water sites throughout their range to survive the winter and show a high degree of fidelity to refugia they have used before (Valade et al. 2020, pp. 2, 4). "These sites include 10 power plants, 23 springs . . . and 34 passive thermal basins" (Valade et al. 2020, p. 2).

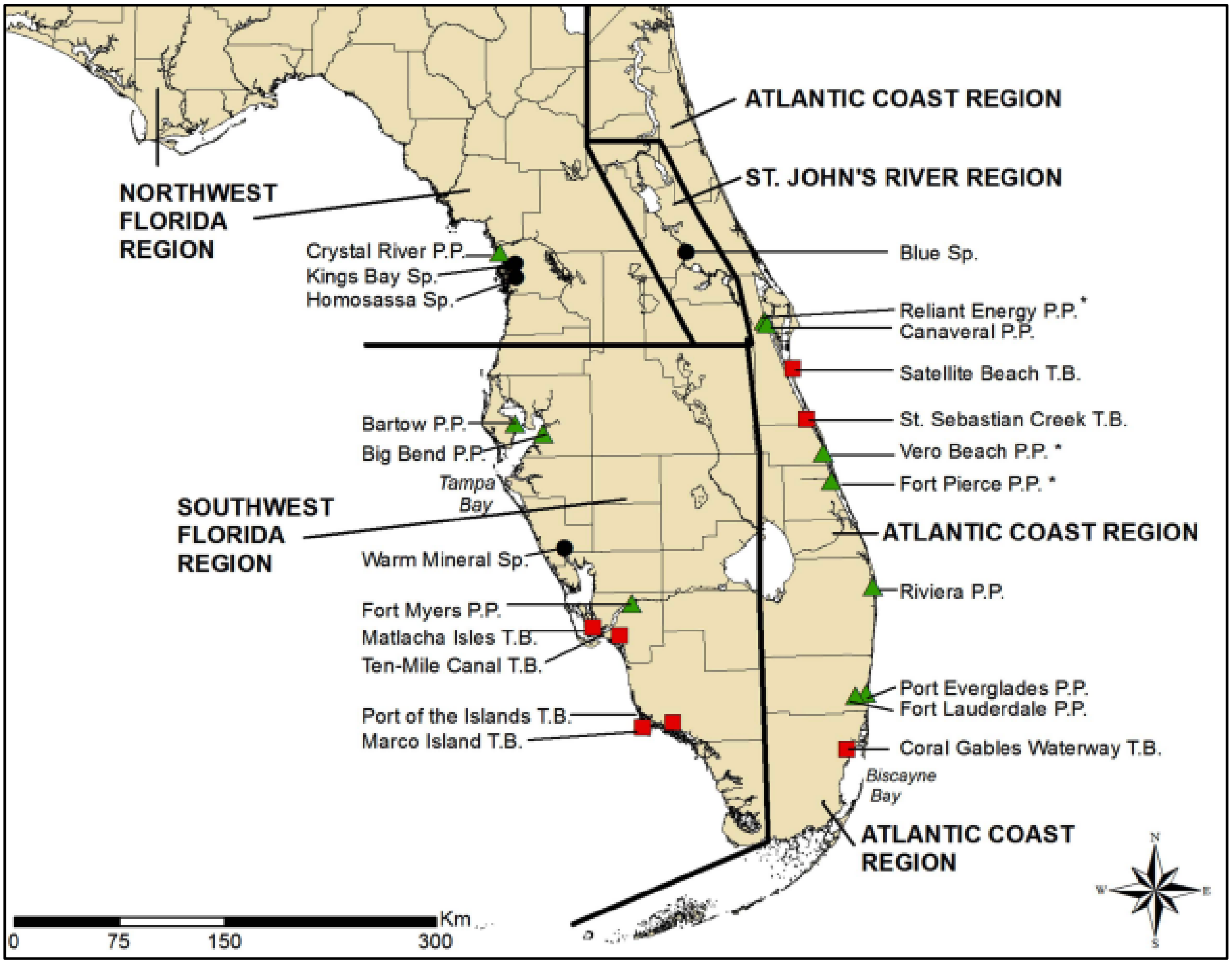


Figure A.20 - Location of warm-water refuges with counts of more than 50 manatees and boundaries for the four Florida manatee subpopulations (● = springs; ▲ = power plants; ■ = passive thermal basins; * = power plants that have been retired or are no longer significant aggregation sites due to reduced operations) (Laist et al. 2013, p. 2)

Many of the natural warm-water features used by manatees in the 20th century were destroyed by human activities; to adapt to these changes, manatees flocked to warm-water industrial discharges from facilities being constructed in the same period (Valade et al. 2020, p. 2). Today, more than half of Florida manatees overwinter at artificial refugia (Valade et al. 2020, p. 2).

a) Power Plants

Manatees congregate in their highest numbers at power plant outfalls, which provide the warm-water habitats used by most Florida manatees to survive winter's cold (Valade et al. 2020, p. 2; Laist et al. 2013, p. 1). Since the Clean Water Act was passed in 1972, regulations have prohibited new power plants from discharging water significantly warmer than the receiving water body. 33 U.S.C. § 1326(b) (Valade et al. 2020, p. 7). Pre-act facilities are exempt from this requirement and, while they last, continue to discharge heated effluent into waterways where large congregations of manatees gather (Valade et al. 2020, pp. 2, 7). Ten such facilities—six primary, and four secondary—currently operate in the state of Florida across three manatee RMUs.

The Atlantic region has four power plants with thermal outfalls used by manatees as primary warm-water habitat: the Florida Power and Light (FPL) Cape Canaveral Energy Center, the FPL Fort Lauderdale Power Plant/Dania Beach Energy Center, the FPL Port Everglades Energy Center, and the FPL Riviera Beach Energy Center (Valade et al. 2020, pp. 11, 27). Notably, FPL has set a goal of "100% decarboniz[ing]" its electricity generating mix "by no later than 2045," which it plans to achieve in part by reducing generation at natural gas-based units such as these (NextEra Energy 2022, entire). The company plans to convert some natural gas facilities into hydrogen-based plants, but it is unclear whether thermal outfalls will continue in hydrogen units (NextEra Energy 2022, entire).

In the Northwest, only one facility continues to provide secondary manatee habitat: the Duke Energy - Crystal River Power Plant (Valade et al. 2020, pp. 11, 29).

Manatees in the Southwest region use two primary sites, the Tampa Electric Company (TECO) Big Bend Power Station and FPL Ft. Myers Power Plant; and three secondary sites at the TECO H.L. Culbreath Bayside Power Station, Duke Energy Anclote Power Plant, and Duke Energy Bartow Power Plant (Valade et al. 2020, pp. 10–11, 31).

The median year of construction for these ten facilities was 1959, and they have been operating for a combined 641 years (Valade et al. 2020, pp. 10–11). As power companies have modernized aging plants to keep them operational, new technology has caused them to discharge less warm water, reducing the size of the warm-water habitat they provide by up to 25% and making outfalls unreliable in extreme cold weather (Valade et al. 2020, pp. 7–8; *see* Extreme Cold Events, *infra*).

Other threats are expected to undermine power plants' reliability and increase incentives for corporate owners to retire them or suspend their operations (Valade et al. 2020, p. 8). Mechanical failures, power outages, economic instability, maintenance construction, contaminant spills, and storms will periodically disable the facilities and interrupt their effluent outfalls (Valade et al. 2020, p. 8; Edwards 2013, p. 731). Climate change is expected to intensify the frequency and severity of storms, while causing rising seas to inundate six of most utilized plants by 2100 (Edwards 2013, p. 731; *see* Climate Change: Storms, *infra*).

But even greater reductions are planned—power companies are now expected to eliminate these warm-water habitats entirely within thirty years (Valade et al. 2020, p. 1). Although the precise timing of shutdowns is hard to predict due to facility-specific factors, volatile economic inputs, and an unstable regulatory environment, much of the gain in manatee population could quickly be undone if proactive management measures are not implemented in response to power plant retirements (Valade et al. 2020, p. 8; Laist et al. 2013, p. 11; *see* Regulatory Inadequacy, *infra*). In the Atlantic region, where the only other sources of warm water are passive thermal basins, the loss of industrial refugia is expected to have an exacerbated effect, with negative consequences for Florida manatees' abundance and effective winter range (Valade et al. 2020, pp. 26–28; Laist and Reynolds 2005b, p. 287).

Even when they are working, power plant outflows can fall below 20° C in cold weather and expose manatees to the effects of CSS (Valade et al. 2020, p. 3). Due to the high degree of fidelity they show to their winter refugia, and because they cannot know how long a shutdown will last, manatees may not move to another location if their heat source is temporarily or permanently disabled (Edwards 2013, p. 731). Nearby refugia with room for displaced manatees might not even be available and searching for them can cause manatees to lose body heat and expend vital energy reserves, making them vulnerable to serious illness or death (Edwards 2013, p. 731; *see* Griffin et al. 2021, pp. 1, 7). Thus, in counties where power plants provide the primary warm-water habitat, cold stress deaths are disproportionately high in the wintertime (Valade et al. 2020, p. 3; Laist et al. 2013, pp. 6–9).

As power plant outflows diminish, and eventually shut off, Florida manatees will have to rely on "remaining springs in the upper St. Johns River and northwest Florida regions and on Warm Mineral Springs in southwest Florida, passive thermal basins, and warm ambient waters in southernmost Florida" to survive. Final Rule 2017, 82 Fed. Reg. at 16,692. Threats to natural springs and passive thermal basins will thus become increasingly salient to the Florida subspecies' survival as the proportion of manatees that relies on these sites more than doubles (Valade et al. 2020, p. 2).

b) Natural Springs

Natural warm-water springs form nine primary and eleven secondary refugia that are estimated to support a fifth to a quarter of wintering manatees in Florida (Valade et al. 2020, pp. 4, 26–31; Laist et al. 2013, p. 9; Edwards 2013, p. 732). Of the primary sites, the St. Johns River unit contains Blue Spring, Salt Springs, Silver Glen Springs, and Silver Springs. The Northwest unit contains Crystal River Springs (including Kings Bay), Homosassa Springs, Wakulla Springs, Weeki Wachee River Springs. Southwest unit manatees use the Warm Mineral Spring (Valade et al. 2020, pp. 7, 26–31).

Human withdrawal of groundwater has "significantly reduced flow rates at many of Florida's springs," and can "reduce the size of thermal plumes to a point where they could no longer support large numbers of manatees." (Valade et al. 2020, p. 4). Ninety-three percent of Floridians get their fresh water from groundwater sources (Marsh et al. 2017, p. 350). This human extraction is projected to reduce flow rates at Blue Spring by 4% per year until at least 2025 (Valade et al. 2020, p. 4). And average flow rates at Homosassa Springs, "a principal warm-water refuge for . . . northwestern Florida," have declined 17% or more from their levels in the mid-20th century (Valade et al. 2020, p. 4).

Greater strain on aquifers is still to come; despite the enactment of Minimum Flows and Levels (MFL) regulations, groundwater is expected to be unable to meet freshwater demand in Florida by 2030 (Valade et al. 2020, pp. 4–5; EPA Saving Water in Florida, 2013, p. 1; *see* Regulatory Inadequacy, *infra*). This is largely driven by population growth: Florida is one of the fastest growing states in the nation, and by 2035, its population is expected to reach 25.5 million—an increase of 300,000 new Floridians each year (EDR 2018, p. 79; Valade et al. 2020, p. 2; Beck et al. 2000, p. 2; Florida Demographic Estimating Conference (FDEC) 2021, entire).

Between 2015 and 2035, water demand in the state is expected to grow by 17% (Florida Office of Economic & Demographic Research 2018, p. 74).

Climate change is expected to exacerbate these impacts. The long-term hydrological phase has already been altered—over the last 50 years, precipitation has declined in parts of Florida by as much as 15% (Edwards 2013, pp 731–32). Dry conditions are expected to continue to decrease the recharge rate of Florida's aquifers and exacerbate the effects of increasing human demand on groundwater (Edwards 2013, pp. 731–32; Abiy et al. 2019a, p. 2; *see also* Figure A.21; Rainfall Changes, *infra*). As rainfall in Florida declines and consumption increases, water entering aquifers will be inadequate to replace that which is extracted (Valade et al. 2020, p. 4). Sea level rise and increasingly frequent storm surge events are also expected to cause saltwater intrusion into springs, which can reduce or eliminate their viability as manatee warm-water habitat (Marsh et al. 2017, p. 337; *see* Salinity, *infra*). And as spring flows decline, their capacity to dilute contaminants decreases, making springs saltier and more polluted (Edwards 2013, p. 732).

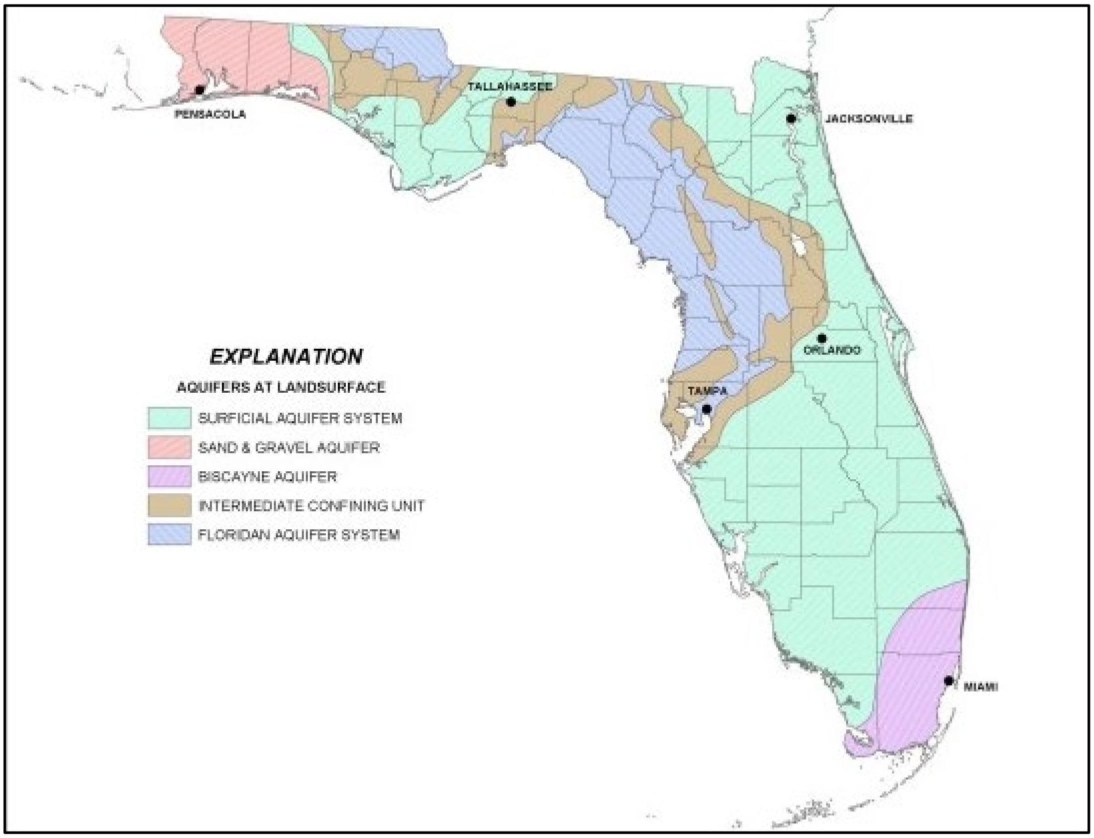


Figure A.21 - Florida's aquifers (FDEP n.d.)

Declining groundwater can cause irreversible aquifer compaction and problematic land subsidence that permanently degrade the quality of groundwater resources (Hung et al. 2021, p. 1). Replenishing depleted aquifers takes years, even if humans significantly reduce their water consumption (Edwards et al. 2013, p. 731). As the water table drops, spring flows will decline, and warm-water habitats will shrink with them in ways that will be difficult to reverse (Valade et al. 2020, p. 4; Edwards 2013, p. 732).

Manatees have been constrained from accessing many important springs by human impediments like locks, dams, fencing, rocks, or sedimentation (Valade et al. 2020, p. 5). For example, Rainbow Springs is inaccessible to manatees due to a downstream lock and dam structure (Valade et al. 2020, p. 5). Weeki Wachee Spring is choked by sediment deposits that make it hard for manatees to access or traverse it (Valade et al. 2020, p. 5). And manatees' access to at least 20 historic springs on the Lower St Johns River is obstructed by the Rodman/Kirkpatrick Dam on the Ocklawaha River (Knight 2022, entire).

The manatee's ability to use a spring as habitat is also curtailed by recreational activity that occurs there (Valade et al. 2020, p. 4). "Vessel traffic[,] . . . water sports, particularly paddling (canoes, kayaks and paddleboards), swimming, fishing and diving, within or directly adjacent to warm-water habitats," can pose "significant threats" to manatees (Valade et al. 2020, p. 5; *see* Overutilization, *infra*). If recreational disturbances drive manatees away from their familiar refugia in the winter, they must expend precious lipid reserves to search for increasingly scarce alternative sites while surviving the effects of cold stress syndrome (Griffin et al. 2021, p. 7). Manatees congregated at warm-water refugia are vulnerable to boat strikes, which can be a source of injury and mortality (Valade et al. 2020, p. 5; Basset et al. 2020, p. 403; *see* Boat Strikes, *infra*). Although Florida has regulations in place designed to mitigate these disturbances, these have not been successful in stopping persistent recreational use from degrading a number of secondary springs with the potential to be primary refugia (Valade et al. 2020, p. 5; *see* Regulatory Inadequacy, *infra*).

c) Passive Thermal Basins

Another portion of Florida manatees, also estimated at slightly less than a quarter of the subspecies' population, relies on passive thermal basins (PTBs) for warm-water habitat in the winter (Laist et al. 2013, p. 9). PTBs can be created by solar radiation, groundwater seeps, or microbial activity (Laist et al. 2013, p. 1). Other PTBs are created by haloclines, or zones in which cooler, lighter fresh water flows atop a layer of warm, heavy seawater; the vertical salinity gradient can obstruct convective mixing in the water column, resulting in a persistent source of warm water for manatees (Stith et al. 2012, p. 288). Halocline sites depend on continuous inflows of fresh water to maintain their thermoregulatory effects, and tidal action can improve their longevity by advecting warm groundwater up into the lower layer of salt water (Stith et al. 2012, p. 288).

These features are mostly located in southern Florida and form the principal warm-water habitat of the Southwest unit (Valade et al. 2020, pp. 2, 12). Of 34 thermal basins used by Florida manatees, 4 are primary sites: the Coral Gables Waterway, the DeSoto Canal, the Port of the Islands Mitigation Site (groundwater seeps), and the Port of the Islands Port Canals (a halocline site) (Valade et al. 2020, p. 2).

Passive springs are generally the least effective type of manatee warm-water refugia, and "it is unclear whether natural warm-water habitats in [southern Florida] can support more animals than current levels" (Valade et al. 2020, p. 38; Laist et al. 2013, p. 2). This is in part because the temperatures of these sites and their ability to retain heat is little researched and poorly understood (Valade et al. 2020, p. 3).

The manatee's ability to use thermal basins is disrupted by humans' recreational use of these sites (Valade et al. 2020, p. 4). Managers have noted that humans interact with manatees at half of primary PTBs (Valade et al. 2020, p. 12). While manatees might respond differently to human presence in its environment, manatees' overall tendency is to avoid areas with high recreational traffic (*See* Overutilization, *infra*).

Climate change is also expected to degrade these formations. As precipitation declines and groundwater resources are strained by population growth in Florida, PTBs formed by haloclines and groundwater seeps could shrink or be destroyed (Laist et al. 2013, p. 2; *see* Rainfall Changes, *infra*; Natural Springs, *supra*).

As manatees displaced by power plant closures and shrinking springs seek shelter at passive thermal basins, impediments to or degradation of these hydrological formations will be especially damaging to Florida manatee populations. *See* Final Rule 2017, 82 Fed. Reg. at 16,697. And, while ambient waters tend to be warmer in southern Florida, "water temperatures throughout mainland Florida, including the southernmost tip, routinely fall below the thermal tolerance levels of at least some manatees during winter periods" (Valade et al. 2020, p. 3).

3. Loss of Freshwater Access

Because they need fresh drinking water, West Indian manatees' abundance is strongly influenced by the availability of freshwater sources in their habitat (See Natural History and Biology, *supra*). For segments of the species that live in completely fresh or slightly saline habitats, freshwater availability is not a limiting factor; in other areas, however, "fresh water is the most limiting resource for manatees" (Favero et al. 2020, p. 1670). Negative impacts are forecasted for manatee populations where, like in the Brazilian state of Piauí, survival is "entirely dependent on the rainfall regime" (Favero et al. 2020, p. 1671). Limited freshwater resources also significantly restrict suitable manatee habitat in the Bahamas, parts of Belize, and Venezuela (Quintana-Rizzo and Reynolds 2010, pp. 18, 20, 81).

Climate change is expected to make the effects of freshwater deprivation more severe. Droughts are becoming more frequent across the West Indian manatee's range, which "could have a significant impact on the survival of the species, reducing its distribution" (Edwards 2013, p. 732; Favero et al. 2020, p. 1671; *see* Rainfall Changes, *infra*). Further "significant drying" is projected throughout the Caribbean, which is prone to intense drought and experienced an unusually prolonged multiyear drought from 2013–2016 (Herrera et al. 2020, p. 10773). In Piauí, Brazil, climate change is already causing drought conditions that, combined with the already-dire state of freshwater habitat there, could further jeopardize the future of Antillean manatees in that state (Favero et al. 2020, p. 1671).

4. Coastal Development

In addition to its effects on seagrasses (*See* Loss of Seagrass, *supra*), human urban development of coastal ecosystems is increasingly degrading, fragmenting, and destroying key West Indian manatee habitat.

Florida manatees and the coastal ecosystems they inhabit are threatened by construction activities related to population growth and associated urbanization (Hieb et al. 2021, pp. 674–75). Increased boating activity surrounding in-water construction projects raises the probability of vessel collisions with manatees or seagrass meadows (Hieb et al. 2021, p. 677; *see* Boat Strikes, *infra*; Habitat, *supra*). Floating construction booms and anchor lines have been documented to cause manatee entanglements (Hieb et al. 2021, p. 677; *see* Entanglements, *infra*). Construction activities like dredging can directly kill manatees through blunt force trauma or drowning from suction-related entrainment, and they affect manatee habitat by destroying seagrass beds and reducing water clarity (*See* Sediment and Turbidity, *supra*). During and after construction, structures including siltation barriers, barge platforms, pilings, foundation elements, and dredge spoils can interfere with manatees' ability to access important areas of habitat (Hieb et al. 2021, p. 679).

Changes in Florida land use have also caused significant changes in surface water behavior. Between the 1920s and 1990s, when urban areas covered 30% of the land-water margin in Indian River Lagoon, stormwater runoff in the lagoon increased by 113% (Herren et al. 2021, p. 1). This wastewater introduces significant quantities of sediment and contaminants to the Indian River Lagoon, causing turbidity, sedimentation, HABs, and loss of water clarity (Herren et al. 2021, pp. 1–2). Furthermore, urban areas in the Indian River Lagoon watershed rely on septic systems for over half of their wastewater disposal; even when they function properly, these systems are significant sources of nutrients and microbes that are washed into waterways (Herren et al. 2021, pp. 2, 10–11; *see* Regulatory Inadequacy, *infra*; Eutrophication, *supra*). Septic systems are contributing to expansive seagrass losses in the Indian River Lagoon and the resultant starvation-driven mortality event in that estuary (Herren et al. 2021, p. 10).

Antillean manatees are similarly affected by alterations in the coastal zone related to human activities. In Mexico, coastal economic development for tourism, urbanization, and fishing in Veracruz, Tabasco, and Campeche is progressively destroying coastal wetland habitat (Quintana-Rizzo and Reynolds 2010, p. 58). Large increases in tourism-oriented development are planned (Quintana-Rizzo and Reynolds 2010, p. 59). Dams in Mexico fragment manatees' habitat and isolate their populations, contributing to population decline (Quintana-Rizzo and Reynolds 2010, pp. 59–60).

In Belize, important habitat for one of the largest remaining populations of Antillean manatees is increasingly altered and destroyed by coastal development largely related to tourism (Edwards et al. 2014, p. 72; Quintana-Rizzo and Reynolds 2010, p. 23). Significant threats to Belize's Turneffe Atoll (the only atoll in Belize with documented manatee presence) include unsustainable fishing, mangrove clearing, overdevelopment, and dredging (Edwards et al. 2014, p. 72). Mangroves provide an especially important habitat for Antillean manatees because they are a secondary source of food and supplemental fresh water (Allen et al. 2018, p. 1835–36). Heavy fishing of coastal ecosystems increases the amount of netting, fishing line, and debris in the water, which can cause injury or death for manatees that ingest or become entangled in it (Edwards et al. 2014, p. 72; *see* Marine Debris, *infra*). Furthermore, waterside structures lead to more pollutants being pumped directly into seas, rivers, or other coastal waterways where manatees are found (Quintana-Rizzo and Reynolds 2010, p. 23).

In Colombia, after the construction of the Urrá Dam on the Río Sinu in 2000, manatees have become rare in areas where they were once reported (Quintana-Rizzo and Reynolds 2010, p. 29). Other development-related threats to Colombian manatee habitat include deforestation, wetlands draining, mining, cattle ranching, shrimp farming, tourist projects, and associated contamination and sedimentation (Quintana-Rizzo and Reynolds 2010, p. 30).

In Brazil's northeast region, tourism, fishing, aquaculture farming, and salt mining are suspected to be increasing Antillean manatee entanglements with marine debris and driving female manatees away from quiet habitat in which to raise their calves (Quintana-Rizzo and Reynolds 2010, p. 26).

5. Boating and Recreational Disturbance

Boating does not just kill manatees and the seagrasses they need; it also interferes with the manatee's ability to make use of its preferred habitat (Smith 1993, p. 22; *See also* Loss of Seagrass: Boating, *supra*; Boat Strikes, *infra*). Manatees will avoid even high-quality habitat if it has heavy vessel traffic, and new watercraft access projects have been documented to reduce manatee sightings in prime areas by more than half (Smith 1993, p. 22). For instance, increased motorboat and jet ski activity in Brazilian mangroves restricts Antillean manatees from freshwater resources and increases mortality due to collisions (Quintana-Rizzo and Reynolds 2010, p. 26).

Other recreational use of manatee habitat, such as swimming and kayaking, is also a significant source of manatee harassment and alters manatee behavior, displacing them from essential areas of habitat (*See* Overutilization, *infra*).

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization of manatees primarily takes the form of harassment or poaching. Harassment occurs throughout the manatee's range, although it varies in severity. Poaching was formerly more widespread but continues to occur in portions of the range outside of the United States, especially in Haiti, Cuba, and Colombia.

Harassment occurs in wintering areas, resting areas, feeding areas, travel corridors, and other important manatee use sites. Final Rule 2017, 82 Fed. Reg. at 16675. Significant harassment is associated with manatee viewing and other tourist activities, such as those that occur in the Crystal River area in Citrus County (Reep and Bonde 2021, p. 169). There, tourists swim with the manatees, and while many do so appropriately, some tourists continue to engage in inappropriate behavior including holding, chasing, and riding manatees (Reep and Bonde 2021, p. 169). According to one report, swimmers harassed manatees in 40% of their encounters (Tripp et al. 2016, p. 5). In the winter of 2014–2015, one person entered the Three Sisters Springs in Crystal River every 16 seconds (Tripp et al. 2016, p. 6). These sites continue to lack appropriate distancing rules to ensure that swimmers do not harass manatees, and even a 10-foot buffer area has not been implemented (Tripp et al. 2016, p. 2). Some manatees swim away from such tourists, at times even leaving the refuge area, while others approach swimmers, but in both cases, manatees are altering their behavior—the definition of harassment. *See* 50 C.F.R. § 17.3 (defining "harass" to mean "an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering.") (Tripp et al. 2016, pp. 2–6). More manatees are observed at Three Sisters Springs on days when it is closed to tourists (Tripp et al. 2016, pp. 4–5).

In 2015, the Fish and Wildlife Service prepared a draft Environmental Assessment reviewing management options to improve protection of Florida manatees, and a coalition of groups, including Save the Manatee Club, the Humane Society of the United States, the Animal Welfare Institute, Public Employees for Environmental Responsibility, the Marine Mammal Commission, and the Center for Biological Diversity, provided extensive comments explaining why stringent rules were necessary to avoid harassment of manatees (USFWS *Press Release* 2015, entire; Tripp et al. 2016, entire; Lent 2015, entire). But USFWS has failed to finalize a management policy, and harassment continues under interim measures (*See* Regulatory Inadequacy, *infra*). Significantly less harassment occurs at manatee viewing areas where tourists only view manatees on land, as shown by such sites as Ellie Schiller Homosassa Springs Wildlife State Park and Blue Spring State Park (Tripp et al. 2016, p. 7).

Harassment also occurs outside Florida. Kayakers, swimmers, and boaters, including speedboat racers in Puerto Rico, are believed to affect manatee behavior, which constitutes harassment. Final Rule 2017, 82 Fed. Reg. at 16,668. Other countries in the West Indian manatees' range also frequently lack adequate protections against harassment. For example, Belize has been described as a current site of harassment "reminiscent of the days 50 years ago in the then small town of Crystal River, Florida" (Reep and Bonde 2021, p. 230).

Poaching also remains a threat to manatees. In recent years, poaching has been reported in Belize, Colombia, Costa Rica, Cuba, the Dominican Republic, French Guiana, Guatemala, Haiti, Honduras, Mexico, Suriname, Trinidad and Tobago, and Venezuela (Rodríguez Mega 2016, entire; Tejo & Maria 2016, p. 41; Alvarez-Alemán, et al. 2021, entire; Marsh et al. 2011, p. 269). Once poached, manatee meat can fetch up to $220 per kilogram, a substantial sum in parts of the species' range, and manatee bones are used to create jewelry and sculptures (Marsh et al. 2011, p. 386). Various body parts are also used to make traditional medicinal products (Tejo & Maria 2016, p. 41). In Haiti, manatees lack official protection, and fishers continue to view manatees as a food source, and to have a negative attitude towards conservation (Tejo & Maria 2016, p. vii). In Northern Nicaragua, poaching rates vary from year to year depending on local social and economic factors (Self-Sullivan and Mignucci-Giannoni 2012, p. 44). In Belize, hunting for meat continues to occur (Rodríguez Mega 2016), although it may be relatively rare today (Castelblanco-Martínez et al. 2018, entire). In Cuba, while manatee poaching is illegal, piles of bones indicate concealment of hunting (Alvarez-Alemán, et al. 2021, entire), which is estimated to cause 38% of manatee deaths and severely threaten the sustainability of the population (Alvarez-Alemán, et al. 2021, p. 1). In Colombia, poaching over the period 1980 to 2004 also accounted for 38% of manatee deaths (Castelblanco-Martínez et al. 2009, p. 238).

C. Disease or Predation

While manatees have fairly strong immune systems, they still face threats from disease, and numerous infectious disease agents and parasites have been observed in manatees (Marsh et al. 2011, p. 294). Various bacterial infections have killed manatees. Mycobacterium strains have killed two captive manatees (Marsh et al. 2011, p. 296). Secondary bacterial infections also cause wild manatee mortality following boat strikes and other physical injuries (Marsh et al. 2011, p. 297; *see* Boat Strikes**,** *infra*). Manatees that have adopted macroalgal diets in response to seagrass loss have suffered significant toxic effects from clostridial infections, which contributed to the 2013 Indian River Lagoon UME (Landsberg et al. 2022, pp. 1-2, 12). This syndrome, while sporadic, occurs as part of the systemic impairment of manatees' ecosystem that makes them less resilient. Papillomavirus and Herpesviruses have caused lesions, warts, and benign tumors (Marsh et al. 2011, p. 295–96).

Parasites also negatively affect manatees. Toxoplasmosis has caused manatee mortality in Puerto Rico (Bossart et al. 2012, p. 139; Marsh et al. 2011, p. 294). In 2007, an adult captive manatee from Belize died of an apparent verminous pneumonia (Auil Gomez 2011, p. 21). Similar cases have also been observed in the Florida manatee, including a case from Georgia where a verminous interstitial pneumonia involving the fluke (parasitic flatworm) *Pulmonicola cochleotrema* likely caused the death of a manatee; a total of 490 flukes were counted in that animal (Auil Gomez 2011, p. 21). In a different case, more than 250 flukes in the manatee's respiratory system caused severe rhinitis and pulmonary edema; left untreated, this parasite can result in airway blockage and asphyxiation (Auil Gomez 2011, p. 21). While most *Pulmonicola* infections only involve a few flukes, accelerated growth of parasitic flatworms appears to occur in some manatee populations, sometimes leading to mortality (Auil Gomez 2011, p. 21). Researchers believe that effluent from shrimp farms may be responsible for introducing these parasites (Auil Gomez 2011, p. 21). Many effects of endoparasites, such as the widespread prevalence of trematode and protozoan infection, are still being discovered (Vélez et al. 2019, entire). New evidence of mosquito parasitism of manatees indicates an additional potential pathway for disease transmission (Reeves and Gillett-Kaufman 2020, p. 1). Other recent research suggests that "severe parasitic infections" of enteric trematodiasis are a significant and increasing to calf mortality in Florida (Weisbrod et al. 2021, p. 121; *see* Figure C.1)

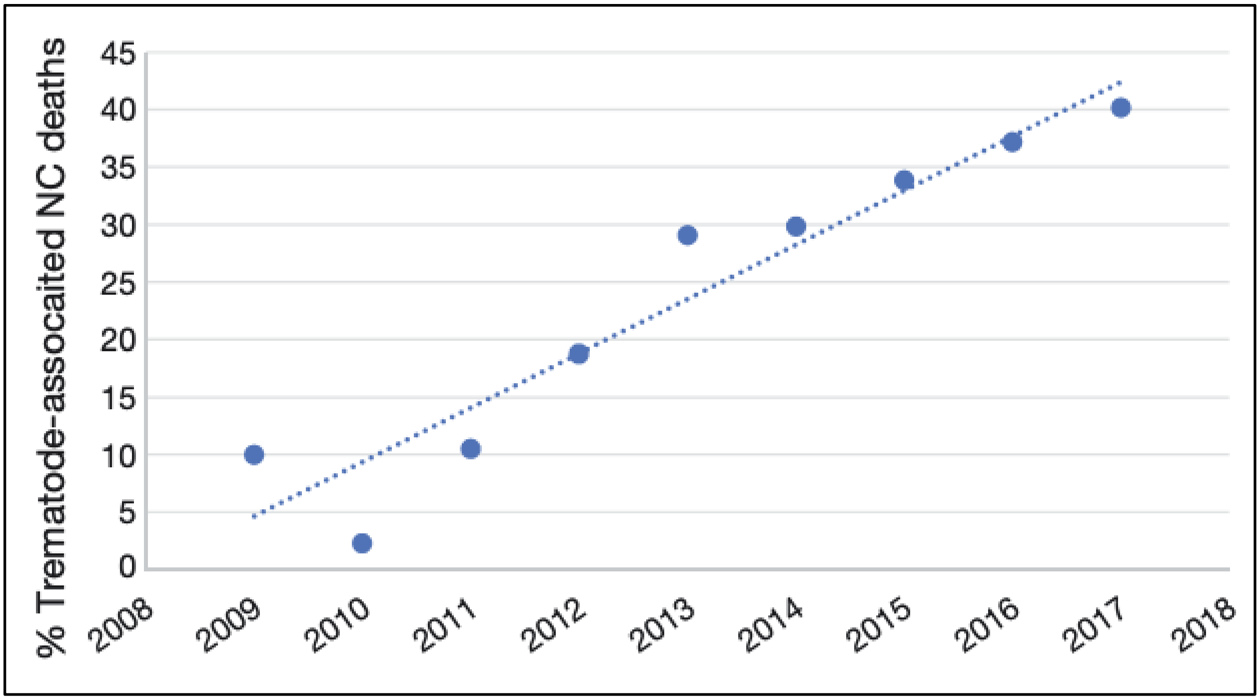


Figure C.1 - Proportions of enteric trematodiasis-associated deaths of manatees in the category of natural causes by year. Trendline (dotted line) R = 0.95. This demonstrates a linear increase in the frequency of manatee carcasses with a positive diagnosis of mono- or co-infections with enteric trematodiasis annually during the study period (Weisbrod et al. 2021, p. 118).

West Indian manatees do not face notable predation in the wild (*Manatees 101*, n.d., entire). Sharks, alligators, crocodiles, and killer whales could theoretically kill and eat manatees, but such incidents rarely occur (NOAA *Manatees 101*, n.d., entire; Marsh et al. 2011, p. 167). Calves are more vulnerable to predation, but this does not seem to occur with frequency. As a practical matter, humans are the most frequent predators of manatees (NOAA *Manatees 101*, n.d., entire; *see* Overutilization, *supra*).

D. Inadequacy of Existing Regulatory Mechanisms

Existing international, federal, state, and local regulatory mechanisms are inadequate to protect manatees from the threats of boat strikes, climate change, and habitat loss. Despite decades of efforts by federal and state officials, which were considered when USFWS reclassified manatees as threatened in 2017, manatees should be listed as endangered because existing regulatory mechanisms have failed to prevent widespread habitat destruction, boat strike mortality, and the inevitable loss of warm-water refugia.

An FWC official made the severity of the situation clear when discussing the 2021–2022 unusual mortality event: “This is an unprecedented event. We’ve had large issues before like red tide where we’ve had a lot of animals impacted but this is different, this is long-term, this is going to take some time to recover some sea grasses here . . . . [W]hat are our other options?” (Leigh 2022, p. 2). Sea World’s chief of zoological operations, who chairs the Manatee Rescue and Rehabilitation Partnership with government agencies, echoed this emergency prognosis when describing ongoing challenges to the Partnership's critical care capacity for sick and injured manatees: "This need doesn't stop at the end of the cold season this year . . . [it's] going to carry on for [a] couple of years, maybe even longer" (Chesnes 2022a, entire). And the projects necessary to restore degraded manatee habitat, "growing and planting new seagrass beds[,] improving storm water drainage[,] and moving properties on septic tanks to sewer systems[,] are expensive and will take years" (Mazzei 2022, entire).

Furthermore, speculative efforts to protect manatees, including promised future actions or voluntary or unenforceable measures, do not qualify as "*existing* regulatory mechanisms." 16 U.S.C. § 1533(a)(1)(D) (emphasis added). Confirming the plain language of the statute, established USFWS policy in the context of evaluating conservation efforts for listing purposes limits USFWS consideration to formalized conservation efforts that have actually been implemented and have been shown to be effective. Policy for Evaluation of Conservation Efforts, 68 Fed. Reg. 15,100 (March 28, 2003). Federal courts have consistently held that the plain language of the statute and USFWS policy preclude consideration of promised future action or voluntary action. *See, e.g.*, *In re Polar Bear*, 794 F. Supp. 2d at 113 ("[T]he ESA does not permit USFWS to consider speculative future conservation actions . . . ."); *Biodiversity Legal Found. v. Babbitt*, 943 F. Supp. 23, 26 (D.D.C. 1996) ("[T]he Secretary . . . cannot use promises of future actions . . . ."); *Or. Nat. Res. Council v. Daley*, 6 F. Supp. 2d 1139, 1154 (D. Or. 1998) ("NMFS may only consider conservation efforts that are currently operational" and "[v]oluntary actions, like those planned in the future, are necessarily speculative.").

1. Regulatory Mechanisms and Conservation Strategies to Address Seagrass Loss are Inadequate

Under the Clean Water Act, states must develop pollution budgets known as "total maximum daily loads" (TMDLs) for each pollutant impairing a waterbody. 33 U.S.C. § 1313(d); 40 C.F.R. § 130.2(i). These TMDLs set a numeric target reflecting the maximum amount of the pollutant that a water body can contain and still be considered compliant with water quality standards. 33 U.S.C. § 1313(d). Once the TMDL is established for an impaired water body, the allowable load is to be "fairly and equitably" allocated to both nonpoint and point sources. Fla. Stat. § 403.067(6)(b) (2014). The TMDL allocation is implemented through a Basin Management Action Plan (BMAP) for any impaired waterways.

A BMAP is a framework for water quality restoration that contains local and state commitments to reduce pollutant loading through current and future projects and achieve the necessary pollutant reductions established by the TMDL. BMAP strategies include permit limits on point source discharges, urban and agricultural best management practices for nonpoint discharges, and analysis of any non-regulatory projects in the basin that will reduce pollution. Fla. Stat. § 403.067(7)(b)1.

TMDL standards and BMAPs are the primary regulatory mechanism for addressing excessive nutrients in Florida waterways. However, the last five years make clear that current TMDLs and BMAPS are inadequate to prevent harmful algal blooms, eutrophication, and the lack of light that destroy seagrass habitat for manatees (*See* Eutrophication, *supra*). In fact, the recent harmful algal bloom crises—unusually prolonged red tides from October 2017 to January 2019 across Florida's gulf coast, an over 1,300 km^2 algal bloom in Lake Okeechobee in 2021, and intensifying HABs in the Indian River Lagoon since 2010 that have destroyed the majority of Indian River Lagoon seagrasses (Phlips et al. 2021, p. 13)—all occurred in areas with established TMDLs and BMAPs. Current TMDLs and BMAPs are inadequate to address continued nutrient loading in vital waterways for manatees for at least three reasons: inadequate regulation of agricultural pollution, inadequate regulation of onsite sewage treatment and disposal systems (septic tanks), and inadequate regulation of "legacy" nutrients.

a) Agricultural Pollution

BMAPs identify agricultural best management practices (BMPs) to address agricultural nonpoint sources and achieve necessary nutrient load reductions adopted in TMDLs. The Florida Department of Agriculture and Consumer Services (FDACS) administers the BMP program. Agricultural landowners located within BMAPs must either enroll in the FDACS BMP program and properly implement BMPs applicable to their property and operation or conduct a water quality monitoring program. Fla. Stat. § 373.4595(2)(a).

Despite the statutory enrollment requirement, only 62% of total agricultural acres in Florida are enrolled in BMPs (FDACS 2021, p. 2). While the 62% figure includes agricultural acreage inside and outside of the BMAP, disaggregated enrollment figures in BMAP areas with vital manatee habitat show strikingly low BMP enrollment. In Kings Bay and Crystal River Springs, only 25% of agricultural acres are enrolled. In Blue Spring, only 5% of agricultural acres are enrolled (FDACS 2021, p. 15). Enrollment numbers are lower than average in the Indian River Lagoon, where 552 manatees died during the Unusual Mortality Event of 2021. (FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire; *See* Loss of Seagrass, *supra*). Only 57% of agricultural acres are currently enrolled in the Central Indian River Lagoon, 6% are enrolled in the North Indian River Lagoon, and 0% are enrolled in the Banana River Lagoon (FDACS 2021, Table 2).

Moreover, enrollment alone does not ensure compliance with BMPs. The BMP program creates a presumption of compliance for enrollees without any data showing environmental improvements (Blue-Green Algae Task Force 2019, p. 5). In June 2020, the Florida Legislature passed the Clean Waterways Act to increase implementation of BMPs and require Implementation Verification (IV) visits every two years. Fla. Stat. § 2020.150(7)(d)(3). Still, FDACS conducted IV visits at only 20% of enrolled sites by the end of 2020 (FDACS 2021, p. 2). The Agricultural Water Policy Director at FDACS reported that the department does not have adequate staff to meet increased inspection goals (Czyzon and Chesnes 2022, entire). In fact, on the 6,600 occasions where FDACS did refer polluters to Florida Department of Environmental Protection (FDEP) for non-compliance, no penalties were assessed (Chesnes 2021b, entire). As Florida Agricultural Commissioner Nikki Fried candidly acknowledged, the existing BMP program has "no teeth" (Czyzon and Chesnes 2022, entire).

In the case of the Lake Okeechobee Basin's BMAP, Florida's Blue-Green Algae Task Force found the presumption of compliance with BMPs unreliable without actual supporting data (Blue-Green Algae Task Force 2019, p. 5). The Lake Okeechobee TMDL was adopted in 2001. Eighty-five percent of the agricultural acres in the Lake Okeechobee Basin BMAP area are enrolled in the BMP program (FDACS 2021, Table 2). Still, Lake Okeechobee has experienced devastating algal blooms in the past decade, most recently in 2021, driven primarily by excessive phosphorus and nitrogen levels from surrounding agricultural lands (Heil and Muni-Morgan 2021, p. 16; Siders and Havens 2020, p. 4222; *see* Figure D.1). Despite high enrollment of agricultural acres, and the presumption of compliance that comes with it, data of phosphorus levels from the South Florida Water Management District reveal consistent violation of BMAP parameters (Czyzon and Chesnes 2022, entire). Phosphorus levels have *never* been within TMDL limits. This illustrates a larger trend of noncompliance with BMPs throughout Florida and highlights the need for stronger enforcement measures as a part of Florida's regulatory mechanisms.

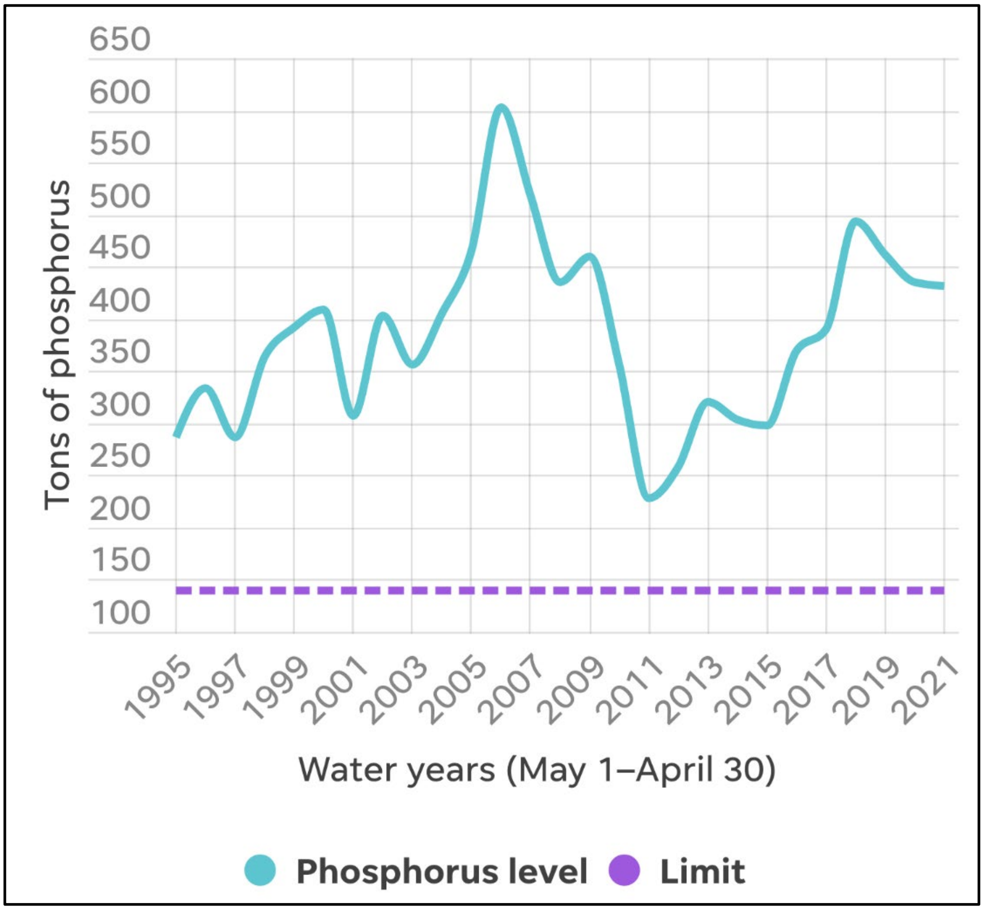


Figure D.1 - Lake Okeechobee phosphorus levels (Czyzon and Chesnes 2022).

This failure to adequately regulate agricultural pollution in Lake Okeechobee directly causes harm to seagrass populations along the coast. Water discharges from Lake Okeechobee are released the east and west coasts via the St. Lucie River and the Caloosahatchee River, respectively, and so nutrient pollution from Lake Okeechobee spreads algal blooms throughout Florida's waterways and triggers eutrophication in key seagrass habitats (*See* Eutrophication, *supra*). Currently, the U.S. Army Corps of Engineers is planning to update the Lake Okeechobee System Operating Manual, ("LOSOM") to change the timing, direction, and quantity of flows of water from Lake Okeechobee (Chesnes 2022b, entire). However, this plan will not be implemented until 2023 at the earliest, meaning its impacts are too speculative to be an adequate regulatory control (Chesnes 2022b, entire). Moreover, the current proposed plan will not stop all the polluted water flow from Lake Okeechobee that is contributing to coastal seagrass die-off.

Notably, only 40% of water discharges to the St. Lucie River and the Indian River Lagoon will stop under the most recent draft, but this reduction is not close enough to the zero-discharge quantity that advocates claim is necessary for the health of both the St. Lucie River and the Indian River Lagoon (Chesnes 2022b, entire). Likewise, the improvements in quantity of water flow to the Caloosahatchee River depend on the amount of rain Florida receives, something that is becoming increasingly uncertain due to climate change (*See* Climate Change, *supra*). At the very least, the impacts of the Lake Okeechobee's new management plan are too speculative and likely not enough to fix the dire problems that are caused when the agricultural pollution present in Lake Okeechobee's water flows into sensitive estuary and seagrass habitats.

b) Legacy Nutrients

According to Florida's Blue-Green Algae Task Force, "[l]egacy nutrients, i.e., nitrogen and phosphorus sequestered in soils, groundwater and sediments, contribute also to excessive nutrient loading of surface waters throughout the state." (Blue-Green Algae Task Force 2019, p. 1). Unfortunately, legacy pollution, also known as legacy muck, is not adequately accounted for in TMDL standards and BMAPs.

For instance, Lake Okeechobee is the largest freshwater lake in Florida, and feeds into the St. Lucie River, part of the Indian River Lagoon system on the Atlantic coast, as well as the Caloosahatchee River on the Southwest Gulf Coast. It is connected to multiple important manatee habitats, and generally feeds into Florida's many waterways. The Lake Okeechobee BMAP, issued in January 2020, states that achieving the TMDL rate for total phosphorus (TP) will take at least 20 years—but only if there are "additional local projects," "additional regional projects," "enhancements to [current] programs," and "significant funding" (FDEP Lake Okeechobee BMAP 2020, p. 15). In other words, the current BMAP cannot achieve the TMDL within 20 years without significant additional funding and additional projects. However, such future additional projects necessarily fall outside the definition of an "*existing* regulatory mechanism." 16 U.S.C. § 1533(a)(1)(D); (*See* Inadequacy of Existing Regulatory Mechanisms *supra*). Furthermore, muck removal projects are "very expensive" and require the use of dredging, which can have harmful secondary effects on manatee habitat (Florida Sea Grant, n.d., p. 1; *see* Coastal Development, *supra*).

One of the primary reasons for this inadequacy is the presence of legacy phosphorus. The BMAP acknowledges that the TMDL is unachievable without a comprehensive strategy for legacy phosphorus (FDEP Lake Okeechobee BMAP 2020, p. 187). A scientific study of legacy phosphorus in Lake Okeechobee confirms it bluntly: "Despite major efforts to control external nutrient loading into the lake, the high frequency of algal blooms will continue until the muds bearing legacy nutrients are removed from the lake." (Missimer et al. 2020, p. 1). Because Lake Okeechobee is shallow, storms and waves easily kick up sediments at the bottom of the lake and resuspend them in the water, making phosphorus available to harmful algal blooms (Missimer et al. 2020, pp. 12–15). Therefore, even if the Lake Okeechobee BMAP achieved all its speculative goals for future projects and funding addressing external nutrient loading, phosphorus levels would remain higher than the TMDL standard for avoiding significant impairment, and harmful algal blooms would persist.

A similar legacy muck issue threatens the Indian River Lagoon. There are an estimated 5 million cubic yards of muck within the Indian River Lagoon, delivering roughly 30% of the total nutrient load of both nitrogen and phosphorus (Fox and Trefry 2019, p. 1). Brevard County recently reported that "[n]itrogen and phosphorus released each year as muck decays are now larger than any current source of nutrient pollution to lagoon waters" (Tetra Tech, Inc. 2022, p. xii). However, despite the central role of legacy nutrients in harmful algal blooms and seagrass loss, the BMAPs for the Indian River Lagoon's three segments do not account for legacy muck in their pollutant allocations (Central Indian River Lagoon BMAP, p. 43; North Indian River Lagoon BMAP, p. 38; Banana River Lagoon BMAP, pp. 34–35).

c) Septic Tanks

More than any other state, Florida relies on onsite sewage treatment and disposal systems (OSTDS), commonly called septic systems. Approximately 30% of Floridians currently use septic systems for wastewater treatment (FDEP *Onsite Sewage Program* 2021, entire). And, because approximately 900 more people move to Florida every single day, septic tank installations have risen every year since 2012 with about 22,000 septic tanks installed in 2018 (Starling 2020, entire). Household wastewater in septic tanks is an important source of nitrogen loading in Florida waterways and a primary driver of harmful algal blooms and seagrass loss, especially in the Indian River Lagoon (Herren et al. 2021, p. 10; Krimsky et al. 2021, p. 1; Lapointe et al. 2019, p. 1; Blue-Green Algae Task Force 2019, p. 6; *see* Coastal Development, *supra*).

As of 2020, in response to the environmental impact of septic systems, the Clean Waterways Act transferred authority for OSTDS regulation from the Department of Health to the Florida Department of Environmental Protection (FDEP Program Transfer 2021, entire). The Clean Waterways Act also requires rulemaking relating to the location of OSTDS to prevent groundwater and surface water contamination, which must consider the recommendations of the OSTDS Technical Advisory Committee. Fla. Stat. § 2020.150(4)(e). The Clean Waterways Act does not include the Blue Green Algae Task Force's urgent recommendation for a "comprehensive" statewide OSTDS monitoring and enforcement program (Blue-Green Algae Task Force 2019, p. 6). Furthermore, FDEP still has not established water quality criteria for cyanotoxins despite the petition and comments of environmental organizations including the Center for Biological Diversity, Calusa Waterkeeper, Sanibel-Captiva Conservation Foundation, and Conservancy of Southwest Florida (Center for Biological Diversity et al. 2019, entire; Center for Biological Diversity et al. 2021, entire).

The Indian River Lagoon crisis again illustrates the persistent inadequacy of this regulatory mechanism. There are more than 300,000 permitted septic systems—comprising over 50% of regional wastewater disposal—in the six counties adjacent to the Indian River Lagoon (Galoustian 2021, entire). A recent study concluded that septic systems were nutrient loading the Indian River Lagoon via groundwater (Herren et al. 2021, entire). "The [nitrogen] enrichment of all systems in this study supports that even 'properly functioning' septic systems contribute [nitrogen] to surficial ground water." (Herren et al. 2021, p. 10). Therefore, reducing reliance on septic systems is necessary to prevent harmful algal blooms and eutrophication in the Indian River Lagoon and other important waterways, but the rapid growth of Florida's population and concomitant development to accommodate it makes an increase in septic systems inevitable (Lant 2018, entire).

d) Phosphogypsum Stacks

Florida is the world's largest phosphate producing area (EPA *TENORM: Fertilizer and Fertilizer Production Wastes* 2021, entire). Processing phosphate ore into phosphoric acid for fertilizer creates immense amounts of toxic, radioactive solid waste called phosphogypsum. Due to its radioactivity, EPA requires that phosphogypsum be kept in piles called phosphogypsum stacks, also known as gypsum stacks or gypstacks. 40 C.F.R. § 60.200 *et seq*. There are 25 phosphogypsum stacks across Florida, of which 4 are still active (FDEP Florida Gypsumstacks, n.d., entire). FDEP regulates the stacks under its Phosphate Management Program (FDEP *Phosphate Management Program*, n.d., entire). FDEP sets engineering standards for stacks, require emissions monitoring for radioactivity, and regulates discharges of surface waters through the National Pollutant Discharge Elimination System (NPDES) (FDEP *Phosphate Management Program*, n.d., entire).

These regulations applied to the Piney Point stack that breached in 2021 and ultimately released approximately 814 million liters of wastewater into the Tampa Bay ecosystem. (Newborn 2021, entire; Beck et al. 2022a, p. 2). The 2021 Piney Point release joins a long list of environmental disasters caused by phosphogypsum stacks. In 2004, hurricane winds caused strong waves that punctured a control dike on top of a gypstack in Hillsborough County just north of Piney Point (Pittman 2017, entire). Sixty-five million gallons of contaminated water flowed into the surrounding water system (Pittman 2017, entire). In 2016, a different gypstack suffered a massive sinkhole and released 215 million gallons of polluted water into the Floridan aquifer (Newborn 2021, entire; O'Donnell 2016, entire). The very same facility had experienced "one of the biggest Florida sinkholes ever recorded" in 1994 (Pittman 2017, entire).

As long as phosphate mining remains an active industry in Florida, gypsum stacks will continue to grow, and eventually these "ticking time bombs" will explode (Pittman 2017, entire; Quintana 2021, entire). Inactive stacks may not grow, but there is no way to dispose of the phosphogypsum. As one scientist put it, "We stack it and say, 'well, we'll figure it out when it comes to it'" (Quintana 2021, entire). But after Piney Point, Florida officials acknowledged, "There was then, and remains now, no plan" for addressing this problem (FDACS 2021, entire). Therefore, without major technological and commercial innovations in the use of phosphogypsum and reductions in the volume of phosphogypsum produced annually, the waste will continue to stack up and threaten Florida's waterways and aquifers—upon which the manatee depends (Nelson et al. 2021, entire). Indeed, even zealous regulation and enforcement cannot solve the "macro-scale problem facing the phosphorus mining industry: its utter lack of sustainability" (Nelson et al. 2021, p. 16268).

e) Seagrass Scarring by Boat

The rise in the number of boats in Florida waters will inevitably increase the quantity and severity of seagrass scarring—i.e., damage to seagrass caused by boat propellers, motors, and hulls (FWC *Help Protect Seagrasses* n.d., entire; Parsons 2019, entire; Sargent et al. 1995, p. 26–29; *see* Seagrass Loss, *supra*). In 1995, FDEP recognized the urgent need for a "statewide management program" of seagrass scarring to complement inadequate and underfunded county-level plans focused on education and navigation aids (Sargent et al. 1995, p. 33). However, despite decades of awareness of the damage caused by seagrass scarring, “there has been little meaningful progress in addressing this largely preventable stressor” (Barry et al. 2020, p. 1). In a recent study of boater behavior, researchers found “a disconnect between the high value boaters assign to seagrass and the low level of concern that most boaters reported about seagrass scarring” (Barry et al. 2020, p. 6). A “high percentage of boaters” self-reported boating activities that destroyed seagrass, even while recognizing the importance of seagrass (Barry et al. 2020, p. 6). Regulatory measures remain inadequate to address seagrass scarring and its threat to manatees.

f) Seagrass Restoration

Proposed seagrass restoration and small-scale pilot programs in the Indian River Lagoon are promising developments, but until the underlying causes of water pollution are addressed, seagrass restoration is not a viable strategy (Green 2022, entire; Lapointe et al. 2020, p. 13; Virnstein 2021, p. 139). Moreover, the models for restoration generally do not assume the current level of seagrass destruction (Green 2022, entire). The director of Brevard County’s Natural Resources Management describes it as trying to plant in an “underwater dust bowl,” since in some areas 96% of the seagrass has been lost (Green 2022, entire). Current restoration efforts will also require monumental funding amounts; the total cost of restoring just the Indian River Lagoon is estimated to be 5 billion dollars, and this restoration is expected to take 20 to 30 years to complete (Green 2022, entire). Thus, unless the lagoon in general is restored—something which is uncertain due to the long timeframe and cost—it’s unlikely that these small-scale seagrass restoration programs will be successful or be able to adequately solve the broad-scale loss of sea-grass habitat that manatees face.

g) Supplemental Feeding

Federal and state officials have acknowledged that much more must be done to prevent continued mass manatee die-offs. For the first time in history, a coordinated federal-state supplemental feeding program provided lettuce to starving manatees—more than 200,000 pounds between December 2021 and March 2022 (Mazzei 2022, entire; Glasser 2022, entire; Kerr 2021, entire; Anderson 2022, entire). It is uncertain whether this program will be repeated during the next winter. While the program slowed down the unusual mortality event, thanks in part to unusually mild winter conditions, FWC officials mentioned that many manatees will still need much time to recover from malnutrition and that “they are still in trouble.” (Mazzei 2022, entire; Anderson 2022, entire). Crucially, this unprecedented, one-time feeding program failed to prevent the death of 479 manatees in the first quarter of 2022—more than double the five-year average of first-quarter mortalities at the time of downlisting (FWC *2022 Preliminary Manatee Mortality Report,* 2022, entire; FWC *Manatee Mortality Summaries 2012-2017,* entire).

h) Sargasso Brown Tides

Physically removing the seaweed from Mexican and Caribbean coastlines is one of the only ways to prevent sargasso brown tides from occurring after an influx of *Sargassum*. This, however, is incredibly labor intensive and involves either using heavy machinery, which damages beaches, or manual labor (Liranzo-Gómez et al. 2021, p. 547). Manual removal requires an extensive community removal effort and a massive labor force. For example, during the 2015 influx of *Sargassum* in Mexico, 4,400 workers were employed to clear beaches (van Tussenbroek et al. 2017, p. 272). However, despite thousands of people working to remove the seaweed, 90% of beaches were not cleared (van Tussenbroek et al. 2017, p. 272). Furthermore, *Sargassum* begins to decompose and produce leachate, which triggers sargasso brown tides, within 24 hours of being on shore (Chavez et al. 2020, p. 10). This puts additional time pressure on an already labor-intensive activity.

An alternative way to prevent the buildup of *Sargassum* on shorelines is through barriers placed around 40–50 meters offshore (Chavez et al. 2020, p. 14). However, these barriers must be emptied of the seaweed every 24–48 hours, as it will start to decompose and sink within that time frame, once again producing leachate and nutrient pollution, which can impact shoreline ecology (Chavez et al. 2020, p. 14). Since the decomposition of *Sargassum* seaweed leads to sargasso brown tides, this very short time frame is significant to preventing seagrass die-offs caused by sargasso brown tides. There are current studies of whether *Sargassum* can be removed while in the open sea; however, the results of these studies have not yet been conclusive or have not been implemented, and so they are too inherently speculative to be an adequate regulatory control of sargasso brown tides (Chavez et al. 2020, p. 16).

The cost of cleaning up *Sargassum* influxes is incredibly high; in 2018 alone, the Mexican government paid 17 million dollars to remove over 500,000 tons of *Sargassum* (Chavez et al. 2020, p. 14). This expenditure also does not take into account the money spent by private companies, like hotels, with beachfront property, which included tens of thousands of dollars for pieces of heavy machinery to remove *Sargassum*, up to a million dollars on each boat necessary to transport any collected Sargassum seaweed, and barriers to prevent *Sargassum* seaweed from arriving on the beach, with costs ranging from $220 to $330 per meter, plus installation costs of up to $50 per meter and anchors costing up to $900 to hold the barriers (Chavez et al. 2020, p. 14). It is also noteworthy that this already very large cost does not capture the full cost of removing all the seaweed on all shores; as noted previously, in 2015 only 10% of the *Sargassum* in Mexico was removed.

Provided that hundreds of thousands of tons of *Sargassum* seaweed are now regularly washing up on various Caribbean shores, the current solutions to removal of the seaweed are not workable at scale. Case studies of the *Sargassum* crisis note that "lessons learned" are not incorporated when a "new" sargasso crisis emerges, meaning each time, an influx of similar mistakes are made (Chavez et al. 2020, p. 18). This is due at least in part to a lack of clear leadership between the stakeholders, which include the tourism industry, academics, and the government (Chavez et al. 2020, p. 18). Worryingly, there also are no adequate forecasting tools to predict *Sargassum* influxes in many countries in the Caribbean, meaning that governments and industries affected by influxes are unable to prepare until their shores are already being inundated (Liranzo-Gómez et al. 2021, p. 547). Even the most advanced forecasting tools are only able to provide a few days' notice (Liranzo-Gómez et al. 2021, p. 547).

Taken together, the high costs, high labor intensity of cleanup, large amount and unpredictability of *Sargassum* influxes, and lack of leadership in responding to these influxes, indicate that current regulatory controls to solve this problem are inadequate. It is likely that seagrass die-offs in essential manatee habitat will continue so long as sargasso brown tides are not adequately mitigated.

2. Regulatory Mechanisms to Address Loss of Warm-Water Refugia Are Inadequate

Most manatees rely on heated effluent from power plants for warm-water refuge (Valade et al. 2020, p. 2; *see* Power Plants, *supra*). This dependency has developed over the last 50 years, and manatees have displayed consistent site fidelity (Valade et al. 2020, p. 1). However, there is currently no regulatory mechanism in place to account for the continued decrease in availability of warm-water discharge from power plants or, more critically, the expected cessation of all such power plant outfalls over the next 30 years (Valade et al. 2020, p. 1). Springs and thermal basins are the natural alternative to industrial warm-water discharges (*See* Natural Springs; Passive Thermal Basins, *supra*). However, existing regulatory mechanisms are inadequate to protect natural warm-water flows and prevent the degradation of what will be the only remaining warm-water refuge for manatees.

a) Artificial and Natural Warm-Water Habitat Restoration

Local, state, and federal officials have acknowledged a looming crisis for Florida manatees due to the ongoing and projected loss of artificial warm-water habitat (Marine Mammal Commission 2022, entire; Deutsch 2021, entire; Valade et al. 2020, entire). Despite certainty that manatees are in crisis because of declining industrial warm-water refugia, and certainty that current industrial warm-water habitat will disappear in the foreseeable future, no regulatory mechanism has emerged to confront the problem. Potential alternatives, like constructing new warm-water areas, relocating manatees, or artificially heating water, are "fiscally" and "technologically" uncertain (Valade et al. 2020, p. 21). There are important research initiatives underway to better understand potential alternatives (Deutsch 2021, entire). But the "necessary" factors identified by the FWC and USFWS to confront the loss of industrial discharges remain unaddressed.

Addressing the loss of warm-water refugia "will require significant funding." (Valade et al. 2020, p. 1). Yet, currently, there is no dedicated funding source even close to sufficient to respond to the scale of the problem, and prior to the 2021–2022 fiscal year, there was no dedicated funding source at all for solving this problem in Florida (Valade et al. 2020, p. 24). Without substantial funding in the range of $100 million, not including initial outlays for extensive pilot studies, none of the potential alternatives identified by FWC and USFWS has any chance of success (Frazier 2020, entire).

Current budget expenditures from the State of Florida are in no way sufficient or certain enough to solve this problem. The State of Florida has allocated 8 million dollars to manatee habitat restoration in the 2021–2022 budget and another 20 million dollars in the 2022-2023 budget to "enhance and expand the network of manatee acute care facilities, restore access to springs, provide habitat restoration in manatee concentrated areas, expand manatee rescue and recovery efforts, and implement pilot projects like the supplemental feeding trials that took place this past winter" (DeSantis 2022, entire). However, it is uncertain what portion of this budget will be dedicated to projects that will replace industrial warm-water refugia. FWC and the State of Florida have not yet disclosed where the $20 million dollars in funding pledged in the 2022–2023 state budget will go, meaning this expenditure is completely speculative. Since any other funding in future budgets is also speculative, there is no adequate regulatory control currently in place to solve the problem of the loss of industrial warm-water refugia.

FWC's current strategy is to slowly replace industrial warm-water refugia with natural habitats, but even if all of the funding from the previous legislative sessions went to habitat restoration or to replace industrial warm-water refugia sites, that funding is still only around one-fifth of the funding necessary to begin to solve this problem, based on the estimates given by experts in the field, which excludes the cost of expensive pilot studies needed to evaluate the scope of the problem (Frazier 2020, entire). It is also unlikely that all of this funding would be attributed to warm-water habitat restoration, since it must also fund manatee acute care facilities and other emergency expenditures like supplemental feeding, both of which are short-term, reactive responses that fail to proactive address the looming issue of habitat loss, including the loss of warm-water refugia.

So far only two restoration projects currently underway are designed to restore warm-water refuges—the Warm Mineral Springs Restoration Project and the Blue-Springs Manatee Warm-water Enhancement (FWC *Manatee Habitat Restoration Projects*, n.d., entire). The Warm Mineral Springs Restoration Project will restore only six acres of creek and provide habitat for up to 100 manatees, a small fraction of Florida manatees' overall population (FWC *Warm Mineral Springs Restoration Project*, n.d., entire). The Blue-Spring Manatee Warm-water Enhancement will enhance only one acre of a spring along the St. John River (FWC *Blue Spring Manatee Warm-water Habitat Enhancement: Phase III*, n.d., entire). Furthermore, Blue Spring is "one of the most visited state parks in Florida," meaning this restoration project would likely still be inadequate even if it were larger due to other regulatory inadequacies involving human interactions with manatees (*Blue Spring Manatee Warm-water Habitat Enhancement: Phase III*, n.d., entire; *see* Boating and Manatee Behavior, *supra*; Overutilization for Commercial, Recreational, Scientific, or Educational Purposes, *supra*).

Importantly, these habitat restoration projects are also not located at the sites of current industrial warm-water refugia. Manatees show high fidelity to winter sites (Valade et al. 2020, p. 12). For example, when industrial power plants closed in the 1990s, many manatees died of cold stress syndrome because they were unable to change their migration patterns quickly enough to find another warm-water refuge (Valade et al. 2020, p. 37). Not only is a mere 7 acres total of improved warm-water habitat nowhere near sufficient to replace current industrial warm-water refugia sites, there also is no plan in place to ensure that manatees will access these newly improved sites, given their high fidelity to their winter refugia.

Finally, a NOAA grant was awarded to FWC in August of 2021 to study warm-water habitat loss along Florida's Gulf Coast, with a projected timeline of releasing a summary and analysis of existing datasets and various environmental and human factors likely to affect manatees by August 2022 (Deutsch 2021, entire). However, as of October 2022, this summary has not yet been released. Once completed, this study will shape further research initiatives and create a set of recommendations for managers to consider when making decisions that may impact manatees (Deutsch 2021, entire). However, as there has been no information from this study released to the public yet, the effects of these and other speculative proposals remain uncertain and incapable of adequately addressing the ongoing crisis caused by manatee dependence on industrial warm-water discharges.

b) Minimum Flow Levels of Natural Springs

Under state law, Florida's five Water Management Districts (WMDs) must establish Minimum Flows and Levels (MFLs) for natural springs. MFLs are "the minimum flow for a watercourse or the minimum water level for groundwater in an aquifer or the minimum water level for a surface water body that is the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Fla. Stat. § 373.042. For water bodies that are below their minimum flow or level or are projected to fall below their MFL within 20 years, the districts are required to implement a "recovery" or "prevention" strategy to ensure the MFL is maintained over the long-term. *Id*. § 373.0421(2). Generally, the projected increase in Florida's human population will continue to accelerate the degradation of flow levels. Therefore, continued reduction of total spring flows is inevitable because of continued groundwater extraction from the Floridan aquifer for drinking water (Howard T. Odum Florida Springs Institute 2018a, p. 23).

The MFL program covers the two most important natural springs currently used by manatees as warm-water habitat: Blue Spring on the St. Johns River, and Kings Bay at the head of Crystal River (Marine Mammal Commission, entire). While the Kings Bay spring is currently meeting its MFL, Blue Spring is in "prevention" status, meaning it is *not* meeting the MFL standard to avoid significant harm from additional groundwater withdrawals (FDEP *Statewide Adopted MFLs* n.d., entire). The St. Johns River Water Management District (SJRWMD) adopted an MFL for Volusia Blue Spring in 2006 that included five-year phases for measuring the successful restoration of Blue Spring's flow (Howard T. Odum Florida Springs Institute 2018b, section 4.3.4). Substantial reductions in groundwater withdrawals—50% of current rates or more as needed—are necessary to prevent further flow degradation at Florida's springs and set the stage for effective restoration (*See* Howard T. Odum Florida Springs Institute 2018a, p. 5).

However, with at least 900 people moving to Florida every day, "no [water management district] can meet its future demand solely with existing source capacity" (Florida Office of Economic & Demographic Research 2022, p. 1). Therefore, achieving necessary reductions will require major new regulatory mechanisms addressing groundwater withdrawal from the Floridan aquifer (White 2019, entire).

3. Regulatory Mechanisms to Address Boat Strikes are Inadequate

Since the manatee's downlisting in 2017, the five-year average of Florida manatees killed by boats has *increased* (*See* Boat Strikes, *infra*). Under existing regulatory mechanisms, an average of 113 manatees have died annually due to boat strikes over the past five years, not including the hundreds of manatee carcasses not necropsied because of logistical issues caused by the COVID-19 pandemic (Waymer 2020, entire). Existing regulatory mechanisms, such as boating speed zones and the Marine Mammal Protection Act, have failed to prevent the continued increase in manatee mortality by boat strike.

a) Boat Speed Zones

Regulations addressing the risk of boat strikes have been in place in Florida since the 1978 Manatee Sanctuary Act was enacted (Rizzardi 1997, p. 378). The Manatee Sanctuary Act authorizes FWC to restrict the speed and operation of vessels where necessary to protect manatees from collisions and harassment. Fla. Stat. § 370.12(2)(f)–(j). In 2002, the Florida Legislature directed 13 "key" counties to develop Manatee Protection Plans for use in evaluating permits for watercraft access (FWC *Manatee Protection Plans - MPPs* n.d., entire). All 13 counties, as well as 3 additional counties, have approved plans (FWC *Manatee Protection Plans - MPPs* n.d., entire; *see* Figure D.2).

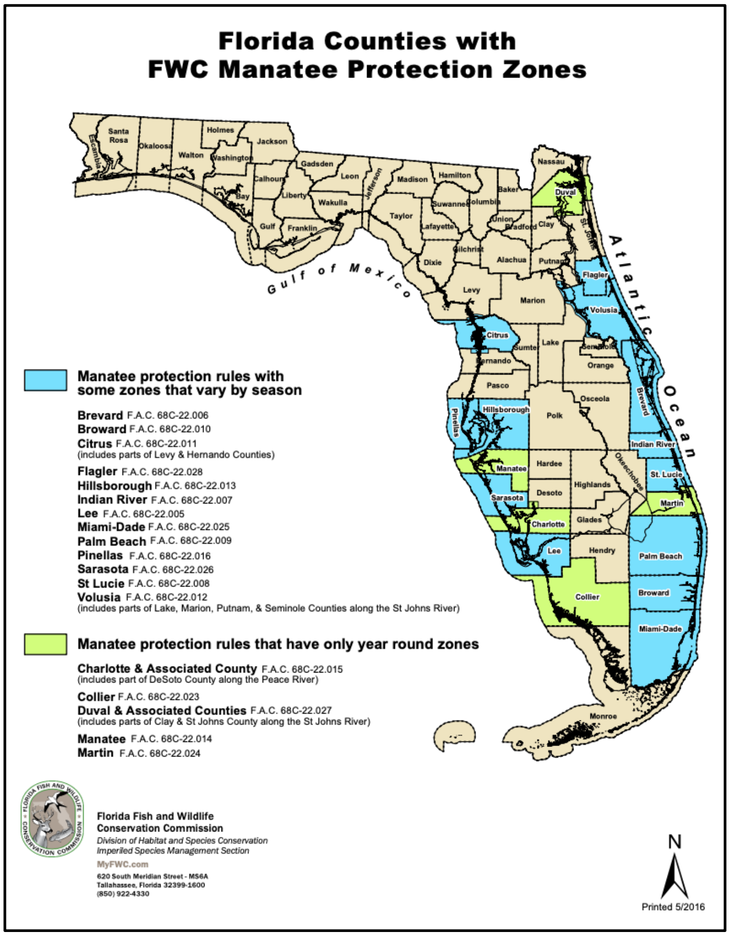


Figure D.2 - Florida counties with FWC Manatee Protection Zones (FWC *Manatee Protection Plans - MPPs* n.d.).

Coordinating with state and local regulations, USFWS has also designated federal manatee protection areas, defined as either refuges or sanctuaries, pursuant to its authority under the ESA and MMPA. 50 C.F.R. § 17.100. In a refuge, certain waterborne activities must be restricted to prevent incidental take of manatees; in a sanctuary, all waterborne activity must be restricted. 50 C.F.R. § 17.102.

Despite the widespread designation of manatee protection zones, boat strikes remain a consistent cause of manatee mortality and injury (*See* Other, *infra*). The 2012–2016 five-year average for boat strike deaths was 83 (FWC *Manatee Mortality Summaries 2012-2016*, entire). After the manatee was downlisted to threatened in 2017, the five-year average of boat strike deaths climbed to 113 in 2021, a known undercount resulting from pandemic limitations (FWC *Manatee Mortality Summaries 2016-2020*, entire; FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire; Waymer 2020, entire). Thus, the mere establishment of manatee protection zones has proven an ineffective regulatory mechanism due to the constantly increasing number of vessels in the water, underenforcement, and boater behavior, as evinced by the large increase in boat-strike mortalities since USFWS downlisted the manatee to threatened.

More than 1,000,000 recreational vessels are registered in Florida, and state officials estimate an additional 100,000 out-of-state vessels are in Florida waters at any given time (Krietz 2022, entire; Zbar 2020, entire). Moreover, since the COVID-19 pandemic began in 2020, boat sales have increased 65% in the state (Zbar 2020, entire). USFWS has succinctly stated the correlation between boat density and manatee mortality: "[s]imply put, more boats in areas used by manatees increases the likelihood of boat strikes to manatees" (USFWS *Environmental Impact Statement* 2003, p. 34; *see also* Ackerman et al. 1995, p. 248). Therefore, even with manatee protection zones in place, more boating activity and watercraft access projects make increased harm to manatees "reasonably certain" (USFWS *Environmental Impact Statement* 2003, p. 33). A 1995 study of manatee mortality by FDEP and USFWS scientists also suggested increased mortality due to more powerful boat engines, a trend that has only accelerated in recent years (Ackerman et al. 1995, p. 248; Larson 2019, entire).

Furthermore, Florida's manatee protection zones are underenforced. Enforcement is a geographical challenge. Florida has hundreds of kilometers of dispersed waterways available to boats and manatees. The presence of law enforcement is a statistically significant indicator of boater compliance with speed zones. Studies suggest, however, that the wide dispersal of manatee protection zones minimizes this effect because law enforcement is unlikely to be visibly present (Gorzelany 2013, p. 35; Gorzelany 2004, p. 219; Jett and Thapa 2010, p. 181). Without effective enforcement, manatee protection zones are essentially voluntary (Gorzelany 2013, p. 35; Jett and Thapa 2010, p. 180). In a Volusia County study comparing actual boater behavior to the same boaters' self-reported behavior, researchers found that "55% of observed boaters failed to fully comply with the mph speed limit estimates corresponding to the idle and slow speed zones" (Jett and Thapa 2010, p. 180). Yet, when the researchers surveyed boaters, only 19% reported having ever received a citation for speeding (Jett and Thapa 2010, p. 174). The most important self-reported factor among speeding boaters was confusing signage, even for highly experienced boaters (Jett and Thapa 2010, p. 182). A possible source of confusion is the "proliferation of unsanctioned signs" leading to a wide variety of sign colors and messages (Jett and Thapa 2010, p. 182; FWC *Approved Uniform Waterway Marker Standards* 2007, p. 16 ("The waters of the state are filled with signs that were posted illegally and only cause to confuse boaters of the legal regulations in addition to being navigational hazards.")). Researchers predict that achieving moderate compliance in areas with large manatee populations is unlikely to prevent watercraft-related deaths (Gorzelany 2004, p. 225).

b) The Marine Mammal Protection Act

At the federal level, the Marine Mammal Protection Act (MMPA) also protects manatees from boat strikes insofar as it imposes a general moratorium on "taking" a covered animal without a permit. 16 U.S.C. § 1371. The MMPA only authorizes "take" where it would have a negligible impact on a species. § 1371(a)(5)(A). In 2002, USFWS initiated a rulemaking to authorize the incidental take of manatees resulting from government activities related to watercraft or watercraft access projects. Florida Manatees; Incidental Take During Specified Activities, 67 Fed. Reg. 69,078 (Jan. 9, 2003).

However, USFWS subsequently concluded that take levels were already too high to establish an MMPA take rule for watercraft activities. Marine Mammals; Incidental Take During Specified Activities, 68 Fed. Reg. 24,700 (May 8, 2003). Thus, a no-take rule still applies to the manatee under the MMPA. The Final Environmental Impact Statement for the final rule found that "the likelihood of boat collisions with manatees is increased proportional to the number of boats using the area" (USFWS *Environmental Impact Statement* 2003, p. 34). More generally, "The frequency and magnitude of boat-manatee interactions, such as boat strikes and separation of calves from their mothers, *are projected to increase with boat density*" (USFWS *Environmental Impact Statement* 2003, p. 76 (emphasis added)).

Despite these findings, government activity related to watercraft access projects that impacts manatees has remained consistent (Center for Biological Diversity 2014, entire (citing NMFS data)). FDEP and the U.S. Army Corps of Engineers (USACE) do not keep a comprehensive database specific to watercraft access permits. Recent permit issuances illustrate that the permitting of new facilities requires construction activities to account for the presence of manatees, such as requiring vessels associated with the construction project to observe manatee speed zones (USACE 2011, entire).

But the agency does not address watercraft access more generally, even though the agency has acknowledged in its previous EIS for incidental take under the MMPA that every increase in boat access incrementally increases harm to manatees (USFWS *Environmental Impact Statement* 2003, p. 76). Thus, the granting of permits for watercraft access projects violates the MMPA's take prohibition, but USACE continues to grant such permits. For instance, USACE recently issued a permit for the expansion of a marina in Port Richey, including "a new 2,341 square foot fixed dock with 14 wet slips" and "a new 2,717 [square foot] floating dock with 16 wet slips" (USACE 2020, entire). USACE issued the permit after a "not likely to adversely affect" finding by USFWS (USACE 2020, entire). Therefore, the expansion of watercraft access and increasing boat density in Florida make clear that the MMPA is insufficient to prevent continued manatee mortality and harassment caused by boating activity.

4. Regulatory Mechanisms to Address Climate Change Are Inadequate

The immediate reduction of greenhouse gas emissions is essential to stabilize the climate system that adversely affects manatees (*See* Climate Change, *infra*). According to the most recent Intergovernmental Panel on Climate Change (IPCC) report, the near-term effects of climate change are locked in through at least 2040 (IPCC 6th Assessment Report 2021, p. SPM-18). Therefore, if even the most optimistic emissions scenario is achieved—keeping warming below a 1.5 degree Celsius increase through massive, coordinated global action—the benefits of decarbonization and adaptation would not be realized until after 2040 IPCC 6th Assessment Report 2021, p. SPM-18). Accordingly, under *any* emissions scenario, manatees will continue to face the threats described for the next two decades and likely beyond (*See* Climate Change, *infra*). Therefore, existing regulatory mechanisms at both the international and national level are unequivocally inadequate to achieve an optimistic climate scenario. Current regulations make at least 1.5ºC of warming likely by 2040, triggering "unavoidable increases in multiple climate hazards" and "multiple risks to ecosystems" (IPCC 2022, pp. SPM-7, 13).

a) Paris Agreement and COP26

The Paris Agreement represented a milestone in climate change global governance. One hundred and ninety-seven countries are party to the agreement (UNFCCC 2022, entire). Under former President Donald Trump, the United States withdrew from the Paris Agreement on November 4, 2020 (McGrath 2020, entire). President Biden rejoined the Paris Agreement in February of 2021 (Blinken 2021, entire). Signatories agree to individually tailored carbon reduction targets called "nationally determined contributions" (NDCs) (UNFCCC 2022, entire). However, there are no specific requirements for NDCs, they are purely voluntary, and no enforcement mechanism exists if a country fails to meet its NDC (Center for Climate and Energy Solutions 2021, entire). Therefore, as a strictly voluntary framework for speculative future action, it is neither "existing" nor "regulatory" under the plain language of the Endangered Species Act, and as defined by USFWS and federal courts. 16 U.S.C. § 1533(a)(1)(D) (*See* Inadequacy of Existing Regulatory Mechanisms, *supra*).

Since 2010, the United Nations Environment Programme (UNEP) has released an Emissions Gap report describing the best available scientific evidence of current and estimated emissions compared to the targets specified by international agreements to keep warming below 2 °C. The "emissions gap" is the difference between "where we are and where we need to be" to confront climate change (UNEP 2018, Executive Summary; *See* Figure D.3). And every year since the Paris Agreement, the "emissions gap" has remained "alarmingly high." (UNEP 2017, Executive Summary). UNEP issued the 2020 report after three consecutive years of increased emissions, finding that the gap had widened once again (UNEP 2020, Executive Summary, p. iv).

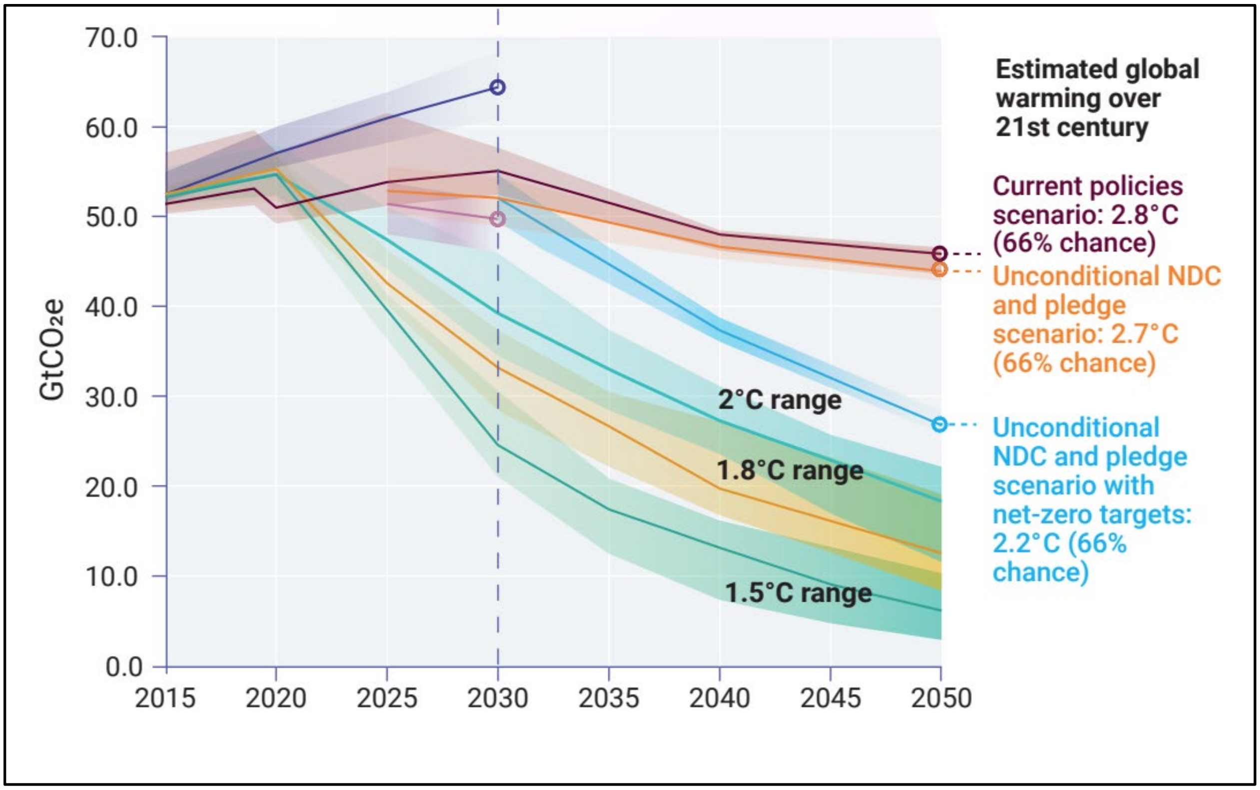


Figure D.3 - Estimated global warming over the 21st century (UNEP Emissions Gap Report 2021, Executive Summary, p. xxv)

In hopes of bridging the gap, Paris signatories met in November 2021 at the COP26 climate summit to revisit NDCs and other climate initiatives. One hundred and fifty-one countries, including the United States, submitted new NDCs. (UN Climate Change Secretariat 2021, p. 2; UNEP 2021, Executive Summary, p. xviii) The emissions gap, however, persists. Even if every country met its new NDC, the aggregate impact would be insufficient to meet the Paris climate goals (UNEP 2021, Executive Summary, p. xvi). Moreover, the same 2021 report makes clear that very few countries are on track to meet their old or new NDCs. Amidst marginally improved *pledges*, very few concrete *policies* suggest any momentum toward keeping climate change below 2 ℃. “There is an urgent need to back these pledges up with near-term targets and actions that give confidence that net-zero emissions can ultimately be achieved and the remaining carbon budget kept” (UNEP 2021, Executive Summary, p. xx).

Thus, although the Paris Agreement is an important milestone in the fight for a stable climate, it remains voluntary and non-binding.Even if current NDCs were fully implemented and made enforceable, the Paris framework still falls well short of an adequate response to the climate change threat faced by manatees (and many other species).

b) United States Policy

In addition to rejoining the Paris Agreement in 2021, President Biden also issued an Executive Order announcing a “whole of government” approach to climate change on January 27, 2021 (Tackling the Climate Crisis at Home and Abroad 2021, entire). Even with these welcome policy changes, existing United States regulatory mechanisms are inadequate to meet

Paris obligations. The most recent Emissions Gap Report warned that the United States was not on track to meet its first NDC and that "significant additional efforts" are necessary to make progress toward its revised NDC (UNEP 2021, Executive Summary, p. viii). Therefore, because the United States is the world's second largest current greenhouse gas emitter per annum, and one of the largest emitters per capita, the lack of a comprehensive and effective United States climate policy makes the worst climate crisis scenarios highly likely (Friedlingstein et al. 2021, pp. 19–20, 85).

5. International and Foreign National Regulatory Mechanisms are Inadequate to Ensure Manatee Survival

a) International

Outside of the United States, manatees are generally covered by a combination of national and international regulations, with some exceptions. Internationally, the manatee is recognized as among the endangered species most threatened with extinction and is thus listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES Appendices 2021, entire. Listing under CITES generally precludes commercial trade and requires import and export permits for any specimens (live, dead, or parts and products). CITES Art. III. Permit issuance requires a finding of no impact to the survival of the species in the wild and that the specimen was lawfully acquired. *Id*. Nonetheless, poaching continues to pose a major problem for many Antillean subpopulations of manatees to this day (*See* Overutilization, *supra*).

Regionally, Caribbean governments established a legal framework for environmental protection called the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (1983), or the Cartagena Convention (Vanzella-Khouri 1998, pp. 54–55). The Convention is supported by the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region, which includes the Antillean manatee as a priority species (Vanzella-Khouri 1998, p. 70).

Every country in the Antillean manatees' range has acceded to either CITES or the SPAW protocol or both, except for Haiti which is not bound by either agreement (*See* Figure D.4).

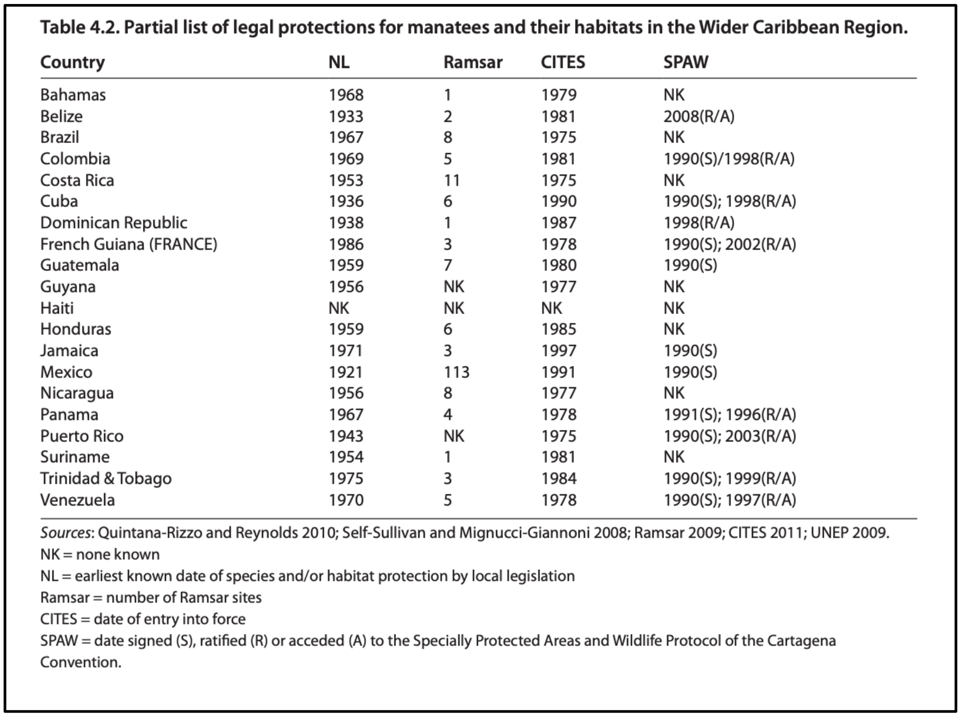


Table 4.2. Partial list of legal protections for manatees and their habitats in the Wider Caribbean Region.

Country	NL	Ramsar	CITES	SPAW
Bahamas	1968	1	1979	NK
Belize	1933	2	1981	2008(R/A)
Brazil	1967	8	1975	NK
Colombia	1969	5	1981	1990(S)/1998(R/A)
Costa Rica	1953	11	1975	NK
Cuba	1936	6	1990	1990(S); 1998(R/A)
Dominican Republic	1938	1	1987	1998(R/A)
French Guiana (FRANCE)	1986	3	1978	1990(S); 2002(R/A)
Guatemala	1959	7	1980	1990(S)
Guyana	1956	NK	1977	NK
Haiti	NK	NK	NK	NK
Honduras	1959	6	1985	NK
Jamaica	1971	3	1997	1990(S)
Mexico	1921	113	1991	1990(S)
Nicaragua	1956	8	1977	NK
Panama	1967	4	1978	1991(S); 1996(R/A)
Puerto Rico	1943	NK	1975	1990(S); 2003(R/A)
Suriname	1954	1	1981	NK
Trinidad & Tobago	1975	3	1984	1990(S); 1999(R/A)
Venezuela	1970	5	1978	1990(S); 1997(R/A)

Sources: Quintana-Rizzo and Reynolds 2010; Self-Sullivan and Mignucci-Giannoni 2008; Ramsar 2009; CITES 2011; UNEP 2009.
NK = none known
NL = earliest known date of species and/or habitat protection by local legislation
Ramsar = number of Ramsar sites
CITES = date of entry into force
SPAW = date signed (S), ratified (R) or acceded (A) to the Specially Protected Areas and Wildlife Protocol of the Cartagena Convention.

Figure D.4 - Partial list of protections for Antillean manatees and their habitats in the Caribbean (Self-Sullivan and Mignucci-Giannoni 2012, p. 41)

International measures for manatee protection are inadequate for several reasons. First, the foreign governmental agencies tasked with manatee protection are generally "small and understaffed" (Self-Sullivan and Mignucci-Giannoni 2012, p. 41). Thus, international agreements and local laws are underenforced and violations are underreported (Sheehy 2004, p. 468–70). Second, manatee population estimates in this region are difficult to assess. For example, the International Union for Conservation of Nature (IUCN) reports a significant decline in Antillean manatee numbers in most countries in the region over the past 30 years, but those reports are estimates based on anecdotal evidence and interviews with local people rather than systematic population studies (Deutsch et al. 2008, p. 7). Without more reliable data, it is "difficult to craft well informed conservation and management decisions both regionally and locally" (Rodas-Trejo et al. 2008, p.323). Nonetheless, as demonstrated below, the most recent studies of manatee mortality in the region confirm worsening threats to the Antillean manatee unsolved by international and national protections.

b) Mexico

Legislation in Mexico prohibits the hunting of manatees and considers them an endangered species. Norma Oficial Mexicana NOM-059-ECOL-1994 (Rodas-Trejo et al. 2008, pp. 322–3).

Like manatees in Florida, the manatees in Tabasco face threats from climate change, the spread of hazardous wastes, and human population growth and development (Rodas-Trejo et al. 2008, p. 330; *see* Coastal Development, *supra*). In 2018, the Mexican government reported at least 48 manatee deaths in the Tabasco region attributed to algal blooms and polluted waters (Núñez-Nogueira and Uribe-López 2021, p. 1; *see* Eutrophication, *supra*). Another major mortality event happened there in the first half of 2019, killing at least another 13 manatees (Núñez-Nogueira and Uribe-López 2021, p. 1). According to researchers, "Mexico has yet to invest the economic resources required to save [manatees]" (Núñez-Nogueira and Uribe-López 2021, p. 1). Manatee habitat remains dangerously unprotected from agrochemicals and petroleum industry byproducts (Núñez-Nogueira and Uribe-López 2021, p. 1). Mexico has protected some wetlands habitat, but not enough, and habitat destruction continues in unprotected areas of the wetlands. "Because of the mobility of manatees throughout the wetland system, populations may be at risk from human activity in these other localities" (Núñez-Nogueira and Uribe-López 2021, p .2).

For the manatees in the Yucatan region, the majority congregate in three different marine protected areas (MPAs): (1) Chetumal Bay Manatee Sanctuary (CHB) and Xcalak-Mahahual coast on the border with Belize; (2) the Sian Ka'an Biosphere Reserve (SKBR); and (3) the coastal zone with artesian springs between the cities of Playa del Carmen and Tulum (Herrejón et al. 2020, p. 2). Researchers rate these MPAs as generally having good or intermediate effectiveness (Herrejón et al. 2020, p. 9). Still, the conservation goals of the MPAs are often stymied by understaffing. Thus, "prohibited and illegal practices are carried out within all three MPAs as a result of the lack of surveillance personnel" (Herrejón et al. 2020, p. 9). Manatees also leave the MPAs. In 2017, at least 20 manatees died by boat strike in Belize (Yucatan Times 2017, entire). Mexican state researchers identified the manatees as part of the Chetumal Bay Manatee Sanctuary population that seasonally traveled to Belize (Yucatan Times 2017, entire).

Thus, while effectively managed MPAs and habitat sanctuaries in Mexico would be an important conservation tool, they are presently inadequate to prevent increasing mortality of manatees in the region.

c) Belize

The manatee is protected in Belize under the Wildlife Protection Act, No. 4 (1981). Under this act, no person shall "kill, take or molest by any method" a manatee. Chapter 220, Part I. Belize established a Manatee Recovery Plan in 1998 that included designation of three manatee sanctuaries: Corozal Bay, Swallow Caye, and Southern Lagoon (Auil 1998, entire).

Belize's tourism industry has developed rapidly in the last few years, causing what researchers describe as an "alarming increase in boat-related mortality for Belize" as a signal of an "an uncontrolled and unattended threat" to manatees (Castelblanco-Martínez et al. 2018, abstract; *see* Boat Strikes and Mortality, *infra*). Heavily trafficked tourist areas remain unregulated and without enforcement (Channel5 Belize 2019, entire). Manatees in Belize will continue to die by boat strike until new protective legislation is put in place (Channel5 Belize 2019, entire).

Existing international, federal, state, and local regulations are inadequate to protect manatees from extinction. In the 2017 downlisting, USFWS emphasized the continued threats of habitat degradation, loss of warm-water refuge, boat strikes, and the intensification of these factors caused by human population growth. Final Rule 2017, 82 Fed. Reg. at 16,668. USFWS warned that "[n]ew and ongoing conservation efforts will be needed to prevent the species from becoming endangered in the foreseeable future." *Id*. at 16,684. But threats to the manatee including boat strikes, harmful algal blooms, seagrass loss, climate change, and loss of warm-water habitat have all escalated since 2017 despite existing regulatory mechanisms (*See* Summary of Factors, *supra*).

d) Brazil

Even though the manatee population in Brazil has been classified as endangered by the IUCN and on Brazil's Red List since 2014, the most recent population models indicate that current populations will decrease by at least 80%, if not more, in the future (Oliviera de Meirelles et al. 2022, abstract). One recent study concluded that "the species national extinction risk needs to be reassessed, and the National Action Plan effectiveness evaluated," given the poor prognosis for Brazilian manatees (Oliviera de Meirelles et al. 2022, abstract). This anticipated decline indicates that the international regulatory controls in place, including IUCN listing and listing on Brazil's Red List, are inadequate to prevent future population decline.

E. Other Natural or Manmade Factors Affecting Manatees' Continued Existence

Natural and manmade factors remain a significant threat to the manatees' continued existence. Current factors that adversely affect manatees include boat strikes, marine debris entanglement and ingestion, injury from water control structures, exposure to contaminants, loss of genetic diversity, and the negative effects of climate change. Reducing such threats to all manatees now is crucial, because the future presents even greater challenges from increasing human populations and a rapidly changing climate (Edwards 2013, p. 735).

1. Boat Strikes

a) Prevalence of Boat Strikes

Boat strikes are a common cause of sirenian mortality around the world where populations of people and sirenians live in proximity (Owen et al. 2017, p. 322; *see* Figure E.1). The prevalence of death and injury of the West Indian manatee resulting from watercraft collisions in Florida is particularly acute and well documented, and only increases as the human population in Florida continues to grow (Marsh et al. 2011, p. 280).

Figure E.1 - West Indian manatee bearing boat propeller scars (Image Credit: Cora Berchem, found from Harvey 2020, entire)

Manatees are subject to significantly more sublethal watercraft strikes than any other studied marine mammal (Basset et al. 2020, pp. 403, 405). In a 10-year study of Florida manatee carcasses recovered from 2007–2016, researchers determined that 1 in 4 adult manatees had been hit 10 or more times (Basset et al. 2020, p. 395). Furthermore, 96% of adults, 70% of subadults, and 34% of calves had watercraft-related scars (Basset et al. 2020, p. 395). With only 4% of adults devoid of these scars, it appears exceedingly rare that individuals reach late adulthood without having been struck multiple times (Basset et al. 2020, p. 405).

A variety of factors contribute to the high rate of boat strikes on manatees. Manatees share the Florida coastal and river system with large concentrations of watercraft—perhaps exceeding two million registered and unregistered vessels (*See* FWC *2021 Boating Accident Statistical Report* 2022, p. IV; Figure E.2). Manatees also spend most of their time within 1.25 meters of the water's surface, where they are within a boat's "strike range" and at greatest risk of being injured by watercraft (Edwards et al. 2016, p. 4). Manatees also typically occupy shallow water habitats, which present the additional risk of a confined space with limited opportunity for escape from approaching watercraft (Edwards et al. 2016, pp. 8, 10). A manatee's opportunity for escape from watercraft is further diminished by its naturally slow movements compared to dolphins and pinnipeds (Basset et al. 2020, p. 403; *see* Species Description, *supra*).

Figure E.2 Distribution of vessels registered in Florida by owner address (Behringer and Swett 2011, p. 4)

Boat strikes are increasing, with further increases expected in the future due to anticipated growth in human population size and numbers of vessels on the water (Bassett et al. 2020, p. 402; Marsh et al. 2011, p. 287; *see* Figure E.3; Regulatory Inadequacy, *supra*). Florida leads the nation for boat ownership, surpassing one million registered vessels in 2022, and it is estimated that up to one million unregistered vessels also actively use Florida's waters (Knowles 2022, entire; FWC, *2021 Boating Accident Statistical Report* 2022, pp. IV, 2). The unregistered segment of the boating population appears to still be growing (FWC *2021 Boating Accident Statistical Report* 2022, p. IV). As coastal development continues to expand and boats increase in number, boat strikes will remain an ever-present and increasing threat to manatee survival (Marsh et al. 2011, p. 282).

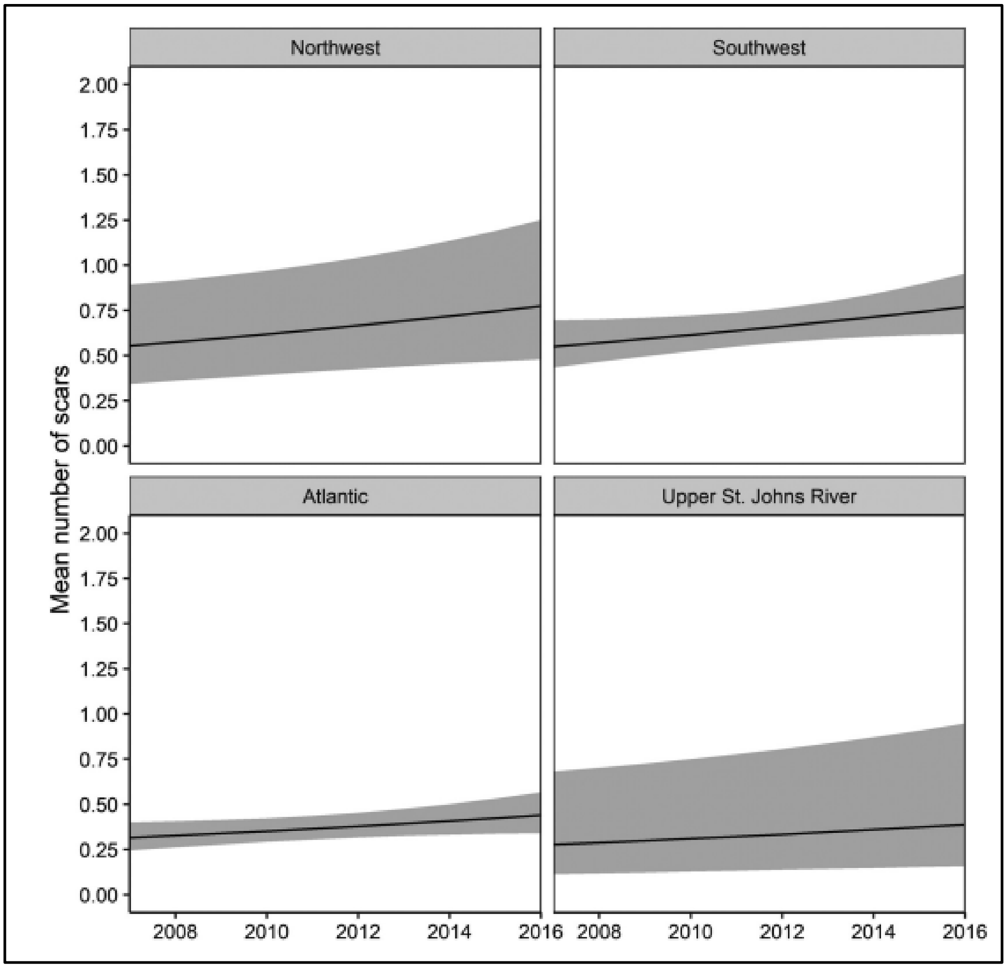


Figure E.3 - Estimated mean number of scar patterns on Florida manatee calves, 2007–2016 (Bassett et al. 2020, p. 402)

b) Boat Strikes and Mortality

Manatees hit by watercraft can suffer fatal injuries from sharp, penetrating trauma from propeller blades, or blunt, crushing trauma from hull collisions (Owen et al. 2017, p. 322; Marsh et al. 2011, p. 280). Both types of injury can result in acute death from extensive hemorrhage and tissue damage (Owen et al. 2017, p. 322).

Watercraft strikes are the leading cause of *determined* anthropogenic manatee mortality in Florida and contribute greatly to the number of manatees requiring rescue there (Reinert et al. 2017, p. 416; FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire; FWC *2022 Preliminary Manatee Mortality Report,* 2022, entire). Boat strikes are purported to account for 20–25% of reported Florida manatee mortalities (Bassett et al. 2020, p. 395). However, this figure likely drastically underrepresents the number of manatee deaths caused by watercraft. The cause of death of many manatee carcasses removed from Florida waters are undetermined (Marsh et al. 2011, p. 281), and most collisions are not reported by boat operators, who often claim to be unaware of the nature of the object they have struck (Marsh et al. 2011, p. 283). Therefore, it is estimated that manatee deaths caused by boat strikes likely comprise a high percentage of undetermined causes of manatee mortality (Bassett et al. 2020, p. 396).

Furthermore, most manatees killed by boats in Florida are adults (Marsh et al. 2011, p. 283). This is particularly concerning, as life history modeling shows that adult manatee survival is the most important parameter in maintaining positive population growth rates for this species (Marsh et al. 2011, p. 283).

In Belize, boat strikes were the predominant cause of death from 1996–2003, and the trend is increasing; in the Drowned Cayes area, an ongoing manatee photo-identification project indicates that 44% of the animals using the area bear boat scars (Quintana-Rizzo and Reynolds 2010, pp. 22–23). Manatees are most vulnerable to collisions in the waters near Belize City because many water taxis travel from the city to the cays nearby (Quintana-Rizzo and Reynolds 2010, pp. 22–23). Belize's cruise tourism industry has led more manatees to die by boat strike, and mortality statistics are rising in general (Kase 2018, entire). Thirty-seven manatees died in 2017 followed by a record-setting 49 manatees in 2018 (ECOMAR Belize, n.d., entire). Forty-seven manatees died in 2019. Because of the tourism slowdown caused by the outbreak of the coronavirus in 2020, only 11 manatees were reported to have died from boat strikes. But tourism is once again ramping up, bringing cruise ships and speed boats to Belize's waters (Channel5 Belize 2021, entire).

c) Boat Strikes and Injury

Boat strikes that do not immediately result in manatee mortality can still lead to serious sublethal injuries, prolonged disability, and synergistic harm with other stressors like cold stress. Sublethal injuries inflicted by boat strikes are common in the Florida manatee (Marsh et al. 2011, p. 284; Owen et al. 2017, p. 323; *see* Figure E.4) and have negative implications for manatee health, behavior, and reproductive success (Basset et al. 2020, p. 405).

Figure E.4 - Female manatee found with a severe injury to tail caused by boat propeller (Image credit: Matt Heyde, FOX 35 Orlando 2019)

Manatee bones are uniquely dense, providing stability in the water, which enables manatees to maintain neutral buoyancy during diving, resting, and feeding (Reep and Bonde 2021, p. 84). As a direct consequence of their density, manatee bones are also more brittle, have lower fracture toughness compared to the bones of other animals, and shatter easily when broken (Marsh et al. 2011, p. 283). These characteristics preclude the typical mammalian bone healing process, so that even a mild strike may break a bone that does not heal well, resulting in a slow death from a bone infection called osteomyelitis (Reep and Bonde 2021, p. 84).

Short-term consequences of sublethal injuries from boat strikes include pain, elevated stress response, and behavioral changes, as well as increased energy expenditure (Basset et al. 2020, p. 401). In Florida manatees, injuries often affect the lungs and bones resulting in fractures, hydrothorax (fluid in the chest cavity), subcutaneous emphysema (air under the skin), and pneumothorax (air leaking from damaged lungs or externally into the thorax) (Owen et al. 2017, p. 323). While not always fatal, these injuries and subsequent pathologies hamper the animal's ability to move, breathe, maintain a stable position in the water, and dive (Owen et al. 2017, p. 323).

Secondary infections from sublethal injuries are common, and include sepsis (septicemia, circulating infection in the tissues and bloodstream), pyothorax (infection and pus in the thorax), pleuritis (inflammation of the lung surface and internal rib cage) and pleuropneumonia (infection in and around the lungs), peritonitis (infection of the tissues which surround the abdominal organs), osteomyelitis (infection within bone) and cellulitis (infections deep in the skin) (Owen et al. 2017, p. 323). Such secondary infections commonly result in chronic debility, and severe disease can take up to 18 months to resolve even with treatment in rehabilitation facilities (Owen et al. 2017, p. 323).

Longer-term impacts of sublethal injuries include decreased mobility due to skeletal remodeling of fractured bone, decreased swimming efficiency (if large portions of the fluke are lost), compromised immune function, and decreased reproductive output (if reproductive systems are damaged) (Basset et al. 2020, p. 402).

d) Boating and Manatee Behavior

The noise associated with fishery and recreational watercraft also adversely affects manatee behavior, with high levels of boat presence near seagrass beds known to negatively correlate with meadow usage by manatees, which reduce their time spent feeding in response (Owen et al. 2017, p. 323; *see also* Marsh et al. 2011, p. 287; Boating and Recreational Disturbance, *supra*). Manatees also spend less time milling and socializing with one another when there are high levels of noise (Owen et al. 2017, pp. 323–24). Such impact on the manatee's habitat results in reduced reproductive success and physical separation of potential breeding individuals, ultimately precluding opportunities to mate and affecting the genetic fitness in the population (Bonde and Flint 2017, pp. 309–10; *see* Genetic Diversity, *infra*). Heavy vessel traffic also obstructs manatees' use of certain warm-water refugia and separate mother and calf pairs (Owen et al. 2017, p. 323–24; Marsh et al. 2011, p. 287; *see* Habitat, *supra*; Strandings, *supra*).

2. Marine Debris

a) Entanglement

Manatees are known to become entangled in various types of fishing gear and other marine debris (Reinert et al. 2017, p. 415). Because Florida is the top recreational fishing destination in the United States, there is plenty of opportunity for lost or discarded monofilament to end up in coastal waters and become a hazard for manatees and other marine life (Reinert et al. 2017, p. 424). In a 2017 study of manatee necropsy records from 1993–2012, entanglement accounted for 21.8% of all rescues, followed by watercraft injury at 20% (Reinert et al. 2017, p. 420). Although it was the primary cause of death for less than 1% of the manatee carcasses examined, marine debris was the leading anthropogenic reason for manatee rescue and rehabilitation during this timeframe (Reinert et al. 2017, pp. 416, 422). The nets, lines, hooks, and traps used in commercial and recreational fisheries are sources of entanglement for manatees (Owen et al. 2017, p. 321). Of 301 cases of manatee entanglement and related rescue from 1993 to 2012, 49.5% involved entanglements in trap lines and 26.9% involved monofilament fishing line (Reinert et al. 2017, p. 420). Monofilament entanglement cases are particularly problematic as they are difficult to detect early. Monofilament is almost transparent in the water, and as a result, an appendage entangled in monofilament may go unnoticed until the damage is extensive, or additional debris accumulates on the entanglement (often forming a ‘nest’ of natural and anthropogenic debris) (Reinert et al. 2017, p. 424).

Although banned in Florida, gill nets are a significant source of incidental manatee capture and can also lead to subsequent stranding internationally (Tejo & Maria 2016, p. 29). For example, incidental capture is the largest cause of manatee mortality in Hispaniola (Tejo & Maria 2016, p. 72).

Entanglement can result in anything from impeded movement to death by drowning if it prevents manatees from surfacing to breathe (Owen et al. 2017, p. 318; Reinert et al. 2017, p. 418; Hieb et al. 2021, p. 677). Entanglement can also produce severe injury affecting deep tissue that can cause limb strangulation, infection, loss of flippers, and ultimately death (Butterworth 2017, p. 318; Marsh et al. 2011, p. 318). Tissue injury from entanglement can occur as a result of the abrasive and cutting nature of some materials, with the animal’s swimming motion likely to further exacerbate the injury in many instances (Owen et al. 2017, p. 319). In severe cases, multiple tissue layers can become necrotic, and, in some instances, infected by opportunistic pathogens (Owen et al. 2017, p. 319; *see* Disease or Predation, *supra*).

Entanglement also causes mechanical trauma, resulting in compromised function, and bone fractures, resulting in disease or complete loss of limb capacity (Owen et al. 2017, p. 319). Extrapolating from other species, it is probable that manatee death in these chronic cases occurs over a period of months (Owen et al. 2017, p. 319).

Florida manatees are exploratory in nature, and this may predispose them to entanglement (Owen et al. 2017, p. 318). Manatees assess objects by using sensory vibrissae, primarily located on the snout, or actively touching with flippers (Hieb et al. 2021, p. 677). Consequently, manatees most often become entangled at the flippers, which can restrict access to axillary (armpit) mammary glands (Hieb et al. 2021, p. 677). In cases where calf access to milk via nursing is impacted by active or chronic entanglement, entanglement can also have generational impacts with reduced fitness of offspring (Reinert et al. 2017, p. 423).

A significantly higher number of adult female manatees become entangled compared to males (Reinert et al. 2017, p. 423). Their increased vulnerability to entanglement may be a function of their larger size (larger manatees have a greater chance of getting entangled) or of their behavior during pregnancy and lactation (Reinert et al. 2017, pp. 422–23). Pregnant or lactating female manatees may intentionally rub against rope or heavy line in the environment to try to relieve milk engorged teats (located at the flipper axilla), occasionally becoming entangled in the process (Reinert et al. 2017, p. 423).

Previous and existing entanglements may also beget future entanglements. An existing entanglement may become an irritant and cause a manatee to rub affected flippers against rope or lines to seek relief, thereby re-entangling the manatee in new marine debris (Reinert et al. 2017, p. 423). This effect has been observed in previously rescued manatees, which had trap line or other rope entanglements over existing, long-term monofilament entanglements (Reinert et al. 2017, p. 423). The manatee isolates injuries with a fibrotic reaction (scar tissue) to reduce the possibility of systemic infection, but this process alone may not remove the entanglement remains (Reinert et al. 2017, p. 423). The scar tissue itself may become irritating and heal with swollen irregularities or notches along flipper or tail margins that may be more likely to catch future debris (Reinert et al. 2017, p. 423; See Figure E.5).

Figure E.5 - Serial entangling manatee from the Florida Keys, Monroe County. Injuries include a partially amputated and swollen right flipper, a healed entanglement scar on the upper left flipper, and an entanglement wound on the lower left flipper, the reason for rescue here. From 1993 to 2012, this manatee was rescued 7 times for entanglement. All 7 occasions included monofilament on 1 or both flippers (Image credit: FWC files; all activities were conducted under the USFWS permit # MA770191) (Reinert et al. 2017, p. 423).

b) Ingestion

Manatees also accidentally ingest marine debris, including when they mistake it for food or try to explore it with their prehensile upper lips and sensory bristles (Owen et al. 2017, p. 317; Marshall et al. 1998, pp. 285–86). Debris often accumulates in the shallow waters where manatees feed, and becomes entrapped in mats of vegetation, increasing the risk of incidental ingestion (Owen et al. 2017, p. 317). Foreign objects are often found in the gastrointestinal tracts of dead manatees (Reinert et al. 2017, p. 415).

Mortality due to internal injuries from ingesting rope, fishing line, hooks or other foreign objects has been reported in manatees (Marsh et al. 2011, p. 318). In a 1991 study on stranded manatee carcasses in Florida, debris was found in the gastrointestinal tract of 14% of the 439 examined manatees (Owen et al. 2017, p. 317). Pieces of monofilament fishing line and fish hooks or wire were the most commonly ingested debris, but a large assortment of other material including string, rope, paper, cellophane and rubber bands was also found (Owen et al. 2017, p. 317). In a later 2017 study of manatee necropsy records from 1993 to 2012, over 11% of manatees had ingested or showed evidence of entanglement in marine debris (Reinert et al. 2017, p. 415). Fishery-related items were associated with 81% of marine debris ingestion deaths and primarily consisted of monofilament fishing line, often in association with hooks (Reinert et al. 2017, p. 418). Other debris included fabrics, sponges, string, rope, wire, balloons, rubber gloves, polystyrene foam, and decorative plastic grass (Reinert et al. 2017, p. 418).

Marine debris ingestion can result in acute death when the gastrointestinal tract is punctured by sharp objects (e.g., hooks and wire), or when intestinal rupture occurs, sometimes secondary to impaction (Owen et al. 2017, p. 317). Linear debris such as monofilament line can cause intestinal plications (folding up of loops of the gut pulled together by the internal monofilament line), and intussusceptions with subsequent intestinal necrosis, rupture and peritonitis (Owen et al. 2017, p. 317–318).

The sublethal impact of marine debris can include extreme weight loss as a result of marine debris obstructing the gastrointestinal tract and causing a physical impediment to the passage of food and reducing nutrient absorption (Owen et al. 2017, p. 317). Debris in the gastrointestinal tract can also reduce food intake by stimulating a feeling of satiety or discomfort (Owen et al. 2017, p. 317). Marine debris can cause discomfort through abrasion or erosion and subsequent ulceration of the mucosal surface of the gastrointestinal tract (Owen et al. 2017, p. 317). Ingested debris may also cause manatees to become more buoyant, preventing the animal's ability to submerge and dive to access seagrass beds and avoid threats at the water's surface (Owen et al. 2017, p. 317).

Ingestion of microplastics can also lead manatees to experience toxicosis (Owen et al. 2017, p. 318). Microplastics are small plastic particles that are introduced to the marine environment through the breakdown of larger plastic items or after their use as microbeads in abrasives such as cosmetic materials (Owen et al. 2017, p. 318). These plastics often contain polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT), which are known to compromise immunity and cause infertility in animals, even at very low levels (Owen et al. 2017, p. 318).

The persistent and continued observation of active or prior entanglement, the discovery of ingested marine debris during necropsy, and continued reports of live, entangled manatees by the public indicate that marine debris remains a constant hazard for Florida manatees (Reinert et al. 2017, p. 425) Overall, entanglement in and ingestion of marine debris demonstrably impact the welfare of the Florida manatee and can hamper its ability to survive and reproduce, highlighting the continuing problem of marine debris in the estuarine environment.

3. Water Control Structures

In Florida, crushing and drowning in locks and gates on canals and other water control structures accounted for about 4–5% of total deaths of manatees from 1976–1992 but may have declined in recent years with installation of pressure sensors and acoustic arrays at some structures (Marsh et al. 2011, pp. 317–318). Official sources claim to have nearly eliminated this source of mortality, but in 2014 the 5-year average remained at 4.2 deaths (compared to 6.5 deaths per year in preceding 20 years). Final Rule 2017, 82 Fed. Reg. at 16,675 (citing FWC FWRI Manatee Carcass Salvage Database, 2016, unpublished data). Water control structures are estimated to account for 1–2% of manatee deaths between 2016 and 2021 (FWC *Manatee Mortality Summaries 2016-2020*, entire; FWC *2021 Preliminary Manatee Mortality Report*, 2021, entire).

4. Contaminants

a) Glyphosate

Glyphosate is the most utilized herbicide worldwide and is used intensively in sugarcane plantations in southern Florida (De María et al. 2021, p. 2). Glyphosate-based herbicides are primarily applied to genetically modified crops (e.g., soybean, maize, and cotton), but they have also been used on non-genetically modified crops for tillage system replacement, to kill weeds, or to speed up harvest operations (De María et al. 2021, p. 2). For sugarcane, glyphosate is used as a ripener to increase the total recoverable sugar and to control invasive aquatic plants (De María et al. 2021, p. 1–2). Glyphosate adheres strongly to particles, and this strong binding allows for long distance transport and persistence in the environment, as binding may help protect glyphosate from degradation (Castro et al. 2015, p. 506).

Glyphosate can reach freshwater environments as runoff (De María et al. 2021, p. 2). When rainfall follows the application of glyphosate-based herbicides, up to 58% of it can be drifted by wind and transported from the soil (De María et al. 2021, p .2). Glyphosate-based herbicides can also be sprayed directly into water bodies to control aquatic weeds (De María et al. 2021, p. 2) It is degraded by microorganisms in soils and biofilms into aminomethylphosphonic acid (AMPA) (De María et al. 2021, p. 2). The half-life of glyphosate in freshwater is 60–70 days and the half-life of AMPA remains unknown (De María et al. 2021, p. 2). AMPA persists longer when there is a high concentration of phosphorus, and Florida water is considered to have 10 times more phosphorus in the watercourse than the basins can assimilate (De María et al. 2021, p. 2).

Florida manatees rely on freshwater environments as a source of drinking water and as warm-water refuges (De María et al. 2021, p. 1). To avoid cold stress, when the Atlantic Ocean and Gulf of Mexico's temperature are below 20 °C, Florida manatees seek freshwater refuges in natural springs or at industrial warm-water resources like power-plant outflows (*See* Loss of Access to Warm-Water Refugia, *supra*). When using these warm-water sites, Florida manatees can be exposed to anthropogenic chemicals such as agricultural runoff (e.g., pesticides and herbicides) and municipal contaminants (De María et al. 2021, p. 1).

In a study sampling Florida manatee plasma from 2009–2019, researchers determined that the concentration of glyphosate has significantly increased in Florida manatee samples in recent years and detected glyphosate in 55.8% of Florida manatee plasma samples (De María et al. 2021, pp. 1, 4). Thus, the presence of glyphosate in Florida freshwater environments is ubiquitous, and manatees are chronically exposed to these contaminants (De María et al. 2021, p. 1).

Florida manatees' exposure to glyphosate and AMPA is higher in south Florida before and during the sugarcane harvest (De María et al. 2021, p. 8). It is worth noting that Florida manatees are also chronically exposed to glyphosate and AMPA beyond the glyphosate applications to sugarcane (De María et al. 2021, p. 1) and in areas isolated from sugarcane plantations (De María et al. 2021, p. 2). This is possibly associated with multiple uses of glyphosate-based herbicides for other crops or to control aquatic weeds (De María et al. 2021, p. 1). For example, manatees have also been exposed to glyphosate and AMPA in non-agricultural areas such as Crystal River (De María et al. 2021, p. 8). This exposure is higher during the colder months of the year, when manatees most depend on the warm water refuges. However, because Florida manatees depend on drinking freshwater all year round, they are exposed to a constant input of low doses of glyphosate and AMPA (De María et al. 2021, p. 8).

The presence of glyphosate and AMPA is a health concern for Florida manatees and their freshwater habitat (De María et al. 2021, p.2). Animal models chronically exposed to glyphosate have developed kidney and liver disease (De María et al. 2021, p. 2). For example, kidney and liver damage was found in rats with oxidative stress and pro-inflammatory signaling pathway alterations after two years of exposure to glyphosate formulations at the same plasma concentrations found in Florida manatees (De María et al. 2021, p. 8). Florida manatees chronically exposed to low doses of glyphosate can experience similar physiological effects as seen in experimental animal models (De María et al. 2021, p. 8). Furthermore, kidney and liver toxicity has also been associated with immune dysfunction, in acute and chronic exposures (De María et al. 2021, p. 8). Humans, fish, and non-human animal models commonly experience an inflammatory state due to glyphosate exposure, and it can affect lymphocyte response in mammalian organisms (De María et al. 2021, p. 8)

Manatees may be especially vulnerable to the effects of glyphosate (De María et al. 2021, p. 2). Their life cycle traits of longevity, late maturity, and low reproductive rate make them vulnerable to the cumulative effects of pollution, and they also lack a functional gene (PON1) that reduces oxidative damage to lipids (De María et al. 2021, p. 2). The West Indian manatee's absence of this gene is concerning. The suggested toxicity mechanism of glyphosate is through the formation of reactive oxygen species that damage macromolecules such as proteins and lipids, and the PON1 gene is typically the main defense against reactive oxygen species possibly intensifying the effects of glyphosate exposure (De María et al. 2021, p. 2).

These immune system consequences must be considered in the context of other environmental stressors that the Florida manatee is exposed to such as red tide and cold stress (*See* Habitat, *supra*). Manatees suffering from cold stress experience immunological disturbances that can affect a manatee's lymphocyte capacity to respond to mitogens (small bioactive proteins or peptides that induce a cell to begin cell division) or produce cell apoptosis (programmed cell death) (De María et al. 2021, p. 8). Glyphosate and AMPA exposure could have additional consequences when compounded with other environmental stressors already contributing to immune system dysfunction (De María et al. 2021, p. 8). In addition, glyphosate exposure can produce gut flora alterations in Florida manatee as has been seen in other animal models (De María et al. 2021, p. 8).

Because colder months coincide with both cold stress and higher glyphosate and AMPA exposure, the synergistic effects of glyphosate exposure and environmental stressors risk serious, compounded effects for the Florida manatee's immune and renal systems (De María et al. 2021, p. 8).

Sugar processing is also believed to have killed manatees in Cuba and may have caused manatees to abandon Cuba's largest bay (Quintana-Rizzo and Reynolds 2010, p. 37). In Panama, the deaths of manatees in Bocas del Toro near extensive banana plantations have been associated with exposure to pesticides (Marsh et al. 2011, p. 387). Although no definitive data exist that describe the extent to which pesticide exposure is lethal to manatees in Panama, this issue has long been a concern in this region (Marsh et al. 2011, p. 387).

b) Oil Spills

Oil pollution is both an acute and a chronic threat to sirenians and their habitats (*See* Loss of Seagrass, *supra*). Manatees are exposed to toxic petroleum compounds via their skin, ingestion, or inhalation long after a leaking well is capped (Martin et al. 2014, p. 2). About 150 dugongs were estimated to be killed in the Arabian/Persian Gulf during the Nowruz oil spill in 1983–1984 (over one million barrels of oil flowed from seven wells damaged during the Iran–Iraq war). Oil spills have taken place on seagrass meadows used by dugongs and manatees (Martin et al. 2014, p. 5). Indirect effects of oil extraction can be more chronic and long lasting, and can include increased turbidity that decreases light penetration, greater ship traffic, and mechanical disruption (Todd et al. 2014, p. 330–31).

5. Genetic Diversity

Genetic diversity provides the raw material for adaptation to an ever-changing environment as a result of climate change, anthropogenic activities, or natural fluctuations in the ecosystem (Tucker et al. 2012, p. 1507). Loss of genetic variation and ensuing inbreeding can render populations susceptible to a variety of threats by increasing the prevalence of deleterious genetic conditions and reducing survival, reproduction, and population growth rate (Marsh et al. 2011, p. 318; Tucker et al. 2012, p. 1507). Such adverse effects on population fitness and persistence are widespread conservation issues for many species of wildlife (Marsh et al. 2011, p. 318).

Genetic diversity is particularly important for small, isolated populations or those occupying fragmented habitats, and may be critical for anthropogenically affected large mammals that tend to have low genetic diversity (Tucker et al. 2012, p. 1507). The West Indian manatee is such a species—a large mammal that has been severely threatened by human activities including habitat fragmentation and degradation, marine debris, boat strikes, and human recreational activities (Tucker et al. 2012, p. 1507–08; *see* Coastal Development, *supra*; Marine Debris, *supra*; Boat Strikes, *supra*; Overutilization, *supra*).

Manatee populations in general are characterized by low levels of genetic diversity (Tucker et al. 2012, p. 1508). While genetic diversity exists between geographically partitioned populations of West Indian manatees, there is much lower diversity within populations, including in Florida, Mexico, and coastal Brazil (Marsh et al. 2011, p. 319). Regional populations such as those of manatees in Belize, Florida, and Puerto Rico show substantial reductions in genetic diversity that are comparable to the values of imperiled mammalian populations (Marsh et al. 2011, p. 321). Florida manatees have particularly low genetic diversity (Tucker et al. 2012, p. 1508). Several analyses of the Florida manatee confirm that its low genetic diversity is definitively below the average for healthy populations (Marsh et al. 2011, p. 321).

In a 2012 study, all measures of Florida manatee genetic diversity were less than the average expected heterozygosity reported for all placental mammals, including fragmented or challenged placental mammals (Tucker et al. 2012, p. 1508). Researchers in this study also found evidence of a population bottleneck in the Gulf Coast population (Tucker et al. 2012, p. 1508) (a population bottleneck is an event that drastically reduces the size of the population, such as environmental disaster, hunting to the point of extinction, or habitat destruction). Such low genetic diversity adversely affects the Florida manatee's ability to adapt to environmental changes (Tucker et al. 2012, p. 1504).

Demographic concerns related to low genetic diversity (e.g., inbreeding depression) in the West Indian manatee is not as severe as compared to other mammals of major conservation concern (e.g., the Florida panther) (Marsh et al. 2011, p. 325; Tucker et al. 2012, p. 1509). However, the West Indian manatee continues to face demographic challenges due to anthropogenic activities and stochastic factors, and further reduction in population size or disruption to gene flow may alter this situation drastically (Tucker et al. 2012, p. 1509).

The number of isolated areas that allow manatees to persist by virtue of a low human presence is shrinking in size and number, making populations more vulnerable, and accelerating the loss of genetic diversity (Marsh et al. 2011, p. 324; *see* Coastal Development, *supra*). As the human population of coastal Florida continues to grow, it will result in increased boat traffic and alteration of natural habitats—both of which can have profound negative effects on the manatee (Tucker et al. 2012, p. 1509). Furthermore, a reduction in the number of available warm-water sites (*See* Loss of Warm-Water Refugia, *supra*), coupled with the colder-than-average winters predicted by some climate change models, may result in a significant reduction in the Florida manatee population size, and may potentially intensify genetic drift and inbreeding depression on the population (Tucker et al. 2012, p. 1509).

Overall, the adverse consequences of low genetic diversity in the West Indian manatee will only become more dire, and the long-term persistence of the manatee more uncertain, as threats such as small population size, collision with watercraft, loss and degradation of habitat, uncertain future of warm-water refugia, entrapment, and entanglement continue to jeopardize its survival (Tucker et al. 2012, p. 1505).

6. Invasive Species

The presence of the invasive armored catfish, *Pterygoplichthys*, also threatens manatees. *Pterygoplichthys*, a "very invasive" species that is "virtually impossible to exterminate once established," has become ubiquitous in Florida waterways (Torres-Pineda & Armbruster 2020, p. 27; Nico et al. 2009, p. 511). Marine biologists have noted large numbers of these catfish—over 40 on one observation—swarming and harassing Florida manatees as they try to feed, especially during the winter (Gibbs et al. 2010, entire; Nico et al. 2009, p. 513; *see* Figure E.6). This causes Florida manatees to expend already-depleted energy reserves to get away from the catfish, which irritate the manatees as they latch onto them in order to feed on algae covering the manatees' bodies (Gibbs et al. 2010, entire; Nico et al. 2009, p. 517).

Figure E.6 - Non-native *Pterygoplichthys* armored catfish gathering around female Florida manatee and her calf, Volusia Blue Spring (Nico et al. 2009, p. 512, photo by James P. Reid).

These behavioral changes would not be a significant issue if Florida manatees had access to adequate amounts of seagrass and warm water; however, given their current habitat decline, manatees simply do not have the resources to escape the harassment of the catfish. They are already struggling to adequately feed themselves and are at risk of cold stress syndrome because of decreased warm-water refugia, so any additional movement further compounds their risk of harm or even death. Manatees do not have the calories to spare in order to evade the catfish, and, since these invasive catfish cannot be exterminated or removed from the ecosystem, there is no regulatory mechanism in place adequate to combat this problem.

7. Climate Change

a) Temperature Increases

Human influence has warmed the atmosphere, ocean, and land. Since 2011, greenhouse gas (GHG) concentrations have continued to increase in the atmosphere, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO_2), 1866 parts per billion (ppb) for methane (CH_4), and 332 ppb for nitrous oxide (N_2O) in 2019 (IPCC 6th Assessment Report 2021, p. SPM-5).

Each of the last four decades has been successively warmer than any decade that preceded it since 1850 (IPCC 6th Assessment Report 2021, p. SPM-5; *see* Figure E.7). Global surface temperature in the first two decades of the 21st century (2001–2020) was 0.99 °C higher than 1850–1900, increasing to 1.09°C higher in 2011–2020 (IPCC 6th Assessment Report 2021, p. SPM-5; *see* Figure E.8).

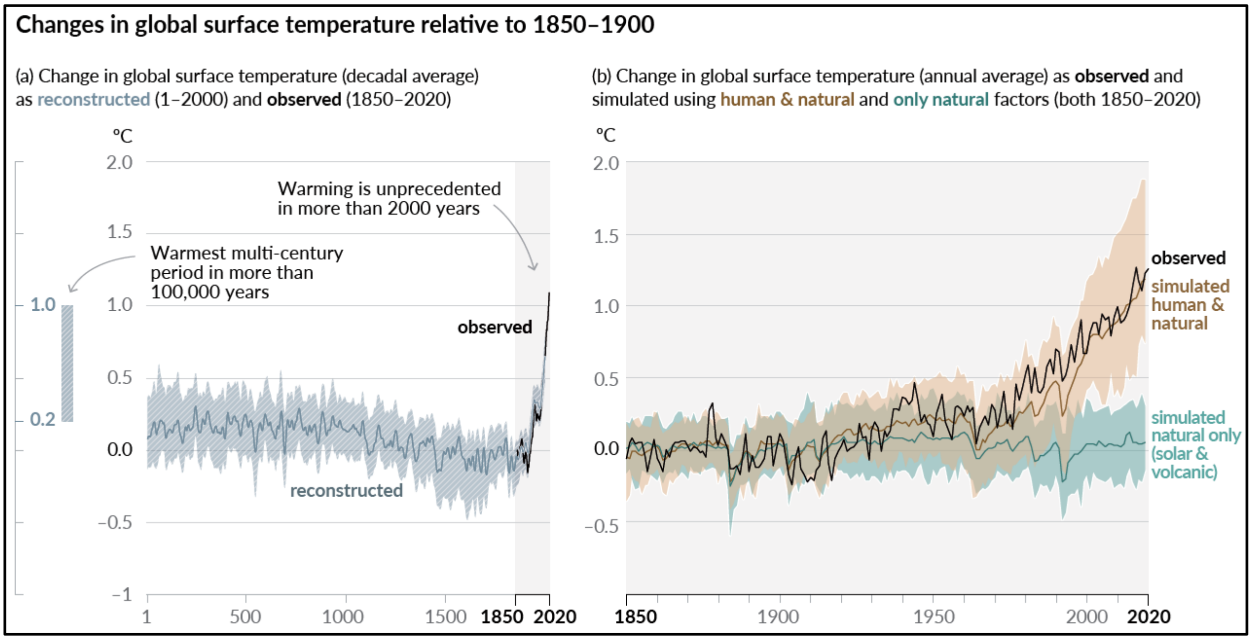


Figure E.7 - History of global temperature change and causes of recent warming (IPCC 6th Assessment Report 2021, p. SPM-7)

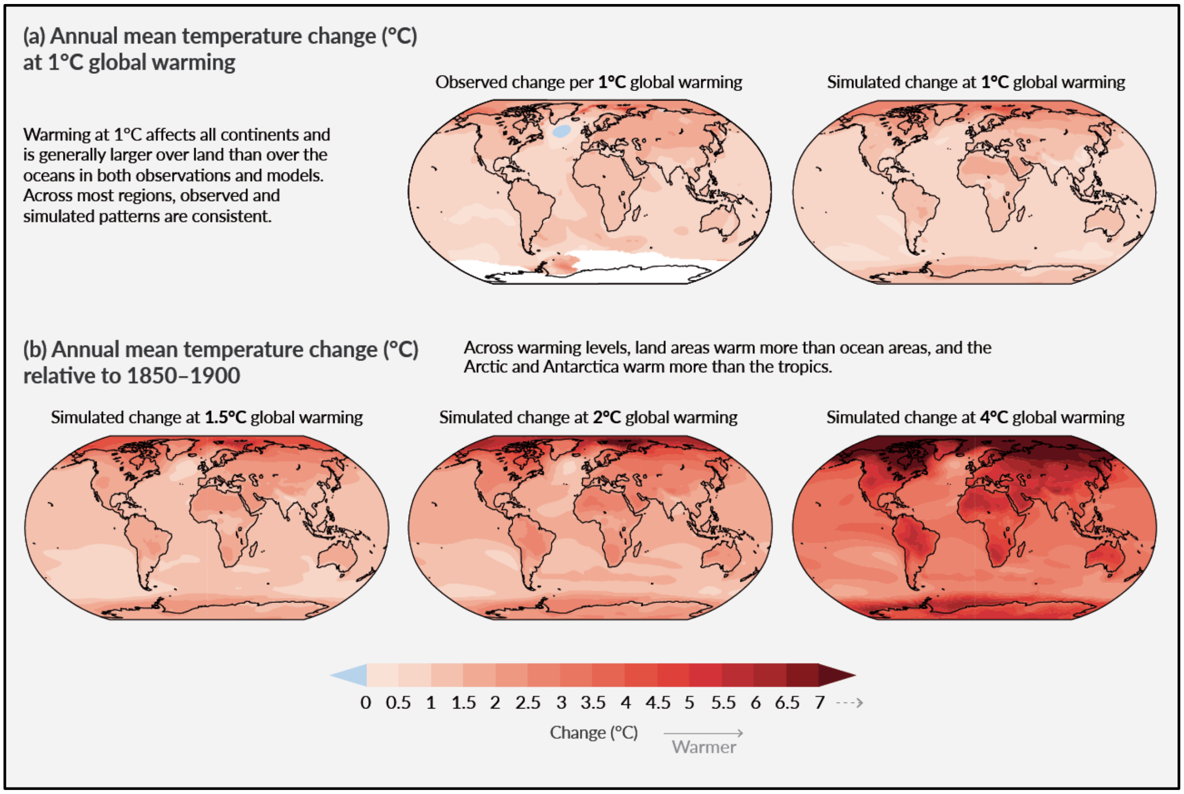


Figure E.8 - Changes in annual mean surface temperature (IPCC 6th Assessment Report 2021, p. SPM-21).

Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered (IPCC 6th Assessment Report 2021, p. SPM-17). Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades IPCC 6th Assessment Report 2021, p. SPM-17; *see* Regulatory Inadequacy, *supra*). Current regulatory resources are inadequate to counteract this effect, and under *any* future emissions scenario, manatees will continue to face the effects of climate change (*See* Regulatory Inadequacy, *supra*; IPCC 6th Assessment Report 2021, p. SPM-18).

Oceans have absorbed the vast majority—about 93%—of excess heat caused by global warming (USGCRP 2017, p. 365). As a result, worldwide sea surfaces have warmed by about 1.3 °C per century since 1900 (USGCRP 2017, p. 367; *see* Figure E.9). By 2080, sea surface temperatures in the Southeast United States, Gulf of Mexico, and Caribbean are expected to increase by 2.6ºC or more under the higher scenario (USGCRP 2017, p. 368).

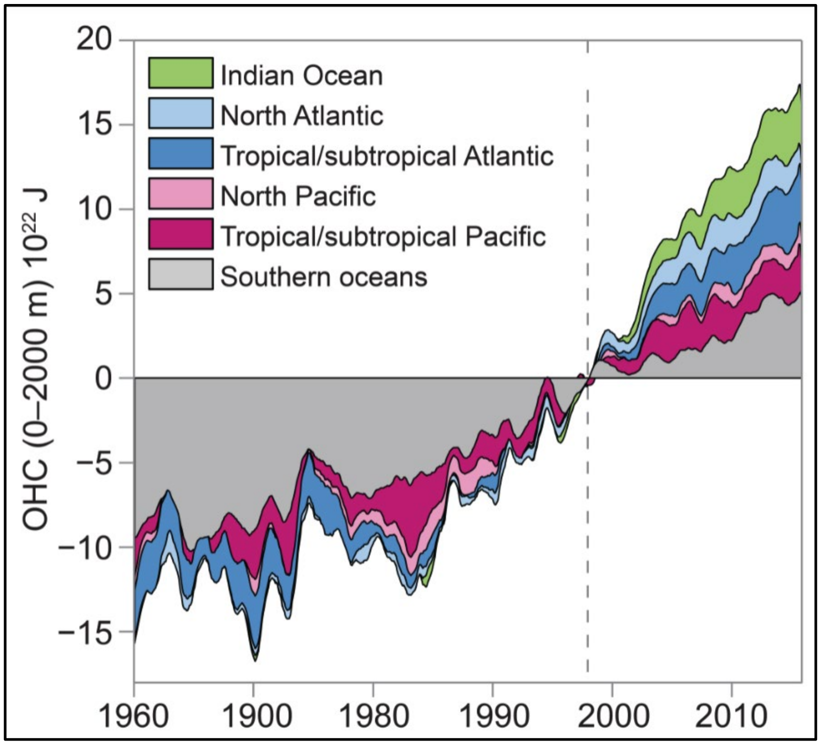


Figure E.9 - Ocean Heat Content (OHC) in surface waters (0–2,000m) relative to 1997–1999 base period (USGCRP 2017, p. 367).

Past GHG emissions since 1750 have committed the global ocean to future warming. The ocean has taken up a near-constant proportion (globally about 56% per year) of CO_2 emissions from human activities over the past six decades (IPCC 6th Assessment Report 2021, p. SPM-5). Changes in global ocean temperature, deep ocean acidification, and deoxygenation are irreversible on centennial to millennial time scales (IPCC 6th Assessment Report 2021, p. SPM-28).

These changes in atmospheric and oceanic temperature will affect coastal ecosystems by altering precipitation patterns affecting delivery of fresh water, nutrients, sediments, and runoff; altering circulation patterns; increasing ocean acidification; increasing the frequency and intensity of coastal storms; and melting polar ice caps, which will lead to a rise in sea level (Edwards 2013, p. 728).

The predicted impacts of climate change on estuaries and nearshore areas of Florida could be highly detrimental to manatee habitat (Marsh et al. 2017, p. 333). Drought conditions interspersed with erratic and powerful rainfall events are expected to undermine freshwater reliability, degrade natural warm-water features, and contribute significantly to sediment and nutrient runoff into waterways (Edwards 2013, p. 728; *see* Natural Springs, *supra*; Rainfall Changes, *infra*). Seagrass habitat will suffer increasing climate-related damage from algal blooms, turbidity, thermal stress, acidification, storms, and sea level rise (*See* Eutrophication, *supra*; Sediment and Turbidity, *supra*; Thermal Stress, *supra*; Storms, *supra*; Sea Level Rise, *supra*).

In addition to the indirect adverse habitat effects from climate change, manatees are expected to be *directly* harmed by climate change. Increasingly powerful storms kill manatees by sweeping them out to sea and stranding them (*See* Storms, *infra*). Wastewater runoff and harmful algal blooms, which can cause pathogenic disease or severe poisoning in manatees, are expected to be exacerbated by climate change as well (*See* Disease and Climate Change, *infra*; Harmful Algal Blooms, *infra*).

b) Acidification

"It is virtually certain that human-caused CO_2 emissions are the main driver of current global acidification of the surface open ocean" (IPCC 6th Assessment Report 2021, p. SPM-6). Currently, seawater absorbs over 1 million tons of anthropogenic CO_2 per hour (Gao et al. 2019, p. 3). As a result, since the Industrial Revolution, surface pH levels have decreased by approximately 0.1 pH units (Hoegh-Guldberg et al. 2014, p. 1673). By the end of the century, further decreases of over 0.4 pH are possible if CO_2 emissions continue to rise, which could cause ocean acidity to more than triple pre-industrial levels (Hoegh-Guldberg et al. 2014, pp. 1673–74; Kwiatkowski and Orr 2018, p. 18; NOAA PMEL Carbon Program, n.d., entire; *see* Figures E.10–12).

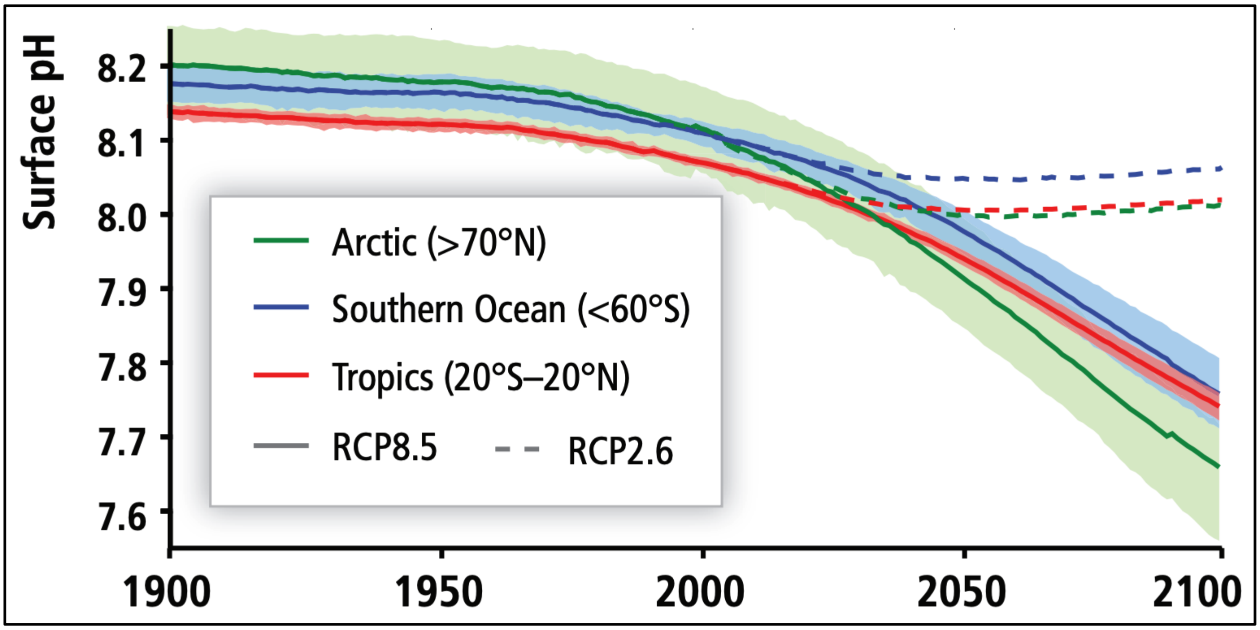


Figure E.10 - Surface pH. The West Indian manatee's range is within the tropics, represented by the red lines (Hoegh-Guldberg et al. 2014, p. 1673; *see* Distribution and Migration, *supra*).

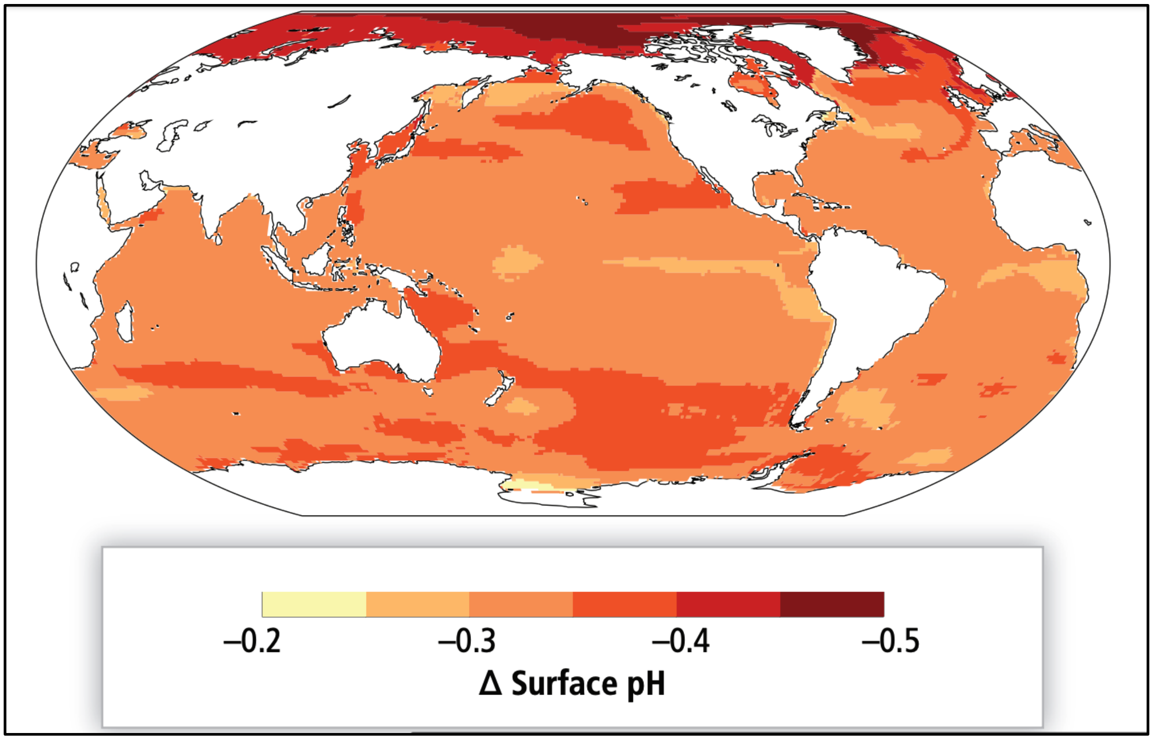


Figure E.11 - Predicted change in surface pH in the 2090s from the 1990s (RCP8.5) (Hoegh-Guldberg et al. 2014, p. 1673)

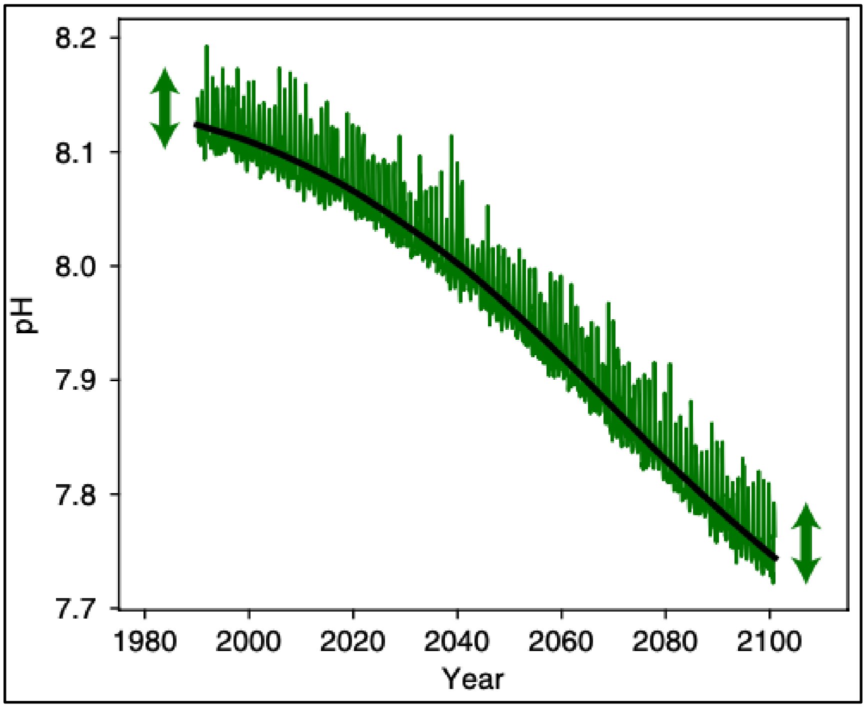


Figure E.12 - Projected monthly pH values and long-term mean trend. Historical and RCP8.5 scenario of one CMIP5 model (MPI-ESM-LR) with data from a grid cell in the South Pacific (Kwiatkowski and Orr 2018, p. 18)

This accelerating trend is expected to pose major threats to marine ecosystems, including those upon which manatees rely (Hall-Spencer et al. 2015, p. 5594). Biological processes like respiration and neural function are sensitive to pH changes (Heogh-Guldberg et al. 2014, p. 1675). The rate of change—possibly unprecedented in the last 300 millenia—raises serious concerns about organisms' ability to react and adapt (Heogh-Guldberg et al. 2014, p. 1675).

Seagrasses' metabolic processes may be significantly disrupted by acidification as oceans warm, resulting in sharp productivity declines (Collier et al. 2018, p. 1013; *see* Thermal Stress, *supra*). And acidifying oceans favor HAB formation, which further jeopardizes the species by poisoning manatees and shading their seagrass ecosystems (*See* Eutrophication, *supra*; Harmful Algal Blooms, *infra*).

c) Harmful Algal Blooms

Harmful algal blooms pose challenges to manatee habitat (*See* Eutrophication, *supra*) but are also expected to have increasingly toxic impacts on manatees themselves (*See* Toxic Algae, *supra*). Red tides have been especially lethal—brevetoxicosis directly caused 612 known or suspected deaths from 2016–2021 (FWC Red Tide Mortalities 2016–2020, entire). This is a known undercount, since USFWS stopped recording red tide mortalities in January, 2020, due to "pandemic-related limitations in necropsy response" (FWC Red Tide Mortalities 2020, entire; Waymer 2020, entire) At least 288 manatees died of known or suspected brevetoxicosis in 2018, fueled by a severe red tide in southwestern Florida (FWC Red Tide Mortalities 2018, entire; *see* Eutrophication, *supra*). This was the most catastrophic red tide mortality event to date at that time, although more than 100 red tide-related mortalities were documented in 1996, 2003, and 2013 (FWC Red Tide Mortalities 1996, 2003, and 2013, entire). Additionally, a massive discharge from the Piney Point phosphogypsum stack in 2021 led to a raging red tide in Tampa Bay (*See* Eutrophication, *supra*; Phosphogypsum Stacks *supra*). More than 30 manatees subsequently died from red tide in nearby counties (Pinellas, Hillsborough, Sarasota, and Manatee) that year (FWC Red Tide Mortalities 2021, entire). The red tide also threatened to degrade important foraging habitat near regional warm-water refugia (*See* Eutrophication, *supra*; Figure A.20, *supra*).

The risk of red tide blooms caused by *K. brevis* is not uniform but may be increasing. Manatees are at high risk of being impacted by a red tide in late winter and spring, when salinities are greatest and large numbers of manatees migrate through or feed in red tide-affected areas (Edwards 2013, p. 729). Several studies have suggested a relationship between the frequency, duration, and magnitude of HABs like red tide and climate change (Edwards 2013, p. 729; Marsh et al. 2017, p. 345). Studies also suggest that the warmer upper-ocean temperatures predicted under future climate scenarios would reduce vertical mixing of the water column, which would influence phytoplankton growth (Edwards 2013, p. 729; Marsh et al. 2017, p. 346). As dinoflagellates, *K. brevis* possess flagella that enable them to move through the water column. Since motile species are expected to prevail over other species, it is likely blooms of motile algae, including *K. brevis*, will increase as a result of climate change (Edwards 2013, p. 729; Marsh et al. 2017, p. 345; Marsh et al. 2011, p. 316). A warmer Earth will be associated with climate conditions similar to those of the Mesozoic Era, when dinoflagellate species were favored.

As ocean waters warm, blooms will begin earlier and last longer, and HABs will expand their range and period of time they occur (Edwards 2013, p. 729; Marsh et al. 2017, p. 345). Large amounts of African dust containing Saharan minerals are carried by wind to the western Atlantic, where nitrogen-fixing bacteria fuel the nitrogen economy of red tides, triggering larger algal blooms (Marsh et al. 2017, p. 346). Decreases in freshwater runoff due to drier climatic conditions could increase salinity and create more favorable conditions in nearshore areas for some species like *K. brevis*, leading to more red tides and greater manatee mortality (Marsh et al. 2017, p. 347; Marsh et al. 2011, p. 316; *see* Rainfall Changes, *supra*). Sporadic but intense rainfall events are expected to provide only short-term salinity-moderating effects (Havens 2015, p. 4).

Ocean acidification and associated increases in dissolved inorganic carbon are expected to increase HAB growth and toxicity (Edwards 2013, pp. 729–30; Hansen et al. 2007, p. 63). While bloom-causing species are diverse and react differently to acidity, field experiments in the Canary Islands found that increased acidity levels caused blooms of the toxic phytoplankton *Vicicitus globosus* to occur (Riebesell et al. 2018, p. 1082). High pH is also a limiting factor for some red-tide dinoflagellates; those species may benefit as surface acidity increases (Hansen et al. 2007, p. 64). Predicted effects include range expansion of HAB species, changes in their abundance and seasonal growth window, and secondary ecosystem impacts (Edwards 2013, p. 730).

d) Rainfall Changes

As climatic conditions are increasingly altered by human influence, rainfall regimes are expected to change significantly throughout the West Indian manatee's range, with negative repercussions anticipated for the species.

In Florida, increasingly frequent droughts deplete surface and groundwater and are expected to worsen in the future; over the last fifty years, rainfall has already declined in parts of the state by as much as 15% (Abiy et al. 2019a, p. 1; Edwards 2013, pp. 731–32; Valade et al. 2020, p. 4). Florida's precipitation arrives seasonally and comprises a significant component of the state's hydrologic budget (Abiy et al. 2019a, p. 1). Seventy-five percent of precipitation falls in the rainy season, which lasts from May through October, while dry weather predominates from November through April (Abiy et al. 2019a, p. 4). But as dry seasons lengthen and rainy seasons shorten, small-scale droughts could proliferate, with effects that tend to accumulate "gradually and unnoticed" before unexpectedly compromising the water system (Abiy et al. 2019a, p. 17).

Although southeast Florida was in the wet phase of long-term hydroclimate variabilities as of 2016, an emerging negative phase of the Atlantic Multidecadal Oscillation (AMO) was reported in September of 2017 (Frajka-Williams et al. 2017, entire; *see* Figure E.13). A negative AMO is strongly associated with decreased rainfall and could cause the region's long-term hydrologic system to enter a sustained dry phase instead (Abiy et al. 2019b, p. 12). This could be devastating—the region's water resources are "completely allocated" right now, and "any change in the precipitation regime" will have a "substantial impact" on the hydrological system (Abiy et al. 2019a, pp. 1, 17). These changes in precipitation and groundwater levels are expected to have markedly negative impacts on Florida manatees' essential warm-water habitat at natural springs and passive thermal basins (*See* Natural Springs; Passive Thermal Basins, *supra*).

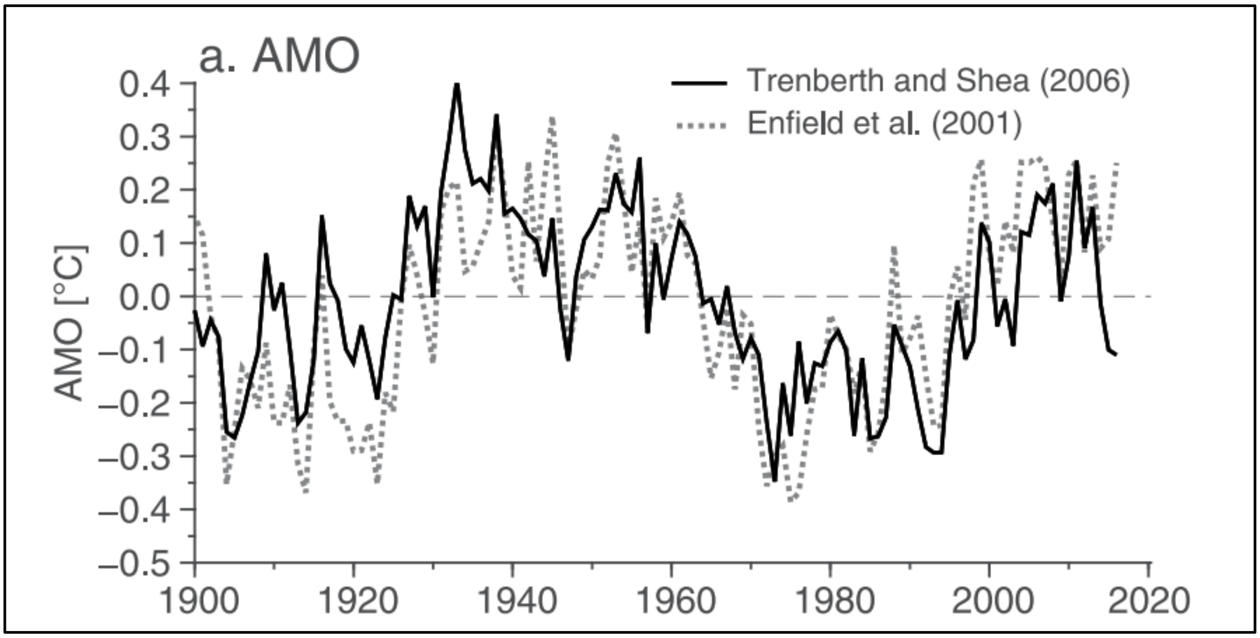


Figure E.13 - Atlantic Multidecadal Oscillation indices. Methodologies are depicted in black and gray dashed lines (Frajka-Williams et al. 2017, p. 2).

While conditions in Florida become drier overall, the number of extreme precipitation events is expected to increase (Marsh et al. 2017, p. 347; Edwards 2013, p. 733). These downpours are associated with significant soil erosion and surface runoff effects that wash sediments, pathogens, and contaminants into waterways (Li et al. 2021, p. 2; Marsh et al. 2017, p. 347; *see* Sediment and Turbidity, *supra*; Contaminants, *supra*; Disease and Climate Change, *infra*).

Although Antillean manatees do not rely on groundwater for thermal refuge, they will also be increasingly affected by climate change-related alterations in the precipitation regime. "Climate models consistently project a significant drying in the Caribbean during climate change, and between 2013 and 2016 the region experienced the worst multiyear drought in the historical period" (Herrera et al. 2020, p. 10773). In the Brazilian state of Piauí, for example, drought conditions are expected to sharply constrain manatees' access to essential freshwater sources, with significant impacts on that subpopulation's ability to survive (Favero et al. 2020, p. 1671; *see* Freshwater Availability, *supra*).

e) Storms

Human-induced climate change is already affecting weather and climate extremes in every region across the globe (IPCC 6th Assessment Report 2021, p. SPM-9). Sea level rise, coupled with an increase in the intensity of extreme weather events, is likely to decrease the welfare of West Indian manatees through increased mortality from strandings, loss of food resources, episodes of separation of mother and calf pairs, and habitat loss and alteration (Marsh et al. 2017, pp. 333, 337; Edwards 2013, p. 730).

Mean adult manatee survival drops significantly following years with intense hurricanes or winter storms (Edwards 2013, p. 730). Florida manatees have lower survival during years with intense storms or hurricanes. The exact mechanisms that cause increased mortality are unknown but likely vary with timing, intensity, and duration of the storms (Marsh et al. 2017, p. 338). Decreases in manatee survival are assumed to be due to either direct or indirect effects of the storms, or due to emigration of manatees from the affected area (Edwards 2013, p. 730).

Direct effects of storms include tidal stranding or manatees being swept out to sea, whereas indirect effects include loss of seagrass and power plant outfall disruptions (Edwards 2013, p. 730; *see* Loss of Seagrass: Storms, *supra*; Power Plants, *supra*).

Since 1996, the frequency of hurricane landfalls in the Southeast has increased, and this pattern of elevated activity is predicted to continue as a result of climate change (Marsh et al. 2017, p. 338; Edwards 2013, p. 730). There is a correlation between local tropical Atlantic sea-surface temperatures and the power dissipation index (a measure of Atlantic hurricane activity which combines frequency, intensity, and duration of hurricanes) (Marsh et al. 2017, p. 338). Both sea surface temperatures and the power dissipation index have risen sharply since the 1970s, and there is evidence that the levels of the power dissipation index in recent years are higher than in the previous active Atlantic hurricane era of the 1950s and 1960s (Marsh et al. 2017, p. 338).

Climate change's projected effect on increasing tropical Atlantic sea-surface temperatures for the late twenty-first century also directly translates to substantial increases in hurricane destructiveness (Marsh et al. 2017, p. 338). According to the IPCC, the coastal U.S. is expected to experience more intense storms and possible changes in El Niño, which could increase threats to coastal habitats (Edwards 2013, p. 730). And, while the overall number of storms is expected to decrease with climate change, that reduction will be outweighed by an increase in storm intensity; the expected increase in category 4–5 storms will result in an estimated 30% increase in damage to manatee habitat (Marsh et al. 2017, p. 339; *see* Loss of Seagrass: Storms, *supra*). Direct mortality of manatees is expected to increase over time as these extreme storms become more frequent in their habitat (Marsh et al. 2017, p. 339).

An increased intensity of severe storms is likely to be associated with higher rainfall rates than the present day, and these events may cause runoff into coastal regions that smother seagrasses (*See* Sediment and Turbidity, *supra*), flushing toxins into waterways (See Contaminants, *supra*), and altering the local habitat through increased water flow (Marsh et al. 2017, p. 338).

f) Disease and Climate Change

Wastewater runoff associated with the increased number of extreme rainfall events expected with climate change also adversely impacts the health of manatees by increasing their exposure to infectious pathogens such as toxoplasmosis and fecal coliform bacteria (derived from human and animal sewage) or to contaminants with immunosuppressive effects (Marsh et al. 2017, p. 347; *see* Rainfall Changes, *supra*). Warmer waters also favor an increased proliferation of disease organisms, putting manatee populations at greater risk (Marsh et al. 2011,

p. 316). Such increased exposure to pathogens and contaminants adds further stress in addition to the current disease threats the West Indian Manatee already faces (*See* Disease or Predation, *supra*).

g) *Extreme Cold Events*

Although average annual water temperatures are expected to rise in the Florida manatee's range, some models predict that extreme cold events (ECEs) may nonetheless proliferate as winters and springs in Florida become cooler than average (Marsh et al. 2017, p. 339; Edwards 2013, p. 728). Generally, climate change is expected to ameliorate cold extremes, but regional patterns may vary, and some regions are expected to experience increases of both extreme heat and cold events as global climate change advances (IPCC 6th Assessment Report 2021, p. SPM-10; La Sorte et al. 2021, p. 1). Since the prevalence of ECEs is spatially variable and seasonally dependent, reliable long-term predictions about their frequency or intensity in a particular region are difficult to make (La Sorte et al. 2021, p. 11).

A 2010 study noted that minimum winter temperatures had decreased in more Florida counties than they had increased for the last 34–108 years (Edwards 2013, p. 731; Von Holle et al. 2010, p. 4). In the particularly harsh winters of 2009–2010 and 2010–2011, extreme cold resulted in sharply elevated Florida manatee mortality rates due to cold stress syndrome (Hardy et al. 2019, p. 2; *see* Cold Stress Syndrome, *supra*). In the winter of 2010, 280–477 manatees died of cold stress, while an additional 49 manatees received treatment for cold stress (Marsh et al. 2017, p. 339). Increases in extreme cold weather events could also contribute to seagrass die-offs (*See* Loss of Seagrass: Extreme Cold, *supra*).

h) *Sea Level Rise*

It is virtually certain that global mean sea level will continue to rise over the 21st century (IPCC 6th Assessment Report 2021, p. SPM-28). The global mean sea level increased by 0.20 meters between 1901 and 2018 and is characterized by a notable pattern of acceleration (IPCC 6th Assessment Report 2021, p. SPM-6). The average rate of sea level rise was 1.3 mm yr^{-1} between 1901 and 1971, increasing to 1.9 mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 mm yr^{-1} between 2006 and 2018 (IPCC 6th Assessment Report 2021, p. SPM-6). Climate models predict that, by the end of the century, sea levels could rise by over a meter compared to 1995–2014 averages (IPCC 6th Assessment Report 2021, p. TS-44).

Sea level rise will have a swath of negative consequences for manatees. An increase in sea level alone could in theory provide more inshore habitats for food plants and expanded manatee access to them, but corresponding increases in depths over existing deep-water seagrasses reduce light penetration and eliminate such resources (Marsh et al. 2011, p. 314). Sea level rise is expected to be especially harmful to seagrasses, which will be degraded by light attenuation, salinity changes, and increased turbidity (*See* Loss of Seagrass: Sea Level Rise, *supra*).

Other factors limit the potential for manatee habitat to adapt or shift as sea levels rise. The landward extent of sea-level expansion could in many areas be prevented by buttresses put in place to protect existing developed shorelines, and expanding waters may simply flow into what may be unsuitable materials for manatee habitats (Marsh et al. 2011, p. 314). This is an example of how the impacts of climate change on terrestrial ecosystems may be felt more directly by manatees. Because manatee populations extend into inland river systems and directly encounter human developments that interfere with their adaptation to changing environments, their prospect for increased habitat range as a result of climate change is significantly restricted (Marsh et al. 2011, p. 312).

Sea level rise will also reduce the availability of artificial warm-water refugia (*See* Loss of Warm-Water Refugia, *supra*). Based on sea level rise predictions of of 1–2 meters within the next 80 years, the location of six of the seven most widely used power plants, several other plants used to a lesser degree, and the largest passive thermal refuge currently used by manatees will be inundated (Edwards 2013, p. 731).

Finally, sea level rise is expected to result in stronger tidal flows that increase water movement in coastal and estuarine areas (Short and Neckles 1999, p. 180). This trend is inherently harmful to slow-moving manatees, the habitable range of which is defined by shallow water and the absence of powerful currents (*See* Bathymetry, Currents, and Wave Action, *supra*).

Sea level rise, climate change, HABs, and other natural and anthropogenic factors threatening West Indian manatees have acute and complex interrelated effects. These effects cumulatively harm manatees and the habitat features upon which they rely (*See* Habitat, *supra*). Persistent, growing threats have been inadequately addressed by existing regulatory mechanisms and now threaten the survival of the species as a result (*See* Regulatory Inadequacy, *supra*).

V. Listable Entities

A. The West Indian Manatee Is in Danger of Extinction Across All of Its Range.

Historically, USFWS has analyzed the status of manatees at the species level, and the currently listed entity is the West Indian manatee. *See* Final Rule 2017, 82 Fed. Reg. at 16,680. Because both the Florida and Antillean subspecies of the West Indian manatee are in danger of extinction across all of their range, the West Indian manatee is also in danger of extinction across all of its range and should be reclassified as endangered.

B. The West Indian Manatee Is in Danger of Extinction Across a Significant Portion of Its Range.

As discussed below, the West Indian manatee is in danger of extinction across the Florida portion of its range. As a preliminary matter, the existence of the Florida portion of the species' range increases the resiliency, redundancy, and representation of the species. The Florida population of manatees is spatially removed from its Caribbean counterpart (*See* Distribution and Migration, *supra*). The loss of this population would remove a major source of redundancy, leaving remnant populations more closely concentrated and more vulnerable to catastrophic events. Furthermore, because these remnants would be almost entirely under the jurisdiction of foreign governments, often with relatively lax monitoring and enforcement regimes, United States laws would have a diminished protective effect on the species, reducing resiliency to random environmental variation. Finally, the loss of the Florida portion would result in the extirpation of the Florida subspecies in the wild, dramatically reducing remaining manatees' breadth of genetic representation and ability to adapt to future threats.

West Indian manatees are also in danger of extinction due to acute threats across the Caribbean portion of their range. As Castelblanco-Martínez et al. (2016) explain, their PVA model found that Antillean manatees will go extinct if even small increases in human-caused mortality occur (p. 3). Although challenges in data quality and collection frustrate an exact determination of human-caused mortality, studies in Brazil, Mexico, Puerto Rico, and Belize have reported significant deterioration in manatee habitat, drastic reductions in population size, decreased manatee sightings, and continued confidence that manatees are critically endangered in the Caribbean (*See* Abundance and Population Trends, *supra*). This portion of range is indisputably significant. Unlike the Florida portion, manatees in this portion of the range benefit from year-round warm water, making it integral to manatees' resiliency to variations in annual water temperature or losses of warm-water sites. It is also the largest source of manatee redundancy because it supports multiple discrete subpopulations, which the Florida portion of the range cannot. Accordingly, the loss of this range would dramatically reduce all West Indian manatees' ability to withstand catastrophic events. The loss of this portion of the range would also constrict the genetic representation of the species to the non-diverse gene pool of the Florida manatee, reducing the species' adaptive capacity.

C. The Florida Manatee Is in Danger of Extinction Across All of Its Range.

Threats to the Florida manatee are so great that the subspecies is in danger of extinction throughout all of its range. Importantly, as USFWS's models recognize, Florida manatees function as a single metapopulation due to their universal reliance on Florida warm-water habitat in the winter (Runge et al. 2016, p. 2). This absolute lack of redundant populations makes Florida manatees especially vulnerable to catastrophic events, such as hurricanes. Furthermore, the entire subspecies suffers from low genetic diversity (*See* Genetic Diversity, supra). Their poor ability to adapt to change because of low genetic representation weighs heavily in favor of a judgment that Florida manatees should be listed as endangered. *Cf. Crow Indian Tribe v. United States*, 965 F.3d 662, 680 (9th Cir. 2020) (invalidating delisting rule as arbitrary and capricious because it failed to describe "concrete, enforceable mechanisms in place to ensure long-term genetic health of the Yellowstone grizzly."); *Defs. of Wildlife v. Jewell*, 176 F. Supp. 3d 975, 1006 (D. Mont. 2016) (invalidating recovery plan because USFWS failed to explain why "a documented loss of genetic diversity with no realistic hope of genetic infusion" was not a threat to wolverines).

Florida manatees' lack of resiliency to changing conditions is illustrated by the continuous population declines they have suffered since 2017. These deaths surged in 2021, when over 13% of the subspecies' estimated minimum population died (See Abundance and Population Trends, *supra*). Starvation is the primary culprit; the Florida seagrass habitats on which manatees depend have been degraded or destroyed in many places due to pollution-fueled blooms of algae, coastal development, boating, erosion and sedimentation, ocean acidification, invasive species, contamination, and effects of climate change like sea level rise, salinization, acidification, and thermal stress. Making matters worse, the warm-water Florida habitats upon which the subspecies must rely in the winter are being eradicated by power plant shutoffs, declining spring flow rates, and degradation of passive thermal sites. These threats to irreplaceable seagrass and warm-water habitat of the Florida manatee are expected to remain constant or increase in the foreseeable future, jeopardizing the entire subspecies' continued ability to exist (*See* Loss of Seagrass Habitat, *supra*; Loss of Warm-Water Refugia, *supra*). Other sources of harm to Florida manatees—including boat strikes, toxic algal blooms, storms, coastal development, marine debris, and climate change—are also increasing as human populations grow, exacerbating the damage caused by habitat loss and placing all Florida manatees in danger of extinction.

D. The Florida Manatee Is in Danger of Extinction Across a Significant Portion of Its Range.

Florida manatees are also in danger of extinction across all of Florida, an undeniably significant portion of their range. As discussed above, indispensable Florida habitat is being threatened by commercial activity, poor water quality causing algal blooms, mass seagrass die-offs, and warm-water refuge degradation. The Florida portion of the manatees' range is so essential to manatees' ability to endure cold winter weather that its loss would likely result in the subspecies' extinction, making it "significant" by any reasonable definition. The areas of Florida range that can no longer serve as winter manatee habitat are already significant and growing. Tens of thousands of acres of Florida seagrass habitat, especially on the Atlantic coast, have been destroyed in the last ten years—a worsening trend that has caused manatee mass-starvation and required the drastic intervention of supplemental feeding. Power plants that provide heated refuge to most Florida manatees in the winter are expected to shut off within 30 years (*See* Power Plants, supra). The natural formations which must replace retiring facilities are already stressed to the breaking point by human activity—namely groundwater withdrawals—and changes to precipitation patterns from climate change are expected to exacerbate the problem.

The portions of Florida manatee range that have been lost in recent years were so important that 100 tons of supplemental forage—aided by a milder-than-usual winter—only slowed the subspecies' resultant population collapse (*See* Supplemental Feeding, supra). Until seagrass habitats are restored, these feedings are likely to remain necessary. Given the subspecies' already poor redundancy, resiliency, and genetic representation, these severe, ongoing reductions in habitable range are undeniably significant and warrant listing the Florida manatee as endangered.

E. The Antillean Manatee Is in Danger of Extinction Across All of Its Range.

As Castelblanco-Martínez et al. (2016) explain, USFWS erred in downlisting the West Indian manatee when it concluded from the authors' 2012 population viability analysis that Antillean manatees were not in danger of extinction (Castelblanco-Martínez et al. 2016, p. 3). Increasing human-caused mortality caused Antillean manatees to go extinct under all but the authors' most optimistic assumptions, and they concluded that further habitat fragmentation or mortality could make the population crash (Castelblanco-Martínez et al. 2016, p. 3). The model also systematically overestimated the subspecies' resiliency and redundancy by failing to consider the effects of climate change on annual variation in climatic factors or the intensity and frequency of catastrophic events (Castelblanco-Martínez et al. 2016, p. 3). The authors disagreed with USFWS's conclusion that threats to Antillean manatees were being adequately managed, noting that manatee sightings are decreasing throughout Latin America and "there is not one reported case of local threats being properly and completely addressed." (Castelblanco-Martínez et al. 2016, p. 4).

In subsequent years, alarming increases in manatee mortality and low manatee density have been documented in Belize, Mexico, and Brazil, suggesting that increased human caused mortality and habitat loss are more likely taking place than the most optimistic modeling assumptions (Castelblanco-Martínez et al. 2018, abstract; Núñez-Nogueira and Uribe-López 2020).

F. The Antillean Manatee Is in Danger of Extinction Across a Significant Portion of Its Range.

Habitat fragmentation is one of the most severe problems facing Antillean manatees, and several significant portions of range contain populations in danger of extinction. As of 2008, fewer than 100 Antillean manatees were estimated to remain in 15 countries across their range, throughout which inconsistent or poor regulatory enforcement is reported (*See* Abundance and Population Trends, supra). Peripheral populations such as these are disproportionately valuable for conserving endangered species because, as "one of the most active regions of speciation," they "are often genetically and morphologically divergent from central populations," generating genetic diversity that improves species' adaptive capacity (Lesica & Allendorf 1995, p. 756)

The Puerto Rico portion of the Antillean manatee's range is particularly significant for the subspecies' redundancy and representation, because of its genetic and geographic discreteness. This portion of the subspecies' range is increasingly threatened by native seagrass decline, coastal development, boating, fishing, *Sargassum* inundation, and recurrent storms made more intense and frequent by climate change. Manatee numbers in this portion of the range may be as low as 300 or less, based on the margin of error included in the study (Collazo et al. 2019, 1344). This portion of the range is also significant because it contains all the subspecies' members in the United States.

The Brazilian range of the Antillean manatee is also under acute threat from coastal economic activity, recreation, low genetic diversity, calf stranding, and freshwater scarcity, resulting in a significantly reduced population. A 2022 study estimated an 80% reduction in the size of the Brazilian population, finding the subspecies to be critically endangered (Oliveira de Mereilles et al. 2022, abstract). Similarly, the Mexico and Belize portions of the Antillean manatees' range have been sites of recent manatee mortality events and declining reported density due to development, boat strikes, toxic algal blooms, seagrass loss, and recreation. (*See* Regulatory Inadequacy – Mexico; Belize, supra). Since these portions of range are believed to contain the largest numbers of Antillean manatees, they should be regarded as especially significant sources of resiliency, redundancy, and representation for the subspecies.

VI. Conclusion

Listing the West Indian manatee, the Florida manatee, and the Antillean manatee as endangered species is warranted and would provide essential protections that only full listing under the ESA can offer. The best available scientific information demonstrates that, since the manatee was downlisted to threatened in 2017, it has become more imperiled and will continue to be adversely impacted by increasing natural and man-made threats, including drastic seagrass habitat loss, loss of access to natural and artificial warm-water refugia, boat strikes, marine debris entanglement and ingestion, contaminants in the water, and algal blooms. A growing human population and increased commercial development will only exacerbate these existing threats, and the on-going effects of climate change, which include but are not limited to, acidification, extreme weather events, algal blooms, and sea level rise, will compound damage to the manatee's critical habitat. The present and threatened destruction of the manatee's habitat, overutilization for commercial and recreational purposes, disease, inadequacy of existing regulatory mechanisms, and other natural or manmade factors necessitate a finding by USFWS that the West Indian manatee and subspecies thereof are "endangered" under the Endangered Species Act. 16 U.S.C. § 1533(a)(1)(A)–(E); 50 C.F.R. § 424.11(c)(1)–(5).

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