MIGRATORY SPECIES

in the Gulf of Mexico Large Marine Ecosystem

PATHWAYS, THREATS & CONSERVATION

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List of Acronyms

BBMM Brownian Bridged Movement Model

CPUE Catch Per Unit Effort

CBD Convention on Biological Diversity

CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora

CMS Convention on the Conservation of Migratory Species of Wild Animals

CONABIO National Commission for Biodiversity Use and Knowledge of Mexico / Comisión Nacional para el Conocimiento y Uso de la Biodiversidad

DWH Deepwater Horizon

EBSA Ecological or Biological Significant Area

ESA Endangered Species Act

GBIF Global Biodiversity Information Facility

GIS Geographic Information System

GSMFC Gulf States Marine Fisheries Commission

HMS Highly Migratory Species

HRI Harte Research Institute for Gulf of Mexico Studies

IAC Inter-American Convention for the Protection and Conservation of Sea Turtles

ICCAT International Commission for the Conservation of Atlantic Tuna

IUCN International Union for Conservation of Nature

IWC International Whaling Commission

LME Large Marine Ecosystem

MBTA Migratory Bird Treaty Act

MMC Marine Mammal Commission

MMPA Marine Mammal Protection Act

MOU Memorandum of Understanding

MSA Magnuson-Stevens Fishery Conservation and Management Act

NMFS National Marine Fisheries Service

NOAA National Oceanic and Atmospheric Administration

OBIS Ocean Biogeographic Information System

SWOT State of the World's Sea Turtles

TED Turtle Excluder Device

TNC The Nature Conservancy

UNCLOS United Nations Convention on the Law of the Sea

U.S. United States of America

USGS United States Geological Survey

USFWS United States Fish and Wildlife Service

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JOEL SARTORE, NATIONAL GEOGRAPHIC PHOTO ARK/GETTY IMAGES

STUDIED FISH

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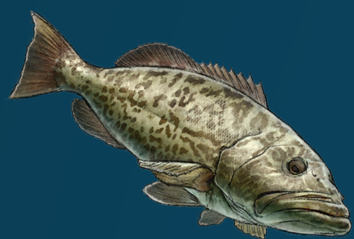

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WILDESTANIMAL/
GETTY IMAGES

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Adults rely exclusively on the coastal habitats along the Texas coast to spend the winter. EN

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JOEL SARTORE/ GETTY IMAGES

REINHARD DIRSCHERL/
GETTY IMAGES

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The largest cetacean that migrates primarily in the northern Gulf, where it has a semi-resident population of about 500 whales. VU

Introduction

Biological migration is a highly specialized behavior with origins in the natural selection of species (Baker 1978). Migratory pathways range from regional to long-distance movements, typically on a seasonal basis. In the Gulf of Mexico, migratory organisms range from minuscule zooplankton that migrate within a 24-hour period up and down the water column to massive leatherback sea turtles that travel thousands of kilometers to nest at the beach in which they were hatched.

A number of reasons may trigger an animal's desire to migrate, including the availability of food, the need to reproduce or a change in climate. Thereafter, migrations satisfy nutritional, energy, and reproductive requirements of the species. Migration can be obligate (individuals must migrate to survive), or partial (individuals choose whether to migrate without apparent effect on the survival of a population). Marine fish migrations may further be classified primarily as oceanodromous (depending on oceanic-scale movements) or diadromous (movements between the ocean and freshwater systems for reproductive reasons) (Grubbs and Kraus 2010). Migration is an adaptation that is essential to the survival of many species (Dingle and Drake 2007), yet details about the movements of individual animals remain unknown. Improved knowledge of migratory triggers, pathways, and stopover grounds for species traversing the Gulf of Mexico region can improve decision making related to the conservation and restoration of marine, coastal, and terrestrial habitats.

Migrations of organisms can be characterized by several attributes, including direction, periodicity, distance, fidelity to a particular geographic location, and homing (ability to find or return to an initial predetermined location). Factors that harm or reduce migratory populations remain poorly and incompletely understood. Effective conservation efforts need to take into account how, where, and when these migratory animals travel, especially if the populations travel outside the temperate areas where most of the current knowledge exists. In the past, it has been difficult to study individuals throughout their annual cycles, but new tracking technology makes it more affordable and practical. The ability to track animals throughout their yearly life cycle can help increase the understanding of the stressors encountered and the events that could have subsequent impacts in their lives. The geographic linkages provided by migratory animals and the habitats that they use are referred to as migratory connectivity. Understanding migratory connectivity has implications for the viability of species and thus for species conservation (Ryder et al. 2011). With a new suite of smaller devices ranging from geolocators to satellite tags, researchers can help advance the knowledge of animal movement, the habitats needed for survival and key needs for conservation.

Although some sites vital to migratory species, such as spawning or nesting areas, have already been protected or managed, the majority of pathways used by these species to access these critical regions are not, and they are subject to a variety of threats. The establishment of protected or managed corridors connecting breeding or nesting areas of many migratory species remains insufficient, often because these corridors are not yet known. Furthermore, many migratory species are rare, or their populations are in decline. All sea turtles in the Gulf are endangered, and several fish, mammal, and bird species that migrate within the Gulf of Mexico region are also endangered or considered vulnerable. Populations of migratory birds in North America have declined dramatically during the past 30 years, and scientists estimate that 10 percent of all bird species on Earth may be extinct by the end of this century (BirdLife International 2013).

Migratory species often move across national boundaries, and, therefore, through different governance frameworks. A number of global and international treaties and agreements pertaining to the species groups and countries in this assessment have been developed. These statutory authorities provide the legal framework for management agencies to conserve the populations of fish, sea turtles, mammals, and birds moving through a variety of jurisdictions in the three countries bounding the Gulf of Mexico. We introduce the main global and national frameworks and statutory authorities for the conservation of migratory biodiversity in Appendix I.

The Nature Conservancy (the Conservancy) stands for nature, in all its diversity. Its mission is to conserve the lands and waters on which all life depends. In a world of resource depletion and degraded habitats, the Conservancy strives to break the vicious cycle of the unsustainable use of biodiversity by transforming the relationship between people and nature. One way to achieve this is to strengthen the links between conservation and society by stressing the value of nature for our sake and its own. The Conservancy implements this vision through its strategic framework: Conservation by Design (The Nature Conservancy 2015a). Guided by this framework, the Conservancy synthesized existing scientific information from more than 100 biologists and researchers from the United States, Mexico, and Cuba to increase our understanding of migratory species and their pathways in the Gulf of Mexico region. The purpose of this assessment is to provide an initial view of the opportunities that exist to integrate animal movement data into species management and conservation in the Gulf of Mexico. We hope that the framework for assessment, techniques, results, and recommendations in this report motivates the scientific, management, and decision-making communities in the Gulf and nearby marine environments to contribute to the understanding of migratory connectivity and its importance to species' movements, life cycles, and survival.

This assessment focuses on data from 26 species of migratory fish, sea turtles, marine mammals, and birds (Table 1). Due to funding and data availability constraints, not all species that migrate in the Gulf could be included in this study. The selected species were carefully chosen to represent the diversity of migration patterns in the Gulf of Mexico (Table 2). They exemplify different migratory strategies such as open-ocean, coastal, trans-Gulf (migratory bird route across the open waters of the Gulf) and circum-Gulf (migratory bird route along the terrestrial coast of the western Gulf), among others. Each one of the 26 species represents many others that share similar movement patterns. Table 1 also presents the conservation status of the species in North America and Cuba. Due to the high conservation status of some species and/or their inclusion in several national and international management efforts, most of these species are managed by federal fish and wildlife agencies in the United States, Mexico or Cuba.

The Conservancy compiled and organized thousands of observation points, hundreds of satellite movement tracks, many aggregation sites, and numerous spatial threats from a multitude of sources in this assessment. We conducted a series of spatial analyses to identify migratory pathways and provide a few recommendations for the conservation of the species' migratory routes. Specifically, the Conservancy determined partial migratory corridors (since in most cases we found that more data is needed than that currently available to determine complete migratory corridors), movement density, occurrence hotspots, aggregations or stopovers, and high-threat areas for each species and combined groups of species.

Table 1. Species assessed and their conservation status in North America.

The following table synthesizes migratory patterns of 26 Gulf species and highlights the threat to those patterns.

GROUP	SUBGROUP	SPECIES	SCIENTIFIC NAME
Fish	Coastal	Atlantic tarpon	*Megalops atlanticus*
		Bull shark	*Carcharhinus leucas*
		Gag grouper	*Mycteroperca microlepis*
		Gulf menhaden	*Brevoortia patronus*
		Gulf sturgeon	*Acipenser oxyrinchus*
		Mutton snapper	*Lutjanus analis*
		Striped bass	*Morone saxatilis*
	Pelagic	Blue marlin	*Makaira nigricans*
		Bluefin tuna	*Thunnus thynnus*
		Dolphin fish	*Coryphaena hippurus*
		Whale shark	*Rhincodon typus*
Sea Turtle	Coastal	Green	*Chelonia mydas*
		Kemp's ridley	*Lepidochelys kempii*
		Loggerhead	*Caretta caretta*
	Pelagic	Leatherback	*Dermochelys coriacea*
Marine Mammal	Coastal	West Indian manatee	*Trichechus manatus*
	Pelagic	Sperm whale	*Physeter macrocephalus*
Bird	Neartic-Neotropical	Broad-winged hawk	*Buteo platypterus*
	Neartic-Neotropical	Cerulean warbler	*Setophaga cerulea*
	Neartic-Neotropical	Osprey	*Pandion haliaetus*
	Neartic-Neotropical	Wood thrush	*Hylocichla mustelina*
	Neartic-Temperate	Black rail	*Laterallus jamaicensis*
	Neartic-Temperate	Black skimmer	*Rynchops niger*
	Neartic-Temperate	Redhead	*Aythya americana*
	Neartic-Temperate	Whooping crane	*Grus americana*
	Pelagic	Audubon's shearwater	*Puffinus lherminieri*

[1]Endemic in the Gulf of Mexico
[2]IUCN Red List of Threatened Species: CR = critically endangered, EN = endangered, VU = vulnerable, NT = near threatened, LC = least concern
[3]NatureServe Global Conservation Status (G-rank): G1 = critically imperiled, G2 = imperiled, G3 = vulnerable, G4 = apparently secure, G5 = secure, GNR = rank not yet assessed
[4]Endangered Species Act (ESA): EN = endangered, TH = threatened, * = Under Review in the Candidate or Petition Process, ** = in FL and TH in other Gulf states, *** = in the Northwestern Atlantic and endangered in other areas outside the Gulf
[5]Native Flora and Fauna Species Protection Rule NOM-059-ECOL: Ex = extirpated, EN = endangered, TH = threatened, SP = special protectionw
[6]Resolution 160 of the Council of Ministries of Species of Special Significance: Appendix I = endangered or critically endangered species, Appendix II = vulnerable and species of high ecological value
[7]Committee on the Status of Endangered Wildlife in Canada (COSEWIC): EN = endangered, TH = threatened, SC = special concern, NAR = not at risk

		GLOBAL		USA	MEXICO	CUBA	CANADA
SUBSPECIES	ENDEMIC[1]	IUCN[2]	G-RANK[3]	ESA[4]	NOM-059-ECOL[5]	RESOLUTION 160[6]	COSEWIC[7]
		VU	G5				
		NT	G5				
		LC	GNR				
	●		GNR				
desotoi		NT	G3T2	TH	Ex		
		VU					
		LC	G5				SC
		VU	GNR				
		EN	GNR				EN
		LC	GNR				
		VU	GNR		TH	II	
		EN	G3	EN**	EN	I	
		CR	G1	EN	EN		
		EN	G3	TH***	EN	I	
		VU	G2	EN	EN	I	EN
latirostris (Florida), manatus (Caribbean)		VU	G2	EN	EN	I	
		VU	G3G4	EN	SP		NAR
platypterus, cubanensis (Cuba), brunnescens (Puerto Rico)		LC	G5		SP	I	
		VU	G4			II	EN
carolinensis (migratory), ridgwayi (Caribbean resident)		LC	G5			I	
		NT	G5			II	TH
jamaicensis		NT	G3G4	*	EN	II	
niger		LC	G5			II	
		LC	G5				
		EN	G1	EN	EN		EN
lherminieri		LC	G4G5				

Sources: COSEWIC cosewic.gc.ca; Endangered Species Act fws.gov/endangered; IUCN red Listiucnredlist.org; NatureServe Explorer explorer.natureserve.org NOM-059-ECOL biodiversidad.gob.mx/especies/pdf/NOM_059_SEMARNAT_2010.pdf; Resolution 160 medioambiente.cu/legislacionambiental/resoluciones/R-160-11-CITMA.pdf

Table 2. Species included in this assessment and the migratory groups they represent.

Group	Species	Migratory group
Fish	Atlantic tarpon	Recreational bony fish fishery
	Bull shark	Recreational and commercial shark fishery
	Gag grouper & mutton snapper	Recreational and commercial reef fish fishery
	Gulf menhaden	Gulf endemic and the largest commercial fishery*
	Gulf sturgeon	Endangered diadromous fish with reduced range
	Striped bass	Diadromous fish with land locked and marine populations
	Blue marlin	Recreational billfish fishery
	Bluefin tuna	High priced commercial tuna in the Gulf**
	Dolphin fish	Unmanaged commercial & recreational fisheries
	Whale shark	Vulnerable long-range migrant shark
Sea Turtle	Green, Kemp's ridley & loggerhead	Endangered and threatened turtle that nest in the Gulf
	Leatherback	Endangered long-range migrant turtle
Marine Mammal	West Indian manatee	Endangered sirenian with restricted seasonal migrations
	Sperm whale	Endangered whale with resident population in Gulf
Bird	Broad-winged hawk	Long-range circum-Gulf migrant raptor
	Osprey	Long-range land & marine migrant raptor
	Cerulean warbler, wood thrush	Long-range trans-Gulf migrant landbird
	Black rail	Endangered*** circum-Gulf nocturnal migrant
	Black skimmer	Circum-Gulf migrant colonial nesting waterbird
	Redhead	Waterfowl with majority of global population wintering in Gulf
	Whooping crane	Endangered crane that winters in restricted sites in the Gulf
	Audubon's shearwater	Long-range migrant seabird

*Largest commercial fishery by weight in the Gulf and second in the U.S. (Vaughan et al. 2007)
**Spawns in Gulf and it is commercially harvested in the Atlantic
***Endangered in Mexico

Migratory Biodiversity in the Gulf of Mexico

The Gulf is one of the top five ocean areas globally in terms of biodiversity (Ellis et al. 2011). However, knowledge about the Gulf's diversity of plants and animals has only recently been developed, and that biodiversity has been described and summarized by Felder and Camp (2009). This compilation listed 15,419 species in 40 phyla from bacteria to vertebrates, including 1,541 species of fish, five species of sea turtles, and 29 species of marine mammals. Felder and Camp (2009), plus this study, indicate at least 491 species of birds are known to occur in the Gulf of Mexico region. Prior to this assessment, the most complete inventory of the biodiversity of the Gulf of Mexico listed only 2,444 species (Galtsoff 1954). The Gulf region accounts for 67 species of endemic marine fish (IUCN 2011) and three species of endemic birds: Yucatán wren, Altamira yellowthroat, and yellow-headed warbler (Gallardo et al. 2009).

Biodiversity in the Gulf of Mexico is subject to multiple threats. IUCN has listed 52 species of marine vertebrates that occur in the Gulf in the Red List of Threatened Species with status of critically endangered, endangered or vulnerable (IUCN 2011). More specifically, there are six fish and three sea turtles listed as critically endangered; six fish, two sea turtles, three marine mammals, and two birds with the status of endangered; and 28 fish (11 bony fish and 17 sharks and rays) and two marine mammals that are vulnerable.

Although not all living organisms perform biological migrations, the groups of species that do perform this function are diverse. Documented biological migrations range from insect and bird movements on land (and in the air), to small planktonic animals and whales in the oceans. Vertebrate migrations are especially ubiquitous because they involve charismatic mega-fauna and, in some cases, very long movements of fish (including sharks); sea turtles; whales, dolphins, and other species of marine mammals; and land birds and seabirds. Migratory animals are almost in constant movement. Although not a rule for every migratory species, in the Northern Hemisphere their populations shift seasonally between their breeding areas in the north and wintering areas in the south in search of better climatic conditions and food availability, or to follow the animals that migrate for these reasons in order to use them as resources. There is an enormous uncertainly in the identification of migratory species, and thus there is no simple way to compile a complete list of all migratory biodiversity. This is especially true of groups of species that possess a small mass (e.g., invertebrates and some groups of fish), that are not well studied because they are not considered a resource (e.g., do not provide a direct ecosystem service such as food), perform partial migrations and are therefore typically not observed (e.g., stripped mullet), or have a range of movement so wide that they may appear to move constantly without a specific purpose (e.g., ocean nomads such as ocean sunfishes).

Migratory vertebrates in the Gulf of Mexico region include species that are small to large, commercially and recreationally harvested, imperiled to very common, endemic to widely distributed, nearshore to offshore and shallow to deep, and that migrate vertically and horizontally across multiple political boundaries and jurisdictions. Below, we present a synthesis of the migratory biodiversity in the Gulf:

FISH

Fish that migrate in the Gulf of Mexico constitute a diverse group, and a compilation of all the species that perform this ecological function is not currently available. Migratory fish species, and species groups such as families or other taxonomic groupings, have been classified using different aspects of migrations for practical and functional purposes. Examples of the criteria commonly used to refer to migratory fish are the range of their movements, whether the fish migrate to freshwater or into the ocean (i.e., diadromous), and a distinction between horizontal and vertical migrations. Pelagic species with wide geographic distribution, those that cross multiple jurisdictions in their movements, and species that undertake migrations of significant but variable distances across oceans for feeding or reproduction, are referred to as Highly Migratory Species (HMS). HMS are referred to in Article 64 of the United Nations Convention on the Law of the Sea (UNCLOS). Although no operational definition of "highly migratory" is given in the Convention, an agreed list of species considered to be highly migratory by the Convention was incorporated into Annex I (UNCLOS 1982). The list includes the following groups of HMS: tuna and tuna-like species (e.g., mackerels), pomfrets, marlins, sailfishes, swordfish, sauries, dolphin fish, oceanic sharks (including whale shark and those in the Family Carcharhinidae, or requiem sharks such as bull shark), and whales and dolphins. Seventy-nine percent of the HMS listed in UNCLOS (1982) are found within the Gulf of Mexico. The only group of HMS that does not appear to be present in the Gulf is the sauries.

Hoese and Moore (1998) recorded 550 fish species occurring in the continental shelf of Texas and Louisiana (and possibly also in the northeastern Gulf). These authors identified 31 fish species in freshwater that are likely to be found in Gulf waters (from estuaries to Gulf waters), and 45 marine fish that commonly invade fresh waters. The knowledge of the occurrence of diadromy is very uneven, and whereas it is well known in North America, it is not a well-recognized phenomenon in tropical rivers. In many cases, fish thought to be diadromous are routinely described as being highly euryhaline — e.g., bull shark is a facultative and not a strict diadromous fish (McDowall 1988). Recognized diadromous species of important fisheries in the Gulf of Mexico are members of the following groups: requiem sharks and some rays, sturgeons, freshwater eels, herrings, shads, sardines, sculpins, snooks, freshwater basses, mullets, and gobies. In comparison to geographic or horizontal migrations, vertical migrations have received little consideration in discussions of fish migration. However, diel (24-hour) marine migrations constitute one of the most dramatic biological processes. These migrations frequently follow nutritional functions and are performed by fresh and marine species. These fish communities spend daylight hours at a depth of 1,000 meters and migrate en masse to shallower depths of 0-200 m at sunset. Although multiple species migrate vertically, perhaps the group that is responsible for the largest amount of movements in the Gulf of Mexico is the Order Stomiiformes. This group constitutes the second most diverse order in the Gulf of Mexico, with 113 species in 35 genera. For example, fish of the Family Stomiidae are mesopelagic fish that spend daylight hours at a depth of 900 meters and at 20 meters during the night, and between 50 and 70 percent of their populations perform daily vertical migrations (Sutton and Hopkins 1996).

SEA TURTLES

All five species of sea turtles occurring in the Gulf of Mexico are migratory: green, Kemp's ridley, loggerhead, hawksbill, and leatherback. Of these, Kemp's ridley and loggerhead are most common in the northern Gulf, green and hawksbill are both widely distributed in the Caribbean and commonly live around coral reefs and leatherback is primarily a pelagic species that spends most of its life in the open ocean. Kemp's ridley sea turtles only nest in the Gulf of Mexico.

MARINE MAMMALS

There are 29 species of marine mammals known in the Gulf of Mexico: 28 whales and dolphins (cetaceans), and one manatee (sirenian). Although baleen whales are not reported to occur regularly in the Gulf of Mexico, they constitute the primary migratory cetacean group in this region. These species commonly travel between their oceanic breeding areas in tropical to temperate waters and their higher productivity feeding areas in the north, and thus are rarely seen in the Gulf (Würsig et al. 2000). The only exceptions to this may be Bryde's whale and the largest toothed whale, the sperm whale. Although these two species are known to be regular migrants in other parts of the world, their populations in the Gulf are considered to be year-round residents. Moreover, a recent study confirmed that the Gulf population of Bryde's whale, estimated at fewer than 50 individuals, has a unique evolutionary lineage, distinct from all others of their kind. This small population size raises conservation concerns with its markedly low genetic diversity (Rosel and Wilcox 2014). In this study we assessed the migratory movements of sperm whales in the northern Gulf of Mexico, and even those of one individual who migrated from the Atlantic Ocean into the Gulf and then to the Caribbean Sea. None of the beaked whale or dolphin species that occur in the Gulf with coastal or oceanic populations has documented evidence of migratory movements in the region (Schmidly and Würsig 2009). The Florida subspecies of the West Indian manatee performs seasonal migrations of typically short-distance movement along the East and northeastern Gulf coast of the United States.

BIRDS

Birds are probably the most diverse of the taxonomic groups studied in this report, with more than 500 species recorded regularly in the waters and adjacent lands of the Gulf of Mexico. This region is used during all phases of the life cycles of many bird species, including breeding, foraging, wintering, and on passage migration. Of particular importance, the Gulf of Mexico region is perhaps the most critically important geographic area for bird migration in North America due to the large number of species that use the region, their abundance and the barrier that the Gulf represents, particularly to terrestrial species. The majority of migratory birds in eastern North America pass across or around the Gulf twice a year during their seasonal migrations primarily during spring and fall; for many, it is clear that they have evolved migration strategies to take this enormous barrier into account. Migratory birds in the Gulf of Mexico region are generally divided into two broad groups depending on the primary pathway they use to cross the Gulf: trans-Gulf migrants fly directly over the waters of the Gulf, and circum-Gulf migrants fly around the western Gulf and seldom, if ever, cross directly over water.

Many other species of birds use the Gulf as year-round or seasonal habitat for extensive periods. For example, the coastal regions of the Gulf are the most important location in all of North America for wintering waterfowl, with more than 3 million ducks and geese spending the winter season in the region. Coastal barrier islands and similar habitats in the Gulf are disproportionately important for beach nesting birds, with 25 percent or more of the U.S. or North American populations of many species found in the area (http://www.fws.gov/gulfrestoration/gulfbirds.html).

The Gulf of Mexico Large Marine Ecosystem

The Gulf of Mexico Large Marine Ecosystem (LME) constitutes an important region at the junction of North and Mesoamerica, where the tropical and warm-temperate marine waters of the North Atlantic Ocean and Caribbean Sea meet. Biologically, both its terrestrial and marine environments merge into ecoregions that constitute the intersection of the nearctic and neotropical ecozone bird faunas, and the Carolinian and Caribbean marine faunal provinces. Combined, this creates a diversity of ecological conditions suitable for the development of complex ecosystems and habitats that make the Gulf of Mexico LME an arena of hemispheric relevance in which vast and constant migratory biological processes take place. Because the Gulf of Mexico and Caribbean Sea are connected via different demographic, genetic, and physical levels, they are able to sustain viable populations of migratory species (Grober-Dunsmore and Keller 2008). The Caribbean Sea and Gulf of Mexico are also connected in social and economic ways that support the economies and the health of the United States, Mexico, and Cuba.

The Gulf of Mexico LME is the ninth largest body of water in the world (Kumpf et al. 1999). It covers approximately 1.6×10^6 km², with waters deeper than the continental shelf of about 8.6×10^5 km². The periphery of the Gulf harbors many shallow (less than 20 meters deep) and intertidal areas. Most of the water enters the Gulf from the Caribbean Sea through the Yucatán Channel, circulates as the Loop Current and exits through the Florida Strait, eventually forming the Gulf Stream in the North Atlantic Ocean. Smaller counter currents exist at each of the straits in the Gulf. Portions of the Loop Current often break away, forming eddies or gyres that affect regional current patterns. The physical oceanography or circulation of the Gulf has been described in many papers (e.g., see Sturges and Lugo-Fernandez 2005, and references in Muller-Karger et al. 2015).

Geomorphic and oceanographic characteristics provide the Gulf of Mexico basin with unique attributes for the development of productive, diverse, and resilient ecosystems (Sherman et al. 1999, Darnell 2015). The continental shelf is topographically diverse and includes reefs, banks, slopes, escarpments, knolls, sub-basins, and submarine canyons. The Gulf receives freshwater from major rivers in the United States and Mexico that are responsible for localized hotspots of primary production. This habitat complexity and biological connectivity supports the region's high biodiversity and allows for estuarine, coastal, continental shelf, and deep-water Gulf habitats to support viable populations of migratory species. For example, the Gulf supports 99 percent of the nesting population of Kemp's ridley sea turtle (Gallaway et al. 2013).

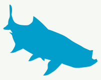
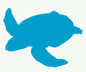
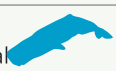
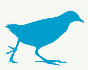
The primary study area of this report is composed of the Gulf of Mexico LME; more specifically, we used the boundary proposed in Felder and Camp (2009) in Figure 1. This includes plants and animals occurring from estuarine to marine waters in the United States from the west coast of Florida to Texas, in Mexico from Tamaulipas to the northeastern part of the Yucatán Peninsula, and along the northwestern coast of Cuba (bounded approximately in the Florida Straight areas by a line from the vicinity of Key Largo, Florida, to Punta Hicacos, Cuba, and in the Yucatán Channel by a line from Cabo Catoche, Mexico, to Cabo San Antonio, Cuba). Adjacent waters of the east coast of Florida and the northwestern Caribbean Sea are included in our maps, but it was not in the scope of this report to provide detailed discussions for those areas.

Figure 1. Study area in the Gulf of Mexico Large Marine Ecosystem, and extent of the Deepwater Horizon oil spill in April 2010.

Methodological Approach

The Conservancy synthesized existing scientific information from more than 100 researchers and institutions to increase understanding of the pathways of migratory species in the Gulf of Mexico LME. The assessment focused on 26 selected migratory species of vertebrates (Table 1). It is important to mention that although all of these species are generally considered migratory (thus migratory movements are essential for the survival of the species), some of their populations in the Gulf are resident or have regional movements and sporadic exchanges with other sub-populations (e.g., striped bass, sperm whale, osprey). The Conservancy gathered, organized, and analyzed distribution areas, reproductive, and foraging aggregation sites, thousands of species occurrence points, hundreds of satellite movement tracks, and numerous additional spatial layers about their threats and management. These spatial data were integrated into different geodatabases in a Geographic Information System (GIS). We conducted a series of spatial analyses using ESRI's ArcGIS to identify critical migratory grounds and opportunities for conservation and restoration in the Gulf. Specifically, this assessment identified partial migratory corridors and movement density within the corridors, occurrence hotspots, aggregations or stopover areas, and threat areas for the species and their taxonomic groups. Table 3 provides a summary of the map products that were created for each of the species included in this assessment. The data sources from numerous collaborators and available databases for these analyses are presented on Appendix II.

Table 3. Map products and tracking data available for each species.

GROUP	SPECIES	OCCURRENCE & DISTRIBUTION MAP	TRACKING DATA TYPE	CORRIDOR & MOVEMENT DESNSITY MAP$
Fish 	Atlantic tarpon	●	Satellite	●
	Bull shark	●	Satellite	●
	Gag grouper	●		
	Gulf menhaden	●		
	Gulf sturgeon	●	Satellite	●
	Mutton snapper	●		
	Striped bass	●		
	Blue marlin	●	Satellite	●
	Bluefin tuna	●	Satellite	●
	Dolphin fish	●	Satellite	*
	Whale shark	●	Satellite	●
Sea Turtle 	Green	●	Satellite	●
	Kemp's ridley	●	Satellite	●
	Loggerhead	●	Satellite	●
	Leatherback	●		
Marine Mammal 	West Indian manatee	●		
	Sperm whale	●	Satellite	●
Bird 	Broad-winged hawk	●	Satellite	●
	Cerulean warbler	●		
	Osprey	●	Satellite	●
	Wood thrush	●	Geolocator	●
	Black rail	●		
	Black skimmer	●		
	Redhead	●		
	Whooping crane	●	**	●
	Audubon's shearwater	●		

$ The number of satellite or geolocator tracks available for each species is stated in each corridor map
*Only one satellite track was available for dolphin fish at the time that this report was developed, and therefore corridor and movement density maps were not created
**Although the satellite tracking dataset was not available for whooping crane, we included the migratory corridor provided by the USFWS in the corridor and movement density analysis

Single Species

SUMMARY OF OCCURRENCES

The point observation occurrence records were gathered from multiple international and national databases that are publicly accessible or from collaborating researchers and institutions. Occurrences were aggregated into 20-by-20-kilometer cells across the study area to generate synthesis products of the observation coverage and human survey effort. This was accomplished by conducting spatial joins of the observation points and the 20-by-20-kilometer "fish net" and representing the result in a regular square grid. The result visually depicts areas in the Gulf with the highest concentrations of records, and when overlaid with the species distribution, it illustrates potential data gaps. The available databases contain a greater number of point observation occurrence records for the northern Gulf than the southern Gulf, and these summaries reflect the differences in knowledge and efforts across the Gulf LME. The number of points (records) used in the analysis is stated on each map.

DISTRIBUTIONS

Data sources for distributions varied depending on the type of species (from species distribution to essential fish habitat to critical habitat) and the scale (from global distribution to remaining/current range). The distributions of fish within the Gulf and adjacent seas were compiled using Essential Fish Habitat layers from NMFS (2014) or species distribution layers from the International Union for the Conservation of Nature (IUCN 2014). A critical habitat designation of areas is used for Gulf sturgeon, which is the only fish species listed under the ESA. The whale shark distribution map was created from Compagno et al. (2005). The Gulf menhaden seasonal distribution was developed by Trudel et al. (1989) and was provided by the Ocean Conservancy. All of the bird distributions are from BirdLife International (2014) and IUCN (2014) except for whooping crane, which was digitized using a U.S. Fish and Wildlife Service map (USFWS 2014) and expert knowledge on current populations. Sea turtle distributions were acquired from IUCN (2014) or State of the World's Sea Turtles (SWOT 2006, 2007, 2008, 2009, 2011, 2012, 2013, Kot et al. 2013). The sperm whale distribution was gathered from IUCN (2014) and the manatee distribution was digitized from multiple sources (Lefebvre et al. 2001, SEMARNAT 2010, IWLearn 2014, Save The Manatee 2014).

MIGRATORY CORRIDORS AND MOVEMENT DENSITY

Animal tracking data, generated using satellite and geolocator devices mounted to individuals, was gathered for migrating animals of all species for which data was available (10 marine species and three bird species). Due to the limitations posed by the size and weight of current satellite devices, it is not possible to implement this technology for all the species included in this assessment (see Table 3 for a list of species with tracking data available for this assessment). Therefore, data was not available for small birds and fish that do not surface to allow for data broadcasting to satellites. Table 4 provides a brief introduction to wildlife tracking technology and a list of available online databases of tracking data. For those species without movement data, we present summaries of their observations and their distributions in the assessment area. Movement tracking datasets for the available species were gathered from dozens of contributing researchers working to understand the migratory movements of animals in the Gulf region (see Appendix II for a complete list of collaborators and data providers). Typically, satellite tracking data is gathered by scientists using the global data relay system Argos CLS™ (http://www.argos-system.org) that uses a constellation of satellites to collect the data and broadcast it to land stations. The track data were preprocessed in GIS, and errors were corrected based on instructions provided by researchers or recommendations in the instruction manual of Argos CLS™. Since the objective of this assessment was not to modify the data provided by researchers (so as not to propagate errors), we requested the most probable track, when available. The most probable track is a postprocessing data modification technique, conducted by the scientists, that uses the locations reported by the satellite system to identify a statistically significant but smooth and error-free animal path. Tracking data that did not include a most probable track consisted of raw tracking data that was also provided by scientists. All fish tracks were filtered to remove error points occurring on land, and all obvious location errors (such as point locations in the Pacific Ocean) were removed for all species. To avoid data bias toward tagging sites, effort was taken to ensure that tracks originated in different locations throughout the Gulf, when possible. Also to avoid foraging and nesting sites emerging as high-movement areas during their migrations, the analysis only used the long-distance migration portion of the track for the majority of the species. The migration portion of the track was partitioned for those species for which we had suitable data and sufficient knowledge about their movements. Despite these efforts, the satellite data is inherently biased toward: 1) the tagging locations used by researchers (whether these locations are used for practical reasons or constitute true aggregation sites of species), 2) the temporal dimension of the tagging efforts (e.g., seasonal opportunities to conduct field work), and 3) duration of the different electronic tags (for example, tags of different sizes and battery capacities are used to tag different species). Although we made a large effort to gather migratory tracking data for these species, in some cases the amount of data available varied greatly depending on the species and the corridors determined from a higher number of individual animal tracks. The number of satellite tracks used in the analyses has been stated in each map.

The species corridors were created with a spatial line density tool in ArcGIS called Line Density. Using the individual movement track, this analysis generated significant movement pathways areas (combination of polylines of tracks). The tool calculates the density of linear features in the neighborhood of each output raster cell. Density is calculated in units of length per unit of area. One of the most crucial steps in this analysis is to determine the most applicable search radius ("bandwidth") for each species (Worton 1989). Although scientists do not agree on how this value should be calculated (Kie et al. 2010), we derived the search radius using the following formula for each individual, following the method suggested by Rodgers and Kie (2011):

$$h_{ref} = n^{-1/6}\sqrt{\frac{var_x + var_y}{2}}$$

where n is the number of points recorded by the satellite tracking device, var_x is the variance in the longitude of all of the recorded points, var_y is the variance in the latitude of all of the recorded points, and h_{ref} is the search radius. The line density analysis used a base raster with 1 kilometer of spatial resolution for the entire Gulf.

The corridor for one species, broad-winged hawk, was developed by the National Commission for Biodiversity Use and Knowledge of Mexico (CONABIO) using a different technique, Brownian Bridges Movement Model (BBMM). We ran several tests to determine a more refined corridor for this species, which migrates along the coast very close to the ocean, and determined that BBMM was the best corridor analysis tool for this species. The utilization distribution maps for migrations were computed with the dynamic BBMM implemented in *Move* library for R™ software (Smolla and Kranstauber 2013). The expected movement path between each pair of locations is calculated with a Brownian motion approach (Horne et al. 2007). The BBMM improves the utilization distribution estimation, because it takes into account the movement of the animal and considers the irregularity of samples in satellite tracking data. One corridor presented in this report for a different species, whooping crane, was developed by USFWS, and the raw tracking data was not available for this analysis (Brei et al. 2009a).

We used the resulting raster layer of the Line Density Analysis to determine the extent of the species' corridor and high movement areas within the corridor. We used the 95 percent line density estimate threshold to represent the corridor for all species except osprey, following similar methodology in other animal movement studies (Pendoley et al. 2013). We used a 98 percent line density estimate for the osprey tracks. The result is a polygon for each of the 14 species that represents its migratory corridor, which is a pathway used by multiple individuals during migration primarily in the Gulf of Mexico. We also determined the movement density areas using the same algorithm given by the spatial density of the tracking data within the migratory corridor. The areas of high movement represent the portions of the corridor most used by the individuals in this analysis. These high movement areas may represent the migration pathways most commonly used by the majority of individuals of these species in the Gulf of Mexico.

We recognize that additional pathways or branches of their migratory corridors most likely exist for each species and that the results presented in this report constitute preliminary and partial corridors. In the majority of cases, only a few tracks were available for each species due to their availability for this project or existence of the data. We suggest users of this information keep in mind the bias and limitations mentioned that might affect these preliminary corridor products. We hope to be able to determine additional corridors or more refined corridors as more data from additional individuals becomes available in the future.

Multiple Species

MIGRATORY CORRIDORS

Corridors for marine species and the bird corridors were combined with the Raster Calculator tool to determine which areas of the Gulf are used as pathways for multiple species. Maps illustrate regions that are used as a corridor for the greatest number of species.

HOTSPOTS

Thousands of point observation occurrence records were aggregated and analyzed using the Point Density tool for all 26 species. The result from each species point density analysis was culled to the top 25 percent, since the top quartile of the data was used in this analysis as the threshold for identification of hotspots. The sum of the top 25 percent point density results for every species represents the hotspots for multiple species occurrences in the Gulf.

FEEDING AND REPRODUCTIVE AGGREGATIONS

Information for all available aggregations of 16 species was also integrated into the analysis (Atlantic tarpon, bull shark, gag grouper, Gulf sturgeon, mutton snapper, blue marlin, bluefin tuna, whale shark, all four sea turtles, the two marine mammals, black skimmer, whooping crane). In this study, an aggregation is defined as an area in which numerous individuals of the same species coverage to forage, nest, breed, spawn or calve. We gathered published, verified aggregation data from multiple sources such as scientific publications, books, field surveys, and databases. The aggregations for the 16 species were overlaid in Raster Calculator to determine which regions of the Gulf represent multispecies aggregation areas.

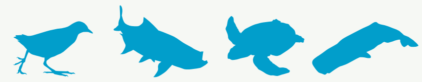
THREAT ANALYSIS

Although fish, sea turtles, marine mammals, and birds in the Gulf of Mexico face numerous threats, we identified specific threats that may represent barriers to completing their migratory cycles. These threats were identified, weighted, and in some cases, mapping using information from recovery plans, management plans, threat assessments, the scientific literature, and expert review. Examples include: By-catch and wetland and mangrove loss for marine fish; dams for anadromous fish; vessel collisions for marine mammals: wetland and forest loss and the growth of urban areas for birds; longline fishing and beach light pollution for sea turtles.

PROTECTED AREAS ANALYSIS

The protected and other managed areas in the Gulf of Mexico LME were overlaid with the marine multispecies corridors in GIS. Protected and managed areas used in this analysis include national parks, national marine sanctuaries, national forest, national wildlife refuges, state parks, state wildlife management areas, and private protected areas owned by the Conservancy, Audubon, and land trusts. Protected areas in the United States, Mexico, and Cuba where obtained from national databases such as Protected Areas Database of the United States (USGS 2012), Cobertura de las Areas Protegidas Federales de México (CONANP 2014), and World Database on Protected Areas (IUCN and UNEP-WCMC 2015), respectively. Other managed areas such as the Conservancy's private preserves and management areas (The Nature Conservancy 2015b) and state wildlife management areas were obtained from a variety of sources. This analysis identified areas of corridors that are protected or under other types of management. A Tabular Intersection Analysis in GIS was conducted to determine the percentage of each species' migratory corridor located in protected areas. This same analysis was used to calculate the percentage of each species' aggregation areas and highest movement density (top 25 percent of movement from movement density analysis) located in protected areas. For birds, the most critical assessment is the percentage of the stopover locations (i.e., stepping stones) located in protected areas. It is in these stopover areas that birds can rest, refuel, and regain lost body fat in the coastal environments in the Gulf of Mexico before continuing on their journey to and from breeding

Table 4. Animal movement tracking techniques and tools.



The vastness of the ocean limits the ability to observe its biodiversity. The table below shows the online movement tools that are currently available to track marine animals and birds in the Gulf of Mexico region.

NAME	TYPE	LINK	BONY FISH	SHARK	SEA TURTLE	MARINE MAMMAL	BIRD
Animal Telemetry Network - Integrated Ocean Observing System	Acoustic/ Satellite	oceanview.pfeg.noaa.gov/ATN	●	●	●	●	
GulfTOPP - Tagging of Pelagic Predators*	Satellite	gulftopp.org	●	●	●	●	●
Guy Harvey Research Institute - Nova Southeastern University	Satellite	nova.edu/ocean/ghri	●	●			
Motus Wildlife Tracking System	Radio	motus-wts.org				●	●
Movebank	All	movebank.org	●	●	●	●	●
OBIS SEAMAP - Duke University	Satellite	seamap.env.duke.edu			●	●	●
Ocean Tracking Network	Acoustic	oceantrackingnetwork.org	●	●	●	●	
OCEARCH**	Satellite	ocearch.org		●			
RJ Dunlap Marine Conservation Program - University of Miami	Satellite	rjd.miami.edu/education/ virtual-learning		●			
Seaturtle.org	Satellite	seaturtle.org/tracking/		●	●	●	●
Wildlife Tracking***	Satellite	wildlifetracking.org/		●	●	●	●

*GulfTOPP site is a private site for researchers working with NOAA in tracking marine vertebrates for NRDA in the Gulf of Mexico
**OCEARCH has an app for smart phones
***Wildlife Tracking is a service of seaturtle.org

areas in North America. Priority migratory bird stopovers were defined by The Nature Conservancy's Migratory Bird Program in a previous study (The Nature Conservancy 2003). Tabular Intersection Analysis in GIS was used to determine the percent of priority stopovers located in protected areas.

Assessment

The Migratory Pathways and Threats of Species

Fish Species

INTRODUCTION

Compilations of fish diversity (especially during the past two decades) from scientific inventories, surveyed targeted fisheries, and surveyed incidental catches by commercial operations in the entire western central Atlantic Ocean reveal that the Gulf of Mexico encompasses a taxonomically and ecologically diverse community of fishes. With 1,541 species recorded, the Gulf contains more than 64 percent of the diversity of fish species and also 90 percent of all fish families in the entire western central Atlantic (McEachran 2009). In the Gulf of Mexico, fish distribution reflects its geological and oceanographic conditions, which in turn define the distribution of habitats. With topographically diverse coastal zones, continental shelf and deeper environments, the Gulf includes a variety of fish habitats that are essential during their migrations. In the northwestern Gulf of Mexico, 552 fish species between Texas and Louisiana were divided into the following habitats: 21 percent estuarine, 31 percent coastal demersal, 14 percent coastal pelagic, 18 percent offshore/tropical reef, and 15 percent epipelagic/deep (Hoese and Moore 1998).

We assessed the migratory pathways of 11 species of fish. In this group we chose two sharks and nine bony fish. Collectively this group of species represents a variety of migratory strategies from coastal to open water offshore migrants and from small movements in localized areas of the Gulf to long-range movements of widely distributed pelagic fish. The majority of the long-range migratory fish in the Gulf are included in epipelagic fish families such as requiem sharks, menhaden, jacks, mackerel, and tunas.

Of the 11 species of fish, seven are considered to be coastal migrants. Gulf sturgeon and striped bass are anadromous fish that migrate up freshwater streams and rivers to spawn. Currently, the distribution of Gulf sturgeon is very restricted to streams and estuaries in the Mississippi Sound area in the northern Gulf of Mexico. The reduction of its range is probably related to the quality of the streams in which the subpopulation originates and to which it shows site fidelity. The capacity of striped bass to migrate has also been limited due to the damming of freshwater streams in the Gulf states in the United States, which have blocked its populations on both sides of these structures and thus limited span of movements. Atlantic tarpon is an amphidromous fish (migrations to and from freshwater systems for reasons other than reproduction) that, in addition to expressing long-range oceanodromous migrations along the coast, moves up freshwater streams in search of fish prey. Gulf menhaden is a catadromous pelagic fish that migrates in large schools between the coastal estuaries and the edge of the continental shelf in the northern Gulf centered on the Mississippi River Delta. Gulf menhaden is the only fish endemic to the Gulf that was included in this assessment, and it is the largest fishery by volume in the northern Gulf of Mexico. Gag and mutton snapper are reef-associated fish that spend most of their time at bottom depths. They migrate between the natural and artificial reef/hard substrate habitat of the eastern and southern areas of the Gulf and the neighboring coastal environments such as estuaries. Bull shark is primarily a coastal shark, but it also uses a large number of habitats in the Gulf of Mexico. It migrates along the coast of the entire Gulf, but it also expresses long movements in the open ocean areas of the Gulf. Although it is also commonly referred to as an amphidromous fish that uses estuarine habitats and even freshwater streams as foraging grounds and as nurseries for its juveniles, it does not seem to require the use of freshwater systems in the completion of its life cycle.

Four of the fish species (dolphin fish, Atlantic bluefin tuna, blue marlin, whale shark) are considered primarily pelagic species that express oceanodromous migratory patterns in the open ocean and deeper areas of the Gulf. Adult and large individuals of these species have a high capacity to move across oceanographic boundaries in the Gulf, such as between the ephemeral and semi-permanent eddies, the Loop Current, and between the Gulf and the Mid-Atlantic Ocean and Caribbean Sea. Due to their high mobility, these species are technically and legally referred as HMS by UNCLOS (1982) and by the National Marine Fisheries Service (NMFS) in the United States. Dolphin fish spend most of their lives around floating natural and artificial habitats such as sargassum, where they find their prey and take refuge. The Atlantic bluefin tuna population depends heavily on the quality of Gulf waters and habitats because they perform regular annual migratory patterns between their winter range areas in the northwestern Atlantic and the north-central Gulf of Mexico where they spawn during the spring. Bluefin tuna constitute one of the most regulated fisheries in the Atlantic Ocean, and its Gulf population is the healthiest stock of its global distribution. Blue marlin concentrate in the Atlantic Ocean, where they spawn during the summer months, and then move into the Gulf from summer to winter to feed on schooling fish. Whale shark illustrates the complexity of a planktivorous fish that depends on the Gulf for its largest globally known feeding aggregation. Whale shark was first discovered in Gulf waters in the 1930s. It has been an icon of marine conservation in the Gulf of Mexico, and in 2009 the Mexican government established the Whale Shark Biosphere Reserve in the northeastern portion of the Yucatán Peninsula.

Of the 11 species of fish assessed in this study, only two are federally listed in the United States, Mexico or Cuba (Table 1). Gulf sturgeon is listed as threatened under the Endangered Species Act in the United States and is listed as extirpated in its historical waters in Mexico by the NOM-059-ECOL. Whale shark is listed as threatened in Mexico by the NOM-059-ECOL and as vulnerable in Appendix II of the Resolution 160 of Cuba (CITMA 2011). Although whale shark is not federally listed in the United States, it is protected from being taken for fishing under the Magnuson-Stevens Fishery Conservation and Management Act (MSA). Globally, the species of fish included in this analysis are listed by IUCN as follows: bluefin tuna is endangered; Atlantic tarpon, blue marlin, mutton snapper and whale shark are vulnerable; bull shark and Gulf sturgeon are near threatened; dolphin fish, gag

Table 5. Migration and aggregation timing of fish species in the Gulf of Mexico.

		GULF MIGRATION PERIODS											
MIGRATORY SUBGROUP	SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Coastal	Atlantic tarpon[1]			TO NORTH						TO SOUTH			
	Bull shark[2]				TO NORTH						TO SOUTH		
	Gag grouper[3]		SPAWNS FLORIDA										
	Gulf menhaden[3]	TO COAST		SPAWN					JUVENILE TO ESTUARIES				ADULT
	Gulf sturgeon[3]	ESTUARIES		UR			SPAWNS				DR		IN
	Mutton snapper[4]					SPAWNS							
	Striped bass[5]	UR		SPAWNS			DR			IN ESTUARIES OR SEA			
Pelagic	Blue marlin[6]						SPAWNS GULF				*SPAWNS ATLANTIC*		
	Bluefin tuna[7]	ATLANTIC				SPAWNS						NORTH	
	Dolphin fish[3]												
	Whale shark[7]								FEEDS				

In the Gulf | In alimentary or reproductive aggregation areas | Peak of aggregation period | Migration period

Italicized font represent activity outside the Gulf of Mexico; UR = up-river migration, DR = down-river migration.

[1]Ault et al. 2008; [2]Hueter 2003; [3]GFMC 2004; [4]SCRFA 2014; [5]GSMFC 2006; [6]NMFS 2006 & Rooker et al. 2013; [7]NMFS 2006

grouper, and striped bass are of least concern; and Gulf menhaden has not yet been evaluated. Under the NatureServe Global Conservation Status (G-ranks), most of the fish are apparently secure (G5) or they have not yet been evaluated. Only Gulf sturgeon has been rated as imperiled (G3T2).

The temporal patterns of fish migration in the Gulf LME are variable. The group of species in question comprises many different migratory strategies and therefore a large variability in migratory behaviors. Additionally, their specific habitat interaction needs result from a suite of physiological and genetic characteristics associated with their migrations. Table 5 shows the approximate periods of migration and, in some cases, estimated times of peak migration. As a general pattern, coastal fish tend to migrate to the southern Gulf along the coast during the fall and winter and return to the northern Gulf in the early spring. Similarly, Gulf sturgeon migrates up freshwater streams in the spring and returns to the Gulf waters in the fall. Some exceptions are the benthic reef fish, such as gag grouper, that migrate early in the winter to their aggregation sites to spawn in the late winter and early spring. Gulf menhaden spawns offshore early in the spring. Pelagic fish tend to migrate during the spring to reach their feeding or reproductive aggregations by the summer, and then they return to their foraging areas in the Gulf and western Atlantic Ocean during the winter. As shown in Table 5, fish migration timing is closely related to their movements to and from their feeding and reproductive aggregation areas.

Migratory fish in the Gulf of Mexico face multiple threats. Abundant literature has described and prioritized the main threats that affect fish populations (Gray 1997, Wilcove et al. 1998). Most of the threats to species in coastal areas are directly related to human activities occurring on land, whereas species in the ocean are threatened by a number of unsustainable activities. The ocean system is open and therefore provides a continuous space for threats to affect a large number of species or the habitats on which they depend. Although research shows that the most critical threat to fish species is habitat loss, other threats include overexploitation and other effects of fishing, pollution (including direct and indirect effects of inorganic and organic chemicals; eutrophication and hypoxia), invasive species, watershed alteration (including hydrological systems and physical alterations of coasts), tourism, and marine litter. Habitat loss, unsustainable resource use, and pollution threaten fish in many different ways as species have different life histories and depend on different environmental structures and states.

ASSESSMENT

Included maps in Appendix IV illustrate the distribution areas and summaries of observations for each fish species, and migratory corridor and movement density for those species with movement tracking data available (pages 72-80). The variability of the amount of records gathered for each species shows some patterns not only in the relative abundance of the species or the size of the populations, but also in the effort to collect information. For example, Gulf menhaden has the largest dataset, with more than 62,000 observations, followed by dolphin fish with more than 26,000 observations; these are two species with large populations in the Gulf. In contrast, the Gulf sturgeon dataset contains approximately 500 observations and striped bass only 238 observations. This could be due to a bias in the observational effort as well as to the small size of the remaining populations of these fish, especially those species that may be subject to multiple coastal threats. Another pattern reflected in these maps is the obvious imbalance between the number of observations in the northern and the southern portions of the Gulf, especially when compared with the extent of their theoretical and historical distributions. The summaries of species occurrence also emphasize spatial patterns in the biology of each species; for example, common differences of distributions between coastal and offshore species are reflected, such as whale shark versus bull shark and bluefin tuna versus striped bass. Another example of different spatial patterns is Gulf-wide versus northern Gulf species, such as Atlantic tarpon versus Gulf menhaden.

Migratory corridors were created for six of the 11 species of fish: four bony fish and two shark species. They also represent three coastal species and three pelagic species. The corridors depicted in Figures 18, 20, 25, 29, 31, and 34 can be considered representative of the species groups that these species represent (Table 2). Each map shows the number of individual satellite tracks used to develop the spatial analyses. Additionally, we have included the seasonal distribution areas for Gulf menhaden that show the extent of their movements in the northern Gulf throughout the year. The corridor maps also show the results of the movement density analysis for each species that was derived using the information in the migratory tracks. These maps represent the variability of the amount of movement that occurs in different portions of the corridors. Although all areas depicted are part of the species' migratory corridor, those with the highest density represent the areas that most of the individuals move during migration.

Table 6. Fish threats in the Gulf of Mexico.

	THREAT RATING	
THREAT	**ANADROMOUS**	**ALL MARINE**
By-catch	●●●●●	●●●●●
Dams	●●●●●	●●
Wetland loss	●●●●	●●●●
Mangrove loss	●●●●	●●●●
Lionfish observation	●●	●●
Hypoxia		●●
Maritime vessel traffic/density	●	●
Oil and gas activity/pollution	●	●
Ocean pollution from marine vessels	●	●
Inorganic nonpoint pollution	●	●
Nutrient pollution	●	●
Oil and gas pipelines	●	●
Shrimp trawling (CPUE)	●	●
Whale shark ecotourism		●

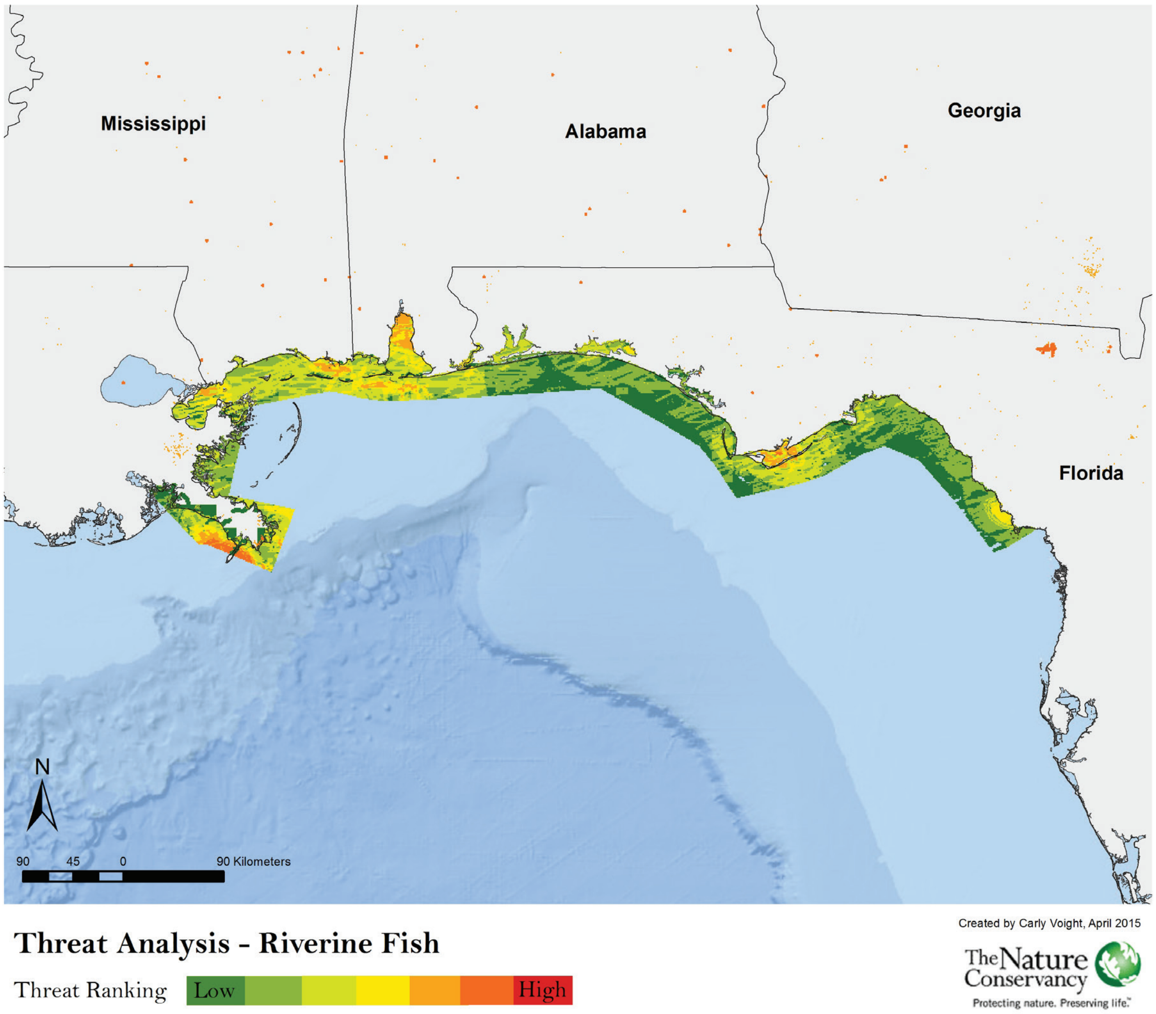
Threat scale: 5 = highest, 1 = lowest CPUE = Catch per unit effort

The two shark species show different migratory movement patterns. The bull shark corridor represents areas of movements primarily limited to the coast and related to areas that have been identified as foraging sites and nurseries in the northern Gulf (Blackburn et al. 2005). These areas include the south Florida coast and the Mississippi River Delta area, which were also the tagging locations. In contrast, the whale shark corridor reflects its long pelagic movement patterns. Whale sharks follow well-defined temporal and spatial patterns while migrating to and from their feeding aggregation sites in the northern and southern portions of the Gulf, which also constitutes their main tagging sites. Therefore, their corridor reflects the main routes that they follow after departing from aggregation sites in the fall. This is especially true in the southern Gulf where the aggregations are much more localized on an annual basis off the northeast coast of the Yucatán Peninsula's Holbox and Isla Mujeres areas (Hueter and Tyminski 2012). The movement density areas are well correlated with the pathways out of the aggregation sites and in the direction of oceanographic features such as eddies and bottom features along the continental shelf where they feed. Due to high variability in the areas of the Gulf used by whale shark, this is the only species of fish for which movement data was partitioned in feeding and movement segments in order to create a more specific corridor that represented its migration pathways.

The corridors of the bony fish species also represent two different areas used to migrate: the coastal areas along the Gulf and the offshore environments of the Gulf. However, even among the two coastal species (Gulf sturgeon, Atlantic tarpon), the migration pathways of the former are much more constrained in space. The anadromous migratory patterns of Gulf sturgeon between the freshwater streams and their nearshore foraging areas in the Gulf are constrained to the immediate marine areas as mentioned in the literature and confirmed by the corridor (Parauka et al. 2001). Nevertheless, only six satellite tracks were available to develop this corridor. The Atlantic tarpon corridor is concentrated in the coastal areas along the continental shelf that the species uses to perform its annual migrations between the northern and southern portions of the Gulf as the water temperature changes. This is a pattern also expressed by other coastal migratory pelagic species, such as some sharks, mackerels, bonitos, and the cobia. A few areas appear to have a large density of movement, but an interesting pattern is the use of a coastal corridor between central Texas and central Veracruz. It is possible that in addition to having a large temperature driver to stimulate migration (Ault et al. 2008), the Atlantic tarpon also takes advantage of fish migrating along this north-south pathway of the Gulf.

The highest bluefin tuna movement density areas occur in their entry to the Gulf through the Florida Strait. Their movements around the annual spawning areas in the northwestern Gulf are also accurately represented. The blue marlin is another species that primarily migrates from the northwestern Atlantic into the Gulf

Figure 2. Threat analysis: riverine fish.

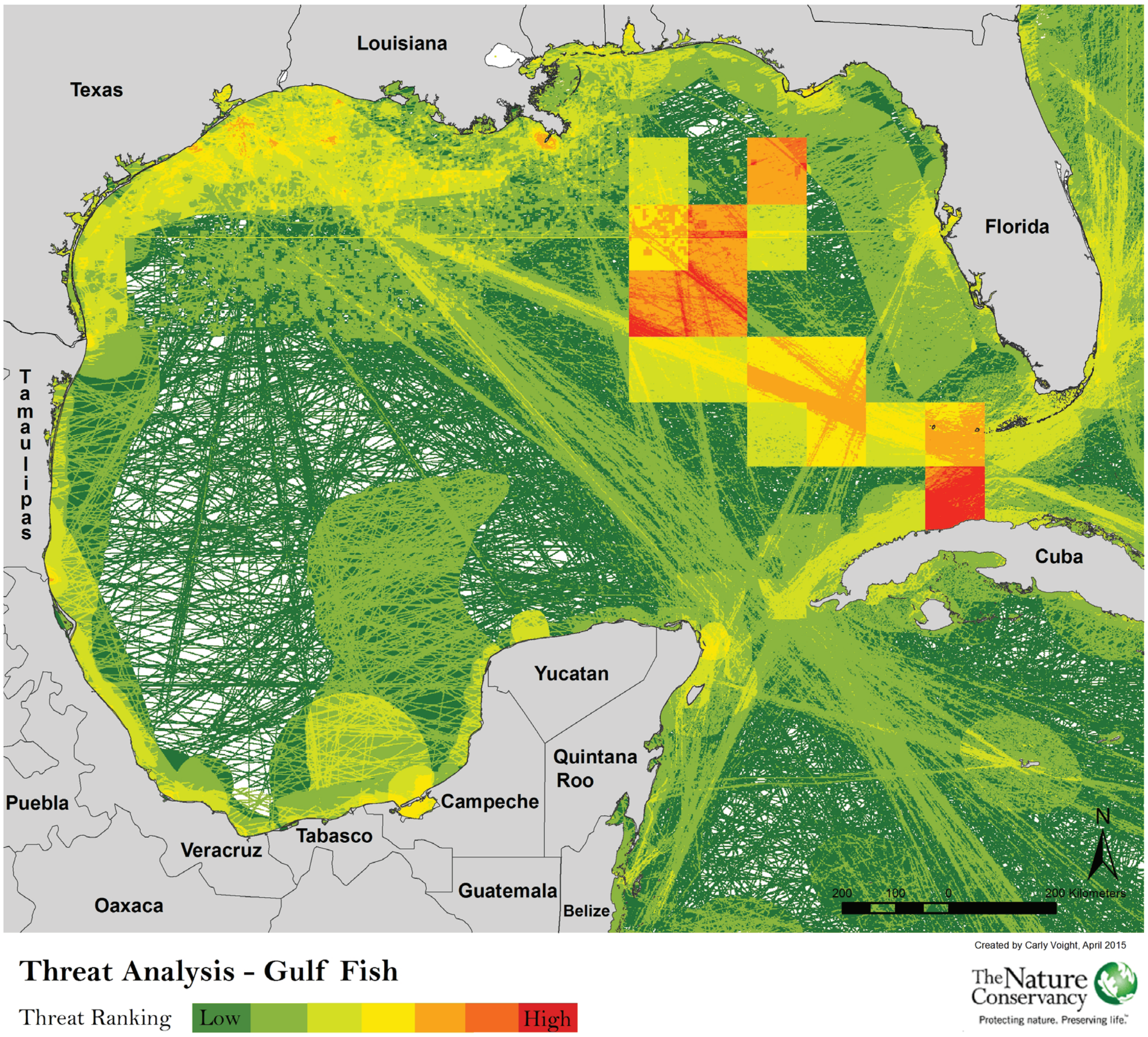


through the Florida Strait during the spring and summer, and its corridor reflects that pattern. Additionally, the density analysis for blue marlin shows a concentration of movement activity in two areas of the Gulf. One is the area of shallow and deep waters between the Mississippi River Delta and the Yucatán Peninsula, which is an area heavily dominated by oceanic fronts (temperature and productivity) produced by the Loop Current. This pathway seems closely associated to the spawning aggregation areas of blue marlin (Brown-Peterson et al. 2008). The second corridor area constitutes the western Gulf, where multiple permanent and semi-permanent oceanographic features create suitable foraging habitat for blue marlin.

As previously mentioned, Gulf menhaden are the species with the largest number of observations in this assessment. Due to this abundance, its reduction fishery constitutes the largest fishery by volume in the Gulf (GSMFC 2010). Although satellite movement data was not available for the menhaden, we have included a map with data published in the Gulf Atlas (Love et al. 2013) of their major egg/larvae and adult summer and winter distribution areas in the northern Gulf. Adults shift between deeper waters over the continental shelf during the winter to shallower areas in summer, while larvae migrate from coastal areas of the continental shelf to near-shore and bay/estuarine waters of the northern Gulf from early spring through fall, when they mature into adults.

We prioritized 14 threats to fish species that have demonstrable effects on fish populations in the region and for which GIS data was available (Table 6). Threats and their weights have been divided

Figure 3. Threat analysis: Gulf fish.



into two groups, those that affect the anadromous fish (including in their migratory pathways in the freshwater streams) such as Gulf sturgeon and striped bass, and those that affect fish while in the marine waters of the Gulf. Therefore, two different sets of weights have been assigned, although they coincide in most cases. Threats also represent two main groups, those that affect individuals directly and in extreme cases could cause death, such as fisheries by-catch, multiple forms of pollution or maritime vessel traffic density, and those that limit the viability of their populations and many inhibit their migratory life cycles in terms of habitat loss. The threats are broadly distributed in the entire Gulf of Mexico region but in some cases only data for the U.S. portion of the Gulf was available (Figures 2 and 3). Another geographic pattern is the concentration of threats in the coastal waters along the continental shelf in the Gulf, including the highest concentration near heavily populated coastal cities and industrial ports.

The weights in Table 6 were assigned based on their relative impact to fish populations as suggested in the literature. Examples of these are the role of by-catch for coastal species (Adams et al. 2014), longline fisheries by-catch for pelagic species (Restrepo et al. 2003), wetland habitats and their loss in fish that use estuaries and other coastal areas as nurseries, and pollution (Jue et al. 2014), hydrological modification and dams (Nelson et al. 2013), hypoxia/dead zone (Breitburg 2002), invasive species (Cote and Maljkovic 2010), and maritime transport and ecotourism activities (Hueter and Tyminski 2012).

Sea Turtle Species

INTRODUCTION

Six of the 11 living species of sea turtles have been documented in the Gulf of Mexico. Of these, one (olive ridley) has only been observed very infrequently, and the Gulf of Mexico is beyond its normal range. The other species—Kemp's ridley, green, loggerhead, hawksbill, and leatherback—are regularly observed in Gulf of Mexico waters (Department of the Navy 2007). We have chosen four of the five sea turtles regularly documented in the Gulf of Mexico for this analysis (Table 1). The only species not included is the hawksbill, which is more common in the Caribbean than in the Gulf.

Adult female sea turtles show a high fidelity to nesting beaches as they return to the same beach on which they were hatched to mate and lay eggs. This behavior strongly influences their migratory and homing patterns. Major nesting beaches are located in the Gulf of Mexico for all species except the leatherback. The main nesting site for Kemp's ridley sea turtles is a single beach at Rancho Nuevo, Tamaulipas, Mexico. Females will also commonly nest on beaches at Padre Island National Seashore, Texas, and in Veracruz, Mexico, and infrequently on beaches in Campeche, Mexico, Galveston Island, Texas, and other areas in Texas, Alabama, Florida, South Carolina, and North Carolina (NMFS, USFWS, and SEMARNAT 2011). The largest green sea turtle nesting beaches within the Gulf of Mexico include several beaches in Mexico in the coasts of Veracruz and northern Yucatán Peninsula. The majority of green sea turtle's major nesting sites are located outside of the Gulf of Mexico, including Florida's Atlantic coast, and in Mexico on Cozumel Island and the area between Playa del Carmen and Tulum, Quintana Roo. Very minor nesting beaches are scattered throughout Mexico, southern Florida, the Florida panhandle, Alabama, and Texas. Several major loggerhead nesting sites are found in or near the Gulf of Mexico. Ninety percent of adult female loggerheads in the United States nest in Florida (FWC 2015). One of the largest nesting beaches in the world is north of Sarasota, Florida. Loggerheads also nest in the Florida Panhandle and the Yucatán Peninsula in great numbers. Minor nesting beaches in the Gulf are found in Alabama and south Texas. Very few leatherbacks lay eggs on beaches along the coasts of the Gulf (Dow et al. 2007).

Table 7. Migration and aggregation timing of sea turtle species in the Gulf of Mexico.

		GULF MIGRATION PERIODS											
SPECIES	LIFESTAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Green	Adult female					MIGRATION	NEST IN FL			MIGRATION			
Green	Juvenile	FORAGE IN WARM AREAS	MIGRATE TO AGGREGATIONS		FORAGE NEAR COAST						MIGRATE TO WARMER AREAS		FORAGE IN WARM AREAS
Kemp's ridley	Adult female			MIGRATION	NEST IN GULF				MIGRATION				
Kemp's ridley	Juvenile	FORAGE IN WARM AREAS	MIGRATE TO AGGREGATIONS		FORAGE NEAR COAST					MIGRATE TO WARMER AREAS			FORAGE IN WARM AREAS
Leatherback	Adult female			MIGRATION		NEST IN NW ATLANTIC			MIGRATION				
Loggerhead	Adult female			MIGRATION	NESTING SEASON IN USA (FL)						MIGRATION		

In foraging areas   At nesting beaches   Migration period

This table represents a simplified account of migration timing for sea turtle species in the Gulf of Mexico. Adult females will not nest or migrate every year. For those females that do nest, the time of nesting varies. For example, some Kemp's ridley sea turtles start migrating in March and nest on beaches in late April, while others may migrate in April and nest in May.

Kemp's ridley is the rarest sea turtle, categorized as critically endangered by IUCN. Loggerhead and green sea turtles are recognized as endangered; leatherbacks are categorized as vulnerable by IUCN. All of the sea turtles in the Gulf are considered to be endangered in Mexico, and except for the loggerhead and green sea turtle, all are also endangered in the United States. The loggerhead population in the Gulf of Mexico is treated as threatened, with endangered populations in other areas. The green sea turtle is currently listed under the U.S. Endangered Species Act as threatened, with endangered populations in Florida and the Mexican Pacific coast. Greens, loggerheads, and leatherbacks are also listed in Appendix I of the Resolution 160 in Cuba (CITMA 2011).

The Gulf of Mexico is an important migratory area for all sea turtles that reside in the region, especially Kemp's ridleys and loggerheads. All four sea turtles in this analysis can be considered highly migratory, making long-distance movements throughout their lives. However, these migrations vary greatly depending on the species and the life stage of the animal. Once entering the water from nesting beaches, post-hatchlings swim until they are transported into the open ocean. Currents propel post-hatchlings to many different areas, depending on the species and at which beach the turtle was hatched. Juvenile loggerheads, greens, and Kemp's ridleys establish foraging areas throughout the coastal Gulf. In general, many juveniles migrate in the fall from foraging areas to overwintering habitats located in warmer waters (Schmid and Witzell 2006, Department of the Navy 2007).

Adult females of all species migrate up to several thousand kilometers from their foraging areas to the nesting beaches. While adult female Kemp's ridley sea turtles mostly migrate along the shallow coast, leatherbacks migrate in deep ocean waters, and loggerheads and greens will use both coastal and oceanic environments. Most Kemp's ridleys, greens, and loggerheads will migrate from foraging areas in the Gulf of Mexico to nesting beaches within the Gulf, while most leatherbacks that forage in the Gulf will migrate to nesting beaches outside of the Gulf, usually to the Atlantic side of Central America. Mating most likely occurs in route or near the shores of nesting beaches, just prior to nesting season. After laying their final nest, adult females migrate back to the foraging areas. The timing of adult female sea turtle migration varies depending on the species, the specific nesting beach, and the individual animal (Table 7). Many adult female sea turtles in the Gulf migrate from foraging areas to nesting beaches in the spring or summer and return to foraging areas in the summer or early fall. Few data exist on the movements of adult males; the females are tagged primarily after nesting at beaches.

The greatest threat to all sea turtles in the Gulf of Mexico is incidental capture as by-catch in fishing gear. While the level of threat for each type of fishery varies by species, all are vulnerable to by-catch in trawls, long-line, driftnet, set-net, pound, gillnet, dredge, and pot traps (Department of the Navy 2007). Shrimp trawling once contributed to thousands of adult sea turtle mortalities in the Gulf, especially for Kemp's ridleys and loggerheads (Magnuson et al. 1990). The number of deaths has decreased due to changes and regulations in the shrimp industry in the late 1980s. Currently, turtle excluder devices (TEDs), instruments that can separate sea turtles from the target fishery catch, are required by all shrimp fisheries in the southeastern United States and Mexico. Despite this requirement, shrimp trawling is still the leading cause of human-related Kemp's ridley and loggerhead deaths in the Gulf (Conant et al. 2009, NMFS, USFWS, and SEMARNAT 2011, Gallaway et al. 2013).

To a lesser degree, all Gulf sea turtles are affected by many other threats. The collection of eggs and harvesting of nesting females was once a great threat to sea turtles in the Gulf of Mexico. This poaching has dramatically declined in the United States and Mexico due to regular patrols of nesting beaches by biologists and armed military personnel (Dow et al. 2007, NMFS, USFWS, and SEMARNAT 2011). However, poaching that occurs on nesting beaches in Central America and the Caribbean definitely affects the Gulf populations, especially leatherback and green sea turtles. Development along beaches has led to increases in artificial lighting, habitat loss, and habitat degradation, especially in the United States. Artificial lighting, which can cause disorientation and possible death to hatchlings and nesting adult females, affects all sea turtles that are active on beaches at night (i.e., loggerheads, greens, and leatherbacks). This may be the most profound in the Gulf along Florida's heavily developed coastline. Beach armoring — including riprap, seawalls, jetties, and sandbag installations — increases with development and can prevent or impede nesting turtles from locating suitable habitat. Other concerns include boat strikes, beach erosion, entanglement and ingestion of synthetic debris (e.g., plastics) and abandoned fishing gear, predation of eggs and post-hatchlings by native and exotic species, and exposure to heavy metals and other contaminants. In the future, climate change may impact sea turtles. Temperature changes may alter sex ratios or the timing of nesting. Also, accelerated sea level rise (due to habitat loss and/or land subsidence) may result in the degradation or loss of available nesting beaches (NMFS, USFWS, and SEMARNAT 2011).

ASSESSMENT

Included maps in Appendix IV illustrate the distribution areas and summaries of observations for each sea turtle species, and migratory corridor and movement density for those species with movement tracking data available (pages 81-84). The highest number of observation records for Kemp's ridley sea turtles are located at their main nesting beach in Rancho Nuevo, Tamaulipas (Figure 37, page 82), and very few records exist about them in deep waters, because they prefer bottom depths of less than 10 meters. The highest number of records for green sea turtles is found in documented foraging areas in the Yucatán Peninsula and Florida Keys (Figure 5). The majority of available observation records in the Gulf of Mexico for leatherback sea turtles come from deep oceanic waters, their preferred habitat (Figure 41, page 84). Loggerhead records occur in both deep and coastal waters, with the highest number of records coming from their preferred foraging and nesting areas (Figure 39, page 83). There is noticeably less data for the southern Gulf region for all species.

The available Kemp's ridley sea turtle track data shows a fairly consistent migration corridor along coastal areas, from nesting beaches in Tamaulipas and southern Texas to foraging areas in Louisiana and western Florida (Figure 38, page 82). The corridor continues from Tamaulipas to the Yucatán Peninsula, as described by Shaver et al. (2015). However, we were not able to delineate this portion of the corridor because the data were not available. A second migratory corridor exists for the Atlantic side of Florida, for turtles that travel north and south along the eastern U.S. coast. The majority of adult female Kemp's ridleys originate from nesting beaches in Rancho Nuevo, Tamaulipas; Padre Island National Seashore, Texas; and Veracruz. Nesters in Mexico and southern Texas migrate either north of beaches toward Texas and Louisiana or south toward the Bay of Campeche in Mexico. They follow the coast, using bays and tidal passes of near-shore, shallow waters. They forage while migrating but tend to establish seasonal residency at specific foraging areas off the coasts of Louisiana, Florida, and the Yucatán Peninsula (Seney and Landry 2011, Shaver et al. 2013). Few data exist on the movements of adult males, and they are not included in this analysis. Satellite studies conducted by Shaver et al. (2005) suggest that they may reside year-round in the waters surrounding nesting sites.

Based on available satellite track data, the coastal area from Houston to the Florida Panhandle and Florida's Big Bend (north of Tampa) are the areas with the greatest density of movement for adult female, juvenile, and sub-adult Kemp's ridley sea turtles (Figure 38, page 82). This is most likely because these sea turtles use these zones for many different activities. Some individuals quickly traverse through the area as a part of their migration route; others spend time foraging in these waters to replenish resources while migrating. Other individuals use the coastal region of these zones as year-round foraging areas. Our analysis shows very little movement by juvenile and adult female Kemp's ridleys in deep waters, a preference that has been documented in the literature (Schmid and Witzell 2006, Seney and Landry 2011).

The results of this analysis indicate several migratory corridor branches for adult green sea turtles in the Gulf of Mexico (Figure 36, page 81). These multiple, connecting sections are geographically located throughout the Gulf as green sea turtles use both coastal and pelagic routes for migration. It is also evident that green sea turtles move into and out of the Gulf through the Florida Strait, the southern coast of Cuba, and in the open ocean from the Yucatán Peninsula to the Cayman Islands. Based on the available satellite track data, the area with the most movement in the Gulf of Mexico for adult female green sea turtles is in the Florida Keys, including the Dry Tortugas (Figure 36, page 81). Other areas of high movement are the eastern coast of Florida (most likely due to a great number of nesting sites in this region) and the northeastern and western Yucatán Peninsula. The most common migration pathway for these individuals is from Florida's eastern coast to the Florida Keys, through the open ocean to the Yucatán Peninsula. This route is most likely taken by adults that nest on the eastern coast of Florida and forage in the Florida Keys or the Yucatán Peninsula and those adults that nest on the Yucatán Peninsula and forage in the Keys. It may represent the migration pathway most commonly used by the majority of green sea turtles in the Gulf of Mexico. These results show less movement of green sea turtles in the western Gulf. This aligns with research, which has shown that adult greens in the Gulf of Mexico are more common in Florida and the Yucatán Peninsula than in other areas. Green sea turtles observed north of Florida are usually juveniles (Lazell 1980, Eppery et al. 1995).

Table 8. Sea turtle threats in the Gulf of Mexico.

THREAT	THREAT RATING
Shrimp trawling (CPUE)	●●●●●
Longline fishing (CPUE)	●●●●
Light pollution at night	●●
Beach erosion	●●
Marine vessel traffic/density	●●
Feral hog density	●
Oil and gas activity/pollution	●
Ocean pollution from marine vessels	●
Inorganic nonpoint pollution	●
Nutrient pollution	●

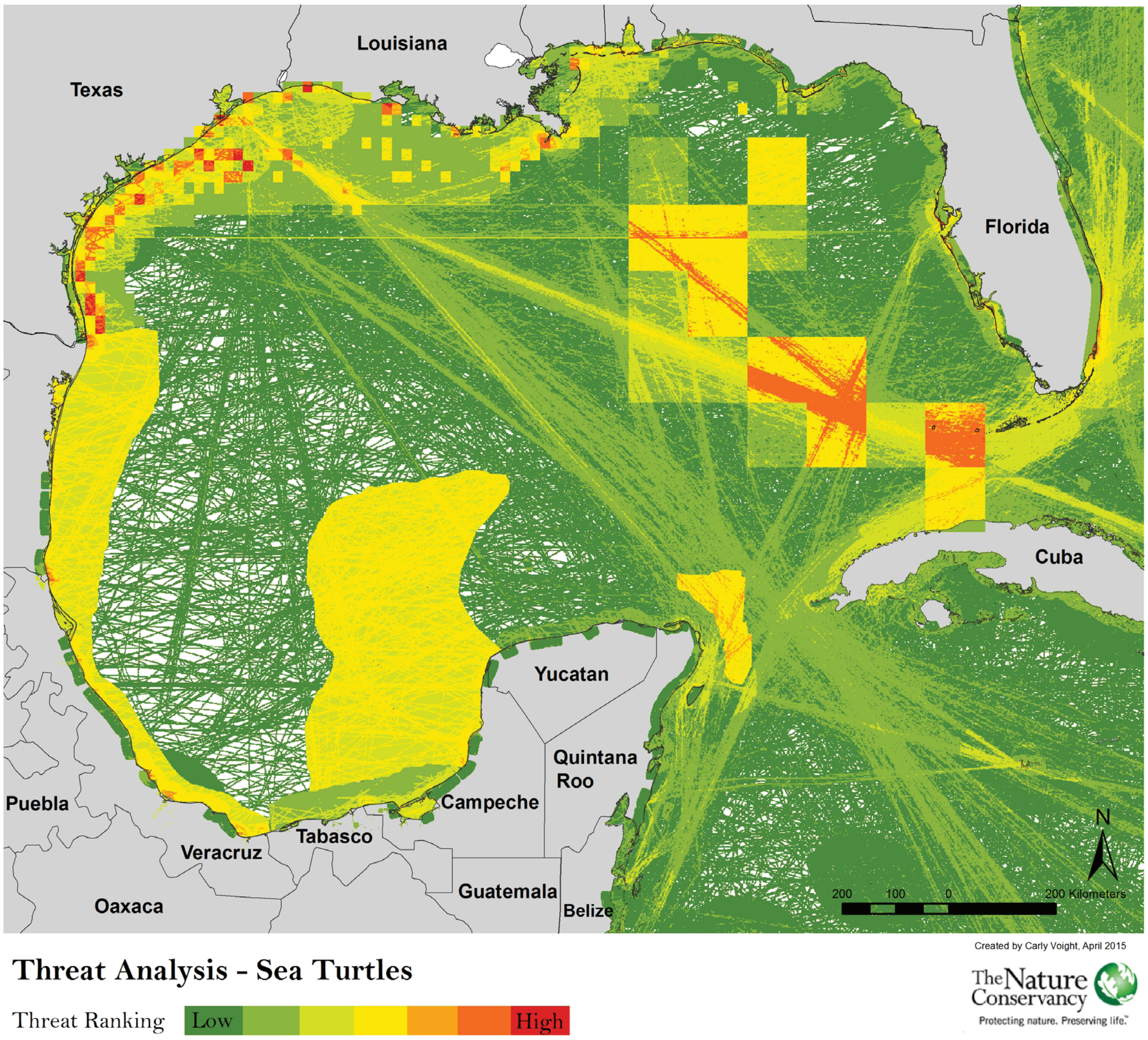
Threat scale: 5 = highest, 1 = lowest CPUE = Catch per unit effort

The migration corridor resulting from available loggerhead sea turtle satellite tracking data shows animals moving from Florida to the Yucatán Peninsula (Figure 40, page 83). This is representative of loggerheads as they are more common in the eastern Gulf, especially along the Florida coast. One of the largest nesting beaches in the world is near Sarasota, Florida. Other major nesting beaches include multiple areas along Florida's Atlantic coast. Therefore, this corridor represents adult female nesters migrating from beaches in Florida to foraging aggregation areas along the coast in Florida and the Yucatán Peninsula as well as the deep waters off of the coast of Florida, as previously reported (Hart et al. 2012, Foley et al. 2014). Areas with the greatest amount of movement for loggerheads are found along Florida's coast, especially near Sarasota and the Florida Keys (Figure 40, page 83). As previously mentioned, great care was taken in processing the satellite track data in order to avoid nesting sites emerging as high migration movement areas. However, since the region near Sarasota is such a major nesting site for this species, it was still highlighted in the results as a high movement area. The most common migration pathway for these individuals is throughout Florida's coast and deep waters. This may be the most common migration pathway for loggerheads in the Gulf of Mexico.

Very few leatherback satellite tracks exist in the Gulf of Mexico, and none was available for this analysis. The majority of adult females that nest in the Caribbean, Central and South America, and eastern Florida travel using corridors outside of the Gulf in the western Atlantic Ocean. Two females deployed with satellite transmitters in northeastern Panama in 2005 and 2006 reached the Gulf of Mexico. One female migrated to the eastern Gulf of Mexico and traveled around the northeastern continental slope. The other traveled to the northern continental slope and the Bay of Campeche (Fossette et al. 2010). A nester from Sandy Point National Wildlife Refuge, St. Croix (U.S. Virgin Islands) was recaptured 3,000 kilometers from the nesting site two years later in the Bay of Campeche near Arrecife Triángulos (Boulon 1989). One female tagged after nesting in Jupiter Beach, Florida, was recaptured near Cayo Arcas in the Bay of Campeche (Hildebrand 1987). Therefore, some females that nest at major nesting sites in eastern Florida, the Caribbean, eastern Costa Rica, and eastern Panama migrate to the Gulf of Mexico to forage after nesting. The few females that lay eggs on minor nesting beaches in the Florida Panhandle most likely also migrate and forage throughout the deep waters in the Gulf. The ability of leatherbacks to swim great distances in all water temperatures allows them to migrate further than any other sea turtle. They can embark on lengthy migrations following deep contours for hundreds to thousands of kilometers.

Although sea turtles face numerous threats, we only included those in the analysis for which data are spatially available and have a demonstrable high impact on Gulf of Mexico populations. Based on recovery plans, threat assessments, and the scientific literature (Department of the Navy 2007, Dow et al. 2007, NMFS and USFWS 2007, Conant et al. 2009, NMFS, USFWS, and SEMARNAT 2011, NMFS and USFWS 2013), we decided to include and weight the threats listed in Table 8.

Figure 4. Threat analysis: sea turtles.



Shrimp trawling, followed closely by long-line fisheries, are considered to be the highest threats to sea turtle populations in the Gulf due to high by-catch rates (Department of the Navy 2007, Conant et al. 2009, NMFS, USFWS, and SEMARNAT 2011) and were ranked appropriately. Data for longline fishery turtle by-catch Catch Per Unit Effort (CPUE) were only available for select areas in the Gulf of Mexico at a very low spatial resolution. Also, data were unavailable for the CPUE of other fisheries that impact sea turtles such as driftnet, set-net, pound, gillnet, dredge, and pot traps. Many regions in the Gulf are most likely more threatened than our results indicate, since the impact throughout the Gulf would be much greater with these additional data. The other threats in Table 8 have been assigned a lower weight because they affect sea turtles to a lesser degree (see threats section). Light pollution, beach erosion, and feral hog density data were clipped to the spatial extent of the beaches to isolate just the impact on nesting beaches. Spatial data for other threats such as beach armoring, poaching of eggs and turtles, density of synthetic debris and abandoned fishing gear and presence of heavy metals in the ocean were unavailable at the time that this assessment was conducted. The inclusion of these into the analysis would have resulted in an increase of the robustness of the threats assessment model.

The resulting combined threats are distributed throughout the region, with very few areas completely unaffected (Figure 4). The areas with the greatest density of high-ranking threats are located off the coast of Texas and Louisiana. These regions have the highest CPUE for shrimp trawling and are also affected by additional threats such as marine vessel traffic/density (an indicator of higher potential for boat strikes) and all pollution types. Areas with a medium-high to medium rank include those with a high long-line CPUE or medium shrimp trawling CPUE combined with other threats. These high to medium threat areas are located within the migration corridor for every sea turtle species. For example, the highest threat areas fall directly within the Kemp's ridley sea turtle corridor. While the threat to nesting beaches appears to be low in relation to specific areas in the ocean, these nesting sites are still very important to the lifecycle and conservation of sea turtles.

Marine Mammal Species

INTRODUCTION

Marine mammals have developed remarkable adaptations to live in the tri-dimensional world of oceans and rivers. Many of these species are formidable divers with thermoregulatory and sensory adaptations to cope with the variable changing conditions of the superficial and deeper waters that they inhabit, as well as the challenges of communicating and finding prey at depth. Relative to many other forms of marine life, some marine mammals are long-lived and feed at high trophic levels, and therefore integrate ecosystem characteristics and effects at high levels.

Of the 29 species of marine mammals that have been documented in the Gulf of Mexico, 28 are cetaceans (seven whales and 21 dolphins) and one is a sirenian (the West Indian manatee). One species of seal, the Caribbean monk seal, once regularly occurred in the Gulf but is now considered extinct. Forty-eight percent of the documented species are considered common in the Gulf, dolphins being the main group and sperm whales the most common whale (Würsig et al. 2000). The whale and dolphin group includes nine cosmopolitan species and four species endemic to the Atlantic Ocean (Sowerby's beaked whale, Gervais's beaked whale, Atlantic spotted dolphin, Clymene dolphin). The whale and dolphin species occurring in the Gulf have larger distributions in the major oceans, and their ranges vary from tropical and warm-temperate species to anti-tropical or disjunct bipolar species (most of the large whales).

Twenty-eight whale and dolphin species reside in or regularly visit the Gulf of Mexico. They comprise 58 stocks, 24 of which are bottlenose dolphin stocks (Waring et al. 2013). Several of these resident or frequent visitors are migratory. These include several species of whales, such as the blue, fin, sei, minke, humpback, northern right, and sperm whales. The sperm and Bryde's whales have also been identified as year-round residents in the Gulf, but sperm whale individuals have been documented to travel to and from their home range in the Gulf to the Atlantic Ocean. Great whales, including sperm whales, are primarily considered the longest-distance migrators due to their capacity to store body fat reserves in order to survive through long fasting periods while moving. We decided to include West Indian manatees and sperm whales in this assessment. Although most marine mammals that inhabit the Gulf make long-distance movements, little is known of their true seasonal migrations. These two species were chosen for this project because much more information is known about their seasonal migratory movements.

Table 9. Migration and aggregation timing of marine mammal species in the Gulf of Mexico.

	GULF MIGRATION PERIODS											
SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
West Indian manatee[1]*	WARM WATER						EXTENDED MOV.					IN
Sperm whale[2]				IN N. GULF								

In the Gulf · In alimentary or reproductive aggregation areas · Migration period

*Migration timing only for Florida subspecies (*Trichechus manatus latirostris*)
[1]FWC 2007
[2]Jochens et al. 2008

Two of the marine mammal species included in this project are federally listed in the United States and Mexico. The manatee is listed as endangered in the ESA and by the NOM-059-ECOL, whereas the sperm whale is listed as endangered in the United States and under special protection in Mexico. Only the manatee is listed in Cuba. Globally both species are considered vulnerable in the Red List by IUCN. The manatee is listed as imperiled (G2) by NatureServe, whereas the sperm whale is considered vulnerable to apparently secure.

The West Indian manatee population in Florida makes short-distance migrations triggered by climatic conditions. Occurring primarily in Florida, this population migrates on an annual basis mainly between their summer foraging grounds in coastal estuaries and adjacent freshwater systems to their warm water aggregation areas (e.g., natural springs, power plant outflows) in the fall and winter to escape cold temperatures (Table 9). Usually they are concentrated in Florida from November through March. In the summer months, manatees are much more widely distributed and may embark on extended movements to as far west as Texas and as far north as Virginia. Although such long journeys are rare, sightings in Alabama, Georgia, and South Carolina are relatively common. Manatees often return to the same wintering areas year after year. The movements of the Caribbean subspecies along the coasts of Mexico and Cuba have been less documented. It is possible that at least in the Gulf individuals of the Caribbean subspecies do not migrate seasonally due to their range in tropical waters.

Very few movement studies have been conducted on sperm whales in the Gulf of Mexico, and therefore little is known of their migrations. The known migratory movements of sperm whales are primarily restricted to the northwestern portion of the Gulf of Mexico. The movement activity of this mainly resident population seems to increase during the spring months along the edge of the continental shelf between Louisiana and Texas (Table 9). New individuals from the Atlantic Ocean will occasionally enter the Gulf in the winter and join the resident population for a time at their feeding aggregation sites in the De Soto Canyon area in the northern Gulf as well as travel to other areas in the southern Gulf portion. One study that analyzed biparentally inherited nuclear DNA found no significant difference between whales in the North Atlantic and the Gulf of Mexico, suggesting possible migratory exchange of male Gulf sperm whales (Engelhaupt et al. 2009). Another study that compared photo-identified sperm whales in the eastern Caribbean with those in the Sargasso Sea and the Gulf of Mexico found no matches, suggesting low to no dispersal (Gero et al. 2007). Due to the ambiguity suggested by these studies, additional research must be conducted in the Gulf of Mexico before a conclusion can be determined on migration patterns. Sperm whales that do move between the Gulf of Mexico and the Caribbean Sea, or possibly the waters of the western North Atlantic, may use the Florida Straits as a corridor (Department of Navy 2007).

The major threat to manatees in Florida is collision with watercraft, including recreational boats and large commercial vessels. This accounts for about 24 percent of known manatee deaths and countless injuries each year (USFWS 2001). The second greatest threat to manatees is the loss and degradation of warm-water aggregation sites. Many natural warm water springs in Florida have been eliminated, developed or altered due to development surrounding the coasts and the springs. The human population in Florida has grown to 18.8 million people, a 580 percent increase since 1950, which has coincided with a 465 percent increase in the total amount of water withdrawn from the state (Marella 2014). Water is diverted from aquifers due to increasing demand from residential, industrial, and agricultural development and production, resulting in low-flowing or dry springs. Other springs have become polluted with nitrates, resulting in an increase in algae growth and a reduction in winter forage availability (USFWS 2001). Since manatees cannot tolerate water colder than 20 degrees Celsius, the loss of these stable, long-term warm water areas will have a significant negative affect on the population. Other human-related causes of death to manatees in the United States include crushing or entrapment in navigation locks or water control structures, entanglement in shrimp nets or fishing gear, ingestion of trash or discarded fishing gear, poaching, and entrapment in culverts and pipes (USFWS 2001). Threats to manatees in Mexico, Cuba, and Belize include incidental by-catch in gillnets, poaching, and habitat loss (USFWS 2001, Morales-Vela et al. 2003, Alvarez-Alemán et al. 2010).

Although commercial hunting of sperm whales in the Gulf of Mexico ended in the early 1900s (Mullin et al 1994), it most likely resulted in a decline in the population that has yet to recover. Whaling may have affected the social structure of sperm whales and reduced their population growth rates, which have always been naturally low at a rate of about 1 percent per year (Whitehead 2003). Although the magnitude of the stressors is considered low, sperm whales face several threats, especially in the Gulf of Mexico. These low-level threats include ship strikes, incidental capture in fishing gear, research impacts, injury from marine debris, and disturbance from whale watching and other vessels. The effect of other threats, such as human-made noise, oil and gas exploration, military sonar and explosives and pollutants is unknown (NMFS 2010). A multiyear study in the northern Gulf of Mexico found no significant horizontal avoidance from anthropogenic noise of seismic airgun arrays used for offshore oil and gas exploration. However, the sample size may not have been high enough to detect significant effects. The results do indicate a decline in foraging effort during full-array airgun exposure (Jochens et al. 2008). The threats mentioned are difficult to assess because many incidents are not detected by humans and others are not reported (NMFS 2010). Therefore it is possible that their effect on the Gulf populations of manatee and sperm whale may be higher than is currently known.

Table 10. Marine mammal threats in the Gulf of Mexico.

	THREAT RATING	
THREAT	**MANATEE**	**SPERM WHALE**
Small boat collision areas	●●●●	
Warm water spring degredation	●●●●	
Mangrove loss	●●●	
Maritime vessel traffic/density	●●●	●●●
Hypoxia		●●
Oil and gas activity/pollution	●	●
Ocean pollution from marine vessels	●	●
Inorganic nonpoint pollution	●	●
Nutrient pollution	●	●

Threat scale: 5 = highest, 1 = lowest

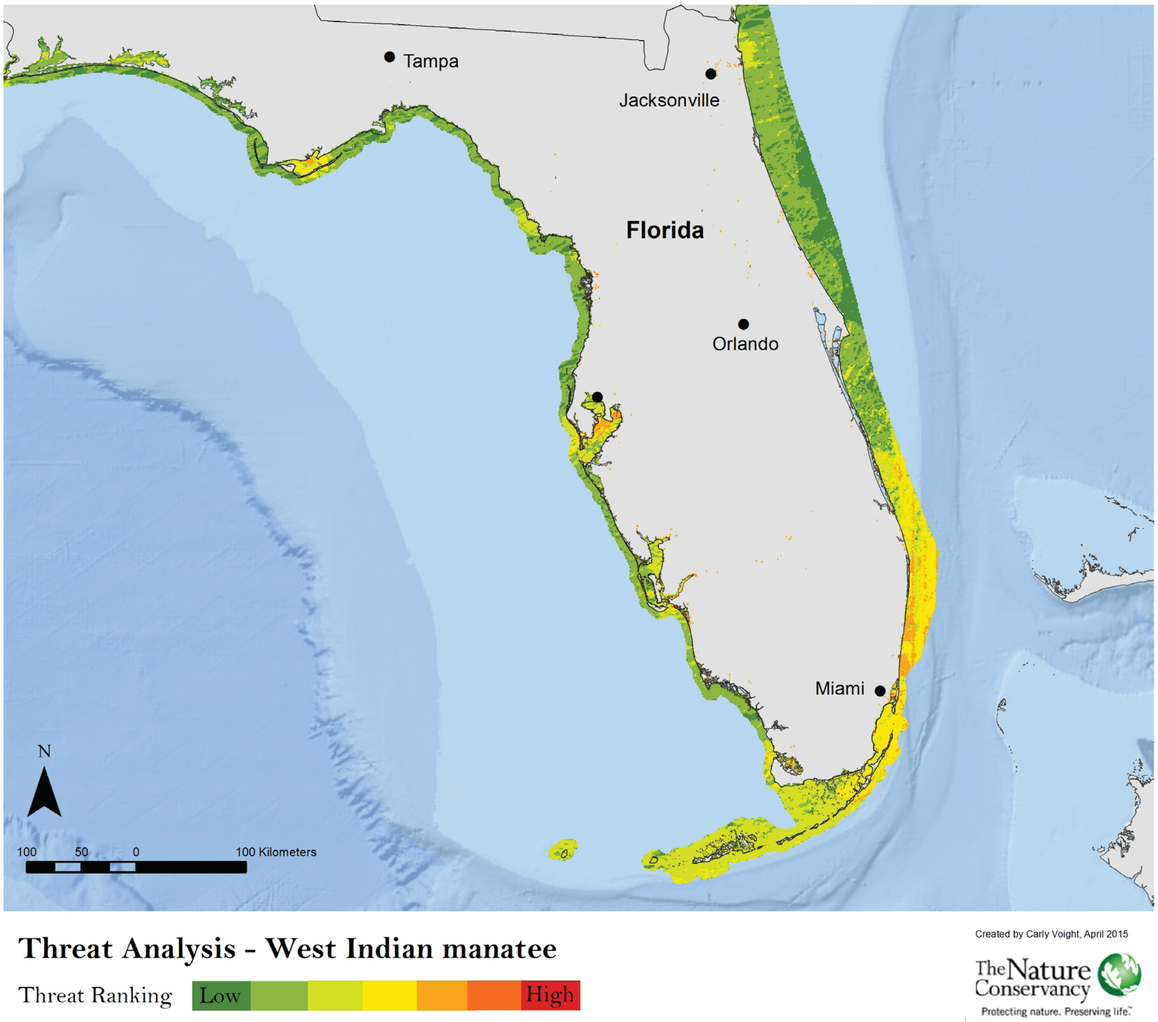
ASSESSMENT

Included maps in Appendix IV illustrate the distribution areas and summaries of observations for both marine mammal species, and migratory corridor and movement density for those species with movement tracking data available (pages 84-86). The highest numbers of occurrence records for manatees are found in mid- to south Florida, especially in the coasts and warm water springs (Figure 42, page 84). This most likely reflects the heavily studied year-round resident population from Apalachicola, Florida, to the southern point of Florida. They are less common in the region from Florida's western Panhandle to Texas. Manatees are frequently found in Tamaulipas (at Río Pánuco and the lagoon system of Chairel–Champayan), Veracruz (Alvarado Lagoon), northern Campeche, and Quintana Roo (Playa del Carmen to Tulum, Bahia de la Ascensión to Bahia Espiritu Santo and Chetumal Bay; Morales-Vela et al. 2003, SEMARNAT-CONANP 2010, Lefebvre et al. 2001). However, this is not reflected in the occurrence records for the southern Gulf due to a lack of data for this region.

Sperm whales are most commonly found in areas of deeper water, as shown by the summary of the observation records (Figure 44, page 85). Because they forage for squid, octopus, fish, shrimp, crab, skates, and sharks on or near the ocean bottom, sperm whales prefer depths of 500-800 meters (Watkins et al. 2002). The highest number of records come from the area between the Mississippi Canyon and the De Soto Canyon, a region where sperm whales aggregate in large numbers. The summary of occurrences illustrates a lower number of records in the southern Gulf due to fewer studies conducted in this area. In reality, they appear to be widely distributed in the continental slope waters of the western Bay of Campeche (Ortega-Ortíz 2002).

Manatees generally make regional, short-distance movements because they are slow moving. Therefore, a corridor was not created for their migrations. In the fall and winter, Florida manatees will migrate to warm water sources to avoid cold temperatures (20 degrees Celsius or colder) (Irvine 1983). Most manatees migrate to warm water springs or artificial warm water areas near power plants or paper mills (Lefebvre et al.

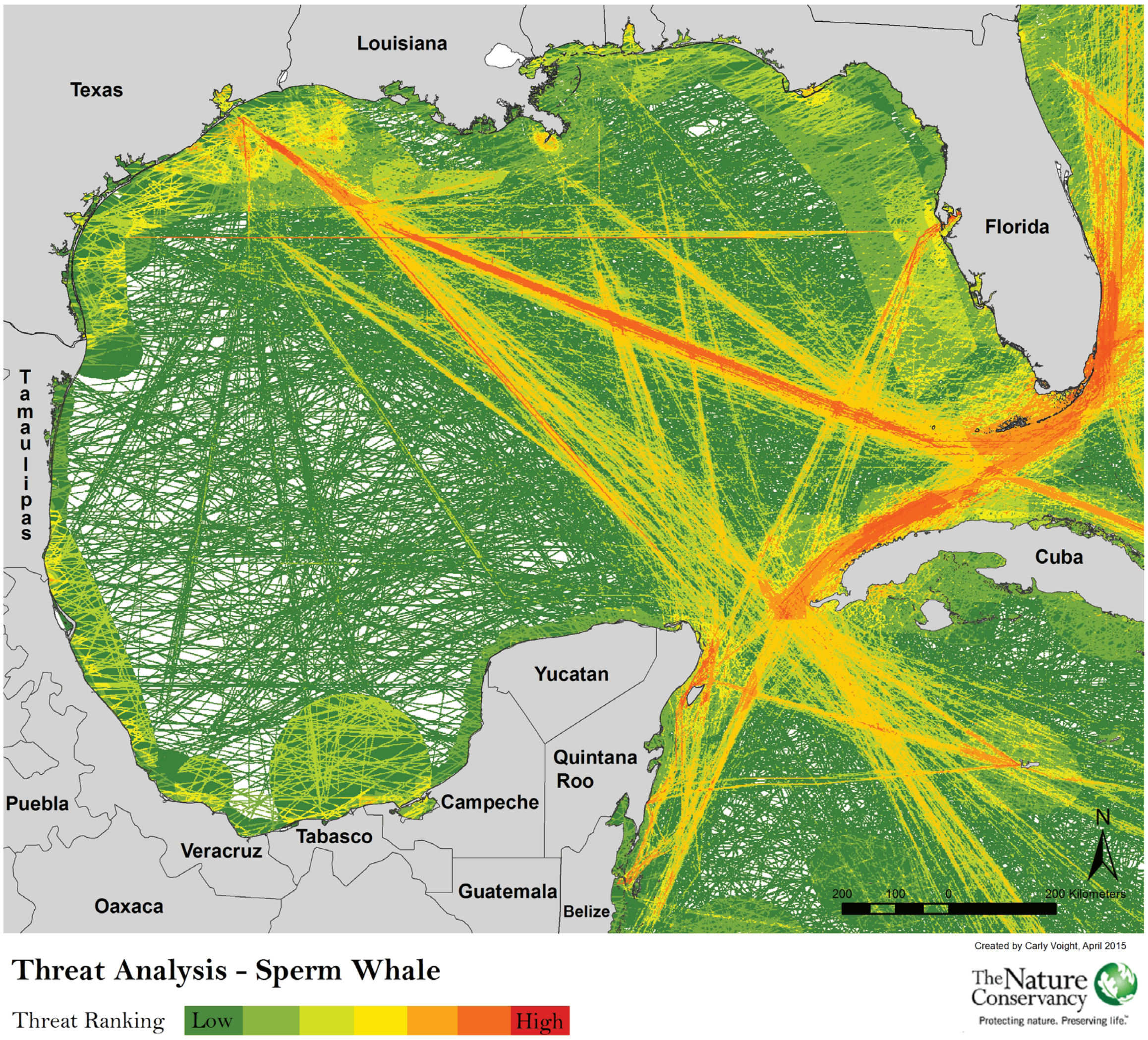
Figure 5. Threat analysis: West Indian manatee.



2001), and others migrate to southern Florida (Snow 1991). Manatees will move from springs and power plants to seagrass beds to forage during warm winter days or even return to their summer habitat during mild winters (Deutsch et al. 2000). As the temperature of the water increases, manatees disperse from their aggregation sites and migrate along the coast or up rivers and canals. Open waterways and channels serve as corridors for their migrations. The movements of manatees do not seem to differ in relation to age or sex. There have been reports of long-distance movements. One manatee photographed in Tampa Bay, Florida, was hit by a boat in Louisiana (Fertl et al. 2005). Another manatee seen on the west coast of Florida was photographed in the Bahamas six years later (Reid 2000). Several Florida manatees have migrated to Virginia, Rhode Island, Massachusetts, and New York (Beck 2006). One manatee from Florida migrated to north of Havana, Cuba, in 2007. Very little is known about local movements of manatees in Mexico, Cuba, and Belize. It is possible that they do not seasonally migrate in these countries because cool weather is shorter in duration and less extreme than in Florida (Alvarez-Alemán et al. 2010).

Sperm whales make long-distance movements throughout the Gulf. This corridor represents available data from the resident population in the northern Gulf and illustrates their movement from the deep waters off of Tamaulipas to Alabama (Figure 45, page 86). The highest density of movement is within their aggregation from the Mississippi Canyon to the De Soto Canyon. Sperm whales most likely use this area because of a high level of primary productivity due to a narrow continental shelf and the presence of a cyclonic eddy from the Loop Current (Davis et al. 2002). Additional data from the

Figure 6. Threat analysis: sperm whale.



populations in the southern Gulf and the area west of the Dry Tortugas in Florida would most likely produce several other corridors in the Gulf of Mexico LME.

We conducted two different threat analyses for the two species included in this project (Figure 5 and 6). We decided this was necessary because manatees and sperm whales vary greatly in their range, habitat, ocean depth preference, and threat types. Weights for these threats were assigned based on recovery plans and the scientific literature (USFWS 2001, Morales-Vela et al. 2003, Department of Navy 2007, FWC 2007, Jochens et al. 2008, Alvarez-Alemán et al. 2010, NMFS 2010).

We identified and weighted eight threats that have a demonstrable impact to manatees and are spatially available (Table 10). The greatest threat to manatees in Florida is collision with watercraft. We used the rate of mortality to Florida manatees from boat collisions within the past 10 years to represent this threat. Because the spatial extent of mortality rates, degradation of warm water aggregation winter habitat, and mangrove loss is very small, the areas with the highest threat impact are also very small and difficult to detect on the large-scale threat analysis maps. The primary areas of highest impact are located in Florida near Tampa, Sarasota, and Miami.

As previously mentioned, the greatest impact on sperm whales is the effect of whaling on this species prior to the early 1900s. The intense pressure from overhunting still greatly affects sperm whales today.

However, this historical threat could not be represented with spatial data and was therefore not included in this analysis. Table 10 illustrates the degree to which threats were ranked lower for sperm whale than for manatee. Regions with the highest threat (orange) to sperm whale are most influenced by areas with the highest marine vessel traffic density, especially those that are also affected by other threats.

Bird Species

INTRODUCTION

The extensive use of the Gulf of Mexico region by migrating birds was first described in the 1940s (Lowery 1945, 1946), and the phenomenon was finally considered mainstream science several decades later (Gauthreaux 1971, Able 1972). The primary discovery of Lowery (1945, 1946) was that many terrestrial landbird species fly directly over the Gulf of Mexico during their spring and fall migrations, a phenomenon known as trans-Gulf migration. So many individuals of so many species use the trans-Gulf route that, particularly in spring, some areas along the northern U.S. coast of the Gulf of Mexico are among the most well-known birding sites in the country (e.g., High Island, Texas; Grand Isle, Louisiana; Dauphin Island, Alabama). Similarly, it was only realized a few decades ago that the western Gulf of Mexico, particularly the state of Veracruz, harbored an enormous migration of those species and individuals that do not migrate across water; this is known as the circum-Gulf route. This route, most heavily used in the fall, is used primarily by migratory raptors, flycatchers, and swallows, which are diurnal migrants and tend not to fly long distances over water. In fact, the hawk migration stations established in the towns of Cardel and Chichicaxtle, Veracruz, have verified that this region is the most heavily used raptor migration corridor on the planet (Bildstein 2004). Together, these discoveries have led to the identification of this geographic region as an important conservation area for migratory bird species (e.g., Moore and Simons 1992; Mehlman et al. 2005) and the development of an array of conservation strategies to protect the varied habitats used by these species in and around the Gulf of Mexico (e.g., PGCLC 2014).

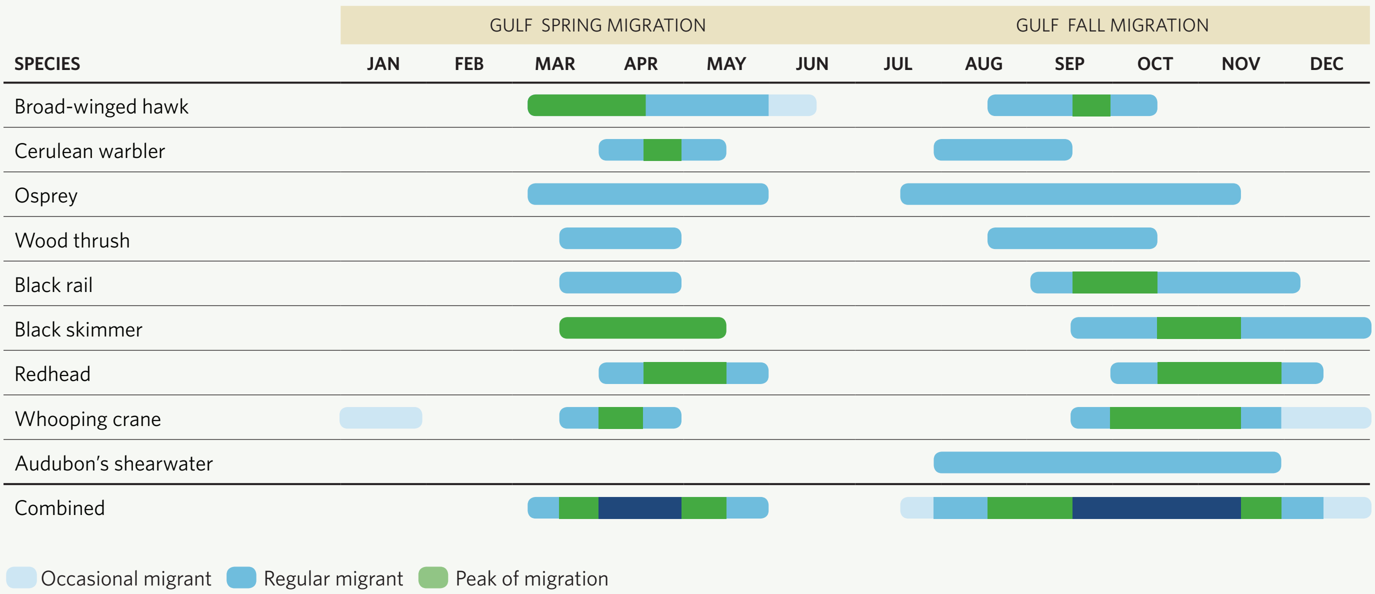
Of the nine species, only one has been federally listed in the United States, the whooping crane, which is listed as endangered (Table 1), except for a reintroduced population in Louisiana. As of February 2015, there were 603 whooping cranes in existence, 161 in captivity and the remainder distributed among the four wild populations. Three species have status in Mexico under the NOM-059-ECOL of 2010 (black rail, broad-winged hawk, and whooping crane). Under the latest IUCN Red List (IUCN 2014), one species is endangered (whooping crane), one is vulnerable (cerulean warbler), one is near threatened (black rail), and the remaining six are considered of least concern. Under the NatureServe conservation status assessment (Faber-Langendoen et al. 2012), most bird species are secure or apparently secure. The two exceptions are black rail, rated as being between vulnerable and apparently secure, and whooping crane, considered critically imperiled.

The approximate periods of migration in spring and fall are shown for all species in Table 11, along with estimated times of peak migration. The species generally show similar migration timing in the Gulf region, which is consistent with other bird species with similar life histories in North America. The primary exception is the Audubon's shearwater; due to its pelagic habit, it does not migrate as the terrestrial species does. Most species show a consistent pattern of a shorter spring than fall migration period, which is common among North American migratory birds. Interesting exceptions to the general pattern are seen particularly in the fall migration (Table 11). The cerulean warbler is an early fall migrant, initiating its southbound journeys in August, well before the fall migration has even started for some species, and having largely left the United States by mid-September. In contrast, the redhead migrates much later in the fall than almost all the other species do, with many migrants still in the Gulf region well into December. This is probably typical of many waterfowl species in North America and is also consistent with the fact that large populations of this species spend the winter along the Gulf of Mexico.

ASSESSMENT

Included maps in Appendix IV illustrate the distribution areas and summaries of observations for each bird species, and migratory corridor and movement density for those species with movement tracking data

Table 11. Migration timing of bird species.



available (pages 86-93). The combined map of all bird observation data from all nine species shows observations from virtually throughout the project area (Figure X). The much higher relative incidence of avian observation data from terrestrial sites in the United States as compared with any areas in Mexico or Cuba, terrestrial or oceanic, accounts for much of the spatial differences in observation distributions in the maps. The great concentration of birders in the United States at well-known birding sites also distorts the data and probably accounts for the noticeably higher concentration of observations seen along the coasts of Texas, Louisiana, Mississippi, Alabama, and Florida. Nevertheless, the map clearly illustrates the importance of the Gulf of Mexico region, particularly its coastlines, to the species of migratory birds analyzed here.

Current high-precision migration tracking technology only allows the detailed determination of routes for the largest birds (see Table 11). Therefore, we were only able to analyze migration routes for the osprey, broad-winged hawk, and wood thrush, though some information exists for whooping crane. For osprey, three primary corridors/routes are revealed by the aggregated tracking data we have assembled (Figure 50, page 88). Birds breeding in the northeastern United States have a broad route along the Atlantic coast. The corridor analysis and tracks of individual birds suggest that although the route is heavily concentrated along and very close to the coastline, some birds appear to migrate long distances over the ocean, and a minority of birds migrate inland. After these eastern birds encounter the Gulf coast or enter Florida, the majority of birds appear to head down the coast and/or peninsula of Florida and cross over to Cuba. These birds then appear to migrate to the east, crossing over to Hispaniola Island (Haiti and the Dominican Republic). Most birds then cross from Hispaniola to South America, making landfall in either northeastern Colombia or northwestern Venezuela and continuing their journey south. Birds from the western United States, however, follow a primarily land-based route to the southeast that eventually intersects with the Gulf of Mexico in Mexico, and then continue south into Central America. Birds from the midwestern United States, although the data are limited, seem to pursue a variety of routes, either around the western Gulf coast, toward the eastern (Atlantic) route, or, in a few cases, apparently directly across the Gulf to the Yucatán Peninsula or the state of Tabasco (Martell et al. 2001).

Unfortunately, our data for broad-winged hawks is limited to that of the nine birds studied in Haines et al. (2003), and Hawk Mountain, though the species has a breeding range that extends across North America and a total estimated population size of 1.8 million individuals (Rich et al. 2004). The corridor analysis for broad-winged hawk shows a concentrated eastern route that roughly parallels the ridge and valley systems of the Appalachian Mountains from the southeastern United States into southern New England.

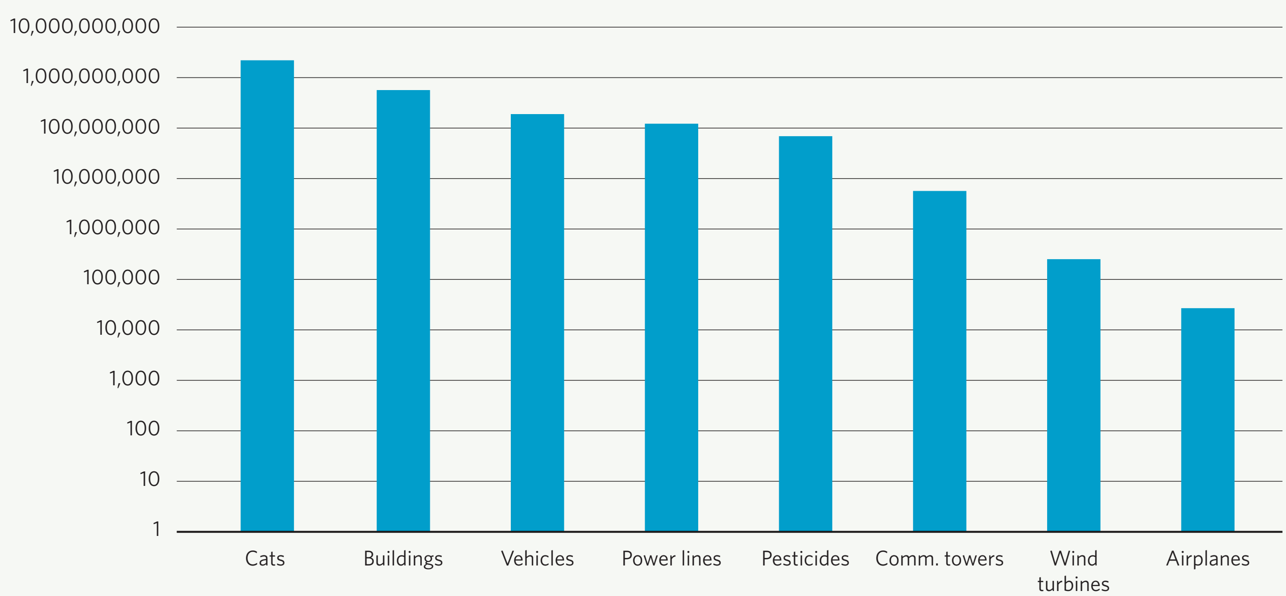
The broad-winged hawk, like many raptor species, uses a more static form of migration that benefits from the updrafts created by the ridges and thermals that form in the valleys. The corridor analysis also shows a secondary corridor in the Midwest, but this is primarily due to the fact that the only birds in the study in this area came from north-central Minnesota. It can be assumed that birds from across the northern extent of the breeding range in the United States and southern Canada follow a broad-front migration southward. All these pathways converge roughly along the central-western Gulf of Mexico coast, which funnels them along the western Gulf of Mexico coast as they migrate south through Central America into South America, regardless of their origin in North America (Figure 47, page 87). In Cardel, Veracruz, 1,372,077 broad-winged hawks were observed during the 2013 fall migration (www.Hawkcount.org data).

The recent development and widespread use of light-weight tracking technology such as geolocators (e.g., Stutchbury et al. 2009), is leading to an increased understanding of migratory routes for the wood thrush and other smaller species (Figures 52 and 53). These data suggest that while most wood thrushes do use a trans-Gulf route in both spring and fall, the position of the migration is shifted more to the eastern Gulf in fall and the western Gulf in spring (Stanley et al. 2014) by over 7.5 degrees of latitude. Some of the individuals appeared to use the circum-Gulf route in spring, contributing to this westward shift. Stanley et al. (2014) also found a relationship between longitude of the breeding area and the migratory route, with birds breeding toward the eastern part of the range migrating more to the east in both seasons.

The Aransas-Wood Buffalo population of the whooping crane migrates along a relatively narrow and well-defined corridor from its breeding grounds in northern Canada to its wintering areas along the Texas Gulf coast. Since it is readily observed along its migration route in the U.S., a database of crane sightings was used by Brei et al. (2009b) to define the migration corridor from the U.S.-Canada border to Texas (Figure 58, page 92). Although almost all sightings during migration are found within a corridor width of 354 kilometers, just over 75 percent of the sightings are found in the 128-kilometer-wide corridor around the migration centerline (USFWS 2009).

Although migratory birds in the Gulf of Mexico region face numerous threats, we have identified and weighted nine threats to bird species that can be mapped and have demonstrable effects on bird pop-

Figure 7. Comparison of anthropogenic sources of avian mortality in the United States.



Source: Erickson et al. (2005), Longcore et al. (2012), and Loss et al. (2013a, 2013b, 2014a, 2014b) ulations in the region (Table 12). These threats include both those where bird habitat is lost, fragmented or otherwise degraded and those that contribute to direct mortality of individual birds; some threats, e.g., roads, may contribute to both. We have given the four factors that have and are currently contributing to habitat loss for multiple bird species in the region the highest weights (urban and suburban areas, wetland, and forest loss). The spread of urban areas and their surroundings has been very pronounced in the Gulf of Mexico region. Urban/suburban areas are responsible for direct loss of avian habitat by their conversion to areas unusable or less usable by the nine species. In addition, urbanization increases the density and abundance of human-associated introduced and native predators (e.g., cats, raccoons, foxes) that depredate birds and their nests in surrounding areas. These combined effects are extensive, long lasting, and essentially irreversible, thus contributing to their high ranking. Although many species of birds are known to use urban and

Table 12. Bird threats in the Gulf of Mexico.

THREAT	THREAT RATING
Urban areas	●●●●●
Wetland loss	●●●●●
Forest loss	●●●●
Suburban areas	●●●●
Roads	●●
Mangrove loss	●
Tall structures	●
Wind turbines	●
Electric lines	●

Threat scale: 5 = highest, 1 = lowest

Figure 8. Threat analysis: birds.

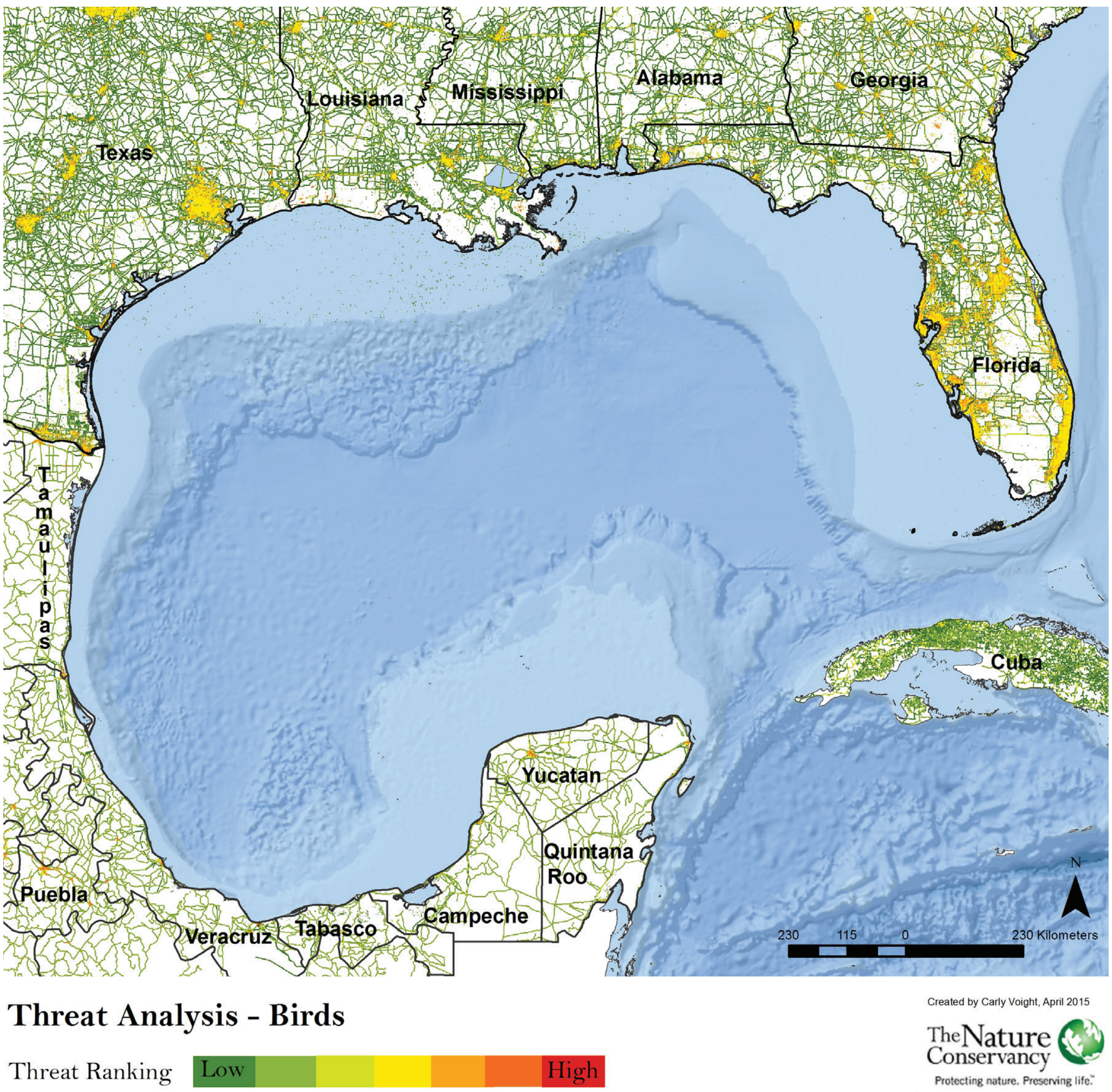
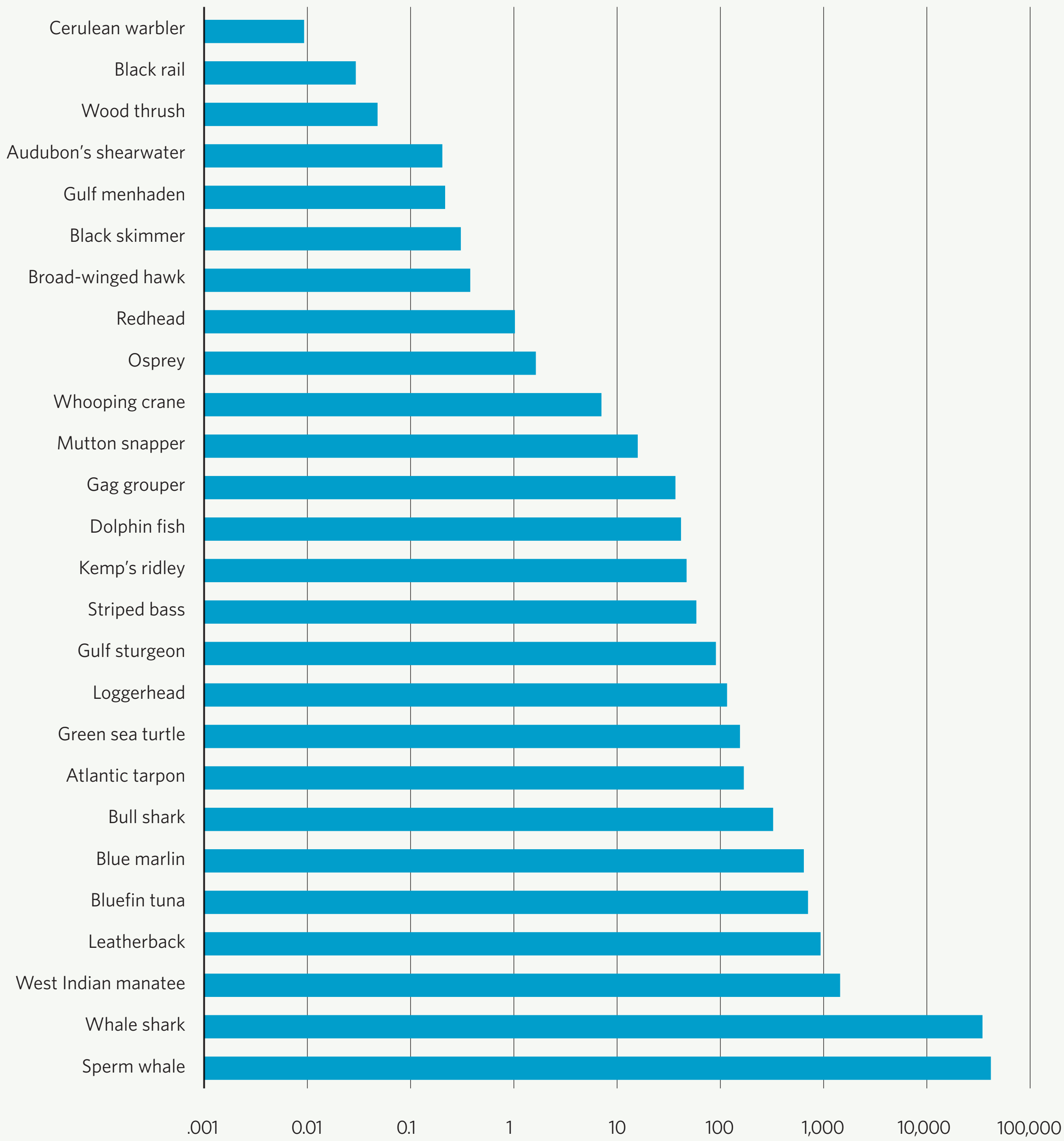


Figure 9. Weight of migratory species (kilograms).



Fish: Weight of adults from Fishbase.org, National Marine Fishery Service, and USFWS.
Sea turtle: Weight of adults from the National Marine Fishery Service (http://www.nmfs.noaa.gov/pr/species/turtles/index.htm)
Marine mammal: Weight at maturity from the Marine Mammal Commission (http://www.mmc.gov/species/specialconcern.shtml), only metrics for males are reported.
Bird: Weight from Sibley 2014.

suburban habitats, especially in migration, the nine bird species analyzed in this study are habitat specialists and are either not found in urban habitats or are at considerable risk in such habitats.

We have given the other threats listed in Table 12 lower weights because they contribute less to widespread habitat loss in the region or they affect only a subset of the species. While roads are generally a significant contributor to habitat fragmentation and are known to cause mortality, the Gulf region still possesses some large and unroaded habitat blocks, and roadkills are therefore not a major problem for most of the nine target species. Similarly, while infrastructure such as communications towers, wind turbines, and power lines are known to kill many individuals of many bird species across the United States, we felt they were not major threats to the nine study species in the Gulf region. Mangrove loss is weighted very low in this analysis because either mangroves are not heavily used by the nine species in the region or an increase in mangroves can be a threat by encroaching on otherwise open habitats for the whooping crane and black rail.

When mapped (Figure 8), the combined threats are broadly distributed across the region, with few areas unaffected. The primary areas of highest combined threat ranking are in and near the major urban areas of the Gulf of Mexico, in particular the Florida peninsula. Encouragingly, some relatively large blocks of habitat near the coast maintain a very low threat level, particularly along the Louisiana coast and parts of the South Texas coast. Threats to birds in Mexico, though they appear lower due to the different level of data available than in the United States, are pervasive throughout the country's Gulf coast.

Multi-Species Group Approach

Diversity of Migratory Strategies

Individual satellite movement tracks were analyzed, and the resulting species corridors as well as other analyses were conducted to elucidate the migratory patterns of the species included in this assessment. Fish species included in this assessment migrate in the Gulf of Mexico to fulfill their nutritional, reproductive, and energetic requirements. In some cases, a fourth function is expressed as refuge migrations (those directly linked with the risk of predation; Grubbs and Kraus 2010). Reproductive migrations to reach their spawning areas are considered the main migratory driver of coastal fish such as gag grouper, mutton snapper, Gulf sturgeon, and striped bass. However, the Gulf population of striped bass is no longer considered migratory, or only partial migrants may perform this function. Dams and locks have been installed at freshwater streams through which they used to migrate, creating two disjunct populations that have been blocked on each side (mostly from Louisiana to Florida; GSMFC 2006). A combination of reproductive and energetic requirements are considered to be the main migratory driver of Atlantic tarpon and bull shark, species that migrate along the Gulf coast during the fall and spring to avoid extreme water temperatures. Gulf menhaden migrations are possibly triggered due to the coupled interaction of nutritional and climatic effects on the availability of food in the estuaries and offshore environments of the northern Gulf. Additionally, Gulf menhaden juveniles migrate to estuaries where they grow over the span of two years before returning to ocean waters. This shows the complexity in spatial patterns and ecological functions of migration processes. Pelagic fish such as bluefin tuna, blue marlin and dolphin fish primarily migrate to fulfill their reproductive requirements, which are also closely related to fulfilling their nutritional needs following the changes in ocean productivity and food availability throughout the temperate seas of the western Atlantic. Little is known about whale shark movements in the Gulf of Mexico, but the species performs a large and regular nutritional migration to feeding aggregation sites in the northern and southern Gulf each summer.

All adult female sea turtles migrate primarily for reproduction, since all members of this group show strong fidelity to their nesting beaches. This process has been termed "homing," (Lohmann et al. 1997). Additionally, juveniles of the sea turtle species generally migrate to warmer waters during the winter. For some individuals, especially leatherbacks, their nesting sites could be hundreds to thousands of kilome-

Table 13. Primary habitats of species.

GROUP	SPECIES	COASTAL FOREST/LONG LEAF*	TROPICAL FOREST	SCRUB/BRUSH	WETLAND/MARSH*	MARSH/WETLAND*	RIVER	MANGROVE*	WARM WATER SPRING	ESTUARY/BAY	SEAGRASS*	OYSTER REEF*	BEACH/DUNE*	BARRIER ISLAND/HEADLAND*	CORAL REEF*	SARGASSUM	HARD BOTTOM (OCEAN)	OPEN OCEAN	EDGE OF CONTINENTAL SHELF	ARTIFICIAL REEF
Fish	Atlantic tarpon					●	●	●		●	●				●					
	Bull shark					●		●		●	●				●			●		?
	Gag grouper					●		●		●	●	●			●		●			●
	Gulf menhaden					●				●								●		
	Gulf sturgeon						●			●										
	Mutton snapper					●		●		●	●				●		●			●
	Striped bass					●	●	●		●	●	●								
	Blue marlin																	●		
	Bluefin tuna																	●	●	
	Dolphin fish									●						●		●		
	Whale shark																	●	●	
Sea Turtle	Green									●	●		●	●	●	●		●		●
	Kemp's ridley									●			●	●		●		●		
	Loggerhead									●	●		●	●	●	●		●		●
	Leatherback												●	●		●		●		
Marine Mammal	West Indian manatee						●	●	●	●	●									
	Sperm whale																	●	●	
Bird	Broad-winged hawk	●	●	●																
	Cerulean warbler	●	●	●																
	Osprey				●	●	●	●		●			●	●						
	Wood thrush	●	●	●																
	Black rail				●	●														
	Black skimmer									●			●	●						
	Redhead				●	●	●			●	●									
	Whooping crane				●	●				●				●						
	Audubon's shearwater									●								●		

*Habitat type included in Shepard et al. 2015
? Suspected (but not supporting literature found)
Source: Fish: GFMC 2004, NMFS 2006, Kingsley-Smith et al. 2012, Lehner and Allen 2012; sea turtle and marine mammal: Department of the Navy 2007; bird: Eddleman et al. 1994, Gochfeld and Burger 1994, Lewis 1995, Poole et al. 2002, Woodin and Michot 2002, Lee and Mackin 2009, Evans et al. 2011, Buehler et al. 2013, Goodrich et al. 2014

ters from the Gulf on other beaches in the Atlantic Ocean. Although Florida manatees can migrate long distances along the Gulf of Mexico coast during the summer, perhaps in search of suitable foraging areas, the majority of their migratory movements are limited to locating springs and artificial warm water sites where they aggregate in the winter. Although not as long as the migratory journeys of other species, the majority of the manatee population has an annual seasonal migration in the northern Gulf. In contrast, the primarily resident population of sperm whales in the northern Gulf performs constant movements along the edge of the continental platform of Texas and Louisiana during the winter and spring seasons. These movements are possibly driven by the availability of prey following ocean currents caused by oceanographic conditions to fulfill their large nutritional requirements.

The nine bird species chosen for this analysis collectively illustrate the wide variety of life histories and migration strategies used by bird species in the Gulf of Mexico region. Many species (e.g., broad-winged hawk, wood thrush, and cerulean warbler) are highly migratory, with their breeding and wintering ranges completely disjunct and separated by long migration pathways. For these species, the Gulf of Mexico is a geographic barrier that must be crossed or traveled around in order to complete their full annual cycle. For these terrestrial bird species, the waters of the Gulf of Mexico represent unusable habitat that would result in their deaths if they landed on it. For other species (redhead and whooping crane), the Gulf of Mexico region represents all or part of their wintering habitat to which they migrate every fall and winter after nesting in their respective breeding ranges further north. The black skimmer is representative of a group of species that use the Gulf for breeding habitat, specifically sandy beaches and barrier islands with little to no predation pressure. The Audubon's shearwater represents an entirely different guild of species that use the Gulf: the pelagic seabirds. These birds nest on islands but spend the rest of their year at sea, foraging on the open ocean and in the Gulf.

Several species illustrate the complexity of migration strategies. For example, populations of osprey that breed in northern North America are highly migratory, with a diversity of wintering areas and migration routes. However, the osprey that breed in Florida and the Caribbean are residents and do not migrate at all. The black rail is another species in which populations that breed in the northern part of North America are migratory and most likely winter around the Gulf, mixing with resident populations of the same species that are found in the region year-round.

Animal migratory movements are not only complex from an ecological perspective, but they might seem unbelievable to the general public, making them hard to conceptualize in many cases. In addition to the diversity of species that migrate, from tiny planktonic organisms to the largest fish and whales on Earth, migratory movements are characterized by the distance traveled by a diverse array of species. Figure 9 presents the species sizes expressed as weight. We do not provide the travel distances for these animals due to the complications of tracking their movements until technology developed recently. However, the figure helps to recognize that although larger animals tend to move longer distances, the distances moved by smaller animals can also be considerable – for example, small birds such as broad-winged hawk and cerulean warbler could travel more than 4,000 km. Therefore, the size of a species is not necessarily indicative of its habitat requirements nor did the geographic area require completing their life cycles and maintaining healthy populations.

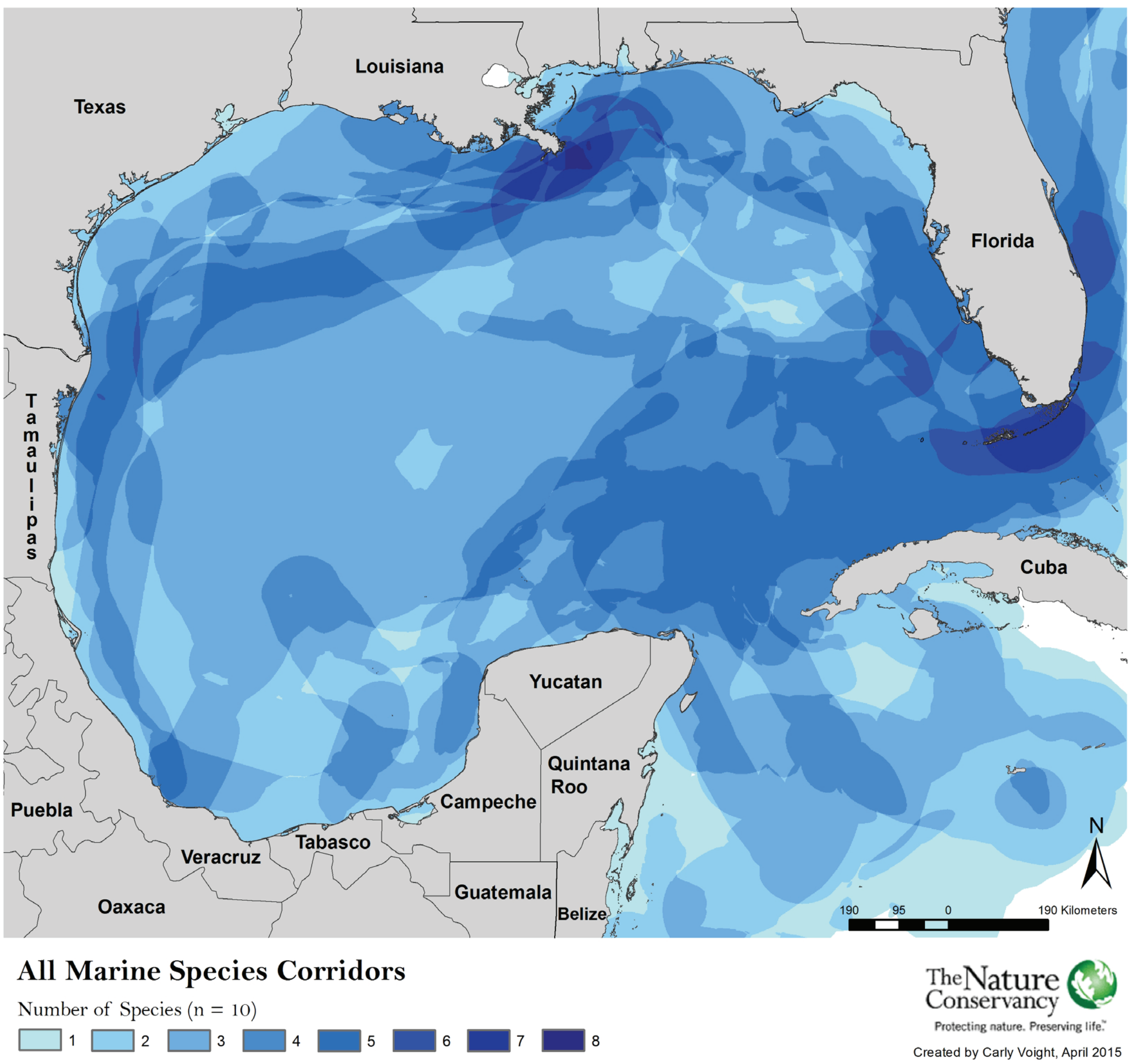
The habitat needs of each of the species vary greatly as well. Independent of the size of the species or the distance of their movements, each species uses multiple habitats throughout their life cycle. Table 13 provides a synthesis of the primary habitats used by these species in the Gulf region. Food resources and other benefits such as refugia obtained from each of these habitats are closely related to their requirements during migration and while performing reproductive functions (from spawning to nursery areas). The table implies that the species spatially connect the multiple habitats they use in their movements and therefore provide a variety of ecological services to the biological communities that coincide in space and time. For example, pelagic fish such as dolphin fish that also use coastal nursery areas during their development will constitute food for a series of other organisms such as fish and marine mammals. Conversely, adult dolphin fish help regulate the populations of other fish species, supporting a healthy balance in those habitats and ecosystems.

Species constitute the biotic components that are essential to the functioning of any ecosystem. Healthy ecosystems provide a diverse suite of services to people. These services are typically recognized as the benefits that humans obtain from nature. Ecosystem services are also essential to the fulfillment of humans' well-being. Migratory species provide a variety of services by using environmental resources, such as habitats in an efficient way in space and time (moving to reach resources in distant areas throughout the year), as well as providing other benefits to the biological and human communities associated with the habitats that they use. Typically ecosystem services are classified as those that help build other services, services that regulate some process (e.g., biological control), those that provide economic goods (e.g., food) and the cultural services that allow humans to benefit from an experience with nature. Undoubtedly, migratory species provide a wealth of services to nature and people.

Diversity of Migratory Pathways

Figure 10 and 11 illustrate which areas of the Gulf are used as corridors for multiple species. The darker colored areas represent regions that are used as a corridor by the greatest number of species. Several multispe-

Figure 10. Integration of corridors for: 10 marine species of fish (6), sea turtle (3), and marine mammal (1).*

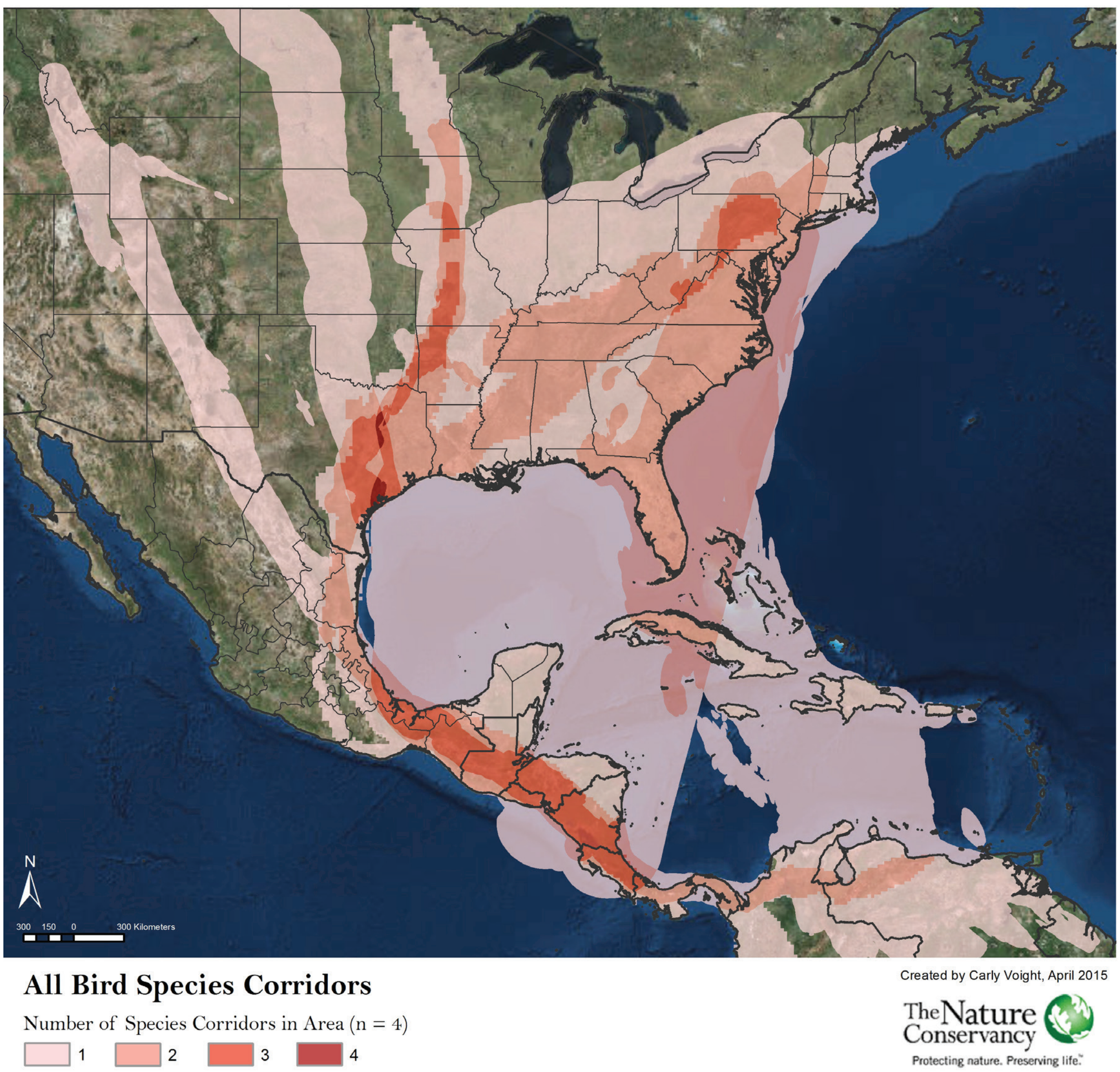


*Map indicates an aggregation of corridors for the following species: bull shark, whale shark, bluefin tuna, blue marlin, Atlantic tarpon, Gulf sturgeon, Kemp's ridley sea turtle, loggerhead sea turtle, green sea turtle, and sperm whale.

cies marine corridors emerge from this analysis. For marine species in Figure 10, the Florida Keys and the area near the mouth of the Mississippi River are portions of corridors for eight of the 10 marine species for which we developed corridors (as shown in Table 3, we were only able to develop corridors for 10 marine species due to the availability of satellite tracking data: six fish, three sea turtles, and one marine mammal). A corridor for multiple species exists from the coast of Louisiana to the state of Veracruz. Another multiple species corridor extends from Florida to the northeastern Yucatán Peninsula, paralleling the northern coast of Cuba. Although this study includes only some of the many marine species that occur in the Gulf of Mexico, these species were specifically chosen to represent many other species that most likely share similar migratory pathways. Therefore, these corridors are probably heavily used by numerous species. Although it was beyond the scope of this project to assess the pathways outside the Gulf, it is clear that migratory connectivity exists between the western Atlantic Ocean and the Caribbean Sea.

The multispecies migratory corridors for the four bird species for which we had satellite tracking data shown in Figure 11 (see Table 3), indicate that the breeding grounds in the eastern United States and wintering grounds in Mexico and Central America are important areas for several species, although this is partially an artifact of the data from the specific species were studied. The trans-Gulf and circum-Gulf pathways that have been previously described are evident in Figure 11.

Figure 11. Integration of corridors of four bird species.



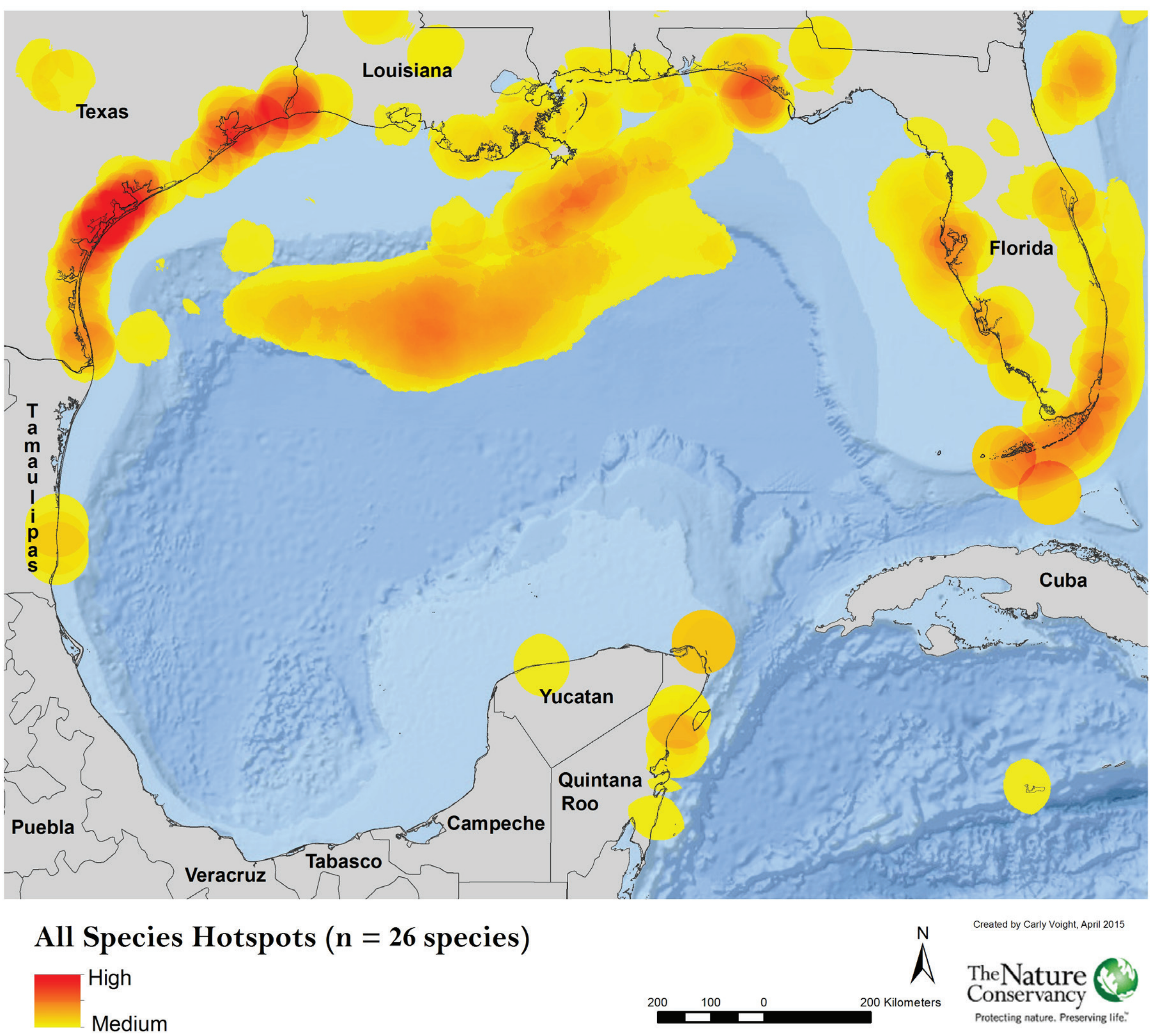
Even with limited data (i.e., a few individuals tracked from their entire populations), the evaluation of the combined marine and bird corridors allows for an assessment of the extent of their pathways in the Gulf in space and time, as migration is a process occurring over a certain timeframe. Although there are clear differences in the extent and density of the movement areas, these results indicate that the movement of animals is a constant process occurring in every corner of the Gulf region.

Implications for Conservation

The hotspots in Figure 12 illustrate important regions for the occurrence of migratory species (the map represents the cells with the top 25 percent of point observation records for all 26 species). Although these observations are driven by the effort of data collection (of which this information was not available for this assessment to normalize the observations), and many regions may not have been highlighted due to reduced effort, the map represents some relevant areas. It is important to note that the lack of data for Mexico and Cuba (especially near the states of Veracruz, Tabasco, and Campeche in Mexico) clearly undervalues the southern Gulf in this analysis. Conservation practitioners and managers should recognize that this map probably does not adequately represent the full scope of hotspots for migratory species in the Gulf of Mexico.

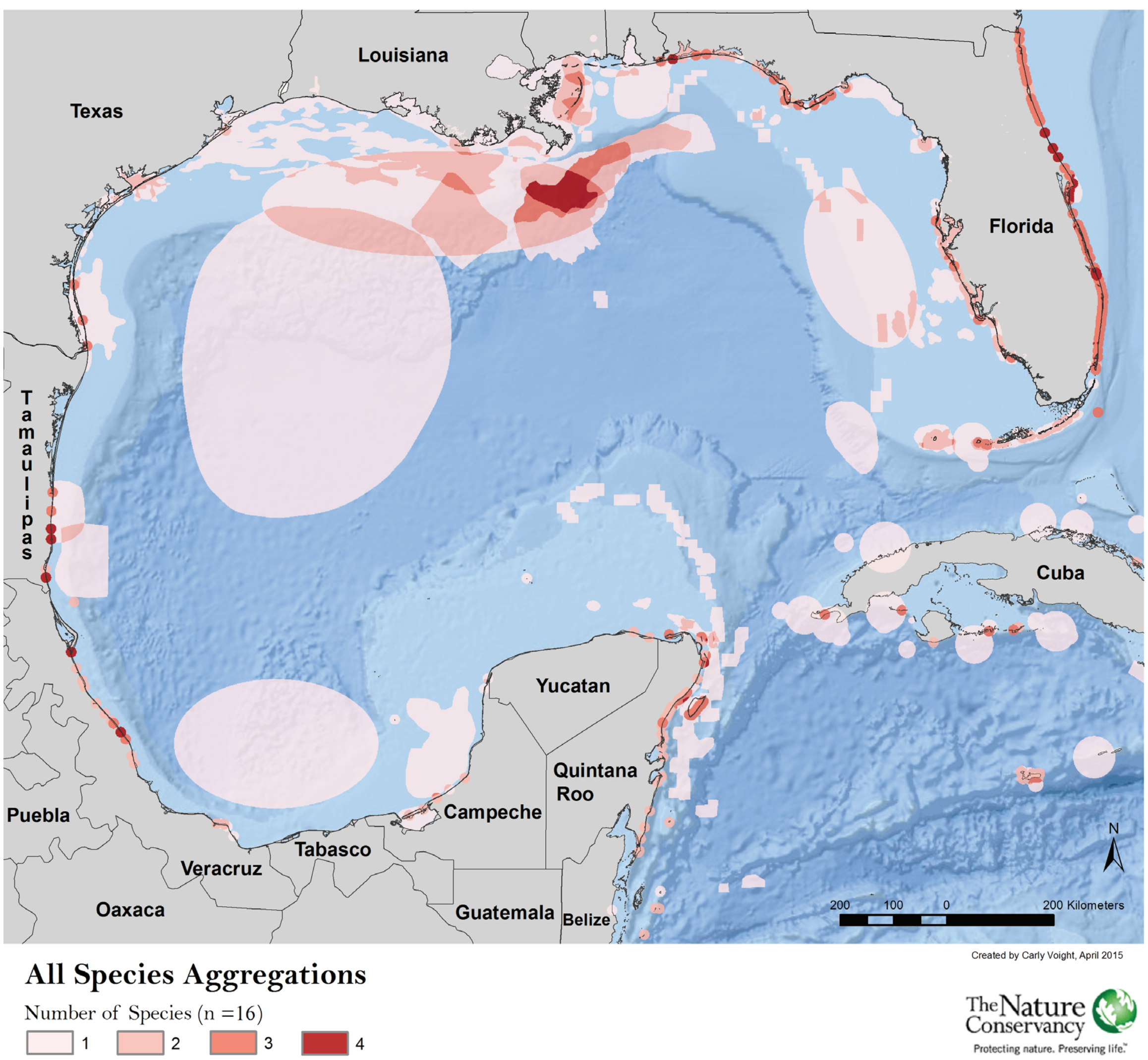
Figure 13 indicates which regions of the Gulf are aggregation areas for multiple marine species included in

Figure 12. Occurrence of hotspots for all migratory species covered in this assessment.



this assessment and available in the literature. Since many aggregation sites are quite small, only a few areas in the Gulf are used as reproductive or feeding areas by more than three marine species. Some of these localities include the De Soto Canyon off the coast of Louisiana, the northeastern Yucatán Peninsula, the western coast of Cuba, and multiple sea turtle nesting beaches in Florida, Veracruz, and Tamaulipas. Interesting patterns emerge from the collective views provided by Figures 10 and 13. Although each of the analyses was created using different types of data (i.e., from occurrences to satellite tracks), they primarily point to three common geographic areas that are relevant for multiple species. These areas are the south Florida Peninsula — Florida Strait area, the continental shelf edge and slope off the Mississippi River Delta, and the northern portion of the Yucatán Peninsula. The importance of these areas is likely attributable to several factors. Undoubtedly the coupled coastal-oceanographic conditions created by multiple features and processes in these areas make them essential habitat for multiple species (Sturges and Lugo-Fernández 2005). For example, stimulated by the strong influence of Mississippi River nutrient discharge and associated coastal wetlands, the central northern Gulf coast and marine environments off of Louisiana form a complex ecosystem. Although this area is subject to large negative environmental impacts, it constitutes one of the most prolific and resilient areas in the entire Gulf of Mexico (Chesney et al. 2000). The south Florida Peninsula-Florida Strait area comprises a corner stone for marine biodiversity due to its variety of coastal habitats, such as extensive shallow coral reefs and deeper coral areas (Grober-Dunsmore and Keller 2008). Waters forming the

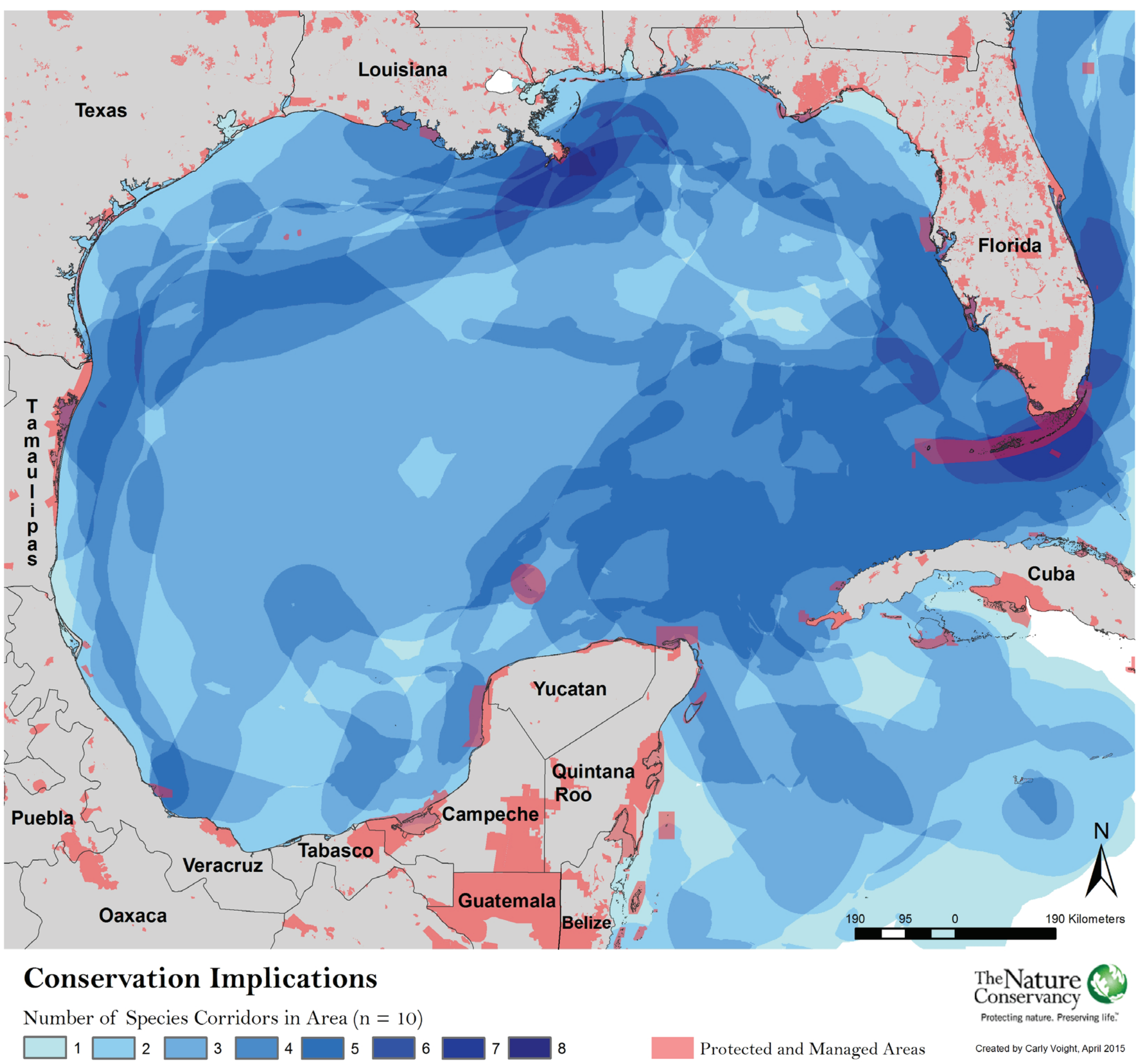
Figure 13. Integration of all species feeding and reproductive aggregations.



Loop Current entering the Gulf through the Yucatán Channel, and interacting with the extensive continental shelf area of the Yucatán Peninsula, provide specific oceanographic conditions to the area such as upwellings that are also relevant to many species (Muller-Karger et al. 2015). Moreover, the identification of these two areas as relevant is consistent with the identification of different biological productivity areas of the Gulf coastal waters using remote sensing data (Salmerón-García et al. 2011, Callejas-Jiménez et al. 2012). The multispecies migratory corridor for fish, sea turtles, and birds that spans from Florida to Cuba to the Yucatán Peninsula appears to be of particular relevance (Figures 10 and 11). This multispecies corridor area is responsible for facilitating biological connectivity between the temperate waters in the northern Gulf and the tropical waters of the Caribbean Sea, creating the diverse area comprised by the wider-Caribbean region (Grober-Dunsmore and Keller 2008).

Figure 14 displays the protected areas in the Gulf of Mexico and the marine multispecies corridors, representing areas of corridors that are under formal protection or other management. In this analysis, we overlaid protected and other managed areas (e.g., national parks, national marine sanctuaries, national forests, wildlife refuges, state parks and wildlife management areas, and private protected areas owned by the Conservancy, Audubon, and land trusts), and found that less than 1 percent of of these marine corri-

Figure 14. Overlay of all marine species corridors of: fish (6), sea turtles (3), and marine mammals (1), and protected and management areas in the Gulf of Mexico.



dors are protected. Fortunately, some of the areas used by multiple species as corridors in south Florida, northern Yucatán Peninsula, and northwestern Cuba are under some form of protection.

Birds are perhaps unique among the groups of species studied in this report in that, for most species, the entire Gulf of Mexico itself represents the major barrier to migration. This is particularly true for the terrestrial species, which must either fly over or around the Gulf and cannot land on the water. There is now evidence that individuals of many terrestrial bird species that migrate over the Gulf will use human-made structures such as oil platforms, which are now present in the marine environment (e.g., Russell 2005). However, the total area of such platforms is minuscule in relation to the area of open water, so such a rescue effect does not contribute to avian survival, at least not at the scale of the North American populations of such species.

For birds, we analyzed the important stopover sites for their protection status (Figure 15) (The Nature Conservancy 2013). The analysis indicated that only about 20 percent of the area of priority bird

Figure 15. Status of protection for bird priority stopovers in the Gulf of Mexico.

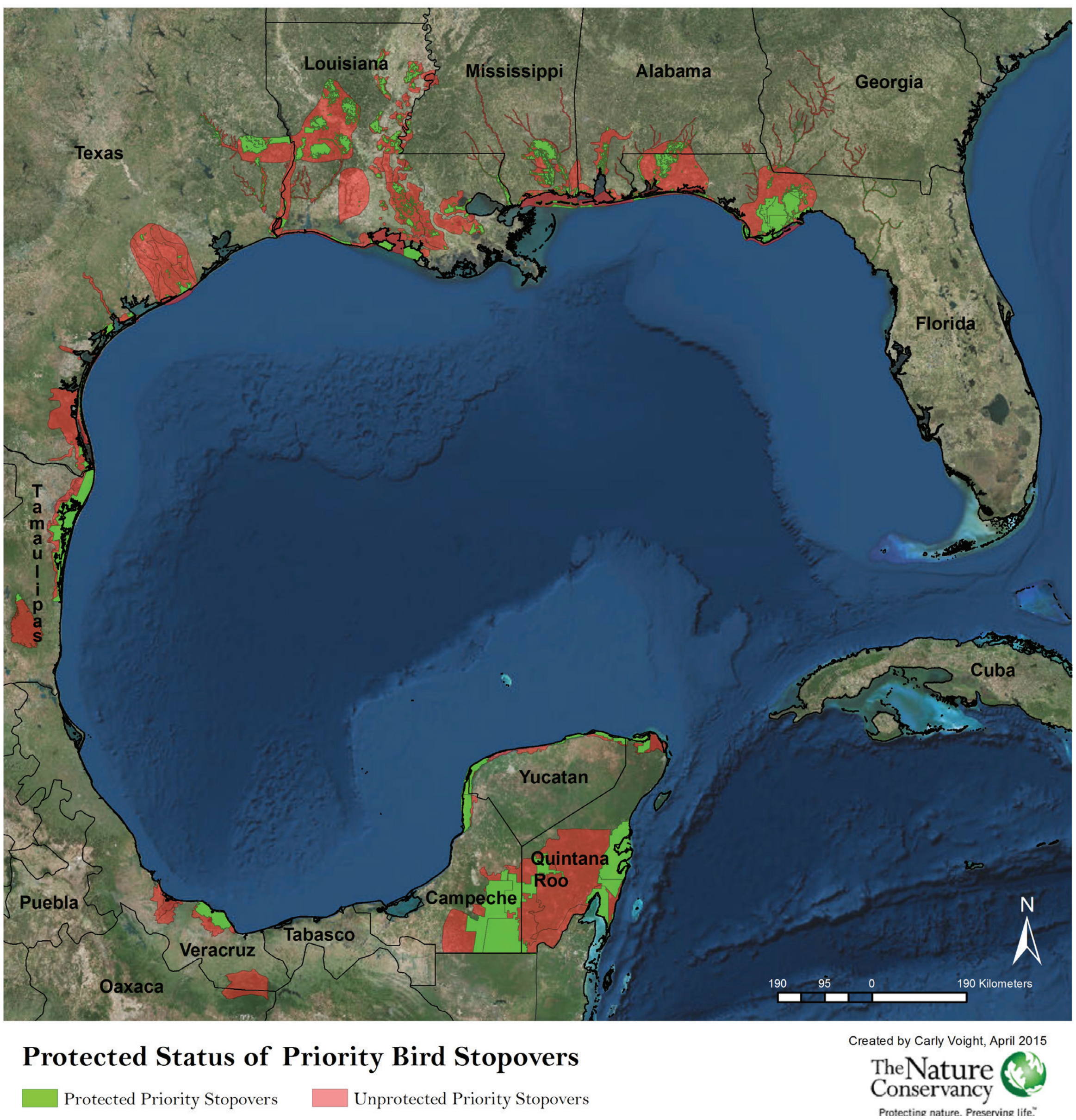
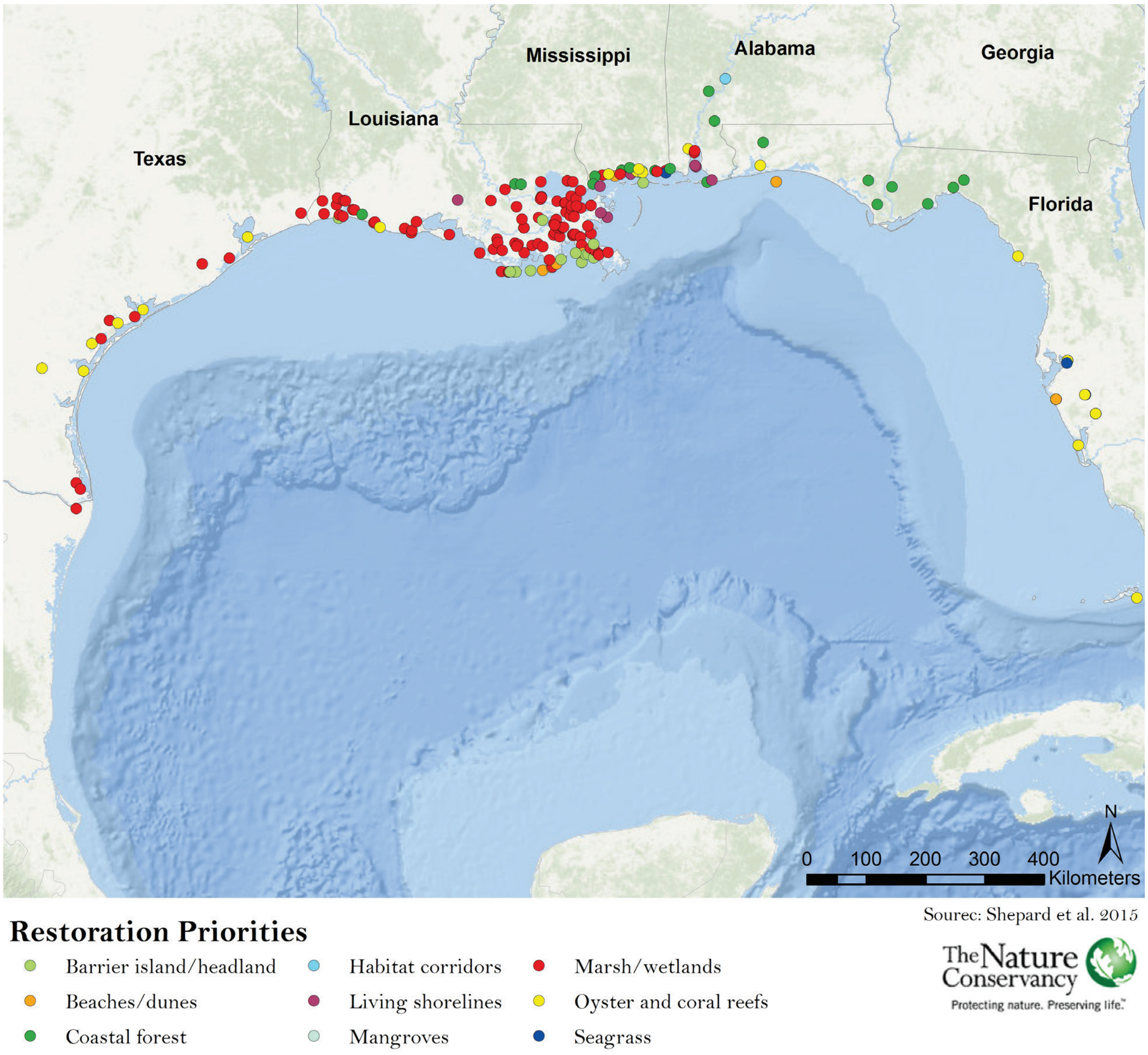


Figure 16. Location of 116 habitat restoration projects in the northern Gulf of Mexico.



Sourec: Shepard et al. 2015

The Nature Conservancy
Protecting nature. Preserving life.

stopover sites in the Gulf of Mexico is preserved in protected or managed areas. From this figure it can be interpreted that a number of stopovers along the Gulf coast constitute conservation opportunities in maintaining the populations of migratory birds that rely on the Gulf of Mexico.

The extent to which habitat loss and degradation have broadly contributed to declines in populations of bird species is well known and documented in the United States (e.g., NABCI 2009). Similarly, avian mortality from a wide variety of human-constructed structures or features has recently been documented, including those from communications towers (Longcore et al. 2012), wind turbines (Loss et al. 2013b), and vehicles (Loss et al. 2014b). However, we have treated habitat loss threats as having greater weight in our analyses of threats to birds given the specificity of this particular issue to the Gulf of Mexico region, as opposed to mortality analyses, which describe impacts over a vast region of North America. Due to the extreme importance of the Gulf region to the target bird species, and the birds of North America in general, abatement of these threats in the region is critically important. Given the extensive loss of habitat that has already occurred, priority should also be given to habitat restoration and enhancement to attempt to bring back some of the area that has been lost.

Mexico has identified biodiversity priority areas in the marine environments in the southern Gulf of Mexico. These areas cover approximately 40 percent of its exclusive economic zone and are distributed primarily along the continental shelf; they also cover large portions of the deeper parts of the Gulf. The rationale for their identification includes the migration areas of species of the four groups included in this study. The range of features considered in defining them includes oceanographic gyres, abyssal basins, coral reefs and banks, estuaries, and other coastal features (Arriaga-Cabrera et al. 1998).

In April 2010 the Deepwater Horizon oil spill focused the attention of the Gulf states and the nation on the ongoing problems in the Gulf of Mexico. During the five years since the oil spill, multiple federal, state and local agencies, nonprofit organizations, and coalitions have developed strategic plans and visions for restoring and conserving the Gulf of Mexico and lands along its coastline. A comprehensive understanding of these existing priorities is crucial to guiding the Gulf restoration process. With this in mind, a report (Shepard et al. 2015) was published that analyzes and synthesizes existing plans to identify common priorities and to demonstrate how priorities differ from state to state; in addition, where possible, this document identified the location of 116 priority actions. Figure 16 presents the location of the priorities that have been identified to restore habitats relevant to migratory species in the northern Gulf of Mexico. Certainly migratory species and other animals will benefit from the restoration proposed or currently under way in these projects. We suggest that in the future, habitat restoration projects should be evaluated for their capacity to restore a network of habitats that can be used by migratory species along their corridors in the Gulf.

Findings and Recommendations

Key Findings

This assessment was built from previous knowledge and multiple pieces of spatial data to identify the migratory pathways of fish, sea turtle, marine mammal, and bird species in the Gulf of Mexico LME. More than 100 collaborating scientists and managers contributed their knowledge and data to increase the understanding of the movements, threats, and management of the 26 species included in the United States, Mexico, and Cuba. The species corridors were assessed with a concern for the threats that these populations may encounter while migrating in the Gulf region. Key aspects of the science and management needed for their survival were identified and are summarized below. It is our hope that the findings of this assessment will motivate conservation awareness and management coordination among the different stakeholders in the three countries around the Gulf of Mexico:

- First, the study has confirmed that the Gulf of Mexico is an exceptionally important region for the migration of marine and avian life and that those migratory pathways link the different parts of the Gulf as a whole and connected ecosystem.

- The diversity of migratory mega-fauna in the Gulf of Mexico includes 79 percent of the UNCLOS-designated Highly Migratory Species of fish in the world, approximately 76 species of diadromous fish and 900-meter-long daily vertical migrations performed by the Stomiiformes, the second most diverse fish order in the Gulf. More than 50 percent of some of their populations migrate every night. All five sea turtles occurring in the Gulf are migratory. At least one large whale, the sperm whale, migrates regularly within the Gulf. About 71 percent of the 491 species of birds known to occur in the Gulf traverse it each spring and fall. Multiple other marine and terrestrial species migrate throughout the Gulf region, including invertebrates on land and in the ocean, such as butterflies and dragonflies, and spiny lobster.

- In addition to endemic fishes such as the Gulf menhaden and Gulf sturgeon (only one subspecies of which is endemic to the Gulf) with distributions limited to the Gulf of Mexico, other species also have populations with ranges limited to the Gulf of Mexico and therefore might require special management needs to maintain their viability. Examples of species with populations fully dependent on Gulf habitats are the sperm whale (the resident in the northern Gulf) and the migratory population of the whooping crane (with its entire population wintering on the Texas coast). Examples of species with populations partially dependent on the Gulf as habitat are bluefin tuna (the spawning grounds of the western Atlantic stock are in the western Gulf), Kemp's ridley sea turtle (nesting beaches in Texas and Tamaulipas) and redhead. Due to the specific habitat requirements and resulting limited ranges of these species, their populations are vulnerable to threats occurring in the Gulf. Therefore natural or anthropogenic catastrophic events could dramatically affect the viability of their populations.

- Eight of the migratory species assessed are listed as endangered or threatened in the United States; 11 are listed in Mexico as endangered, threatened or subject to special protection; and 11 are listed in Cuba as species of special significance. Additionally, Kemp's ridley sea turtle is listed as critically endangered, and Gulf sturgeon, green sea turtle, loggerhead sea turtle, and whooping crane are listed as endangered by IUCN's Red List. A number of the other species assessed are under some other status on the Red List.

- Although a number of international and national laws and treaties exist to conserve biodiversity, including those that migrate, the main focus of conservation implementation remains management of national priorities within national boundaries. We found a small number of multinational agreements that provide operational protection to migratory species across the region.

- Some of these migratory species have developed resident or nonmigratory populations in the Gulf, such as striped bass and sperm whale. Other species not included in this assessment have also non-fully migratory populations in the Gulf, making the region a zone of high intra-specific population divergence.

- The timing of many of these species' migrations is also very variable, and thus migration as a process is a constant throughout the year in the Gulf. Whereas the majority of the birds tend to migrate regularly during the spring and fall between their breeding and wintering areas, respectively, the rest of the groups have more varied timing for their migratory movements. Fish species migrate throughout the entire year, sea turtles primarily migrate in late spring and summer, and marine mammals migrate primarily during the winter in the Gulf.

- The majority of our knowledge of species occurrence, ranges, and movements is biased toward the northern Gulf and, specifically, the United States. Moreover, most of the knowledge is also biased toward species that have an economic value, such as the species that are part of commercial and recreational fisheries in North America. Endangered species also account for a considerable amount of data and information, and that knowledge, too, is primarily obtained in the northern Gulf.

- Most animal satellite tracking data is only available for larger species that spend most of their time on the surface of the ocean or in the air. Therefore, our ability to understand the movements of small fish and birds that cannot carry large tracking devices or that spend most of their lives at the bottom of the ocean is limited. In the ocean the largest amount of data comes from sea turtles due to their capacity to carry larger devices on their shells, and from charismatic species and wildlife resources, such as sharks and recreational fish such as tunas and billfishes.

- As a result of the above, we only found existing information on specific migratory corridors for three birds (whooping crane, osprey, and wood thrush). Additionally, a few of the species assessed had some information available on their migratory areas or routes, such as bluefin tuna and the coastal sea turtles. We created corridors for 13 of the species assessed using tracking data available from collaborating researchers across the Gulf.

- Recent assessments in the literature suggest that the main threats to migratory species of fish and sea turtles are from by-catch mortality and habitat loss. Although the latter is also a major threat source for manatees and birds, the main threat to the marine mammals assessed is vessel collision, and the main threat to the assessed bird species are the hazards of traversing urban areas. The Deepwater Horizon oil spill disaster in 2010 constituted a major barrier for the populations of a variety of migratory marine animals and birds whose journeys were disrupted due to beached, superficial, dissolved, and deep deposits of oil in the water. The Gulf of Mexico includes multiple other threats for migratory animals in their journeys to complete their life cycles. Water quality and other types of pollution events, including hypoxia ("dead zones"), habitat loss, unsustainable use of wildlife resources, and invasive species remain at the top of the list of issues that need systematic attention.

- Results of this species corridor assessment suggest that some species of coastal fish, sea turtles, and marine mammals may also use deeper parts of the ocean to complete specific phases of their life cycles, such as reproduction (e.g., Atlantic tarpon spawn in deeper areas of the continental slope) and foraging (e.g., coastal sea turtles move across deeper water between the Florida Peninsula and the Yucatán Peninsula), or for unknown reasons in other cases (e.g., Florida subspecies of manatee moving to Cuba). Alternatively, pelagic species of fish and sea turtles may come to near-shore waters as part of their life cycles (e.g., pelagic fish with larvae and/or juveniles using estuaries, and leatherback turtles nesting on beaches in the Gulf).

- We found that three areas of the Gulf are particularly significant migratory pathways for multiple species, making them a focus for future conservation efforts. These are: the area off of the Mississippi River Delta for eight species of fish, sea turtles, and marine mammals; the Florida Strait and Florida Keys also for eight species of fish, sea turtles, and marine mammals; and the northern area of the Yucatán Peninsula and the western tip of Cuba that are pathways for at least five species of fish and sea turtles. Many of the migratory corridors of fish, sea turtles, mammals, and bird species that we found show a strong relationship to the Louisiana continental shelf and the deeper canyons in the northern Gulf. In particular, the area off of the Mississippi River Delta seems to be a primary pathway for species of coastal fish such as tarpon, bull sharks, and all sea turtles, and the area at the edge of the continental shelf, including the deeper parts of the De Soto Canyon, appears to be a primary pathway for sperm whales. Dozens of migratory birds that winter in Meso and South America also migrate via the Mississippi Flyway from the northern Gulf straight to the southern Gulf coasts of the Yucatán Peninsula in Mexico and continue their journeys to other tropical areas.
- Similarly, different species of fish, sea turtles, and marine mammals migrating for reproductive and nutritional purposes may aggregate at the same areas (e.g., offshore of the Mississippi River Delta, south Florida Peninsula, northeastern area of the Yucatán Peninsula). These areas might represent hotspots for the completion of their lifecycles and be critically important for the survival of their populations in the Gulf.
- Less than 1 percent of the identified aquatic corridors are protected, and less than 20 percent of the area of priority bird stopovers within the bird species corridors is protected under existing managed areas in the three countries bordering the Gulf.

Recommendations for Science and Management

The following recommendations are presented to: 1) expand the current state of knowledge and understanding of migratory species, and 2) enhance the conservation and management of migratory species populations in the Gulf of Mexico LME. These recommendations constitute relevant aspects identified for the conservation of migratory species during the development of this assessment and do not constitute a comprehensive list of all possible needed research and management actions. More research is needed to develop such a comprehensive approach.

SCIENCE

DATA:

- Increase monitoring effort to determine species occurrence (presence and absence), regional ranges, movements, response to threats, and results of management actions. This is especially needed in the following areas: 1) central Gulf area off the Mississippi River Delta where the annual dead zone occurs, and 2) southeastern Gulf area that connects south Florida, Cuba, and the Yucatán Peninsula of Mexico. Include: survey effort information, use of standard survey protocols and methods, and making metadata available, whenever possible.
- Include in the monitoring efforts species and groups that are underrepresented at present, such as invertebrates, non-consumptively used, abundant or relatively secure species, small and cryptic species, partially migratory populations of well-known species and diadromous fish.
- Make spatial data on movement available through specialized but interoperable data in-

frastructures that specialize in tracking technology of all kinds (e.g., geolocators, radio and acoustic telemetry, satellite, and GPS sensors), such as Movebank (https://www.movebank.org). Create movement data management standards, data use policies, and geospatial interoperability frameworks.

ANALYSIS AND SYNTHESIS:

- Develop and promote the use of practical data models and analysis frameworks that integrate spatiotemporal animal movement data with existing approaches to assess species stocks, habitat use, population health, vulnerability and risks, and implications of climate change.
- Research practical geospatial techniques to determine the "search radius" needed for the delineation of corridors for different groups of species. Determine acceptability of criteria for analysis by creating consensus among groups conducting research on different taxa.
- Promote the use of new tracking technology and geospatial analyses to assess species' full life cycle needs and seasonal interactions using migratory connectivity frameworks of analysis to increase the understanding of the biological and environmental conditions that may limit the viability of their populations throughout their entire life cycles.
- Create management-oriented species data profiles that synthesize migration-specific information with a focus on migratory routes (even if a specific corridor does not exist, a general route and direction will be informative), migration timing (including seasons and specific times for movement peaks and aggregations), behavior, and physiology, using the model of the Birds of North America compendium (Poole 2014).

MANAGEMENT

- Make migratory species' movement data available in ways that are of practical use for resource and protected area managers. Examples include stock assessments, migratory corridors, high movement areas, aggregation locations, threats, and management strategies. When needed, generalize the information in ways so that it can be used by the public in a way that does not cause harm to the species.
- Define scales for the management of species and the areas that they use that are relevant to the scales of their migratory patterns in space and time. This includes international cooperation agreements for the co-management of transboundary species. Use a landscape/seascape/watershed scale, if appropriate for the management of populations of migratory species and the abatement of their threats, such as the connections between the Mississippi River watershed and the northern Gulf of Mexico.
- Adopt multispecies management approaches in which the needs of multiple migratory species are included in existing or new ecosystem-based management frameworks. Adaptively managing for migratory species diversity could help to build ecological resilience. Although migratory species do not constitute *per se* an ecological functional group (because they do not all play similar roles in functioning of an ecosystem), they support a variety of ecological functions that are related to ecosystem resilience, such as the link, memory, and response functions provided by fish that contribute to an ecosystem's stability (Brenner 2005).
- Use migratory species that perform relevant ecological functions and have values to communities and stakeholders as sentinel species of the health and resilience of the Gulf of Mexico LME. Migratory species can be used as sentinel species to inform managers and the public of rapid changes in status and trends not only of their populations, but also of other components of the ecosystems. Because they provide information on migratory connectivity at

the system-level and often use multiple habitats in different regions, they can help monitor changes occurring hundreds to thousands of kilometers away that could affect the viability of their entire population in the Gulf.

- Identify ecologically or biologically significant areas (EBSA) for the conservation of migratory species and other key biodiversity. Although EBSAs have been identified for resident and migratory populations and aggregations of marine mammals in the Gulf (LaBrecque et al. 2015), the identification of EBSAs for other migratory species groups will allow for a whole system view of management and conservation needs.

CONSERVATION

- Although species with limited movement areas or restricted ranges are not directly endangered by those limitations, those with very specific habitat needs (such as spawning or feeding aggregation reefs, nesting beaches, and bird stopovers) could be more vulnerable in the presence of threats that limit their capacity to complete their life cycles. In general the combination of restricted distribution, certain life history characteristics, and direct and indirect stressors can certainly threaten their populations. Examples of these species could be the West Indian manatee — which is slow moving, has specific sea grass habitat requirements and occurs in coastal areas — and the sea turtles in need of specific beach locations for nesting and with long maturation periods (ranging from six to 50 years for all four species). Conservation actions that target the abatement of specific barriers for the movements of migratory species should increase their capacity to complete their life cycles.

- Current conservation strategies for migratory species have focused on protecting and managing spawning or nesting areas for specific species. Due to the extreme importance of the Gulf of Mexico region to migratory species, additional conservation focused on migratory corridors is vital to maintain or increase the viability of these populations. Conservation objectives for each species should also focus on areas within the corridors, especially the critical areas with the highest density of movement or most commonly used pathways that are not currently protected. Additionally, strategies should focus on reducing pressures in areas with the highest threat ranking within each species' migratory corridor. Existing regulations could be adjusted and enforcement could be strengthened to provide increased protection.

- Conservation in the entire Gulf of Mexico LME should focus on areas that are critical to the viability of multiple marine species. Although this analysis was limited to only 17 marine species and the data for each species are imperfect, Figures 10 to 13 suggest a series of spatial priorities for conservation and potential restoration. Feasible strategies include conserving areas that are not currently protected in the form of new reserves and protected areas (as suggested by Figure 14) and strengthening management by collaborating in the enforcement of regulations across jurisdictions in managed areas that are relevant for transboundary populations such as those mentioned previously – i.e., the area off of the Mississippi River Delta, the Florida Strait and Florida Keys, and the northern area of the Yucatán Peninsula and the western tip of Cuba. Correspondingly, efforts to abate threats in areas with multiple or spatially generalized pressures, such as the dead zone in the northern Gulf of Mexico, would contribute to the conservation of large portions of the corridors of multiple species.

- The most serious threat to bird species is habitat loss and fragmentation caused by unsustainable development. Since migratory birds travel such great distances and have different food, shelter, and habitat requirements along the way, halting the decline of these birds means preserving a series of habitats along their entire migration path: wintering grounds, summer breeding grounds and the vital stopover sites in between. However, developing coordinated conservation programs between many groups in different countries is challenging. Specific conservation activities vary depending on the site, but they include land protection, conservation easements, habitat restoration, development of protected area management plans and implementation of payment for environmental services programs. Figure 15 suggests significant areas in the Gulf of Mexico to concentrate the above conservation activities for priority bird stopovers. These activities should be complemented by an environmental education and outreach program to highlight the continental and global importance of the Gulf region for birds. It is important to note that this is a region where we believe that even very small protected areas and reserves, if properly situated, can have a major impact on the bird populations of the entire hemisphere.

The Way Forward

The Gulf of Mexico LME is an extraordinarily important area for marine migratory species. These migrations are critical to the interconnection of the Gulf ecosystem. Our findings have only scratched the surface of understanding animal migration in the Gulf, but we hope that they spur additional research to document the full extent of Gulf migration and identify conservation actions that protect the life cycles of a wide range of important migratory species. Particular attention is needed to the four most significant "migratory blueways" identified in this study and to determining whether additional similar locations exist in the Gulf.

Although the basic biology and distribution for many species is known, the vast majority of knowledge focuses on places and stages at which animals spend most of their time. Not enough attention has been paid to their time traveling from place to place and to the threats to their survival associated with those journeys and with the aggregations of organisms that are often part of their migratory cycles. A further bias of past research has been a focus on the coastal temperate regions, which in some cases may constitute only half or less of the life cycles of some species migrating between temperate and tropical areas. Understanding the drivers of migration, the threats encountered, and seasonal interactions is imperative to increasing the viability of the populations of migratory species.

One of the first steps in assessing the migratory connectivity of populations is to be able to track their movements. New tracking technology is making it possible to assess the movements of a growing number of species (Table 4). These tracking tools not only provide a deeper understanding of the habitats they use while migrating, they also document multiple environmental stressors (such as water quality and areas of conflict with human activities) that can influence their survival. These tools can be used to evaluate the extent to which environmental or management problems impact migratory processes.

This report highlights the need for more research that will use these new tools and other evolving science to build on the creative and successful work done by the field researchers who produced the data behind this report. More work is needed, as well, to compile the data in ways that can guide the conservation and management practices of the United States, Mexico, and Cuba to protect the exceptional biodiversity of their shared resource—the Gulf of Mexico LME.

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Appendices

Appendix I. Global and National Statutory Authorities Pertaining to the Management of Migratory Species in the Gulf of Mexico.

Links to the species included in each authority are provided in the footnotes at the end of this appendix.

GLOBAL

United Nations Convention on the Law of the Sea

The United Nations Convention on the Law of the Sea (UNCLOS) of 1982 is the most comprehensive attempt at creating a unified governance regime of the rights of nations with respect to the world's oceans. The treaty addresses a number of topics including navigational rights, economic rights, pollution, conservation of marine life, scientific exploration, piracy, among other topics. Article 64 states that States whose nationals fish in the region for the highly migratory species listed in Annex I shall cooperate directly or through appropriate international organizations with a view to ensuring conservation and promoting the objective of optimum utilization of such species throughout the region, including in their economic exclusive zones. Annex I states the 17 taxonomic groups of fish, sharks and cetaceans that are included in UNCLOS's mandate[1]. The convention entered into force in 1994 and it has been ratified by 166 states, including Mexico and Cuba. Although the U.S. recognizes the UNCLOS as a codification of customary international law, it has not ratified it. Annex I includes the following species covered by this report: blue marlin, bluefin tuna, bull shark, whale shark, dolphin fish and sperm whale.

Convention on Biological Diversity

The Convention on Biological Diversity (CBD) of 1993 is a multilateral agreement that provides a global framework for the conservation of biodiversity. The CBD was inspired by the world community's growing commitment to sustainable development and it aims at promoting biodiversity's sustainable use, and the fair sharing of the benefits of its utilization. There are currently 196 parties to the CBD. Mexico and Cuba are parties to the convention and have ratified it, but the U.S. has not. All the biodiversity on earth is covered by the CBD.

Convention on International Trade in Endangered Species of Wild Fauna and Flora

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) of 1975 is an international agreement between governments that aims to ensure that international trade in wild animals and plants does not threaten their survival. CITES has gathered consensus among its parties on varying degrees of protection for more than 35,000 species of animals and plants, whether they are traded as live specimens, fur coats or dried herbs. Its Appendix I includes about 1,200 species that are threatened with extinction and are or may be affected by trade[2]. The U.S., Mexico and Cuba have ratified the convention. The four sea turtles and two marine mammals included in this report and the Whooping Crane are listed in Appendix I. The Gulf sturgeon, whale shark, Broad-winged Hawk and Osprey are listed in Appendix II. This appendix lists species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled.

Convention on the Conservation of Migratory Species of Wild Animals

The Convention on the Conservation of Migratory Species of Wild Animals of 1983 (CMS or the Bonn Convention) is an environmental treaty under the guidance of the

United Nations Environment Programme. The CMS provides a global platform for the conservation and sustainable use of migratory animals and their habitats, including mitigating obstacles to migration and controlling other factors that might endanger them. The convention brings together the countries through which migratory animals pass, also known as the range countries, and lays the legal foundation for internationally coordinated conservation measures throughout a migratory pathway. Migratory species threatened with extinction are listed in Appendix I and species that need or would significantly benefit from international co-operation are listed in Appendix II[3]. The convention has 210 parties and although only Cuba is a member in the Gulf of Mexico region, the U.S. and Mexico are considered range countries. The convention also encourages the range countries to develop global or regional agreements that may range from legally binding treaties to less formal instruments, such as Memoranda of Understanding (MOU), and can be adapted to the requirements of particular regions. An example of these instruments that pertains the Gulf of Mexico region is the MOU on the Conservation of Migratory Sharks that was signed in 2011. This agreement constitutes the first global instrument for the conservation of migratory species of sharks. The MOU is a legally non-binding international instrument that currently includes seven species[4]. The U.S. is the only MOU signatory country of the three countries bordering the Gulf of Mexico. All four sea turtle species and the sperm whale are included in Appendix I. Additionally whale shark, Redhead and Osprey are mentioned in Appendix II. Whale shark is the only species in this report that is included in the Shark MOU.

International Whaling Commission

The International Whaling Commission (IWC) is an international body set up by the terms of the International Convention for the Regulation of Whaling of 1946. The IWC is the global body charged with the conservation of whales and the management of whaling. The role of the IWC is to periodically review and revise the Schedule to the Convention, controlling the conduct of whaling by setting the protection of certain species; designating areas as whale sanctuaries; and setting limits on the numbers and size of catches. The IWC currently has 88 member governments. Uncertainty over whale numbers led to the introduction of a 'moratorium' on commercial whaling in 1986. This remains in place although the IWC continues to set catch limits for aboriginal subsistence whaling. Today, the IWC also works to understand and address a wide range of non-whaling threats to cetaceans including entanglement, ship strike, marine debris and climate change. The U.S. and Mexico are member states of the commission. The IWC regulates the sperm whale.

International Commission for the Conservation of Atlantic Tunas

The International Commission for the Conservation of Atlantic Tunas (ICCAT) is an inter-governmental fishery organization responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and its adjacent seas. The ICCAT was established at a Conference of Plenipotentiaries which prepared the International Convention for the Conservation of Atlantic Tunas, in Rio de Janeiro, Brazil, in 1966. After a ratification process, the Convention entered formally into force in 1969. About 30 species of tunas, billfish and sharks are of direct concern to ICCAT. The Convention compiles data for species that are caught during tuna fishing as bycatch, principally sharks. The ICCAT may be joined by any government that is a member of the United Nations. The U.S. and Mexico are currently members of ICCAT; Cuba was a member from 1975 to 1991. Blue marlin, Bluefin tuna and the two shark species included in this report are covered under the ICCAT.

Inter-American Convention for the Protection and Conservation of Sea Turtles

The Inter-American Convention for the Protection and Conservation of Sea Turtles of 2001 (IAC) is a legally binding intergovernmental treaty that provides the legal framework for countries in the Americas and the Caribbean to take actions for the benefit of sea turtles. The IAC promotes the protection, conservation, and recovery of sea turtles and those habitats on which they depend on the basis of the best available data and consideration of the environmental, socioeconomic, and cultural characteristics of the Parties. The treaty applies to all territorial waters of the contracting parties and their flagged vessels, encompassing the Pacific and Atlantic Oceans, including the Caribbean Sea and Gulf of Mexico. There are 15 Contracting Parties to the IAC, and the U.S. and Mexico are members. Six sea turtle species are protected under the IAC, including the four species included in this report.

Convention on Wetlands of International Importance

The Convention on Wetlands of International Importance of 1975, also known as the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The Convention uses a broad definition of wetlands. This includes all lakes and rivers, underground aquifers, swamps and marshes, wet grasslands, peatlands, oases, estuaries, deltas and tidal flats, mangroves and other coastal areas, coral reefs, and all human-made sites such as fish ponds, rice paddies, reservoirs and salt pans. By setting international standards for wetland conservation this convention has helped protect 2,193 sites[5] and 208,843,795 ha globally (more than the total area of Mexico). The convention has 168 parties. The U.S., Mexico and Cuba are contracting parties of the convention then they have designated 35, 138, and 6 Ramsar sites, respectively.

UNITED STATES OF AMERICA

Endangered Species Act

The Endangered Species Act (ESA) of 1973 provides a program for the conservation of threatened and endangered plants and animals and the habitats critical to their survival. The lead federal agencies in the U.S. for implementing ESA are the Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration. All federal agencies are required to use their authorities in implementing the act by carrying out programs for the conservation of endangered and threatened species. The Act requires federal agencies to ensure that actions they authorize, fund, or conduct will not jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat of such species, in consultation with its two leading agencies. With a few exceptions, the Act prohibits any action that results in 'take' of a listed species. The list of endangered or threatened species of insects and other invertebrates, fish, reptiles, mammals, birds, flowers, grasses, and trees is maintained by USFWS[6]. NMFS has jurisdiction over 125 endangered and threatened species of marine invertebrates, fish, turtles, mammals and plants[7]. In several cases the two agencies share responsibility for the management of species listed in the ESA – e.g., Gulf sturgeon and sea turtles. This act protects the following species included in this report: Gulf sturgeon, the four sea turtles, the two marine mammals, and Whooping Crane. A petition for listing Black Rail in the ESA is currently under review.

Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act, commonly referred as the Magnuson-Stevens Act (MSA) is the primary law governing marine fisheries management in U.S. federal waters. The Act was first enacted in 1976 and amended in 1996. To manage the fisheries and promote conservation, the Act created eight regional fishery management councils. The MSA enumerates the types of actions authorized for use by councils to achieve optimal catch goals: permitting vessels or operators, designating Zones and periods where fishing is limited, limiting sale, catch or transport of certain fish, regulating types of fishing equipment, and requiring observers on board vessels. The 1996 amendments focused on rebuilding overfished fisheries, protecting essential fish habitat, and reducing bycatch. In 2006 the MSA was reauthorized and its focus was to end overfishing, increased use of market-based management tools, creation of a national saltwater angler registry, and an emphasis on ecosystem approaches to management[8]. The MSA covers all commercial and recreational fish species included in this report.

Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) of 1972 seeks to conserve marine mammal species and population stocks from diminishing, as a result of human activities, beyond the point at which they cease to be significant functioning elements of their marine ecosystems. For any particular species or stock, the MMPA defines that point as the lower limit of its optimum sustainable population, which is defined as the population's maximum net productivity level. Determining whether a species or stock has fallen below that level requires information on population stock structure and abundance. The MMPA includes a general moratorium on the take of marine mammals, subject to certain exceptions. The Marine Mammal Commission (MMC) was created under Title II of the MMPA as an independent agency of the U.S. Government whose primary focus is to provide independent oversight of the marine mammal conservation policies and programs being carried out by federal regulatory agencies. Although federal agencies are not required to adopt the MMC's recommendations, the MMPA specifies that an agency that declines to follow any such recommendations is required to provide detailed written explanations. This act protects the two marine mammals included in this report.

Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) is the implementing legislation in the U.S. for bilateral Conventions between the U.S. and Canada, Mexico, Japan, and Russia to protect migratory birds. MBTA was first passed in 1918 to implement the 1916 Convention with Canada (part of Great Britain at the time) and later amended to add in the other three countries. The Act makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations by the USFWS. Violations of the law are punishable by a fine, imprisonment, or both. The bird species protected by the Act are listed in one or more of the Conventions, but are currently restricted to species native to the U.S. or its territories and that do not occur as a result of intentional or unintentional human-assisted introduction[9]. All nine bird species discussed in this report are covered under MBTA.

MEXICO

Native Flora and Fauna Species Protection Rule

The Native Flora and Fauna Species Protection Rule, known as NOM-059-ECOL, was first enacted in 1994. The rule's goal is to identify plant and animal species that are endangered. Additionally, it defines the risk categories and the criteria to list a species. The rule has been revised several times and the version of 2001 included new groups and species within or elevated the risk category of the species. The current version of 2010 includes a revised list of species that were derived from a public consultation process that started in 2004. The 2010 version also revised the criteria for the definition of risk criteria, and enhanced the methodology to rank rare and less represented species and habitats[10]. This rule protects these species included in this report: Gulf sturgeon, whale shark, the four sea turtles, the two marine mammals, and Broad-winged Hawk, Black Rail and Whooping Crane.

Shark and Ray Sustainable Fishing and Use Rule

The rule with the specification of Shark and Ray Sustainable Fishing and Use of 2006, known as NOM-029-PESC, regulates the industrial and artisanal fisheries of sharks and rays. The rule regulates the sustainable use of elasmobranchs and the species that are caught incidentally in this fishery, by specifying the allowable species, fishing gear and location (including exclusion zones for the protection of other species). It also includes a framework to coordinate with the NOM-059-ECOL for the protection of listed species. The rule lists the species of sharks and rays that are subject of commercial fisheries in the Gulf of Mexico[11]. This rule includes the two species of sharks included in this report.

Management and Protection of Sea Turtle Nesting Habitat Rule

The Management and Protection of Sea Turtle Nesting Habitat Rule of 2012, known as NOM-162-SEMARNAT, specify criteria for the protection, recovery and management of the populations of sea turtles while in their nesting habitats[12]. The specifications it provides regulate sea turtle nest management and research procedures. The rule applies to all species of sea turtles nesting on Mexican beaches, including the four species in this report.

CUBA

Resolution 160 of the Council of Ministries of Species of Special Significance

Resolution number 160 of the Council of Ministries, approved by its Executive Council in 2011, approved the legal regulatory framework in Cuba to control and protect biodiversity considered of special significance. The implementation of the resolution is coordinated by the Ministry of Science, Technology and Environment and it is framed within the Environmental Law that regulates biodiversity. The resolution aims at identifying the species that are considered of special significance in Cuba due to their status as endemic, threatened, endangered, representative of ecosystems, or of high ecological and economic value. The resolution also regulates the sustainable use of these species. Appendix I includes species or their products that are endangered and those species present in Cuba that are included in international treaties of which Cuba is a member, such as Appendix I of CITES, CMS, the Protocol Concerning Specially Protected Areas and Wildlife (referred as the SPAW Protocol), and the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, known as the Cartagena Convention. Appendix II includes species considered vulnerable, not evaluated but of high ecological value, species listed in CITES appendices II and III, and those in taxonomic groups whose majority of its members are in Appendix I of the resolution. Therefore it lists the entire genus or higher taxonomic level whose species are protected under the resolution[13]. The resolution includes the following species included in this report: whale shark, green sea turtle, loggerhead sea turtle, leatherback sea turtle, West Indian manatee, Broad-winged Hawk, Cerulean Warbler, Osprey, Wood Thrush, Black Rail and Black Skimmer.

Decree Law 164 of the State Council of Fisheries Regulations

The Decree Law 164 of fisheries regulations approved by the State Council of Cuba in 1996 provides the main set of rules that govern fisheries in the country[14]. The implementation of the decree is responsibility of the Ministry of Food Industry, and it is done in coordination with the Ministry of Fishery Industry and the Ministry of Agriculture. The decree classifies the interior and marine fishing waters for the industry, closed areas, and protected areas in which certain fishing activities are restricted. The regulation also divides fishing efforts between commercial, recreational and scientific purposes. This regulation calls for the development of a scientific basis to manage fishing activities. Additionally it also includes provisions to conserve water quality and coastal habitats that serve as refuges for fishery species, such as mangroves. The regulation is overseen by a Fisheries Commission established at the Ministry of Fishery Industry. The Commission is responsible for the zoning and management of fisheries activities.

FOOTNOTES

1. http://www.un.org/depts/los/convention_agreements/texts/unclos/annex1.htm
2. http://cites.org/eng/app/appendices.php
3. http://www.cms.int/sites/default/files/basic_page_documents/Appendices_COP11_E.pdf
4. http://www.cms.int/en/legalinstrument/sharks
5. http://www.ramsar.org/sites-countries/the-ramsar-sites
6. http://ecos.fws.gov/tess_public/reports/ad-hoc-species-report?kingdom=V&kingdom=I&status=E&status=T&status=EmE&status=EmT&status=EXPE&status=EXPN&status=SAE&status=SAT&mapstatus=3&fcrithab=on&fstatus=on&fspecrule=on&finvpop=on&fgroup=on&header=Listed+Animals
7. http://www.nmfs.noaa.gov/pr/species/esa/listed.htm
8. http://www.nmfs.noaa.gov/msa2005/docs/MSA_amended_msa%20_20070112_FINAL.pdf
9. http://www.fws.gov/migratorybirds/regulationspolicies/mbta/MBTANDX.HTML
10. http://www.biodiversidad.gob.mx/especies/pdf/NOM_059_SEMARNAT_2010.pdf
11. http://www.conapesca.gob.mx/work/sites/cona/resources/PDFContent/2042/norma_de_tiburn_dof.pdf
12. http://dof.gob.mx/nota_detalle.php?codigo=5286506&fecha=01/02/2013
13. http://www.medioambiente.cu/legislacionambiental/resoluciones/R-160-11-CITMA.pdf
14. http://www.medioambiente.cu/legislacionambiental/decretos-ley/DL-164.htm

Appendix II. Species Data Contributing Researchers and Institutions.

SPECIES GROUP	DATA FILE TYPE	CITATION	INSTITUTION
Fish	point	AquaMaps. no date. Reviewed native distribution map for Makaira nigricans (modelled 2100 map based on IPCC A2 emissions scenario) (Blue marlin). AquaMaps is a project of FishBase and SealifeBase. http:// www.aquamaps.org (October 2014).	AquaMaps
Fish	point	CONABIO. 2014. Bases de datos del Sistema Nacional de Información sobre Biodiversidad (SNIB). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). México, D.F.	CONABIO
Fish	point	Cooperative Science Services, LLC. no date. Dolphin fish Research Program point data. Unpublished data. Cooperative Science Services, LLC. Charleston. http://www.dolphintagging.com (August 2014).	Cooperative Science Services, LLC
Fish	point	Edwards, R.E., K.J. Sulak, M.T. Randall, and C.B. Grimes. 2003. Movements of Gulf sturgeon (Acipenser oxyrinchus desotoi) in nearshore habitat as determined by acoustic telemetry. Gulf of Mexico Science 21(1): 59-70.	USGS, University of South Florida & NMFS
Fish	point	Fox, D.A., J.E. Hightower, and F.M. Parauka. 2000. Gulf sturgeon spawning migration and habitat in the Choctawhatchee River system, Alabama-Florida. Transactions of the American Fisheries Society 129: 811-826.	North Carolina State University, USGS & USFWS
Fish	point	Fox, D.A., J.E. Hightower, and F.M. Parauka. 2002. Estuarine and nearshore marine habitat use by Gulf sturgeon from the Choctawhatchee River system, Florida. In Van Winkle, W., P.J. Anders, D.H. Secor, and D.A. Dixon (Eds.). Biology, management and protection of North American sturgeon. American Fisheries Society Symposium 28. Bethesda, pages 111-126.	North Carolina State University, USGS & USFWS
Fish	point	Froese, R., and D. Pauly (Eds.). 2011. Multiple fish species data. FishBase. http://www.fishbase.org (April 2014).	FishBase
Fish	point	Global Biodiversity Information Facility. no date. Multiple fish point data sources. http://www.gbif.org (August 2014).	GBIF
Fish	point	GSMFC. no date. SEAMAP access database. Fisheries Independent Sampling Program. Gulf States Marine Fisheries Commission (GSMFC). http://seamap.gsmfc.org (September 2014).	GSMFC
Fish	point	Heise, R.J., W.T. Slack, S.T. Ross, and M.A. Dugo. 2004. Spawning and associated movement patterns of Gulf sturgeon in the Pascagoula River drainage, Mississippi. Transactions of the American Fisheries Society 133: 221-230.	University of Southern Mississippi & Mississippi Department of Wildlife, Fisheries, and Parks
Fish	point	Hightower, J.E., K.P. Zehfuss, D.A Fox, and F.M. Parauka. 2002. Summer habitat use by Gulf sturgeon in the Choctawhatchee River, Florida. Journal of Applied Ichthyology 18(4Ð6): 595-600.	USGS, North Carolina State University & USFWS
Fish	point	Hoffmayer, E. 2013. Whale Shark Research Program sightings. Gulf Coast Research Laboratory. University of Southern Mississippi, Ocean Springs.	University of Southern Mississippi
Fish	point	Hueter, R.E., and J.P. Tyminski. no date. Whale shark data points. Unpublished data. Center for Shark Research. Mote Marine Laboratory. Sarasota.	Mote Marine Laboratory
Fish	point	Hueter, R.E., J.P. Tyminski, and J.J. Morris. no date. Bull shark data points. Unpublished data. Center for Shark Research. Mote Marine Laboratory. Sarasota.	Mote Marine Laboratory
Fish	point	ICCAT. no date. Tuna data points. International Commission for the Conservation of Atlantic Tunas (ICCAT). Madrid. https://www.iccat.int/en/accesingdb.htm (August 2014).	ICCAT
Fish	point	iNaturalist.org. 2014. Verified sightings for whale and bull sharks. https://www.inaturalist.org/ (September 2014).	iNaturalist.org
Fish	point	LDWF. no date. Fishery-independent sampling data of multiple species. Unpublished data. Louisiana Department of Wildlife and Fisheries. Baton Rouge.	Louisiana Department of Wildlife and Fisheries
Fish	point	OBIS. 2014. Ocean Biogeographic Information System (OBIS). Intergovernmental Oceanographic Commission of UNESCO and Duke University. http://iobis.org (August 2014).	OBIS
Fish	point	OBIS-USA. 2014. Ocean Biogeographic Information System (OBIS)-USA. Http://www.usgs.gov/obis-usa August 2014).	OBIS-USA
Fish	point	Ortiz, M. 2008. Gag grouper data. Southeast data, assessment, and Review (SEDAR). Mote Marine Laboratory. Sarasota.	Mote Marine Laboratory
Fish	point	Pérez-Jiménez, J.C. no date. Bull shark observation data. Unpublished data. Laboratorio de Pesquerias. El Colegio de la Frontera Sur (ECOSUR). Campeche.	ECOSUR
Fish	point	Rester, J.K. 2014. SEAMAP environmental and biological atlas of the Gulf of Mexico, 2011. Gulf States Marine Fisheries Commission (GSMFC). No. 229. Ocean Springs.	GSMFC
Fish	point	Ross, S.T., W.T. Slack, R.J. Heise, M.A. Dugo, H. Rogillio, B.R. Bowen, P. Mickle, and R.W. Heard. 2009. Estuarine and coastal habitat use of Gulf sturgeon (Acipenser oxyrinchus desotoi) in the North-Central Gulf of Mexico. Estuaries and Coasts 32: 360-374.	University of Southern Mississippi, Mississippi Department of Wildlife, Fisheries, and Parks & Louisiana Department of Wildlife and Fisheries
Fish	point	SCRFA. 2014. Multiple fish spcies from the Fish Aggregation Database. Science and Conservation of Fish Aggregations (SCRFA). http://www.scrfa.org.	Science and Conservation of Fish Aggregations

SPECIES GROUP	DATA FILE TYPE	CITATION	INSTITUTION
Fish	point	Stunz, G. no date. Bull shark observations. Unpublished data. Harte Research Institute at Texas A&M University - Corpus Christi.	Harte Research Institute
Fish	point	TPWD. No date. Multiple species data points. Unpublished data. Coastal Fisheries Division. Texas Parks and Wildlife (TPWD). Austin.	Texas Parks and Wildlife Department
Fish	point	TPWD. 2011. Fisheries independent data: Bull shark captured in Gill Net in Sabine Lake, 1986-2008. Texas Coastal Fisheries Resource Monitoring Program. Houston Advanced Research Center and Galveston Bay Estuary Program (Eds). Houston.	Houston Advanced Research Center
Fish	point	Whaleshark.org. no date. Wildbook for whale sharks photo-identification library (observation data points). Unpublished data. Whaleshark.org. http://www.whaleshark.org (October 2014).	Whaleshark.org
Fish	point, track	Edwards, R.E., F.M. Parauka, and K.J. Sulak. 2007. New insights into marine migration and winter habitat of Gulf sturgeon. In Munro, J., D. Hatin, J. Hightower, K. McKown, K. J. Sulak, A. Kahnle, and F. Caron (Eds.). Anadromous sturgeons: Habitats, threats and management. American Fisheries Society Symposium 56. Bethesda, pages 183-196.	USGS & NMFS
Fish	track	Ault, J.S., R. Humston, M.F. Larkin, E. Perusquia, N.A. Farmer, J. Luo, N. Zurcher, S.G. Smith, L. Barbieri, and J. Posada. 2008. Population dynamics and resource ecology of Atlantic tarpon and bonefish. In Ault, J.S. (Ed.). Biology and Management of the World Tarpon and Bonefish Fisheries. CRC Series on Marine Biology, Vol. 9. Taylor and Francis Group. Boca Raton, pages 183-196; ProjectTarpon.com and the Bonefish and Tarpon Research Center, Univeristy of Miami.	University of Miami
Fish	track	Block, B.A., G.L. Lawson, A.M. Boustany, M.J. Stokesbury, M. Castleton, A. Spares, J.D. Neilson, and S.E. Campana. 2009. Preliminary results from electronic tagging of bluefin tuna (Thunnus thynnus) in the Gulf of St. Lawrence, Canada. Collect. Vol. Sci. Pap. ICCAT 64(2): 469-479.	Stanford University, Duke University, Dalhouse University & Department of Fisheries and Oceans Canada.
Fish	track	Carlson, J.K. , M.M. Ribera, C.L. Conrath, M.R. Heupel, and G.H. Burgess. 2010. Habitat use and movement patterns of bull sharks Carcharhinus leucas determined using pop-up satellite archival tags. Journal of Fish biology 77: 661-675.	NMFS
Fish	track	Hammerschlag, N. 2014. Bull shark tracking data. Hammerschlag Lab. R.J. Dunlap Marine Conservation Program. University of Miami, Miami; Hammerschlag, N., J. Luo, D.J. Irschich, J.S. Ault. 2012. A Comparison of spatial and movement patterns between sympatric predators: Bull sharks (Carcharhinus leucas) and Atlantic tarpon (Megalops atlanticus). PLoS ONE 7(9): e45958.	University of Miami
Fish	track	Hendon, J.M., J.Higgs, and J. Franks. 2014. Bull shark tracking data. Unpublished data. Center for Fisheries Research and Development. Gulf Coast Research Laboratory. The University of Southern Mississippi. Ocean Springs.	University of Southern Mississippi
Fish	track	Hoffmayer, E. 2014. Whale Shark Research Program Satellite Tracks. Gulf Coast Research Laboratory, University of Southern Mississippi. Ocean Springs.	University of Southern Mississippi
Fish	track	Hueter, R.E., J.P. Tyminski, and J.J. Morris. Whale shark tracking data. Unpublished data. Center for Shark Research. Mote Marine Laboratory. Sarasota; Hueter, R.E., J.P. Tyminski, and R. de la Parra. 2013. Horizontal movements, migration patterns, and population structure of whale sharks in the Gulf of Mexico and northwestern Caribbean Sea. PLoS ONE. 8(8): e71883.	Mote Marine Laboratory
Fish	track	Kraus, R.T., R.J.D Wels, J.R. Rooker. 2011. Horizontal movement of Atlantic blue marlin (Makaira nigricans) in the Gulf of Mexico. Marine Biology 158: 699-713.	George Mason University
Fish	track	Shivji, M. 2010. Blue marlin tracking data. Unpublished data. Guy Harvey Research Institute. Nova Southeastern University. Dania Beach.	Guy Harvey Research Institute
Fish	track	Stokesbury, M.J.W., S.L.H. Teo, A. Seitz, R.K. O'Dor, and B.A. Block. 2004. Movement of Atlantic bluefin tuna (Thunnus thynnus) as determined by satellite tagging experiments initiated off New England. Can. J. Fish. Aquat. Sci. 61: 1976–1987.	Dalhouse University, Stanford University & Monterey Bay Aquarium
Fish	track	Stunz, G. no date. Bull shark and dolphin fish satellite tracking data. Unpublished data. Harte Research Institute at Texas A&M University - Corpus Christi.	Harte Research Institute
Fish	track	Teo, S.L.H., A. Boustany, and B.A. Block. 2007. Oceanographic preferences of Atlantic bluefin tuna, Thunnus thynnus, on their Gulf of Mexico breeding grounds. Marine Biology 152: 1105–1119.	Stanford University
Fish	track	Teo, S.L.H., A. Boustany, H. Dewar, M. Stokesbury, K. Weng, S. Beemer, A. Seitz, C. Farwell, E. D. Prince, and B.A. Block. 2007. Annual migrations, diving behavior and thermal biology of Atlantic bluefin tuna, Thunnus thynnus, to breeding grounds in the Gulf of Mexico. Marine Biology 151: 1–18.	Stanford University, Dalhouse University, Monterey Bay Aquarium & NMFS
Fish	track	TOPPs - Tagging of Pacific Predators - Census of Marine Life Project. Whale shark and bluefin tuna tracks.	TOPPs
Fish	track	WildlifeTracking.org. no date. Multiple fish satellite track datasets. http://www.wildlifetracking.org (September 2014).	WildlifeTracking.org

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Sea Turtle	nest density	Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, and Statewide Nesting Beach Survey program coordinator. 2013. http://ocean.floridamarine.org/mrgis/Description_Layers_Marine.htm#benthic (August 2014).	Florida Fish and Wildlife Conservation Commission
Sea Turtle	nesting beaches	Dow, W., K. Eckert, M. Palmer and P. Kramer. 2007. An atlas of sea turtle nesting habitat for the Wider Caribbean Region. The Wider Caribbean Sea Turtle Conservation Network (WIDECAST) and The Nature Conservancy. WIDECAST Technical Report No. 6. Beaufort, 267 pp. http://seamap.env.duke.edu/widecast (August 2014).	WIDECAST
Sea Turtle	nesting beaches	SWOT: SWOT Report - State of the World's Sea Turtles, vol. I (2006); SWOT Report - State of the World's Sea Turtles, vol. II (2006); SWOT Report - State of the World's Sea Turtles, vol. III (2008); SWOT Report - State of the World's Sea Turtles, vol. IV (2009); SWOT Report - State of the World's Sea Turtles, vol. V (2010); SWOT Report - State of the World's Sea Turtles, vol. VI (2011); SWOT Report - State of the World's Sea Turtles, vol. VII (2012); SWOT Report - State of the World's Sea Turtles, vol. VIII (2013), State of the World's Sea Turtles (SWOT), Arlington; Kot, C.Y., A. DiMatteo, E. Fujioka, B. Wallace, B. Hutchinson, J. Cleary, P. Halpin, and R. Mast. 2013. The state of the world's sea turtles online database: Data provided by the SWOT Team and hosted on OBIS-SEAMAP. Oceanic Society, Conservation International, IUCN Marine Turtle Specialist Group (MTSG), and Marine Geospatial Ecology Lab, Duke University. http://seamap.env.duke.edu/swot (August 2014).	SWOT
Sea Turtle	point	AquaMaps. no date. Reviewed native distribution map for Chelonia mydas (green sea turtle). Aquamaps is a project of FishBase and SealifeBase. http://www.aquamaps.org (September 2014).	AquaMaps
Sea Turtle	point	CONABIO. 2014. Bases de datos del Sistema Nacional de Información sobre Biodiversidad (SNIB). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). México, D.F.	CONABIO
Sea Turtle	point	Global Biodiversity Information Facility. no date. Multiple sea turtle point data sources. http://www.gbif.org (September 2014).	GBIF
Sea Turtle	point	GSMFC. no date. SEAMAP access database. Fisheries Independent Sampling Program. Gulf States Marine Fisheries Commission (GSMFC). http://seamap.gsmfc.org/ (August 2014).	GSMFC
Sea Turtle	point	OBIS Seamap. 2014. Ocean Biogeographic Information System (OBIS) Seamap. Intergovernmental Oceanographic Commission of UNESCO and Duke University. http://seamap.env.duke.edu/ (August 2014).	OBIS Seamap
Sea Turtle	point	OBIS-USA. 2014. Ocean Biogeographic Information System (OBIS)-USA. Http://www.usgs.gov/obis-usa (September 2014).	OBIS-USA
Sea Turtle	point	Rester, J.K. 2014. SEAMAP environmental and biological atlas of the Gulf of Mexico, 2011. Gulf States Marine Fisheries Commission (GSMFC). No. 229. Ocean Springs.	GSMFC
Sea Turtle	point, track	Department of the Navy. 2007. Marine resources assessment for the Gulf of Mexico. Department of the Navy, U.S. Fleet Forces Command. Contract # N62470-02-D-9997, CTO 0030. Norfolk. Prepared by Geo-Marine, Inc., Hampton.	Department of Navy
Sea Turtle	track	Cayman Turtle Farm: Island Wildlife Encounter. 2012. Grand Cayman, Cayman Islands. http://www.turtle.ky (September 2014).	Cayman Turtle Farm
Sea Turtle	track	Coleman, A. no date. Sea turtle satellite track data. Unpublished data. Institute for Marine Mammal Studies. Gulfport.	Institute for Marine Mammal Studies
Sea Turtle	track	Cuevas, E., B.I. González-Garza, V. Guzmán-Hernández, R.P. van-Dam, and P. García. 2012. Migratory corridors and feeding hotspots for hawksbill and green turtles in waters adjacent to the Yucatan Peninsula, Mexico. The State of the World´s Sea Turtle Report, Vol. VII; Méndez, D., E. Cuevas, J. Navarro, B.I. González-Garza, and V. Guzmán-Hernández. 2013. Satellite tracking of green turtle females Chelonia mydas and the evaluation of their home ranges in the north coast of the Yucatan Peninsula, Mexico. Revista de Biología Marina y Oceanografía 3: 497-509.	Pronatura Península de Yucatán
Sea Turtle	track	Dodd, M. no date. Loggerhead sea turtle satellite track data. Unpublished data. Georgia Department of Natural Resources.	Georgia Department of Natural Resources
Sea Turtle	track	Eastman, S. no date. Green sea turtle satellite tracks. Unpublished data. Eastman Environmental.	Eastman Environmental
Sea Turtle	track	Foley, A.M., B.A. Schroeder, R. Hardy, S.L. MacPherson, and M. Nicholas. 2014. Long-term behavior at foraging sites of adult female loggerhead sea turtles (Caretta caretta) from three Florida rookeries. Marine Biology 161: 1251–1262; Foley, A.M., B.A. Schroeder, R. Hardy, S.L. MacPherson, M. Nicholas, and M.S. Coyne. 2013. Postnesting migratory behavior of loggerhead sea turtles Caretta caretta from three Florida rookeries. Endangered Species Research 21: 129–142.	Florida Fish and Wildlife Conservation Commission, NMFS, USFWS & National Park Service
Sea Turtle	track	Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2): 104-115.	Duke University

SPECIES GROUP	DATA FILE TYPE	CITATION	INSTITUTION
Sea Turtle	track	"Hawkes, L.A., A.C. Broderick, M.S. Coyne, M.H. Godfrey, and B.J. Godley. 2007. Only some like it hot - quantifying the environmental niche of the loggerhead sea turtle. Diversity and Distributions 13: 447-457. http://www.seaturtle.org/library/?v=1632 (September 2014).	University of Exeter, Seaturtle.org & North Carolina Wildlife Resources Commission
Sea Turtle	track	Hickerson, E.L. 2000. Assessing and tracking resident, immature loggerheads (Caretta caretta) in and around the Flower Garden Banks, Northwest Gulf of Mexico. Master of Science Thesis. Texas A&M University, College Station.	Texas A&M University
Sea Turtle	track	Blumenthal, J.M., J.L. Solomon, C.D. Bell, T.J. Austin, G. Ebanks-Petrie, M.S. Coyne, A.C. Broderick, and B.J. Godley. 2006. Satellite tracking highlights the need for international cooperation in marine turtle management. Endangered Species Research. 2: 51-61.	Cayman Islands Department of Environment
Sea Turtle	track	"McClellan, C.M. 2009. Behavior, ecology, and conservation of sea turtles in the North Atlantic Ocean. Ph.D. Dissertation. Department of Environment. Duke University, Durham, 161 pp.	Centre for Ecology and Conservation, University of Exeter & Duke University
Sea Turtle	track	McClellan, C.M., and A.J. Read. 2007. Complexity and variation in loggerhead sea turtle life history. Biology Letters 3: 592-594.	Centre for Ecology and Conservation & University of Exeter & Duke University
Sea Turtle	track	"McClellan, C.M., and A.J. Read. 2009. Confronting the gauntlet: Understanding incidental capture of green turtles through fine-scale movement studies. Endangered Species Research 10: 165-179.	Centre for Ecology and Conservation, University of Exeter & Duke University
Sea Turtle	track	Nelson, D. 1999. Sea turtle relative abundance and seasonal movements in Tampa Bay entrance channel. US Army Corps of Engineers. Waterways Experiment Station, Vicksburg.	U.S. Army Corps of Engineers
Sea Turtle	track	Researchers: Blair Witherington, Disney's Animals, Science, and Environment, Archie Carr Center for Sea Turtle Research, University of Florida, and Shigetomo Hirama, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute; Witherington, B., and S. Hirama. 2011. Movements and Habitat Associations for Neonate Kemp's ridley Sea Turtles. Unpublished data. Florida Fish and Wildlife Conservation Commission. http://www.seaturtle.org/tracking/?project_id=636 (September 2014).	Disney's Animals, Science, and Environment, Archie Carr Center for Sea Turtle Research, University of Florida & Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute
Sea Turtle	track	Researchers: Christi L. Hughes, Sea Turtle Rescue Program, South Carolina Aquarium and Andre M. Landry, Jr., Marine Biology and Wildlife and Fisheries Sciences (Retired), Texas A&M University at Galveston; Hughes, C.L., and A.M. Landry. 2008. TAMUG Kemp's Ridley Nesters 2007-2008. Unpublished data. Texas A&M University at Galveston – Sea Turtle and Fisheries Ecology Research Lab., Galveston.	South Carolina Aquarium & Texas A&M University at Galveston
Sea Turtle	track	"Researchers: Katrina Phillips, University of Central Florida; Kate Mansfield, University of Central Florida; and David Addison, Conservancy of Southwest Florida; Phillips, K. 2011. Beyond the beach: Population trends and foraging site selection of a Florida loggerhead nesting assemblage. Open Access Theses, Paper No. 245.	University of Central Florida & Conservancy of Southwest Florida
Sea Turtle	track	Hirsch, S. no date. Sea turtle research database. Loggerhead Marinelife Center. Juno Beach. http://www.marinelife.org/ (August 2014).	Loggerhead Marinelife Center
Sea Turtle	track	Schmid, J.R., and W.N. Witzell. 2006. Seasonal migrations of immature Kemp's ridley turtles (Lepidochelys kempii Garman) along the west coast of Florida. Gulf of Mexico Science 24(1/2): 28-40.	Conservancy of Southwest Florida
Sea Turtle	track	Sea Turtle Rehabilitation Facility. no date. Gumbo Limbo Nature Center. Unpublished data. Boca Raton. http://www.gumbolimbo.org (August 2014).	Gumbo Limbo Nature Center
Sea Turtle	track	SeaTurtle.org. no date. Multiple sea turtle satellite track datasets. http://www.seaturtle.org (August 2014).	Seaturtle.org
Sea Turtle	track	Seney, E.E., and A.M. Landry, Jr. 2011. Movement patterns of immature and adult female Kemp's Ridley sea turtles in the northwestern Gulf of Mexico. Marine Ecology Progress Series 440: 241-254.	Texas A&M University at Galveston
Sea Turtle	track	The Aquarium at Moody Gardens. no date. Galveston. http://www.moodygardens.com (August 2014).	The Aquarium at Moody Gardens
Sea Turtle	track	Tiburcio, P.G., G.R. Bravo, and M.R. Kinzel. 2001. Satellite telemetry of green sea turtles (Chelonia mydas) nesting in Lechuguillas, Veracruz-Mexico (Perliminary results). Abstracts XXI Annual Symposium on Sea Turtle Biology and Conservation. Philadelphia; Kinzel, M.R., G. Carter, P.G. Tiburcio, and G.R. Bravo. 2003. Home range and habitats analysis of green sea turtles, Chelonia mydas, in the Gulf of Mexico. Abstracts XXII Annual Symposium on Sea Turtle Biology and Conservation. Miami; Tiburcio, P.G. 2003. Informe sobre actividades realizadas "Seguimiento vía satélite de la migración de tortuga blanca (Chelonia mydas), capturadas en Lechuguillas, Mpio. de La Torre, Veracruz-México". Oceanic Resource Foundation; Tiburcio, P.G., G. Balaz, D. Parker, and G.R. Bravo. 2004. "The adventure of the green sea turtle: turtles crossing the Gulf of Mexico" (Post-nesting migrations of green sea turtkes in lechuguillas, Veracruz-Mexico). Abstracts XXIV Annual Symposium on Sea Turtle Biology and Conservation. San José, Costa Rica.	

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Sea Turtle	track	Virginia Aquarium. 2014. Section 6 Progress Report JanuaryÐJune 2014. Virginia and Maryland Sea Turtle Research and Conservation Initiative. Progress Report submitted to National Marine Fisheries Service; Lockhart, G.G., Barco, S.G., D'eri, and L. 2014. A preliminary home-range analysis of loggerhead sea turtles released in Virginia, USA. Poster session presentation at the 34th Annual Symposium on Sea Turtle Biology and Conservation. New Orleans.	Virginia Aquarium & Marine Science Center Foundation
Marine Mammal	point	Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute. 2014. Manatee synoptic survey sightings (1991-present). http://ocean.floridamarine.org/mrgis/ (August 2014).	Florida Fish and Wildlife Conservation Commission
Marine Mammal	point	Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute. Unpublished material. Aerial distribution survey for manatees. http://ocean.floridamarine.org/mrgis/ (August 2014).	Florida Fish and Wildlife Conservation Commission
Marine Mammal	point	Global Biodiversity Information Facility. no date. Multiple marine mammal point data sources. Http://www.gbif.org (July 2014).	GBIF
Marine Mammal	point	Jefferson, T.A., and A.J. Schiro. 1997. Distribution of cetaceans in the offshore Gulf of Mexico. Mammal Review 27: 27–50.	
Marine Mammal	point	Morales, J.B., and G.L. Medrano. 1997. Monitoreo de manatí (Trichechus manatus) con radiotransmisores en Quintana Roo. Escala 1:250 000. Extraído del proyecto H164 Variación genética del manatí (Trichechus manatus), en el sureste de México y monitoreo con radiotransmisores en Quintana Roo. El Colegio de la Frontera Sur (ECOSUR), Unidad Chetumal, Chetumal. Funded by: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO).	CONABIO & ECOSUR
Marine Mammal	point	OBIS Seamap. 2014. Ocean Biogeographic Information System (OBIS) Seamap. Intergovernmental Oceanographic Commission of UNESCO and Duke University. http://seamap.env.duke.edu/ (August 2014).	OBIS Seamap
Marine Mammal	point	OBIS-USA. 2014. Ocean Biogeographic Information System (OBIS)-USA. Http://www.usgs.gov/obis-usa (September 2014).	OBIS-USA
Marine Mammal	point	Rester, J.K. 2014. SEAMAP environmental and biological atlas of the Gulf of Mexico, 2011. Gulf States Marine Fisheries Commission (GSMFC). No. 229. Ocean Springs.	GSMFC
Marine Mammal	point	CONABIO. 2014. Bases de datos del Sistema Nacional de Información sobre Biodiversidad (SNIB). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). México, D.F.	CONABIO
Marine Mammal	point, track	Department of the Navy. 2007. Marine resources assessment for the Gulf of Mexico. Department of the Navy, U.S. Fleet Forces Command, Norfolk. Contract #N62470-02-D-9997, CTO 0030. Prepared by Geo-Marine, Inc., Hampton.	Department of Navy
Marine Mammal	track	Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2): 104-115.	Duke University
Marine Mammal	track	Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhaupt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, and B. Würsig. 2008. Sperm whale seismic study in the Gulf of Mexico: Synthesis report. U.S. Dept. of the Interior. Minerals Management Service, Gulf of Mexico OCS Region. OCS Study MMS 2008-006. New Orleans, 341 pp. The Sperm Whale Seismic Study (SWSS) is sponsored by the U.S. Minerals Management Service and involves researchers from Texas A&M University, Oregon State University, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, Texas A&M University-Galveston, University of Durham, and Ecologic with support and cooperation from the Industry Research Funders Coalition (International Association of Geophysical Contractors (IAGC) and oil and gas companies), National Fish and Wildlife Foundation, National Science Foundation, and Office of Naval Research.	Minerals Management Service
Bird	point	"Austin, E.A., and A.L. Richert. 2001. A comprehensive review of observational and site evaluation data of migrant Whooping Cranes in the United States, 1943-1999. U.S. Geological Survey (USGS), Northern Prairie Wildlife Research Center, Jamestown, North Dakota, and State Museum, University of Nebraska, Lincoln, Nebraska. 157 pp.	USGS & USFWS
Bird	point	Christmas Bird Count. CBC data is provided by National Audubon Society and through the generous efforts of Bird Studies Canada and countless volunteers across the western hemisphere. www.audubon.org, www.christmasbirdcount.org	National Audubon Society
Bird	point	CONABIO. 2014. Sistema de Información Nacional de Informacion de Biodiversidad (SNIB). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). México, D.F.	CONABIO
Bird	point	Global Biodiversity Information Facility (GBIF). no date. Multiple bird point data sources. www.gbif.org (September 2014).	GBIF
Bird	point	Jodice, P.G.R., W. Mackin, and R. Phillips. 2012. Audubon's shearwater. Unpublished data. South Carolina Cooperative Wildlife Research Unit. Clemson University, Clemson.	Clemson University

SPECIES GROUP	DATA FILE TYPE	CITATION	INSTITUTION
Bird	point	Panama Audubon Society. no date. Raptor migration data. Provided with support from: Hawk Mountain, CEASPA, Peregrine Fund, Smithsonian Tropical Research Institute, Canopy Tower, Gamboa Rainforest Discovery Center, Advantage Tours, Birders' View, AES Changuinola, ENEL Fortuna, Ocean Pollution Control, S.A., ENSOL, Fundación Natura, and members and volunteers of Panama Audubon Society.	Panama Audubon Society
Bird	point	TCWS. 2013. Texas Colonial Waterbird Society annual census and database. Texas Colonial Waterbird Society (TCWS). Audubon Texas (Ed.), Texas City.	Texas Coastal Waterbird Society
Bird	polygon, corridor	Brei, J., A. Bishop, M. Tacha, and R. Grosse. 2009. Whooping Crane migration corridors methods summary. U.S. Fish and Wildlife Service, Platte River Recovery Implementation Program and Rainwater Basin Joint Venture Report.	USFWS
Bird	polygon	GSGS. 2013. U.S. Geological survey gap analysis program species distribution models. U.S. Geological Survey (USGS). http://gapanalysis.usgs.gov/species/data/download/ (August 2014).	USGS
Bird	track	Bedrosian, B., and S. Cain. no date. Osprey satellite track data. Unpublished data. Grand Teton National Park, the Grand Teton National Park Foundation, and Craighead Beringia South.	Grand Teton National Park, the Grand Teton National Park Foundation & Craighead Beringia South
Bird	track	Bierregaard, R. no date. Osprey satellite track data. Unpublished data. Academy of Natural Sciences of Drexel University.	Drexel University
Bird	track	"Domenech, R., A. Shreading, and E. Greene. 2012-2014. Montana Osprey satellite tracking data. Unpublished data. Raptor View Research Institute, The MPG Ranch, and University of Montana.	Raptor View Research Institute, The MPG Ranch & University of Montana
Bird	track	Haines, A.M., M.J. McGrady, M.S. Martell, B.J. Dayton, M.B. Henke, and W.S. Seegar. 2003. Migration routes and wintering locations of Broad-winged Hawks tracked by satellite telemetry. Wilson Bulletin 115(2): 166–169.	Millersville University
Bird	track, corridor	Martell, M.S., C.J. Henny, P.E. Nye, and M.J. Solensky. 2001. Fall migration routes, timing, and wintering sites of North American Ospreys as determined by satellite telemetry. The Condor 103: 715-724.	National Audubon Society
Bird	track	McCabe, R. , L. Goodrich, K. Bildstein, D. Barber, and T. Master. 2014. Conserving Pennsylvania's common raptors year-round: Broad-winged Hawk habitat use, range, and movement ecology during nesting, wintering, and migration. www.hawkmountain.org/broadwing. Funded by: Pennsylvania Game Commission State Wildlife Grants, ATUS, Inc., Kittatinny Coalition, and Audubon Pennsylvania, and many private donors.	Hawk Mountain Sanctuary
Bird	track	Movebank. no date. Movebank: For animal tracking data. Multiple bird datasets. http://www.movebank.org (November 2014).	Movebank
Bird	track	"Postupalsky, S., B. Jensen, and B. Washburn. 2013-2014. Osprey satellite tracks. OWSEM/Michigan Osprey, MDNR-Wildlife Division, Detroit Zoological Society, USDA-Wildlife Services, and Huron Valley Audubon Society. Funded by: American Tower Corporation, DTE Energy, 2013. Huron Valley Audubon Society, DTE Energy, Federal Aviation Agency and private donors in 2014. Support from: Detroit River International Wildlife Refuge, Skyline Services LLC, Clearlink Wireless Solutions, Newkirk Electric, PYP Contracting, and numerous volunteers.	OWSEM/Michigan Osprey, MDNR-Wildlife Division, Detroit Zoological Society, USDA-Wildlife Services & Huron Valley Audubon Society
Bird	track	Stutchbury, B.J.M., S.A. Tarof, T. Done, E. Gow, P.M. Kramer, J. Tautin, J.W. Fox, and V. Afanasyev. 2009. Tracking long-distance songbird migration by using geolocators. Science. 232: 896; Stanley, C.Q., E.A. McKinnon, K.C. Fraser, M.P. MacPherson, G. Casbourn, L. Friesen, P.P. Marra, C. Studds, T.B. Ryder, N.E. Diggs, and B.J.M. Stutchbury. 2015. Connectivity of Wood Thrush breeding, wintering, and migration sites based on range-wide tracking. Conservation Biology 29(1): 164-174.	York University, Smithsonian Conservation Biology Institute, Canadian Wildlife Service, Purple Martin Conservation Association, & British Antarctic Survey
Bird	track	WildlifeTracking.org. no date. Multiple bird satellite track datasets. http://www.wildlifetracking.org (September 2014).	WildlifeTracking.org

Appendix III. Data Sources of Threat Analysis.

THREAT TYPE	SOURCE
Beach erosion	Thieler, E.R., and E.S. Hammar-Klose. 2010. Coastal vulnerability to sea-level rise: A preliminary database for the U.S. Gulf Coast. U.S. Geological Survey.
Dams	National Atlas of the United States. 2006. Major dams of the United States. http://nationalatlas.gov/atlasftp.html?openChapters=chp-water#chpwater
Electric lines	NERC. 2013. Electric transmission lines. North American Electric Reliability Corporation (NERC). Washington, D.C. http://www.nerc.com
Feral hog density	University of Florida. no date. Population density of wild hogs in Florida map. Tallahassee. http://taylor.ifas.ufl.edu/marine_game_hog.shtml
Forest loss	CEC. 2013. 2005-2010 land cover change of North America at 250 meters. Edition: 1.0. North American Environmental Atlas. Commission for Environmental Cooperation (CEC). Montreal. http://www.cec.org/naatlas/
Hypoxia/dead zone	Diaz, R., M. Selman, and C. Chique. 2011. Global eutrophic and hypoxic coastal systems. Eutrophication and Hypoxia: Nutrient Pollution in Coastal Waters. World Resources Institute. Washington, D.C. http://docs.wri.org/wri_eutrophic_hypoxic_dataset_2011-03.xls
Inorganic nonpoint pollution	Halpern, B.S., S. Walbridge, K.A. Selkoe, C.V. Kappel, F. Micheli, C. D'Agrosa, J.F. Bruno, K.S. Casey, C. Ebert, H.E. Fox, R. Fujita, D. Heinemann, H.S. Lenihan, E.M.P. Madin, M.T. Perry, E.R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008. A global map of human impact on marine ecosystems. Science 319(5865): 948-952.
Light pollution at night	Earth Observatory. 2012. Earth at night 2012. NASA. http://earthobservatory.nasa.gov/Features/NightLights/page3.php
Lionfish observations	GCOOS-TNC. 2014. Lionfish observation application. Gulf of Mexico Coastal Ocean Observing System (GCOOS) and The Nature Conservancy (TNC). College Station. http://gcoos.org/products/maps/lionfish/
Longline fishing (CPUE)	NMFS. 2013. Pelagic longline catch per unit effort data. National Marine Fisheries Service (NMFS).
Mangrove loss	CONABIO. 2014. Monitoreo de manglares. Portal de geoinformación: Sistema nacional de información sobre biodiversidad. http://www.conabio.gob.mx/informacion/gis/?vns=gis_root/biodiv/monmang/manglegw
Maritime vessel traffic/density	Halpern, B.S., S. Walbridge, K.A. Selkoe, C.V. Kappel, F. Micheli, C. D'Agrosa, J.F. Bruno, K.S. Casey, C. Ebert, H.E. Fox, R. Fujita, D. Heinemann, H.S. Lenihan, E.M.P. Madin, M.T. Perry, E.R. Selig, M. Spalding, R. Steneck, and R. Watson, R. 2008. A global map of human impact on marine ecosystems. Science 319(5865): 948-952.
Nutrient pollution	Halpern, B.S., S. Walbridge, K.A. Selkoe, C.V. Kappel, F. Micheli, C. D'Agrosa, J.F. Bruno, K.S. Casey, C. Ebert, H.E. Fox, R. Fujita, D. Heinemann, H.S. Lenihan, E.M.P. Madin, M.T. Perry, E.R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008. A global map of human impact on marine ecosystems. Science 319(5865): 948-952.
Ocean pollution from marine vessels	Halpern, B.S., S. Walbridge, K.A. Selkoe, C.V. Kappel, F. Micheli, C. D'Agrosa, J.F. Bruno, K.S. Casey, C. Ebert, H.E. Fox, R. Fujita, D. Heinemann, H.S. Lenihan, E.M.P. Madin, M.T. Perry, E.R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008. A global map of human impact on marine ecosystems. Science 319(5865): 948-952.
Oil and gas activity/pollution	BOEM. 2014. Gulf of Mexico OCS blocks and leases. Gulf of Mexico OCS Region; Office of Leasing & Plans, Mapping & Automation Section. Bureau of Ocean Energy Management (BOEM). Washington, D.C. http://www.data.boem.gov/homepg/data_center/mapping/geographic_mapping.asp; National Geographic Society. 2010. Gulf of Mexico: A geography of offshore oil map. Washington, D.C.
Oil and gas pipelines	BOEM. 2014. GOMR pipelines. Gulf of Mexico OCS Region; Office of Leasing & Plans, Mapping & Automation Section. Bureau of Ocean Energy Management (BOEM). Washngton, D.C. http://www.data.boem.gov/homepg/data_center/mapping/geographic_mapping.asp
Roads	ESRI ArcGIS Online, DeLorme, and TomTom. 2015. US major roads. ESRI. Redlands; ESRI ArcGIS Online. 2015. Roads of Mexico, North America from Digital Chart of the World. ESRI. Redlands.
Shrimp trawling (CPUE)	Hainsko, D., and J. Rester. Brown shrimp and white shrimp In Gulf of Mexico data atlas. Coastal Data Development Center, NOAA. Stennis Space Center. http://gulfatlas.noaa.gov; Trudel, B.K., B.J. Jessiman, S.L. Ross, R.C. Belore, and J.D. Morrison.1989. White shrimp young May-Jun and brown shrimp plankton Sept-Dec. MIRG/S.L. Ross Oil Spill Impact Assessment Model. SL Ross Environmental Research, LTD. Ottawa.
Small boat collision areas	FWC. unknown publication date. Manatee carcass recovery locations in Florida. Florida Fish and Wildlife Conservation Commission (FWC)-Fish and Wildlife Research Institute. Tallahassee. http://ocean.floridamarine.org/mrgis/
Tall structures (cell, TV, radio, etc. towers)	FCC. 2014. Cellular, antenna structures, AM and FM, TV, and microwave databases. Federal Communications Commission (FCC). http://wireless.fcc.gov/geographic/index.htm?&job=home
Urban & suburban areas	CEC. 2013. 2010 Land Cover of North America at 250 meters. Edition: 1.0. North American Environmental Atlas. Commission for Environmental Cooperation (CEC). Montreal. http://www.cec.org/naatlas/
Warm water spring degradation	FWC. 2014. Manatee synoptic survey sightings (1991-present). Florida Fish and Wildlife Conservation Commission (FWC)-Fish and Wildlife Research Institute. Tallahassee. http://ocean.floridamarine.org/mrgis/; FWC. unpublished material. Aerial distribution survey for manatees. Florida Fish and Wildlife Conservation Commission (FWC)-Fish and Wildlife Research Institute. Tallahassee. http://ocean.floridamarine.org/mrgis/; Taylor, C.R. 2006. A survey of Florida springs to determine sccessibility to Florida manatees (Trichechus manatus latirostris): Developing a sustainable thermal network. Report submitted to the U.S. Marine Mammal Commission. The Wildlife Trust. Newark.
Wetland loss	CEC. 2013. 2005-2010 Land Cover Change of North America at 250 meters. Edition: 1.0. North American Environmental Atlas. Commission for Environmental Cooperation (CEC). Montreal. http://www.cec.org/naatlas/
Whale shark ecotourism	Hueter, R., and J. Tyminski. 2012. Issues and options for whale shark conservation in Gulf of Mexico and western Caribbean waters of the U.S., Mexico and Cuba. A background paper prepared for Environmental Defense Fund. Mote Marine Laboratory, Technical Report 1633, Sarasota, 43 pp.
Wind turbines	USFWS. no date. Federal Aviation Administration obstruction evaluation / airport airspace analysis (OE-AAA) database. U.S. Fish and Wildlife Service (USFWS). Washington, D.C. http://www.fws.gov/southwest/es/Energy_Wind_FAA.html

Appendix IV. Species Observations, Distributions, and Pathways Maps.

Figure 17. Atlantic tarpon distribution and observations.

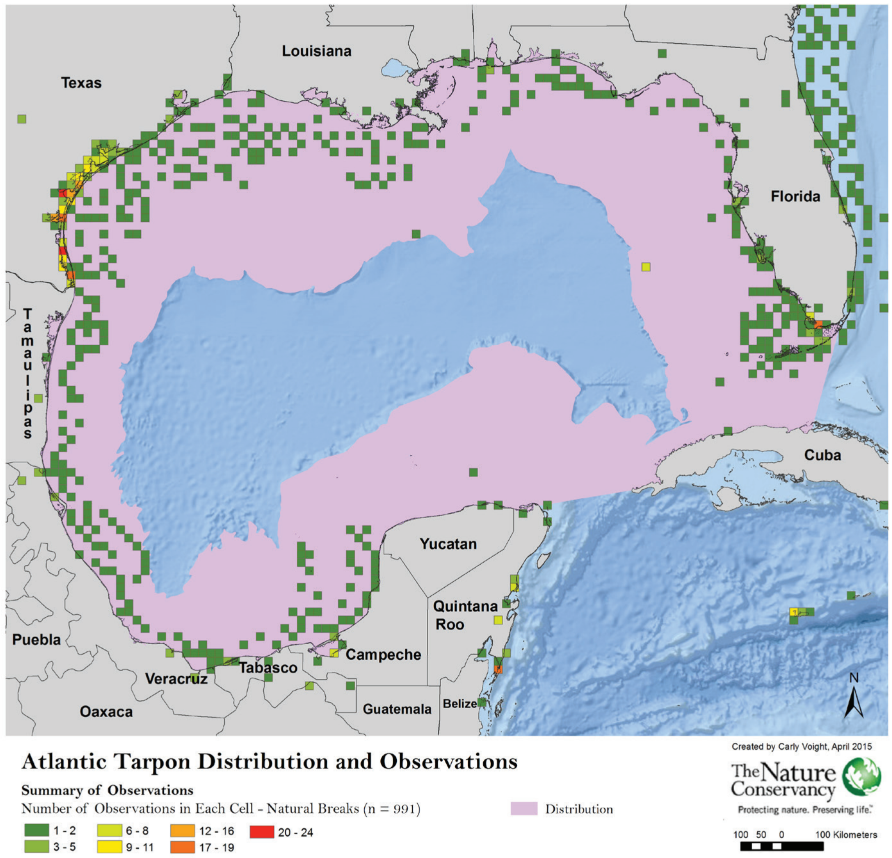


Figure 18. Atlantic tarpon migration corridor and movement density.

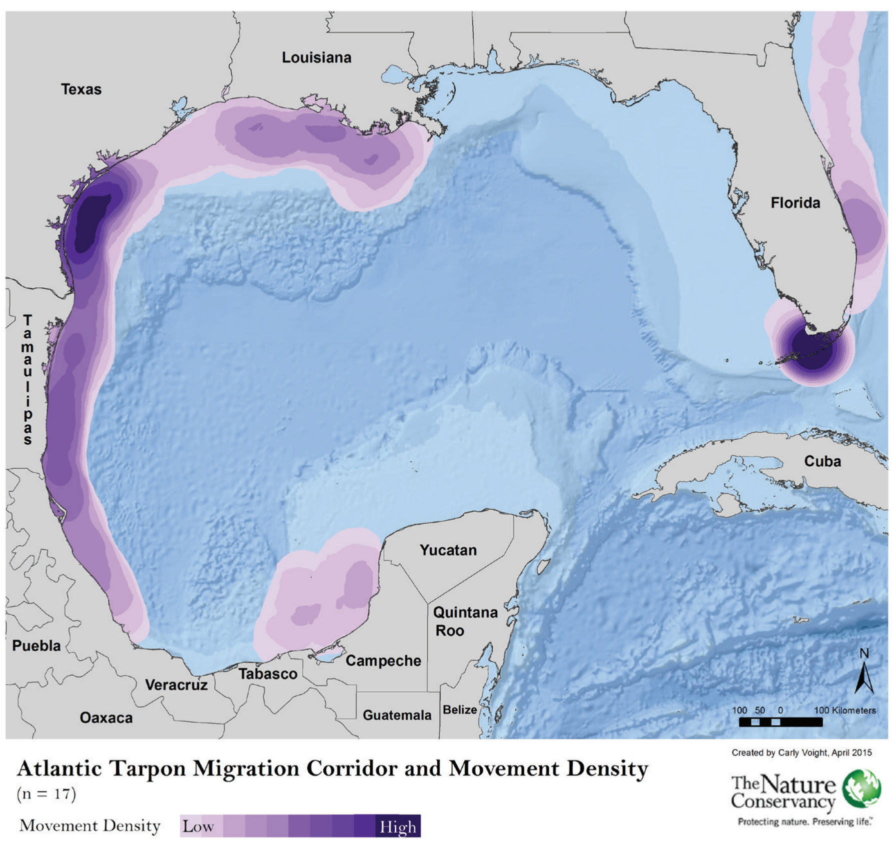


Figure 19. Bull shark distribution and observations.

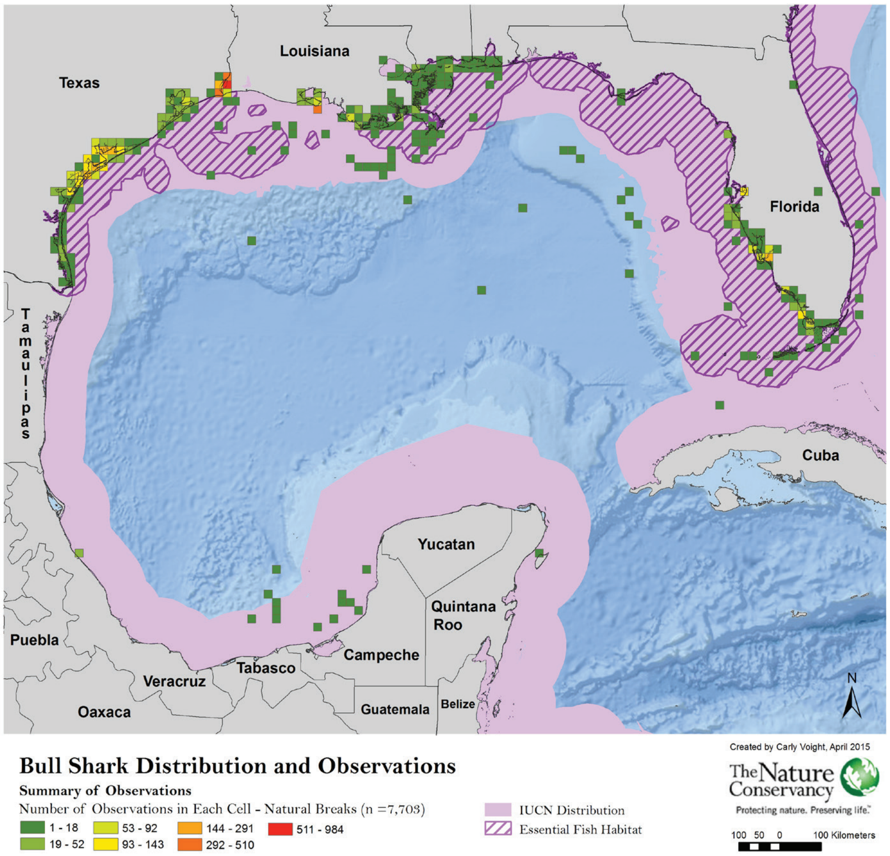


Figure 20. Bull shark migration corridor and movement density.

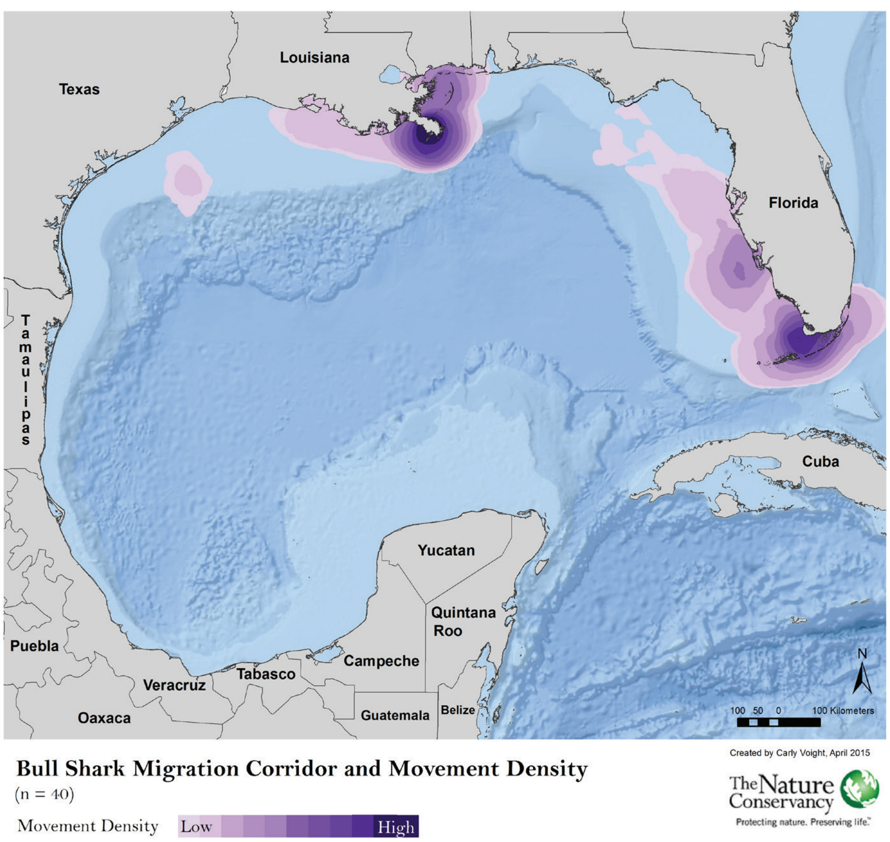


Figure 21. Gag grouper distribution and observations.

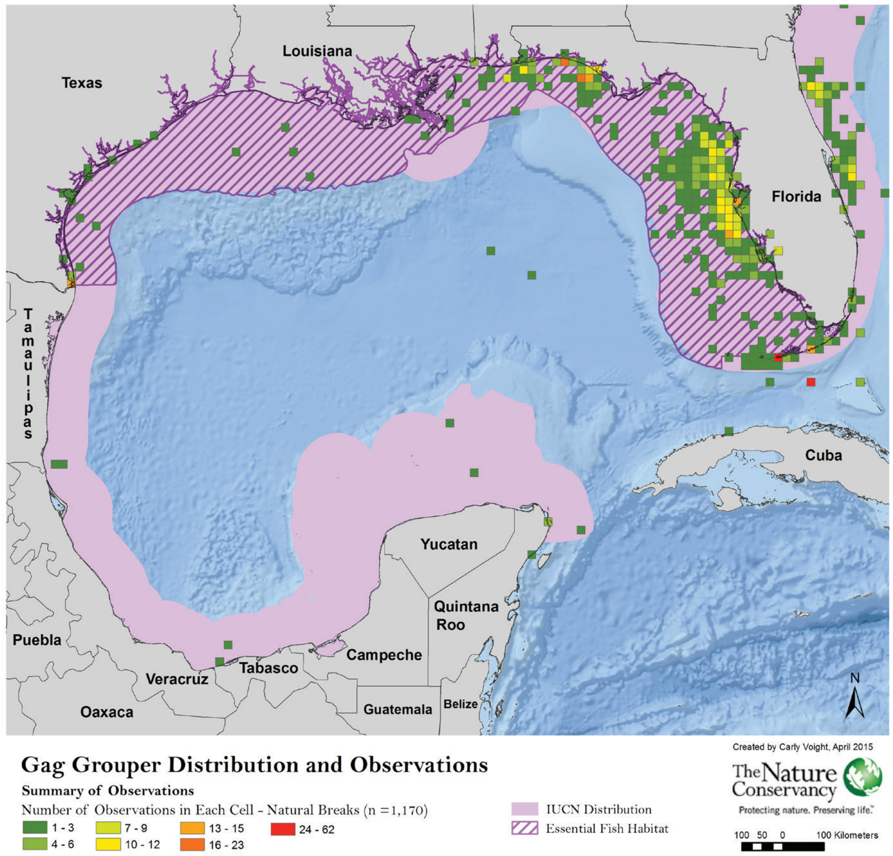


Figure 22. Gulf menhaden distribution and observations.

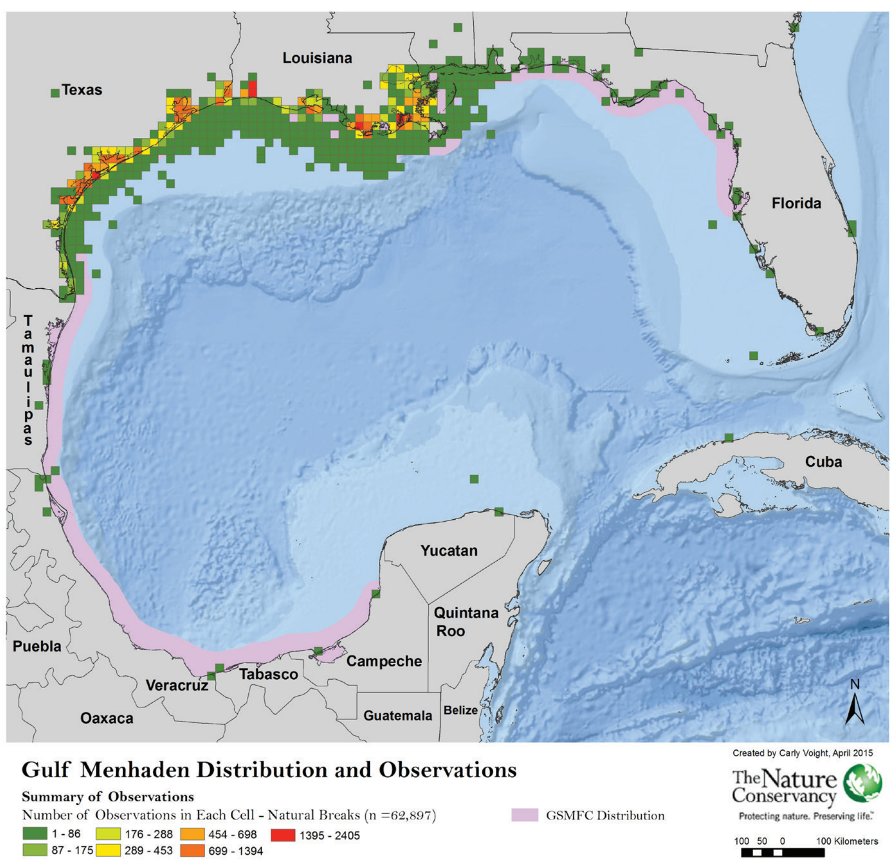


Figure 23. Gulf menhaden distribution.

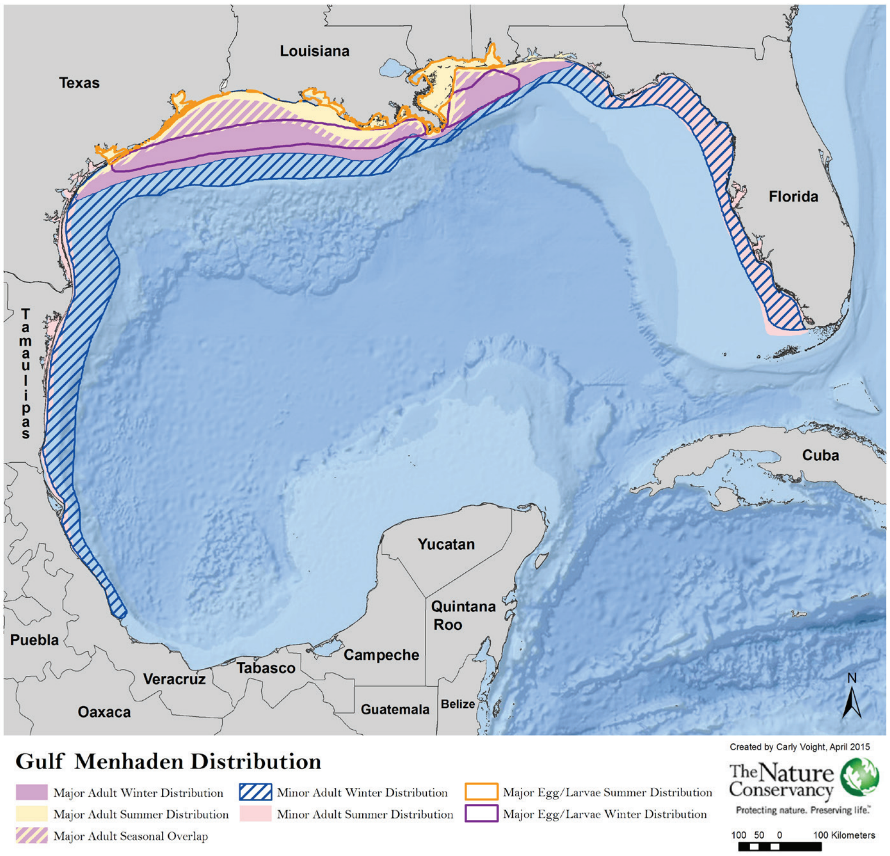


Figure 24. Gulf sturgeon distribution and observations.

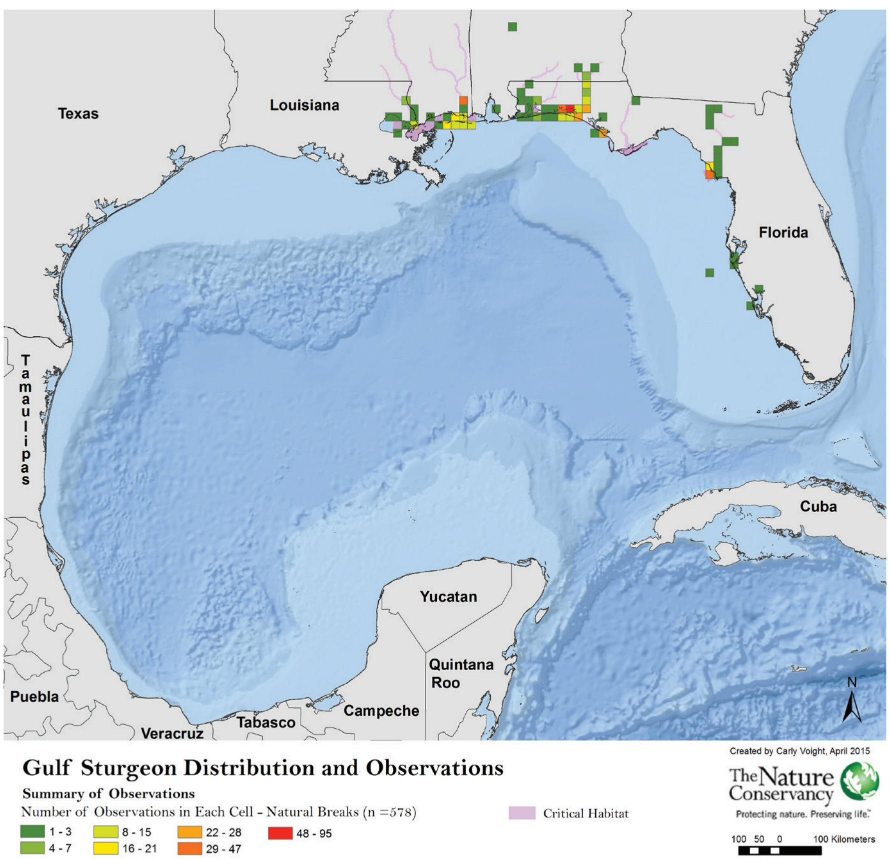


Figure 25. Gulf sturgeon migration corridor and movement density.

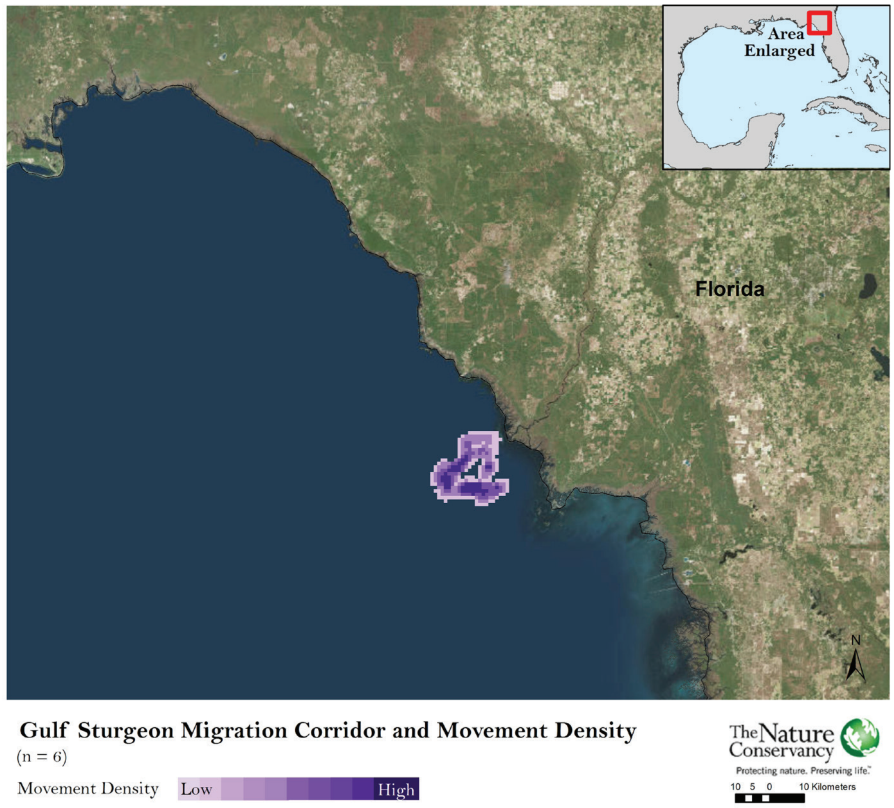


Figure 26. Mutton snapper distribution and observations.

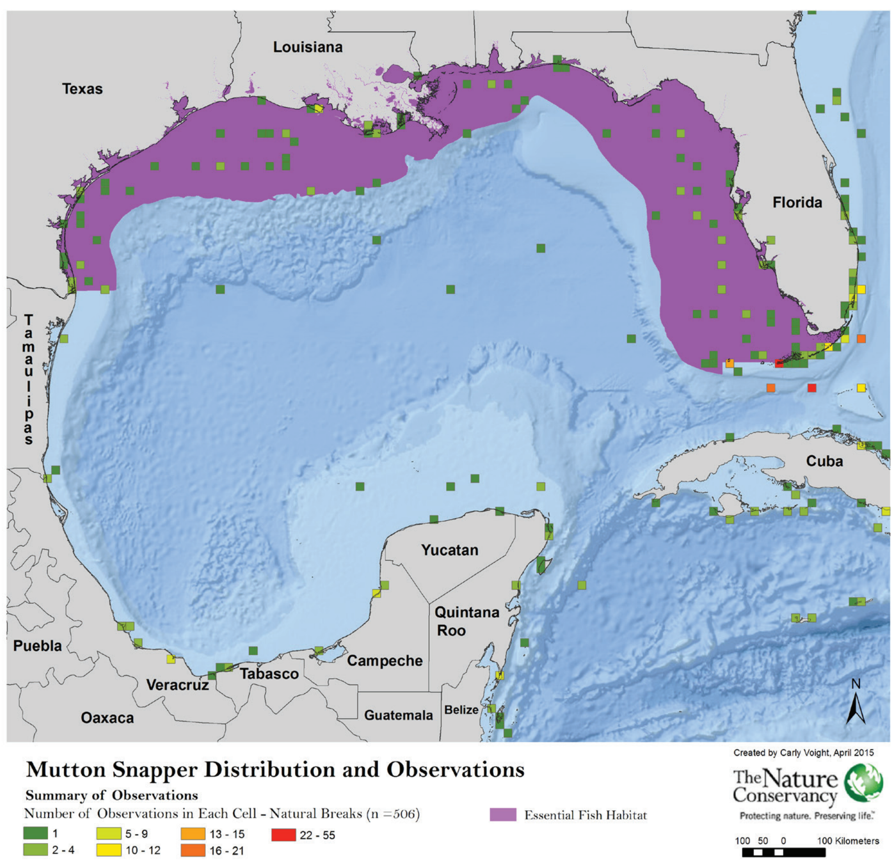


Figure 27. Striped bass distribution and observations.

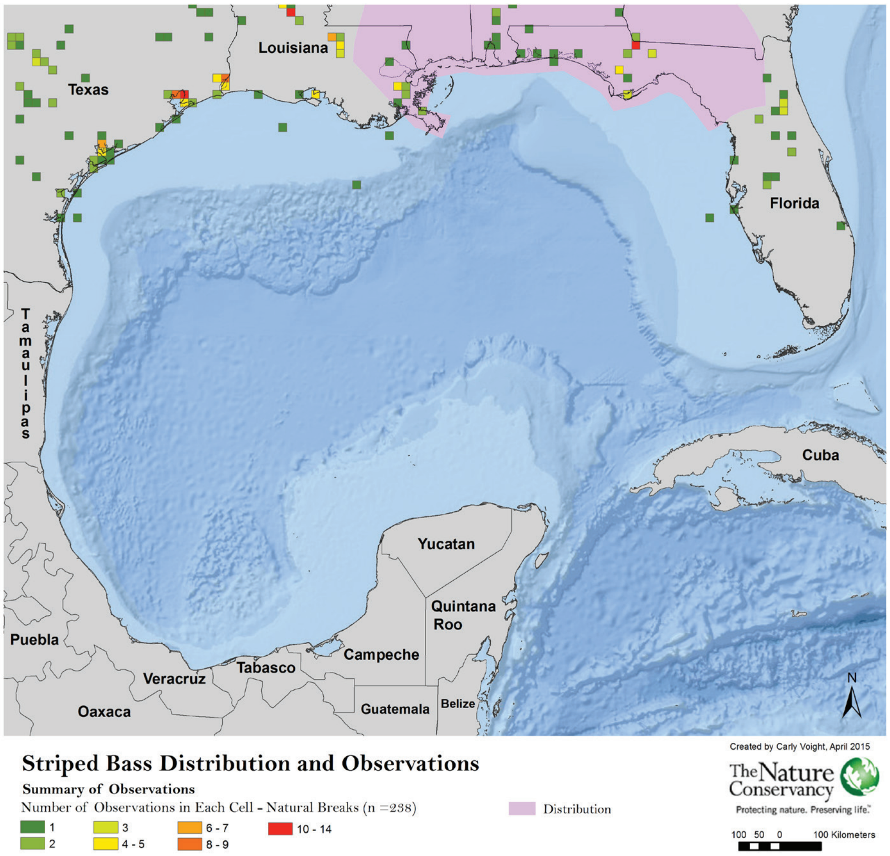


Figure 28. Blue marlin distribution and observations.

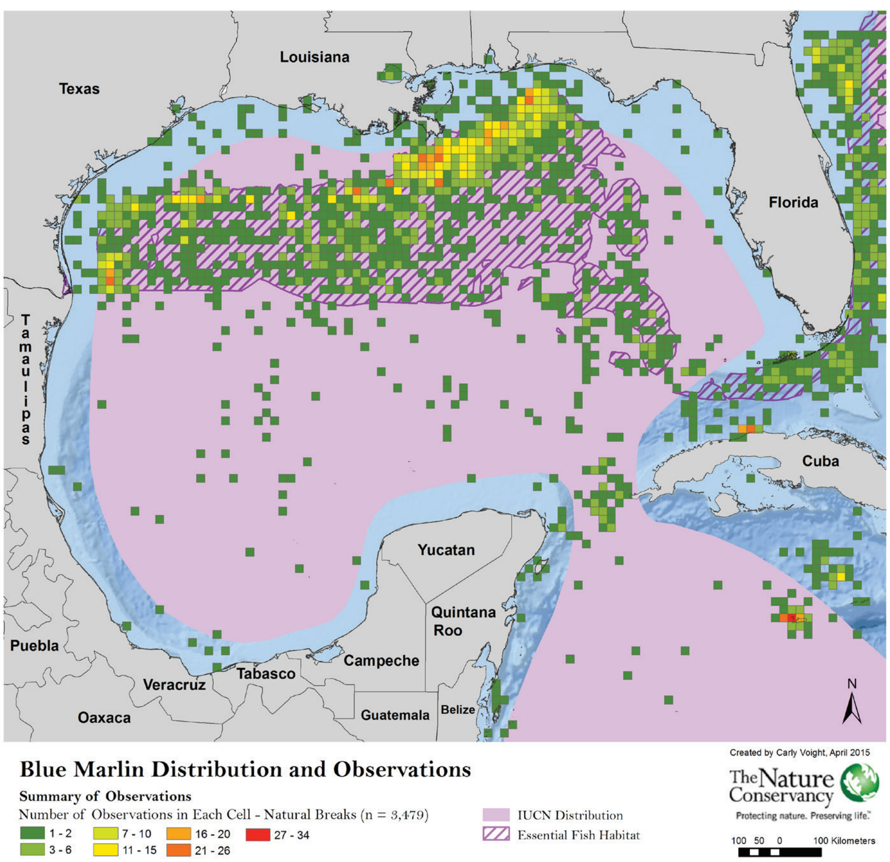


Figure 29. Blue marlin migration corridor and movement density.

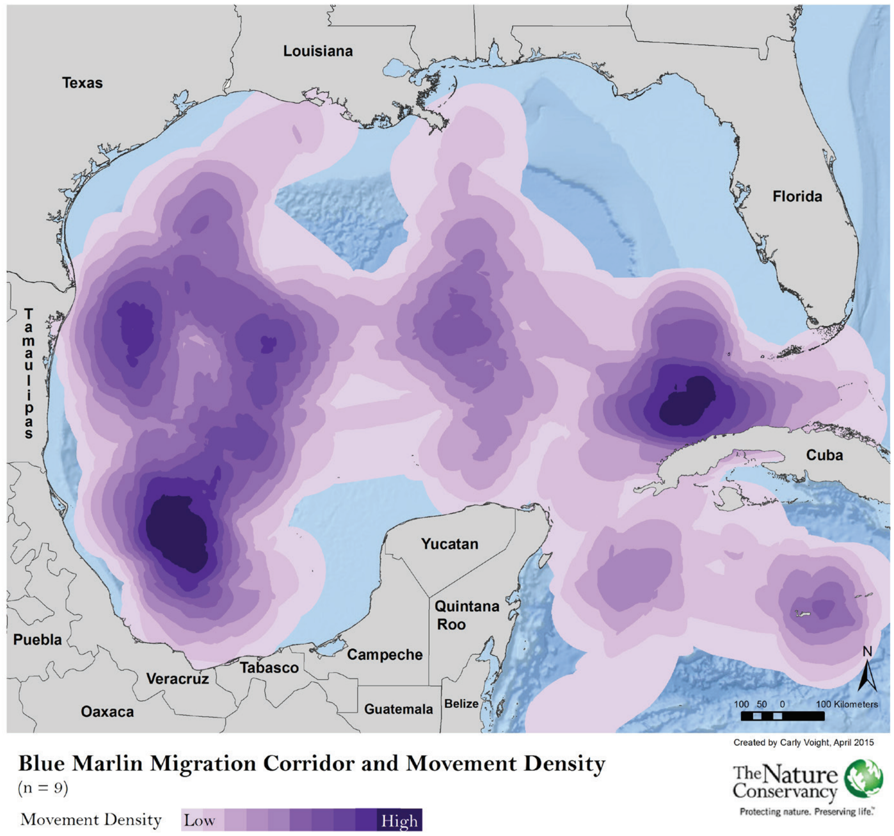


Figure 30. Bluefin tuna distribution and observations.

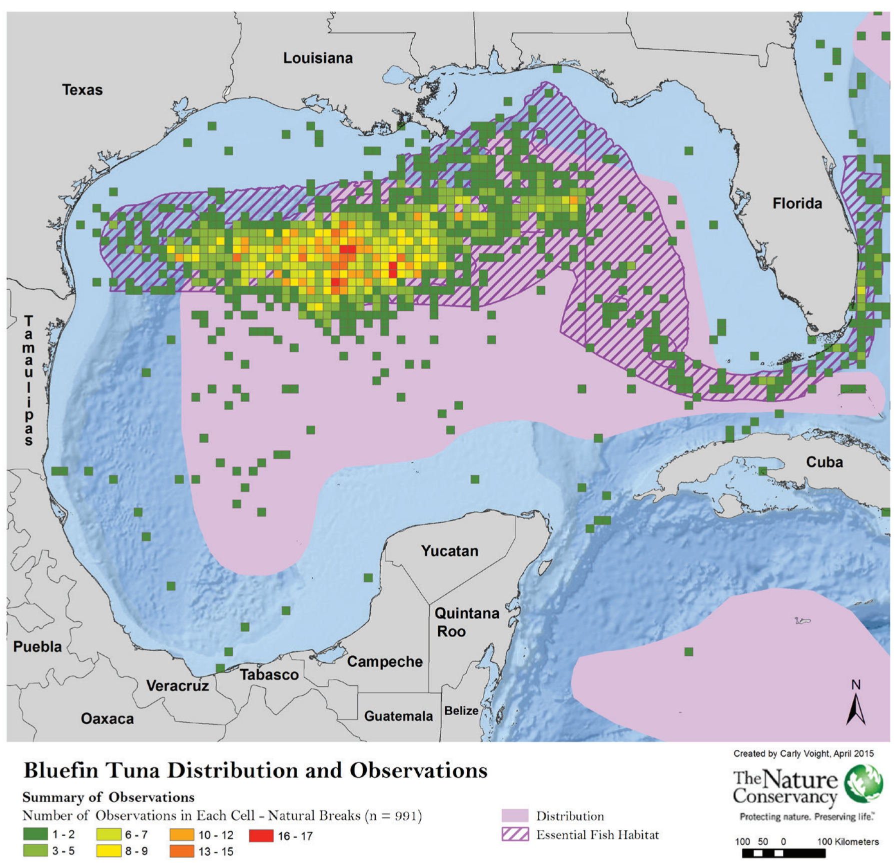


Figure 31. Bluefin tuna migration corridor and movement density.

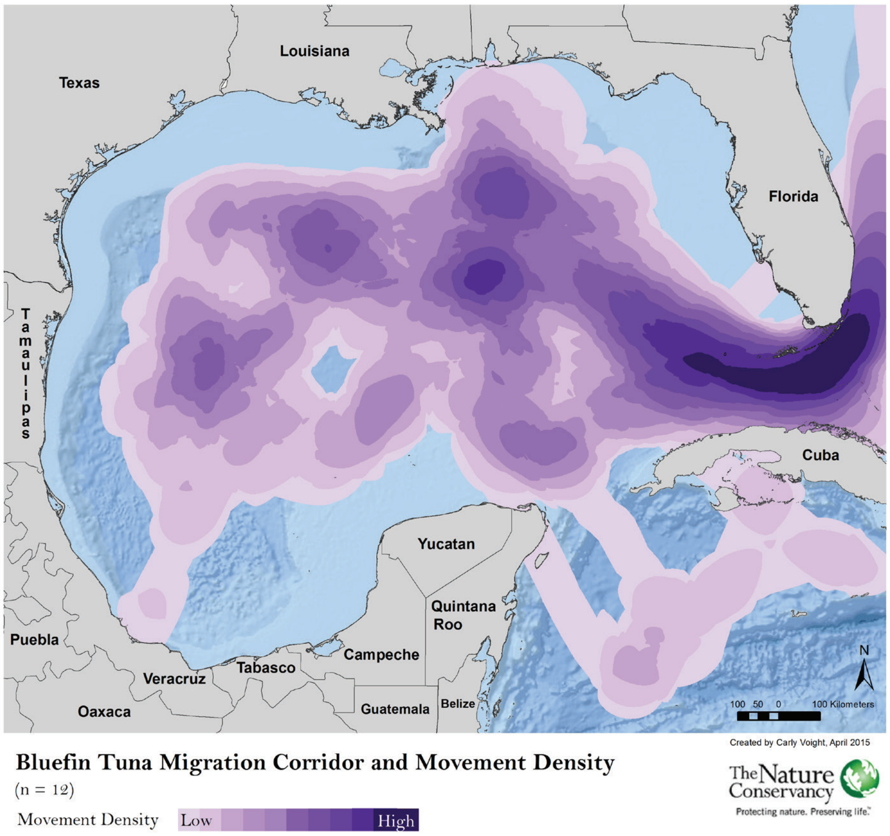


Figure 32. Dolphin fish distribution and observations.

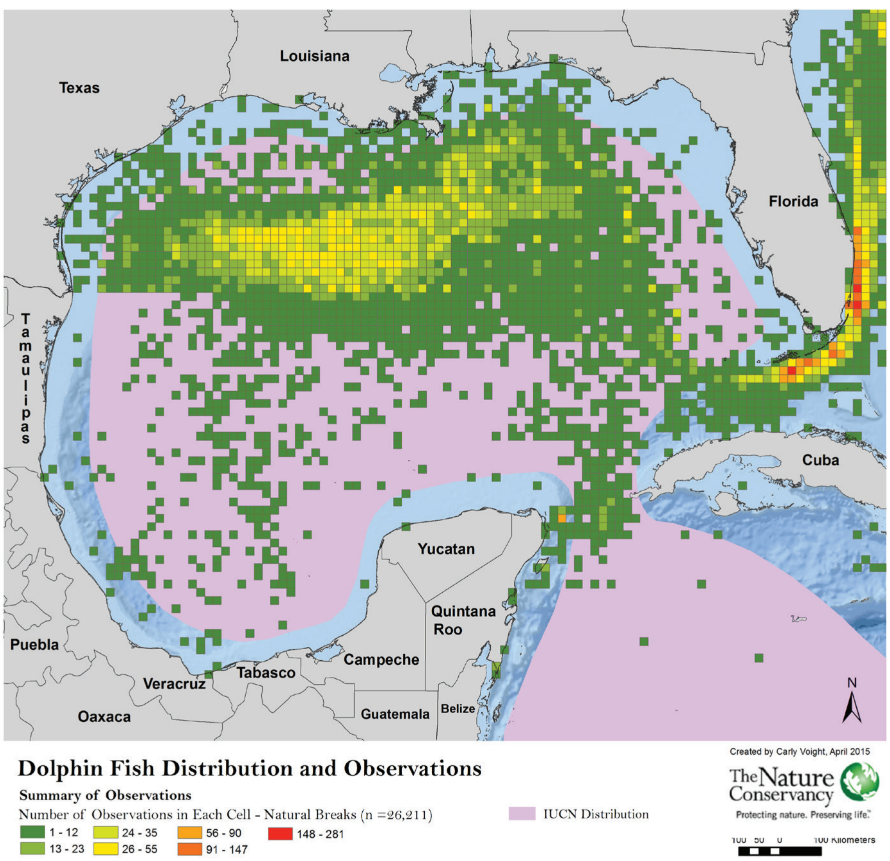


Figure 33. Whale shark distribution and observations.

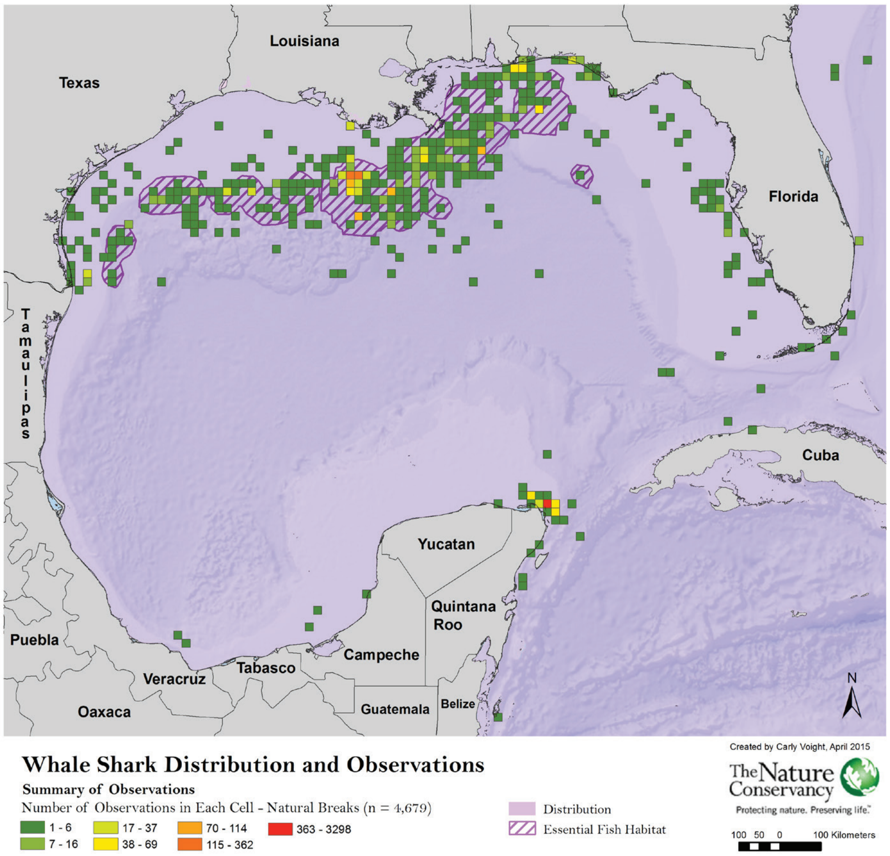


Figure 34. Whale shark migration corridor and movement density.

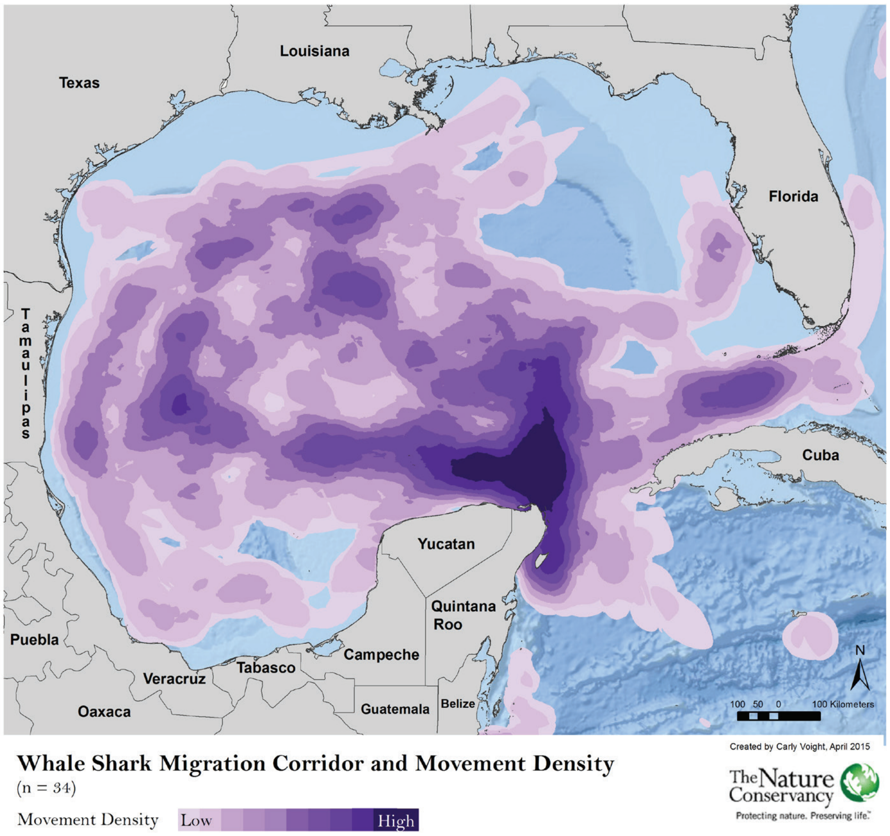


Figure 35. Green sea turtle distribution and observations.

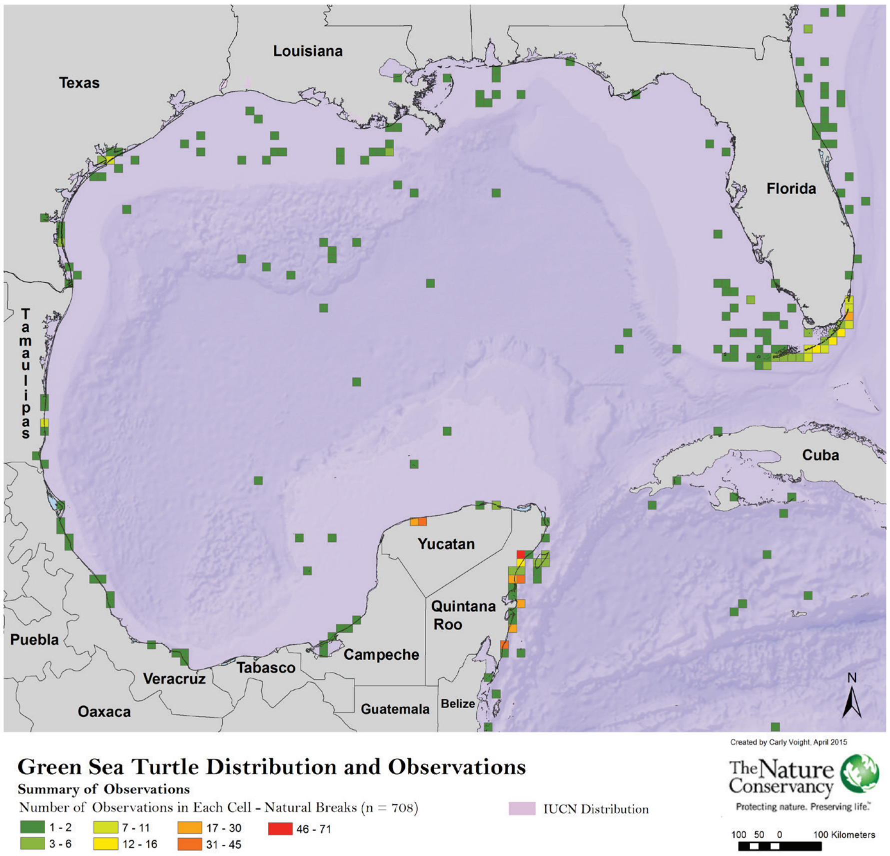


Figure 36. Adult female green sea turtle migration corridor and movement density.

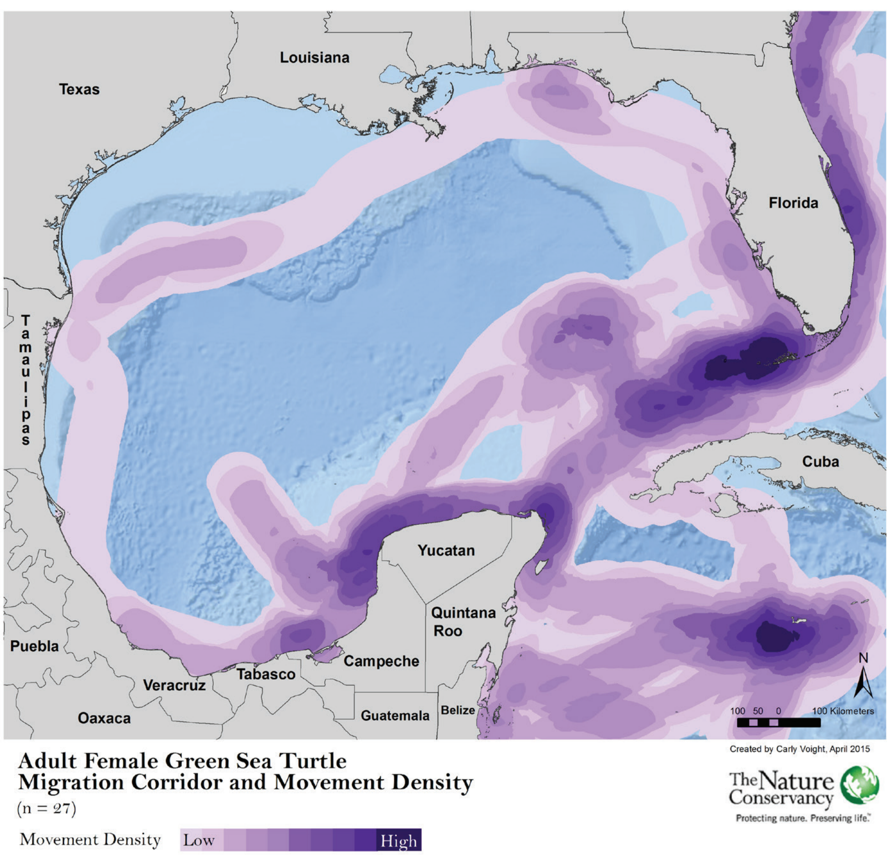


Figure 37. Kemp's ridley sea turtle distribution and observations.

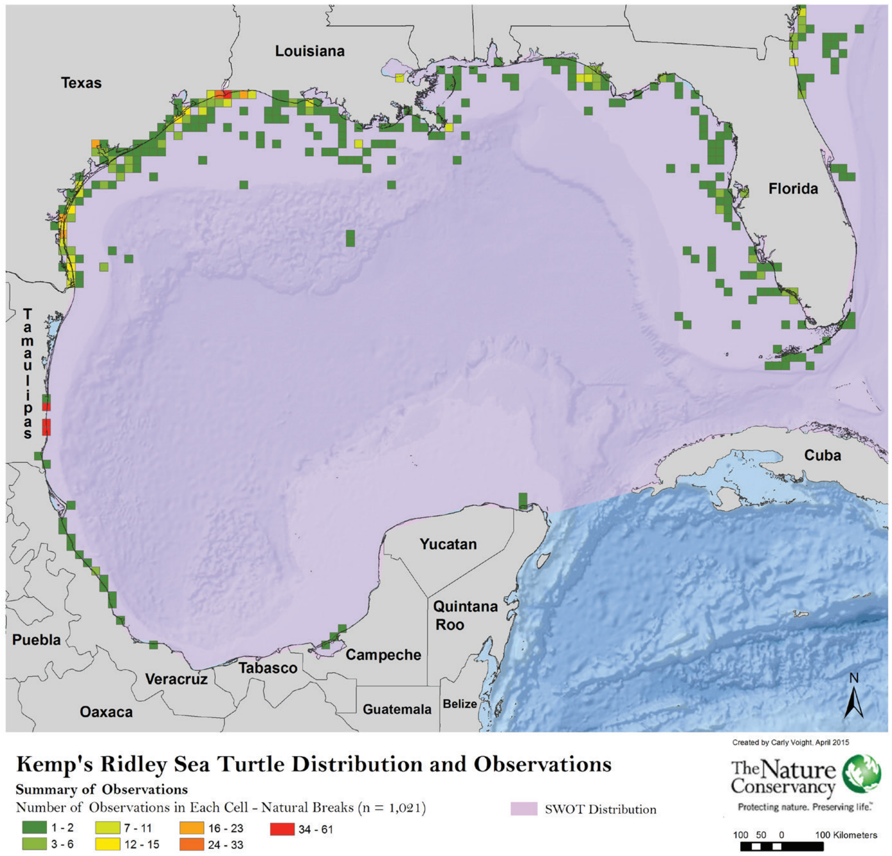


Figure 38. Adult female and juvenile Kemp's ridley sea turtle migration corridor and movement density.

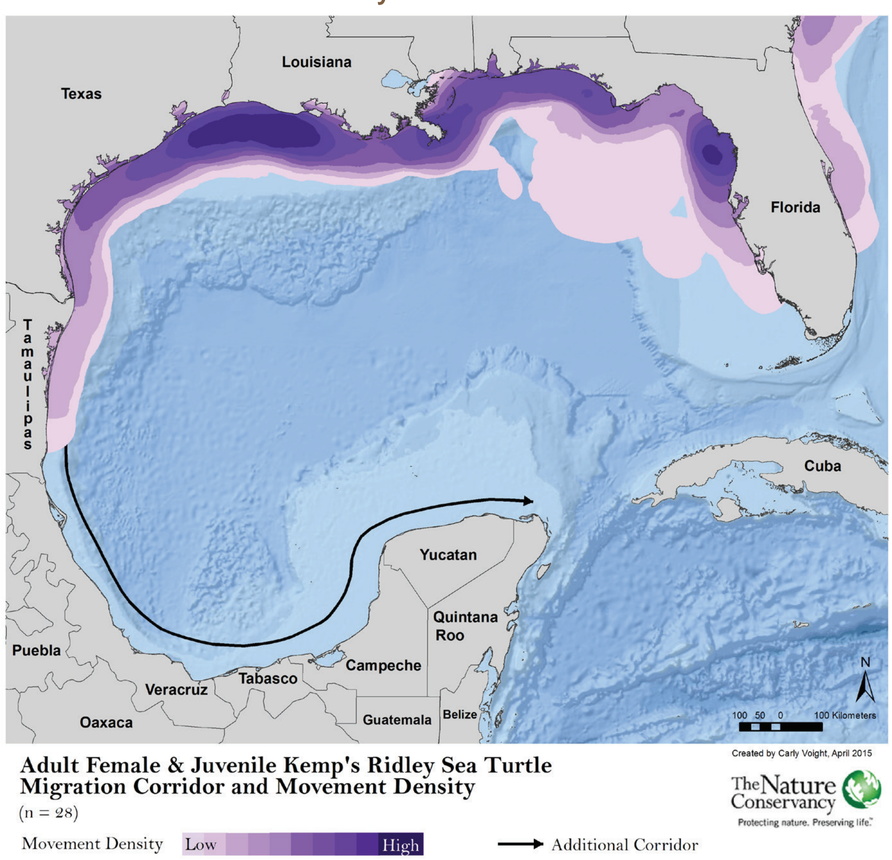


Figure 39. Loggerhead sea turtle distribution and observations.

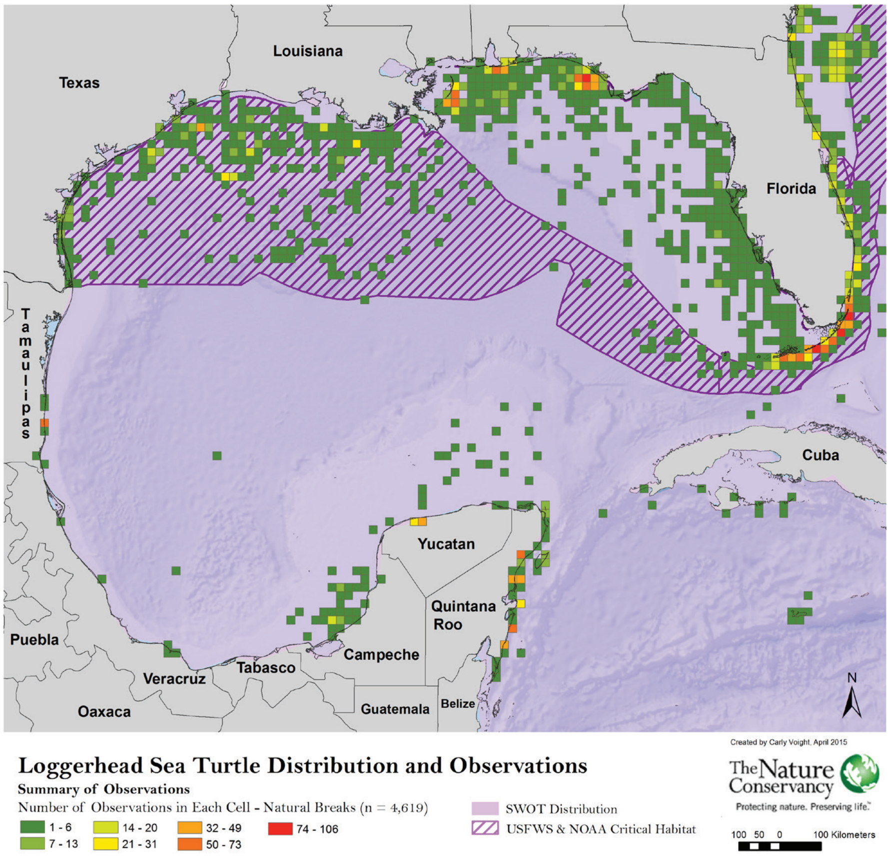


Figure 40. Adult female loggerhead sea turtle migration corridor and movement density.

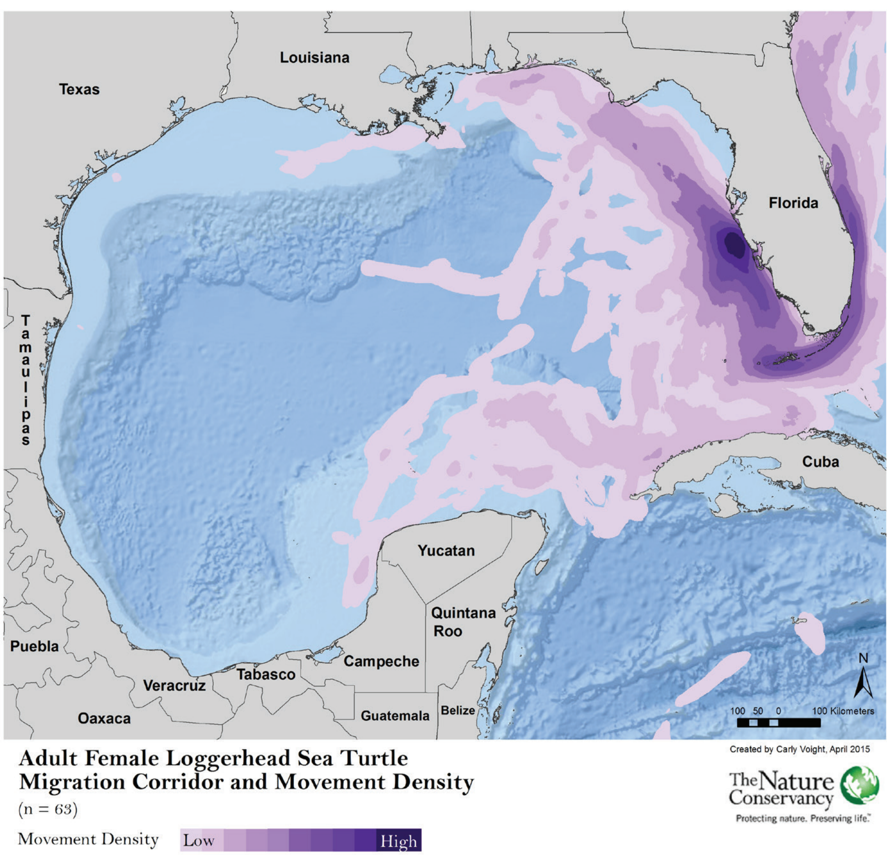


Figure 41. Leatherback sea turtle distribution and observations.

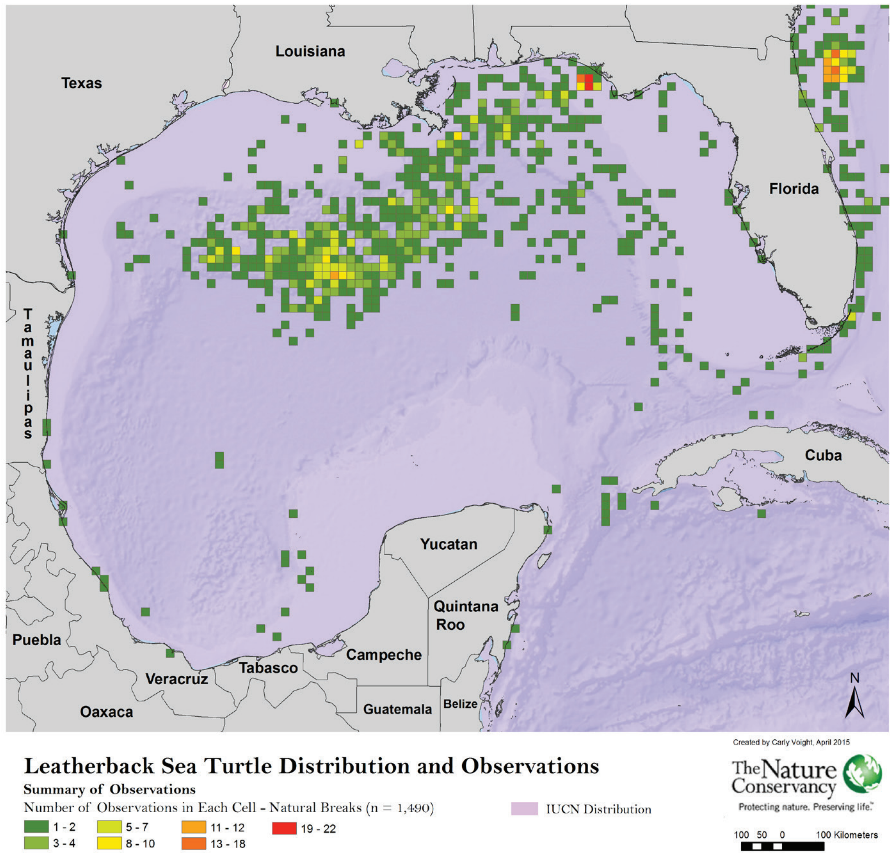


Figure 42. West Indian manatee distribution and observations.

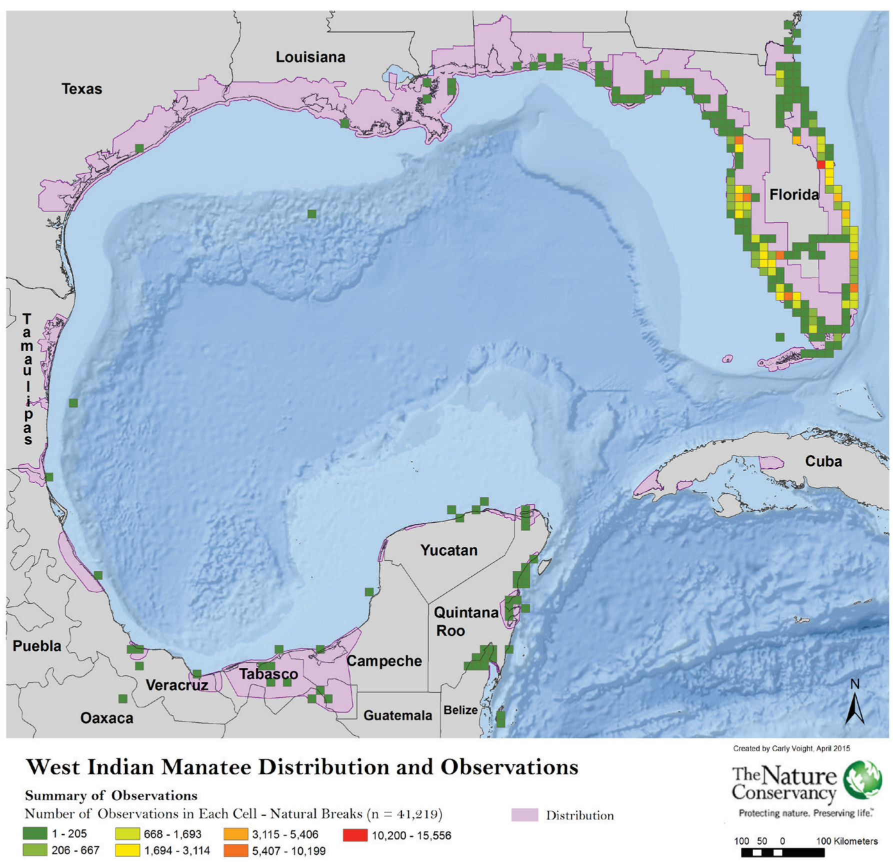


Figure 43. West Indian manatee distribution.

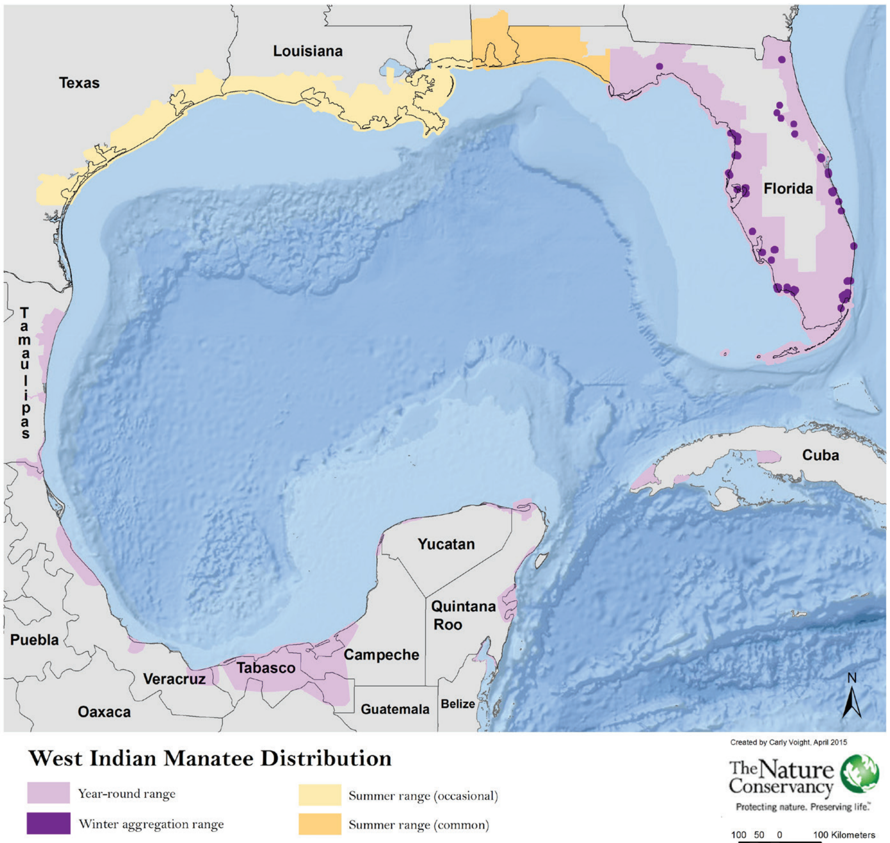


Figure 44. Sperm whale distribution and observations.

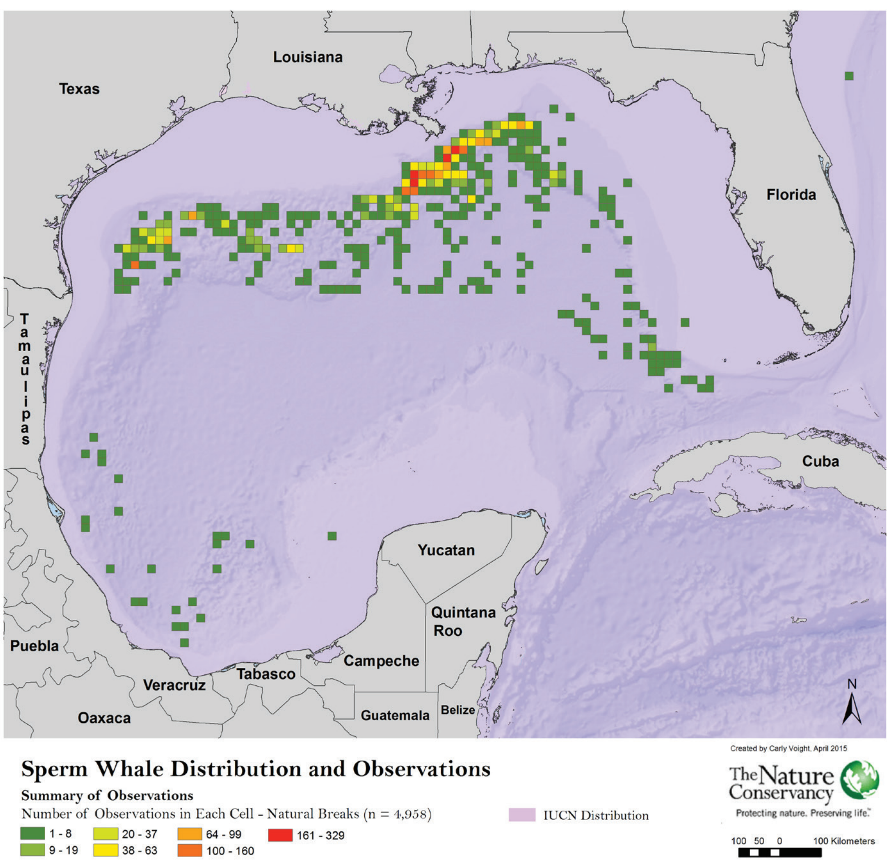


Figure 45. Sperm whale migration corridor and movement density.

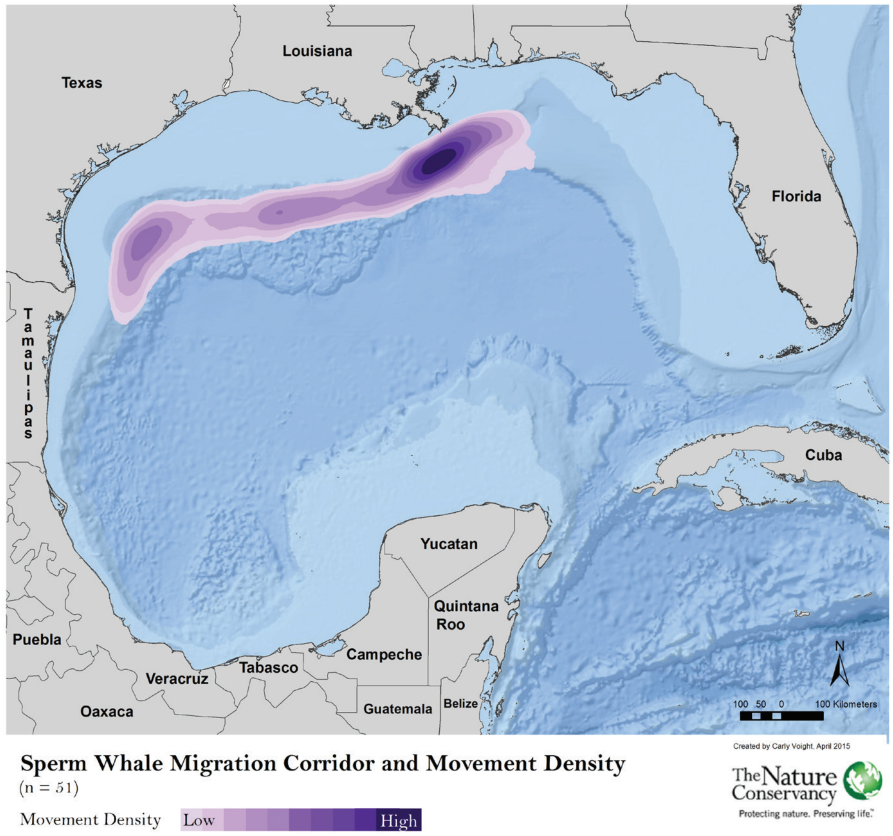
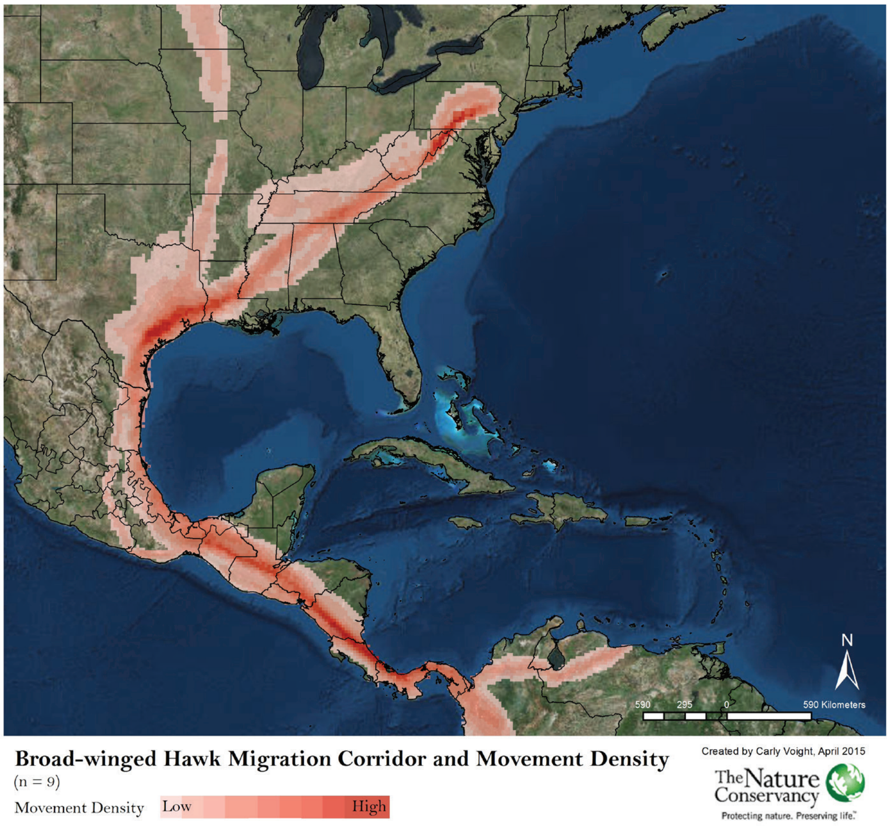


Figure 46. Broad-winged hawk summary of observations.

Figure 47. Broad-winged hawk migration corridor and movement density.



Analysis conducted by Abigail Uribe of CONABIO

Figure 48. Cerulean warbler summary of observations.

Figure 49. Osprey summary of observations.

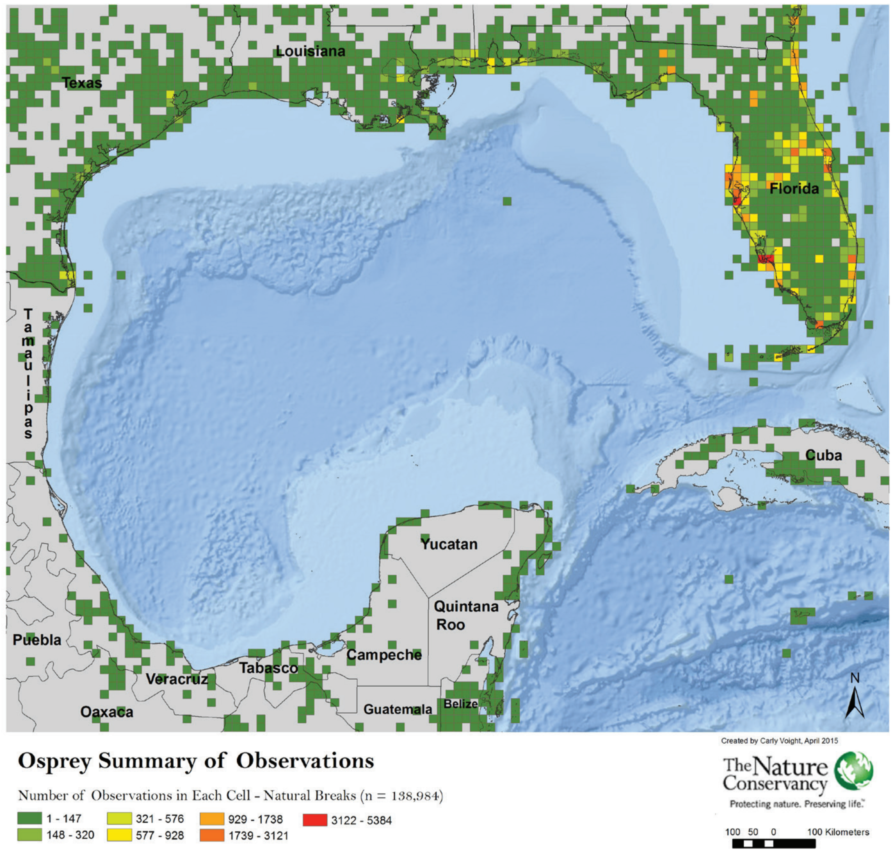


Figure 50. Osprey migration corridor and movement density.

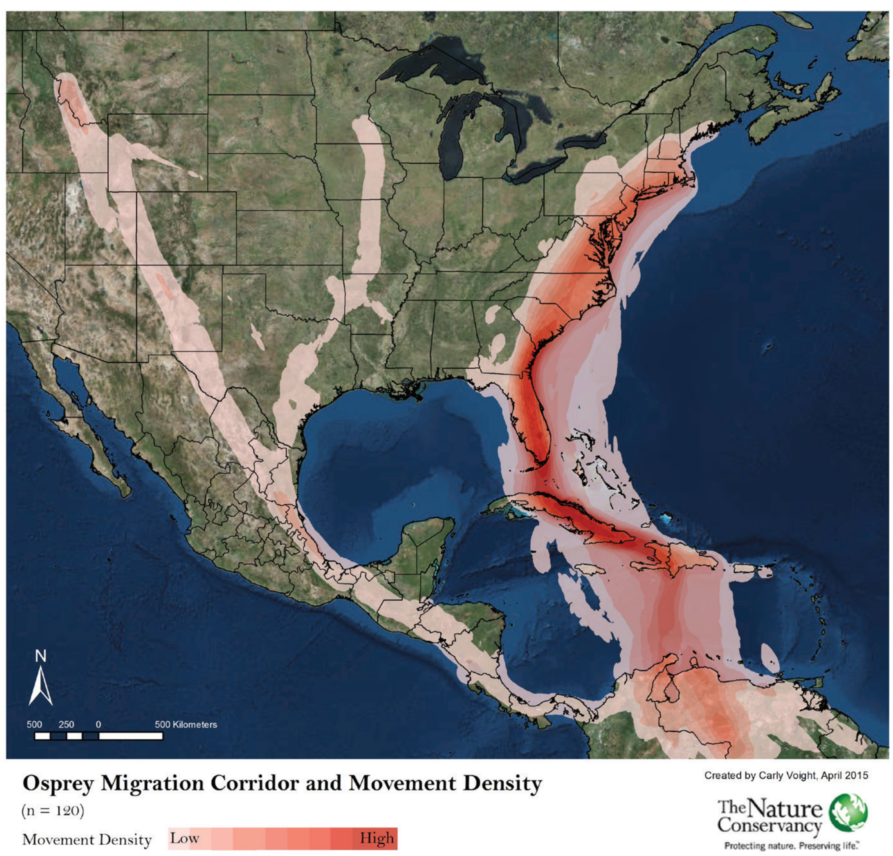


Figure 51. Wood thrush summary of observations.

Figure 52. Wood thrush spring migration: migratory corridor and movement density.

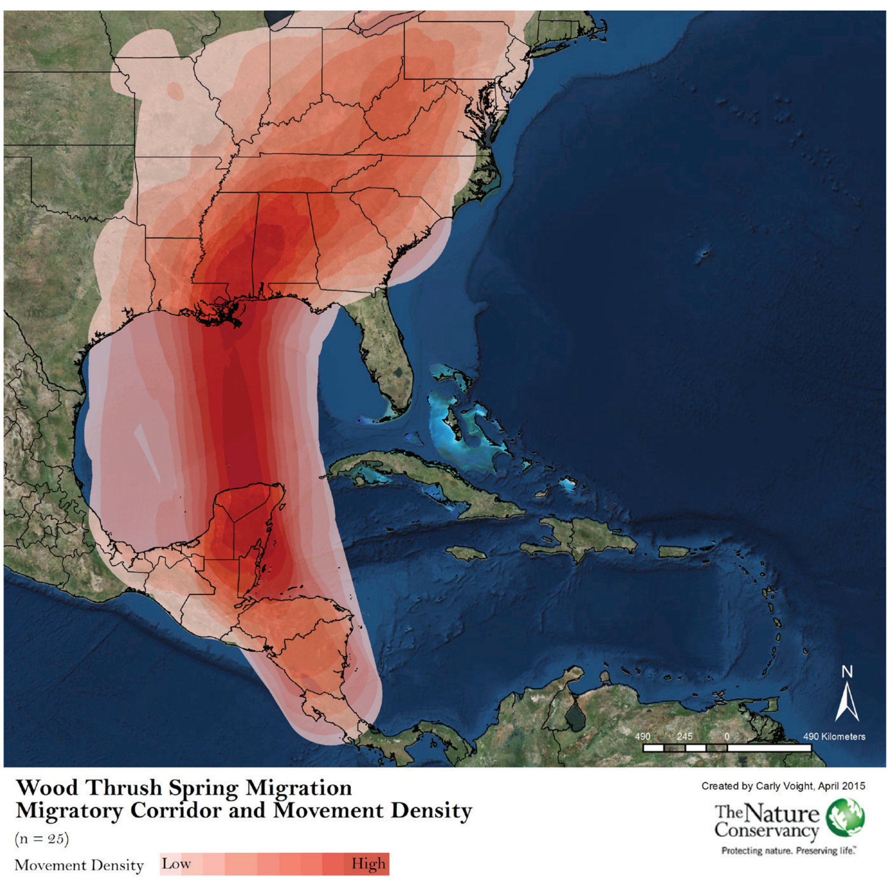


Figure 53. Wood thrush fall migration: migratory corridor and movement density.

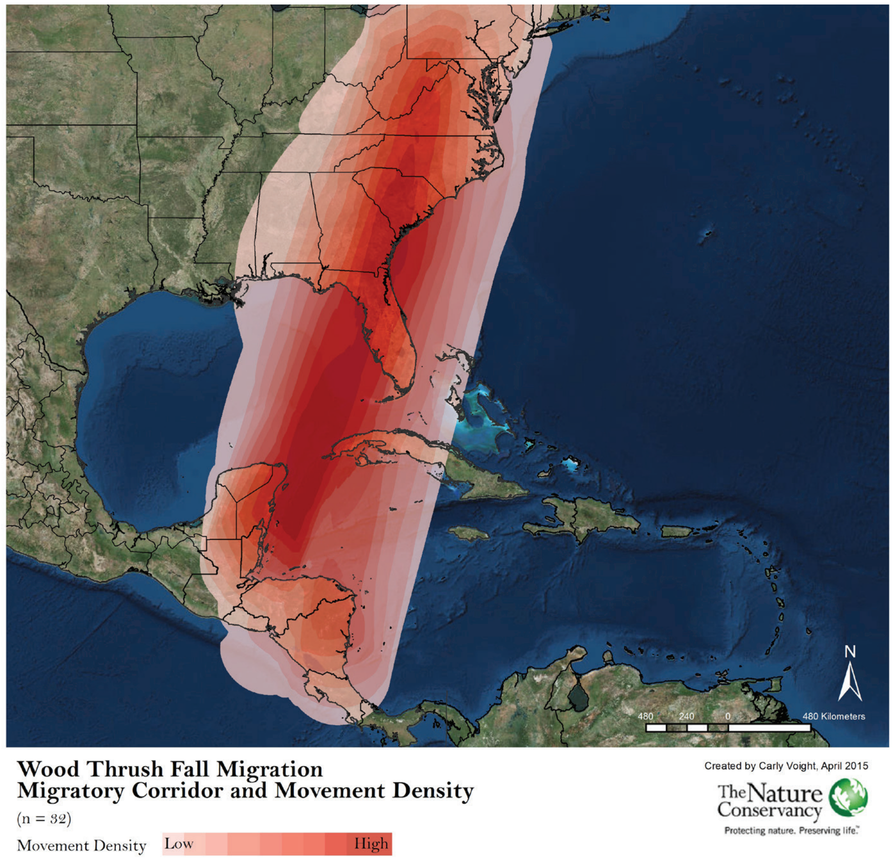


Figure 54. Black rail summary of observations.

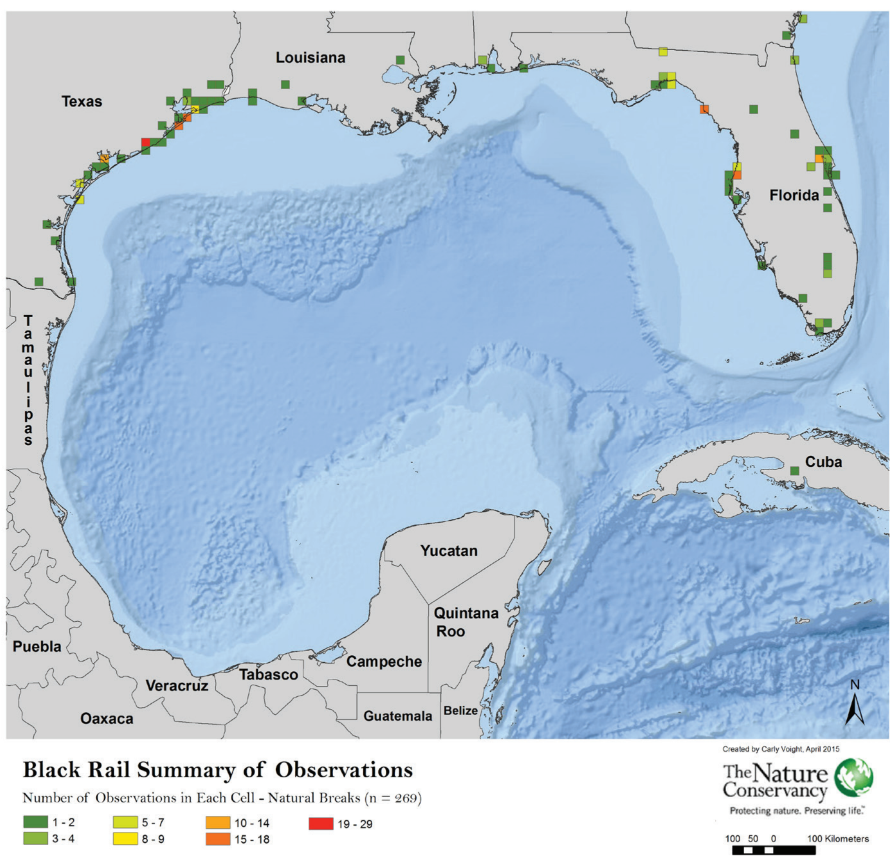


Figure 55. Black skimmer summary of observations.

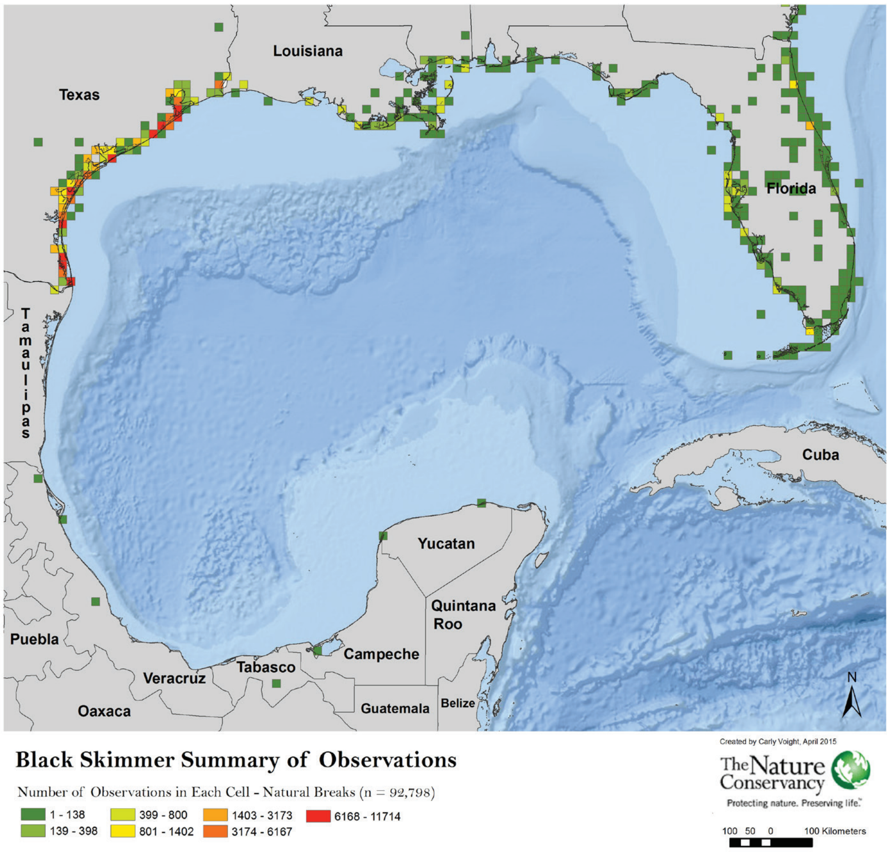


Figure 56. Redhead summary of observations.

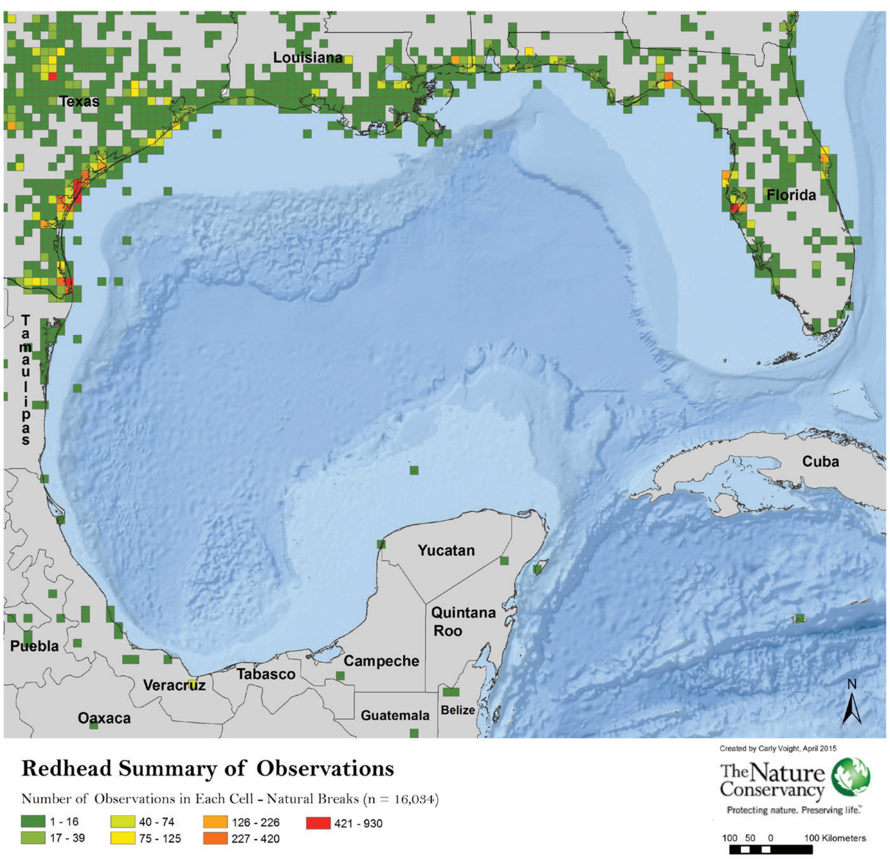


Figure 57. Whooping crane summary of observations.

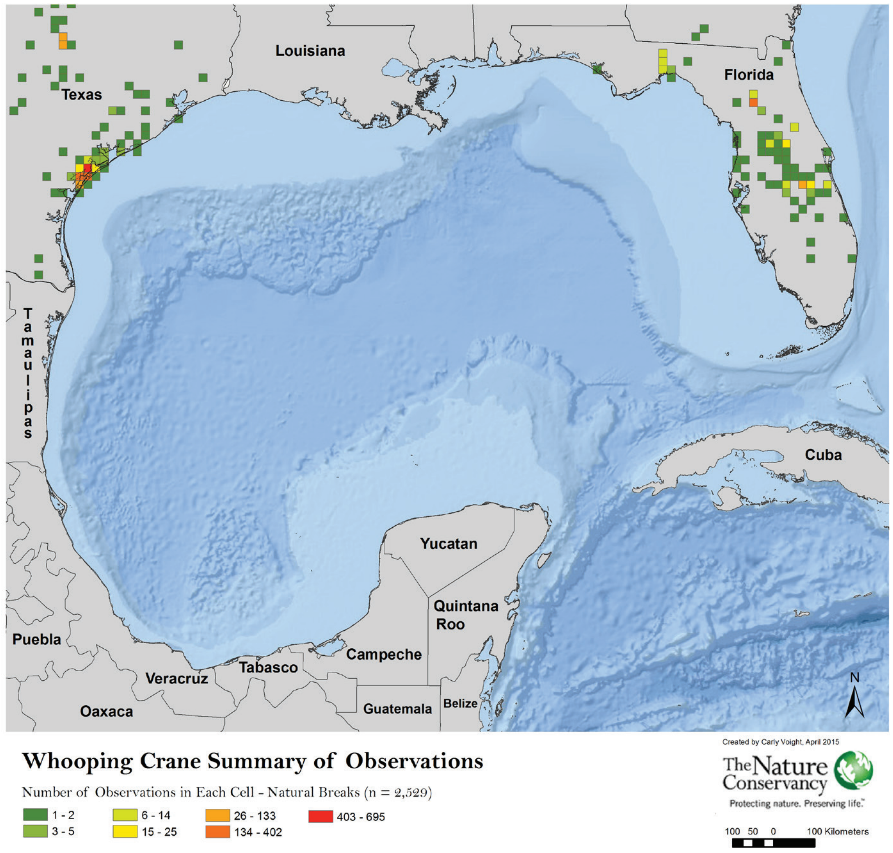


Figure 58. Whooping crane corridor and movement density.

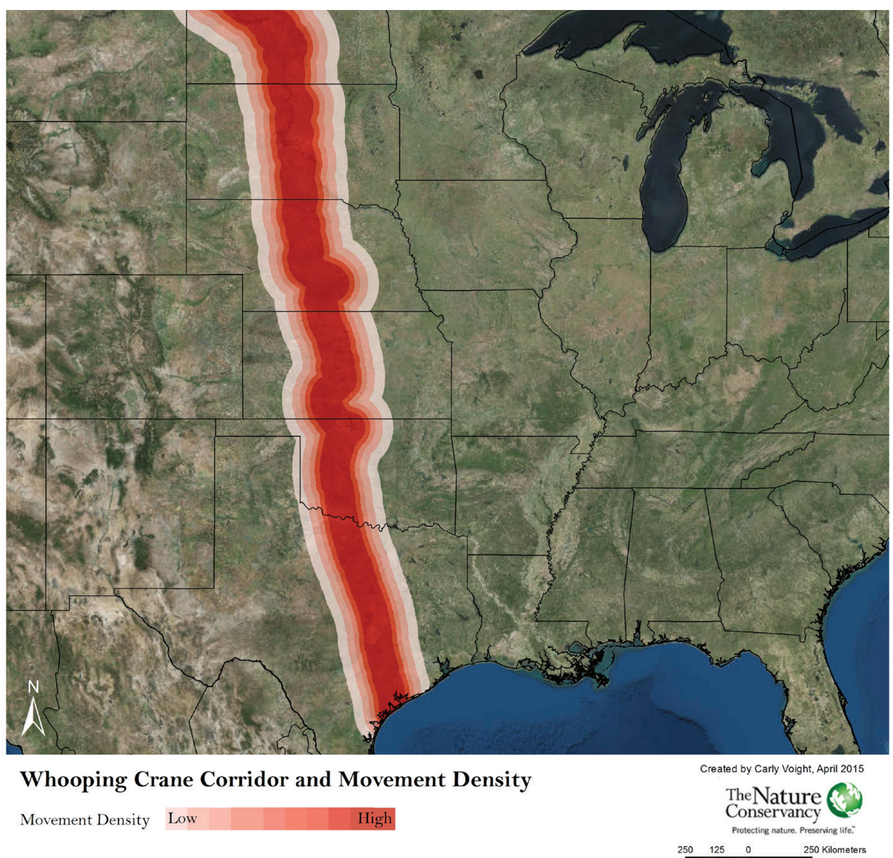
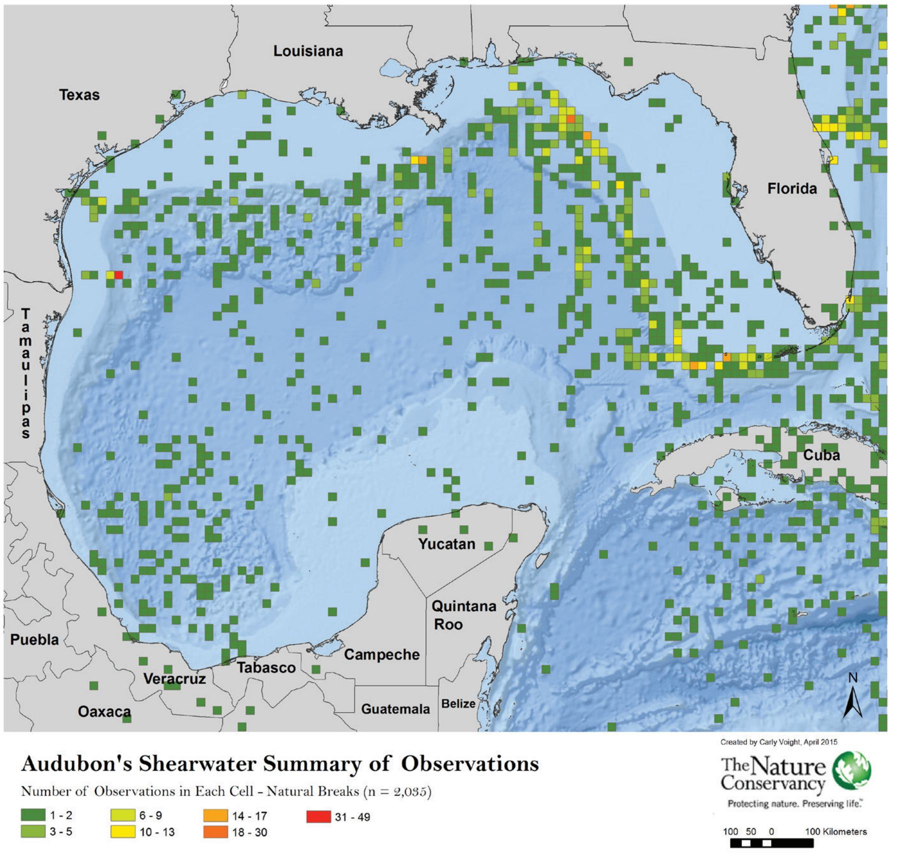


Figure 59. Audubon's shearwater summary of observations.



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